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GEORGINA BASIN RECONNAISSANCE GRAVITY SURVEYS USING HELICOPTERS,

NORTHERN TERRITORY AND QUEENSLAND 1960 - 1961

by

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SUMMARY

A preliminary Bouguer anomaly contour map is presented, based mainly on the results of reconnaissance helicopter gravity surveys made by the Bureau of Mineral Resources in 1960 and 1961 in, and marginal to, the Georgina Basin, but also including results from other gravity surveys made by the Bureau and private companies.

The gravity anomaly pattern is rather complex over most of the area owing to the complex lithology, but is of considerable value in delineating the margins of the Georgina Basin, in assessing the broader structure of the basin, and in establishing major structural features within the basin. Two such features are evident: one in the Huckitta area, where a gravity 'low' indicates a depressed basin-type feature; the other near Ooratippra, in an area of a major gravity 'high'.

1. INTRODUCTION

Interest in the search for oil in the Georgina Basin was heightened by an occurrence of hydrocarbon gas in the Cherry Creek Waterbore (Ammaroo Station) near the western margin of the Georgina Basin (Mackay & Jones, 1956). Marine fossils are common in the Cambrian sediments of the Georgina Basin, and the Middle Cambrian shales and limestones are known to be bituminous.

During 1960 a helicopter gravity survey was carried out over parts of the Georgina and Great Artesian Basins in the Northern Territory and Queensland by the Bureau of Mineral Resources (BMR). Owing to a delay in the commencement of this survey and subsequent unserviceability of the helicopter on several occasions the proposed survey programme was not completed.

During 1961 the remaining portion of the survey area was covered as part of a programme embracing portions of three major sedimentary basins. The results obtained in the Amadeus and Great Artesian Basins are discussed in other reports (Langron, 1962; Lonsdale, 1962); this report discusses results obtained in and marginal to the Georgina Basin area.

Gravity stations were established on an approximate 7 mile by 7 mile grid over the area shown in Plate 1. Additional stations were read in various localities selected for follow-up work on the basis of geological or geophysical interest. The techniques used in this type of survey have been described by Vale (1962), the method of traversing in both 1960 and 1961 being the 'line method' described by Hastie and Walker (1962). Details concerning techniques will not be repeated in this report.

The results of the 1960-61 helicopter surveys are presented in the form of a preliminary Bouguer anomaly map which incorporates the results of other gravity surveys (see Section 3). For various reasons the final production of this report has been delayed for several years, but the draft and the Bouguer anomaly map have been used as a basis for further exploratory work in the area since 1962. This report takes no note of this subsequent work, and correlation of the gravity data with later information obtained from seismic and aeromagnetic surveys and from exploratory drilling will be made in the final report on gravity surveys in the area.

The technique of helicopter gravity traversing was developed extensively during the 1960 and 1961 surveys. In particular, the difficulties experienced during single-helicopter operations in 1960 lead to the use of two helicopters in this type of work as from 1961. The logistics of the survey operations in 1960 and 1961 are given in Appendices A and B, and notes on the performance of the equipment used during these surveys are given in Appendices C and D.

The physiography of the survey area has been described by Barlow (1965).

2. GEOLOGY

The area surveyed forms mainly the southern portion of the Georgina Basin. The Great Artesian and Amadeus Basins are marginal to the survey area. To the west, the Georgina Basin is bounded by the Arunta Block composed of a complex of raised Precambrian rocks, including various types of intrusives.

The regional geology of the area is shown in Plate 2. It is described in the following text under four headings, namely:

(a) Georgina Basin
(b) Great Artesian Basin
(c) Amadeus Basin
(d) Arunta Block

Since 1956, geological parties of the BMR have been investigating the area, and consequently the geological knowledge of the region has been advanced considerably. In a later report, all gravity results in the area will be correlated with the more recent geological information.

The following brief description of the regional geology of the area is based mainly on the geological notes in explanation of the Tectonic Map of Australia (BMR, 1962).

Georgina Basin

In the Georgina Basin, flat-lying Cambrian and Ordovician sediments, consisting mainly of limestone and dolomite (Opik et al, 1957), thicken towards the south-east. These are conformably underlain by Upper Proterozoic rocks consisting of boulder beds, arkose, sandstone, red siltstone, and dolomite, which are about 3000 feet thick near Huckitta and about 7000 feet thick in the Field River area further to the south-east.

The extent of the Georgina Basin is defined by the transgressive Cambrian sediments and the boundaries of the basin are marked in the east and north-east by Precambrian rocks of the Cloncurry Fold Belt and in the west and south-west by Precambrian and early Cambrian rocks (Casey et al, 1960). These boundaries are shown in Plate 2. The Georgina Basin extends north-west of the survey area into the region known as the Barkly Tableland. In the south-east, Lower Palaeozoic beds, including Cambrian and Ordovician sediments, occupy the Toko Syncline. It is not known whether these beds continue further to the south-east under a cover of Mesozoic sediments contained in the Great Artesian Basin (BMR, 1960).

Middle Cambrian sedimentation in most of the Georgina Basin began with the deposition of siltstone, chert, dolomite, and sandstone, followed by carbonate rocks containing chert nodules. In the south, micaceous red sandstone, greywacke, and dolomite were the first Cambrian units deposited. The sequence is about 1000 feet thick and can be presumed to be fairly uniform over the area. From the Middle Cambrian to the Lower Ordovician, gentle subsidence, interrupted by periodic emergence, prevailed, and mainly carbonate sediments with some sandstone and shale were laid down. During the Upper Cambrian, about 1500 feet of largely carbonate sediments were laid down in HUCKITTA and TOBERMORY. In contrast to the Middle Cambrian to Lower Ordovician sediments, the Middle Ordovician sediments (about 1000 feet thick) are clastic. They crop out only in the Toko, Tarlton, and Dulcie Ranges (Plate 3) and form mesa cappings near Barrow Creek. Like the underlying sequences they thicken to the south-east. A long period of stability ensued after the Middle Ordovician and there is no further record of sedimentation until the Upper Devonian, although microfossils from shot-hole samples in the Toko Syncline suggest sedimentation occurred in the Lower Devonian. 2100 feet of Devonian sandstone with calcareous siltstone interbeds have been measured in the Dulcie Syncline. No angular unconformity has been observed between these sediments and the underlying Ordovician clastics.

In general, the outcropping Palaeozoic strata are very gently folded and in places faulted. Faulting with some steepening of depositional dip occurs in places where the strata abut older rocks on the eastern margin of the basin. The western side of the Toko Syncline is bounded by the Toomba-Pulchera Fault, extending south-south-east from Twin Hills and

TABLE 1

Stratigraphical comparison of the Georgina Basin with the Ammaroo Sub-basin

(After J. N. Casey, pers.comm.)

		MAIN GEORGINA BASIN		AMMAROO SUB-BASIN	
Era	Period	Formation	Lithology	Formation	Lithology
Cainozoic	Quaternary		Alluvium, soil, sand		Alluvium, soil, sand
	Tertiary	Austral Downs Limestone	Limestone, marl, chalcedony	Arltunga Beds	Limestone, marl, chalcedony
Mesozoic	(undifferentiated)		Sandstone, siltstone		(absent)
				UNCONFORMITY	
Palaeozoic	Permian	Tarlton Fm.	Boulder beds, sandstone	Tarlton Fm.	Sandstone, conglomerate
	UNCONFORMITY			UNCONFORMITY	
	Devonian	(not known in outcrops)		Dulie Sdst.	Sandstone, silty calcareous beds containing fresh water fish remains
				UNCONFORMITY	
	Ordovician	Mithaka Fm.	Sandstone, limestone		
		Carlo Sdst.	Sandstone		
		Nora Fm.	Siltstone, sandst. Coquinite	Nora Fm	Siltstone, dolomite, white iron, sandstone
		Coolibah Lst.	Limestone		
		Kelly Creek Fm.	Sandst. siltst. chert beds, dolimite		
		Ninmaroo Fm.	Dolomite, limest. sandy dolomite		
	Cambro-Ordovician	(Not named)	Sandstone	Tomahawk Fm.	Sandy dolomite, dolomite, glouconite, sandstone
	Upper Cambrian	Arrinthrunga Fm.	Oolitic limestone, sandy dolomite sandstone, (good aquifer)	Arrinthrunga Fm	Oolitic limestone, sandy dolomite sandstone (good aquifer)
	Middle Cambrian	Marqua Beds	Grey limestone	Arthur Creek Beds	Dark limestone, sandstone lenses (gas in the Cherry Ck. Bore)
		Sandover Beds	Siltstone, chert, sandstone	Sandover Beds equivalent	Calcareous shale, some sandstone siltstone, chert nodules
	UNCONFORMITY			UNCONFORMITY	
	Lower Cambrian	(not known in outcrops)		Mt. Baldwin Fm	Dolomite, greywacke, red mica sdst. dolomite, siltstone (MOPUNGA GROUP)
Precambrian		Grant Bluff Fm.	Sandstone, siltstone some dolomite	Grant Bluff Fm	Sandstone, siltstone, some dolomite (MOPUNGA GROUP)
		(Not named)	Dolomite, arkose, etc.	Elyuah Fm	Arkose, red beds, shale
		Field River Beds		Mt. Cornish Fm	
	UNCONFORMITY			UNCONFORMITY	
	Lower Proterozoic	(Not named)	Granite	Dneiper, Jervois, Jinka, Marshall, Mt. Swan	Granite
	Archaean			Brady, Irindina, Entia	
		Arunta Complex	Undifferentiated gneiss, schist, metamorphics	Arunta Complex	Undifferentiated gneiss, schist, metamorphics

possibly extending well into the Bedourie map area. Near Elkedra, Cambrian rocks, which overlap the heavily intruded Precambrian sediments (Warramunga and Hatches Creek Groups) of the Davenport Range area, do not appear to have been affected by post-depositional movements. The structure of the Palaeozoic rocks in areas covered by more recent sediments is unknwon.

Also included in the Georgina Basin is the area referred to by Mackay and Jones (1956) as the Ammaroo Basin. Recent geological and gravity surveys have indicated that this area should be considered a sub-basin of the Georgina Basin. The Dulcie Syncline lies within this sub-basin and contains the sedimentary succession of maximum known thickness in the region under review.

In the Ammaroo Sub-basin, the sediments differ to some extent from those deposited in the main Georgina Basin. In Table 1 the stratigraphic sequence that occurs in the Ammaroo Sub-basin is compared with that of the main Georgina Basin in more detail. Where beds are shown as being equivalent, this concept is based on an unpublished preliminary correlation by the Geological Branch of the BMR (J. Casey, pers. comm.). A significant feature of the Ammaroo Sub-basin is the deposition of Lower Cambrian sediments up to 1400 feet thick which include the quartz sandstone, quartz greywacke, dolomite limestone, and dolomite of the Mount Baldwin Formation. These Lower Cambrian sediments are unconformably overlain by beds composed of siltstone, chert, and sandstone, and are considered the equivalent of the Sandover Beds. In the main Georgina Basin, Palaeozoic deposition commenced with the Sandover Beds, which overlie conformably the Upper Proterozoic sediments. The unique development of Devonian rocks in the Ammaroo Sub-basin area includes sandstone, haematitic sandstone, limestone, and oolitic haematite, known as the Dulcie Sandstone.

Great Artesian Basin

Extensive Mesozoic sediments occur in the Great Artesian Basin, and although there has been sedimentation in the area of this basin since the Proterozoic time, little is known of the distribution, stratigraphy, and structure of the pre-Mesozoic sequence. A major pre-Mesozoic unconformity cuts across Permian, Carboniferous, Devonian, Cambro-Ordovician, and Proterozoic sediments, granite, and metamorphic rocks in various parts of the basin. It has been suggested that the Pre-Mesozoic sediments are most likely underlain by metamorphic and granitic basement rocks of Archaean age.

The Mesozoic basin is developed as a downwarp subdivided by structural 'highs' into sub-basins (BMR, 1960). Mesozoic sediments, including lower Cretaceous marine and fresh water sediments underlain by Jurassic and Triassic sediments, are thicker over the areas of the sub-basins and thinner over the basement ridges.

In the Boulia region, the Precambrian and Lower Palaeozoic rocks of the Mount Isa/Cloncurry area form a shelf (the Boulia Shelf) that extends south-south-west to a latitude of about 24°. The Boulia Shelf coincides with a well expressed gravity anomaly to the east and south-east of the survey area.

In the southern part of the area under review the Mesozoic sediments of the Great Artesian Basin overlap the Cambrian sediments of the Georgina Basin. However, these rocks are covered by a monotonous veneer of Cainozoic sand dunes, and the extent of various formations under the Simpson Desert is unknown. (Later seismic work and drilling have unravelled many of the problems of the extension of the units below this Cainozoic cover in this area.)

Amadeus Basin

The Amadeus Basin, contains thick Upper Proterozoic and Palaeozoic sedimentary rocks. The total thickness of sediments deposited in this basin is about 35,000 feet.

Sedimentation commenced with 1500 feet of Upper Proterozoic beds of the Heavitree Formation, mainly including quartzite, followed by 2000 feet of Bitter Springs gypsum, limestone, dolomite, and sandstone, which in turn are overlain by the Proterozoic Areyonga Formation (mainly composed of sandstone with some shale) and shales of the Pertatataka Formation. These sediments are overlain conformably by Cambrian sediments including the Arumbera Formation (also referred to as Upper Proterozoic), Jay Creek, and Goyder Formations. In the western part of the Amadeus Basin, Ordovician rocks are represented by the Pacoota, Horn Valley, Stairway, and Stokes Formations, comprising mainly alternating sandstones and shales. An unconformity separates these sediments from the Middle Palaeozoic Mereenie Sandstone, which in turn is unconformably overlain by the continental Pertnjarra Formation, of Upper Devonian to Carboniferous age.

The Amadeus Basin is an asymmetric east-west trough. It is bounded to the north by the Archaean rocks of the Arunta Block, against which a thick section of sediments has been strongly folded and faulted. In the south, diapiric structure and thrusting are known to occur within the sediments. The basin floor rises gradually and is seen as the Archaean outcrops of the Musgrave Block, which forms the southern boundary of the basin.

The Ngalia Trough, north of the Amadeus Basin, has a tectonic environment similar to that of the Amadeus Trough, but although it has not been mapped in detail, the sequence will probably be similar to the Upper Proterozoic and Cambrian rocks of the Amadeus Basin with sediments equivalent to the Mereenie Sandstone and Pertnjarra Formation blanketing most of the basin away from the northern rim.

Arunta Block

The Arunta Block is a vast triangular area of complex lithology, mainly including Archaean rocks. It extends north and northwest from the Alice Springs/Harts Range region over a distance of about 300 miles and forms the northern margin of the Amadeus Basin and the south-western margin of the Georgina Basin.

The gneissic and schistose rocks that form the block are referred to as Arunta Complex. The parent rocks included greywacke of great thickness, sandstone, shale, limestone, and basic lava flows or sills. These rocks were transformed by intense regional metamorphism and metasomatism into gneiss, shist, amphibolite, and quartzite. Later, the metamorphic rocks were intruded by acid (?Proterozoic granite and pegmatite), intermediate (granodiorite), and basic (gabbro and dolerite) igneous rocks. Major intrusions of acid rocks occur in the area between the Jervois and Harts Ranges.

In some areas, the rocks of the Arunta Block are strongly folded, but the tectonic history is not clear even in the area of the Harts Range, which has been mapped in detail by Joklik (1955). The lineation and intense small-scale folding, commonly trending north-north-east, are probably Archaean, but the major east-trending folds and faults are similar in style and trend to those further south in the Amadeus Basin, and, like these, are probably of Middle Palaeozoic age.

Minerals occur in several parts of the Arunta Block, particularly in the Harts Range/Plenty River (Huckitta) area, where excellent mica has been mined from pegmatite veins. None of the mica mines was operating in 1961. Gold has been mined in the Harts Range area for intermittent periods.

Copper carbonate ore occurs in a ridge of quartz-mica schist on the south-eastern side of the Jervois Range. Test quantities of this ore have been mined and an acid leaching plant was partly constructed near the mine. Neither the mine nor the plant was operating in 1961.

The Arunta Complex possibly forms the basement of the Georgina Basin, and, if this is so, evidence from outcrops suggests that density contrasts within the basement may be considerable and widespread.

3. OTHER GEOPHYSICAL SURVEYS IN THE AREA

Gravity

The location of all gravity traverses and boundaries of gravity survey areas up to 1962 are shown in Plate 3.

During 1951, gravity traverses were surveyed by Marshall and Narain (1954) along the Stuart Highway north of Alice Springs, along the railway line south of Alice Springs, and along various roads south and south-west of Alice Springs.

Extensive reconnaissance gravity surveys have been made by the BMR over parts of western Queensland adjoining the present survey area on its eastern margin. Ground traverses along existing roads and tracks were read during 1957 and 1958 (Neumann, 1959a & b). During 1959, this ground work was supplemented, and a grid pattern of gravity stations was established over a wide area by a BMR gravity party using helicopter transport (Gibb, 1966). Parts of URANDANGI, GLENORMISTON, and MOUNT WHELAN were included in this survey.

In early 1959, regional gravity stations were observed by the BMR on airstrips of isolated homesteads, using the regular flights of commercial airlines (Radeski, 1962). During the survey, elevations were determined by barometric methods referred to a base at Alice Springs. The drift of the gravity meter was determined by infrequent reoccupations of the Alice Springs pendulum station. Many of these stations were reoccupied when later ground traverses were made, and more accurate observations were obtained for both elevation and observed gravity values.

Also in 1959, some of the BMR Queensland ground traverses were extended into the area under discussion and tied to the Alice Springs pendulum station (Barlow, 1965). All the ground traverses were levelled by survey parties of the Commonwealth Department of the Interior using conventional methods. These traverses provided a regional network of stations with accurate levels and observed gravity values for the purpose of controlling the later helicopter surveys.

A group of six 1:250,000 map areas west and south of Alice Springs was covered in the Amadeus Basin during 1961 by BMR helicopter gravity survey (Langron, 1962), and BEDOURIE and BIRDSVILLE were part of an area covered by a BMR helicopter gravity survey in 1961 in the Great Artesian Basin (Lonsdale, 1962).

During 1962, the BMR established helicopter gravity coverage over the remaining parts of ALCOOTA, ILLOGWA CREEK, and HALE RIVER (Lonsdale & Flavelle, 1963).

The results of the gravity surveys mentioned above have been used in contouring the Bouguer anomaly map (Plate 4).

A number of gravity surveys have also been made in the area by various private companies and these are listed in Table 2. The results of some of these (indicated by asterisks) surveys have been used in drawing the Bouguer anomaly contours shown in Plate 4.

TABLE 2

Gravity surveys
made by private companies in the
Amadeus and Georgina Basin areas, Northern Territory

Name of survey	Company	Area covered
Allambi *	Flamingo Petroleum Pty Ltd	RODINGA (part) HALE RIVER " CHARLOTTE WATERS"
Andado *	Geosurveys of Australia Ltd	McDILLS "
Simpson Desert *	Associated Freney Oil Fields N.L.	SIMPSON DESERT SOUTH (part)
Hale River *	Beach Petroleum N.L.	McDILLS " SIMPSON DESERT SOUTH (part)
Various detailed surveys	Magellan Petroleum (NT) Pty Ltd	ALICE SPRINGS " HERMANNSBURG " HENBURY " RODINGA "

Detailed gravity surveys made by the BMR over ALICE SPRINGS, HERMANNSBURG, and RODINGA will be reported on separately.

All gravity surveys in the area have been tied both to each other and to the BMR gravity pendulum station No. 35 at Alice Springs. Final re-adjustment of the results of all these surveys is in progress. However, this adjustment will not materially affect the Bouguer anomaly contours shown in Plate 4.

Aeromagnetic

The only** aeromagnetic work done in the area covered by this report before 1962 were two traverses over the extreme south-eastern part of the area (Jewell, 1960). These traverses originate from Dajarra and run to Alice Springs and to The Curralulla as shown in Plate 2. The magnetic profiles are disturbed over their whole length, which indicates that the basement is shallow. Maximum basement depth has been assessed to be in the range of 3300 feet near Tarlton Downs Homestead.

Seismic

The only** seismic work done in any part of the area covered by Plate 4 before 1962 includes a number of traverses made by the BMR in the region south and west of Alice Springs. These traverses lie outside the Georgina Basin.

Miscellaneous geophysical work

In very restricted areas, geophysical surveys have been made in order to assist in the siting of water bores and also in copper and mica mining. Magnetic, gravity, and electrical methods have been used for this purpose. The results of these surveys are not relevant to this discussion.

** Since this report was written, further seismic and aeromagnetic surveys have been carried out in the area, but the results of these surveys are not considered in this report.

4. OBJECTIVES

The objectives of the 1960-61 helicopter surveys were:

1. To provide a uniform reconnaissance gravity coverage of the area in order to further delineate known structures and to attempt to discover new subsurface structures.

2. To establish the boundaries of the southern portion of the Georgina Basin in places where the boundaries could not be determined from surface geology.

3. To determine the relation between the Palaeozoic sediments of the Georgina Basin and the Mesozoic sediments of the Great Artesian Basin under cover of later Cainozoic deposits in the Simpson Desert area. It was believed that the Mesozoic sediments extended north to a line running approximately north-north-east across the centre of SIMPSON DESERT NORTH and possibly overlapping Palaeozoics of the Georgina Basin. There are no geological outcrops in this region.

4. To establish follow-up stations to further delineate anomaly features and to test gravity gradients detected by the regular grid coverage.

5. PRESENTATION OF RESULTS

Plate 4 shows the preliminary Bouguer anomaly contours of the surveyed and surrounding areas drawn on a scale of 40 miles to one inch. The contours are based on the combined results of various gravity surveys in the region.

Re-computation of the gravity data, involving a more extensive distribution of loop misclosures and misties between different gravity surveys, is necessary before final Bouguer anomaly values can be determined. However, this re-computation is not expected to alter significantly the pattern of contours shown in Plate 4.

A density of 1.9 g/cm^3 was used in reducing observations made in the region of the Georgina Basin and shown in the right-hand half of Plate 4. This density had already been used for the near-surface rocks when reducing the results of extensive surveys further east, in and marginal to the Great Artesian Basin. The near-surface rocks in the Amadeus Basin are of higher density, and a density of 2.2 g/cm^3 was used when reducing observations made in the region of the Amadeus Basin, part of which appears on the left-hand half of Plate 4. For this reason, the Bouguer anomaly contours are not continuous across the dashed line shown in Plate 4, there being an average displacement of about 8 milligals. Nevertheless, because the survey area has only limited topographic relief, the pattern of the reconnaissance contours is not significantly affected by this change of density used in reducing the observations.

6. DISCUSSION OF RESULTS

Plate 4 has been shaded to bring out the 'highs' and 'lows' in the Bouguer anomaly contour pattern, and the resulting major gravity units are outlined by hachuring. The more important gravity features within each unit are numbered for easy reference.

General gravity anomaly picture

An overall assessment of the Bouguer anomaly contours of the Georgina Basin immediately indicates that the eastern boundary of the Georgina Basin is well expressed as a distinct north-north-west gravity gradient trend continuous over a distance of more than 200 miles along the western edge of the Cloncurry Gravity High.

Extending over an even longer distance is the north-west trend in the contours that follows the south-western boundary of the basin. This trend is expressed in the Lake Caroline Gravity Ridge (Lonsdale & Flavelle, 1963) and also in the Hay River and Huckitta Gravity Lows, which accompany this gravity ridge on its north-eastern side.

The region bounded by these trends forms the southern portion of the Georgina Basin. It can be further sub-divided by examination of the contour pattern in Plate 4.

In the south-east corner of the region the Toko Syncline is well expressed as a gravity 'low' which is bounded to the west by a gravity 'high' named the Field River Gravity Spur, which diverges from the Lake Caroline Gravity Ridge.

Further to the north, an area of low gravity relief, the Tobermory Gravity Shelf, occupies nearly all of TOBERMORY and extends over considerable portions of the neighbouring 1:250,000 map areas.

This unit is bounded to the north-west by the Sandover Gravity Low, which covers most of SANDOVER RIVER, and which, in turn, is bounded to the west by the Ooratippra Gravity High, which occurs mainly in the eastern part of ELKEDRA.

The gravity relief in the western part of ELKEDRA is not pronounced, but there is evidence for the existence of a ridge of high values of gravity in the Davenport Range area. This ridge separates a region of low gravity values in northern ELKEDRA from the gravity 'low' that is the expression of the Ammaroo Sub-basin centred in HUCKITTA. This sub-basin is bounded to the south-west by the western-most extension of the Lake Caroline Gravity Ridge.

Other major gravity units that appear in Plate 4 lie outside the margins of the Georgina Basin. The units south and south-west of the Lake Caroline Gravity Ridge include the Annandale Gravity Depression, the Hale River Gravity Platform, and the Alcoota Gravity Platform. Further to the west and south-west occur a number of units within and marginal to the Amadeus Basin, which have been described by other authors, particularly Langron (1962) and Lonsdale and Flavelle (1963).

The major gravity anomaly units and detailed features relating to the Georgina Basin gravity picture are discussed in more detail in the following paragraphs.

Cloncurry Gravity High

The western portion of the Cloncurry Gravity High extends into the eastern margin of the area shown in Plate 4. Separate gravity features that occur within this major gravity unit have been described by Gibb (1966). Gravity trends are mainly sub-meridional and the gravity picture shows alternative gravity 'highs' and 'lows' within the boundaries of the unit.

The Cloncurry Gravity High is bounded to the west by a steep north-north-west gravity gradient trend (feature 1) which is continuous over a distance of more than 200 miles. In Plate 4, this gravity trend of steep gradients is shown commencing in eastern BEDOURIE and extending across MOUNT WHELAN and GLENORMISTON into western URANDANGI.

Lake Caroline Gravity Ridge

The Lake Caroline Gravity Ridge (Lonsdale & Flavelle, 1963) is a belt of gravity 'highs' (feature 2), which in the area of Plate 4 extend in a north-westerly direction from western BEDOURIE across parts of SIMPSON DESERT NORTH, HAY RIVER, ILLOGWA CREEK, and HUCKITTA into ALCOOTA. This ridge is linked with the Field River Gravity Spur further north-east, which extends from the south-east corner of BEDOURIE into the south-west portion of MOUNT WHELAN and re-appears as an irregular gravity 'high' in the north-east portion of HAY RIVER and near the south-east corner of TOBERMORY. Strong gravity gradients (feature 3) continue further to the east and provide a link between the Lake Caroline Gravity Ridge and the Boulia Shelf, which is described in detail by Gibb (1966). At its north-western end the Lake Caroline Gravity Ridge is clearly terminated by contours that are a boundary of a major gravity depression in western ALCOOTA.

Huckitta Gravity Low

This gravity 'low' occupies parts of central HUCKITTA and east ALCOOTA, being bounded to the south by a trend of strong gravity gradients (feature 4), which runs west-north-west. The northern and western boundaries of the Huckitta Gravity Low are not clearly expressed as this 'low' merges into the gravity expression of the Ammaroo Sub-basin.

Feature 5 is a gravity 'low' or gravity 'sink' that is small in area but closed on all sides by steep gravity gradients. It occurs at the eastern end of the Huckitta Gravity Low.

Hay River Gravity Low

This elongated gravity 'low' extends across HAY RIVER with a north-west trend parallel to, and on the northern side of, the Lake Caroline Gravity Ridge. A gravity 'sink' (feature 6) occurs in the north-west corner of HAY RIVER, being similar in size and type to feature 5 mentioned above as a portion of the Huckitta Gravity Low.

Toko Syncline

Gravitationally, the Toko Syncline is well expressed as a low anomaly mainly in the western portion of MOUNT WHELAN. The axis of the lowest gravity variation runs generally south-east, extending into the northern portion of BEDOURIE.

Within the limits of this anomaly as a major unit, there are two separate closed gravity 'lows' (features 7 and 8). Feature 7, the larger of the two, is reasonably symmetrical. Feature 8 is asymmetrical, with the stronger gradients (feature 9) occurring on the western side of the anomaly. This strong gradient trend continues south-south-east near the western margin of MOUNT WHELAN for a distance of approximately 40 miles; it then swings east-south-east for roughly 20 miles and finally runs south-east across the boundary between MOUNT WHELAN and BEDOURIE.

A similar trend of relatively steep gravity gradients (feature 1) bounds the Toko Syncline to the east along the margin of the Cloncurry Gravity High (see above).

Field River Gravity Spur

The Field River Gravity Spur diverges from the Lake Caroline Gravity Ridge in central BEDOURIE and runs north-north-west across western MOUNT WHELAN and eastern HAY RIVER with an irregular extension into the south-east corner of TOBERMORY. The spur is clearly bounded to the east by the steep gravity gradient mentioned previously as feature 9. The western boundary is less pronounced.

A 'peak' (feature 10) is reached in the gravity anomaly near the south-west corner of MOUNT WHELAN, where a closed positive gravity variation occurs east of Field River.

Tobermory Gravity Shelf

A large area of generally low gravity relief, the Tobermory Gravity Shelf, occupies almost the whole of TOBERMORY and extends into neighbouring parts of GLENORMISTON, HAY RIVER, HUCKITTA, SANDOVER RIVER, and URANDANGI.

In the north-west corner of TOBERMORY the gravity pattern is more irregular. Feature 11 consists of a pair of local anomalies, a gravity 'high' accompanied to the south-east by a gravity 'low', which is separated from the 'high' by a relatively steep gravity gradient. Between Tobermory and Urandangi two weak gravity 'lows' (features 12 and 13) separated by a north-west narrow ridge, are superimposed as smaller anomalies on the major unit.

The eastern limit of the Tobermory Gravity Shelf is clearly marked by the strong gravity gradient trend of feature 1. The south-western, western, and northern limits are also well expressed by corresponding trends in the contours. To the south-east, in the area of the Toko Range, the limit of the Tobermory Gravity Shelf is not clearly marked in relation to the north-western end of the Field River Gravity Spur.

Sandover Gravity Low

This is a rather irregular area of low gravity anomaly which occupies most of SANDOVER RIVER and which encompasses a number of closures in locally low anomalies.

A sharp 'nose' (feature 14) extends south-westerly into the north-east corner of HUCKITTA. A broader 'nose' (feature 15) extends to the west into the north-east corner of ELKEDRA.

The Sandover Gravity Low might be closed to the north but the present data are insufficient to determine this.

Ooratippra Gravity High

An outstanding feature, the Ooratippra Gravity High, occupies mainly the south-eastern part of ELKEDRA and extends into HUCKITTA to the south and into SANDOVER RIVER to the east and north-east. The predominant north-north-east trend which appears in the contours of this 'high' is perpendicular to the general trend of the gravity contours in the area. The Ooratippra Gravity High is terminated to the north by the Sandover Gravity Low, or more precisely by the closed gravity 'low' of feature 5. According to the present data this 'high' may possibly extend north-east into AVON DOWNS.

The maximum value (feature 16) of the Ooratippra Gravity High is centered in south-east ELKEDRA as a reasonably symmetrical gravity peak.

A trend of steep gravity gradients (feature 17) terminates the Ooratippra Gravity High to the west.

Ammaroo Sub-basin

Bouguer anomaly values in the area of the Ammaroo Sub-basin are generally low. The sub-basin occupies a major portion of north-west HUCKITTA and extends west into ALCOOTA, north into ELKEDRA, and possibly north-west into BARROW CREEK.

The eastern limit of the Ammaroo Sub-basin is clearly marked by the prominent gravity gradient of feature 17. In the north, the sub-basin is terminated by a gravity 'ridge' (feature 19), which occurs in central and western ELKEDRA, and which separates the Ammaroo Sub-basin from the gravity 'low' in northern ELKEDRA (feature 18). Feature 18 is open to the north and may extend well into FREW RIVER. Gravity data available along the Stuart Highway suggest that the gravity 'ridge' (feature 19) may develop to the north-west into a major anomaly. South of the Ammaroo Sub-basin 'low', Bouguer anomaly values further decrease in the Huckitta Gravity Low.

Gravity data available at present are insufficient to define the north-western limit of the Ammaroo Sub-basin.

Annandale Gravity Depression

Near the south-east corner of the area shown in Plate 4, the Annandale Gravity Depression occurs as a major feature. This gravity anomaly occupies most of BIRDSVILLE and has been described by Lonsdale (1962). The northern limit is marked by the strong gravity contour trend (feature 3) that extends into south-east SIMPSON DESERT NORTH.

Hale River Gravity Platform

The name Hale River Gravity Platform has been given to a broad region of high gravity anomaly that encompasses central and south-east ILLOGWA CREEK, central and north-east HALE RIVER, the western half of SIMPSON DESERT NORTH, and north-west SIMPSON DESERT SOUTH.

The region is generally of a shelving nature as the Bouguer anomaly values decrease westerly and north-westerly from the higher values in the western portion of SIMPSON DESERT NORTH towards the huge gravity depression of the Amadeus Basin area. Two gravity 'highs' (features 20) are superimposed on the major anomaly in the northern portion of HALE RIVER and near the centre of ILLOGWA CREEK.

Alcoota Gravity Platform

A small area of high anomaly in south-east ALCOOTA and north-east ALICE SPRINGS has been named Alcoota Gravity Platform. It includes several gravity 'highs' and 'lows' of limited extent. This gravity unit abuts the south-western edge of the western end of the Lake Caroline Gravity Ridge. The boundary between the ridge and this platform is not clearly marked. The southern boundary of the gravity platform in relation to the Amadeus Basin Gravity Depression is marked by extremely steep gravity gradients.

7. INTERPRETATION

The interpretation of gravity data in the area of the Georgina Basin is complicated by the relatively small density contrast that can be expected to exist between the Cambrian limestones and the basement rocks (see Appendix F). Further difficulties arise because of the existence of numerous local gravity anomalies, bounded by steep gravity gradients, in areas of outcropping Precambrian rocks. For this reason, lateral density variations of considerable magnitude must be inferred to occur within the basement rock complex, composed of metamorphics into which numerous types of basic and acid igneous rocks have been intruded. Notwithstanding these difficulties, which originate from complex lithology, the gravity data are of considerable value in delineating the margins of the Georgina Basin, in assessing the broader structure of this basin, and in establishing major structural features associated with sedimentary rocks that occur within the limits of the basin.

The steep gravity gradient of feature 1 has been interpreted by Gibb (1966) as the gravity expression of the westerly limit of the Precambrian Cloncurry Fold Belt under transgressive Palaeozoic sediments of the Georgina Basin.

The distinct and persistent north-west gravity trend in the extensive zone of the Lake Caroline Gravity Ridge and the group of gravity 'lows' that accompany it to the north-east is tentatively interpreted as indicative of a major tectonic lineament. In the western-most portion of this gravity ridge the gravity 'highs' (features 2) are known to occur over outcropping Archaean rocks of the Arunta Complex. The gravity 'sink' (feature 5) appears to be caused mainly by extensive intrusions of huge masses of granite into metamorphic rocks of Archaean age. There is evidence of further intrusions of granite into the Archaean complex in the vicinity of the gravity 'sink' of feature 6.

As a whole, the distorted zone comprising the Lake Caroline Gravity Ridge and the adjacent chain of gravity 'lows' is interpreted as the gravity expression of a major basement ridge of raised Archaean rocks occurring in a narrow zone of tectonic weakness, into which various types of magma have been intruded.

It appears unlikely that Palaeozoic sediments of a type similar to those deposited in the Georgina Basin continue to the south beyond the Lake Caroline Gravity Ridge under cover of the transgressive Mesozoic sediments of the Great Artesian Basin.

Toko Syncline

The Toko Syncline is well expressed in the gravity anomaly contours in MOUNT WHELAN. In the southern part of the syncline, gravity data indicate a deeply depressed symmetrical synclinal structure under feature 7, whereas further to the north feature 8 indicates this syncline to be shallower and distinctly asymmetrical. This has been confirmed by geological evidence. Feature 9 has been interpreted by Gibb (1966) as the gravity expression of the Toomba-Pulchera Fault known to exist near Twin Hills. The extension of the steep gravity gradient further to the south indicates an extension of the fault in this direction.

Field River Gravity Spur

The high gravity values of feature 10 indicate that the major southern part of the Field River Gravity Spur probably forms a portion of the Boulia Shelf.

At its extreme northern end the Field River Gravity Spur fans out over the south-eastern corner of TOBERMORY across the extended axis of the Toko Syncline. Consequently, from gravity data it can be suggested that, as a deeply depressed area, the Toko Syncline does not extend beyond the north-west corner of MOUNT WHELAN. Nevertheless, because of the high density of the Cambrian limestones, the gravity data would support the concept of shallow synclinal development in the Cambrian sediments as suggested from the dip angles in the Cambrian rocks. Thick Middle and Upper Palaeozoic rocks of lower density, which occur in the southern portion of the Toko Syncline, explain the low anomaly in that area.

Tobermory Gravity Shelf

This is interpreted as a region of generally shallow basement. The depth to the basement throughout this region is not expected to differ greatly from the depth of approximately 3300 feet estimated near Tarlton Downs by Jewell (1960).

Feature 11 is interpreted as indicating a raised block of Archaean basement in that area.

Sandover Gravity Low

This is interpreted as a rather depressed area containing a section of Palaeozoic sediments thicker than that found in the area of the Tobermory Gravity Shelf.

The interpretation of features 14 and 15 is open to discussion. They may be considered to be due to limited areas of a thick section of sediments or alternatively as deeply-rooted granitic intrusions. There is a similarity between these features and features 5 and 6. If feature 4 is assessed in relation to reatures 16 and 11, the alternating arrangement of gravity 'highs' and 'lows' resembles the pattern in the contours obtained over outcropping Precambrian rocks along the southern margin of HUCKITTA. For this reason, it may be more correct to consider features 11, 14, and 15 in association with the Ooratippra Gravity High as representing the margin of a large high-standing complex of basement rocks.

Ammaroo Sub-basin

The relatively low values of gravity prevailing in the Ammaroo Sub-basin support the geological concept of this area as a basin containing a thicker sequence of sediments than that existing in the main part of the Georgina Basin further to the east.

The deepest portion of this sub-basin is the Dulcie Syncline, which occurs near its southern margin. The lowest gravity values were measured in the Huckitta Gravity Low beyond the southern margin of the sedimentary basin as determined from surface geology. Hence the axis of the gravity 'low' is displaced well to the south of the synclinal axis. The maximum gradient (feature 4) which terminates the Huckitta Gravity Low to the south occurs over outcropping Arunta Complex. The conditions resemble those that exist along the northern margin of the Amadeus Basin, where another trend of very steep gravity gradient also occurs over rock outcrops of the Arunta Complex. The gravity 'sink' (feature 5) correlates with a major intrusion of Lower Proterozoic granite, the Jinka Granite. Granitic intrusions along this margin are frequent. Consequently, it is suggested that the gravity 'lows' in this particular area result mainly from a zone of weakness and/or high mobility that has been extensively intruded by granite. For this reason, caution must be exercised in interpreting the gravity data; for example, it is unlikely that they can be used to give depth estimates in the Dulcie Syncline.

The gravity anomaly associated with the Ammaroo Sub-basin is bounded to the north and north-west by feature 19, a weak gravity 'ridge' which is interpreted as the gravity expression of Lower Proterozoic sediments exposed in the Davenport Range area.

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APPENDIX A

Logistics of survey operations, 1960

Duration

Departed Melbourne:	11th April 1960
Commenced Georgina Basin survey:	29th August 1960 at Alice Springs, NT
Completed Georgina Basin survey:	8th November 1960 at Boulia, Qld
Returned to Melbourne:	21st November 1960

Camps

Base camps:	Lake Caroline NT, Junction Bore NT, and Duck Point Qld
Flycamps:	Lake Caroline and No. 5 Bore Tobermory, NT

Area

1:250,000 map areas:	Hay River, Simpson Desert North, Tobermory, Huckitta (part), Mount Whelan (part)
Total area:	2500 square miles (approx)

Stations

New gravity stations:	522
Total gravity readings:	657

Helicopter

Aircraft chartered from:	Helicopter Utilities Pty Ltd
Number of helicopters:	One
Type of helicopter:	Bell 47G (VH-UTB)
Total flying hours (including transits, geological, and D. of I. surveying flights):	270:15
Total days lost through aircraft fully unserviceable:	20½
Total days lost through weather:	4

BMR personnel

Party leader/geophysicist:	B.C. Barlow
Other geophysicists:	2 (3 for short period)
Draftsmen:	1
Computing assistants:	1
Wages hands:	Mechanic, cook, field-hand

Helicopter crew

Pilots:	2 (1 during part of survey)
Engineer:	1 (none during part of survey)

Instruments

Gravity meter:	Worden No. 140 Calibration factor 0.11126 mgal/scale div.
Microbarometers:	Askania type Gb5 Nos. 5112473, 531306, and 531308

Radios

Helicopter VH-UTB:	Sunair, 35 watt
Base camp:	Collins 18S-4A, 100 watt (during last part of survey)
R.F.D.S.:	Traegar 59 M10, 10 watt
Mobile:	Traegar 59 M10, 10 watt

Vehicles

C90122	International 1-ton 4 x 4 SWB AA120
C90126	International 1-ton 4 x 4 SWB AA120
C89944	International 1-ton 4 x 4 SWB AA120
C85974	International 3-ton 4 x 4 ASW 160
Generator trailer, 2-wheel	

Gravity data files

The gravity data from the 1960 BMR Helicopter gravity survey used in this Record are stored in the Gravity Group of the Geophysical Branch of the BMR under the following reference numbers:

6006.1	Area map, key to new station numbers, gravity and field barometer sheets, and drift sheets
6006.2	Base barometer sheets and diurnal curves
6006.3	Elevation computations
6006.4	Bouguer anomalies
6006.5	Flight details
6006.6	Preview report
6006.7	Preliminary report

APPENDIX B

Logistics of survey operations, 1961

Duration

Departed Melbourne:	18th May 1961
Commenced Georgina Basin survey:	17th July 1961 at Alice Springs, NT
Completed Georgina Basin survey:	14th August 1961 at Boulia, Qld
Returned to Melbourne:	18th October 1961

Camps

Base camp:	New Ooratippra Homestead
Flycamps:	Kurrajong, New Huckitta, Elkedra, Annitowa, Georgina Downs, and Glenormiston Homesteads

Area

1:250,000 map areas:	ALCOOTA (part), ELKEDRA, HUCKITTA, SANDOVER RIVER, MOUNT WHELAN (completion of earlier work)
Total area:	25,000 square miles (approx)

Stations

New gravity stations:	502
Total gravity readings:	734

Helicopters

Aircraft chartered from:	Ansett-ANA Helicopter Division
Number of helicopters:	2
Types of helicopters:	Bell 47J (VH-INF) and Bristol Sycamore (VH-INQ)
Total flying hours (including transits and geological flights):	195:35
Total days lost through aircraft unserviceable (excluding maintenance on each Sunday for both aircraft):	6½
Total days lost through weather:	½ (dust and wind)

BMR personnel

Party leader/geophysicist:	B.C. Barlow
Other geophysicists:	4
Draftsmen:	2
Wages hands:	Mechanic, cook, cook's offsider, 4 field-hands

Ansett-ANA crew

Senior pilots:	Capt. R. Larder
Other pilots:	2 (normally)
Engineers:	2 (normally)

Instruments

Gravity meter:	World-Wide No. 35 Calibration factor 0.11505 mgal/scale div.

	Worden No. 140 (replacing Master Worden No. 548) Calibration factor 0.11120 mgal/scale div.
Microbarometers:	Askania type Gb5 Nos. 5112362, 5112395, 5112473, 531306, 531333, 562696, and 531308
Microbarograph:	Askania type Gb5r 1438 GE type B

Radios

Helicopter VH-INF:	Sunair, 35 watt
Helicopter VH-INQ:	Hack 1, 50 watt
Base camp:	Collins 18S-4A, 100 watt
R.F.D.S.:	Traegar 59 M10, 10 watt
Flycamp and mobile:	Traegar 59 M10, 10 watt

Vehicles

C90122	International 1-ton 4 x 4 SWB (Office vehicle)
C90126	International 1-ton 4 x 4 SWB (Drafting vehicle)
C89944	International 1-ton 4 x 4 SWB (Flycamp vehicle)
C89985	International 1-ton 4 x 4 LWB (Helicopter vehicle)
C90121	International 3-ton 4 x 2 AA160 (Mess vehicle)
C84424	International 3-ton 4 x 2 AS160 (Tanker No. 1)
C84425	International 3-ton 4 x 2 AS160 (Tanker No. 2)
C85974	International 3-ton 4 x 4 ASW160 (Basecamp vehicle)
C90223	International 3-ton 4 x 4 AAC0162 (Flycamp vehicle)
C10675	Bedford 1-ton 4 x 4 (Mechanics vehicle)

Trailer (Jeep-type), 2-wheel (Generator trailer)

Gravity data files

The gravity data from the 1961 BMR Helicopter gravity survey used in this Record are stored in the Gravity Group of the Geophysical Branch of the BMR under the following reference numbers:

6111.11	Flight details and maps
6111.12	Key to new station numbers, gravity and field barometer sheets, and drift sheets
6111.13	Base barometer sheets and diurnal curves
6111.14	Flycamp base barometer sheets and diurnal curves
6111.15	Elevation computations
6111.16	Bouguer anomalies
6111.17	Preview report
6111.18	Preliminary report

APPENDIX C

Performance of equipment, 1960

The following remarks, and those in Appendix D, are intended as a guide to future surveys. Details of operational techniques have been described by Vale (1962) and by Hastie and Walker (1962).

Gravity meter Worden 140

The meter had steeper drift than usual. This was probably due to the need for evacuation. It had been used in the field for approximately six months before the commencement of this survey. A tendency for the beam to stick to the stops necessitated tapping the top of the meter lightly with the end of a pen or pencil to free the beam.

Microbarometers

Performance of the microbarometers was satisfactory although the instrumental errors (as distinct from errors due to the technique of barometric levelling) were larger than anticipated. Some instruments appear to be extremely sensitive to shock, and extremely careful handling at all times was necessary to obtain good results.

Radios

The party was equipped with two Traegar 59 M10 transceivers and towards the end of the survey with a Collins 100 watt transceiver. The helicopter was fitted with a Sunair transceiver.

Performance of these radios was not completely satisfactory. When it was in the air the helicopter was not able to receive the base at distances greater than a few miles. This was possibly due to the helicopter aerial being unsuitable for the frequency of 6815 kc/s. Reception of helicopter transmissions at the base was more successful, but still unsatisfactory on several occasions. Two-way contact with the helicopter on the ground using a long wire aerial was nearly always possible. A tendency of the receiving unit to drift off tune on the R.F.D.S. frequency caused some embarrassment. Crystal locked receiving units are recommended to overcome this difficulty.

Helicopter (VH-UTB. Type : Bell 47G)

Performance of the helicopter was poor. Of the 75 days duration of the survey the helicopter was fully unserviceable for 20½ days because of engine trouble, radio breakdown, and erosion of the rotor blades by sand. However, this period would have been considerably shorter had there not been appreciable delay in the delivery of replacement parts. Engine trouble caused the survey to be terminated on 8th November before the completion of MOUNT WHELAN.

On one occasion the helicopter was stranded in part of the Simpson Desert for a period of four days (2/9/60 - 6/9/60). This area was inaccessible to ground vehicles and emergency supplies had to be dropped from an aircraft. This incident pointed out the possible danger in operating with one helicopter of this type and the shortcomings of the party's radio communications system. The actions taken by the pilot during this critical period are highly commended. The use of two helicopters would save time in cases of breakdown and would be much safer. Although the provision of two helicopter pilots at all times was written into the contract, this was not adhered to and for nearly half of the survey only one pilot was present. The engineer left the party before the end of the survey. Relief of helicopter crew personnel, for whom a tour of duty is not more than six weeks, caused little interference to the survey.

Vehicles

The Bedford 3-ton truck proved to be an excellent vehicle for this type of work and did an outstanding job carting drums of fuel and water down the Hay River through very heavy sand.

The 3-ton International truck served its purpose as a bulk supply vehicle. However, it could not make the trip down the Hay River and had to be left behind when the party went to the Lake Caroline camp. This caused considerable inconvenience as this truck was the only one fitted with a large capacity water tank.

The three International 1-ton trucks proved satisfactory except that a weakness in the front end of this type of vehicle resulted in several breakdowns. Some alarm was caused by the violent wheel wobble which all three trucks developed on the bitumen. Attempts to cure this fault in Alice Springs were unsuccessful. The problem was referred to the Stores and Transport Branch and to the manufacturers.

The party was further inconvenienced when one of the 1-ton trucks developed gear box trouble in Alice Springs and had to be abandoned there for a period of several weeks while awaiting special parts.

Camping equipment

All the standard camping equipment proved satisfactory. Porta Gas was used for lighting, cooking, and refrigeration and proved very satisfactory.

APPENDIX D

Performance of equipment, 1961

Gravity meters

Two gravity meters were used, one with each helicopter. Initially these were World-Wide No. 35 and Master Worden No. 548.

The drift of World-Wide No. 35 was generally uniform during the helicopter traverses and the drift rate reasonable. This meter was, however, inconvenient to set up because of difficulty in seeing the level-bubbles. The digital counter attached to the small dial proved convenient and greatly reduced the possibility of reading errors.

The drift of Master Worden No. 548 was disappointing. Although this is a temperature-controlled quartz-type gravity meter and was maintained on heat both day and night, the drift was erratic and the drift rate often excessive. The new type of turns counter attached to the small dial effectively eliminated reading errors sometimes made when reading the earlier types of Worden dial. The small dial range of the Master Worden is 200 mgal compared with 80 mgal for all other quartz-type gravity meters used by the BMR. This extended small dial range greatly reduced the number of resets required. This is a very desirable feature as any reset during a helicopter traverse interferes with repeat readings required for drift control. Master Worden No. 548 was severely damaged on 22nd July by explosion of the rechargeable nickel-cadmium cells used to supply the heating current to the meter. Worden No. 140 was used as a replacement and its drift was satisfactory.

Microbarometers

An Askania mircobarometer type Gb5 was used as the field heighting barometer in each helicopter. Similar microbarometers were used in the base camp and various flycamps to establish the diurnal pressure curve at those places during each flight. A recording Askania microbarograph was set up at the base camp, but, owing to continual breakdowns, useful records were obtained for only short periods during the survey. Wet and dry bulb thermometers were read at the various camps to determine the humidity and temperature corrections.

Performance of the microbarometers was poor, and purely instrumental faults were responsible for considerable errors in heighting. These faults are revealed by the failure of the field instrument to agree with the corrected base reading at the conclusion of each flight and by discrepancies between various microbarometers when more than one instrument was taken on traverse. It is recommended that the Askania instruments be subjected to rigorous testing and overhaul. If possible other types of pressure-sensitive altimeters should be tested side by side with the Askania microbarometer.

Radios

Reliable radio communication between the base camp, flycamp, and helicopters is essential for the efficient and safe conduct of this type of survey. Communications during the 1961 survey were better than those during earlier surveys owing to the use of a 100-watt transceiver in the base camp and to special aerial equipment in the helicopters. Radio breakdowns were fairly frequent and standby equipment should be carried by the party. An additional radio for use by supply vehicles would be advantageous. As the result of a series of field tests the following aerials are recommended:

(1)	Collins base radio	½-wavelength horizontal, as high as possible
(2)	R.F.D.S. camp radio	¼-wavelength vertical

(3) Flycamp (to helicopter) ¼-wavelength vertical

(4) Flycamp (to base) ¼- to ½-wavelength horizontal, directed towards base

Helicopters

The two helicopters used on this survey were a Bell 47J Ranger and a Bristol Sycamore operated by Ansett-ANA. These two types of aircraft differ in many ways, and in particular require different grades of fuel and oil. The availability of a specific helicopter for any flycamp could not be carried out. However, the two aircraft did have similar endurances when loaded for normal gravity traversing and most flight plans could therefore be made out in advance without nominating which helicopter was to be used.

Auxiliary fuel was carried by both aircraft in 5-gallon plastic jerricans and 12½-gallon drums to restrict container weight. The use of jerricans did not interfere with operations but specially fitted auxiliary tanks would be far more convenient and safer.

The Bristol Sycamore was not particularly suitable for this type of survey. The Bell 47J was fitted with a specially designed navigation table and proved particularly convenient for gravity traversing.

Some revised performance figures, based on field experience, are given below for both aircraft.

Characteristics	Bell 47J	Bristol Sycamore
Cruising speed (statute m.p.h.)	72	80
Average effective flying time for 7 miles including take-off and landing (minutes)	6½	6½
Average effective fuel consumption per hour of charge time (imperial gallons per hour)	12	22
Fuel capacity on gravity traverse, i.e. carrying geophysicist (170lb) and equipment (55lb)		
(a) Main tank (imp. galls.)	39	63
(b) Jerricans (imp. galls.)	50	87
Maximum endurance, loaded for traverse (hours: minutes)	6:10	6:05
Usable endurance after allowing safety reserve (hours: minutes)	5:40	5:35
Maximum planned traverse (statute miles)	280	260

Unserviceability of the aircraft (including Sundays) was roughly 25%. Major overhauls included two engine changes for the Bell 47J and one engine change and two exhaust manifold changes for the Bristol Sycamore. Excessive wear in the Bell engine was cured by installing a centrifugal air filter to prevent entry of the coarser particles of dust stirred up during each landing and take off.

Ansett-ANA carried a large stock of spare parts at the base camp and at Alice Springs (including spare engines), and provided excellent service by carrying out all repairs with a minimum of delay.

Vehicles

Performance of all vehicles was in general satisfactory. Although the area covered by this survey is reasonably well served by unmade (dirt) roads, the two-wheel-drive vehicles delayed the party during several camp shifts. The wide variety of vehicles necessitated a large supply of spare parts including eight different sets of road springs and five different sizes of tyres.

It is recommended that future parties standardise on S.W.B. 1-ton Internationals (with modifications as fitted to C90122) and 3-ton Bedfords for both trucks and tankers. A heavy duty four-wheel trailer for motor spirit would be advisable, and if dual purpose flat-top tankers can be obtained it should be possible to reduce the vehicle fleet by omitting the base camp truck. All vehicles should be 4 x 4's if the party is to operate in remote areas.

Camping equipment

The camping equipment provided for the party was satisfactory. The gas refrigerators and stoves were found to be reliable, safe, and convenient. The Sievert gas lamps proved fragile, and although care was exercised, breakages of mantles and glasses were numerous; difficulty was experienced in obtaining replacements.

APPENDIX E

Additional helicopter-usage, 1960

During the 1960 survey, the helicopter was made available for work other than gravity traversing as set out below:

Topographic surveying

Department of the Interior surveyors joined the party for a period of three weeks at the Lake Caroline base camp. During this time they established levels at 18 stations down the Hay River to a point about 70 miles south of the Lake Caroline camp. They established an astrofix at the southermost station, 62/38.

This levelling was carried out on foot by a surveyor with one chainman holding the staff. The arrangements suggested before the survey in the Preview Report could not be used because of a Department of the Interior ruling that the surveyor had to be returned to the base camp every night. This work, which was in the nature of an experiment, was very successful from the surveying point of view as 7 miles of levelling was walked each day. The utilisation of the helicopter was high particularly when the surveyor was some distance from the camp, and this severely interferred with the programme of gravity traversing. It is not advisable to combine the two types of operation in this manner.

Regional magnetic

BMR geophysicist J. van der Linden established a regional magnetic station at gravity station 62/38.

Geological

BMR geologist M. Reynolds joined the party at Duck Point base camp. The helicopter was made available to him for three days during which he visited isolated rock outcrops in inaccessible desert areas along the eastern margins of Simpson Desert North and Simpson Desert South near Poeppel's Corner.

APPENDIX F

Density determinations on rock samples

Density determinations have been made on various rock samples collected throughout the survey area by geological and geophysical field parties (Table 3). The method of weighing the samples in air and in water was used. Porous samples were coated with paraffin wax before immersion in water and in these cases a correction has been applied to allow for the buoyancy of the wax.

The densities so determined are the in situ density of surface samples and may not be representative of the densities of rocks at depth. Wherever possible, fresh samples were selected in preference to weathered samples.

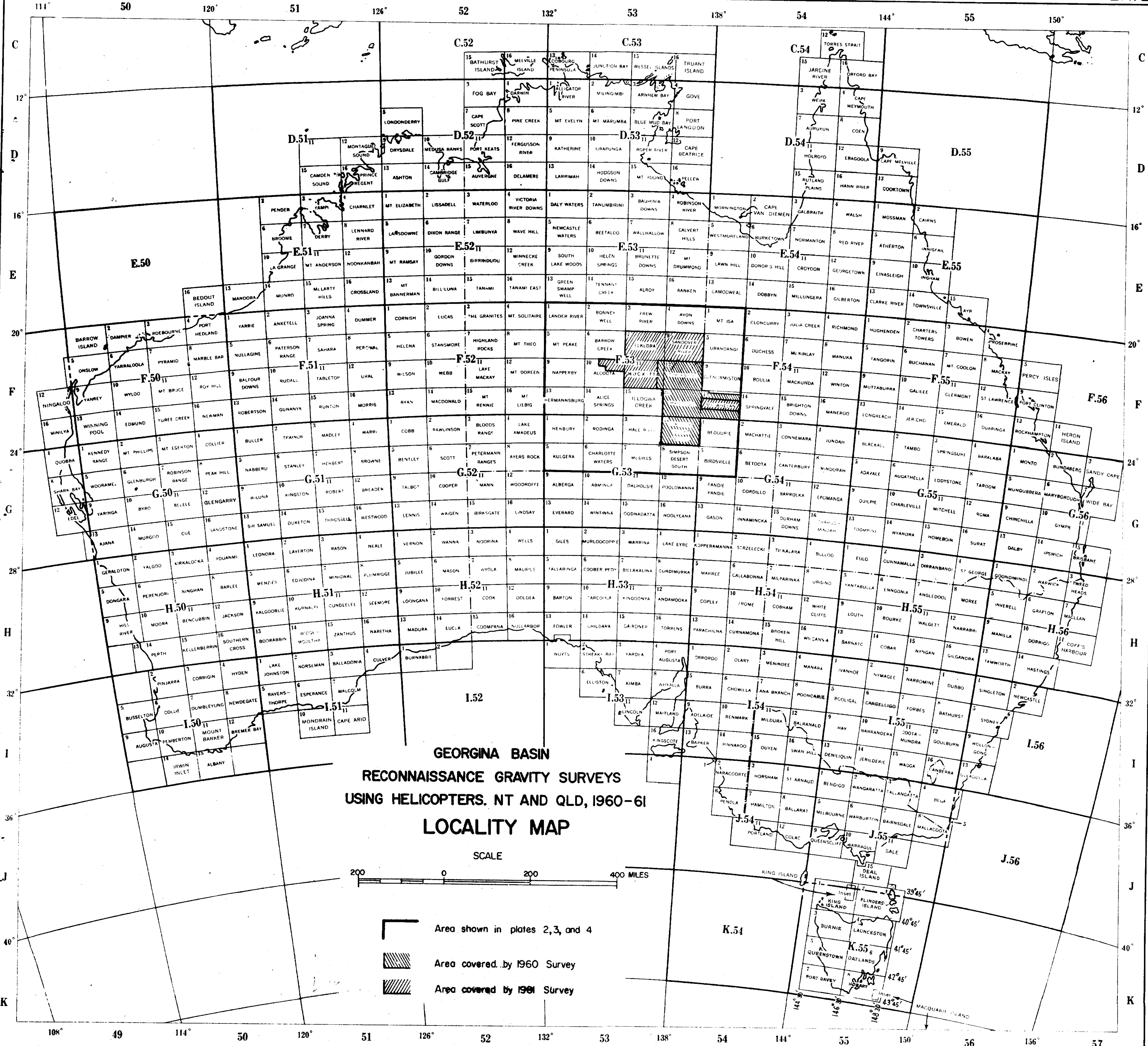
The densities of the Cambrian limestones are quite high (2.7-2.8 g/cc) and in fact are higher than the densities of most of the underlying Precambrian rocks. Densities within the Proterozoic rocks vary between 2.4 and 2.8 g/cc (the dolerite of density 3.0 g/cc is not widespread). Densities within the basement complex of Archaean rocks intruded by Lower Proterozoic granites vary between 2.5 and 2.8 g/cc. The densities of Upper Cambrian sandstone and post-Cambrian sediments are lower (1.7-2.5 g/cc).

Development of a thickness of Cambrian limestones may lead to a local gravity 'high', whereas development of a thick succession of post-Cambrian sediments will generally lead to a local gravity 'low'. Density variations within the Precambrian rocks may also give local gravity 'highs' and 'lows'; consequently, the interpretation of gravity data based on rock densities only is difficult in areas where other geophysical and geological data are unknown.

TABLE 3

Densities of rock samples

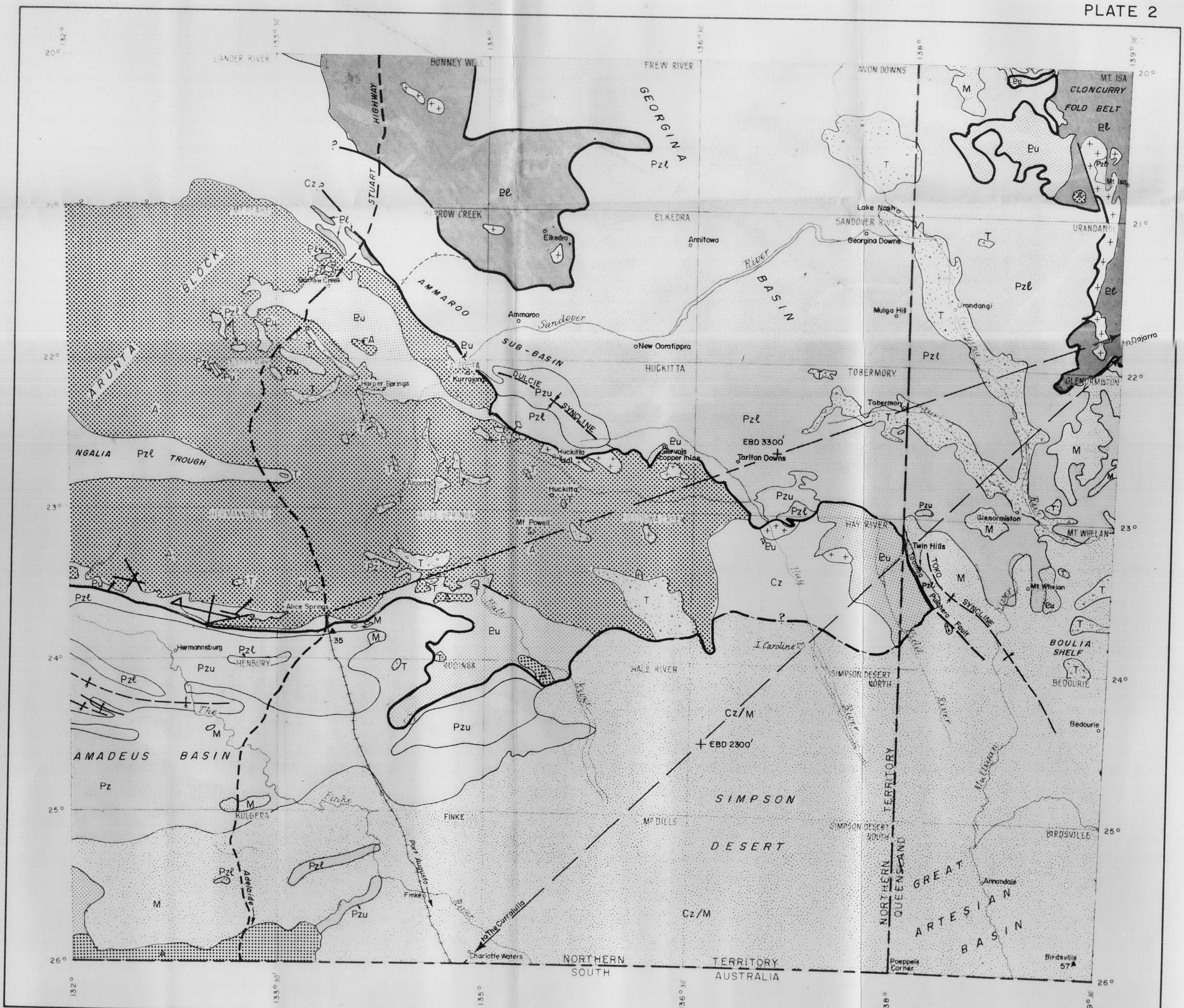
Sample No.	Locality and photo Reference	Age and Formation	Type	Density (g/cc)
-	Tobermory, Run 4 Photo 5041	Tertiary	Silicified limestone, overcrusted	2.50
-	Hay River (near Lake Caroline)	Cretaceous	Reddish claystone (? siltstone)	1.68 (porous)
-	Hay River (near Lake Caroline)	Cretaceous	Reddish sandstone	2.23 (very porous)
-	-	Lower Ordovician/ Upper Cambrian (Ninmaroo Limestone)	Limestone	2.71
To 18	Tobermory	Upper Cambrian	Yellow sandstone	1.88 (very porous)
Ha 85	Huckitta, Run 12, Photo 5161	Upper Cambrian (Arrinthrunga Fm)	Silicified limestone	2.84
Ha 96	Huckitta	Cambrian	Dark grey-brown, fine-grained limestone	2.68
Ha146	Huckitta	Lower Cambrian (Mt.Baldwin Fm)	Quartz greywacke	2.51 (porous)
Ha 90	Huckitta, Run 11, Photo 5199	Upper Proterozoic (Corabbra Arkose)	Silicified arkose	2.56
Ha 31	Huckitta, Run 11, Photo 5211	Upper Proterozoic	Dark dolerite, fine-grained	3.04
Ha 20	Hay River	Upper Proterozoic	Reddish-grey (purple) dolomite	2.76
Ha 19	Hay River	Upper Proterozoic	Brown dolomite	2.66
Ha 16	Hay River, Run 3 Photo 5083	Upper Proterozoic	Dark greyish silty sandstone (? glacial)	2.65
Ha 15	Hay River, Run 3, Photo 5013	Upper Proterozoic (Grant Bluff Fm)	Quartz sandstone	2.39
Ha 18	Hay River, Run 3, Photo 5061	Lower Proterozoic	Coarse porphyritic granite	2.56 (weathered)
Ha 99	Huckitta	Lower Proterozoic	Reddish granite	2.59 (porous)
Ha145	Huckitta (Bellbird Mine)	in Archaean	Copper ore (carbonates)	2.64 (porous)
Ha 33	Huckitta	Archaean	Orthoclose-quartz-biotite gneiss	2.66 (weathered)
Ha 56	Huckitta	Archaean	Reddish mica schist	2.47 (weathered)
Ha238	Alcoota	Archaean	Quartz-feldspar-muscovite gneiss	2.77 (weathered)
Ha 17	Hay River	-	Fine banded ferrugious sandstone; some mica	2.17 (porous)



NMP/59/151-1

To Accompany Record No 1966/147 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

F53/B2-23



Based on G371-12-0

Cz	Cainozoic
T	Tertiary
Cz/M M	Mesozoic
Pz Pzu Pzℓ	Palaeozoic
Ꝑu	Upper Proterozoic
Ꝑℓ	Lower Proterozoic
A	Archaean
+ + +	Granite

▲35 BMR gravity pendulum station

KULGERA 1:250,000 map area

Fault
Fault, indefinite

Anticlinal axis

Synclinal axis

BMR aeromagnetic flight line

+EBD Estimated basement depth

Basin boundary (Precambrian against younger sediments)

COMPILED AND DRAWN MARCH 1961

GEORGINA BASIN
RECONNAISSANCE GRAVITY SURVEYS USING HELICOPTERS. NT AND QLD, 1960-61
REGIONAL GEOLOGY

SCALE IN MILES

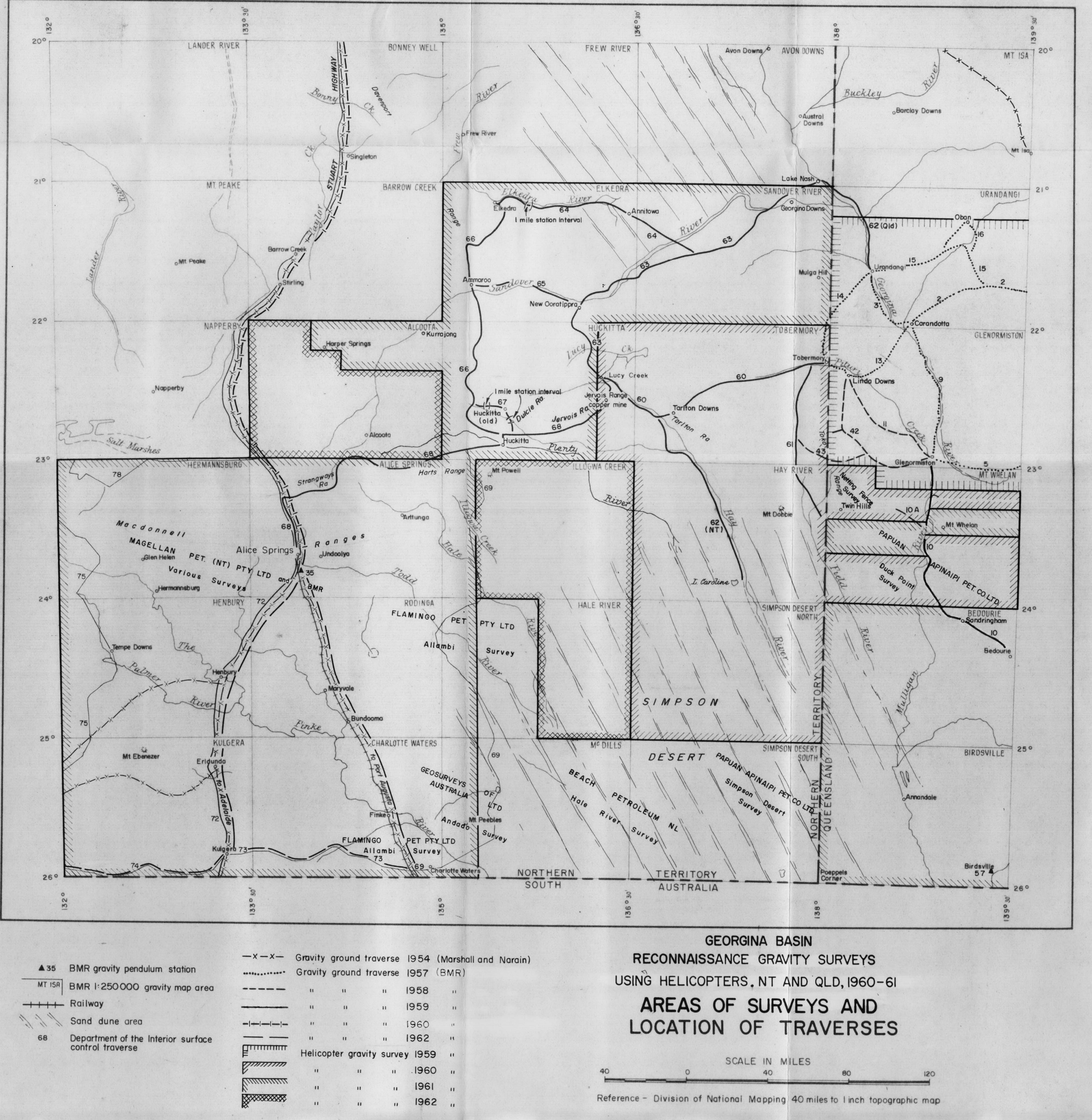
40 0 40 80 120

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

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

To Accompany Record No 1966/147

F53/B2-20-1



GEORGINA BASIN
RECONNAISSANCE GRAVITY SURVEYS
USING HELICOPTERS, NT AND QLD, 1960-61

AREAS OF SURVEYS AND LOCATION OF TRAVERSES

SCALE IN MILES

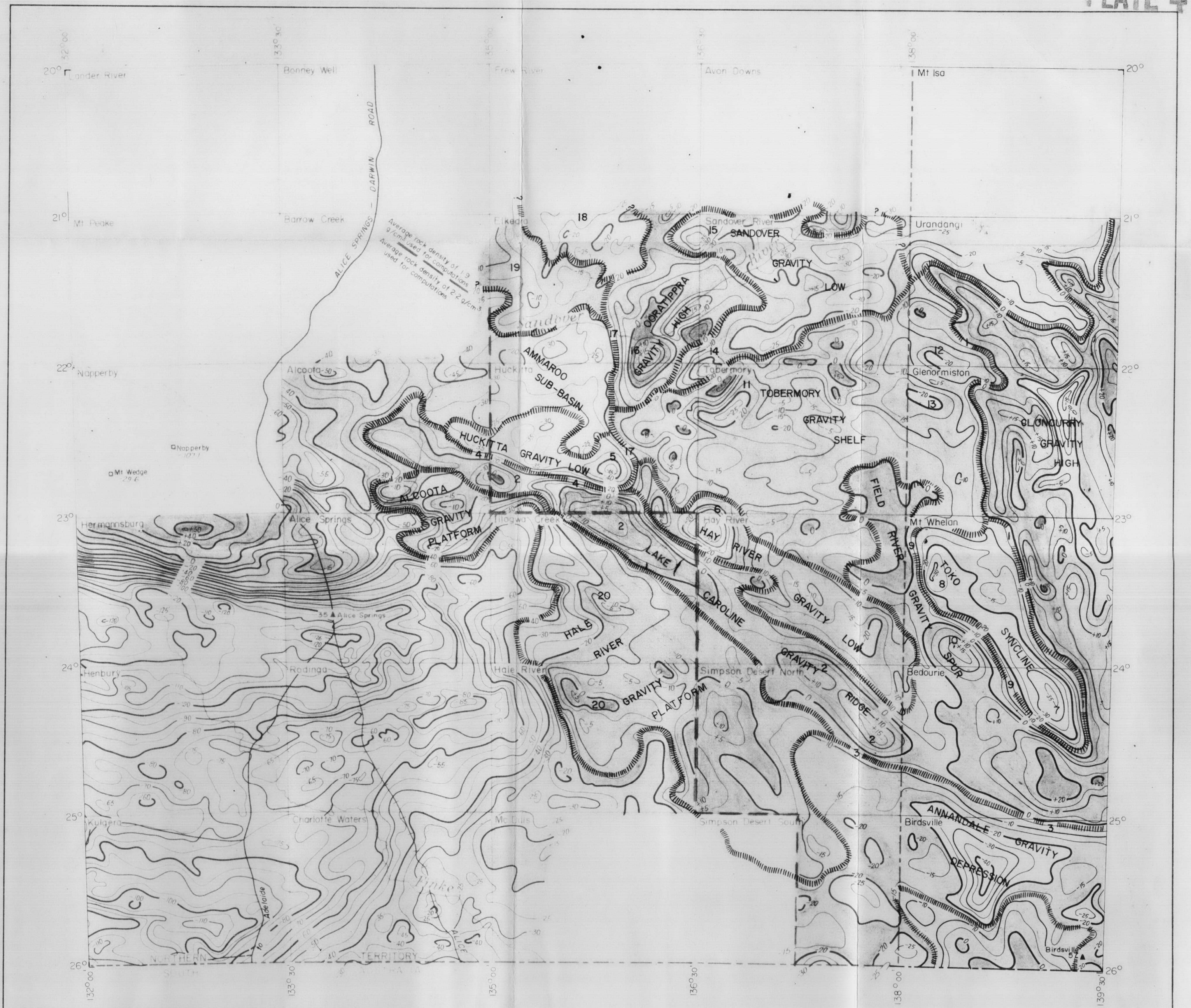
40 0 40 80 120

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

COMPILED AND DRAWN MARCH 1961

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS F53/B2-24

PLATE 4



LEGEND

- Isogals, values in milligals
- ▲35 BMR gravity pendulum station
- ▫ BMR gravity reading at aerodrome
- Mt Isa — BMR 1:250,000 gravity map area
- Gravity 'High'
- Gravity 'Low'
- 12 — Gravity feature number
- Gravity province boundary

Bouguer Anomalies are based on the observed gravity values at BMR pendulum station:

No.35 Alice Springs	978,653·7 milligals	
No.54 Longreach	978,790·2	"
No.55 Cloncurry	978,651·4	"
No.56 Boulia	978,793·2	"
No.57 Birdsville	979,003·7	"

Elevation datum: Queensland State

GEORGINA BASIN
RECONNAISSANCE GRAVITY SURVEYS USING HELICOPTERS
NT AND QLD, 1960-61

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

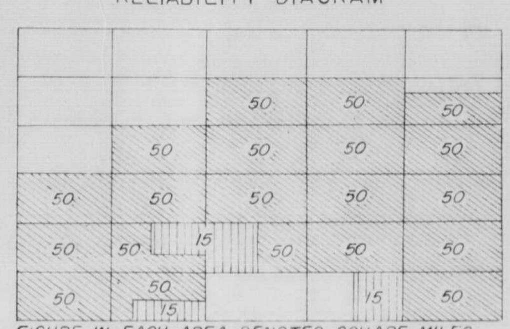


FIGURE IN EACH AREA DENOTES SQUARE MILES PER GRAVITY STATION.

G R A V I T Y	
SURVEY	METHOD
Helicopter by BMR	Regular grid coverage, air photography, barometric levelling.
Semi-detailed by Flamingo and Papuan Apinaipi	Helicopter traverses, conventional and barometric levelling.

COMPILED JUNE 1963

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS F 53/B2-22-1A
TO ACCOMPANY RECORD No 1965/52
AND RECORD No 1966/142
AND RECORD No 1966/147