COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1970 / 15

Reconnaissance Gravity Survey of parts of Northern Territory and Western Australia, 1967

by

R. Whitworth

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SUMMARY

In 1967 a reconnaissance helicopter gravity survey from Arnhem Land (Northern Territory) to the Kimberleys (Western Australia) was carried out by Rotorwork Helicopters Pty Ltd under contract to the Bureau of Mineral Resources. About 7200 stations were occupied during the course of the survey. Ties were made to previous gravity surveys to aid integration of all surveys in the area.

Nineteen gravity provinces were delineated by the survey. In sedimentary areas, the provinces correlate well with the geology. The results indicate that the Ord Basin is the Cambrian remnant of an extensive Proterozoic-Palaeozoic basin that is overlain by the Canning Basin in the south. A series of Bouguer anomaly lows along the edge of the McArthur Block are interpreted as minor sedimentary basins. An intense Bouguer anomaly low suggests that the Ngalia Basin may be considerably larger than its surface expression.

Over the metamorphosed areas, the Bouguer anomaly pattern is generally smooth and simple and shows poor correlation with the geology. It is thought that the grade of metamorphism rather than geological structure dominates the regional density variation. If the original rock types were fairly uniformly distributed throughout the area, intense folding would not alter the regional density distribution, while the higher-density metamorphic mineral assemblages are found in the areas of high degree of metamorphism.

1. INTRODUCTION

The 1967 helicopter gravity survey covered about 820,000 square kilometres of the Northern Territory and northern Western Australia from Arnhem Land to the Kimberleys. A small area about 300 kilometres north-west of Alice Springs was also surveyed. Plate 1 shows the areas covered. The survey was carried out under contract to BMR by Rotorwork Helicopters Pty Ltd, the geophysical work being sub-contracted to Kenneth McMahon and Partners.

This report outlines the main geological features (Plates 2 and 3), and summarises the results of previous geophysical surveys. The preliminary analysis presented is orientated towards interpretation of the regional features exhibited by the Bouguer anomaly values. The station density of one station per 125 square kilometres does not allow detailed analysis of the more intensely folded and faulted areas.

The barometric levelling network has been adjusted onto third-order benchmarks placed and levelled by the Department of the Interior. Gravity control was provided by the Isogal gravity base station network set up by the BMR Regional Gravity Group (see Plate 5). The accuracy of the results is indicated by the standard deviations of the network adjustments, which are tabulated in Appendix B.

Previous gravity data obtained around the periphery of the Bonaparte Gulf have not yet been integrated with the helicopter gravity results. However, reoccupations of key points in old surveys were made in 1967 using Bigg-Wither's very useful compilation of ties necessary to remove errors in survey connections and achieve satisfactory integration at a later date (Bigg-Wither, 1965). Sufficient ties were attempted to guarantee redundancy even if some of the tie points could not be reliably identified. In fact, only points on surveys conducted by Companie Generale de Geophysique in the Port Keats area could be definitely identified. Elsewhere, landing and reading at the "pin-prick" point on the airphoto was the only thing possible as the previous markers had disappeared.

The following works, though not always specifically mentioned in the text, have been drawn upon heavily for geological, tectonic, and geophysical details: Bigg-Wither (1963, 1965), David (1950), Fairbridge (1953a) Geol. Soc. Aust. (1962), B.F. Jones (1969), McWhae et al., (1958), and Noakes (1949).

2. GEOLOGY

The geology of northern Australia is known mainly at a reconnaissance level. In some cases, the geology is based almost entirely on photo interpretation. More intensive geological surveying has been carried out over localised areas of economic significance. It is useful to summarise the regional geological setting before discussing the area in more detail.

The major geological features are strongly influenced by, and usually orientated along, one of two prominent structural trends or lineaments which are roughly at right angles. In the north, the trends are north-east and north-west, but there is a gradual shift to an E-W and N-S orientation in central Australia. The tectonic trends appear to have developed in the Lower Proterozoic, when the only intense folding, faulting, and metamorphism occurred. Since then, the major tectonic activity has been vertical adjustment of basement blocks by faulting along reactivated Lower Proterozoic fault lines. Horizontal movements seem to have been negligible.

Thick sequences of sub-horizontal Upper Proterozoic sediments in the Kimberleys, Victoria River, and Arnhem Land are bounded by highly faulted, folded, and intruded geosynclinal belts of Lower Proterozoic age. Only minor Palaeozoic basins occur in the north in the Daly River and Ord River areas, but in the south and west, thick Palaeozoic deposits are found in the Canning, Wiso, Ngalia, and Amadeus basins. Structural ridges or Precambrian mobile belts bound the majority of the basins.

The presence of sedimentary basins offshore is inferred from seismic and aeromagnetic work. From north of Melville Island south-westward along the continental shelf to offshore of the Canning Basin the deposits are believed to be Mesozoic to Tertiary in age, while in the Arafura Sea the sediments are postulated to be Palaeozoic. The trend of these features appears to parallel the edge of the continental shelf rather than onshore tectonic lineaments.

There have been few true geosynclinal deposits within the region since the Lower Proterozoic. Most deposition has been in intracratonic basins bordering the older unstable areas. The basins are generally broad and asymmetric, controlled by hinge-line faults and basement irregularities. As mentioned before, much of the folding is consistent with vertical movement and tilting of basement blocks rather than with compression.

Several geological or structural provinces have been identified within and around the survey areas. These are shown in Plate 2. It is possible to separate these provinces into three main classes or types based upon observable features such as folding, faulting, degree of intrusion, and rock type. These descriptive classes are not meant to imply any particular origin or genetic relationship; they are:

(a) Block - an area of sub-horizontal sediments, little deformed since deposition; generally of Upper Proterozoic age.

(b) Basin - an area of sediments, frequently of considerable thickness, with contemporaneous folding and faulting; generally of Phanerozoic age.

(c) Mobile Belt - an area of folded, faulted, intruded, and metamorphosed rocks; generally of Lower Proterozoic age.

The sedimentary and tectonic history of the geological provinces that fall within the survey area are discussed in more detail below.

Arafura Basin

Little is known about the Arafura Basin. It has a land area of around 10,000 square kilometres, and may develop into a basin continuous with the Arafura Depression (Reynolds et al., 1963).

Arenites, lutites, and carbonates between 1500 and 3000 metres thick are exposed on the north coast of Arnhem Land and the nearby islands. They rest unconformably upon Upper Proterozoic rocks, and are thought to be of Cambrian age. There is a thin veneer of Mesozoic sediments. To the north, the magnetic basement is estimated to be 6000 to 9000 metres below sea level (Shell Development, 1966a). Marine seismic work (Shell Development, 1966b) indicates about 300 metres of flat-lying beds presumed to be Mesozoic, overlying up to 5200 metres of folded beds of uncertain age. It is suggested that these beds are of Upper Proterozoic age, but possibly Palaeozoic deposits are preserved in the deep parts of the basin.

Arunta Complex

One hundred and eighty thousand square kilometres of supposedly stable Archaean rocks crop out north of the Amadeus Basin and form the Arunta Complex. The elongate Ngalia Basin of Palaeozoic age is superimposed upon it. The structural relation of the area with the adjoining Canning Basin, Tanami Mobile Belt, and Wiso Basin is not well known.

Greywacke, sandstone, shale, limestone, and basic flows or sills, of unknown but probably great thickness, have been intensely metamorphosed and metasomatised, forming gneiss, schist, amphibolite, and quartzite. Later intrusions of possible Proterozoic and Palaeozoic age have occurred.

The dominant trend of lineations is NNE, as are the axes of the intense, small-scale folds. However, the large folds and major faulting trend easterly, similar to the trend in the Amadeus Basin. The Archaean may possibly be thrust over the northern edge of the Ngalia Basin. Such movement is probably of Middle Palaeozoic age. Therefore the Arunta Mobile Belt may not be part of the stable Australian Precambrian shield.

Bonaparte Gulf Basin

The basin has a land area of 20,000 square kilometres and a possible seaward extension of 100,000 square kilometres or more. It abuts the Halls Creek Mobile Belt to the east, and overlies the Proterozoic sediments of the Kimberleys in the west. The rocks appear to become younger from south-west (Cambrian) to north-east (Permian) suggesting an asymmetric basin, but marine seismic work (Smith, 1966) shows there is a considerable thickness (3000 metres) of Mesozoic and Tertiary sediments in the middle of the Bonaparte Gulf.

On land, the Proterozoic basement is overlain by Antrim Plateau Volcanics in the south-west. Then 1000 metres of Middle to Upper Cambrian sandstones with minor shale and limestone are followed by 200 metres of Lower Ordovician greensand. A large erosional gap occurs, and the next sediments are Middle to Upper Devonian conglomeratic sandstones, with some carbonates, perhaps 1200 metres thick. These are succeeded by a further 1200 metres of a sandstone-limestone sequence lasting into the early Carboniferous. Lower Carboniferous sediments of a similar type occur for 300 to 600 metres followed by an erosional break. More than 300 metres of later Carboniferous sandstones were succeeded by marine beds and glacial deposits of the Permian. To the north-east a further 500 metres of Upper Permian sandstone and shale with coal crop out in the coastal area. Only occassional outliers of Mesozoic and Cainozoic sediments are found on the land.

Aeromagnetic work in the Gulf (Australian Aquitaine, 1966c) suggests the magnetic basement deepens to 6000 metres along a fairly narrow zone running northwards to the Timor Sea. Several possible folds and faults have been detected on the flanks of the basin. The magnetic basement seems to correspond to the Proterozoic rocks. As the seismic work (Smith, 1966) has shown that there is 3000 metres or so of Mesozoic and later sediments within the Gulf, there should be also Palaeozoic rocks in the order of 3000 metres.

Faulting has been the dominant structural element within the basin, with the north-east and north-west trends characteristic of the Proterozoic. At the beginning of the Palaeozoic, downfaulting formed a depression within which the basin developed. Interruptions have occurred more frequently at the edges while sedimentation has been more continuous in the middle of the basin. Reactivation along the old fault lines during the Palaeozoic has been the main cause of facies and thickness variations across the basin.

Daly River Basin

The Daly River Basin is bounded by Proterozoic metamorphics in the north. Its southerly limits are masked by Mesozoic sediments. The basin could have an area up to 80,000 square kilometres.

The Buldiva Quartzite of Upper Proterozoic age is the oldest rock that crops out within the basin. It consists of sandstone and quartzite with some grit, shale, and conglomerate. Presumably these beds are the equivalent of the Victoria River Group to the south-west. Unconformable Antrim Plateau Volcanics were extruded over much of the region, followed by the Lower Cambrian limestone, sandstone, and shale of the Daly River Group. The Group probably does not exceed 300 metres in thickness. The volcanics may have been folded slightly and eroded before deposition of the Daly River Group, as in some cases the sediments rest directly on Proterozoic rocks. To the south, the basin is covered by the unconformable mudstone, sandstone, grit, and conglomerate of the Mullaman Group of Mesozoic age.

The Buldiva Quartzite and Daly River Group have been subjected to broad folding movements. Pronounced jointing and monoclinal folding of the quartzite suggest stronger forces than those responsible for the Cambrian movements. The dominant movement has been vertical, with little accompanying deformation.

Halls Creek and King Leopold Mobile Belts

The Kimberley Block is bounded on its landward side by highly metamorphosed, faulted, folded, and intruded rocks in two narrow belts running north-east to Darwin (Halls Creek Mobile Belt) and north-west to Yampi Sound (King Leopold Mobile Belt). The belts have an area of about 120,000 square kilometres.

The oldest rocks exposed are Lower Proterozoic geosynclinal rocks of predominantly greywacke type, with some carbonates and volcanics, in a highly metamorphosed state, called the Halls Creek Metamorphics. The total thickness of strata is unknown. The rocks have been intruded by dolerite and gabbro, followed by large-scale granitic intrusions (the Lamboo Complex) and granitisation. Intrusion does not affect the King Leopold Formation of Upper Proterozoic age. Considering the degree of folding and metamorphism, the Metamorphics and granites are placed in the Lower Proterozoic. Isolated inliers of probably Upper Proterozoic rocks have been found in fault zones.

The axes of folding and major faults run parallel to the major axes of the two complexes. The Halls Creek Mobile Belt has been interpreted as a Lower Proterozoic geosyncline, possibly a continuation of the Pine Creek geosyncline. The King Leopold Mobile Belt, along with the Tanami Mobile Belt has been thought to be an extension of the Warramunga Mobile Belt (Traves, 1955). However, the Wiso Basin, with a considerable thickness of Upper Proterozoic to Devonian sediments, has been discovered between the Tanami Mobile Belt and the Warramunga Mobile Belt (Milligan et al., 1966).

Kimberley Block

The Kimberley Block covers an area of 150,000 square kilometres, and consists of sub-horizontal Upper Proterozoic and undifferentiated Proterozoic sediments and volcanics. It is bounded in the south-west and south-east by highly metamorphosed rocks of Lower Proterozoic age. The Palaeozoic Bonaparte Gulf Basin adjoins it in the north-east while its north-west boundary has not been determined.

The Upper Proterozoic sediments were unconformably deposited upon the Halls Creek Metamorphics of presumably Lower Proterozoic age when the area sank to become a nuclear basin. About 25,000 meters of an arenite-volcanic sequence (King Leopold Formation, Mornington Volcanics, and Warton Beds) were laid down in lower Upper Proterozoic times, followed by tillite (Walsh Tillite), dolomite, siltstone and arenite (Mount House Beds) in the upper Upper Proterozoic. The volcanics and tillites are found only in the west. At the end of the Precambrian, the region was raised and deeply dissected. Possibly Antrim Plateau Volcanics were extruded over some of the block, but only two small areas remain in the north-east.

Since Precambrian times, the block has been tilted and has risen and sunk, but actual deformation has been slight. The rocks are gently folded into two broad basins. Adjacent to the mobile belts, folding is intense, but faulting is more prevalent than folding. In places, faults and jointing may run for many miles. Fault trends are parallel to the bounding complexes. Most of the faults developed in Precambrian time, probably in the lower Proterozoic, with reactivation in later times.

McArthur Block

The McArthur Block embraces the McArthur River Basin and Bulman Basin of the Tectonic Map of Australia. It is more logical in this context to consider them as a single unit, covering perhaps 150,000 square kilometres.

In the north-west, about 3000 metres of coarse arenites and volcanic rocks unconformably overlie the Lower Proterozoic and Archaean rocks. The basal unit is mainly volcanics up to 1000 metres thick (? the equivalent of the Mornington Volcanics of the Kimberley Block) confined to the westerly part of the Arnhem Land Plateau. Then a coarse arenite sequence with large lenses of volcanic flows grades up into less coarse arenites with basalts. The deposits increase in thickness in local basins. Farther south, the earliest rocks are a mixed arenite-rudite-volcanic sequence, now thought to be of the same age as the northern deposits. Thicknesses may reach 3600 metres. A carbonate sequence follows with some volcanics and arenites. Algal biostromes and bioherms occur. This sequence is thickest around the McArthur River (4300 metres). The deposition of carbonates was succeeded by vertical movements and shift of foci of sedimentation to other areas where arenites predominated in deposits up to 3000 metres thick.

The rocks are strongly faulted and well jointed along north-east and north-west directions. Faulting is most strongly developed along basin margins. The area is notable for fault movement contemporaneous with sedimentation, resulting in sharp local unconformities and abrupt changes in thickness and lithology from place to place.

Melville Island Basin

A basin of Cretaceous sediments is known to extend offshore from Darwin, encompassing Bathurst and Melville Islands. The southern margin is bounded by the Pine Creek Mobile Belt, but its other limits are unknown. This basin has been considered as a Mesozoic peripheral development of the Bonaparte Gulf Basin (Smith, 1966).

An aeromagnetic survey suggests there could be up to 9000 metres of sediments north of Melville Island (Shell Development, 1966a). Marine seismic work for the same company shows 4500 metres of Mesozoic deposits in the same area. (Shell Development, 1966b). Refraction seismic work on Bathurst Island (Oil Development, 1962a) indicates that the Mesozoic rocks dip gently northward and are probably underlain by Upper Proterozoic rocks. The Cretaceous sediments on land include glauconitic sandstone, mudstone, and siltstone.

No major structures are known. The Mesozoic rocks are mainly flat lying, and deformation is slight. Folding occurs in the underlying Proterozoic in the Arafura Sea.

Ngalia Basin

The Ngalia Basin is an elongate Upper Proterozoic-Lower Palaeozoic feature running east-west within the Arunta Mobile Belt, and covering an area of about 18,000 square kilometres.

During Proterozoic times, vertical movements within the Arunta Mobile Belt resulted in a topographic depression, within which an almost continuous sequence of sediments was laid down. A tillitic basal layer was followed by an estimated 1100 metres of sandstone, arkose, limestone, and more sandstone. A hundred metres or so of slightly unconformable Lower Palaeozoic sandstone and greywacke was then laid down. The older sediments are therefore thought to be Upper Proterozoic in part. A thick (2000 metres) development of conglomeratic sandstone unconformably overlies the greywacke. From sililarity to the Amadeus Basin, the movement prior to deposition of the coarser sandstones is correlated with the Middle Devonian Tabberabberan Orogeny. The rocks were folded into a series of east-west folds, possibly during the Upper Carboniferous Kanimblan Orogeny (Cook, 1963). The apparent absence of post-Palaeozoic deposits suggests the area has been stable during this time.

Possibly block faulting in the Proterozoic was the cause of the original Ngalia Basin. Faulting is fairly common in the Arunta Mobile Belt but is infrequent within the sediments. Plunging synclines and anticlines with east-west axes are the major feature within the basin. A pattern of broad synclines and narrow anticlines is found, as in the Amadeus Basin. An aeromagnetic survey (Pacific American, 1963) suggests that the sediments could reach 5200 metres in thickness. The gravity minimum and geological basin do not coincide, (Flavelle, 1965), suggesting that the structure may be complex. It is now suspected that the northern edge of the basin may be an overthrust of Archaean rocks onto the basin (Cook & Scott, 1966).

Ord Basin

The southern part of the Sturt Block as defined by Traves (1955) has been folded to form the Ord Basin, covering an area of 30,000 square kilometres. The Argyle, Hardman, and Rosewood sub-basins occur within the main basin (Traves, op. cit.). The northern part of the Sturt Block forms the Victoria River Block as defined in this report.

Up to 900 metres of Antrim Plateau Volcanics are separated from the underlying Upper Proterozoic sediments by a considerable erosional unconformity. The basalts occur in several flows and are apparently overlain conformably by 600 metres of alternating limestone and shale of the Negri Group, deposited during Middle Cambrian times. A 500-metre sequence of conformable, unfossiliferous Elder Sandstone constitutes the youngest rocks in the basin except for small outliers of lacustrine sediments of Tertiary-Quaternary age. The sedimentary sequence is preserved only in the subsidiary basins.

The area has been fairly stable since Proterozoic times. Faulting is rare except in the tongue of Proterozoic rocks jutting out from the Halls Creek Mobile Belt. The sub-basins appear to be post-depositional features of no great magnitude. They are possibly the result of basement adjustments.

Pine Creek Mobile Belt

About 50,000 square kilometres of Lower Proterozoic metamorphics and granites form the Pine Creek Mobile Belt or Geosyncline. This area is very similar in character to the Halls Creek Mobile Belt, and possibly they form a continuous mobile zone.

The oldest sediments comprise perhaps 3000 metres of coarse arkose, siltstone, and greywacke with occasional algal dolomite. These rocks grade into greywacke and carbonaceous lutites, and finally into a mixed lutite-dolomite-chert sequence. Then about 2700 metres of greywacke was deposited, at which stage faulting occurred and a secondary trough developed to the east. In this trough, 6000 metres of dolomite, chert, and carbonaceous rocks, overlain by siltstone and greywacke, was deposited. The sediments were intruded by sills and dykes. Finally, up to 1500 metres of sandstone was laid down on an unstable platform in the west. Folding and some fault movement were followed by intrusion of granites and moderate metamorphism.

The basins in which sediments were deposited were asymmetric, steep on the western side and shelving gradually to the east. They appear to have been fault controlled. Faulting continued throughout the period of deposition. It was mainly slight and spasmodic vertical movement. Folding was never severe, and lack of foreshortening of the geosyncline suggests that differential vertical movement may have been the cause of the faults.

Tanami Mobile Belt

This area of 50,000 square kilometres of metamorphosed Lower Proterozoic and undifferentiated Precambrian sediments forms a possible south-easterly extension of the King Leopold Mobile Belt. The belt grades north and south into postulated Precambrian structural ridges.

An unknown thickness of metamorphosed greywacke and siltstone is tightly folded along south-easterly axes, and intruded by Precambrian granites. Metamorphism is of the greenschist facies. In places, the metamorphics are unconformably overlain by undifferentiated Proterozoic arenites more gently folded in sub-parallel directions.

The tectonic history of the region and its structural relation to adjoining areas is uncertain. The existence of the Wiso Basin must limit its easterly extent. Folding and faulting along north-west axes suggests a common origin with the King Leopold Mobile Belt.

Victoria River Block

About 47,000 square kilometres of sub-horizontal upper Upper Proterozoic sediments crop out east of theBonaparte Gulf. The northern extension of the Halls Creek Mobile Belt forms the block's north-west edge, while the other sides merge into the Daly River and Ord Basins and the structural ridges that bound the Wiso Basin.

The sedimentary sequence of the Victoria River Group is at least 600 metres thick, but may be much thicker. It contains calcareous, arenaceous, and cherty rocks with some siltstone, similar in lithology to the Kimberley Block sediments. The rocks are placed in the upper Upper Proterozoic (equivalent to the Mount House Beds of the Kimberley) though the uppermost portion may extend into the Lower Cambrian. The Antrim Plateau Volcanics overlie the Victoria River Group at the edges of the block, separated by an erosional unconformity.

The tectonic history of the area is very similar to that of the Kimberley Block. Since deposition, the sediments have been folded only slightly. Deformation increases against the Halls Creek Mobile Belt, but elsewhere faulting is the major event.

3. SUMMARY OF PREVIOUS GEOPHYSICAL WORK

A considerable number of geophysical surveys have been carried out within and around the area, the majority of them in the Bonaparte Gulf and Canning Basins and their offshore extensions. Surveys of limited extent have been made over metalliferous Precambrian areas such as Tennant Creek and Rum Jungle. Unfortunately, many of the land surveys to date have covered only local structures so are of little value in elucidating the major tectonic features.

Several seismic and gravity surveys have been made along the coastal periphery of the Bonaparte Gulf Basin. These have generally been over local anticlinal structures or sub-basins (e.g. Alliance, 1964c; Australian Aquitaine, 1965a). The relation of the sub-basins to one another in the south is uncertain. Density reversals are suggested, but some apparent structures may be due only to poor ties between surveys (see Big-Wither, 1963, for a comprehensive compilation up to 1962). The latest aeromagnetic survey over the Gulf (Australian Aquitaine, 1966c) indicates that the basement deepens to 6000 metres - along a fairly narrow zone running northwards to the Timor Sea. Several possible faults and structures are suggested along the flanks of the basin. A marine seismic survey (Smith, 1966) suggests that about 3000 metres of Mesozoic and Tertiary sediments exist in the middle of the basin, so up to 3000 metres of Palaeozoic and ?Upper Proterozoic sediments could occur beneath them. A gravity high of considerable magnitude* coincides with the structural low. This could possibly be due to intra-basement density variations. B.F. Jones (1969) has collated the major results of the marine surveys up to 1967 in his report on a marine contract survey carried out in 1967 for BMR.

The offshore areas of the Melville Island and Arafura Basins have been investigated by Shell Development (1966a, 1966b). The magnetic survey (1966a) indicates that the basement is shallow along the coast, deepening northwards to greater than 9000 metres in two depressions, one north of Arnhem Land, the other north of Melville Island. A zone of shallower magnetic rocks separates the two basins. This zone could be an extension of the Archaean rocks in the Cobourg Peninsula. The marine seismic survey results (1966b) suggested that the Mesozoic cover is thin over the Arafura Basin, but deepens to 4500 metres north of Melville Island in a basin with an east-west trend. A poorly identified reflector in the Arafura Basin at around 5200 metres is possibly magnetic basement. The sub-Mesozoic beds are considerably folded and of uncertain age. They possibly consist of Palaeozoic and perhaps some Proterozoic sediments. Hence the Arafura Basin appears to be a Proterozoic-Palaeozoic basin perhaps 6000 metres deep with a thin veneer of Mesozoic and later sediments. The Melville Island Basin would seem to be a predominantly Mesozoic feature, possibly contiguous with the Bonaparte Gulf Basin.

*Wickham Gravity High

The Ngalia Basin could be 5200 metres deep according to an airborne magnetic survey (Pacific American, 1963). The basin appears to be wedge-shaped, thickening northwards. A major fault zone probably controls the northern edge of the basin, and horsts may occur within the basin. A peculiar feature of the survey results is that large depth figures are obtained over the northern boundary in an area of metamorphic outcrop. A gravity and seismic survey (Pacific American, 1964) confirms the general interpretation. It further suggests that the northern flank may be overthrust. Local features of shallow origin were indicated by the gravity work, but no corresponding seismic anomalies were found. No evidence of salt underlying the principle seismic anomalies has been detected.

A regional gravity survey over the Katherine-Darwin area (Pine Creek Complex) indicates two troughs with a median ridge (Stott & Langron, 1959). Possibly there is a greater accumulation of Proterozoic sediments in the eastern trough. Local gravity highs coincide with basic intrusives, while the granites generate lows. The greatest thickness of Proterozoic sediments may exist in the west under the Daly River Basin.

In the north-east Canning Basin, a Bouguer anomaly low feature with north-easterly trend crosses the basin boundary without attenuation. This suggests that a Proterozoic basin extends beneath the Palaeozoic basin (Flavelle, in prep.). The feature could be the expression of an extension of the Upper Proterozoic-Cambrian Ord Basin. A feature running northwards on STANSMORE* could be interpreted in a similar fashion (Geosurveys, 1965).

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*In this report the names of 1:250,000 sheet areas are written in capital letters to distinguish them from ordinary place names.

4. OBJECTIVES OF THE SURVEY

The major objective of the survey was the continuation of the reconnaissance gravity survey of Australia. There have been few gravity surveys in the area, and most of them have been over local structures or along roads (see Chapter 3).

It was hoped to delineate the major structural units and their relation to one another by means of the helicopter survey. It was expected that there would be three descriptive classes of Bouguer anomaly province corresponding to the geological classes:

(a) Platform (equivalent to Block) - an area of small- to long-wavelength Bouguer anomalies.

(b) Low (equivalent to Basin) - an area of large-amplitude, long-wavelength Bouguer anomalies.

(c) Complex (equivalent to Mobile Belt) - an area of large-amplitude, small-wavelength Bouguer anomalies.

Bound up with the problem of defining the structural units were a variety of geophysical and geological problems which are outlined below.

1. There is a considerable thickness of Proterozoic and Palaeozoic sediments in the Arafura Basin. The landward edge of the basin has never been determined. Nowdays it is thought that sediments of such ages could be petroliferous (Murray, 1965).

2. Basins of considerable size exist within the Proterozoic blocks. Much of the sediment is of similar character to Lower Palaeozoic sediments, and so could be considered as an oil prospect.

3. The Daly River Basin is almost completely unknown. Only a moderate thickness of Palaeozoic sediments is expected, but there may be a considerable development of Proterozoic sediments underneath the basin (Stott & Langron, 1959).

4. The Ord Basin has several sub-basins of small dimensions within it. As the sub-basins' general strike is northerly, more intense surveying along east-west lines would be useful. Traces of asphaltite have been found associated with the Antrim Plateau Volcanics, but its origin is uncertain.

5. The western end of the Ngalia Basin is unsurveyed. The structure appears to be highly asymmetric, and deep intrusives may be involved with the more intense movements. The geological features show considerable similarity to those of the Amadeus Basin, within which hydrocarbons have been found.

6. The form of the junction of the Halls Creek and Pine Creek Mobile Belts is uncertain. They may form a continuous belt or, more likely, subparallel fold systems. Possibly an extension of the Pine Creek Mobile Belt forms the basement ridge postulated to run between the Arafura and Melville Island Basins.

7. The limits of the Halls Creek, King Leopold, and Tanami Mobile Belts are uncertain. Suggested extensions of their structural trends have been put forward several times (e.g. Traves, 1955). Should the Ord Basin continue under the Canning Basin, the Tanami Mobile Belt would be isolated. The structural trend of this mobile belt is uncertain, and it is not known whether the mobile belt dips beneath the Wiso Basin or joins the Arunta Mobile Belt.

8. The Arunta Mobile Belt is not yet fully surveyed. The indications so far are that the geology is extremely complex. Basement density changes and possibly mineralisation are the major causes of the complex Bouguer anomalies.

9. Previous gravity work around the periphery of the Bonaparte Gulf needs to be co-ordinated (Bigg-Wither, 1965) and brought to a common datum. "Structures" that have been outlined on the flanks of the Bonaparte Gulf Basin may be caused only by inaccurate ties between surveys.

5. DESCRIPTION AND INTERPRETATION OF RESULTS

The survey area has been divided into regional Bouguer anomaly provinces; where possible, major Bouguer anomaly units within the provinces have been delineated. Previously recognised features on the edges of the survey area have been retained wherever possible. This has required some adaptation and/or modification at times, but this has been kept to a minimum.

A brief description of each province is made and a tentative interpretation given. Often more than one interpretation is plausible, so all are presented to give an idea of the range of possibilities. The analysis is preliminary only and may later require revision. A simple approach has been made at this stage, and usually a single cause is postulated for each feature.

To aid interpretation, approximate density contrasts have been used to derive rough thicknesses for sediments and intrusive bodies. These are: sediments to basement - 0.3 g/cm^3; basement to basic bodies - 0.3 g/cm^3; and basement to mantle - 0.6 g/cm^3. They correspond to densities of 2.4, 2.7, 3.0 and 3.3 g/cm^3 for sediments, basement, basic bodies, and mantle respectively. These figures are used only to obtain the order of magnitude of thickness of the bodies postulated.

In calculating thicknesses, it has been assumed that the total amplitude of the feature is due to the density contrast suggested. This would only rarely be true, but as the density contrasts used are the maximum likely, the two errors should tend to cancel. As a result, it is thought that the computed thicknesses should be within a factor of two of the correct value - if the body or structure postulated to have this density contrast is the right one.

1. KIMBERLEY REGIONAL GRAVITY PLATFORM (new name - after Kimberley Division)

   Unit (a) Durack Gravity Low (new name - after Durack Ranges)
   (b) Glenroy Gravity Low (new name - after Glenroy homestead)
   (c) Hann Gravity Shelf (new name - after Mount Hann)
   (d) Archipelago Gravity Rise (new name - after Bonaparte Archipelago)
   (e) Seppelt Gravity Ridge (new name - after Seppelt Range)

2. SPRINGVALE REGIONAL GRAVITY RIDGE (new name - after Springvale homestead)

   (a) McIntosh Gravity High (new name - after McIntosh Hills)
   (b) Halls Creek Gravity Ridge (Flavelle, in prep. - redefined here)

3. ORD REGIONAL GRAVITY DEPRESSION (new name - after Ord River)

   (a) Rosewood Gravity Low (new name - after Rosewood homestead)
   (b) Hardman Gravity Low (new name - after Hardman Range)
   (c) Flora Gravity Low (new name - after Flora Valley homestead)
   (d) Mount Bannerman Gravity Depression (Flavelle, in prep. - redefined here)

4. TANAMI REGIONAL GRAVITY COMPLEX (new name - recognised by Flavelle, 1965, but redefined here)

   (a) Billiluna Gravity Plateau (Flavelle, in prep.)
   (b) Coomarie Gravity Complex (Flavelle, 1965 - redefined here as unit)
   (c) Ptilotus Gravity Shelf (new name - after Mount Ptilotus)

5. Pedestal Gravity Low (new name - after Pedestal Hills)

6. WILLOWRA REGIONAL GRAVITY RIDGE (Flavelle, 1965 - redefined here)

7. YUENDUMU REGIONAL GRAVITY LOW (new name - recognised by Flavelle, 1965, but redefined here)

   (a) Treuer Gravity Low (new name - after Treuer Range)
   (b) Napperby Gravity Low (Flavelle, 1965 - redefined here as a unit)

8. PAPUNYA REGIONAL GRAVITY RIDGE (Flavelle, 1965 - redefined here)

9. BUCHANAN REGIONAL GRAVITY PLATFORM (Flavelle, 1965 - redefined here)
   (a) Inverway Gravity Ridge (new name - after Inverway homestead)
   (b) Canfield Gravity Complex (new name - after Canfield homestead)
   (c) Murranji Gravity Shelf (new name - after the Murranji Track)

10. VICTORIA REGIONAL GRAVITY SHELF (new name - after Victoria River)

11. WANGITES REGIONAL GRAVITY RIDGE (new name - after Wangites aboriginal reserve)

12. MARY REGIONAL GRAVITY SHELF (new name - after Mary River)

    (a) Marrakai Gravity Plateau (new name - after Marrakai homestead)
    (b) Van Diemen Gravity Low (new name - after Van Diemen Gulf)

13. TIPPERARY REGIONAL GRAVITY LOW (new name - after Tipperary homestead)

14. DUNMARA REGIONAL GRAVITY LOW (Flavelle, 1965 - redefined here)

    (a) Elsey Gravity Low (new name - after Elsey Creek)
    (b) Amungee Gravity Low (new name - after Amungee Mungee W.H.)

15. OENPELLI REGIONAL GRAVITY COMPLEX (new name - after Oenpelli Mission)

16. ARNHEM REGIONAL GRAVITY PLATFORM (new name - after Arnhem Land)

    (a) Cato Gravity Low (new name - after Cato River)
    (b) Parsons Gravity Low (new name - after Parsons Range)

17. ELCHO REGIONAL GRAVITY HIGH (new name - after Elcho Island)

18. PELLEW REGIONAL GRAVITY HIGH (new name - after Sir Edward Pellew Group)

19. McARTHUR REGIONAL GRAVITY HIGH (Flavelle, 1965 - redefined here)

    (a) Borroloola Gravity High (Flavelle, 1965 - redefined here)

Kimberley Regional Gravity Platform

This province stretches from LONDONDERRY in the north to MOUNT RAMSAY in the south, CAMDEN SOUND in the west to CAMBRIDGE GULF in the east, an area of about 150,000 square kilometres. There is no very prominent trend in the Bouguer anomaly pattern, but there does appear to be an alignment of the broader features parallel with the boundaries of the province. The area is one of small-amplitude (about 10 mgal), fairly long-wavelength (about 160 km) anomalies with an average Bouguer anomaly around zero.

Five units may be distinguished within the province. The Durack Gravity Low is a broad, shallow low trending north-east from LANSDOWNE to CAMBRIDGE GULF. It correlates reasonably well with the eastern basin of the Kimberley Block. The more intense low of the Glenroy Gravity Low along the south-west margin of the province is probably connected with a small unnamed basin abutting the King Leopold Mobile Belt. Its greater amplitude is possibly the result of involvement of the sediments in movement along the edge of the block. An area with indeterminate trend around CHARNLEY and ASHTON comprises the Hann Gravity Shelf. This feature coincides with the western basin within the Block, but does not appear to show much correlation. However, the structural relief of the basin is small, so the corresponding low could be masked by local effects.

Two broad gravity highs run from YAMPI to LONDONDERRY (the Archipelago Gravity Rise) and from LONDONDERRY to CAMBRIDGE GULF (the Seppelt Gravity Ridge). They show no apparent correlation with the surface geology. Elsewhere in the survey area, the seaward edges of the Proterozoic areas are characteristically bounded by intense gravity highs of such magnitude that considerable density contrasts deep in the crust may be the only explanation. In this case, however, the features are of low amplitude, so upwarping of the Lower Proterozoic metamorphic rocks along the edges of the Kimberley Block would seem a reasonable and simpler explanation.

The considerable faulting within the province has little effect upon the Bouguer anomaly pattern, indicative of fairly uniform density within the sediments. Considering that the Upper Proterozoic sediments are sub-horizontal with only very broad flexures, and the general correlation of these downwarps with broad Bouguer anomaly lows, the results suggest that the major gravity features are caused by variations in depth of the metamorphic basement. The parallelism of the main units with the boundaries of the province and the increased amplitude adjacent to the margins point to post-depositional warping of a very uniform flat-lying nuclear basin. The Bouguer anomaly highs along the northern edges of the Kimberley Block plus the moderately steep and linear gradient on the northern flank of the Seppelt Gravity Ridge suggest the possibility that the coastline is controlled by faulting.

Springvale Regional Gravity Ridge

A singular Bouguer anomaly high runs from LISSADELL to north-west GORDON DOWNS, then continues southward as a less prominent feature as far as southern MOUNT RAMSAY. It reaches a maximum of +65 mgal, about 85 mgal above the regional average. Both flanks are marked by very high gradients in the north, exceeding 4 mgal/km in places. To the south the amplitude and gradients fall off, and in the west the edge of the province is rather vague. The trend is parallel to that of the Halls Creek Mobile Belt - about NNE.

The province can be split into two units. The Halls Creek Gravity Ridge was defined by Flavelle (in prep.). Its eastern boundary is the intensely deformed and faulted eastern edge of the Halls Creek Mobile Belt. The major part of the gradient appears to be caused by the large throw on the Old Halls Creek Fault (Flavelle, in prep.). The western flank is rather arbitrary, probably owing to the gradual transition from the Halls Creek to King Leopold Mobile Belt trend. The Bouguer anomaly lows within the unit are most probably caused by intrusions of the Bow River Granite or equivalents. The gravity ridge is correlated with the anticlinorium within the metamorphic Olympic Formation of Lower Proterozoic age.

In the north, the McIntosh Gravity High is so intense that structure within the metamorphic rocks does not seem a reasonable explanation. It may be associated with a large gabbroic intrusion. Assuming a density contrast of 0.2 g/cm^3 - the maximum likely difference - the Bouguer anomaly high would be generated by a body 6700 metres thick, 150 kilometres long and 30 kilometres wide. Whether or not such a large intrusion could occur seems open to doubt.

A significant point is the very conspicuous simplicity of the Bouguer anomaly pattern, a feature that is common to most of the mobile belt zones in the area. These belts are Lower Proterozoic metamorphic zones of considerable structural complexity, and one would expect a corresponding complexity in the gravity pattern. The station interval would remove the very short-wavelength anomalies or might alias them into larger wavelengths. However, the large number of stations within the provinces and the smooth, simple pattern observed suggest that aliasing has not significantly affected the form of the contours. As mentioned, the major contribution to the Bouguer anomaly feature could be from a massive, dense intrusion. In some instances the intrusive body would have to be 500 kilometres or more long, e.g. for the Papunya Regional Gravity Ridge. A more reasonable interpretation would be densification of the crust by large-scale internal metamorphism. Metamorphism produces high-density mineral assemblages, and the density zones would parallel the metamorphic zones. As all the crust would be involved, the increase in density need only be slight, in the order of 0.05 g/cm^3. A simple, single Bouguer anomaly feature would usually be generated without having to postulate the intrusion of many hundreds of cubic kilometres of magma.

A point worthy of comment is the abrupt termination of the northern edge of the province in LISSADELL. The Halls Creek Mobile Belt has been interpreted as a continuous mobile belt from Halls Creek to Darwin. Around the southern edge of the Bonaparte Gulf, the Palaeozoic sediments are presumed to overlie much of the metamorphosed Lower Proterozoic rocks. However, the degree of metamorphism of the rocks within the area is much less than elsewhere, and there is no significant Bouguer anomaly feature associated with the Mobile Belt from central LISSADELL to southern PORT KEATS. This surprising lack of Bouguer anomaly feature compared to the prominent features to the north and south plus the lower degree of metamorphism suggests that the degree of tectonism is greatly reduced to the north of the Springvale Regional Gravity Ridge. The apparent break in the mobile belt plus the geological affinities of the King Leopold Mobile Belt and southern Halls Creek Mobile Belt, and the Pine Creek Mobile Belt and northern Halls Creek Mobile Belt could be interpreted as indicating that there are only two, not three, mobile belts between Derby and Darwin. These suggested mobile belts are shown in Plate 6.

Ord Regional Gravity Depression

This regional gravity low stretches along an arcuate path from MOUNT BANNERMAN through GORDON DOWNS to WATERLOO, a distance of 550 kilometres. A maximum width of about 130 kilometres is attained. The boundary gradients are moderate except in the west, where the province abuts the Springvale Regional Gravity Ridge, along the edge of which intense faulting is known to occur. In the south the edge of the feature is rather vague, mainly because of small, fairly intense anomalies disturbing the regional pattern. The lowest Bouguer anomaly value of -60 mgal occurs in three well defined areas. In all, four units may be distinguished including a less intense low reaching -40 mgal in the north. The Mount Bannerman Gravity Depression has been recognised by Flavelle (in prep.).

The Hardman Gravity Low coincides with the major development of the Ord Basin, though offset slightly. The similarity in form of the Bouguer anomaly contours and the outline of the Hardman sub-basin strongly suggest that the two derive from the same tectonic activity. The Cambrian Ord Basin is said to be a post-depositional feature of no great magnitude. Assuming a maximum likely density contrast of 0.3 g/cm^3 between sediments and basement and an average regional Bouguer anomaly of -20 mgal, there would be at least 3000 metres of sediments. The Cambrian deposits do not exceed about 1500 metres, so this implies a considerable thickening of the Upper Proterozoic sediments beneath the Cambrian sediments; i.e. the Ord Basin is probably an Upper Proterozoic-Palaeozoic basin.

The Mount Bannerman Gravity Depression crosses the edge of the Canning Basin at right angles and with little attenuation. Flavelle (in prep.) interprets this as either a thick development of Proterozoic sediments or low-density intrusions, the sediments being the more likely interpretation. The overall picture of the province strengthens such a hypothesis.

The northerly Rosewood Gravity Low is somewhat detached from the main part of the province. Although correlation of the Bouguer anomaly features with the Argyle and Rosewood sub-basins is not very apparent, allowance for the gravity gradient along the edge of the Halls Creek Mobile Belt assists their identification. The gravity ridge that separates the Rosewood Gravity Low from the southern part of the province coincides with a faulted Proterozoic ridge jutting out from the Halls Creek Mobile Belt.

Paucity of geological knowledge does not allow correlation of the Flora Gravity Low with a known geological feature. All the evidence indicates that the whole province is primarily caused by a late Proterozoic and early Palaeozoic basin of far more considerable extent than is suggested by the available geological maps. The gravity pattern suggests four main areas of deposition corresponding with the minima of the gravity units, separated by tectonic ridges. The Cambrian basins are probably remnants preserved in local downwarping.

Tanami Regional Gravity Complex

The province consists predominantly of a series of high-intensity, short-wavelength Bouguer anomalies in BILLILUNA, TANAMI, and THE GRANITES. The value of the Bouguer anomaly varies from +10 to -40 mgal within a few kilometres. The margins of the province are marked by moderate gradients except in the south-east adjoining the Willowra Regional Gravity Ridge. A NNE trend is dominant in the central part of the province, but in the north-west a WNW trend may be discerned. Three units may be demarcated on trend and intensity of the Bouguer anomaly values.

The Billiluna Gravity Plateau has been outlined in part by Flavelle (in prep.). In the west of the unit the trend parallels that of the King Leopold Mobile Belt, but gradually changes eastwards to the Halls Creek Mobile Belt orientation. Flavelle (op. cit.) suggests that the highs can be correlated with the highly metamorphosed sediments of Lower Proterozoic age. As there is no great thickness of Upper Proterozoic sediments, the lows are thought to be caused by granitic intrusions.

The second unit was also first identified by Flavelle (1965) as the Coomarie Regional Gravity Complex but it has been redefined as a unit in this report. The dominant north-easterly trend is at variance with the surface folding and faulting observed within the area. This suggests that the observed folding cannot be deep seated, and that the Bouguer anomaly pattern is probably caused by density discontinuities deeper in the crust (Flavelle, op. cit.). The deep seated trend indicates that the area may be tectonically related to the Halls Creek Mobile Belt.

The south-eastern Ptilotus Gravity Shelf does not exhibit any significant trend. The influence of the Halls Creek Mobile Belt appears to have faded away almost completely.

Generally the province correlates well with the geological Tanami Mobile Belt. The existence of the Ord Regional Gravity Depression and the Lander Regional Gravity Low shows that the Tanami Mobile Belt does not form part of a continuous tectonic zone, the King Leopold-Tanami-Warramunga geosyncline, suggested by Traves (1955). Similarity of the trend to that of the Halls Creek area does suggest that they were affected by a common fundamental tectonic process, and perhaps may be penecontemporaneous.

Pedestal Gravity Low (tentatively defined as a gravity unit)

The eastern part of a Bouguer anomaly low can be seen in THE GRANITES. The southern and northern marginal gradients are fairly steep where the unit abuts the Willowra Regional Gravity Ridge and the Tanami Regional Gravity Complex. Several small closures about 30 mgal below the regional average Bouguer anomaly occur within the feature, but no very distinct trend is evident. A few widely separated observations in LUCAS suggest that the Stansmore Gravity Trough (Flavelle, in prep.) and the Pedestal Gravity Low are connected. Further observations obtained on the 1968 helicopter gravity survey should enable this hypothesis to be accepted or rejected with confidence.

The feature seems to coincide with a small Proterozoic-Palaeozoic basin on the edge of the Canning Basin. The small closures may be caused by minor granite intrusions, which are fairly common in the neighbourhood. Excluding the effect of the small closures, the amplitude of the Low is about 20 mgal, equivalent to 1500 metres of sediments, with density contrast 0.3 g/cm^3 relative to basement.

Willowra Regional Gravity Ridge

This feature stretches westwards from BARROW CREEK along a slightly arcuate path at least as far as HIGHLAND ROCKS. Completion of surveying of STANSMORE in 1968 should define the western edge. The Bouguer anomaly value reaches 0 to 45 mgal on the crest of the Ridge, about 35 mgal above the average regional value. There is a suggestion of a division into two units with the saddle a little to the west of the division found in the Yuendumu Regional Gravity Low and the Papunya Regional Gravity Ridge, but it is not very marked. Both the northern and southern margins exhibit steep gradients that decrease from east to west.

In LANDER RIVER, the northern gradient is probably caused by faulting along the southern margin of the Wiso Basin (American Overseas Petroleum, 1967). The high gradients in the south could also be caused by faulting, but the surface geology in MOUNT PEAKE does not support this hypothesis. Faulting within the ridge does not produce a corresponding gravity gradient, and faults cross the southern margin of the Ridge at high angles with no apparent effect on the Bouguer anomaly contours. The geology is poorly known over much of the length of the Ridge, however. In the Barrow Creek area, the Ridge corresponds to a mineralised zone (Flavelle, 1965), so an extensive zone of mineralised metamorphic rocks of the Arunta Complex may extend to the west. The general easterly trend of the ridge points to involvement of the area in the movements that created the Ngalia and Amadeus Basins.

Similarity to other regional gravity ridges found elsewhere in northern Australia is evident. Each of the gravity ridges appears to correspond with a mobile zone that has undergone very intense metamorphism. The Willowra Regional Gravity Ridge is possibly alone caused by metamorphic densification with concomitant mineralisation in the east.

Yuendumu Regional Gravity Low

The Yuendumu Regional Gravity Low is one of the most striking gravity features in Central Australia, reaching a low of -105 mgal at its nadir. It extends along a slightly arcuate path, concave southwards, from NAPPERBY to LAKE MACKAY. Like the Willowra Regional Gravity Ridge, its western extremity is uncertain until surveying is completed in WEBB. The province may terminate at the small NE-trending ridge in LAKE MACKAY. If not, it would seem that the Stansmore Gravity Trough (Flavelle, in prep.) and the Yuendumu Regional Gravity Low form a continuous feature that could extend into the Pedestal Gravity Low. The province covers an area about 400 kilometres by 200 kilometres, and is bounded north and south by gravity ridges. The southern boundary is characterised by very high gradients that decrease gradually to the west. In the north, the boundary gradient is extremely steep in NAPPERBY but becomes fairly moderate from MOUNT THEO westwards.

Two major units may be discerned within the province. The eastern unit was first recognised by Flavelle (1965) as the Napperby Regional Gravity Low but has been redefined here as a unit. Within the Treuer and Napperby Gravity Lows there are two separate closures. The one in Napperby, which may itself be subdivided, has been correlated with granitic outcrops by Flavelle, who postulated that the Low was primarily caused by low-density granites. However, this was before the greater western part of the province had been outlined. It is difficult to believe that intrusions would occur on such a huge scale. Further, the size, trend, and boundary features of the province are very similar to the Bouguer anomaly features that occur over the Amadeus Basin. The Ngalia Basin is within the borders of the feature, but it lies within the southern gradient rather than the nadir. Pacific American (1964) suggest that the Bouguer anomaly gradient is caused by a thickening northwards of low-density sediments in an asymmetric basin, an interpretation that is strengthened by the results of seismic work in the basin (Pacific American, op. cit.; P. Jones, 1969). If so, the basin would appear to be far larger than its surface expression indicates. This suggestion is partially corroborated by aeromagnetic results (Pacific America, 1963) but is in contradiction with what is known about the local geology (e.g. Cook & Scott, 1966).

Therefore several explanations of the observed features, all considerably speculative, are outlined below. An added complication in the interpretation is that the expected regional Bouguer anomaly for the average height of the area, assuming isostatic compensation, is about -70 mgal (e.g. Woollard, 1962, part 8, p. 3). The gravity expression of the Amadeus and Ngalia Basins would then be roughly the value expected for the thicknesses of sediments believed to occur within the basins. The Papunya and Willowra Regional Ridges would become extremely positive features by comparison, reaching 120 mgal above the regional Bouguer anomaly value. However, the average regional value appears to be about -30 mgal, and the shift of 40 mgal in the background value could not remove the problems associated with the size of the province compared with the Ngalia Basin.

1. The Yuendumu Regional Gravity Low is caused by considerable density variations within the basement. This could include very large scale granitic intrusions, which with a density contrast of 0.3 g/cm^3 would require 5200 metres of granite over most of the area to produce a low of -100 mgal, 70 mgal below the average regional Bouguer anomaly value. Whether such a large intrusion would occur seems dubious. Another possibility is that the crustal thickness varies. If the total amplitude of the Papunya Regional Gravity Ridge-Yuendumu Regional Gravity Low difference is caused by variation in the depth of the Moho, a Moho relief of about 18,000 metres is indicated as the density contrast between crust and mantle would be about 0.3 g/cm^3. However, some of the Bouguer anomaly difference is presumably caused by sediments within the basins, so the structural relief might not exceed 9000 metres. Such intense and localised deformation would be difficult to explain, and calculations indicate that the maximum depth to the body must be less than about 13 kilometres (Flavelle, pers. comm.).

2. The Ngalia Basin is the outcrop of a much larger basin, the northern part of which is covered by Archaen rocks overthrust many tens of kilometres from the north. The hidden sediments produce the Bouguer anomaly low as has been postulated in the Amadeus Basin (Langron, 1962). Much faulting of the thrust type occurs on the northern edge of the basin and at least two large-scale thrusts occur within the Amadeus Basin just to the south (Wells et al., 1967), so there would seem to be some justification for such an interpretation. However, it is thought (Wells, pers. comm.) that the faults are fairly high-angle ones and the degree of overthrusting is slight.

3. The area north of the basin is covered by drift and the geology is poorly known, but there are isolated exposures of Palaeozoic and Upper Proterozoic sediments in MOUNT THEO and HIGHLAND ROCKS. Considering the gravity pattern, this could be interpreted as a faulted Proterozoic-Palaeozoic basin with the northern half overthrust slightly southward and the Palaeozoic sediments preserved only on the downthrown block except for a few scattered outliers or downfaulted wedges in the north.

Papunya Regional Gravity Ridge

An intensive, elongate Bouguer anomaly high about 550 kilometres long and 100 kilometres wide occurs between MOUNT RENNIE and HERMANNSBURG. The gradients on its northern and southern flanks are very high, averaging 3 mgal/km for many kilometres. Two maxima occur - one of +25, the other of +50 mgal. These appear to be related to the two minima of the Yuendumu Regional Gravity Low. There is no surface geological feature that could be the cause of this twin pattern in the area.

Several interpretations of this gravity ridge have been put forward. Langron (1962) postulated that either the Archaean and Proterozoic rocks were overfolded southwards on the edge of the Amadeus Basin, or that faulting brought ultrabasic rocks to the surface to produce the high gradients on the southern flank. A fundamental horizontal density change within the crust was suggested by Flavelle (1965). Wells et al. (1967) have advocated crustal warping, with the mantle considerably closer to the surface under the gravity ridge. Analysis of the observed profile indicates that the top of the body cannot be deeper than 13 kilometres (Flavelle, pers. comm.). The shallowness of the body plus the known thrusting and overfolding in the Amadeus Basin suggests that a combination of Landgron and Flavelle's interpretations might be the most realistic. The high density is probably the result of a high-density mineral assemblage caused by intense metamorphism in the centre of the metamorphic zone.

Buchanan Regional Gravity Platform

The Buchanan Regional Gravity Platform is an extensive area of undulating, intermediate-value Bouguer anomalies stretching from WATERLOO and DALY WATERS in the north to BIRRINDUDU and WINNECKE CREEK in the south. The Bouguer anomaly varies from -25 to +20 mgals. The trend is variable but predominantly northerly in the west and centre; no trend is discernible in the north and east. The boundary with the Ord Regional Gravity Depression is a fairly steep and linear gradient which swings south-west to form the boundary with the Tanami Regional Gravity Complex. In the north and east the borders are arbitrary as the province merges gradually into neighbouring provinces.

It is possible to roughly define three units, though there does not appear to be much correlation between the gravity features and the surface geology. However, much of the area is drift covered and the geology is poorly known. A northerly trending gravity high forms the Inverway Gravity Ridge. Possibly it is caused by a structural ridge of Lower Proterozoic rocks under a considerable thickness of Upper Proterozoic sediments.

The more complicated Canfield Gravity Complex has similarities with the Victoria Regional Gravity Shelf and the Ooratippra Gravity High, a unit of the Georgina Regional Gravity Shelf. The Bouguer anomaly contour pattern becomes less elongate and loses its north to north-westerly trend going from south to north. The

Ooratippra Gravity High corresponds to the metamorphic area of the Warramunga Mobile Belt, while the Victoria Regional Gravity Shelf is an area of thick sub-horizontal sediments. This suggests that the Canfield Gravity Complex corresponds to a transition zone between the two, where the metamorphic rocks become buried under the thickening sediments going northwards.

The Murranji Gravity Shelf correlates with an area of thin Palaeozoic sediments (Randal & Brown, 1967), but it is suggested that the gravity pattern indicates a development of Proterozoic sediments beneath the Palaeozoic rocks that gradually thicken from the metamorphic ridge in WAVE HILL towards the minor basin postulated to cause the Elsey Gravity Low.

Victoria Regional Gravity Shelf

The Gravity Shelf covers most of AUVERGNE and DELAMERE, and parts of the adjoining sheet areas. It is an area of undulating Bouguer anomalies generally similar in character to the Buchanan Regional Gravity Platform, and the boundary between them is somewhat arbitrary. The Bouguer anomaly veries from zero to -20 mgal and does not exhibit a significant trend. The north-west margin shows moderate gradients where it passes into the Wangites Regional Gravity Ridge. The boundary between the Gravity Shelf and the remaining provinces to the north and east is not pronounced and is therefore arbitrarily defined.

The feature corresponds geologically to the Victoria River Block, an area of thick sub-horizontal Proterozoic sediments. Faulting appears to have little effect upon the Bouguer anomaly values except along the edge of the Halls Creek Mobile Belt. Elsewhere, the gradual change both geologically and gravitationally into the neighbouring areas indicates a smooth transition structurally, with the Proterozoic rocks dipping below the Phanerozoic sediments. Possibly the undulations in the Bouguer anomaly values correspond to variation in depth of the basement rocks, but there is no substantial evidence for the hypothesis.

A peculiarity of the province is that there is no Bouguer anomaly indication of the Halls Creek Mobile Belt on the western border with the Carlton sub-basin. Elsewhere the Bouguer anomaly features associated with the Halls Creek Mobile Belt are so intense that even under very deep burial some detectable gravity effect would be expected at the surface. The only conclusion seems to be that metamorphism was slight with little concomitant densification of rock, and major tectonic activity took place only to the north and south.

Wangites Regional Gravity Ridge

This feature forms a prominent positive lineament in the Bouguer anomaly pattern, stretching from BATHURST ISLAND to PORT KEATS. It has trend and characteristics similar to gravity provinces and geological structure within the Joseph Bonaparte Gulf. North of Darwin, the province reaches a width of 150 kilometres, but elsewhere it is about 80 kilometres wide. The maximum value along the crest of the gravity ridge decreases southward from +75 mgal in the Beagle Gulf to +10 mgal in central PORT KEATS. The margins are marked by steep linear gradients, which also decrease southwards until the province verges into the background.

There is some indication that the province is correlated with the Halls Creek and Pine Creek Mobile Belts, with a shape like an inverted tuning fork. However, the surface geology does not seem to affect the Bouguer anomaly pattern much, so much of the Pine Creek Mobile Belt falls within the Bouguer anomaly low in the Van Diemen Gulf, and this forms part of the Mary Regional Gravity Shelf.

The crest of the Wangites Regional Gravity Ridge coincides with faults running along the western edge of the Halls Creek Mobile Belt, while the maximum gradients occur well within the Bonaparte Gulf Basin. The fairly substantial granitic outcrops of both the Halls Creek and Pine Creek Mobile Belts do not generate Bouguer anomaly lows, nor do the larger faults in the area give rise to gravity gradients except in eastern PORT KEATS. These observations all suggest that density contrasts between Phanerozoic and Proterozoic or within the Lower Proterozoic rocks are not the likely cause of the Ridge. The only alternative explanation would seem to be deep-seated density variations within the crust. The maximum Bouguer anomaly within the Ridge occurs at the junction of the two mobile belts, where metamorphism would be expected to be most intense.

Flavelle has studied the Bouguer anomaly profiles across the Springvale, Papunya, and Wangites Regional Gravity Ridges in some detail (pers. comm.). His analysis of amplitude, width, and maximum gradients using the methods outlined in Parasnis (1962) and Skeels (1963) indicates that the tops of the bodies that generate the Gravity Ridges are all fairly shallow. In the case of the Wangites Regional Gravity Ridge, the top of the density contrast is not deeper than 13 kilometres, so the possibility that the gravity effects are due to an upwarp in the mantle would seem to be excluded. Densification of the country rock by extreme metamorphism would appear to be the most likely interpretation.

Mary Regional Gravity Shelf

This wedge shaped feature has an apex in PINE CREEK and a base along the northern edge of MELVILLE ISLAND. Its western edge is one of moderate gradients where it meets the Wangites Regional Gravity Ridge and the Tipperary Regional Gravity Low. The eastern edge is bounded by the more complicated Oenpelli Regional Gravity Complex. The northern boundary is marked by a steep gradient, which forms the southern boundary of a prominent Bouguer anomaly ridge out to sea parallel to the shoreline.

The Shelf may be split into two units on the basis of average Bouguer anomaly and geology. The southern Marrakai Gravity Plateau does not exhibit the complexity in Bouguer anomaly pattern expected over geosynclinal deposits. The intensity is far lower than the gravity feature caused by the Halls Creek Mobile Belt to the west. No large gravity gradients are associated with the faults, so density contrasts within the metamorphics seem to be low. Only the small granite intrusions generate negative Bouguer anomaly features, in PINE CREEK. The larger bodies may possibly contain much partly digested denser country rock, which would reduce the density contrast.

The Van Diemen Gravity Low corresponds to the little faulted and intruded area of Lower Proterozoic rocks and the thin (?) Mesozoic deposits of the Van Diemen Gulf. The pattern suggests that the structure is simple, and minor thickening of the Mesozoic strata could be the cause of the Bouguer anomaly low. With a density contrast of 0.5 g/cm^3 between Mesozoic and basement, the thickening would only be of the order of 450 metres.

Tipperary Regional Gravity Low

The Gravity Low is a fairly small-amplitude feature trending NNW from DELAMERE to DARWIN. It is bounded by the Wangites Regional Gravity Ridge and the Mary Regional Gravity Shelf in the north, and passes gradationally into the Victoria Regional Gravity Shelf and the Dunmara Regional Gravity Low. There is a gradual fall in the average Bouguer anomaly southwards. The axis of the Low is erratic and its amplitude is at most 15 mgal.

The Bouguer anomaly pattern in the peripheral areas of the province is complicated by the effects of many faults and intrusions. The Low correlates quite well with the Daly River Basin, though its axis is offset to the west of the basin axis. The indistinct boundary with the Victoria Regional Gravity Shelf and Dunmara Regional Gravity Low is probably due to the smallness of structural relief in the Daly River Basin and to the continuity of Proterozoic sedimentation across the margins. Assuming a density contrast of 0.3 $g/cm3$ between sediments and basement, a thickening of the sediments of the order of 1200 metres would be the maximum expected. The Cambrian Daly River Group is about 300 metres thick. If the Antrim Plateau Volcanics are about as thick here as in the Ord Basin (900 metres), the observed Bouguer anomaly pattern could be explained by folding of the sediments without thickening, as the structural relief is perhaps 1200 metres. However, considering that the volcanics are basic and so comparatively dense, it is felt that a minor thickening of a thousand metres or so in the Proterozoic sediments probably occurs.

Dunmara Regional Gravity Low

The province stretches for 400 kilometres from LARRIMAH to BEETALOO. The north-east boundary with the Arnhem Regional Gravity Platform and the Oenpelli Regional Gravity Complex is a moderate gradient that trends in a fairly straight line for 600 kilometres, suggesting that it marks a fundamental change in the geological pattern. In the south-east, the margin adjoining the McArthur Regional Gravity High is also quite well marked. In the west the boundary is gradational into the Buchanan Regional Gravity Platform. The predominant trend is north-south, with a median ridge dividing the Low into two units.

The Elsey Gravity Low has a Bouguer anomaly relief of 10 mgal. It corresponds to an area of thin Palaeozoic sediments of low structural relief. The thickness and relief are both about 200 metres (Randal & Brown, 1967). Ten milligals would be equivalent to 750 metres of sediments (density contrast 0.3 g/cm^3). This would suggest a possible local thickening of Upper Proterozoic sediments of perhaps 600 metres. The more pronounced Amungee Gravity Low drops to 25 mgal below the regional average Bouguer anomaly. The eastern embayment has been associated with a considerable thickness of Upper Proterozoic sediments of the Roper River Group (Flavelle, 1965). The geological evidence points to fairly thin Palaeozoic sediments throughout the area, so the low could well be caused by perhaps 2000 metres of Precambrian sediments.

Randal and Brown (op. cit.) have interpreted this area of Palaeozoic rocks as being a northerly extension of the Wiso Basin. However, the Bouguer anomaly pattern of the Buchanan Regional Gravity Platform and the Ooratippra Gravity High strongly suggest that the Wiso Basin is separated from the basins postulated to cause the Dunmara Regional Gravity Low by a Lower Proterozoic ridge that dips northward from the Warramunga Mobile Belt. It is felt that the Tipperary Regional Gravity Low and the Elsey and Amungee Gravity Lows correspond to a series of en-echelon Proterozoic-Palaeozoic basins with predominantly northerly trend separated from each other by minor structural ridges. The depths of the basins are interpreted as increasing south-eastwards; thickening is postulated to occur mainly in the Proterozoic section, which increases from approximately zero in the north-west to around 2000 metres or so in the south-east.

Oenpelli Regional Gravity Complex

This area of fairly intense Bouguer anomaly features with wavelengths of the order of 30 kilometres or more extends along a 150-kilometre band from KATHERINE to COBOURG PENNINSULA. The southern boundary is the linear gradient that marks the Proterozoic-Palaeozoic boundary along the edge of the McArthur Block. The eastern and western boundaries are based on change in intensity of the Bouguer anomaly features. The northern boundary is not yet defined. The Bouguer anomaly values range from zero to +50 mgal, but the amplitude of features is less than this as there is a gradual increase in the average Bouguer anomaly northwards. There is no marked trend, but in the south it tends to be easterly while in the north is is more northerly.

Correlation with the geology is poor. The most unusual feature is that the Upper Proterozoic sediments in this province generate a more complex Bouguer anomaly pattern than the Lower Proterozoic metamorphic rocks to the west. There seems to be a negative correlation between Bouguer anomaly and structure, i.e. the structural highs produce Bouguer anomaly lows and vice versa. The complexity could be the result of folding, faulting, and intrusions, particularly in the south. However, to the east, these phenomena have no marked effect on the Bouguer anomaly pattern, so intra-basement density variations may be the prime cause there. The only reasonable correlation between Bouguer anomaly and geology is in the north, where Archaean metasediments generate a Bouguer anomaly high. There is a westward offset of the high from the outcrop, but this is probably due to the gravity effect of the Nimbuwah Granite which would cause a reduction in the Bouguer anomaly values directly over it.

Arnhem Regional Gravity Platform

The platform stretches from JUNCTION BAY to TRUANT ISLAND in the north, and southwards as far as HODGSON DOWNS and MOUNT YOUNG. The area has an average Bouguer anomaly around zero, and shows an undulating pattern of low amplitude and intermediate wavelength (fifty kilometres or so). Localised anomalies are more intense than on the geologically similar Kimberley Block. The seaward limits of the province are uncertain. Presumably the Arafura Basin would limit its extension northwards, while the Elcho Regional Gravity High creates a large embayment in the feature on ARNHEM BAY. The Pellew Regional Gravity High, which may extend as far north as Groot Eylandt, likewise limits the province in the east. In the west, the increasing intensity of the Bouguer anomaly features is used to define the margin of the province, while to the south-west the linear gradient marking the edge of the McArthur Block forms a natural limit. No regional trend is evident, but a local moderate NNE trend may be discerned in BLUE MUD BAY and GOVE.

Correlation of the regional features of the province with the geology is ill-defined. The small-amplitude Cato Gravity Low may be related to the granitic outcrops in GOVE. Possibly a series of batholiths occur at greater depths to the west of the outcrops. The Parsons Gravity Low may be associated with a thick development of McArthur Group sediments to the west of the Parsons Range Fault Zone. The major depositional basins are fault controlled, with concomitant abrupt changes in thickness and lithology of the sediments, yet no corresponding Bouguer anomaly features are discernable. There is some evidence that the Bouguer anomaly lows correspond to the younger Roper River Group sediments in the south, but it is probably unsafe to extrapolate the correlation to the north.

Elcho Regional Gravity High

This roughly circular Bouguer anomaly province covers part of ARNHEM BAY and WESSEL ISLANDS. The Bouguer anomaly value rises steadily throughout the province to a culmination of +70 mgal, which is about 50 mgal above the regional value. The gradient on the eastern edge of the province is particularly steep. The feature projects into the Arnhem Regional Gravity Platform for a considerable distance, and a minor gravity ridge running southwards from it on the Platform may have a similar origin.

The Upper Proterozoic sediments within the area are subhorizontal though considerably faulted. The faults generally do not generate a gravity feature. For example, the gravity ridge running southwards from the Elcho Regional Gravity High is associated with the Mitchell Range fault zone, but no faults coincide with the steep Bouguer anomaly gradient on the western side of the gravity ridge. This suggests that gravity features in this area may be caused by denser basement rocks having been brought nearer the surface in the fault blocks.

However, the culmination of the province occurs well away from the faulted area, and the province's circular form suggests a very large intrusive body. A possible interpretation that seems to tie most of the observed features together is as follows. Large scale intrusion by basic material ocurred in a weak zone of the earth's crust. Close to the centre of the intrusive area, heating made the rocks plastic so little faulting occurred. Farther away from the centre, where the rocks were not heated as much, a gradual transition from plastic flow to faulting with minor peripheral intrusion occurred.

The faulting cuts Upper Proterozoic rocks yet there is no evidence of arching over the postulated body in rocks of that age. Therefore the body was probably emplaced in Lower Proterozoic times with later reactivation along the old fault lines. With a density contrast of 0.3 g/cm^3 the body would be about 5500 metres thick and about 50 kilometres in diameter.

Pellew Regional Gravity High

Only the western part of this feature in PELLEW has been outlined. The few offshore gravity station results suggest that the Bouguer anomaly contours may close to the east (Williams & Waterlander, 1958). A maximum Bouguer anomaly of +50 mgal has been observed, about 40 mgal above the regional average. The gradient is fairly uniform along the periphery. A slight depression separates the feature from the McArthur Regional Gravity High.

No definite correlation with the geology is possible. Bouguer anomaly highs in the area generally correlate with outcropping of the metamorphic Tawallah Group, so possibly there is a local structural high within the Tawallah Group. Another possible interpretation is that the Gravity High is caused by a dense intrusive body. The apparent roughly circular shape would be more in line with such a hypothesis. A crude estimate of its thickness would be 3000 metres with a density contrast of 0.3 g/cm^3.

Analysis of shape, gradients, and amplitude by Flavelle (pers. comm.) points to a shallow crustal origin to the gravity highs both in this province and in the Elcho Regional Gravity High. The probable depth is less than 10 kilometres.

McArthur Regional Gravity High

The McArthur Regional Gravity High covers a considerable area from HELEN SPRINGS north and north-eastwards to CALVERT HILLS and MOUNT YOUNG. The Bouguer anomaly value rises to +15 mgal along a gravity ridge called the Borroloola Gravity High, which extends into the survey area. This unit, originally defined by Flavelle (1965) is here retained as a unit of the McArthur Regional Gravity High, but its relation to the Pellew Gravity High is uncertain.

Flavelle (op. cit.) noted that the culmination appears to correlate with outcrops of the Lower Proterozoic Tawallah Group, and he suggested that the High is caused by the relatively dense metamorphic rocks of the Group.

6. CONCLUSIONS

A description of the various Bouguer anomaly provinces has been given in Chapter 5. Possible causes of the features have been noted and, where possible, the most likely interpretation given. Most of the objectives outlined in Chapter 4 have been successfully achieved; but, as might be expected, several unusual features have been outlined and some of these are difficult to explain at our present state of knowledge. The more important conclusions are summarised below.

1. The expected correspondence between geological and Bouguer anomaly provinces on the descriptive level did not occur for mobile belts, except in the case of the Tanami Mobile Belt. All other metamorphic zones gave rise to simple, singular Bouguer anomaly highs of great intensity. The most reasonable interpretation seems to be that metamorphism has been so intense that density variations due to ancient geological structures have been obliterated and that the grade of metamorphism, which controls the type of mineral assemblage produced, also controls the variation in density. The highest densities occur along the centre of the mobile belts, where the degree of metamorphism and metasomatism would be greatest.

2. The gravity results indicate that the Halls Creek Mobile Belt appears to be in two discontinuous sections. This suggests that there are only two major mobile belts in the area, the King Leopold-Southern Halls Creek Mobile Belt and the Pine Creek-Northern Halls Creek Mobile Belt, not three as given in the geological literature (see references cited in Chapter 2).

3. Two other mobile belts corresponding to the Willowra and Papunya Regional Gravity Ridges may exist within what has been termed the Arunta Block (Geol. Soc. Aust., 1962). The similarity to other gravity provinces over metamorphic areas and the parallelism of these two zones with the Ngalia and Amadeus Basins suggest that the Arunta Block has been greatly affected by the same tectonic activity that has affected the basins in Palaeozoic times.

4. The gravity provinces correlated with the Palaeozoic Ord, Daly River, and Northern Wiso (as named by Randel & Brown, 1967) Basins are far greater than the surface outcrop of the basins. This suggests that the basins are more extensive features of Proterozoic to Palaeozoic age, and the Palaeozoic outcrop is preserved only in the centre of the downwarped areas. The Palaeozoic section is generally thin, with little thickening in the middle of the basins. In all cases, the known structural throw in the Palaeozoic rocks is less than the degree of downwarping computed from the gravity results. This indicates that considerable thickening probably takes place in the Proterozoic section.

5. The Daly River Basin corresponds to the northernmost of three en-echelon gravity lows that indicate a series of basins along the edge of the Proterozoic rocks of Arnhem Land. The basins appear to increase in thickness to the south-east, and the thickening, if real, is probably in the Upper Proterozoic section as the Palaeozoic sediments are fairly thin throughout the area.

6. The Victoria River Block and the Warramunga Mobile Belt are probably connected by a transition zone corresponding to the Buchanan Regional Gravity Platform, which separates the Wiso Basin from the small basins along the edge of the McArthur Block.

7. The previous three points suggest that the tectonic movements causing the formation of the basins were initiated in Upper Proterozoic times and continued well into the Palaeozoic era. Breaks in the geological succession at the base of the Cambrian would appear to be small-scale, possibly local, events and not of any great significance in the regional tectonic picture.

8. The Yuendumu Regional Gravity Low covers an area several times that of the associated Ngalia Basin. Possibly variation in crustal density occurs, due either to intrusion by extremely massive granites or to crustal warping. Other possible explanations are that the northern edge of the basin is overthrust and covers large quantities of sediment, or that considerable thicknesses of Proterozoic sediments occur to the north of the basin.

9. In the coastal areas, there are several unusual, intense gravity highs that have no related surface geological expression. Analysis of the Bouguer anomaly profiles across these features indicates that the tops of the bodies causing them are less than 10 kilometres deep and may be only half that depth. The Elcho and Pellew Regional Gravity Highs may be caused by large basic intrusive bodies, while the Wickham Gravity High could possibly be a large extrusive sheet (not confirmed by magnetics) or other dense formation within the sedimentary section.

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APPENDIX A

SURVEY STATISTICS

Area surveyed	:	815,000 square kilometres
Survey started	:	28 February
Survey finished	:	21 August
Follow-up completed	:	3 November
New readings; mainland	:	7189
; island	:	517
Follow-up; mainland	:	122
; island	:	16
Loops flown	:	1025

Helicopter Serviceability (in Days)

Half-monthly Period	Available	U/S	Serviceable	Flying	Not Flying					
					W	C.M.	F.	P.D.O.	I.U.	?
1	64	2	62	31	-	-	-	-	-	31
2	61	1	60	42	1	-	-	2	3	12
3	46	10	36	24	2	-	-	2	-	8
4	45	15	30	20	-	-	2	2	-	6
5	45	1	44	29	-	1	3	10	-	1
6	48	2	46	39	-	2	1	3	-	4
7	45	2	43	37	-	1	-	4	-	1
8	41	1	40	34	-	2	1	1	-	2
9	45	6	39	31	-	4	-	4	-	-
10	42	11	31	19	-	5	-	4	-	3
11	42	4	38	36	-	-	-	-	2	-
TOTALS:	524	55	469	339	3	15	7	32	5	68

W = Weather; C.M. = Camp move; F = Fuelling; P.D.O. = Pilot's day off and field breaks;
I.U. = Instruments U/S; ? = Uncertain, no reason given.

These figures were abstracted from Certification of Results forms.

Loops; per day available: 1.96
; per day serviceable: 2.19
; per day flying : 3.02

Days helicopters serviceable: 89.5%
Days helicopters flying : 64.7%

APPENDIX B

STANDARD DEVIATIONS OF NETWORK ADJUSTMENTS

The networks of gravity and barometric observations are reduced in segments of a suitable size for the computer programme. Each segment is surrounded by a ring of fixed values such that no errors within one segment are propagated into another. In this way each segment may be adjusted in isolation without affecting surrounding areas.

In the height network, each segment is surrounded by a line of benchmarks at which all boundary loops must end. The reduction is done in three stages, to enable an assessment of the quality of the network and the accuracy of the final values to be obtained. The standard deviation of the adjustments to the observations is used as the criterion of quality.

First the Internal Standard Deviation (I.S.D.) is obtained when the network is adjusted using only one of the fixed benchmark heights. The I.S.D. is about two-thirds that of the error of observation for the segments covering two map sheets or more. It shows the internal consistency of the network of observations. Misreadings are usually quite obvious in this stage of the adjustments.

When all the benchmarks are used as fixed nodes, the External Standard Deviation (E.S.D.) is obtained. Systematic errors in the network due to pressure gradients and lapse rate effects are most obvious in this adjustment. The E.S.D. is approximately equal to the errors in the adjusted height differences. However, the relation between errors in adjusted differences and errors in the final values is uncertain.

To obtain a figure of merit for the final data accuracy, a further network adjustment using only half of the benchmarks as fixed nodes is carried out, and the standard deviation of the difference between predicted and actual heights of the remaining benchmarks is computed. This is the Forecast Standard Deviation (F.S.D.), and is a fairly reasonable appraisal of the accuracy of the final height values.

As there are only two or so fixed ("Isogal") values in each segment of the gravity network, a different approach is used. The I.S.D., F.S.D., and E.S.D. would be almost identical as the number of conditions affecting the adjustments (number of closures and number of fixed values) would be almost the same in each case. First the network adjustment is carried out using all available fixed values. The Boundary values in this case are not fixed, but the multiple values at each point common to more than one segment rarely differ by more than a few hundredths of a milligal. The multiple values are meaned and adopted as fixed, and the equivalent of the E.S.D. for height is computed.

Values of the various standard deviations and maximum adjustments of the preliminary data reduction are tabulated below.

Segment	Heighting						Gravity	
	Internal		External		Forecast			
	S.D.	M.A.	S.D.	M.A.	S.D.	M.A.	S.D.	M.A.
A	3.97	12.15	5.78	20.03*	3.82	8.40	0.05	0.15
B	3.95	9.16	6.24	16.56	3.16	9.41	0.03	0.05
C	1.93	4.73	(95.23)	(678.62)	4.70	11.92	0.04	0.11
D	4.64	15.08	6.42	19.60	6.98	18.90	0.02	0.06
E	4.67	8.54	8.71	(56.83)	5.03	14.14	0.02	0.03
F	4.25	8.66	5.10	14.24	3.63	8.75	0.04	0.10
G	5.03	11.72	6.61	18.47	5.43	13.82	0.03	0.10
H	4.83	15.19	8.87	22.06	7.84	23.76?	0.04	0.11
I	3.73	11.72	7.14	21.74	5.81	15.63	0.03	0.07
J	4.75	14.23	5.34	11.98	4.02	10.52	0.02	0.05
K	5.41	14.47	11.67	(61.80)	13.13	(55.75)	0.03	0.09
L	3.07	7.83	6.37	19.14	6.94	16.81	0.07	0.27*
M	3.77	8.35	6.01	15.43	5.37	11.88	0.02	0.05
N	2.41	7.56	5.20	16.26	4.09	9.08	0.03	0.08
O	2.46	5.07	5.66	26.65*	3.81	10.70	0.03	0.06
P	3.29	7.74	7.12	22.07	5.44	21.58*	0.03	0.08
Q	2.24	5.80	4.71	11.84	3.87	8.40	0.03	0.09
R	3.98	14.17	5.05	15.23	3.78	9.71	0.03	0.09

M.A. = maximum adjustment; ( ) = obvious error;

* = non-normal distribution; ? = possible error

The preliminary computing is primarily used to detect and remove errors in the survey. Standard deviations of 3 metres in heighting and 0.1 mgal in gravity are levels of accuracy that are fairly readily achieved. High adjustments and misclosures are studied and, where necessary, further flights are made in follow-up to check the original observations.

APPENDIX C

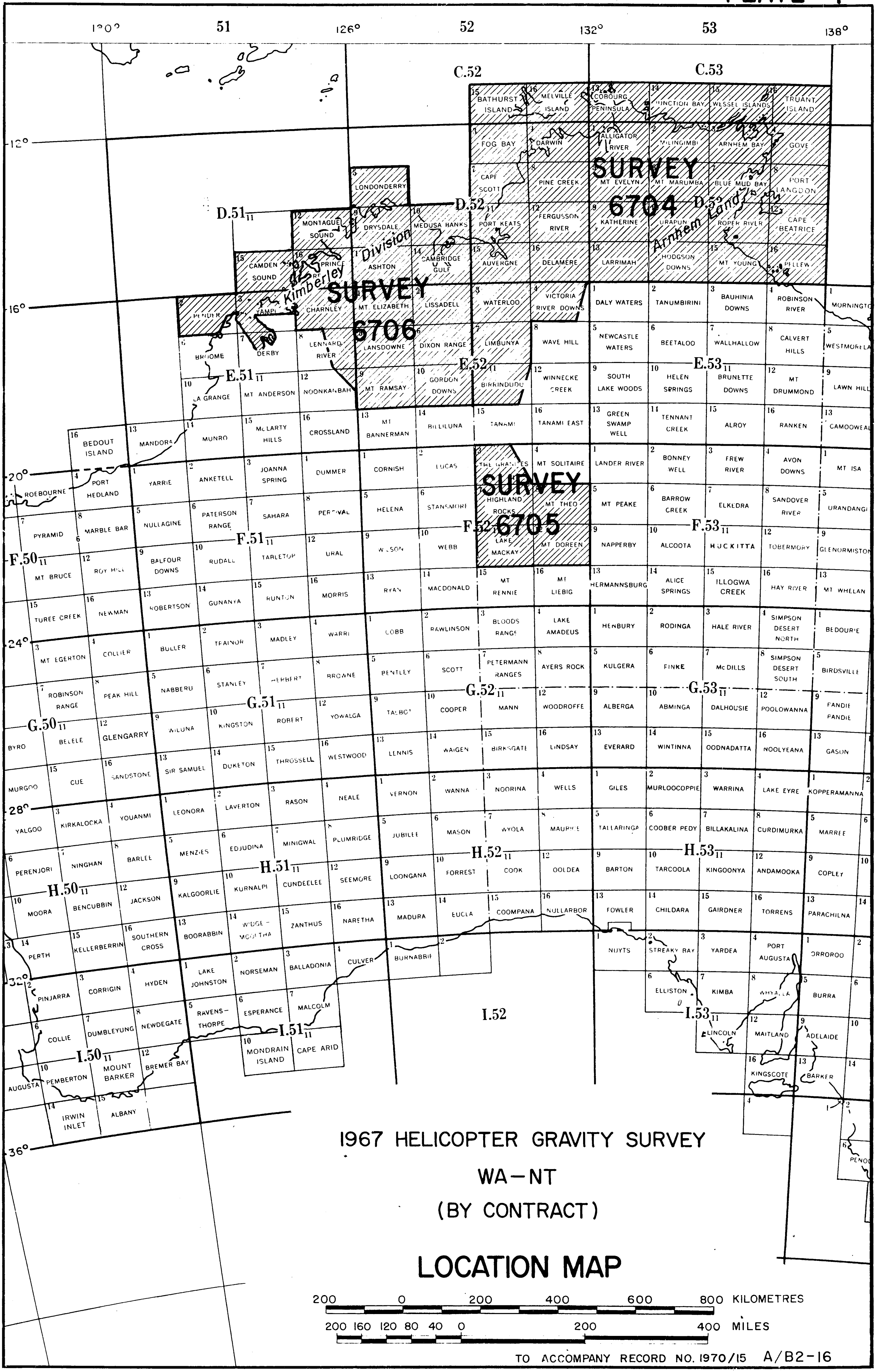
STRATIGRAPHIC BORES IN OR NEAR THE SURVEY AREA

Bonaparte Well No. 1 (Alliance Oil Development, 1964a)

Age	Formation name	Lithology	Thickness
U. Carb	Point Spring Sandstone	sandstone, some shale layers	190 m
L. Carb	Tanmurra Formation	carbonate-sst sequence	302 m
L. Carb	Milligans Beds	shale, interbedded sst and siltstone	1783 m
U. Dev to L. Carb	Burt Range Formation	shale-sst sequence with siltstone	613 m
U. Dev	Cockatoo Sandstone	interbedded sst, siltstone and shale	262+ m

Kulshill Well No. 1 (Australian Aquitaine, 1966a)

Age	Formation name	Lithology	Thickness
Mesozoic	undifferentiated	argillite and siltstone	549 m
L. Perm	Sugarloaf Formation	shale with sst upon sst with shale and coal	544 m
L. Perm	Kulshill Formation	greywacke upon tillites upon siliceous sst	1220 m
L.Carb-L.Perm	unnamed	shale upon sst	64 m
L. Carb	Tanmurra Formation	sst with minor shale & dolomite	162 m
L. Carb	Milligans Beds	sst-shale sequence with some lst	1717 m
U. Dev	Ninbing Formation	shale to siltstone with occasional sst	296 m
U. Dev	Cockatoo Formation	sst with shale, minor siltstone and lst	337+ m



1967 HELICOPTER GRAVITY SURVEY

WA–NT

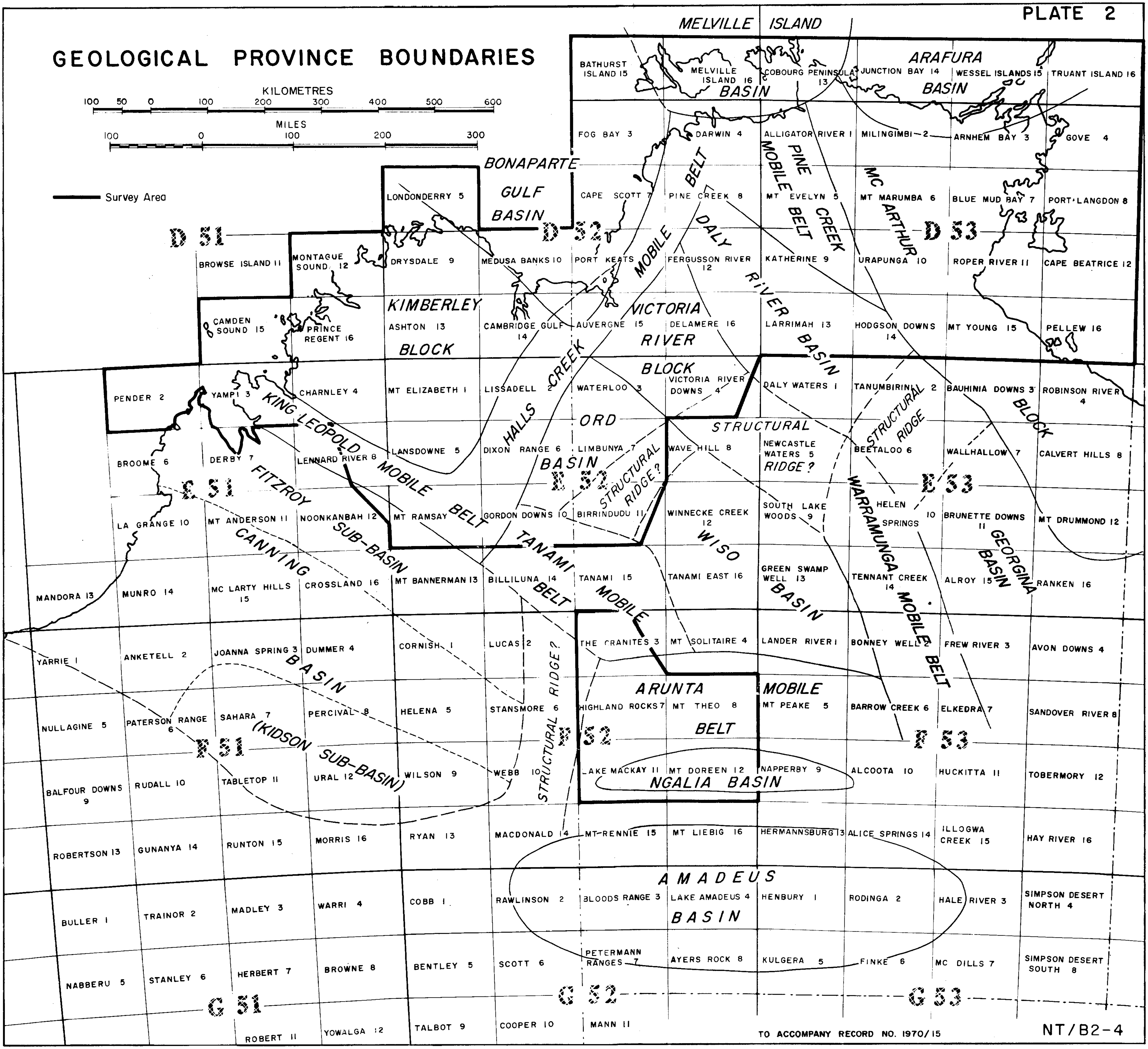
(BY CONTRACT)

LOCATION MAP

TO ACCOMPANY RECORD NO. 1970/15 A/B2-16

PLATE 2

GEOLOGICAL PROVINCE BOUNDARIES



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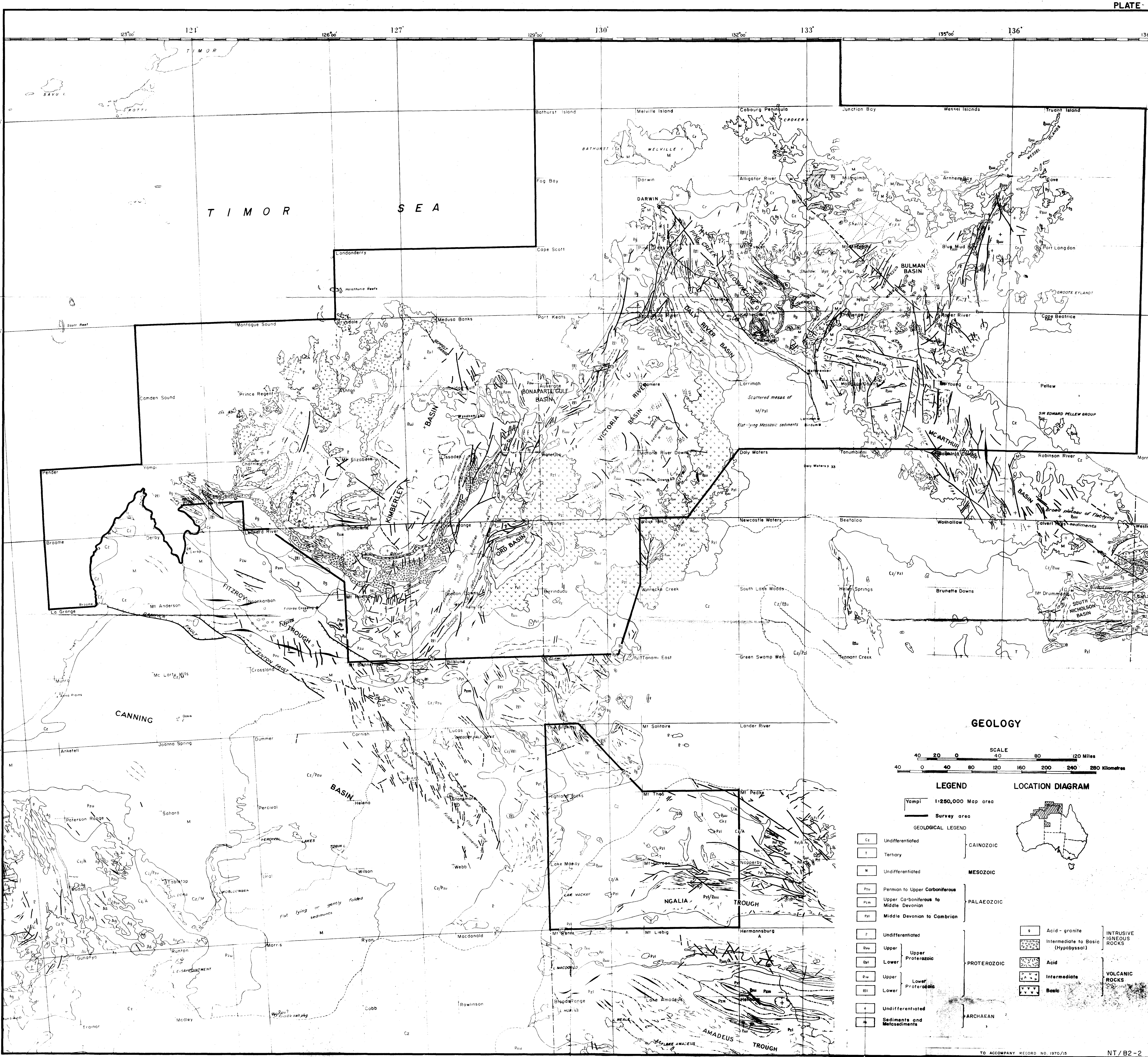
NT/B2-4



TO ACCOMPANY RECORD NO. 1970/15

NT/B2-2

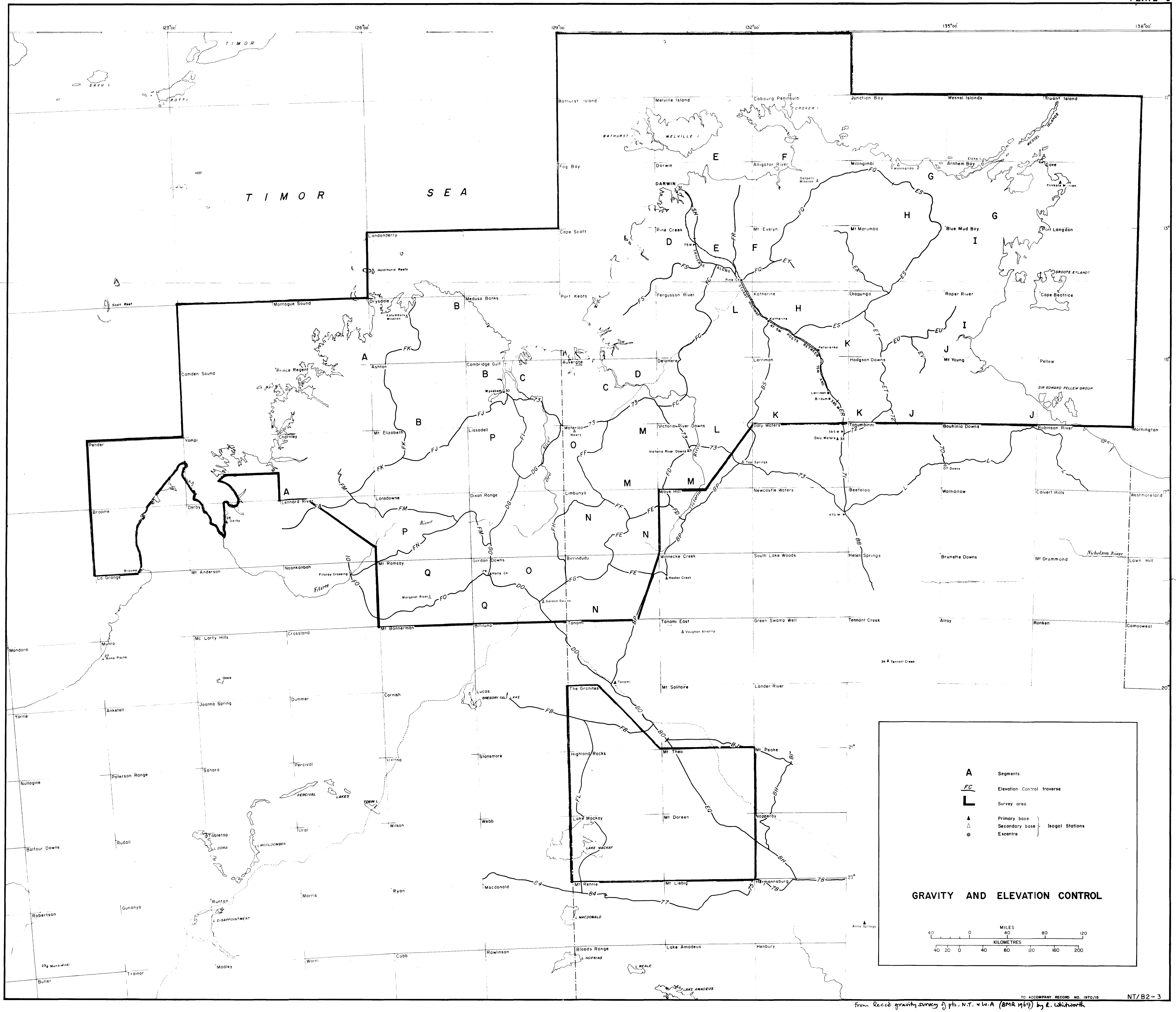
from Recce Gravity Survey of pts. N.T. & W.A. (BMR 1967 by R. Whitworth)

AND GRAVITY FEATURES

2

from Recce Gravity Survey of pts. N.T. & W.A. (BMR 1967 by R. Whitworth) TO OVERLAY NT/B2-5-1

PLATE 5



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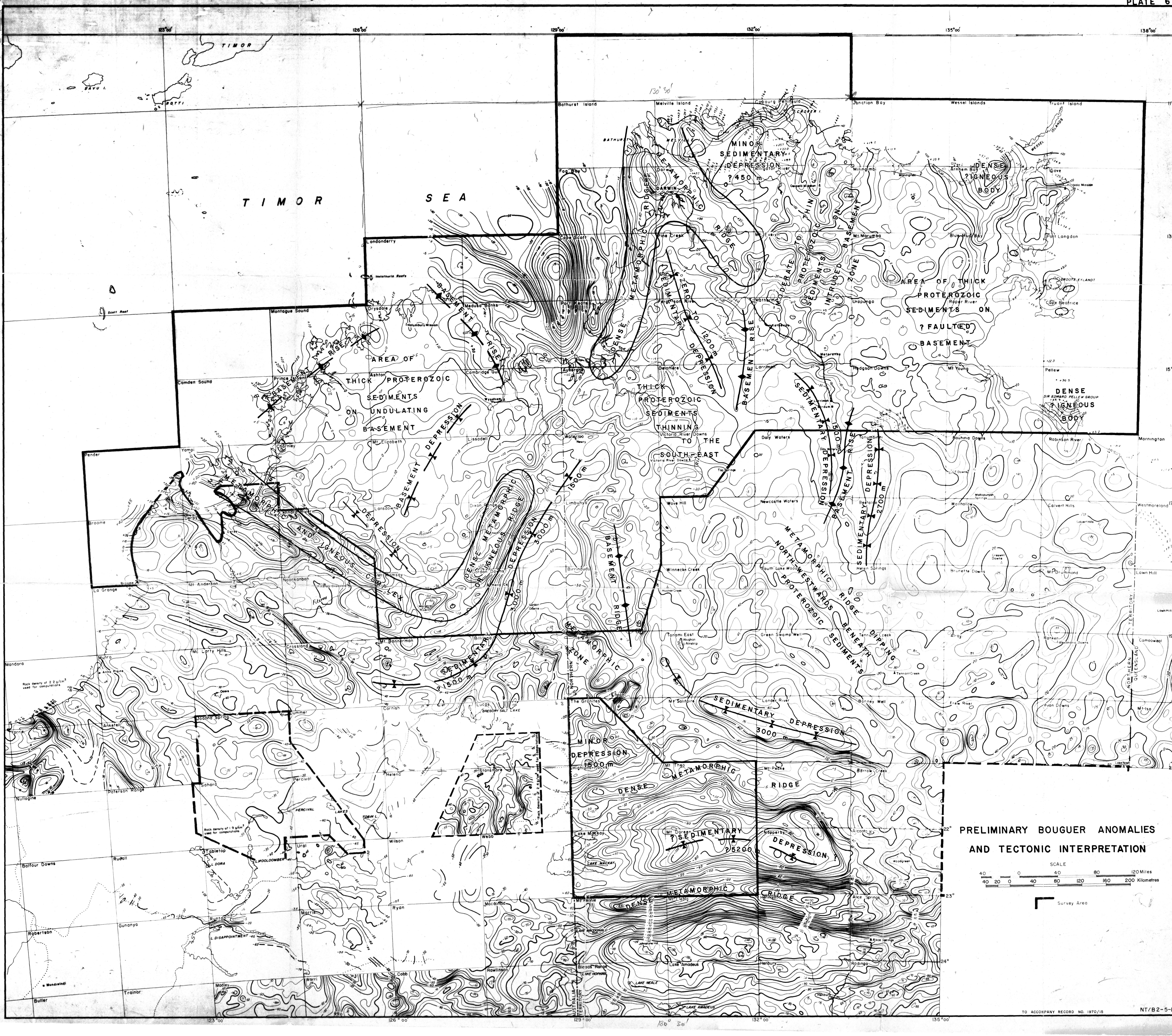
NT/B2-3

From Recce gravity survey of pts. N.T. & W.A. (BMR 1967) by R. Whitworth

PLATE 6



PRELIMINARY BOUGUER ANOMALIES AND TECTONIC INTERPRETATION

TO ACCOMPANY RECORD NO. 1970/15

NT/B2-5-11