COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1962/130

RECONNAISSANCE GRAVITY SURVEYS, USING HELICOPTERS, FOR OIL SEARCH IN AUSTRALIA

by

K. R. VALE

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ILLUSTRATIONS

SUMMARY

In Australia the Bureau of Mineral Resources, Geology and Geophysics is engaged on uniform reconnaissance gravity coverage of all sedimentary basins and eventually the entire continent. The programme employs some 7 geophysicists (university graduates) and 7 technicians such as draftsmen, gravity meter readers, and computers. Field parties of up to 22 men using two helicopters operate in the field for up to five months each year, and establish a station density in excess of one per 50 square miles (90 per one-degree square) over an area of up to 150,000 square miles (36 one-degree squares). Altitudes are measured with barometers.

It is considered that areas of Bouguer anomaly relief having a relief of 10 milligals or more and continued expression over a width of 10 miles will be reliably detected. This allows clear definition of any major gravity anomalies that are likely to correlate with major geological provinces in sedimentary areas. A network of accurately levelled base traverses is established in conjunction with the helicopter surveys. This provides level data which are used to keep altitude errors within acceptable limits and to provide suitable tie points for detailed gravity surveys that may follow.

Total cost of the survey including administration costs, the establishment of basic traverses, and map production may be as high as £A25 per station in remote semi-desert areas such as Central Australia.

At the current rate of working, it would take 18 years to cover the Australian continent. However, by cooperation with mapping authorities, particularly on their independently organised levelling programmes, the continent could be covered in eight years with little increase in staff.

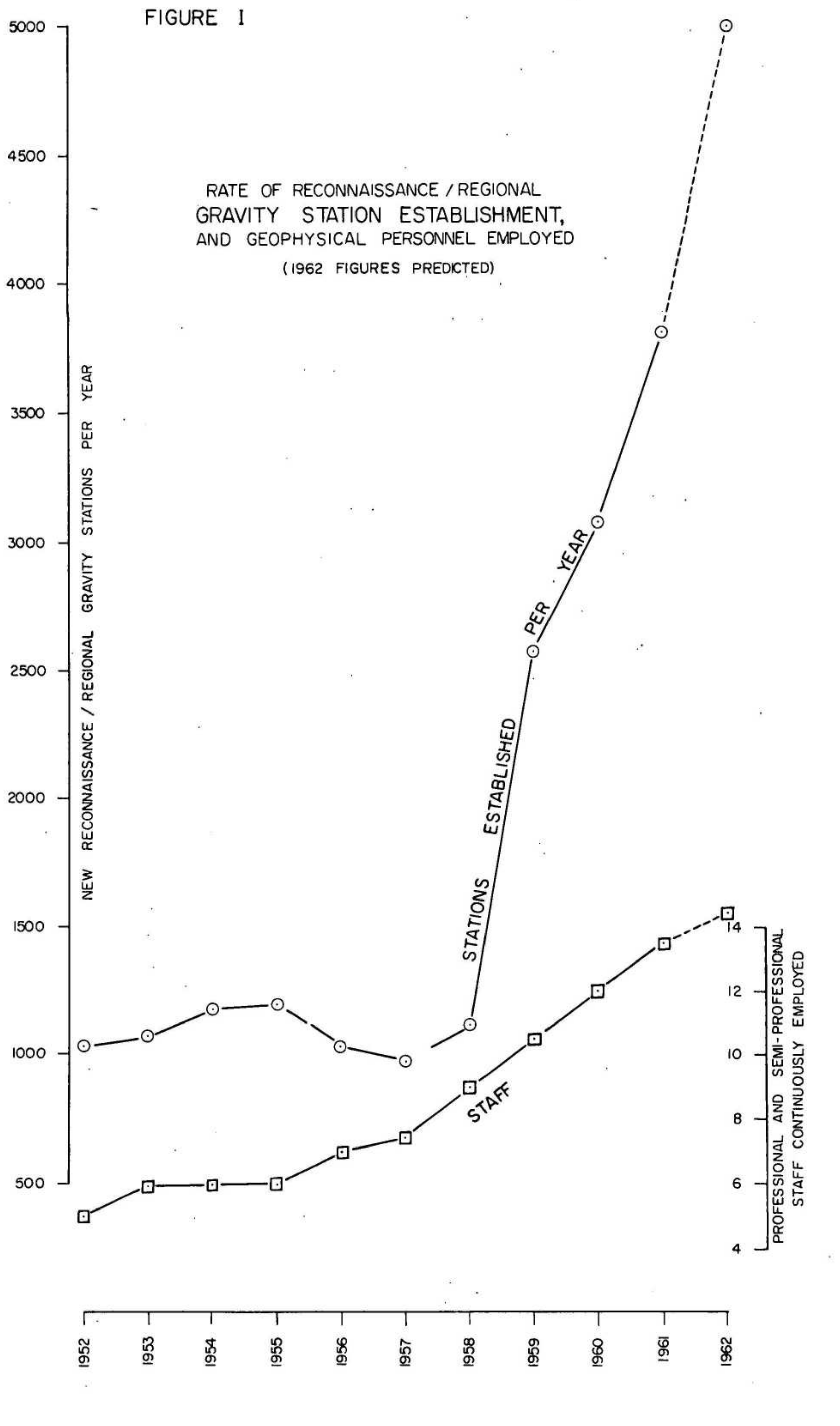


FIGURE I
RATE OF RECONNAISSANCE / REGIONAL
GRAVITY STATION ESTABLISHMENT,
AND GEOPHYSICAL PERSONNEL EMPLOYED
(1962 FIGURES PREDICTED)
NEW RECONNAISSANCE / REGIONAL GRAVITY STATIONS PER YEAR
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
STATIONS ESTABLISHED PER YEAR
STAFF
PROFESSIONAL AND SEMI-PROFESSIONAL STAFF CONTINUOUSLY EMPLOYED
14
12
10
8
6
4
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962

1. INTRODUCTION

A reconnaissance gravity survey is defined, for purposes of this report, as a survey with sufficient station density and accuracy to elucidate, in so far as Bouguer anomalies can directly do so, the major units or provinces of a sedimentary basin. Interpretation, of course, requires a certain amount of control data, e.g. surface geological, borehole, seismic, or aeromagnetic data. As will be discussed later, a density of about one station per 50 square miles (90 per one-degree square) and an accuracy within 1 to 2 milligals (mgal) have been selected as the minimum that will meet the requirement. It is considered that surveys of this nature are of immense practical value in the search for oil.

Within the next 8 to 10 years, using the existing resources of Commonwealth Government Organisations, the entire Australian continent could be covered by reconnaissance gravity surveys without seriously upsetting other current geophysical programmes. At present about seven geophysicists (university graduates) and about seven semi-professionals (draftsmen, gravity meter operators, and computers) are continuously employed. Operating costs of roughly £A80,000 ($U.S. 175,000) per year are involved; these include vehicle and helicopter hire, the services of helicopter pilots, mechanics, and field assistants, and camping costs.

However, it should be noted that the estimate of 8 to 10 years for complete coverage of the continent is based on assistance not included in the above costs. Australian mapping authorities are engaged in a levelling programme whose requirements may reasonably be equated to the requirements for the gravity surveys; the above estimate assumes that an arrangement can be made to merge their levelling programme and the Bureau's gravity programme. Without the cooperation of the mapping authorities the coverage of the continent could take up to 18 years to complete.

As described in Appendix 1 a single party, in some 18 operating weeks, will cover up to twenty-four 1:250,000 map areas (36 one-degree squares) with about 4000 new stations. An example of the results that can be achieved by this class of survey can be seen on Plate 4.

Figure 1 shows the number of gravity stations established and the number of staff engaged on such work during the last 10 years. The Bureau of Mineral Resources carries out a programme of regional gravity traverses linking a pendulum station network. These traverses often serve as ground reconnaissance traverses for sedimentary basin study, and therefore are included in Figure 1. Before 1959, map drafting and final reductions did not keep pace with station establishment. A total of eight geophysical personnel would have been appropriate for those years. From 1959, although a balance has been maintained, the graph shows that the speed-up of station establishment is proportionally much greater than the increase in staff.

2. OBJECTIVE OF RECONNAISSANCE SURVEY

The objective of a reconnaissance gravity survey for oil search as employed by the Bureau is, in conjunction with known geology and other geophysical data, to define important 'provinces' and tectonic features immediately suitable for more intensive methods of investigations. The predictions based on gravity should be tested by more precise methods, e.g. seismic surveying, before any deep drilling, even purely stratigraphic, is attempted. Such tests add to the control, and permit the selection of areas where more detailed and precise gravity surveys may best be used to delineate detailed structure.

Although reconnaissance gravity surveys have much the same objectives as aeromagnetic surveys, it is not considered that one replaces the other but rather that one supplements the other. A discussion of their relative or complementary merits is not intended here. It is sufficient to say that the aeromagnetic method provides valuable data on magnetic basement but does not always provide the data where they are most required. When available, aeromagnetic data are of substantial help in assessing the probable cause of gravity anomalies, thus permitting improved gravity interpretation and better direction of subsequent exploration.

3. STATION DENSITY AND ACCURACY FOR ACHIEVEMENT OF OBJECTIVE

Sedimentary basins may include a number of 'provinces'; each province may be important as a prospective area for oil accumulation,or otherwise important in its contribution to generation and migration or a general understanding of palaeogeography and its control of sedimentation. Such provinces include those with descriptive names such as platform, shelf, depression, hinge line, major fault, ridge, trough, spur,and embayment. They are, for the purpose of this report, features along which (in the case of faults and hinge lines), or around which, substantial gravity relief may be expected. 'Substantial relief' varies in meaning with different areas, but in all places it may be expected to exceed 10 mgal; also, the associated gradient may be expected to have a width exceeding three miles and the relief to have continued expression across a width of some 10 miles or more.

Of course, tectonic relief does not always find expression in recognisable gravity relief, nor does gravity relief always imply tectonic relief; sometimes the correlation between gravity and tectonic relief is the reverse of what one would expect. These are the things that create the demand for control data. However, gravity and tectonic relief are directly correlated often enough to justify reconnaissance gravity surveys in relatively unknown areas, and a first interpretation is based on the assumption that they are directly correlated.

On the above considerations one may reasonably afford a station error as great as 2 mgal and yet be confident that substantial gravity relief, as defined, will not be obscured by station error. Furthermore, with stations on a 7-mile-square grid the gradient associated with the gravityrelief cannot escape detection; there should be several stations on each side of, or actually on, the gradient. In fact, randomly oriented elliptical anomalies having sufficient relief over ten miles length and five miles width can be detected with some 95 per cent certainty by a 7-mile-square grid of stations.

The Bureau has accepted the 7-mile-square grid as a minimum station density. It aims at, and generally achieves, higher Bouguer anomaly accuracy than 2 mgal. The accuracy limitation is posed almost solely by the altitude measurements. However, it is hoped to improve on past performance. Additional stations are established wherever their need is suggested by known or suspected structures or by the preliminary contouring. For example, a gradient first detected by stations seven miles apart may, in the preliminary contouring, have its centre line misplaced by some miles and its width and steepness badly misrepresented. This can be corrected by a few extra stations, judiciously placed.

For the surveys made by the Bureau to date it is considered that Bouguer anomaly values have a standard deviation of about 2 mgal except in rugged country, where this may be exceeded. Any local anomaly of say 5 mgal must therefore be confirmed by more than one reading to attain valid significance; 5 mgal may be considered as the smallest anomaly that the results will reliably detect. However, even an anomaly greater than 5 mgal but recorded only at one station must be checked by establishment of additional stations, as it may be due to a gross error or misreading. If the accurate delineation of small anomalies is considered important in a reconnaissance survey, additional stations can be put in where necessary, but careful consideration should be given to more accurate ground traversing methods (even if access conditions require that the gravity meter operator and surveyor should walk) and the detail required must be related to the cost involved.

The Bureau currently engages the services of two helicopters for 18 to 20 weeks per year for its own operations. Depending mainly on helicopter serviceability, up to twenty-four 1:250,000 map areas (36 one-degree squares) may be covered. At present it is hard to achieve an average rate much in excess of one map area per week. It is hoped that experience, principally in improving helicopter reliability in excessively dusty conditions, will raise this to nearer one and a half map areas per week.

4. PRESENTATION OF RECONNAISSANCE GRAVITY MAPS

Plate 6 shows a 1:250,000 map area contoured in final presentation form at 1:500,000 scale. This area was flown in 1960 and a 10-mile by 5-mile station grid was used. This was part of a very fast survey using one helicopter. The 10 x 5 grid was chosen for speed, and relatively few follow-up flights were made. Helicopter stations and ground control stations are clearly marked with the Bouguer and altitude values at each station. Anyone wishing to make a gravity tie to any station could compute the observed gravity value. Contours are at 1-mgal intervals, but as the standard deviation of the station value in most areas is 2 mgal, and in some areas is still greater, the 1-mgal contours have no significance individually. They help to emphasise the pattern, but the reader is probably well advised to ignore them; their inclusion is certainly debatable.

These 1:500,000 maps represent the final presentation of the results of the survey. However, to assist in their assimilation and interpretation, maps covering larger areas at approximately one fifth the scale of the above maps are produced. These include a map contoured at 5-mgal intervals (Plate 2), a similar map with shaded tones for each 20-mgal interval (Plate 3), and a shaded map with some interpretation added (Plate 4). Also, for interest, a relief model was made of the area covered by these maps. Vertical and oblique photographs of this model are shown on Plate 7.

A geological map of the same area is shown on Plate 5, and the general correlation between known geology and gravity can be readily seen. The reliability index on Plates 2, 3, and 4 shows the parts covered by helicopter gravity survey or otherwise having a similar station density (one per 50 square miles). The maps illustrate rather well the amount of detail, in delineating province boundaries, that can be expected from this class of survey. Even surveys with lower station density can be seen to have value.

On Plate 5 the provinces whose names include the word 'gravity' are postulated solely on gravity evidence. The others have been previously postulated by geological observation or deduction. However, many of those postulated initially on geological grounds have had their boundaries defined by gravity.

5. THE ROLE OF THE HELICOPTER IN EXTENDED REGIONAL GRAVITY COVERAGE

The Bureau is currently employing helicopters as traversing vehicles for extending uniform gravity coverage over substantial parts of the sedimentary basins. The helicopter overcomes many access problems and permits flexibility in the selection of a desired pattern of stations. For a gravity survey it is necessary to establish at each station:

(a) a value of gravity

(b) a location; this enables the gravity values to be corrected for latitude, and the station to be reoccupied and plotted on the map

(c) a value of altitude.

In the Bureau's surveys this is done as described in the following paragraphs.

Gravity

A small commercial quartz-system gravity meter is used. Readings at selected or previously established stations are usually made within two hours to control instrument drift and diurnal variation. The meters used undoubtedly suffer from some form of 'airsickness' caused by the frequent changes in altitude, but accuracy appears to be fairly consistently within 0.2 mgal.

Location

The stations occupied are pricked onto airphotos which in turn are controlled by astro-fixes and slotted-template mosaic assemblies. In general, station location is considered to be no better than about 1000 feet of true latitude and longitude, but station intervals are considered to be accurate within about 600 ft. These errors may cause a regional-type error in normal gravity and error in calculated Bouguer anomaly of about 0.25 mgal, but the random component (the more important in its effect on interpretation) will generally not exceed 0.15 mgal.

Altitude

A precise microbarometer with a reading accuracy of about 0.05 millibars is used in conjunction with a control system of base barometers and spirit-levelled base stations. In the worst case, for traverses ranging up to 100 miles from a single base barometer, in fair weather a standard deviation of about 30 ft was obtained. However, it is probable that the standard deviation is generally 20 ft and in some cases is as little as 10 ft. With base barometers stationed at three bases, a new type of barometer, and a new flying system that will reduce the maximum distance of the helicopter from its principal base to 20 miles, it is expected that substantial improvements will be obtained.

As it stands at the moment, all the above errors represent a standard deviation in reduced Bouguer anomaly of about 2.0 mgal in the worst case or less than 1.0 mgal in the best case. The survey technique provides a network of small loops to which a least-square adjustment can be applied. Digital computers facilitate this operation. The resultant standard deviations after all adjustments should lie between 0.5 and 1.0 mgal. Although these errors are within acceptable limits for a reconnaissance survey as previously defined, they preclude this type of use of the helicopter for detailed surveys.

6. A BASIC NETWORK TO CONTROL AND MAINTAIN ACCURACY

As the entire continent is to be covered by reconnaissance surveys, it is highly desirable that all observed gravity values and all altitude values be as accurate as possible in the absolute as well as the relative sense. This will minimise the adjustment when independent surveys are eventually linked, and will give the surveys their maximum geodetic value. To ensure this, adequate control must be maintained on gravity meter drift, and as many stations as possible should be linked with spirit-levelled ground traverses. A compromise is necessary between available ground survey services, speed, and cost. Experiments in techniques are currently aimed at reducing standard deviation of the absolute altitude measurements to 5 ft and observed gravity to 0.1 mgal. Consistency of gravity values should be possible but altitude accuracies vary with climate and type of terrain. Fortunately, much of Australia provides good terrain for this purpose along with good climatic conditions over much of the year.

The Commonwealth department responsible for surveying has been asked to provide spirit-levelled traverses, preferably running north and south, at distances no greater than 50 miles apart, with bench marks established at about 5-mile intervals; it is important to locate bench marks so that they can be readily recognised and approached from the air. The department, to date, has been able to meet less than half of the above requirements but it is expected that the requirements will be fully met for most future surveys. The separation of 50 miles has been somewhat arbitrarily chosen, and time will tell whether it is a correct choice. Certainly the more control the better, but this separation represents the closest that can presently be obtained.

Within the survey area, flights are looped, common stations are established with previous flights, and ties are made to spirit-levelled traverses to control diurnal and instrument drift and to establish a pattern for estimation and distribution of errors. However, owing to 'airsickness' of the gravity meter it is considered that the accuracy of observed gravity values is no better than 0.1 mgal relative to the base station. Although this accuracy can maintain observed gravity values within accepted limits over a fairly large area, it does require that a gravity value be established in the survey area by transport other than helicopter. One of the spirit-levelled traverses is usually read by conventional ground traversing gravity techniques to establish a chain of acceptable base stations.

APPENDIX 1

CONSTITUTION OF A GRAVITY SURVEY PARTY USING HELICOPTERS

The table opposite shows an analysis of five different types of party based on either one or two helicopters. The parties vary with planned low or high utilisation of the helicopters. The effect of helicopter unserviceability is shown. No clear pattern of unserviceability has yet emerged except that individual helicopter performance is very irregular, with substantial periods of serviceability interspersed with substantial periods of unserviceability. The decision on type of party has to date been made on an assumption of about 25 per cent unserviceability. However, as the helicopter operators gain more experience with this class of operation it is expected that unserviceability time will be reduced and party organisation will need review. The organisation chosen (Party Type D) is tailored to average fair utilisation of two helicopters or maximum utilisation of one helicopter. Provided only one helicopter at a time is unserviceable, such a party shows a minimum of output or cost variation related to unserviceability. At about 25 per cent unserviceability it appears as the most economical in both cost and geophysical personnel man-hours.

The estimated cost shown in Item 14 included such items as helicopter hire and flying charge, personnel wages during positioning and conduct and winding-up of survey, preparation of final maps and preliminary report, and vehicle hire for eight months. It allows for helicopter unserviceability, being the equivalent of one helicopter unserviceable for nine weeks of the survey. It does not include certain rather indeterminate costs such as departmental administration, cost of aerial photographs, early planning of survey, and other preliminary preparations. As far as it goes it is considered to be a fair estimate These indeterminate costs (departmental administration etc.) may be expected to have a uniform effect on all types of party. An interesting point is that the estimate for Party Type D is higher than for Party Type E for helicopter charges, but the reverse applies for overall cost of the survey. In round figures it may be assumed that total charges including administration, map production, and establishment of basic traverses may be as high as £A25 per gravity station.

It is emphasised here that the table should not be considered even approximately applicable in other countries. Such factors as

(a) type of machine

(b) basis of helicopter charges

(c) responsibility for continuing utilisation of helicopters

(d) basis of vehicle charges

(e) availability of trained staff

(f) wages rates in context of helicopter and other transport costs

(g) quality of airphotos for navigation and station location

(h) tree cover and ability to land

can greatly influence the cost of a survey and make different types of party organisation more attractive. Each proposed project should be analysed on its own merits in the context of local conditions. It is worthy of note that the cost of gravity operations as outlined here is substantially less than the annual cost of a seismic party.

It might be pointed out here that in drawing up a contract for helicopter services the utmost attention must be given to detail; e.g. precise duration of charge time (engine running time or flying time), policy on engine shut-down during meter reading, responsibilities in navigation, assistance of pilots and engineers in breaking camp and shifting ground vehicles, guaranteed helicopter performance, penalty rates for helicopter failure. All these points of detail can very materially effect the size and cost of the party. Undoubtedly the first survey in a new region will highlight substantial areas for organisational improvement.

FIGURE 2

GEOPHYSICAL BRANCH
BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS

(Facing Page 9)

HELICOPTER GRAVITY SURVEY

FLIGHT DETAILS

SURVEY AREA Bedourie	FLIGHT No. F 110		DATE 19.8.'61
OBSERVER M.A. Reid	PILOT R. Larder	VH- INF	TAKE OFF TIME 08 33

°M	Leg	Dist.	Elapsed Time Int.	Elapsed Time Total (h m)	Flying Time Int.	Flying Time Total (h m)	Radio Log
SSW	3400T-3475	8	10	00 : 10	10	00 : 10	
W	3036	7	15	25	9	19	
W	35	7	15	40	9	28	L09:00
W	34	7	15	55	9	37	
W	33	7	15	01 : 10	9	46	
W	M 32	7	15	25	9	55	
W	31	7	15	40	9	01 : 04	
W	30	8	16	56	10	14	L10:00
SW	T 36/25	11	19	02 : 15	13	27	L10:55
NW	3029	9	17	32	11	38	
W	28	7	15	47	9	47	
W	M 27	7	15	03 : 02	9	56	
W	26	7	15	17	9	02 : 05	
S	25	7	15	32	9	14	L11:31
S	M 3201	7	15	47	9	23	
NE	3024	10	18	04 : 05	12	35	
N	R 27	7	15	20	9	44	
SE	23	10	18	38	12	56	
E	22	7	15	53	9	03 : 05	
E	TR 36/25	8	16	05 : 09	10	15	L14:00
E	3021	11	19	28	13	28	
E	20	7	15	43	9	37	
E	19	7	15	58	9	46	
E	R 32	7	15	06 : 13	9	55	L15:00
SE	18	9	17	30	11	04 : 06	
E	17	7	15	45	9	: 15	
E	16	9	17	07 : 02	11	26	
N	R 35	7	15	17	9	35	L15:58
SE	15	10	18	35	12	47	
E	3476	7	15	50	9	56	A/B16:27
NNE	TR 3400	16	24	08 : 14	18	05 : 14	L16:43

A/B - Airborne
L - Landing
O/G - On Ground

O/N - Operations Normal
N/U - Message Not Understood
??? - Call Sign Uncertain

CHARGE TIME ....

TOTAL CHARGE TIME ....

To accompany Record Nº 1962/130

APPENDIX 2

FLIGHT PLANNING AND COLLABORATION WITH OTHER AUTHORITIES

There are two basic types of flight plan at present under consideration by the Bureau. These are termed

(a) Line Method

(b) Cell Method

Diagrams illustrating these methods are shown on Plate 8. Both operate on the basis of a main base camp where plotting and preliminary computing of results are carried on, plus flying camps which become temporary outlying bases for individual helicopters for up to three days. The cell method entails the establishment of a temporary base in the centre of each day's operation, and embodies a number of readings at the centre of the cell to control diurnal and instrument drift. The traversing and station barometers are checked side by side. The cell method should provide better instrument control and consequently more accurate results; otherwise, there is not much to choose between the two methods. The flight time involved is a few per cent in favour of the line method, but better utilisation may result from the smaller flight units of the cell method. Before 1962 the line method was used exclusively. This year the cell method will be used as an experiment.

Whichever method is used, flight planning and flying are much the same. These follow the following order:

(1) Where possible, base camp and flying camp locations are selected before entry into an area.

(2) Desirable flight plans to cover the area are drawn upon a 1:250,000 map showing the principal points of the mosaic photographs, and the area is tentatively apportioned between helicopters.

(3) Flight plans are modified to make use, where possible, of helicopters flying between bases or temporary bases.

(4) Airphotos are drawn from the party's photo library to cover each proposed flight.

(5) Any bench marks or previously read stations are marked on the photos.

(6) The proposed flight is marked on the airphotos together with photo overlap and a preferred locality for each proposed new station.

(7) The photos are stacked in order in a hand folder ready for use on the flight.

(8) A flight plan is laid down on a flight details sheet with estimated times shown for each landing. A sample sheet is shown on Figure 2.

(9) Times are estimated on the basis of one minute for take-off, one minute per mile between stations, one minute for landing, and six minutes for taking gravity and barometer readings.

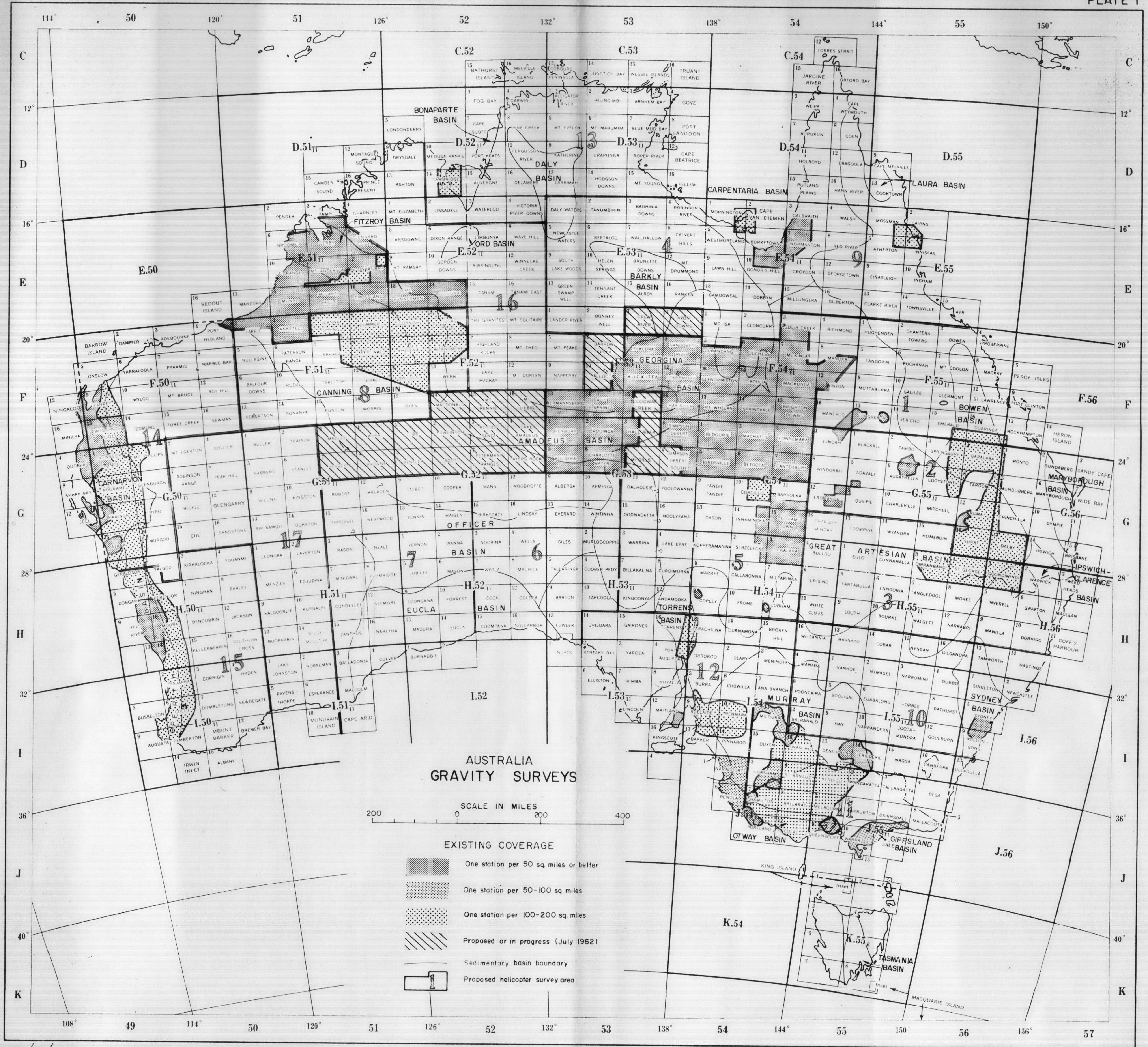
(10) The precise location occupied is pricked onto the airphoto.

Most flights go faster than indicated in (9) above, thus providing a reserve of time. The reserve is in addition to that allowed for normal safety requirements, but is necessary for reasonable insurance that completion of the traverse will not be jeopardised by temporary difficulties in recognising and following the planned route. For very long flights it may be necessary to allow an additional half hour each for lunch and refuelling.

Immediately on return of a helicopter to the main base camp, preliminary altitudes are computed for each new station. All station locations are transferred from the airphotos to the final base map. From this, latitudes are taken and preliminary Bouguer anomalies calculated. Preliminary contours are then drawn and flights for extra stations are planned.

A measure of collaboration with other authorities is possible and may help to raise helicopter utilisation if both machines remain serviceable for extended periods. A geologist can generally co-operate; he can travel as a passenger on medium and short flights, or take a helicopter for long flights on days when no gravity flight is planned. Surveyors can also be assisted by dropping them in inaccessible areas so that they can extend spirit-levelled traverses on foot. Such forms of co-operation are often sufficiently attractive for the geologist or surveyor to be content to await their opportunity when a machine is free. They can often adjust their current work to take advantage of an opportunity as it arises. The presence on the party of a geologist who is familiar with the area can be of substantial assistance in ensuring fullest appreciation of geologically significant anomalies and places where follow-up flights are needed.

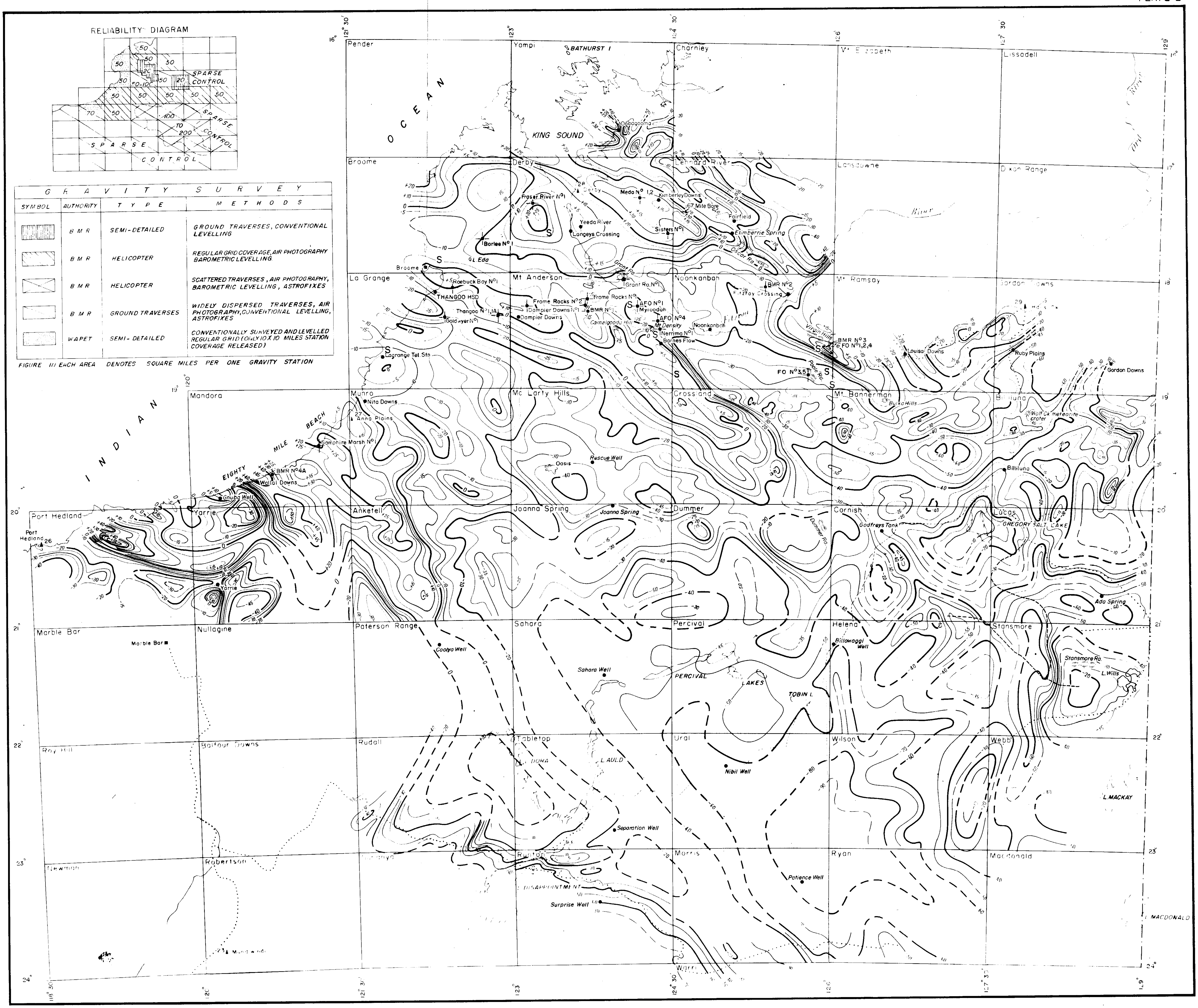
PLATE I



NMP/59/151-1

To accompany Record N° 1962/130

G 65-35



SYMBOL	AUTHORITY	TYPE	METHODS
	B M R	SEMI-DETAILED	GROUND TRAVERSES, CONVENTIONAL LEVELLING
	B M R	HELICOPTER	REGULAR GRID COVERAGE, AIR PHOTOGRAPHY BAROMETRIC LEVELLING
	B M R	HELICOPTER	SCATTERED TRAVERSES, AIR PHOTOGRAPHY, BAROMETRIC LEVELLING, ASTROFIXES
	B M R	GROUND TRAVERSES	WIDELY DISPERSED TRAVERSES, AIR PHOTOGRAPHY, CONVENTIONAL LEVELLING, ASTROFIXES
	WAPET	SEMI-DETAILED	CONVENTIONALLY SURVEYED AND LEVELLED REGULAR GRID (ONLY 10 X 10 MILES STATION COVERAGE RELEASED)

Yampi — B M R 4-mile gravity map area

▲28 — B M R gravity pendulum station

S — B M R seismic survey

Bore

.... B M R gravity traverse — Area of sparse control

- - - - - WAPET gravity traverse — Area of sparse control

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

No 26 Port Hedland	978,645·2 milligals	
No 27 Anna Plains	978,623·2	"
No 28 Derby	978,519·4	"
No 29 Halls Creek	978,461·4	"

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

Elevation datum M.S.L., Derby, W.A.

RECONNAISSANCE GRAVITY SURVEY (1952-1960)
FITZROY AND CANNING BASINS, WA
BOUGUER ANOMALIES

SCALE IN MILES

40 0 40 80 120

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

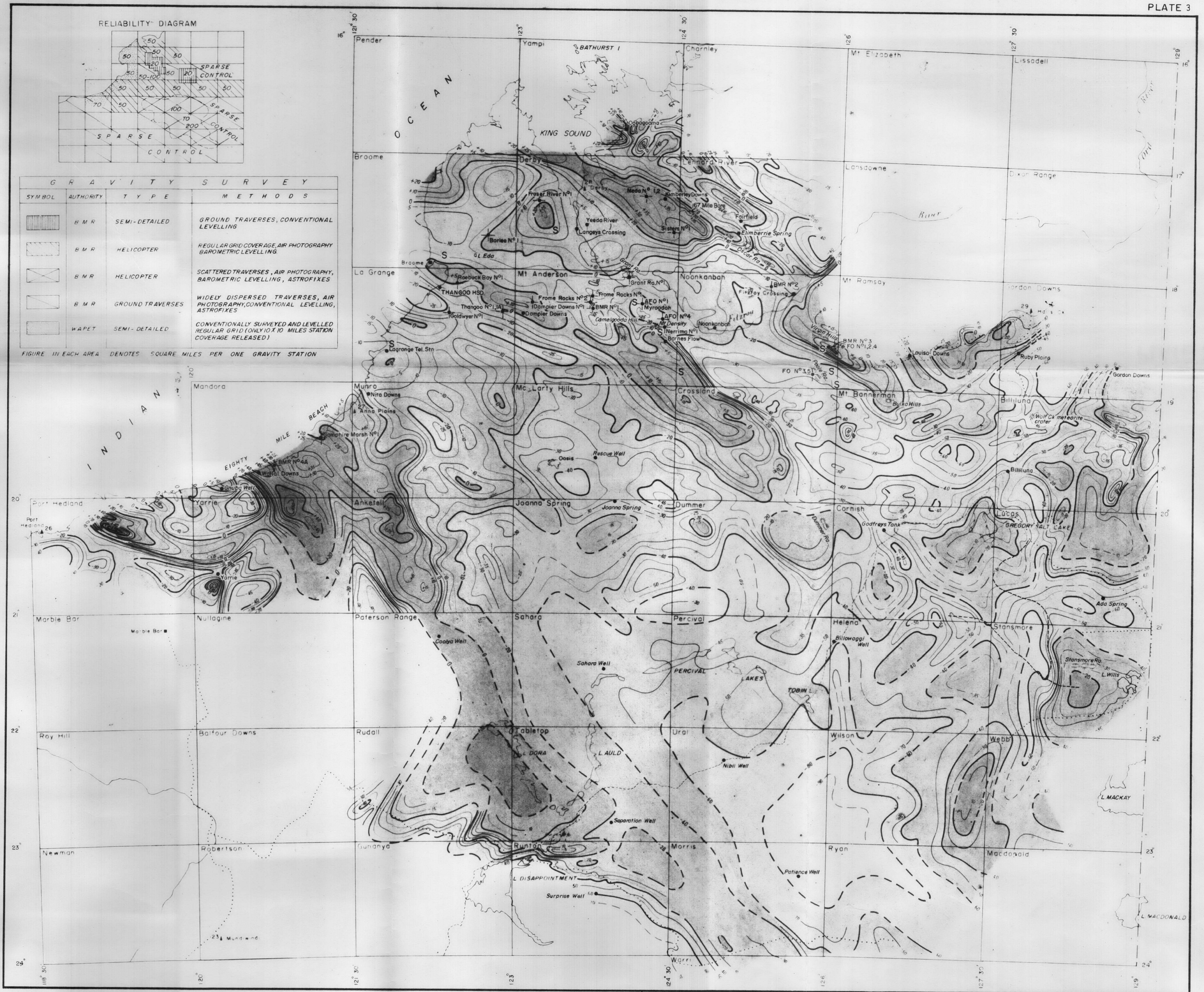
COMPILED JULY 1961
REVISED MAY 1962

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

G 228-39-8

To accompany Record No 1962/130

PLATE 3



SYMBOL	AUTHORITY	TYPE	METHODS
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	WAPET	SEMI-DETAILED	CONVENTIONALLY SURVEYED AND LEVELLED REGULAR GRID (ONLY 10 X 10 MILES STATION COVERAGE RELEASED)

Isogals (values in milligals)
Yampi — B M R 4-mile gravity map area
28 — B M R gravity pendulum station
S — B M R seismic survey
Bore
B M R gravity traverse
WAPET gravity traverse } Area of sparse control

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Elevation datum M S L, Derby, W A

RECONNAISSANCE GRAVITY SURVEYS (1952–1960) FITZROY AND CANNING BASINS, WA

BOUGUER ANOMALIES

WITH SHADING EMPHASIS

Gravity 'High'
Gravity 'Low'

SCALE IN MILES
40 0 40 80 120

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

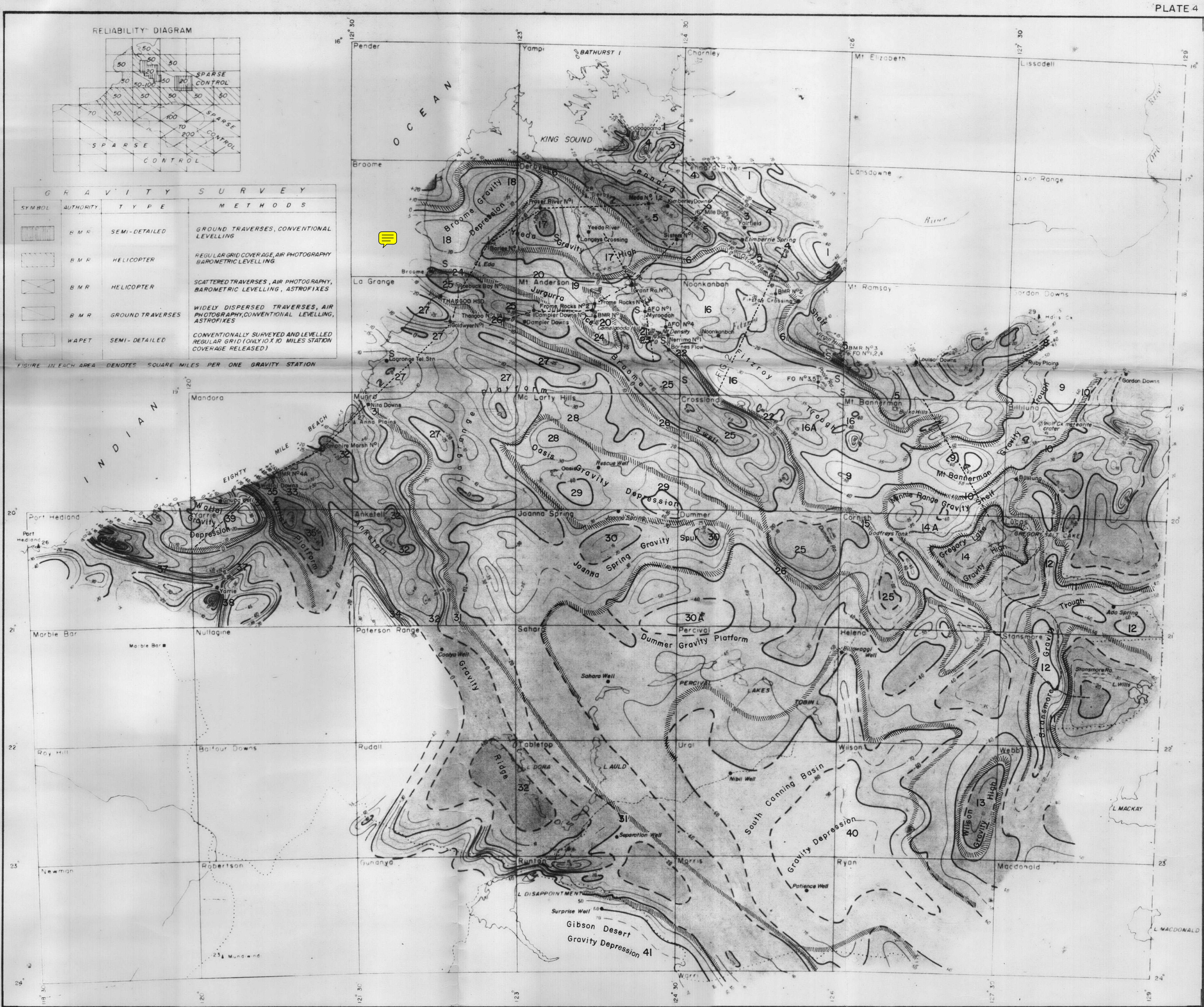
COMPILED JULY 1961
REVISED MAY 1962

(Based on G 228-39-8)

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G 228-39-9

To accompany Record No 1962/130

Drg. No G228-39-9A Plate 4 of Record 1962/130. (Overlay to 1



Isogals (values in milligals)

Yampi — B M R 4-mile gravity map area

28 — B M R gravity pendulum station

S — B M R seismic survey

Bore

B M R gravity traverse

WAPET gravity traverse — Area of sparse control

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

No 26 Port Hedland	978,645·2 milligals
No 27 Anna Plains	978,623·2 "
No 28 Derby	978,519·4 "
No 29 Halls Creek	978,461·4 "

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

Elevation datum M.S.L, Derby, WA

RECONNAISSANCE GRAVITY SURVEY (1952-1960)
FITZROY AND CANNING BASINS, WA

BOUGUER ANOMALIES
WITH SHADING EMPHASIS AND AN INTERPRETATION

SCALE IN MILES

40 0 40 80 120

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

Gravity 'High'
Gravity 'Low'

25 — Reference number in text

Gravity unit boundary

3 — Cross-section

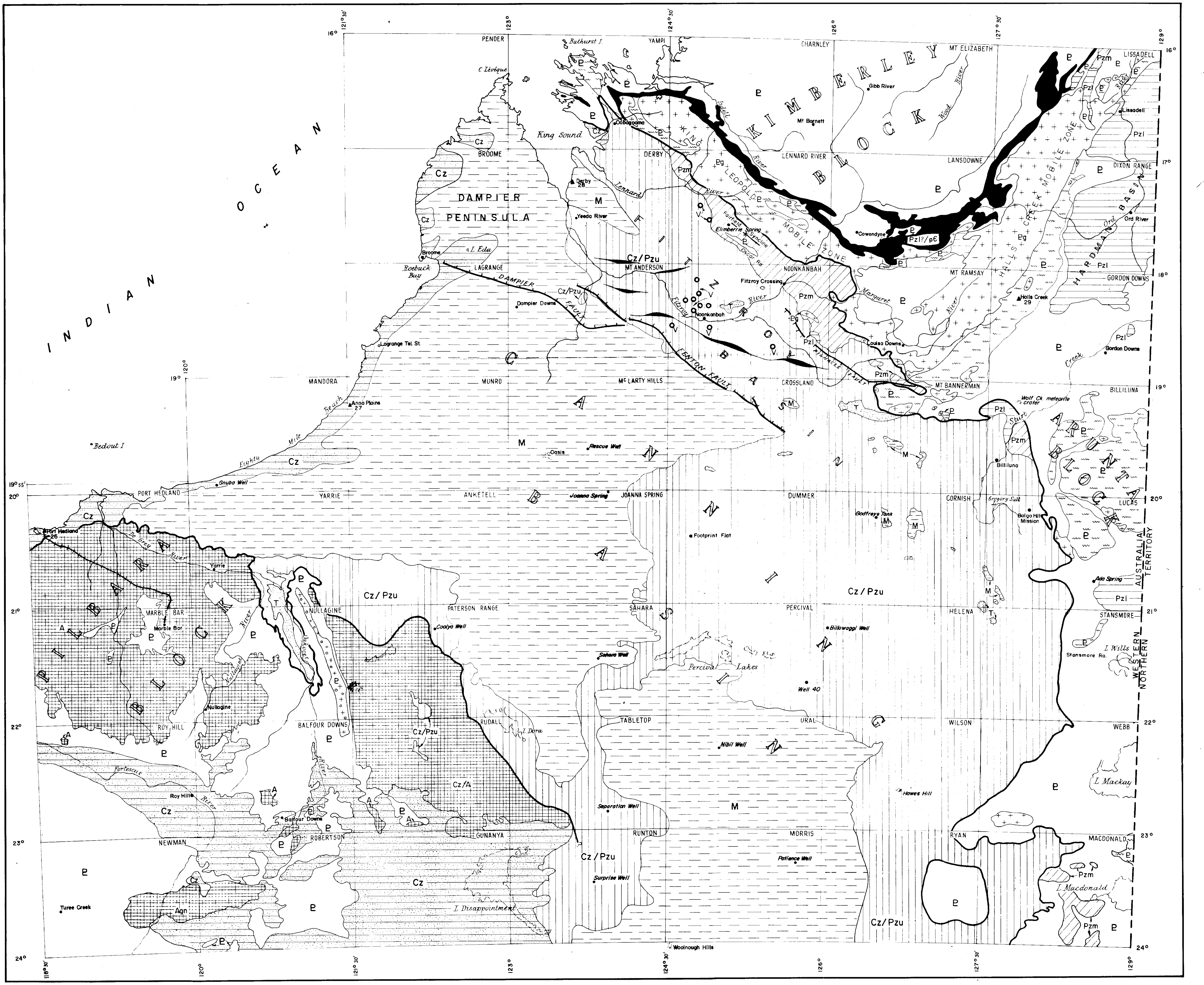
COMPILED JULY 1961
REVISED MAY 1962

(Based on G228-39-8)

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G228-39-9A

To accompany Record N° 1962/130

Drg. No G228-39-9A Plate 4 of Record 1962/130 (Overlay to G228-39-9)



LEGEND

Cz	Alluvium, limestone	Cainozoic
T	Marine and continental sediments	Cainozoic
M	Sandstone, siltstone, shale	Mesozoic
Cz/Pzu	Marine and continental sediments	Palaeozoic – Upper
Pzm	Mainly limestone, shale, sandstone, and siltstone	Palaeozoic – Middle
Pzl	Volcanics in Lower Palaeozoic	Palaeozoic – Lower
Pzl?/p€	Belt of Lower Palaeozoic basic intrusions following edge of Kimberley Block	Palaeozoic – Lower
P	Mainly sandstone and shale	Proterozoic
P	Metamorphic rock	Proterozoic
	Archaean (undifferentiated)	
	Porphyry	
	Granite	
	Leucitite - Lamproite intrusives	

- ▲ 28 BMR gravity pendulum station
- DERBY BMR 4-mile gravity map area
- Railway
- Basin boundary
- Anticlinal culmination
- Fault

COMPILED JULY 1961

RECONNAISSANCE GRAVITY SURVEYS (1952-1960)
FITZROY AND CANNING BASINS, WA
GEOLOGY AND MAJOR TECTONIC FEATURES

SCALE IN MILES

40 0 40 80 120

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

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G 228-39-2

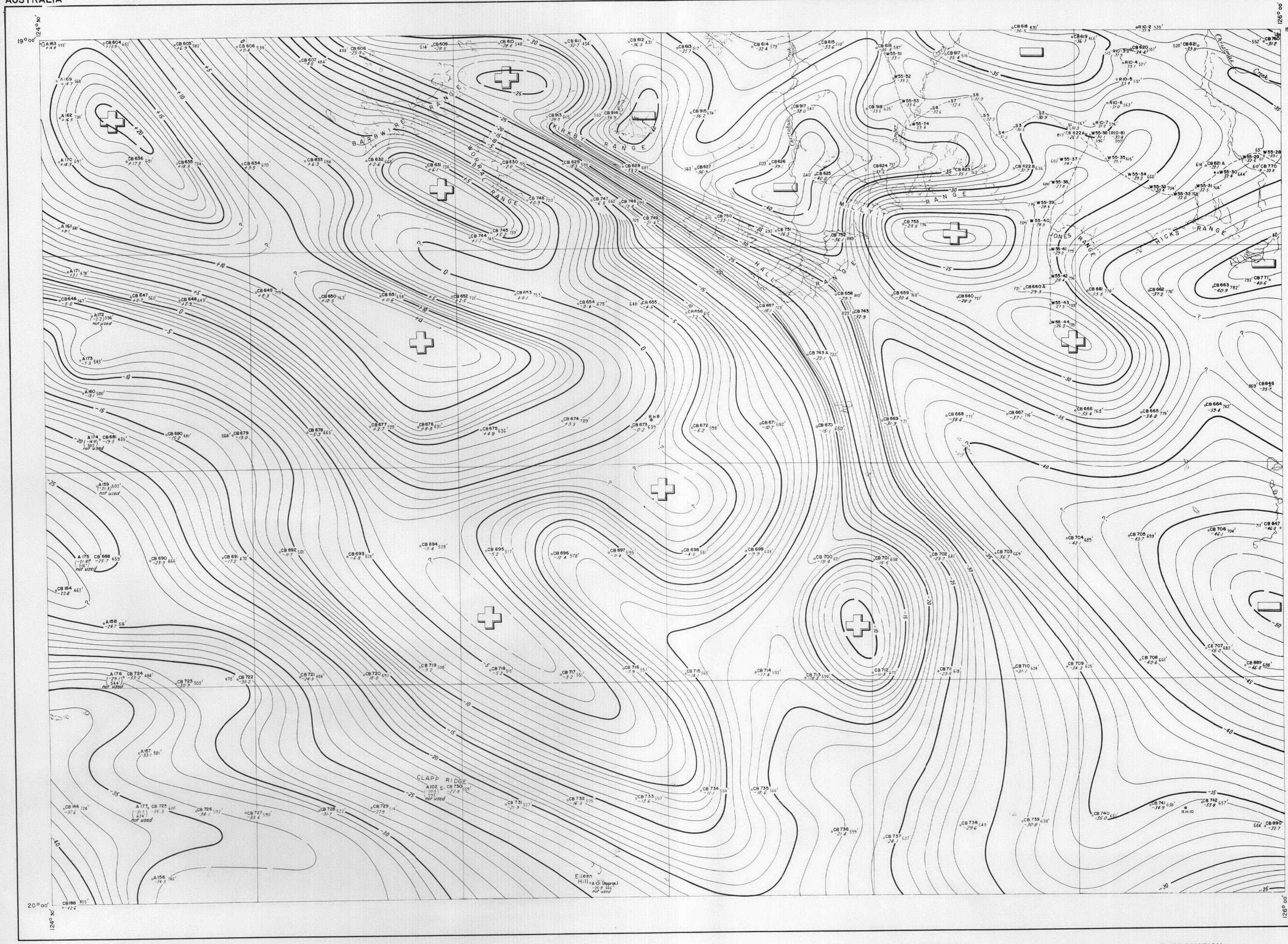
To accompany Record No 1962/130

CROSSLAND

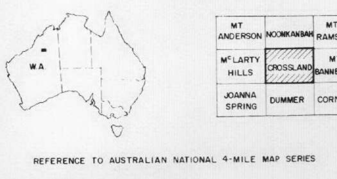
AUSTRALIA 1:500,000

WESTERN AUSTRALIA

E 51-16, ZONE 3



LOCATION



REFERENCE TO AUSTRALIAN NATIONAL 4-MILE MAP SERIES

MAP DATA

PROJECTION: *TRANSVERSE MERCATOR, AUSTRALIA SERIES*

CONTROL: *W.A. DEPT OF LANDS AND SURVEYS 4 MILES TO 1 INCH PLANIMETRIC MAP WITH THE SAME NAME*

DETAIL: *PLANIMETRY AFTER W.A. DEPT OF LANDS AND SURVEYS*
BMR GROUND TRAVERSES PLOTTED FROM DEPT OF THE INTERIOR 1:63,360 GRAVITY SURFACE CONTROL MAPS, MISC 46 Sheets 7 and 9 (NOV 1955)
BMR HELICOPTER GRAVITY TRAVERSES PLOTTED FROM AIR PHOTOGRAPHS

RELIABILITY: *PLANIMETRIC - GOOD (FROM ASTRONOMICALLY CONTROLLED AIR-PHOTO ASSEMBLY). GEOPHYSICAL - GRAVITY RECONNAISSANCE*

RECONNAISSANCE GRAVITY SURVEY (1955-1960)
CANNING BASIN, W.A.
BOUGUER ANOMALIES

SCALE IN MILES

4 0 4 8 12 16

CONTOUR INTERVAL 1 MILLIGAL

LEGEND

TOPOGRAPHY

TRACK

ASTRONOMICAL FIXATION

WATERCOURSE (NON-PERENNIAL)

GRAVITY

W55-44 BMR GRAVITY STN (GROUND)

A156 BMR GRAVITY STN (HELICOPTER 1957)

CB 736 BMR GRAVITY STN (HELICOPTER 1960)

-21·3 RELATIVE BOUGUER ANOMALY (MILLIGALS)

637' ELEVATION

ISOGALS

'HIGH' ANOMALY

'LOW' ANOMALY

EXPLANATION

RELATIVE BOUGUER ANOMALIES ARE BASED ON THE OBSERVED GRAVITY VALUE OF 978,623·2 MILLIGALS AT BMR No27 PENDULUM STN ANNA PLAINS, W.A. AND 978,461·4 " " No29 " " HALLS CREEK, W.A.

FOR THE CALCULATION OF BOUGUER ANOMALIES 2·2 g/cm³ HAS BEEN ADOPTED AS AN AVERAGE ROCK DENSITY.

ELEVATION DATUM - MSL DERBY, WA

ELEVATIONS FROM ASKANIA MICROBAROMETER READINGS CONTROLLED BY THE DEPARTMENT OF THE INTERIOR LEVELLED TRAVERSES

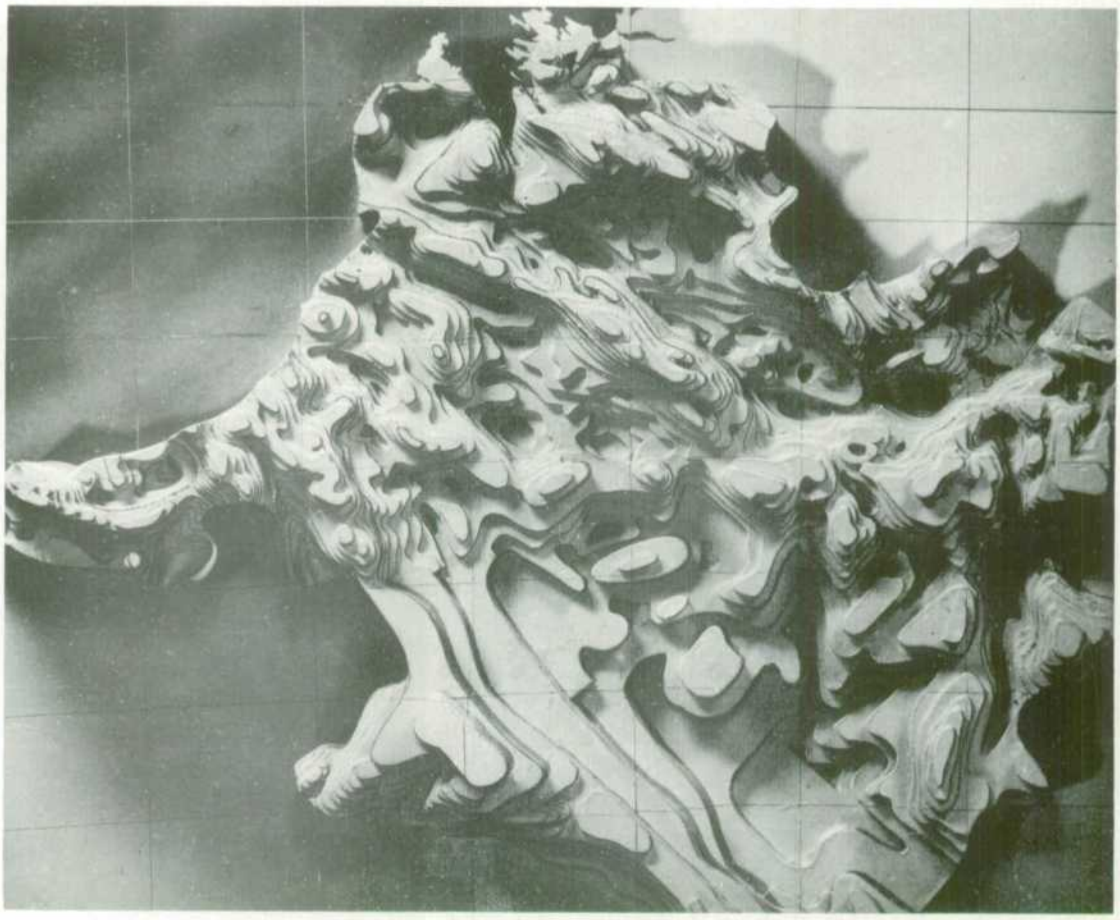
TOPOGRAPHY AND CULTURAL FEATURES SHOWN ONLY TO LOCATE GEOPHYSICAL DATA

LONGITUDINAL SAND-RIDGES IN A GENERAL NW TO SE DIRECTION ARE THE MAIN FEATURE OF THE AREA

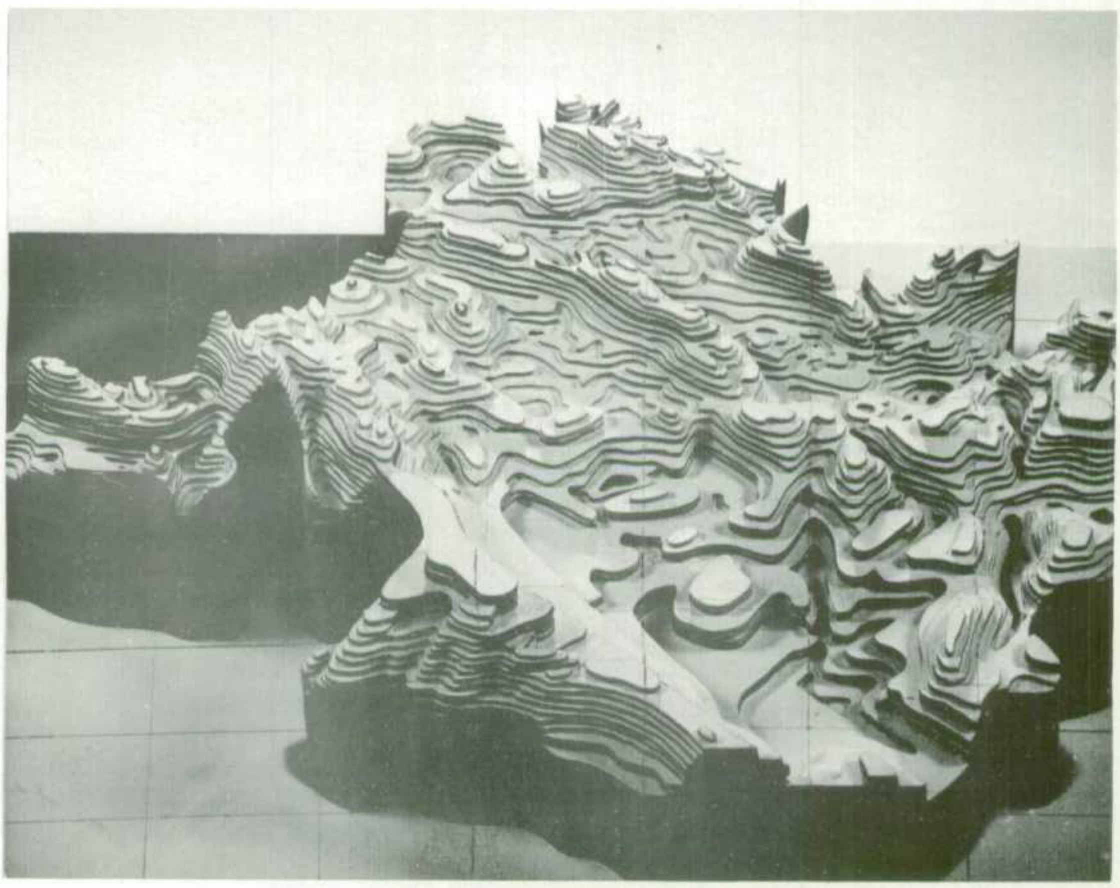
AIR PHOTOGRAPHY, RAAF 1949

COMPILED OCTOBER 1960
REVISED FEBRUARY 1962

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G 69-351-3



VERTICAL PHOTOGRAPH

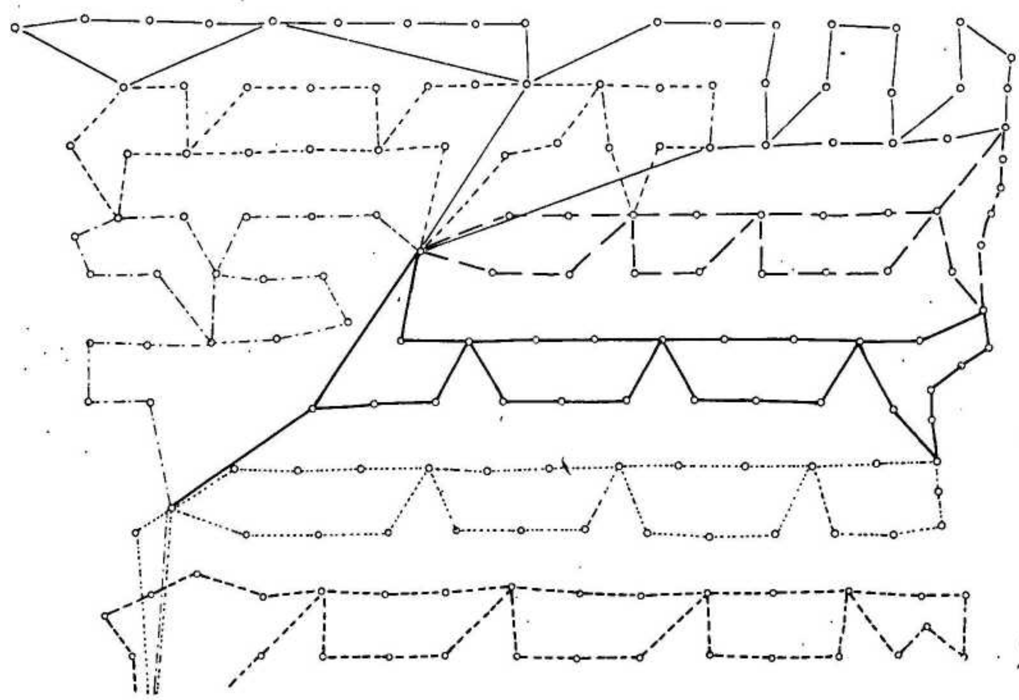


OBLIQUE PHOTOGRAPH

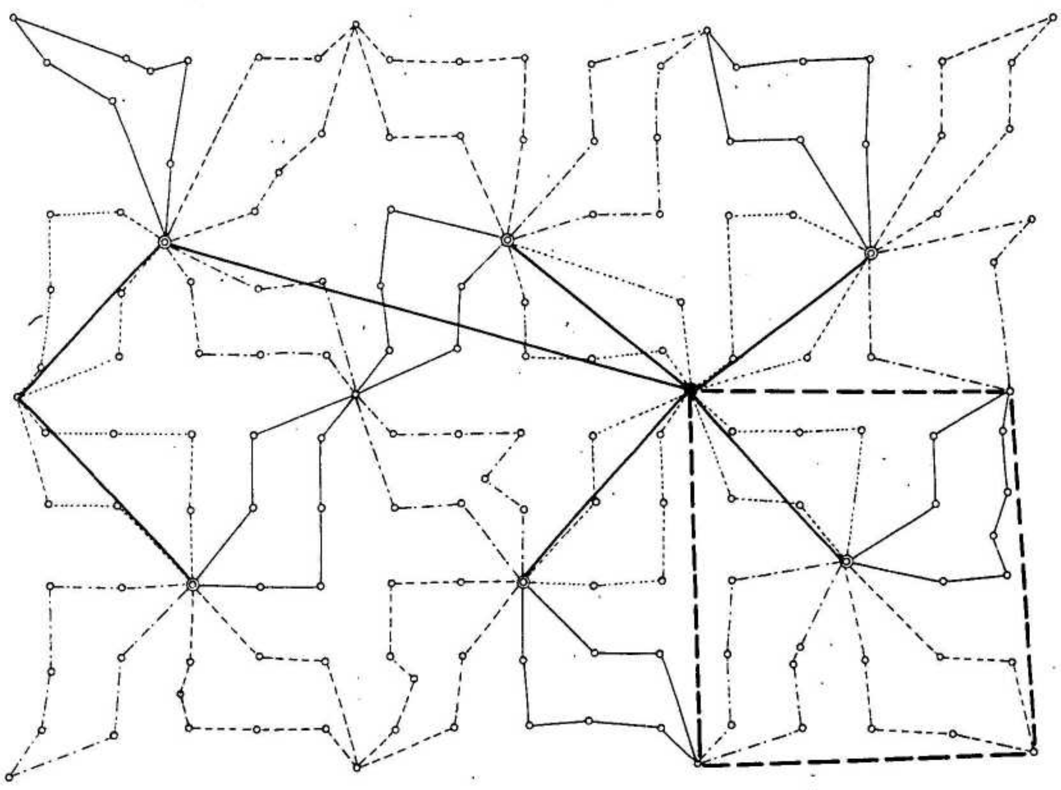
FITZROY AND CANNING BASINS, W.A.

BOUGUER ANOMALY RELIEF MODEL

A. LINE METHOD OF FLIGHT PLAN



B. CELL METHOD OF FLIGHT PLAN



Operation cell

Cell centre

Flight lines in order of flying 1 2 3 4

Positioning flight

Gravity station

Base station

HELICOPTER GRAVITY TRAVERSING

MILES
0 10 20 30 40 50

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics G 65-33-1

To accompany Record N° 1962/130