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Record 1973/93

GRAVITY READINGS ON SEISMIC TRAVERSES AT OORAMINNA, 1961-62, AND ALICE SPRINGS DETAILED GRAVITY SURVEY, 1959, AMADEUS BASIN, NORTHERN TERRITORY

by

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FOREWORD

The Bouguer anomaly maps in this Record are contoured at closer spacing than is strictly justified by the gravity measurements, and are thus somewhat subjective. It is not BMR policy to prepare contour maps in this way, but this report was written many years ago and is issued now to place the findings of the survey on record.

A.T. Wells has prepared the following notes on the geology:

Since this Record was written, regional geological mapping by BMR field parties in the Amadeus Basin has been completed and a synthesis of the stratigraphy and structure compiled. For the most up-to-date information on the geology the reader is referred to Wells et al. (1970) and Forman & Shaw (1973).

In particular the structure south of Alice Springs has been examined closely by Stewart (1967). He interprets it as a thrust nappe which was subsequently folded. This interpretation differs significantly from the one given in Plate 8 of this Record. The Bouguer anomalies shown on the profile in the area of repeated quartzite ridges can probably best be explained by the presence of dolomite and often carbonate rocks of the Bitter Springs Formation which are of slightly higher density than the enveloping rocks and are also repeated in the structure above the quartzite ridges.

A modification of Stewart's interpretation has recently been presented by Clarke (1973) but the interpretation as a thrust nappe is essentially the same.

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SUMMARY

This report describes the results of two gravity surveys conducted by the Bureau of Mineral Resources, Geology & Geophysics in the northeastern part of the Amadeus Basin, Northern Territory, in 1961-62 and 1959.

In 1961-62 the Ooraminna area southeast of Alice Springs was subjected to a gravity investigation for the purpose of further examining the structure of the Ooraminna Anticline. Residual gravity data are interpreted as indicating that salt flowage has caused a doming in the sediments, which overlie a core of halite.

The purpose of the 1959 detailed survey south of Alice Springs was to elucidate basin margin structure in the area of the Heavitree Gap. Gravity anomalies there are interpreted as most likely confirming the geological concept of thrusting.

1. INTRODUCTION

The Amadeus Basin of central Australia has recently attracted interest because of prolific natural gas production with condensate and traces of oil from strata ranging in age from Upper Proterozoic to Ordovician.

Prior to the drilling for hydrocarbons the region of the Amadeus Basin had been subjected to geological and geophysical studies over several years by the Bureau of Mineral Resources, Geology & Geophysics (BMR) and by private companies. Objectives of this work include elucidation of the basin structure and also of the stratigraphy and the lithology of the beds in the Amadeus Basin. More detailed investigations have been made of particular domes and anticlines. Certain local structures have been explained as a result of diapirism and flowage of salt originating from bedded evaporites.

In the Ooraminna area, 25 miles southeast of Alice Springs, gravity investigations were made by BMR during the 1961 and 1962 field seasons, when shot-holes drilled for seismic surveys were used as gravity stations in order to further investigate the area of the Ooraminna Anticline. This anticline has been known for some time as a major structure, which was later considered to be a potential trap of hydrocarbons (McNaughton, 1962).

In the Ooraminna area the large regional gravity gradient caused by the gross structure of the Amadeus Basin makes it difficult to interpret local gravity anomaly features caused by smaller structures. Consequently it seemed advisable to extend the BMR work there in the hope that a more comprehensive coverage would simplify interpretation.

The detailed gravity survey south of Alice Springs was requested early in 1959 by BMR's Resident Geologist at Alice Springs. In the area immediately south of Alice Springs the repetition in outcrops of the Heavitree Quartzite is a topographic and geological feature of particular interest. The purpose of the Alice Springs gravity investigation was to determine gravity variations in relation to the outcrops of older rocks mainly in the area south and north of Heavitree Gap and to assist, if possible, in assessing the nature of the tectonics which in the area surveyed control the contact between sediments and Precambrian basement rocks exposed along the northern margin of the Amadeus Basin. The field work required for the Alice Springs survey was carried out later during 1959 together with a gravity tie to the BMR pendulum station No. 35, established at the civil aerodrome eight miles south of Heavitree Gap (Dooley et al., 1961).

2. GEOLOGY

STRATIGRAPHY

The Amadeus Basin extends east from Western Australia into the Northern Territory between latitudes 23 and 26°S and longitudes 126 and 136°E. It covers an area of sediments of almost 80,000 square miles. In the deeper portions of this huge basin sedimentary rocks have been deposited as a continuous sequence ranging in age from Upper Proterozoic to Upper Palaeozoic (Plate 1).

Reconnaissance mapping in the Amadeus Basin has been carried out by BMR geological parties since 1958. This work is due to be completed in 1964 (Reynolds, 1963). Photo-geological maps have been issued on behalf of BMR by the Institut Francais Du Petrole, Mission in Australia (Scanvic, 1961).

Photo-geological information has been used to revise the geological boundaries shown on the geological map of the Alice Springs area (Plate 2), issued in 1962 (CSIRO, 1962).

The following notes on stratigraphy and geology are based on information available from BMR's geological surveys and from the geological reconnaissance work by private companies interested in the search for oil.

The sedimentation in the Amadeus Basin area commenced with the deposition of the Heavitree Quartzite of Upper Proterozoic age, laid down on a Precambrian basement. The Precambrian rocks are strongly folded formations including ortho- and paragneisses, schist, and metamorphic slate, intruded by granite, pegmatite, and basic igneous rocks.

Proterozoic

The slabby and blocky fine-grained and slightly micaceous Heavitree Quartzite is associated with the transgressive phase of the late Proterozoic sea. The quartzitic nature of the main portion of this formation is assumed to be a surface phenomenon caused by silicification some time after deposition (Stelck & Hopkins, 1962). The overlying Bitter Springs Limestone comprises foetid limestone, glauconitic beds, and evaporites containing gypsum and halite, intersected in bores.

TABLE 1: STRATIGRAPHIC SEQUENCE IN THE AMADEUS BASIN

(After Reynolds, 1963; Stelck & Hopkins, 1962; Prichard & Quinlan, 1962)

AGE (Group)	FORMATION	LITHOLOGY	ESTIMATED THICKNESS (ft)
Quaternary	-	alluvium, gravel beds, aeolian sands	-
Tertiary	-	calcareous and gypsiferous silt, laterite	-
Cretaceous	Rumbalara Shale	transgressive shale, clay-stone, silty sandstone	130
(?) Jurassic	De Souza Sandstone (Upper Finke Series)	sandstone	-
		U N C O N F O R M I T Y	
Permian	Lower Finke Series	glacial boulders, cobbles conglomerate, silty sandstone	-
		U N C O N F O R M I T Y	
Post Ordovician	Pertnjara Fm.	continental sandstone, conglomerate, sandy shale	0 to 10 000
	Mereenie Sandstone	cross-bedded continental sandstone	0 to 3200
		U N C O N F O R M I T Y	
Ordovician (Larapinta)	Stokes Fm.	silty shale, evaporites	0 to 2000
	Stairway Sandstone	porous sandstone	1800
	Horn Valley Fm.	fossiliferous siltstone and shale	400 to 1400
	Pacoota Sandstone	well sorted sandstone	2000 to 3000
Cambrian (Pertaoorrta)	Goyder Fm.	tight sandstone, siltstone	300 to 1600
	Jay Creek Limestone	algal limestone, pellet limestone	0 to 300
	Hugh River Shale	shale, silty shale, limestone bands	1100 to 1600
	Arumbera Sandstone	greywacke, conglomerate well-sorted sandstone	800 to 2800
Upper Proterozoic	Pertatataka Fm.	silty shale, algal limest.	2200 to 4000
	Areyonga "	arkosic greywacke, boulders, varved limest.	1300
	Bitter Springs Limestone	limestone and evaporites	2500
	Heavitree Quartzite	slightly micaceous limestone	1500
		U N C O N F O R M I T Y	

AGE (Group)	FORMATION	LITHOLOGY	ESTIMATED THICKNESS (ft)
Archaean	Arunta Complex	strongly folded gneiss, schist, slate, granite, pegmatite, amphibolite.	

The overlying Areyonga Formation is mainly coarse sandstone and conglomerate with reservoir potential. Erratic boulder and varved limestone beds indicate periglacial conditions during the deposition period. The Pertatataka Formation includes the youngest Proterozoic beds, which are similar in lithological nature to the Bitter Springs Limestone. Shale and foetid limestone members within the Pertatataka Formation have been considered potential source beds of hydrocarbons.

Cambrian

Sediments of Cambrian age deposited in the Amadeus Basin area have been named the Pertaoorrta Group (Chewings, 1935).

The Arumbera Sandstone is the basal member of the Cambrian rock succession. It is considered a potential reservoir formation, as it contains well sorted, porous, sandy beds. Cambrian sediments above the Arumbera Sandstone include more carbonates in the eastern portion and more shaly and sandy beds in the western portion of the Amadeus Basin.

The Jay Creek Limestone, which overlies the Arumbera Sandstone, has yielded oil-bleeding cores recovered from the Alice No. 1 well. Jay Creek Limestone interfingers farther west with Mission Shale, Gardiner Sandstone and Hugh River Shale. The overlying Goyder Formation, a fairly tight transgressive sandstone, is the youngest member of the Cambrian sequence.

Ordovician

The Larapinta Group comprises the Ordovician beds of the Amadeus Basin. These sediments are thickest in the northern portion of the basin along the Macdonnell Ranges.

The Pacoota Sandstone is the lowest member of the Larapinta Group. It is a clean, porous sandstone with favourable reservoir characteristics over most of the area, but has been silicified along the Macdonnell front. The fossiliferous Horn Valley Formation overlies the Pacoota Sandstone. Natural gas in quantity has been recovered from the Horn Valley Formation, intersected in the Mereenie No. 1 and East Mereenie No. 1 wells.

Stairway Sandstone, considered a potential reservoir, and Stokes Formation, a sequence of shale with some evaporite, are known only from the western part of the Amadeus Basin, where these strata comprise the youngest Ordovician beds.

Post-Ordovician

A thick sequence of cross-bedded, continental sandstone beds named Mereenie Sandstone, overlies the Larapinta Group on a strong unconformity. This sandstone is thickest near the Macdonnell Ranges. It is overlain by the Pertnjara Formation, a rock sequence of continental sandstone, conglomerate, and sandy shale. The Pertnjara Formation is extremely thick in the western portion of the Amadeus Basin but entirely absent in the east.

Permian and Mesozoic sediments extend from the Great Artesian Basin of Queensland into the eastern portion of the Amadeus Basin. A northeast trend in the gravity anomaly contours in connexion with a strong gravity gradient negative to the northwest terminates geophysically the deeper portion of the Amadeus Basin in the area of the FINKE 1:250 000 Sheet area (Plate 1).

Glacial deposits of boulders, conglomerate, and silty sandstone of Permian age compose the lower portion of the Finke Series, in the FINKE area. The upper sandstone portion of the Finke Series is the De Souza Sandstone of probable Jurassic age. A regional unconformity separates the De Souza Sandstone from the underlying glacial beds.

The transgressive Rumbalara Shale of Cretaceous age extends from the east into the Amadeus Basin area, where it forms low lateritized hills.

Tertiary deposits include scattered occurrences of thin horizontal calcareous and gypsiferous silt beds. River alluvials, gravel beds, and aeolian sand form the Recent sediments of the Amadeus Basin.

STRUCTURAL DEVELOPMENT

The first geological concept of the Amadeus Basin was that of an west-east elongated sunkland, bounded to the north and to the south by major faults (Chewings, 1935). Later the Amadeus Basin was regarded as a portion of an ancient mobile zone peripheral to a major craton, i.e. the Precambrian Western Australian Shield. According to this concept a geosynclinal belt, the Lower Adelaidean Geosyncline (David, 1950), was postulated to extend into the Amadeus Basin area during early Upper Proterozoic time. This geosyncline was possibly connected with the Flinders Trough in South Australia and may have continued by a channel to the northwest on the southwestern flank of the Canning Basin. This concept is supported by more recent geophysical work (Flavelle & Goodspeed, 1962).

Recent geological surveys show the Amadeus Basin in early Upper Proterozoic time forming a shallow-marine epicontinental basin or shelf area, where sedimentation was thickest in the region of the present Macdonnell Ranges. This shallow basin has been visualized as being formed by the warping of a block (Joklik, 1955) between Precambrian rocks of the Arunta Shield to the north and the Precambrian Musgrave-Mann complex to the south. During the period from Upper Proterozoic to Ordovician time, sedimentation in the Amadeus Basin took place in several lithological cycles, alternating from sandstone beds to shale and to limestone. Three successive cycles were possibly caused by oscillating epeirogenic movements.

A major orogeny occurred in post-Ordovician time. Cambrian-Ordovician and older rocks were folded and raised into almost vertical attitudes along the Macdonnell front (Plate 8). At the same time the area south of the ranges was downwarped to form a trough, which filled with continental clastic sediments, greatly varying in thickness, of the Mereenie Sandstone and Pertnjara Formation. Simultaneously with the forming of a trough south of the Macdonnell Ranges a large anticlinorium came into existence north of the present Amadeus Basin and south of the Ngalia Trough (Plate 1). The inner structure of this anticlinorium has been studies in detail in the area of the Harts Ranges northeast of Alice Springs (Joklik, 1955). The Harts Range forms the core of an anticlinal structure composed of Archaeozoic granite, gneiss, and schist overlain by late Proterozoic beds.

In the southern part of the Amadeus Basin and north of the Precambrian Musgrave-Mann complex, gravity data indicate another downwarp in the general basin structure under the area of the 'Ayers

Rock Gravity Depression' (Lonsdale & Flavelle, 1963). Recent seismic work by private companies in the KULGERA 1:250 000 Sheet area indicates the presence of warped sediments of considerable thickness (Webb, pers. comm. 1964).

OIL POTENTIALITY

In the Amadeus Basin, potential source beds of hydrocarbons occur in the form of marine shale of substantial thickness together with foetid limestone and dolomite, rich in organic content. These beds are interlaced with porous sandstones of various age. Structurally the presence of evaporites in the Amadeus Basin has facilitated the development of doming and warping of the sediments to provide potential oil and gas traps.

A favourable factor is the great thickness of both source beds and reservoir beds. Major unconformities are absent in the sedimentary column from Upper Proterozoic to Ordovician time. No volcanic activity has occurred during or after deposition.

The preservation of hydrocarbons could have been adversely affected by shallow water conditions predominating during the period of sedimentation over much of the Amadeus Basin. The great age of the prospective source formations can also be considered as an unfavourable factor. No natural oil seeps of major significance have been reported from the Amadeus Basin. The location of a possible oil seep is known from the eastern bank of the Finke River four miles northwest of Hermannsburg Mission. It has been explained that the occurrence of oil seepages would be unlikely in the Amadeus Basin region because of the relatively old land surface, which dates back to Mesozoic time (McNaughton, 1962). The extreme depth of the water-table complete with the elevation and aridity of the region would also inhibit escape of natural hydrocarbons to the surface (Sprigg, 1964).

During 1963 a shallow core hole sunk by BMR in the Johnnys Creek area near Mereenie (Plate 2) intersected an oil-bearing sandstone in the 652 to 675 ft interval. In this bore, which was drilled in the search for phosphate, residual hydrocarbons were present in occasional fractures down to the total depth of 918 ft. Bores recently drilled by Exoil NL in a formout agreement with Magellan Petroleum Corp. are tabulated in Table 2.

From Ooraminna No. 1 (Plate 7) a significant but non-commercial flow of petroliferous gas was obtained from a thin limestone bed of the Areyonga Formation between 3768 to 3784 ft. During 1963, Alice No. 1 encountered black asphaltic oil in dolomitic sand at 3510 to 3520 ft; from

TABLE 2: BORES DRILLED IN SEARCH FOR OIL IN THE AMADEUS BASIN, 1963-64

NAME	YEAR WHEN COMPLETED	TOTAL DEPTH (ft)
Ooraminna No. 1	1962	6107
Alice No. 1	1963	7520
Mereenie No. 1 (gas discovery bore)	1963	3983
East Mereenie No. 1 (gas producer)	1964	4710

6116 to 6137 ft, oil-bleeding cores were recovered. This oil occurs in a dolomite of the Jay Creek Formation.

Natural gas in major quantities flowed for the first time in the Amadeus Basin from Mereenie No. 1, 140 miles west-southwest of Alice Springs. In this bore gas shows were almost continuously encountered in the Stairway Sandstone from 2600 to 4000 ft. During a stabilized open-flow test, gas flowed from this bore at the rate of 11 million cubic feet a day.

By the time when this report was written, East Mereenie No. 1 was completed as a gas producer at a total depth of 4710 ft. This bore produced gas at the rate of 30 million cubic feet a day from the 3580 to 4710 ft interval, accompanied by 120 barrels a day of condensate. This production was obtained from the Stairway Sandstone, Horn Valley Formation, and Pacoota Sandstone.

3. PREVIOUS SURVEYS

During 1951, gravity-meter readings were made by Sydney University geophysicists on a traverse connecting Tennant Creek (N.T.) via Alice Springs with Oodnadatta in South Australia. From Alice Springs gravity traverses were also established southwest as far as Erldunda and westwards to Ayers Rock. Large negative anomalies were measured south and southwest of Alice Springs (Marshall & Narain, 1954).

As a prelude to BMR's combined geological and gravity reconnaissance of the eastern Canning Basin (Veevers & Wells, 1961), a gravity tie was made in 1957 between BMR Pendulum Station No. 35 south of Alice Springs and the Meteorological Observatory at Giles (Western Australia). This survey followed the road from Alice Springs to Mount Cavenagh and thence the track along the Northern Territory and South Australia border (Neumann, unpublished). As a result of this survey the existence of a prominent gravity 'low' south of Alice Springs was confirmed and a second 'low' of similar magnitude was traversed in the southern part of the Amadeus Basin. This anomaly was more completely investigated during the Bureau's 1962 reconnaissance helicopter gravity survey over the Amadeus Basin and South Canning Basin (Lonsdale & Flavelle, 1963). This southern gravity 'low' is now known as the 'Ayers Rock Gravity Depression'.

During 1959 a ground reconnaissance gravity survey was made by BMR extending from Queensland westwards across the Georgina Basin and ending at the Alice Springs Pendulum Station. The purpose was to establish a network of ground traverses providing altitude and gravity control stations in advance of helicopter coverage (B.C. Barlow, unpublished). At the conclusion of that survey the detailed gravity work in the Alice Springs area was carried out by Barlow and the writer.

During the period December 1960 to July 1961, gravity reconnaissance was carried out in support of geological mapping over portions of the Amadeus Basin by International Resource Surveys Incorporated on behalf of Magellan Petroleum Corporation. This work included gravity traverses in the area of the Ooraminna Anticline. The data obtained are shown in Plate 3.

A reconnaissance gravity survey using helicopters for transport was conducted by BMR during 1961 in the area of the ALICE SPRINGS, RODINGA, FINKE, HERMANNSBURG, HENBURY, and KULGERA 1:250 000 Sheet areas (Langron, 1962a); the gravity stations are shown in Plate 3.

The results of a seismic survey, carried out by BMR during 1962 in the Ooraminna area were evaluated at the time when this report was written (Moss, unpublished). During 1963 a supplemental reflection seismic survey was made by Namco International Incorporated on behalf of the Exoil Company in the area of the 'Alice Prospect' southeast of Alice Springs (Namco International, 1963).

4. OBJECTIVES OF THE SURVEYS

(i) Ooraminna survey

The 1961 gravity reconnaissance survey by International Resource Surveys Incorporated showed the superposition of a gravity anomaly due to local geological structure upon the regional gravity field caused by the much larger structure of the Amadeus Basin as a whole.

In more detail the results of this first survey indicate the occurrence of a local gravity 'low' somewhere near the axis of the Ooraminna fold. With this information at hand, the main objectives of BMR's 1961-62 gravity work were:

Firstly a denser coverage by a network of gravity traverses was required to provide more closely spaced data for contouring and anomaly evaluation.

Secondly it was considered desirable to determine more accurately the regional gravity gradient which obscures the gravity effect caused by local structure. With the regional gradient removed it could be expected to obtain a more reliable picture of the magnitude and the type of the local gravity anomaly.

Thirdly it was intended to generally investigate the value of gravity data for elucidation of diapiric structure. The Ooraminna Anticline was considered a useful example for this particular purpose (the existence of a salt core was later confirmed by drilling).

(ii) Alice Springs survey

The geological problem in the area south of Alice Springs is posed by the repetition of the Heavitree Quartzite, obviously caused by a complex system of faulting and/or thrusting. This situation can be briefly described as follows: Immediately south of the Alice Springs 'Town Basin' an arcuate topographic ridge, the Mount Gillen Arch (Joklik, 1955), is formed by Heavitree Quartzite outcrops which occur on either side of the Heavitree Gap (Plates 4, 5). The quartzite dips south at 40 to 50 degrees. A second outcrop of Heavitree Quartzite occurs approximately two miles south of the Heavitree Gap, mainly in the area west of the Alice Springs to Port Augusta railway line. An isolated hill, Mount Blatherskite, forms the eastern extension of the main outcrops east of the railway track and main road. At this locality the southerly dips in the quartzite range from 70 to 80 degrees. Bitter Springs Limestone and a ridge of Archaean basement rocks occur between the two Heavitree Quartzite outcrops mentioned (Scanvic, 1961).

As the position of a fault or thrust-plane is not known two theories have been offered. The first is that the southern part of the Heavitree Quartzite is thrust upon the northern outcrop of the quartzite on a thrust-plane dipping south (Jones, 1962). The second includes the suggestion that a north-dipping normal fault has caused the repetition in the beds (Scanvic, 1961). Consequently the purpose of the Alice Springs gravity survey was:

Firstly to measure in detail Bouguer anomalies in the vicinity of the older rock outcrops and to determine local gravity features in relation to the regional gravity anomaly map derived from the gravity work already accomplished.

Secondly to evaluate the more detailed gravity data in relation to known geology in order to examine the possible nature of the tectonic junction between the two Heavitree Quartzite outcrops mentioned.

5. FIELD PROCEDURE AND REDUCTIONS

Ooraminna survey procedure

Gravity readings in the Ooraminna area were made at seismic shot holes. A survey party provided by the Commonwealth Department of the Interior applied the conventional level and staff method for altitude control and surveyed the shot-holes at quarter-mile separation. Gravity-meter readings in the field were performed after the end of BMR's 1961 Amadeus Basin reconnaissance gravity survey using helicopters (Langron, 1962a, b). The field work commenced on the traverse near Mount Polhill and on the traverse connecting Ooraminna Station with Deep Well. During October 1962, the remaining gravity readings were completed after the conclusion of BMR's 1962 reconnaissance gravity survey using helicopters in the South Canning Basin and Amadeus Basin (Lonsdale & Flavelle, 1963).

Details of the field work, the equipment used, and the performance of the instruments are given in Appendix A.

The positions of the traverses at Ooraminna are in Plate 3 together with the gravity stations established in the map area during BMR's 1962 reconnaissance helicopter gravity survey (Langron, 1962a). Also shown in Plate 3 are the gravity traverses surveyed by International Resource Surveys Incorporated during 1961.

Alice Springs survey procedure

The Alice Springs detailed survey was carried out at the conclusion of BMR's 1959 reconnaissance gravity survey in the Georgina Basin. One traverse extends from Alice Springs township south through Heavitree Gap along the main road to the civil aerodrome, and a second traverse follows the road to Amoonguna on the northern side of the Todd River. The majority of the gravity stations was sited at benchmarks 20 chains apart, established by the Department of the Interior, Alice Springs. A number of stations occupied between the benchmarks were barometrically levelled.

Reductions

For each gravity station the meter readings were corrected for instrument drift by using the results of repeated observations in order to control the time-drift of the instruments used. The drift-corrected data were then converted into milligals by using the appropriate scale factor.

The observed gravity value of 978,653.6 mGal determined at the Bureau's Pendulum Station No. 35 (Dooley and others, 1961) was used as a gravity datum in order to refer the relative readings taken in the field to the international system.

The results of the gravity surveys have been represented in the form of Bouguer anomaly contour plans. The resulting anomaly contour patterns are shown in Plates 3 and 5. For the calculation of Bouguer anomaly values an average rock density of 2.2 g/cm^3 was adopted.

In order to sort out local anomalies caused by structural features nearer to the surface, residual gravity reductions were applied for the stations observed on outcrops of older rocks near the axis of the Ooraminna Anticline (Plate 6). The residual gravity anomalies were determined by the method described by Griffin (1949). This method defines the regional gravity anomaly at a chosen point as the average value of gravity on the periphery of a circle, the 'averaging circle', centred on that point. By subtracting the regional value thus determined from the actual value of gravity measured, the residual gravity anomaly at that point is found.

With an averaging circle of small radius, the residual gravity pattern demonstrates correspondingly small local anomalies. As the radius increases, more widespread anomalies are recorded.

In the case of the Ooraminna Anticline (Plate 6) a radius slightly larger than three miles was considered appropriate for the averaging circle. Mathematical detail concerning the Griffin residual gravity reduction method are referred to in APPENDIX B.

6. ROCK DENSITIES

The availability of rock density data is important for the purpose of gravity anomaly interpretation. In the Amadeus Basin, rock densities have been determined at random on surface specimens collected from outcrops. Naturally this method lacks systematic planning and does not provide reliable average densities typical for the whole of any particular geological formation. This fact must be considered in connexion with surface specimen densities tabulated in Table 3.

Bores drilled in the Amadeus Basin area have been used to obtain density data from cores recovered at various depths. These bores were drilled by the Water Resources Branch in shallow groundwater basins near Alice Springs. Core density information is also available from two of the deeper bores, Alice No. 1 and the Ooraminna No. 1, sunk by Exoil.

Density data obtained from bore cores (Tables 4, 5 and 6)., is probably more reliable because outcropping beds are exposed to chemical and/or mechanical weathering and have been subjected to alterations of their physical properties.

From all the available information, an average density of 2.6 g/cm^3 has been adopted as the most likely value relating to the whole column of sediments in the eastern portion of the Amadeus Basin. The composition of the underlying basement rocks is not known, but huge masses of granite crop out along the northern margin of the Amadeus Basin, as e.g. in the northwestern portion of MOUNT LIEBIG 1:250 000 Sheet area (Plate 2). Granite of density 2.65 might also form a major portion of the complex of basement rocks below the sediments in the Alice Springs and Ooraminna area. If so, the density contrast between basement and sediments would be small.

TABLE 3: DENSITIES OF SPECIMENS COLLECTED FROM OUTCROPS, AMADEUS BASIN

ROCK TYPE	FORMATION	LOCALITY	DENSITY g/cm^3
sandstone	Pertnjara	Arumbera Creek area	2.30
"	Mereenie	"	2.16
black foetid limestone	Horn Valley	Mereenie Bluff Section Mt Liebig Sheet	*2.64
limestone	"	Gosses Bluff area	2.70
sandstone	"	"	2.45
"	"	Arumbera Creek area	2.52
dense sandstone	Pacoota Sandstone	"	2.45
limestone with refinery odour	Jay Creek	Jay Creek area	2.61
limestone	"	Mt Peachy	2.84
"	"	Ooraminna structure	*2.56
sandstone	Pertaoorrta	Arumbera Creek area	2.26
quartzitic sandstone	Arumbera	"	2.38
limestone	"	East Areyonga	*2.73
medium-grained band sandstone	Pertatataka	Twin Bore Anticline	2.11
limestone	"	Alalgara Yard	*2.68
"	"	Todd River Anticline	*2.79
medium-grained friable sandstone	Areyonga	Twin Bore Anticline	2.40
limestone	"	East Areyonga	*2.70
"	Bitter Springs	Govt Bore No. 4, Rodinga Sheet	2.69
"	"	Love Creek Road east of Undoolya Bore	2.23
quartzite	Heavitree Quartzite	Arumbera Creek area	2.61

<u>Note</u>: Specimens used for density determination were collected in the field by geologists of Frome-Broken Hill Company and Magellan Petroleum Corporation during 1958 and 1961-62. Densities prefixed with an asterisk are mean values obtained from testing of more than one specimen. The densities were determined either at BMR's Petroleum Technology Laboratory, Canberra, or at the Geophysical Laboratory, Footscray.

TABLE 4: DENSITIES OF CORES FROM ALICE SPRINGS WATER BORES

ROCK TYPE	FORMATION	DENSITY (g/cm^3)	DEPTH (ft)
fine-grained silty quartz sandstone	Pertnjara	2.25	740
medium to fine-grained quartz sandstone	Mereenie	*2.05	288 to 713
cherty dolomitic limestone	Bitter Springs	2.56	75

<u>Note</u>: Specimens tabulated were collected by the Resident Geologist, Alice Springs. Densities were determined at BMR's Petroleum Technology Laboratory, Canberra. The density value prefixed with an asterisk is the mean value from testing of ten bore cores from several bores.

TABLE 5: DENSITIES OF CORES FROM ALICE NO. 1 WELL

CORE NO.	DEPTH (ft)	LITHOLOGY	FORMATION	DENSITY g/cm^3
1	520	sandstone	PERTNJARA	*2.31
2	826	"		2.09
3	1124	sandstone	MEREENIE	*2.15
4	1430	"		2.44
5	1764	"		2.38
6	2153	sandstone	PACOOTA	2.24
7	2712	"		2.31
8	2977	siliceous sandstone	GOYDER	2.54
9	3125 to 3129	" "		2.50
10	3412	" "		2.55
11	3587	shale		2.50
12	3889	limestone	JAY CREEK	2.66
14	4193	"		2.67
15	4527	"		2.69
16	4845	"		2.68
17	5167 to 5173	"		*2.64
18	5455	red brown calcareous shale		*2.69
19	5723	" "		2.61
20	6064	limestone		2.77
21	6096 to 6098	"		*2.78
22	6118	marly limestone		2.74
23	6133	calcareous shale		2.77
24	6443	dolomitic limestone		2.82
25	6760 to 6762	limestone		2.47
26	6880	halite		2.21

CORE NO.	DEPTH (ft)	LITHOLOGY	FORMATION	DENSITY g/cm^3
27	7305	red brown calcareous shale	ARUMBERA	2.65
28	7518 to 7520	calcareous shale		*2.68

Note: Densities were determined at BMR's Petroleum Technological Laboratory, Canberra. Densities prefixed with an asterisk are mean values obtained from testing of more than one specimen. 'Bulk dry density' is shown. Geology after Webb (1964).

TABLE 6: DENSITIES OF CORES FROM OORAMINNA NO. 1 WELL

CORE NO.	DEPTH (ft)	LITHOLOGY	FORMATION	DENSITY g/cm^3
1	270	quartzitic sandstone	ARUMBERA	2.56
2	609	calcareous "		2.34
3	713	ferruginous siltstone		2.62
4	847	" "		2.58
5	1357	" sandstone		2.13
6	1570	dolomite	PERTATATAKA	2.71
7	2056	shale		2.66
8	2357	"		2.67
9	2704	"		2.63
11	3443	"		2.69
13	3921	shale	AREYONGA	2.67
15	4433	ferruginous mudstone		2.72
16	4649	dolomitic siltstone	BITTER SPRINGS	2.93
17	4939 to 4941	limestone		2.67
18	5223	ferruginous siltstone		2.79
20	5881	shale		2.78
21	6007	halite with clay inclusions		2.16

Note: Specimens were selected by Exoil N.L., and densities were determined at BMR's Petroleum Technological Laboratory, Canberra. 'Bulk dry density' is shown. Geology after Webb (1964).

Generally the rock density data show that sandstones are relatively low in density. They become denser with increasing age, e.g. post-Ordovician sandstone = 2.2 g/cm^3, Arumbera Sandstone = 2.38 g/cm^3, and Heavitree Quartzite = 2.61 g/cm^3. Specimens collected from Horn Valley Sandstone outcrops give relatively high densities from 2.45 to 2.52 g/cm^3. The tabulated data show that limestone is generally denser than sandstone. The following figures have been estimated to be the most appropriate ones for mean densities in the Alice Springs and Ooraminna areas:

Post-Ordovician beds	...... 2.21 g/cm^3
Ordovician "	...... 2.40
Cambrian "	...... 2.6 to 2.7
Upper Proterozoic beds, excepting halite	...... 2.72
Upper Proterozoic halite	...... 2.20

7. INTERPRETATION OF RESULTS

Ooraminna structure

In Plate 7 Bouguer anomaly and residual gravity curves are superimposed on geological cross-section B-B' through the Ooraminna Anticline. Geology known from outcrops and airphoto interpretation has been used together with the depth data from Ooraminna No. 1 well (Webb, 1964) to estimate the probable dips of the folded beds and the thickness of the various formations in the anticlinal fold.

Gravity data obtained along the section line B-B' indicate quite clearly the presence of three different types of components contained in the gravity curve measured, namely:

(a) A regional gravity gradient.

(b) Two residual gravity 'highs', one on each side of the anticline.

(c) A residual gravity 'low' near the crest of the structure.

On the three gravity anomaly components mentioned the following comment is offered:

(a) The regional gravity gradient of one milligal per mile, negative to the northwest, is sufficiently explained by the gross structure of the Amadeus Basin.

(b) When this gradient (a) is removed, a residual gravity curve results, which in cross-section B-B' discloses two residual 'highs'. One occurs on the northern flank of the anticline (+2.5 mGal) and the other (+4 mGal) is on the southern side of the anticline. The contour plan (Plate 6) shows that farther away from the section-line, the residual gravity anomaly is most likely crescent shaped, as it follows the outcrops of the Pacoota Sandstone. Additional station coverage south of Station No. 990 (Plate 6) is required to supplement the residual gravity contour pattern on the southwestern portion of the Ooraminna structure.

(c) The magnitude of the residual gravity 'low' centrally located between the residually 'high' values can be approximately determined by extending from either side of the 'low' an arcuate line across the central anomaly. This procedure leads to the suggestion of a 7.5 mGal negative gravity variation, obviously caused by a geological body of low density, at depth underneath the centre of the residual gravity 'low'. The dimensions of this body can be determined theoretically by using a formula from Dobrin (1952) whereby a theoretical cylindrical body can be suggested which could produce the negative residual anomaly under review.

Assuming that the body that causes the 'low' is cylindrical and has a density contrast of 0.5 g/cm^3, this theoretical cylinder would have the following dimensions:

diameter	14,000 feet
height	5,000 "
depth to top of cylinder	6,000 "

Layers of salt and gypsum contained in the Bitter Springs Formation were intersected in Ooraminna No. 1, which ended at a total depth of 6107 ft in finely fissured, reddish salt containing small clay inclusions. Consequently the suggested density contrast of 0.5 g/cm^3 between the cylinder and the denser beds surrounding it, can be related to measured rock densities, viz. those of Bitter Springs Limestone

(2.7 g/cm^3) and halite (2.2 g/cm^3).

The relative position of the low density cylinder is shown in cross-section B-B' (Plate 7). This theoretical position and the dimensions of the cylinder fit reasonably well with the known geological facts. Consequently the low density cylinder postulated from the analysis of the residual gravity curve can be suggested to correspond to a geological body of similar dimensions composed of rock salt. It can be concluded that this salt mass was originally deposited as a bedded layer within a sequence of evaporites. Initial tectonic stress was caused by orogenic movements referred to earlier. This caused lateral flowage within these evaporites, facilitated by the plasticity of rock salt. Finally the original salt layer was deformed into a diapiric mass, which now forms the inner core of the Ooraminna Anticline. Geology based on outcrops shows that this fold is slightly asymmetrical, with a steeper southern limb (McNaughton, 1962). According to the cylindrical model, the thickness of the formations contained in the Ooraminna structure from the surface to the bottom of the rock salt is approximately 11,000 ft.

Tectonic setting south of Alice Springs

The results of the Alice Springs detailed gravity survey are shown as Bouguer anomaly contours in Plate 5. A much denser coverage by gravity stations would be required in order to draw a more reliable gravity contour pattern and more accurately correlate gravity features with the main geological features known from outcrops. The contouring in Plate 5 is an attempt to integrate the results of the detailed Alice Springs work into the more important anomaly trends established by the Bureau's regional gravity work.

Considering the gravity picture as a whole, higher readings are related to outcropping ridges of older rocks: metamorphic basement rocks, Heavitree Quartzite, Bitter Springs Limestone, and Arumbera Greywacke. On the other hand, three areas of relatively low gravity anomaly are obviously related to the low topography of the Alice Springs Town Basin, the Emily Plain, and the western extension of the 'Farm Area' south of Heavitree Gap.

Plate 5 also shows some results of BMR's 1956 seismic investigations for a water supply (Dyson & Wiebenga, 1957). The seismic soundings indicated shallow basement rocks in the area of the Alice Springs Town Basin and in the 'Farm Area' south of Heavitree Gap.

The Alice Springs Town Basin is a small alluvial basin excavated by fluvial erosion. It contains a maximum thickness of 75 ft of fluviatile Pleistocene and Recent sediments deposited by the Todd and Charles Rivers (Quinlan & Woolley, 1962). In the 'Farm Area' between Heavitree Gap and Mount Blatherskite, freshwater sediments occur which range in age from Cretaceous to Quaternary.

On Traverse QR near station 4600 ft of the seismic survey a small fault has been seismically located. Farther southeast between this fault and point R a relatively shallow portion of a buried ridge of older rocks is indicated in the two refraction profiles QR and XY. This ridge forms in some way an extension of the faulted and broken-up ridge which extends west and east of the Mount Blatherskite area. Cross-faulting perpendicular to the regional geological strike direction along the Mount Blatherskite Range has been suggested by Quinlan (1957). South of the buried ridge referred to above, seismic profile XY shows the thickness of the younger sediments increasing, with a channel-like depression in the underlying basement rocks near the southern end of this traverse.

There is a general agreement between the Bouguer anomaly curve measured and the seismic results on the basement ridge of the Mount Blathersk te area, as gravity readings are highest near point R, where basement rocks come nearest to the surface. However, the variation in gravity is obviously too large to be explained by the density contrast between the shallow and relatively thin low-density beds of Recent age and the underlying denser basement rocks. A similar conclusion is reached in respect of the Alice Springs Town Basin area, where a gravity low of at least two milligals was measured. However, this low appears to be elongated east-southeast, though more gravity data would be required to obtain a more reliable contour picture covering its whole extent. As the axis of the Alice Springs Town Basin runs parallel to the course of the Todd River, no immediate relation can be recognized between the shallow river alluvials deposited by the Todd River and the gravity data available.

The results of the detailed gravity work in the Alice Springs area are shown in Plate 8 in relation to the regional Bouguer anomaly measured over a wider distance north and south of Alice Springs. Cross-section A-A' through Alice Springs has been chosen, in order to correlate gravity data and geology.

In the cross-section A-A' the presence of Heavitree Quartzite known from two outcrops is interpreted as caused by a thrust, as suggested by Jones (1962). According to this concept the southern part of the quartzite is raised and thrust upon the northern portion of the Heavitree Quartzite. Dip angles and geological boundaries are plotted as known from outcrops and from the interpretation of airphotos. The maximum thickness of sediments south of Alice Springs has been adopted as slightly more than 20 000 ft. Farther south along cross-section A-A' the thickness of the beds is shown as gradually decreasing to about 13 000 ft beneath the western extension of the Ooraminna structure. The beds continue to thin towards the southern margin of the basin, where formation outcrops from Bitter Springs Limestone to Pacoota Sandstone have been mapped.

An isolated occurrence of Bitter Springs Limestone in the area four miles east of Deep Well is shown in cross-section A-A' as being caused by a diapiric structure. This interpretation is based on the assumption that evaporites of low density are contained in the Bitter Springs Formation and that these beds become thicker in the area of low gravity readings east of Deep Well and south of Mount Brunonia (Plate 3) by penetrating the overlying beds.

From a consideration of the relatively high rock densities of the sediments in the eastern portion of the Amadeus Basin it is obvious that the density contrast between the bedded rock sequence and the underlying basement rocks can only be small. In actual fact, the Bouguer anomaly curve discloses very little gravity variation near the Alice Springs basin margin, where almost vertical-dipping sediments in contact with Archaean metamorphics must be expected to attain maximum thickness immediately south of the Macdonnell Range. Langron (1962a) found as a result of BMR's 1961 reconnaissance gravity work in the Amadeus Basin that the Macdonnell Ranges have no obvious expression in the gravity results. Farther north of the ranges the most prominent feature of the regional gravity anomaly map is a zone of steep gravity gradient which trends westerly across most of the ALICE SPRINGS Sheet area and extends farther west across the HERMANNSBURG, MOUNT LIEBIG, and MOUNG RENNIE Sheets. This prominent anomaly trend has a maximum gradient of 4.2 mGal per mile in cross-section A-A' (Plate 8) northwards from Alice Springs.

To explain this steep gravity gradient various interpretations have been offered. Langron (1962a) considers as a possible geological cause the occurrence of extensive movements in the Archaean rocks thrust upon sediments approximately 40 000 ft thick. Marshall & Narain (1954) have discussed the gravity effect of crustal warping in addition to a moderate gravity anomaly caused by the relatively small density contrast between sediments and basement rocks. They accept in the crust of the earth a density difference of 0.2 g/cm^3 between a sialic layer, ten kilometres thick, of density 2.67 g/cm^3, and an underlying simatic layer, 30 km thick, of density 2.87 g/cm^3 in addition to the density contrast of 0.45 g/cm^3 between the simatic layer mentioned and ultra-simatic material of density 3.32 g/cm^3, at the Mohorovicic Discontinuity. According to Marshall & Narain this sequence of layers would cause a negative anomaly of -90 mGal when the crust is down warped to about 10 000 ft.

In this report the attempt is made to approach the problem more simply; the large gravity gradient north of Alice Springs in relation to the gravity anomaly south of the Macdonnell Ranges is interpreted in terms of a two-layer model, illustrated in Plate 8.

As a first step the Bouguer anomaly curve has been modified by removing the gravity effect of the sediments south of the Macdonnell Ranges, adopting a density difference of 0.05 g/cm^3 between the sediments (2.62 g/cm^3) and the underlying granitic rocks (2.67 g/cm^3). This involves an increase of 12 mGal over the thickest section of the sediments south of Alice Springs, gradually decreasing south as the bedded strata are thinning in this direction.

The modified anomaly curve can now be considered as the expression of a gravity effect caused solely by density variations within the basement proper. It would be reasonable to accept that rock densities within the basement complex increase with depth. This assumption agrees with Marshall's & Narain's concept of a sialic or granitic layer 10 km thick, underlain by a somewhat denser layer of simatic rocks.

As the modified gravity curve shows the anomaly south of the Macdonnell Ranges considerably higher than that in the area north of Alice Springs, the negative gravity anomaly measured in the Alice Springs Town Basin area would become even more significant as a relative gravity 'low'.

In principle the modified Bouguer anomaly curve would be explained by assuming basement rocks of higher density in a raised position south of the Macdonnell Ranges. In terms of tectonics this assumption corresponds to the concept of a thrust associated with a high-angle thrust plane dipping south, as offered by Jones (1962).

Naturally more complete gravity data, would probably clarify the complex tectonics, which near Alice Springs control the contact between sediments and basement rocks along the northern margin of the Amadeus Basin. In this connection it should be mentioned that cross-faulting in the older rocks exposed along the Mount Blatherskite ridge has been suggested to be mainly north-northwest (Quinlan, 1957). However, the steep gravity gradient southwest of Mount Blatherskite and west of the Emily Plain, if confirmed by additional gravity data, can be interpreted as the expression of a major cross-fault running north-northeast. This suggested fault possibly forms the eastward termination of the outcrops of Arumbera Sandstone which occur at the Alice Springs to Port Augusta railway line.

8. CONCLUSIONS AND RECOMMENDATIONS

In the Ooraminna area the gravity readings on seismic traverses show the value of more detailed gravity data for the elucidation of geological structure. However, a regular grid of gravity stations distributed over the whole area of the survey would better serve the purpose of the gravity analysis by providing a more reliable gravity contour picture.

Residual gravity anomaly data were useful in determining more accurately the position at depth and the dimensions of the salt body, confirmed by drilling, which forms the inner core of the Ooraminna Anticline beneath a sequence of warped sediments.

In the Alice Springs area detailed gravity work along a few traverses has shown the importance of closely spaced gravity stations in order to investigate more completely the complex pattern of tectonics around the Heavitree Gap area. The geological concept of a high-angle thrust separating the two outcrops of Heavitree Quartzite is supported by gravity data available at this stage. Future gravity work should be conducted over the whole extent of the Mount Gillen Arch and should completely cover the outcrops of older rocks with stations preferably based on a regular grid pattern.

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APPENDIX 'A'

OORAMINNA SURVEY (1961-62)

Staff

1961 W.J. Langron, Senior Geophysicist.

1962 A.J. Flavelle, Geophysicist, Party Leader.
P. Campbell, Technical Assistant, Observer.
I.R. Thomas, Field Assistant.

Equipment

1961 Worden gravity-meter No. 61
Calibration factor 0.08994 mGal per dial division.

1962 Worden gravity-meter No. 169
Calibration factor 0.1058 mGal per dial division.

Calibration

The calibration factor of Worden instrument No. 61 was checked on the Alice Springs calibration range after the completion of the field work. Worden meter No. 169 was calibrated prior to the field work at the Melbourne calibration range between Brenock Park and Kallista and also at the calibration range established by BMR near Brisbane. The calibration factor used in computing Bouguer anomalies is the mean value obtained on the various calibration runs mentioned.

Gravity ties

A gravity tie was made between each traverse and the nearest convenient mile-post on the railway track. During 1962 these mile-posts were included in a gravity tie between the Alice Springs and Oodnadatta Pendulum Stations. In this manner all the gravity stations have been adjusted to the pendulum network.

Survey statistics

(a) Deep Well traverse and portion of Mount Polhill traverse .... 27 and 28 August 1961

(b) Seismic traverses G, GY, NX, N, and NW: .... 2 to 9 October 1962

Number of gravity stations completed, including the reoccupation of stations of earlier surveys for control purposes and tie to the Alice Springs Pendulum Station No. 35 .... 394 stations

Note

The Ooraminna gravity readings on seismic traverses were carried out in 1961 after the conclusion of BMR's reconnaissance gravity survey using helicopters over the eastern part of the Amadeus Basin (Langron, 1962a) and in 1962 after the end of the Amadeus Basin and South Canning Basin reconnaissance gravity survey using helicopters (Lonsdale & Flavelle, 1963).

Surveying method

Shot-points used as gravity stations were levelled on seismic traverses by the conventional level and staff method. A survey party was provided by the Lands and Survey Branch, Dept of the Interior, Canberra. All shot-point levels have been tied to the level datum of the Central Australian railway line.

ALICE SPRINGS SURVEY (1959)

Staff

B.C. Barlow, Geophysicist, Party Leader.

C. Bannermann, Mechanic.

(F.J.G. Neumann, Senior Geophysicist, participated in taking gravity-meter and barometer readings while visiting the party).

Equipment

Worden gravity-meter No. 260
Calibration factor 0.10802 mGal per dial division.

Calibration

The Worden instrument was calibrated prior to the field work and after the end of the field operations at BMR's calibration range between Brenock Park and Kallista near Melbourne (on 5 May 1959 and 11 January 1960).

Comment on performance

The performance of Worden No. 260 was satisfactory except for severe sticking on the stops. All stations were read twice to provide accurate drift control.

Gravity tie

A gravity tie was made to the Alice Springs Pendulum Station.

Surveying method

Stations of the Alice Springs detailed gravity survey were selected as near as possible to benchmarks surveyed by the Lands and Survey Branch of the Department of the Interior, stationed at Alice Springs. The altitudes of additional stations were barometrically determined by using two Askania micro-barometers (No. 562696 and No. 5112473).

For control purposes all the altitudes of the stations occupied near benchmarks were also experimentally levelled by using the two microbarometers mentioned. The performance of the micro-barometers was satisfactory.

Plotting

The positions of gravity stations established during the course of the Alice Springs survey were marked on the topographic base maps supplied by the Lands and Survey Branch.

Survey statistics

Commenced field work	...... 14 November 1959
Completed " "	...... 24 " 1959
Number of gravity stations completed, including the reoccupation of earlier survey stations and tie to Alice Springs Pendulum Station	...... 49 stations

Note:

The Alice Springs detailed gravity survey was carried out after the end of BMR's reconnaissance gravity survey conducted during 1959 in the area of the Georgina Basin of Queensland and Northern Territory.

APPENDIX 'B'

A. Residual gravity anomaly determination.

Various procedures are used in removing the regional gravity gradient from local anomaly features. The two main methods of residual gravity anomaly determination are:

(a) graphical

(b) grid methods.

Graphical methods are carried out by drawing smooth anomaly contours on any particular gravity map submitted to residual gravity interpretation. The smoothed-out lines are suggested to represent the regional gravity anomaly contour pattern with local irregularities omitted. The departure of a contour based on actually measured gravity values from the smoothed-out lines is taken to indicate the amount of the residual gravity anomaly. The resulting values are then used to draw a residual anomaly contour map relating only to local density variations. The reliability of the graphical methods depends mainly on the individual judgement of the interpretating person, whereas the grid methods, being mechanical, will produce consistent results.

Grid methods for residual gravity determinations may be divided into three groups:

(a) simple residual reduction methods (e.g. the Griffin method),

(b) second-derivative methods,

(c) polynomial trend approximation methods.

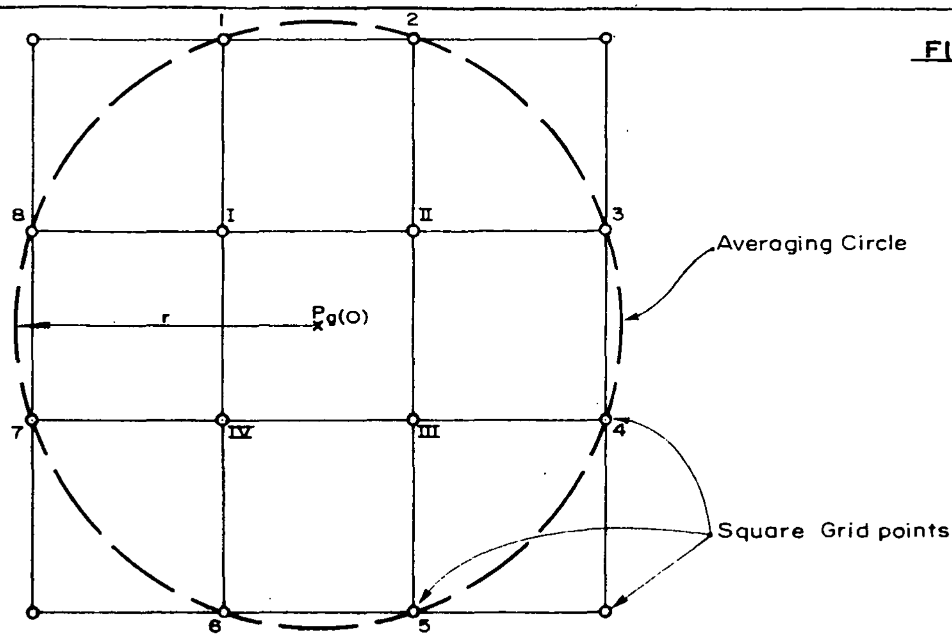
The Griffin Method was adopted in preference to the second-derivative and polynomial approximation methods, as it is simple and just as effective.

In the Griffin method, the regional gravity value at point P is the average of the values at every point on a circle of radius r, centred at P. In practice, the average is obtained from only eight grid points on the circle (Fig. 1), and these eight values must be interpolated from the measured values closest to the eight points. The residual gravity value is the measured value at P minus the regional value for P.

B. Gravitational effect of buried vertical cylinder

The case of a buried cylinder is illustrated in Fig. 2 (after Dobrin, 1952), the cylinder having a radius r and height L and its top surface being buried to a distance d.

FIG 1

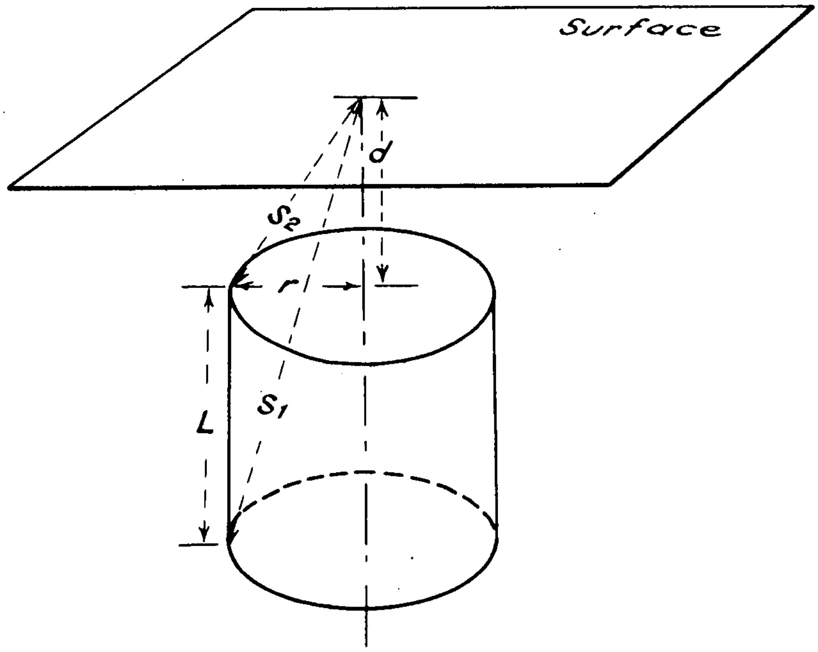


RESIDUAL GRAVITY ANOMALY DETERMINATION
according to Griffin (1949)

LEGEND

P	Reference point with actual gravity value g(o).
g(o)	Average of the gravity values at the 4 grid points I to IV.
r	Radius of the averaging circle
1 to 8	Grid points on averaging circle used to determine the regional gravity value $\bar{g}(r)$

Fig. 2



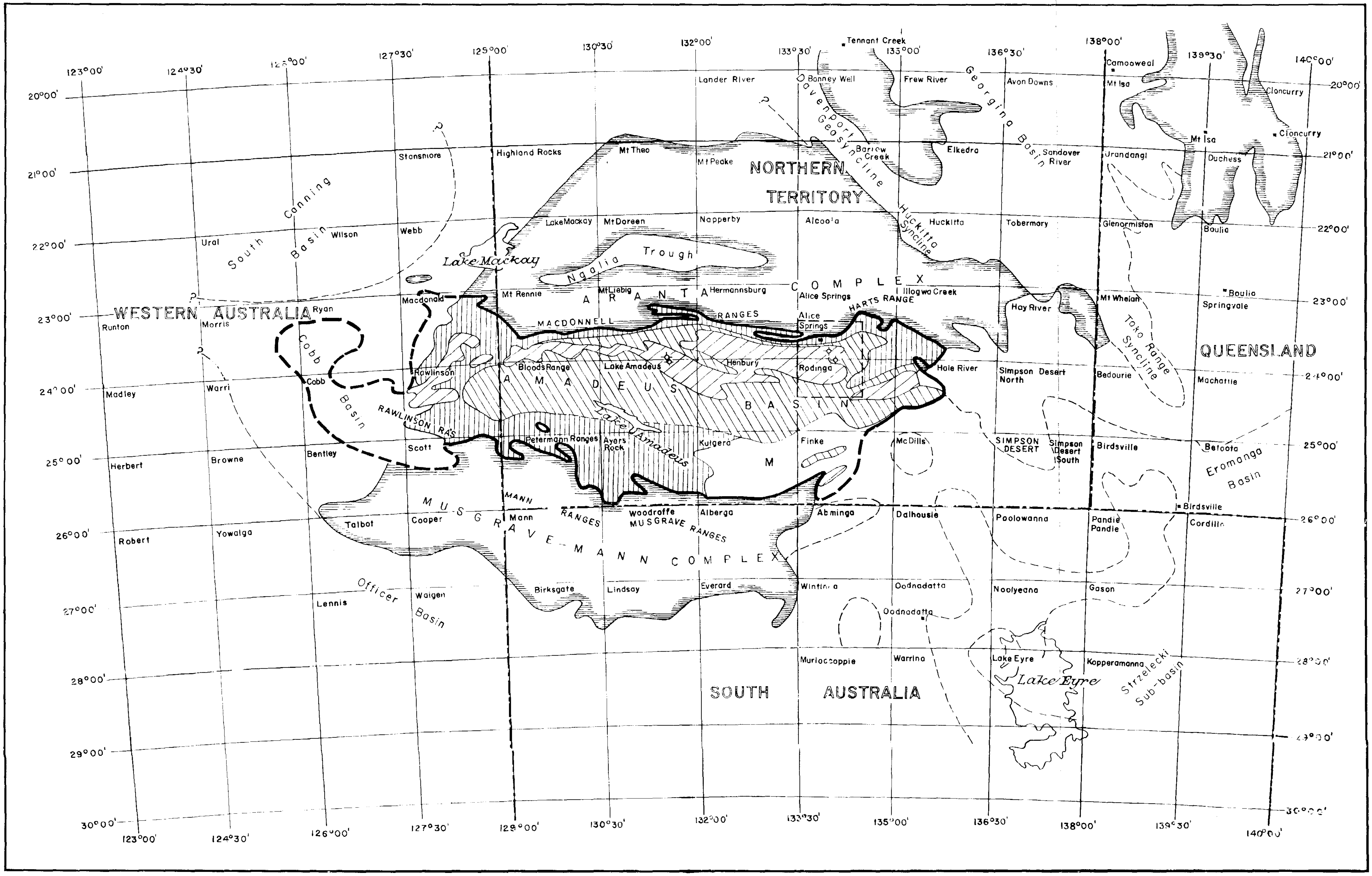
GRAVITY EFFECT
VERTICAL CYLINDER

(after M.B. Dobrin, 1952)

$$g_z = 12.77\,\sigma\,(L - S_1 + S_2)$$

- g_z = Gravity effect in milligals
- σ = Density contrast in g/cm³
- L = Height of cylinder
- S_1 = Distance from cylinder axis/surface intersection to cylinder bottom edge
- S_2 = Distance from cylinder axis/surface intersection to cylinder top edge
- d = Depth; surface to cylinder top
- r = Radius of cylinder

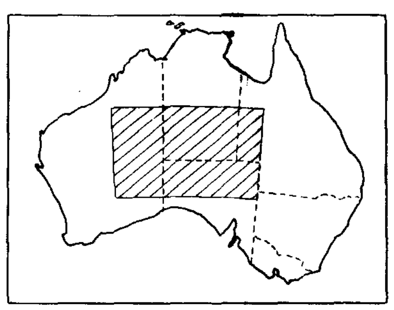
All distances in kilofeet



LEGEND

- M — Mesozoic
- Post-Ordovician
- Lower Palaeozoic
- Proterozoic
- Metamorphic basement exposed
- Shallow basement suggested from gravity data
- Amadeus Basin boundary
- Amadeus Basin boundary suggested from gravity data
- Area surveyed 1959/1962
- 1:250,000 map areas
- Bore

LOCATION DIAGRAM



ALICE SPRINGS - OORAMINNA SURVEYS, 1959 - 62

LOCALITY PLAN

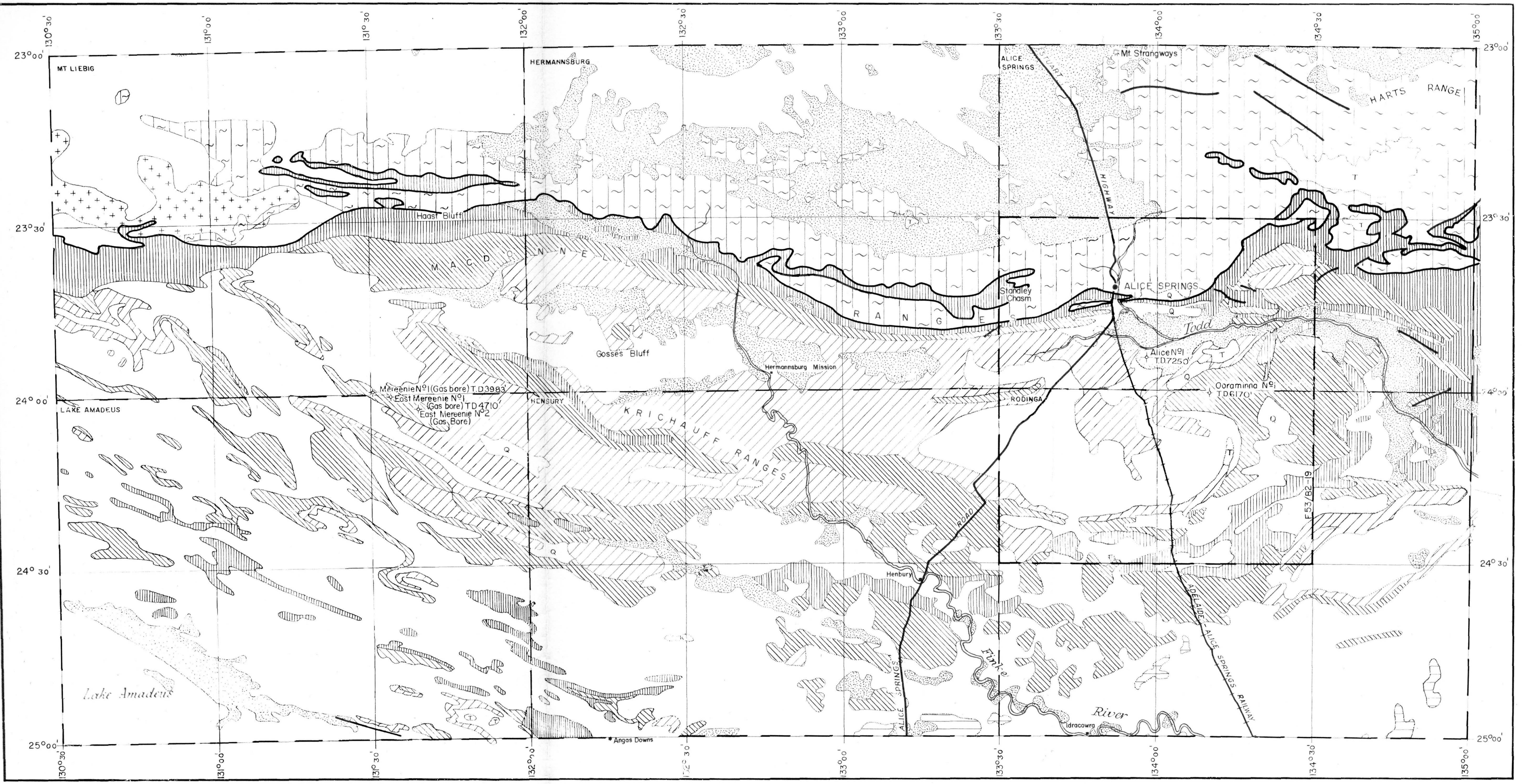
SCALE OF MILES

100 0 100 200 300

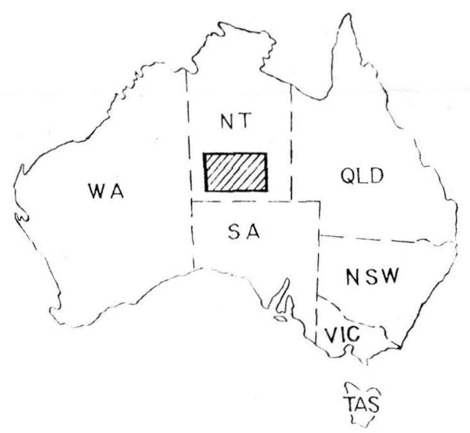
Reference: Map of Australia, National Mapping Division, 1956

TO ACCOMPANY RECORD NO. 1973/93

G53/B2-22



LOCATION



Geology after Quinlan (1962) with BMR photo-geological information added

LEGEND

- Q Quaternary
- Recent alluvium
- T Tertiary
- K Cretaceous
- Post-Ordovician
- Archaean/Proterozoic boundary
- Lower Palaeozoic
- Upper Proterozoic
- Granite
- Archaean Metamorphics
- 1:250,000 map area
- Bore

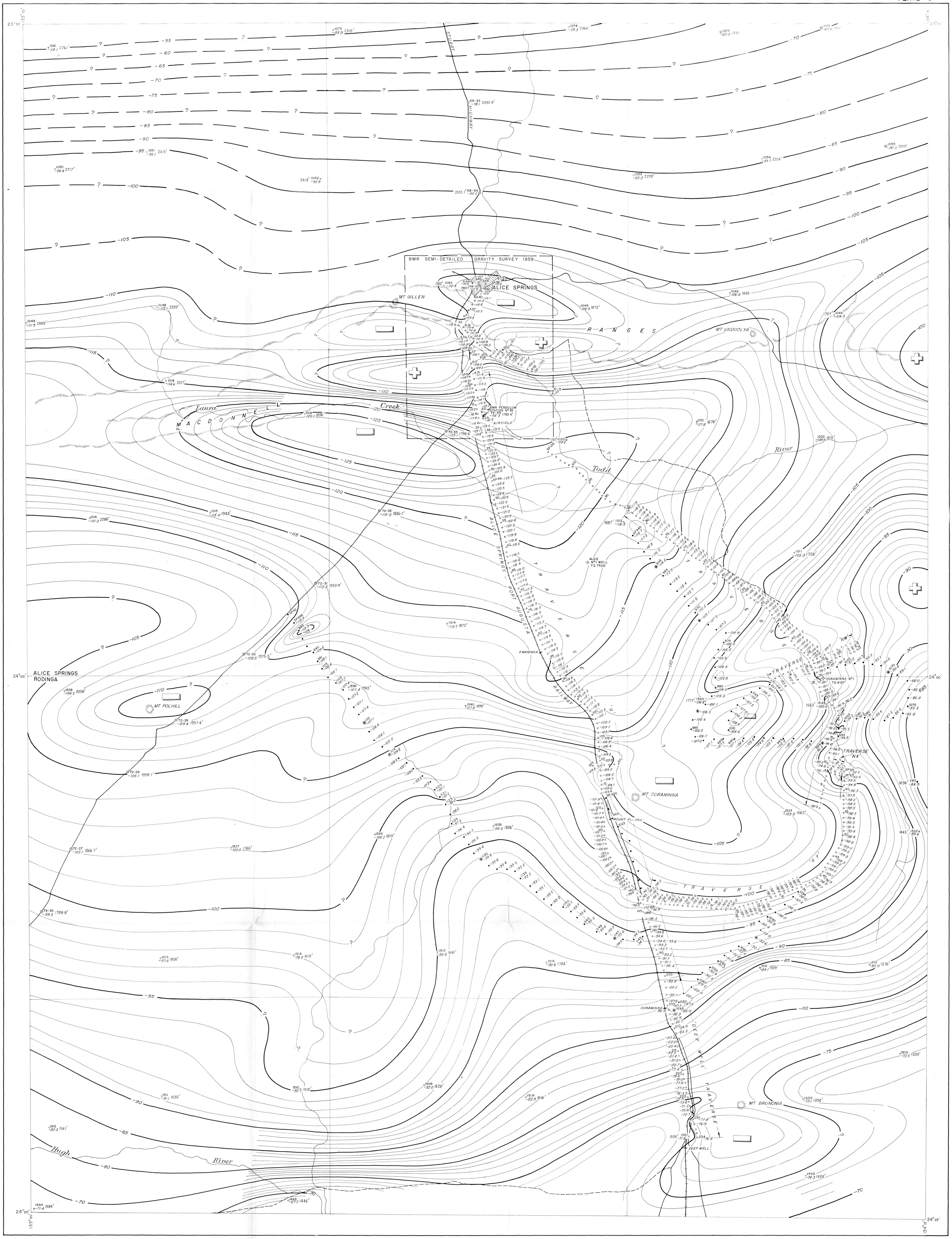
REGIONAL GEOLOGY

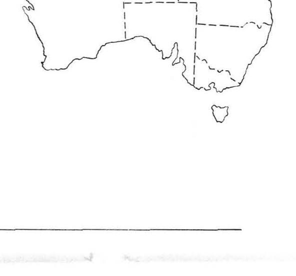
AMADEUS BASIN, (NORTH EASTERN AREA) NT

SCALE IN MILES
20 10 0 20 40 60

TO ACCOMPANY RECORD NO 1973/93

G53/B2-21





BMR gravity station
" " " permanently marked
Magellan gravity station
" " " permanently marked
Isogals, values in milligals
'High' anomaly
'Low' anomaly

Bouguer anomalies are based on the observed gravity value at BMR pendulum station: Nº 35 Alice Springs ..... 978,653·7 milligals

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

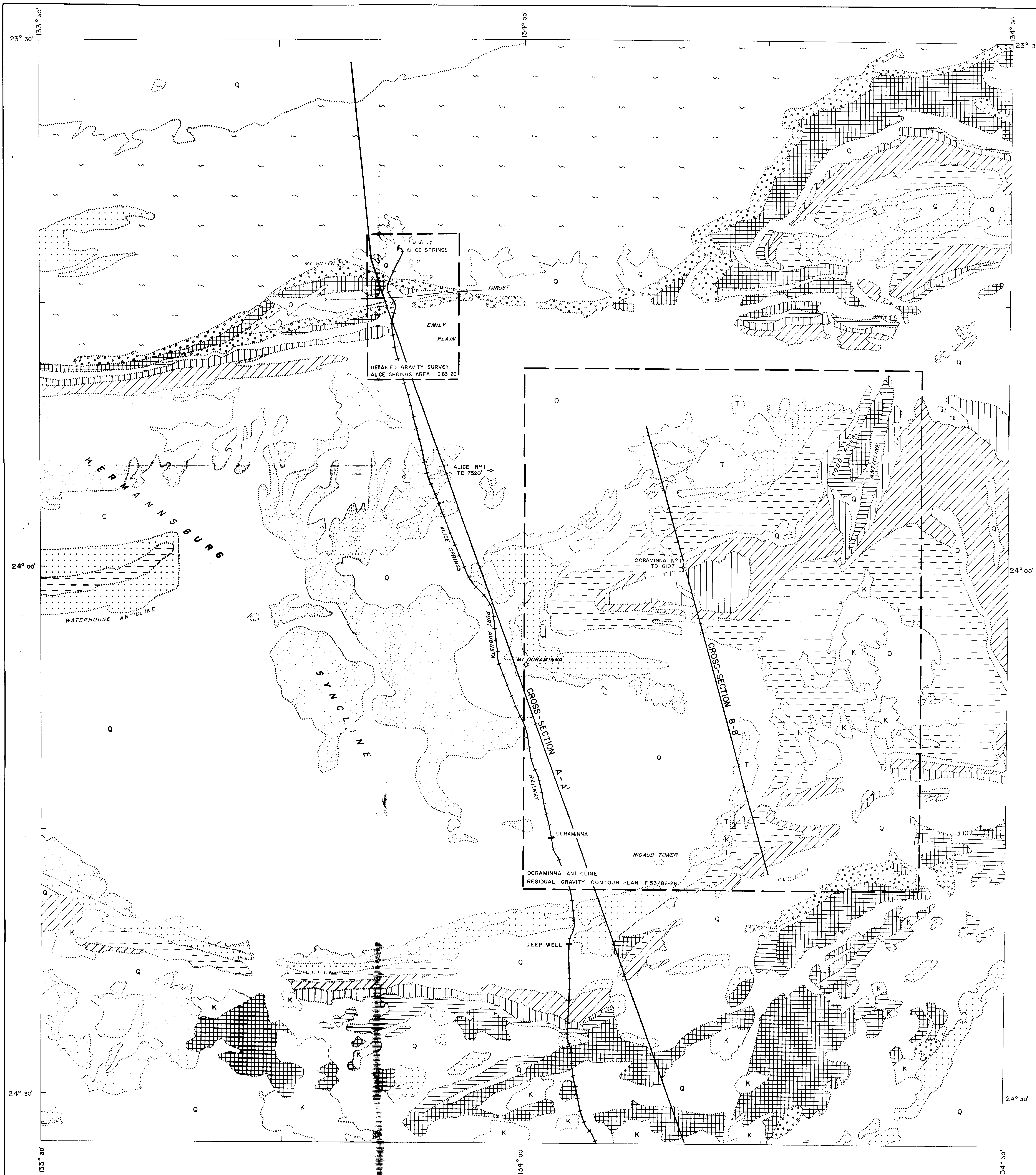
OORAMINNA-ALICE SPRINGS DETAILED GRAVITY SURVEY, 1959

AND GRAVITY READINGS ALONG SEISMIC TRAVERSES 1961-62

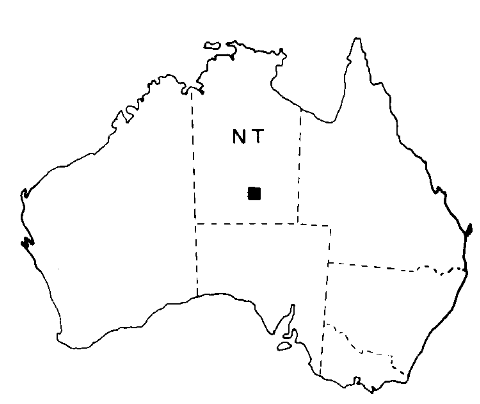
BOUGUER ANOMALIES

TO ACCOMPANY RECORD NO. 1973/93

F53/B2-27



LOCATION DIAGRAM



Geology after BMR 1:250,000
Photogeological maps Alice Springs and Rodinga

LEGEND

- Q — Quaternary — Cainozoic
- T — Tertiary — Cainozoic
- K — Cretaceous – Mesozoic
- Pertnjara – Upper Palaeozoic
- Mereenie – Post Ordovician — Lower Palaeozoic
- Pacoota – Ordovician — Lower Palaeozoic
- Pertaoorrta — Cambrian — Lower Palaeozoic
- Arumbera — Cambrian — Lower Palaeozoic
- Pertatataka — Upper Proterozoic
- Bitter Springs Formation — Upper Proterozoic
- Heavitree Quartzite — Upper Proterozoic
- Arunta Metamorphics – Archaean

GEOLOGY

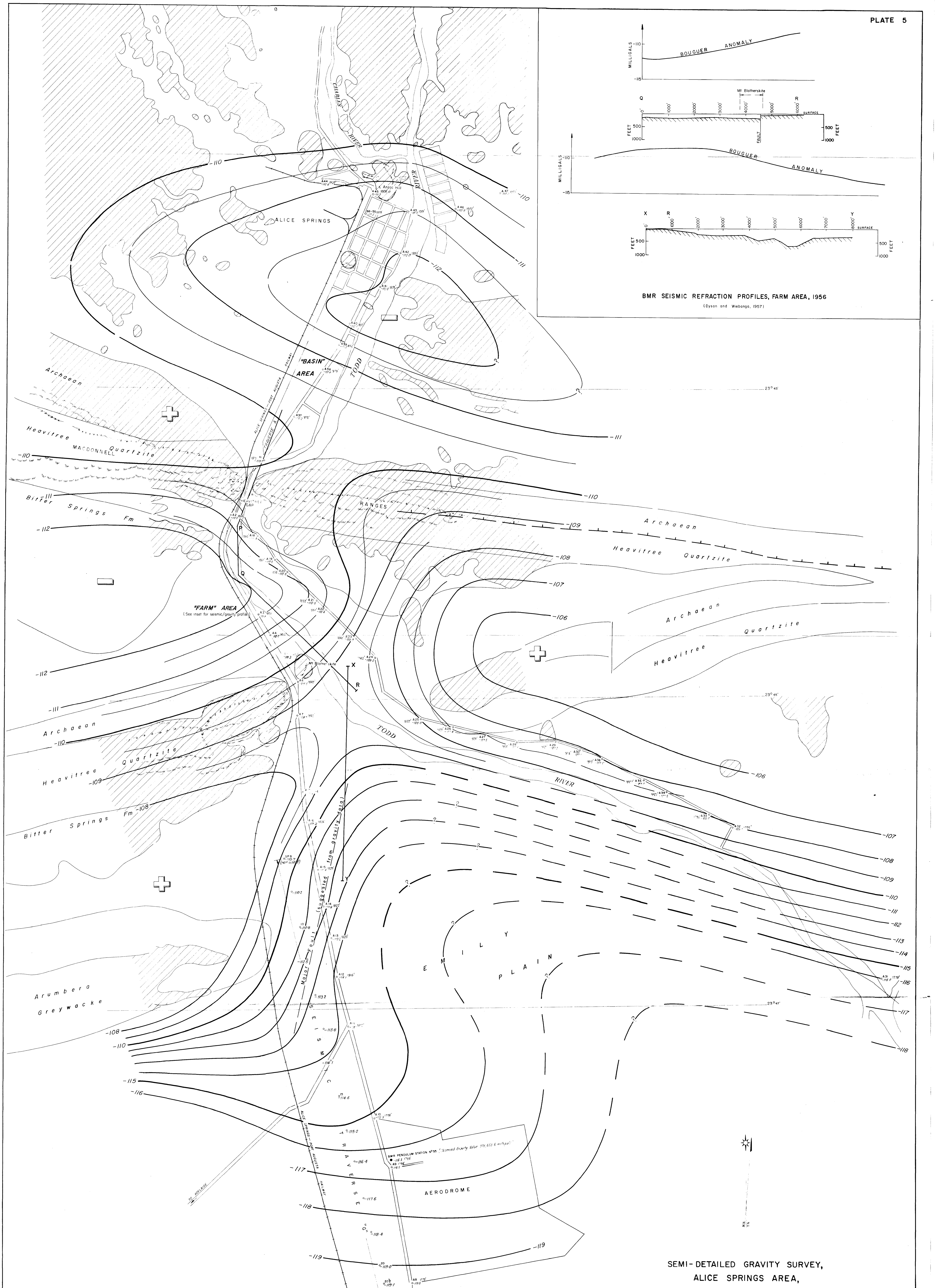
ALICE SPRINGS – OORAMINNA AREA

SCALE

MILES 5 0 5 10 15 20 MILES

TO ACCOMPANY RECORD NO. 1973/93

F53/B2-29



SEMI-DETAILED GRAVITY SURVEY, ALICE SPRINGS AREA, NORTHERN TERRITORY, 1959

BOUGUER ANOMALIES AND GEOLOGY

SCALE IN CHAINS

CONTOUR INTERVALS AS SHOWN

LEGEND

- GRAVITY STATION
- −116·5 BOUGUER ANOMALY (MILLIGALS)
- 1794' ELEVATION
- HIGH ANOMALY
- LOW ANOMALY
- BASEMENT ROCK OUTCROPS
- BMR SEISMIC TRAVERSE (1956)

EXPLANATION

RELATIVE BOUGUER ANOMALIES ARE BASED ON B.M.R. N°35 PENDULUM STATION.

FOR THE CALCULATION OF BOUGUER ANOMALIES 2·2 GR/CM^3 HAS BEEN ADOPTED AS AN AVERAGE ROCK DENSITY.

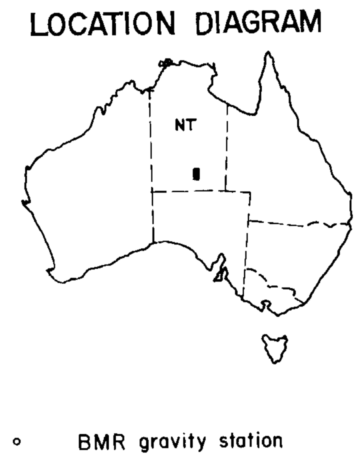
BASED ON TOPOGRAPHICAL MAP OF ALICE SPRINGS AND ENVIRONS BY LANDS AND SURVEY SECTION, NT ADMINISTRATIVE BRANCH, AUGUST 1949

TO ACCOMPANY RECORD No 1963/93

G 63-26

PLATE 6

LOCATION DIAGRAM



- ∘ BMR gravity station
- • Magellan gravity station
- ⊙ " " " permanently marked
- Isogals, values in milligals
- 'High' anomaly
- 'Low' anomaly

Q	Quaternary		Cainozoic
T	Tertiary		Cainozoic
K	Cretaceous	– Mesozoic	
	Pertnjara	– Upper Palaeozoic	
	Mereenie	– Post Ordovician	Lower Palaeozoic
	Pacoota	– Ordovician	Lower Palaeozoic
	Pertaoorrta	Cambrian	Lower Palaeozoic
	Arumbera	Cambrian	Lower Palaeozoic
	Pertatataka		Upper Proterozoic
	Bitter Springs Formation		Upper Proterozoic
	Heavitree Quartzite		Upper Proterozoic

OORAMINNA ANTICLINE
AMADEUS BASIN, NT
RESIDUAL GRAVITY AND GEOLOGY

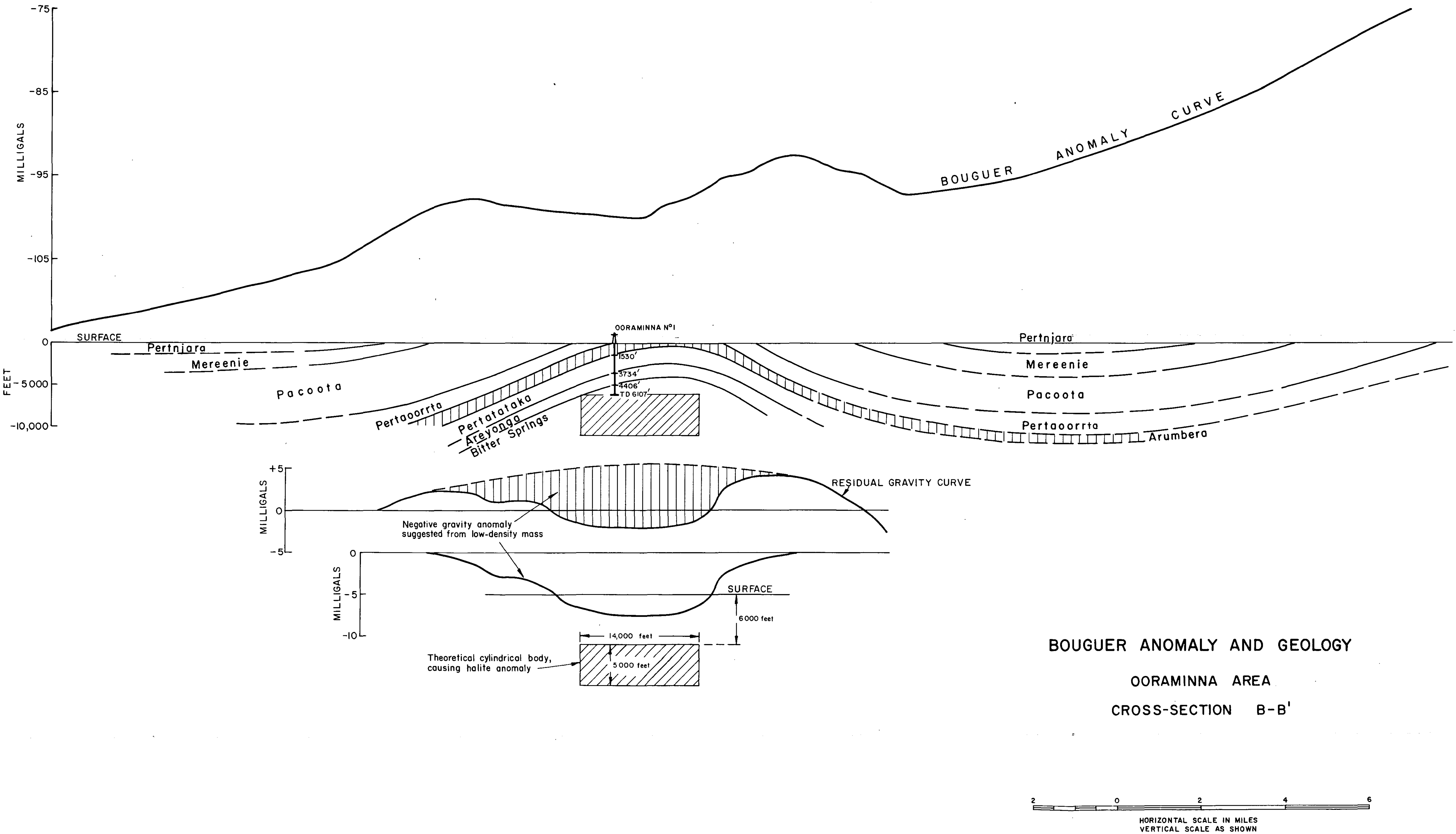
2 0 2 4 6 MILES

CONTOUR INTERVAL 1 MILLIGAL

Geology after 1:250,000 BMR photogeological sheets "Alice Springs and Rodinga"

TO ACCOMPANY RECORD NO. 1973/93 F53/B2-28

PLATE 7



BOUGUER ANOMALY AND GEOLOGY

OORAMINNA AREA

CROSS-SECTION B-B'

TO ACCOMPANY RECORD NO.1973/93 F 53/B2-30

PLATE 8

ALICE SPRINGS

CORRELATION OF GRAVITY AND GEOLOGY CROSS-SECTION A–A'

Reference: Geology after BMR 1:250,000 photogeological maps, Alice Springs and Rodinga and N Jones (1962)
Drilling data after E A Webb (1964)

TO ACCOMPANY RECORD NO. 1973/93

F53/B2-31