COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PETROLEUM SEARCH SUBSIDY ACTS

Publication No. 37

BOULIA AREA GRAVITY SURVEY, QUEENSLAND, 1959

BY

THE PAPUAN APINAIPI PETROLEUM COMPANY LIMITED

**Issued under the Authority of Senator the Hon. W. H. Spooner,
Minister for National Development
1962**

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

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FOREWORD

In 1959 the Commonwealth Government enacted the Petroleum Search Subsidy Act 1959. This Act enables companies that drill for new stratigraphic information, or carry out geophysical or bore-hole surveys in search of petroleum, to be subsidized for the cost of the operation, provided the operation is approved by the Minister for National Development.

The Bureau of Mineral Resources, Geology and Geophysics is required, on behalf of the Department of National Development, to examine the applications, maintain surveillance of the operations, and in due course publish the results.

A gravity survey was carried out under the Petroleum Search Subsidy Act 1959 over an area around Boulia in north-western Queensland by The Papuan Apinaipi Petroleum Company Limited. This Publication deals with that survey and contains the information furnished by The Papuan Apinaipi Petroleum Company Limited and edited in the Geophysical Branch of the Bureau of Mineral Resources. The final geophysical report was written by L.J. Starkey under the supervision of D.M. Traves, Chief Geologist, both of Mines Administration Pty Limited. The survey methods and the results obtained are presented in detail.

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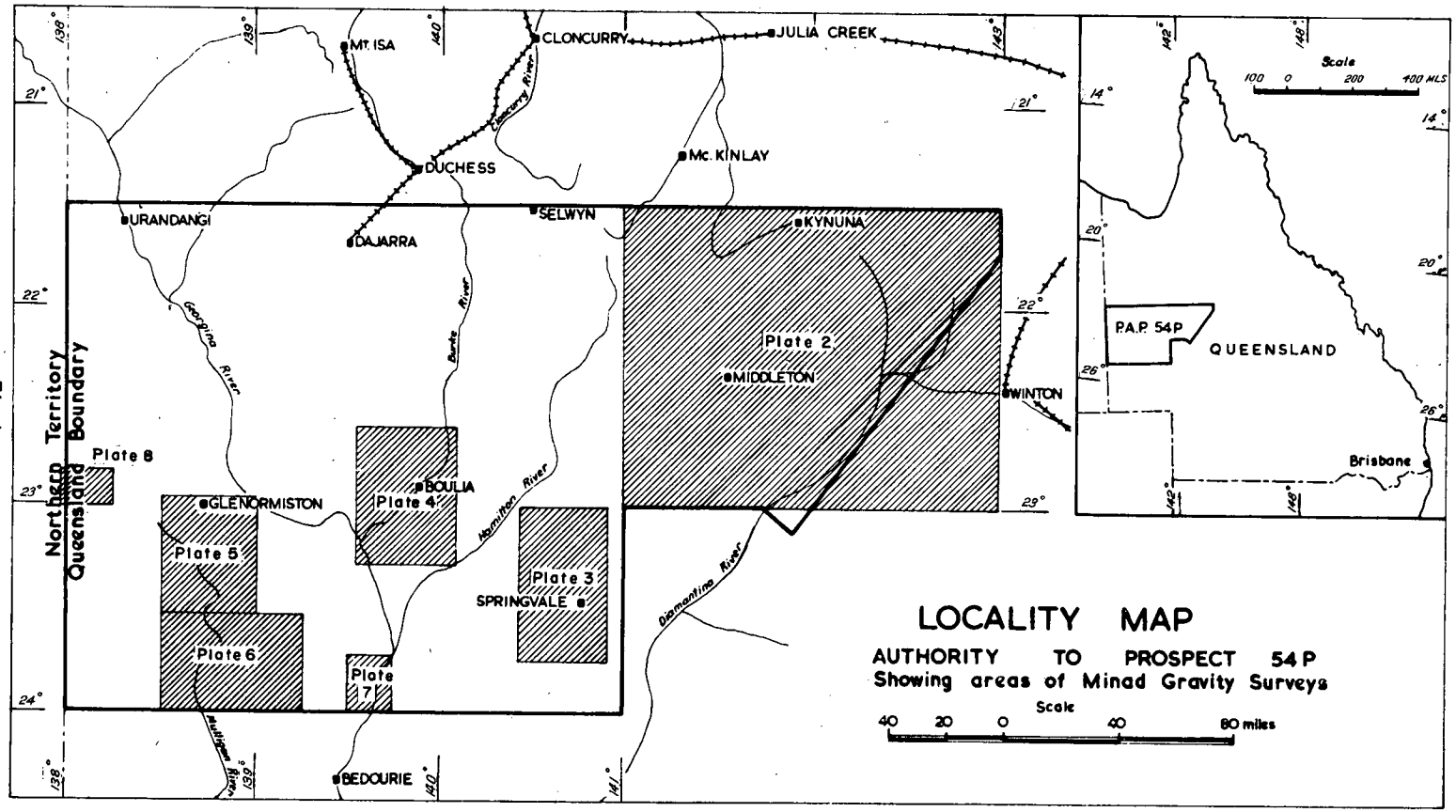
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Fig. 1

ABSTRACT

A gravity survey was conducted by Mines Administration Pty Limited for The Papuan Apinaipi Petroleum Company Limited between May and August 1959. The survey took place over seven separate areas within Authority to Prospect 54P in north-western Queensland. The areas surveyed are partly within the Georgina Basin and partly within the Diamantina Basin. These Basins contain Palaeozoic sedimentary rocks. Sedimentary rocks of the Great Artesian Basin overlap the whole of the Diamantina Basin and part of the Georgina Basin.

The survey results, together with data obtained previously by the Bureau of Mineral Resources, indicated four distinct zones of gravity "highs" which all trend north-north-west. Most and perhaps all of these zones coincide in the north with structural features in the Proterozoic sediments. The gravity anomalies associated with these Proterozoic structural features continue southward, where the Proterozoic rocks are overlain by later sediments, with little or no decrease in absolute gravity. In some areas these Proterozoic structural features have influenced structural development in the Palaeozoic and Cretaceous sediments. The four zones of gravity "highs" are therefore regarded as areas of structural interest that are worthy of further exploration.

1. INTRODUCTION

The Boulia area is situated in north-western Queensland, south of Cloncurry, with Boulia near its centre. It represents the land included in Authority to Prospect 54P granted by the Queensland Department of Development and Mines to The Papuan Apinaipi Petroleum Company Limited.

The Bureau of Mineral Resources in 1957 conducted a limited gravity survey in the Boulia-Dajarra-Mount Isa area. During 1958 this survey was extended farther south and also east as far as Winton. The work is described in two Bureau of Mineral Resources Records (Neumann, 1959a, b). As a result of these surveys The Papuan Apinaipi Petroleum Company Limited decided to conduct a semi-detailed gravity survey in specified areas on the Georgina Basin, within Authority to Prospect 54P. The purpose of the survey was to delineate sub-surface structure within these specified areas.

The areas covered by this semi-detailed survey are:

(1) Middleton-Kynuna area.
(2) Springvale area.
(3) Boulia area.
(4) Glenormiston area.
(5) Duck Point area.
(6) Breadalbane area.
(7) Toko Range area.

These areas (see frontispiece), were selected by the Company because they were ones in which interesting gravity anomalies were found by the Bureau of Mineral Resources. The present survey confirmed the existence of the anomalies and outlines them in more detail.

2. FIELD WORK

The present gravity survey was conducted by Mines Administration Pty Limited for The Papuan Apinaipi Petroleum Company Limited from May to August 1959. L.J. Starkey (geophysicist) was in charge of the survey and was assisted by A.C.M. Laing, L.C. Miller, and K. Bowen. Some 1,300 gravity stations were established.

The gravity values were obtained with Worden Gravity Meter No. 207 having a sensitivity of 0.10135 mgal per scale division, determined by the manufacturer at the time of manufacture. On 15th September 1959, after the survey, this meter was checked against calibration stations in Brisbane. The stations used were Mines Administration Pty Limited office basement and the trigonometrical station on Mount Coot-tha, and the measured difference was 587.7 scale divisions(1).

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(1) Footnote by Bureau of Mineral Resources:
The gravity interval between the stations used for the calibration of Worden gravity meter No. 207 was subsequently (January 1960) determined by the Bureau of Mineral Resources as 59.15 mgal. The sensitivity based on this value would by 0.10064 mgal per scale division.

The heights of stations were obtained by two Paulin micro-altimeters Nos. KK1422N and KK1394N using the surveyed Bureau pegs as bases at which to check the altimeters. The moving base method of altimeter surveying was adopted throughout.

Positions of stations were obtained from airphotos and then plotted on Department of the Interior photo-mosaics at a scale of 1 in. = 1 mile, and adjusted to enlarged 4-mile military sheets. Latitudes and longitudes were obtained from astrofixes made by the Department of the Army, the Department of the Interior, and the Division of National Mapping.

3. CORRECTIONS TO DATA

Gravity meter readings were corrected for drift by repeat readings within 2 to 3 hours. An observed value of 978,793.20 mgal for the Boulia pendulum station was used as datum for the survey. Bouguer gravity values were obtained by correcting the observed gravity vaules first for closure, then for altitude using a correction factor of 0.06982 mgal/ft, and finally for latitude. The gravity corrections for the latitude of each station were read from tables based upon the International Ellipsoid formula.

Micro-altimeter readings were corrected for temperature (instrument calibrated at 50°F) and barometric diurnal variation to give the height above the datum plane. The barometric diurnal variation was obtained from a base micro-altimeter whose readings had been corrected for temperature. No corrections were applied for humidity as an average humidity correction is incorporated in the reading scale of the micro-altimeter. Elevations are relative to Mean Sea Level.

Gravity and levelling traverses were tied into all Bureau stations that were located. Differences in observed gravity and elevation at these tie-ins did not exceed 0.35 mgal and six feet respectively, except in the Glenormiston area where, in connecting from Bureau stations at Breadalbane through Duck Point to Glenormiston (approximately 100 miles of surveying (see Plate 1)), differences of + 17 ft in altitude and -1.47 mgal in observed gravity were recorded.

4. ACCURACY OF DATA

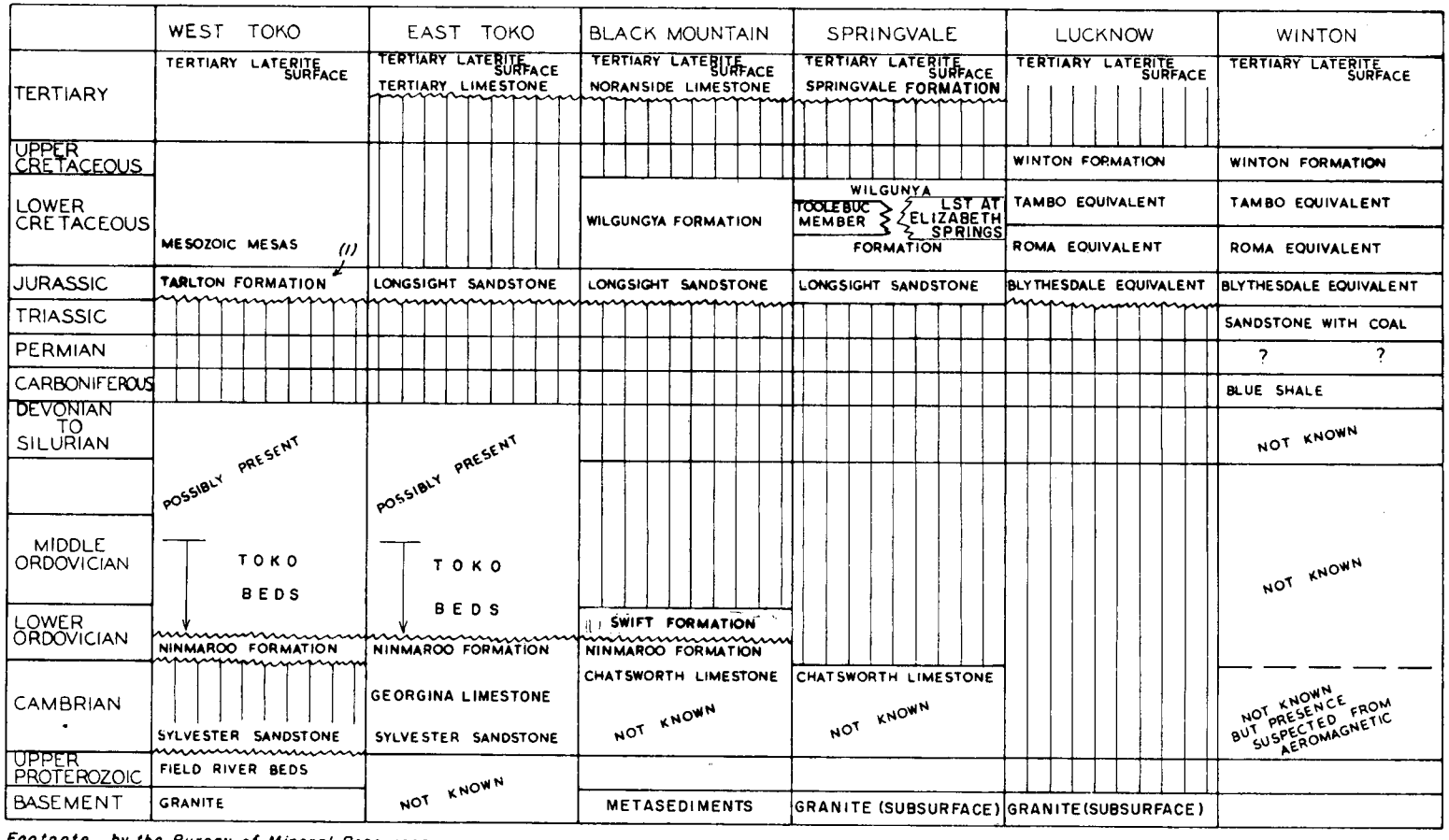
The accuracy of the final Bouguer anomaly values is the root mean square of the following terms expressed in milligals:

Accuracy of meter reading	$\pm$ 0.05 mgal
Accuracy of altitude ($\pm$ 6 ft)	$\pm$ 0.42 mgal (density approx. 2 g/c.c.)
Accuracy of latitude determination	$\pm$ 0.25 mgal;

the root mean square value of these three terms is $\pm$ 0.49 mgal.

5. GEOLOGY

The following summary of the geology of Authority to Prospect 54P is after Laing (1960). A map showing surface geology and generalised structure contours at the base



STRATIGRAPHIC SUCCESSION, BOULIA AREA

Fig. 2

Footnote by the Bureau of Mineral Resources:

(1) Recent plant collections near the type area in the Tarlton Range have been given a probable Upper Triassic or Jurassic age.

of marine Cretaceous is included in Plate 9.

About two-thirds of A.T.P. 54P is covered by the Mesozoic sediments of the Great Artesian Basin; these reach a maximum thickness of about 3,500 ft and include several hundred feet of apparently non-marine sandstone beneath the marine Cretaceous sediments. However, the average thickness of the Mesozoic in A.T.P. 54P is about 1,000 ft.

Two pre-Mesozoic basins are partly, and one wholly, overlapped by the Great Artesian Basin.

On the eastern side of A.T.P. 54P is the Diamantina Basin (2) which contains an unknown thickness of Palaeozoic sediments. The Diamantina Basin is wholly overlapped by the Great Artesian Basin.

The Diamantina Basin is separated from the Georgina Basin to the west by an area of granite (granite in subsurface near Lucknow) directly beneath the Mesozoic sediments. The Georgina Basin contains about 6,000 ft of limestone, marl, and dolomite of Cambrian and Ordovician age. It is partly overlapped from the south by the Great Artesian Basin. The carbonate sediments of the Georgina Basin appear to thin southwards underneath the Mesozoic sediments.

About 1,200 ft of Lower and Middle Ordovician, and possible younger, sediments are exposed in the Toko Syncline in the western part of A.T.P. 54P. The Toko Syncline is thinly overlapped by Mesozoic sediments in the south-west of A.T.P. 54P. Water-bore records suggest that some of the limestones of the Georgina Basin and some of the clastic sediments of the Toko Syncline are permeable.

Figure 2 gives the stratigraphic succession at six places in the area. The major structural elements of A.T.P. 54P are as follows:

Georgina Basin

This Basin contains up to 6,000 ft of Middle Cambrian to Lower Ordovician carbonate sediments. Its present limits, including its southern limits under the Cretaceous rocks, are shown in the area of Cambrian to Ordovician limestone on Plate 9. It probably extends westward from A.T.P. 54P towards Alice Springs. The thickest sediments in the basin will probably be:

(a) In the graben-like feature (see Plate 9) with Black Mountain on its western side and the Momedah anticline on its eastern side.

(b) North of Linda Downs, i.e., north of the Toko Syncline (Neumann, 1959a).

The beds in the Black Mountain graben feature are folded with dips up to 20 degrees, but outside this locality, beds in the Georgina Basin are almost flat. The Black Mountain

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(2) Footnote by Bureau of Mineral Resources:
The existence of this basin is not yet recognized by the Bureau. Little is known of its possible extent, or of the age and type of its sediments.

fault has a post-Ordovician up-throw to the west of approximately 2,000 ft [3]. There are suspected monoclines under the Cretaceous rocks around Boulia. South-south-west of Glenormiston there are inliers of Lower Cambrian rocks within the regions occupied by Cambrian limestone (Plate 9). A similar probable "high" extends south-west towards the Toko Syncline along the line of the Mungerebar structure (Plate 9).

The carbonate sequence thins eastward under the Cretaceous rocks onto the granite basement (granite in subsurface near Lucknow) indicated by water bores parallel to, and about 16 miles west of the Mackunda fault (Plate 9).

Toko Syncline

The Toko Syncline is an asymmetrical fold with a gentle eastern limb (3 to 5°) and a steep western limb (60°) in which 800 to 1,500 ft of Lower and Middle Ordovician, and possibly younger, clastic and carbonate sediments are exposed. An important structural feature in the Toko Syncline is the cross-faulting which in some places occurs together with small asymmetrical anticlinal noses.

Diamantina Basin

This basin covers the eastern part of A.T.P. 54P east of the granite in subsurface near Lucknow. The Basin is wholly overlapped by Cretaceous rocks, so little is known about it. Aeromagnetic profiles suggest a thick sequence of sedimentary rocks east of the granite in subsurface near Lucknow and extending south.

Great Artesian Basin

Part of the Great Artesian Basin covers most of A.T.P. 54P, partially overlapping the Georgina Basin and wholly overlapping the Diamantina Basin. Most of A.T.P. 54P lies within the subdivision of the Great Artesian Basin known as the Boulia Shelf (Whitehouse, 1954), but part lies within the Thomson Sub-basin (op. cit.).

Plate 9 shows structure contours on the base of the marine Cretaceous rocks; these contours suggest that there is a maximum thickness of about 3,000 ft on the eastern edge of A.T.P. 54P. Off the Boulia Shelf (about the minus-1,200-ft contour on Plate 9), thick sandstone with coal probably of Jurassic age has been noted in water bores below the marine Cretaceous sediments.

Three general structural features of this part of the Great Artesian Basin are noted as follows:

(a) There appears to be a greater relief on the basement of the Cretaceous sediments down to the minus-300-ft contour than below that contour. This may, however, be a reflection of the greater density of water bores in the shallower part of the basin.

(b) Certain anticlinal structures (e.g. round Boulia, Momedah, Springvale, and Black Mountain) are reflections of pre-Cretaceous structure.

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(3) Footnote by Bureau of Mineral Resources:
Bureau mapping shows the throw of this fault to be about 1,000 ft.

(c) Some faults (e.g. Black Mountain), appear to have moved after the Ordovician Period and then again after the Cretaceous Period. As in the Carpentaria Sub-basin (Laing, 1958), seismic surveying may show many post-Cretaceous faults of small throw.

6. RESULTS AND INTERPRETATION

The following is a list of the rock densities (obtained from Neumann, 1959a) used in the interpretation of results in this Publication:

South-eastern Georgina Basin and Great Artesian Basin

Type:	Age/Locality :	Density :
Greenstone	Precambrian Dajarra	2.92
Limestone	Ordovician Linda Downs	2.82
Limestone	Cambrian Urandangi	2.80
Shale	Precambrian Dajarra	2.73
Limestone	Ordovician Linda Downs	2.72
Limestone	Cambrian Dajarra	2.63
Sandstone	Ordovician Toko Range	2.12
Weathered sandstone	Ordovician Toko Range	1.6
Sandstone, shale	Winton Formation	1.82 (mean value)

(1) Regional

Plate 1 is the Regional Bouguer Gravity Map of A.T.P. 54P. Contours are based on results of Bureau of Mineral Resources and Mines Administration Pty Limited gravity traverses. Station positions and gravity values are not shown on this regional map but all are shown on the accompanying detailed maps and Bureau of Mineral Resources 4-mile maps.

The Bouguer gravity contours show a distinct north-north-west trend; this is generally parallel to the geological trends throughout the area. There is a series of gravity "highs" and "lows" with amplitudes averaging 35 mgal.

There are four distinct zones of gravity "highs", all trending north-north-west:

(a) One zone extends through Glenormiston in the western part of the area. The maximum value along this zone is 25 mgal, north-west of Glenormiston. In the north this zone broadens south of Douglas Downs. In the south, the zone swings south-east and appears associated with a "high" near Breadalbane.

(b) A second, very prominent, zone extends from Dajarra to just west of Boulia and east of Marion Downs. This zone reaches a maximum value of 30 mgal both in the north, just south of Dajarra, and in the south, east of Marion Downs.

(c) A third zone (4) extends as a broad feature from north of Chatsworth. This "high" has a maximum value of 45 mgal north of Warenda over the Momedah anticline. In the Springvale area the maximum value is 30 mgal.

(d) A fourth zone lies near Middleton in the eastern part of the area. The maximum value over this "high" is 15 mgal. Extension of this "high" to the south has not been determined, but is inferred.

On the eastern edge of the area the gravity trend seems to change to east-west.

The most outstanding feature of the gravity pattern is the fact that gravity anomalies that coincide with Proterozoic outcrops in the north of the area extend with little or no decrease in absolute gravity value to the south where Proterozoic rocks are overlain by later sediments. The best example of this is the second gravity "high" zone ('b') which runs just west of Boulia. Values along this "high" do not vary appreciably from Dajarra, on Proterozoic outcrop, to east of Marion Downs where the geological sequence is Mesozoic and Palaeozoic.

This gravity pattern indicates that the highly folded and faulted rocks of Precambrian age in the Cloncurry-Duchess area extend southwards under the Palaeozoic and Mesozoic sediments and that variations in density associated with structural and other features in these older rocks are responsible for the major gravity anomalies in the central and southern part of A.T.P. 54P.

The fact that the gravity values do not decrease appreciably over the area in the Georgina Basin seems best explained by the presence of a dense limestone sequence above the Precambrian rocks, thickening to the south-east as the depth to basement increases. This is borne out in the area of Black Mountain and the Momedah anticline, north-east of Boulia, where there is a regional gravity "high" where the Cambro-Ordovician limestones are considered to be thickest (up to 6,000 ft; Laing, 1960). Density determinations show that these limestones have similar densities to the rocks of Precambrian age and hence the delineation of areas in which there is limestone above Precambrian basement would be difficult.

The effect of the low-density Mesozoic rocks is not clearly seen on the gravity map. In the Springvale area, and the area east of Middleton, a broadening of the gravity

(4) Footnote by Bureau of Mineral Resources:
This broad zone contains gravity "highs" on two main axes; one on the western side extending from north of Noranside through Payton Downs to Springvale, and one on the eastern side extending from north of Chatsworth to Hamilton Hotel (Plate 1).

anomalies occurs which would be due to the thickening of low-density Mesozoic rocks in these areas. This is most apparent east of Middleton where gravity values fall appreciably to minus 25 mgal in the far east of A.T.P. 54P. Up to 4,000 ft of Mesozoic rock is known in this part of the area. Four thousand feet of Mesozoic sediments instead of limestone of Precambrian basement would account for a decrease of approximately 31 mgal.

North of the survey area and just east of Duchess, a fault in Precambrian rocks, up-thrown to the west, is associated with an extremely strong gravity gradient (Neumann, 1959a). This gradient extends south into A.T.P. 54P at longitude approximately 140°E. The fault has been mapped geologically as extending through Digby Peaks, Black Mountain, and Springvale in A.T.P. 54P. The strong gravity gradient does not persist far into A.T.P. 54P, but broadens into a line of gravity "highs" that parallels the trace of the geological fault.

East of this fault trace, at Black Mountain, a closed gravity "high" coincides with the Momedah anticline. Gravity closure is approximately 25 mgal and the maximum value is approximately 50 mgal. A very steep gravity gradient along the western side of this "high" suggests faulting down-thrown to the west. This indicates a graben-type structure between Black Mountain and the Momedah anticline.

East of the Momedah gravity "high", the gravity values decrease to form an elongate gravity "low" feature with a minimum value of minus 15 mgal. Water-bore logs in this area suggest a granite ridge (Laing, 1960) as shown on Plate 9. Thinning of the dense Cambro-Ordovician limestone above this granite ridge could account for the decrease in gravity. However, the gravity minimum and the trace of the granite ridge do not coincide and it is considered that granite basement is farther east than shown on Plate 9.

The gravity "high" zone passing just west of Boulia closely parallels the anticlinal Boulia structure which has been mapped (Plate 9) as a well-defined south-plunging ridge some 75 miles long in the structure contours at the base of the Cretaceous marine sediments (Laing, 1960). Structural relief of about 2,000 to 3,000 ft at the Mesozoic-Cambro-Ordovician horizon, where there would be a density contrast of approximately 0.6 g/c.c., could account for this gravity "high" zone. However, as the gravity "high" zone extends north onto Proterozoic outcrop, it seems it is caused principally by structure within the Proterozoic that extends south below the Georgina Basin. Steep gravity gradients on both flanks of this zone indicate faulting; this faulting could have been persistent through Proterozoic to Mesozoic Eras as indicated in faults in the Black Mountain area (Laing, 1960).

At the northern end of the same zone the steep flank gradients are associated with major faults mapped in the Proterozoic rocks. It is considered that this zone is an expression of an old horst-type structure that would have some expression in the Palaeozoic and Mesozoic sequence.

The gravity "high" trend west of Glenormiston appears similar in nature to the one just discussed. The gradient on the eastern flank is more gentle and faulting seems less likely. Near Glenormiston the gravity "high" trend follows the trend of the Glenormiston anticline (Laing, 1960), indicating that structure in the Cambro-Ordovician sequence has some effect on the gravity. However, as the size of the geological structure mapped is insufficient to account for the gravity anomaly, structure within Proterozoic basement must be responsible for the greater part of the anomaly.

West of the Glenormiston anticline the gravity contours form a small "high" over the outcropping area of the Toko Syncline; south of Glenormiston they form a pronounced "low" near Sylvester Creek where the Toko Syncline is covered by Mesozoic sediments. The "high" over the outcropping area of the Toko Syncline is most probably due to the effect of dense limestone at the surface. North of the outcropping Toko Syncline there are low gravity values over an outcrop of Lower Ordovician Ninmaroo Formation. This could be due to a granitic basement close to the surface.

A more detailed analysis of the gravity anomalies in the individual areas of A.T.P. 54P is given below.

From a study of the regional gravity map it is apparent that variations in density in the Precambrian rocks are responsible for major gravity anomalies as seen in the northern part of A.T.P. 54P and that these anomalies persist south into the Georgina Basin. It also appears that major structural features in the Precambrian rocks have had an influence on structure in the Palaeozoic and Mesozoic sequence. It is therefore inferred that, to some extent, gravity anomalies over A.T.P. 54P can be related to structures in the Palaeozoic and Mesozoic sequences.

(2) Middleton-Kynuna area

The Bouguer gravity map of this area is shown on Plate 2. The contours are based on surveys by the Bureau of Mineral Resources and Mines Administration Pty Limited. On this map and other detailed maps in this report, Bureau of Mineral Resources stations are shown by double numbers (e.g. 58-7 or 58/7) while Mines Administration Pty Limited stations are numbered by single numbers (e.g. 54). B.M.R. helicopter gravity stations are numbered B14, B15, etc.

The most prominent feature of this map is the gravity "high" extending through Stations 20-45 and 58-13. The maximum value, approximately 15 mgal, is at Station 20-45 on the Boulia-Winton road. The western side of the "high" has a very steep gradient; the contours along this gradient have been drawn extending north onto Proterozoic outcrop where the gradient could be related to faulting. However, no faulting along the line of this gradient has been observed in the Mesozoic sediments. It appears therefore that Precambrian structure is responsible for the gravity "high" and that there is only a thin sequence of Mesozoic sediments in the region of the "high".

East of this gravity "high" the gravity decreases to form a small closed gravity "low" about Station 20-53 and then decreases again farther east to a minimum value of approximately minus 27 mgal at Station 57-5. This is the lowest value observed in A.T.P. 54P and must be due to the greater thickness of Mesozoic sediments in that locality. Contours on the base of the marine Cretaceous sediments show a trough in the area of the gravity "low" and the depth to this horizon is approximately 3,000 ft below sea level.

A gravity "high" to the south of this "low" must be due to a basement variation as no structural "high" appears on the contours at the base of the marine Cretaceous rocks.

There is a broad area of relatively high gravity values around Kynuna. Maximum values are approximately minus 4 mgal, a rise of 23 mgal from the area of low gravity to the south-east. The structure contours of Plate 9 also show a rise of approximately 2,000 ft

north-westerly towards Kynuna. Such a thinning of low-density Mesozoic sediments over limestone or basement (density contrast 0.6) would account for a rise of approximately 16 mgal; some change in basement type must account for the remaining 7 mgal.

(3) Springvale area

The Bouguer gravity map of this area is shown on Plate 3.

The area is one of relatively high gravity values; + 11 mgal in the far north of the sheet is the lowest value recorded. Gradients throughout the area are more gentle than those observed in most other parts of A.T.P. 54P. Several small gravity "highs" exist and form part of the gravity "high" zone discussed in the regional results (see previous footnote) and which passes through Noranside, north of Boulia.

A fault (up-thrown to the west), which is considered to be an extension of the Black Mountain fault, has been mapped geologically passing through Springvale and Elizabeth Springs as shown on Plate 9. Several small gravity "highs" mentioned above occur immediately west of this fault line and could be an expression of the up-thrown side of the fault. No steep gravity gradients appear along the fault trace. About seven miles south of Springvale a gravity rise of approximately 5 mgal between Stations 467 and 463 could represent the gradient associated with the fault. With either limestone or Proterozoic basement underlying the Cretaceous rocks, a fault with a throw of approximately 650 ft would account for the 5-mgal rise.

The position of the fault is not clearly seen on the gravity map, but the east-west gradient just south of Elizabeth Springs could represent the fault in that vicinity.

It is suggested that the gradient through Stations 324 to 329 and 360 to 363, which on the regional Bouguer gravity map is seen to continue north, represents a fault that extends north-north-west to connect with the Black Mountain fault.

(4) Boulia area

The Bouguer gravity map of this area is shown on Plate 4. Two prominent gravity "highs" and one gravity "low" are indicated.

The most prominent feature is the gravity "high" centered about Stations 61 and 231 on the Glenormiston and Bedourie roads respectively; this is part of the second zone ('b') discussed earlier in this chapter. Maximum reversal over this "high" is approximately 21 mgal. The gravity gradients are very steep on both flanks close to the axis; this could indicate faulting.

Immediately west of this "high", there is another closed gravity "high" with a reversal of approximately 8 mgal. This "high" appears to be associated with the one just discussed, the two being separated by a small gravity "low" area centered about B.M.R. Station 5/4.

These two gravity "high" features coincide with geological structures mapped in the Mesozoic rocks (Laing, 1960). However, the geological structures mapped are too small to account for the large gravity reversals observed. It must therefore be inferred that structure

within Proterozoic basement accounts for the greater part of the gravity anomalies. Large-scale faulting in the Proterozoic rocks, indicated by the steep gravity gradients over the larger "high", could persist through Palaeozoic and Mesozoic sediments as seen at Black Mountain (Laing, 1960). It is impossible to isolate the gravity effect due to post-Palaeozoic structure.

The gravity "low" just east of Boulia reaches a minimum value of approximately minus 6 mgal at Stations 486 and 185. This "low" is part of a very prominent "low" which, on the regional map (Plate 1) extends north onto Proterozoic outcrop and extends south to Coora-bulka. It is most probably an expression of structure within the Proterozoic basement, but it could also represent a greater thickness of Mesozoic sediments above the Cambro-Ordovician limestone.

(5) Glenormiston area

The Bouguer gravity map of this area is shown on Plate 5.

The main anomalous feature of the map is a large gravity "high" running south-south-east from five miles south-west of Glenormiston. Three gravity maxima occur along this "high"; their maximum values are 12.6 mgal at Station 160, 14.4 mgal at Station 20 (near Twenty Mile Bore) and 15.1 mgal at Station 49 in the south-east of the area.

Gravity closure of approximately 5 mgal has been established near Twenty Mile Bore. Closure for the maximum west of Glenormiston has been inferred from regional results. Gravity closure on the southern maximum is uncertain. Maximum reversal over the "high" is 12 mgal through Twenty Mile Bore. Geological mapping has indicated an anticlinal structure - the Glenormiston anticline (Laing, 1960) - which follows the axis of the gravity "high" from west of Glenormiston to Twenty Mile Bore. A south-south-eastern extension of this geological structure is inferred from the gravity results. The Glenormiston anticline was mapped in Cambrian Georgina Limestone with low flank dip (2 to 5 degrees) and indefinite closure. The size of the geological structure and the unlikely occurrence of a large density contrast within, or at the base of, the Cambrian rocks, make it necessary to infer that structure within Proterozoic basement is the major cause of the gravity anomaly. The coincidence of the gravity "high" and the surface geological structure indicates that structures on the Proterozoic rocks have influenced structure in the Palaeozoic sediments.

South-west of the zone of gravity "high" the gravity falls continuously for approximately 15 miles towards the axis of the Toko Syncline.

A localised "high" in the south-western corner of the sheet could be due to dense limestone such as that which crops out nearby.

(6) Duck Point area

The Bouguer map of this area is shown in Plate 6.

The Bouguer contours show a continuous south-west gradient of approximately 2 mgal/mile towards a broad low-gravity area which trends south-east through Stations 291, 147 and 155, and 192. Minimum values of approximately minus 30 mgal occur at the south-eastern end of the "low". The "low" appears to be an expression of the south-eastern extension of the Toko Syncline and indicates that the syncline is still plunging to the south-east below the Cretaceous sediments in this area.

(7) Breadalbane area

The Bouguer gravity map of this area is shown on Plate 7. It shows a gravity "high" with a maximum value of+22.9 mgal at Station 355.

On the regional map (Plate 1), the Breadalbane gravity "high" appears to be on a south-eastern extension of the gravity "high" trend that coincides with the Glenormiston anticline. If this is so, geological structure could be expected in the Cretaceous and underlying Palaeozoic rocks at Breadalbane. However, estimates of the size of such structure cannot be given with any certainty, owing to the likelihood of Proterozoic structure being responsible for part of the anomaly.

(8) Toko Range area

The Bouguer gravity map of this area is shown on Plate 8.

The gravity rises approximately 11 mgal from east to west, and forms a "high" that has a closure of two or more milligals. The area of this gravity "high" is much greater than that of the surface geological structure - the "Netting Fence anticline" (Laing, 1960). Along the axis of the geological structure, as shown on the Bouguer gravity map, there are two small gravity "lows". These are most probably due to low-density Jurassic sediments surrounded by dense Ordovician limestones.

The size of the gravity "high" anomaly is possibly due to a bigger structure in the basement.

The steep gravity gradient between Stations 1 and 2 indicates faulting up-thrown to the west.

7. CONCLUSIONS

The gravity survey has indicated four areas of structural interest that are worthy of further exploration. These areas extend along those parts of the four major gravity "high" zones that occur over the Georgina Basin and Great Artesian Basin sedimentary areas.

These zones are:-

(a) one through Glenormiston in the western part of the area;

(b) one extending from Dajarra to just west of Boulia;

(c) one extending as a broad feature from north of Chatsworth and Noranside to Springvale; and

(d) one near Middleton in the eastern part of the area.

The survey has shown that structural and physical features in the Proterozoic sediments in the north of the area continue south below the Georgina and Diamantina Basins and that in some areas there Proterozoic structural features have influenced structural growth in the Palaeozoic and Cretaceous sediments.

It has not been possible to isolate the gravity effect due to Palaeozoic and Cretaceous structures from that due to the Proterozoic rocks. The reason for this is that the gravity anomalies over the Proterozoic outcrop in the north of the area are not uniform and therefore it is not possible to determine the anomaly arising from Proterozoic rocks under cover.

This survey has, however, confirmed the presence of previously suspected, important structural elements in the Palaeozoic and Cretaceous sequences of the Boulia area.

8. REFERENCES

LAING, A.C.M. 1958 Report on Gulf of Carpentaria Authority to Prospect, A.A.O. 45P and A.F.O. 49P. Mines Administration Pty Limited, Report No. Q/45P-49P/56. (Unpubl.).

LAING, A.C.M. 1960 Geology and oil prospects of Boulia, Authority to Prospect 54P. Mines Administration Pty Limited, Report No. Q/54P/76. (Unpubl.).

NEUMANN, F.J.G. 1959a Preliminary report on a reconnaissance gravity survey in the Georgina Basin area, Queensland. Bur.Min.Resour.Aust.Rec. 1959/8. (Unpubl.).

NEUMANN, F.J.G. 1959b Preliminary report on a gravity survey in the Toko Range area, western Queensland. Bur.Min.Resour.Aust.Rec. 1959/51. (Unpubl.).

WHITEHOUSE, F.W. 1954 Artesian water supplies in Queensland; Appendix G - The geology of the Queensland portion of the Great Australian Artesian Basin. Govt Printer, Brisbane.

ADDITIONAL DATA ON FILE

The following additional data have been filed with the Bureau of Mineral Resources and are available for reference:-

(i) a complete set of gravity-meter and micro-altimeter field sheets;

(ii) a map showing gravity and altitude loop closures.

PLATE I

MAP COMPILED FROM SURVEYS BY BUREAU OF MINERAL RESOURCES AND MINES ADMINISTRATION PTY LTD. 1957, '58, '59

ALL STATION POSITIONS AND BOUGUER GRAVITY VALUES ARE SHOWN ON BUREAU OF MINERAL RESOURCES 4 MILE MAPS AND MINES ADMINISTRATION PTY LTD 1 MILE MAPS INCLUDED WITH THIS REPORT

OBSERVED GRAVITY VALUES BASED ON VALUE OF 978·7932O GALS AT BOULIA PENDULUM STATION

ELEVATION CORRECTION FACTOR O·O6982 MG/FT

LEGEND

- Isogals
- High anomaly
- Low anomaly
- Main roads
- Tracks
- Homestead

MINAD SURVEYS

BMR SURVEY

The Papuan Apinaipi Petroleum Co. Ltd.

AUTHORITY TO PROSPECT 54P

REGIONAL BOUGUER GRAVITY MAP

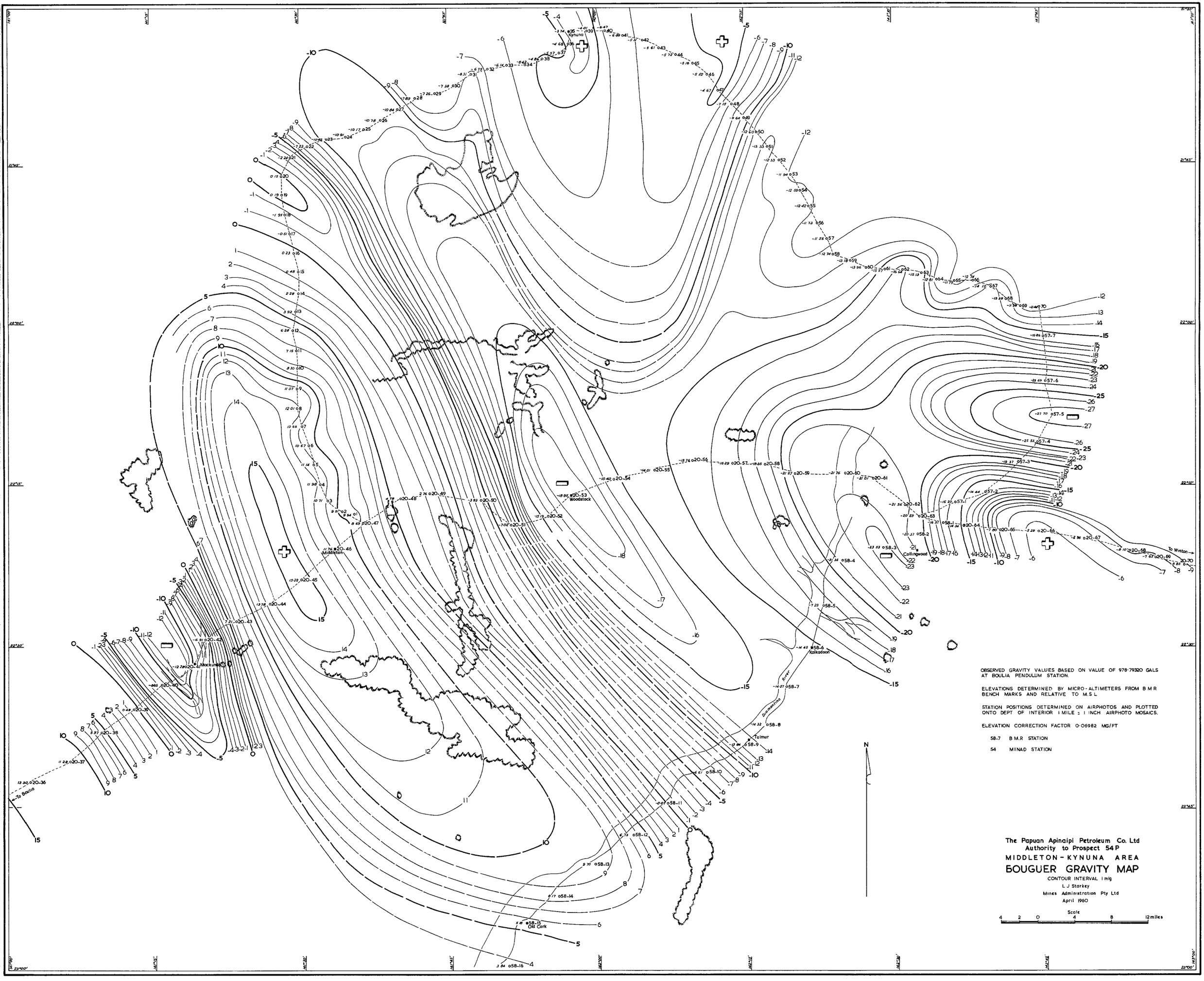
CONTOUR INTERVAL 5 milligals

L.J Starkey
Mines Administration Pty Ltd

April 1960

Scale

8 4 O 8 16 24 miles



OBSERVED GRAVITY VALUES BASED ON VALUE OF 978·79320 GALS AT BOULIA PENDULUM STATION.

ELEVATIONS DETERMINED BY MICRO-ALTIMETERS FROM B M R BENCH MARKS AND RELATIVE TO M.S.L.

STATION POSITIONS DETERMINED ON AIRPHOTOS AND PLOTTED ONTO DEPT OF INTERIOR 1 MILE = 1 INCH AIRPHOTO MOSAICS.

ELEVATION CORRECTION FACTOR 0·06982 MG/FT

58-7 B M.R STATION

54 MINAD STATION

N

The Papuan Apinaipi Petroleum Co. Ltd
Authority to Prospect 54P

MIDDLETON - KYNUNA AREA

BOUGUER GRAVITY MAP

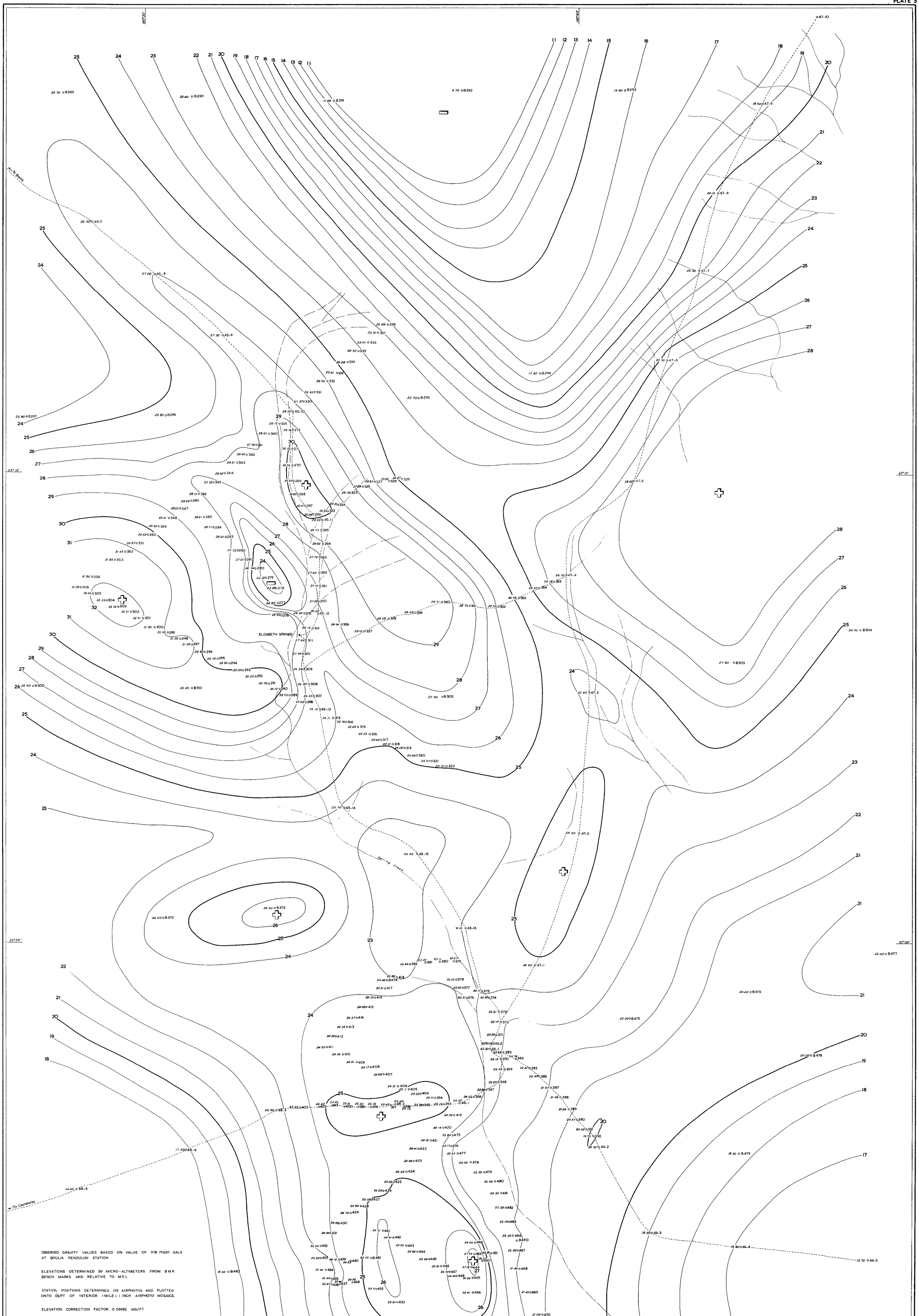
CONTOUR INTERVAL 1 mlg

L.J Starkey
Mines Administration Pty Ltd

April 1960

Scale
4 2 0 4 8 12 miles

PLATE 3



OBSERVED GRAVITY VALUES BASED ON VALUE OF 978 79320 GALS AT BOULIA PENDULUM STATION

ELEVATIONS DETERMINED BY MICRO-ALTIMETERS FROM BMR BENCH MARKS AND RELATIVE TO MSL

STATION POSITIONS DETERMINED ON AIRPHOTOS AND PLOTTED ONTO DEPT OF INTERIOR 1 MILE = 1 INCH AIRPHOTO MOSAICS.

ELEVATION CORRECTION FACTOR 0 06982 MG/FT

o 48-5 BMR STATION

o B 482 BMR. HELICOPTER STATION

o 434 MINAD STATION

The Papuan Apinaipi Petroleum Co. Ltd.
Authority to Prospect 54 P
SPRINGVALE AREA

BOUGUER GRAVITY MAP

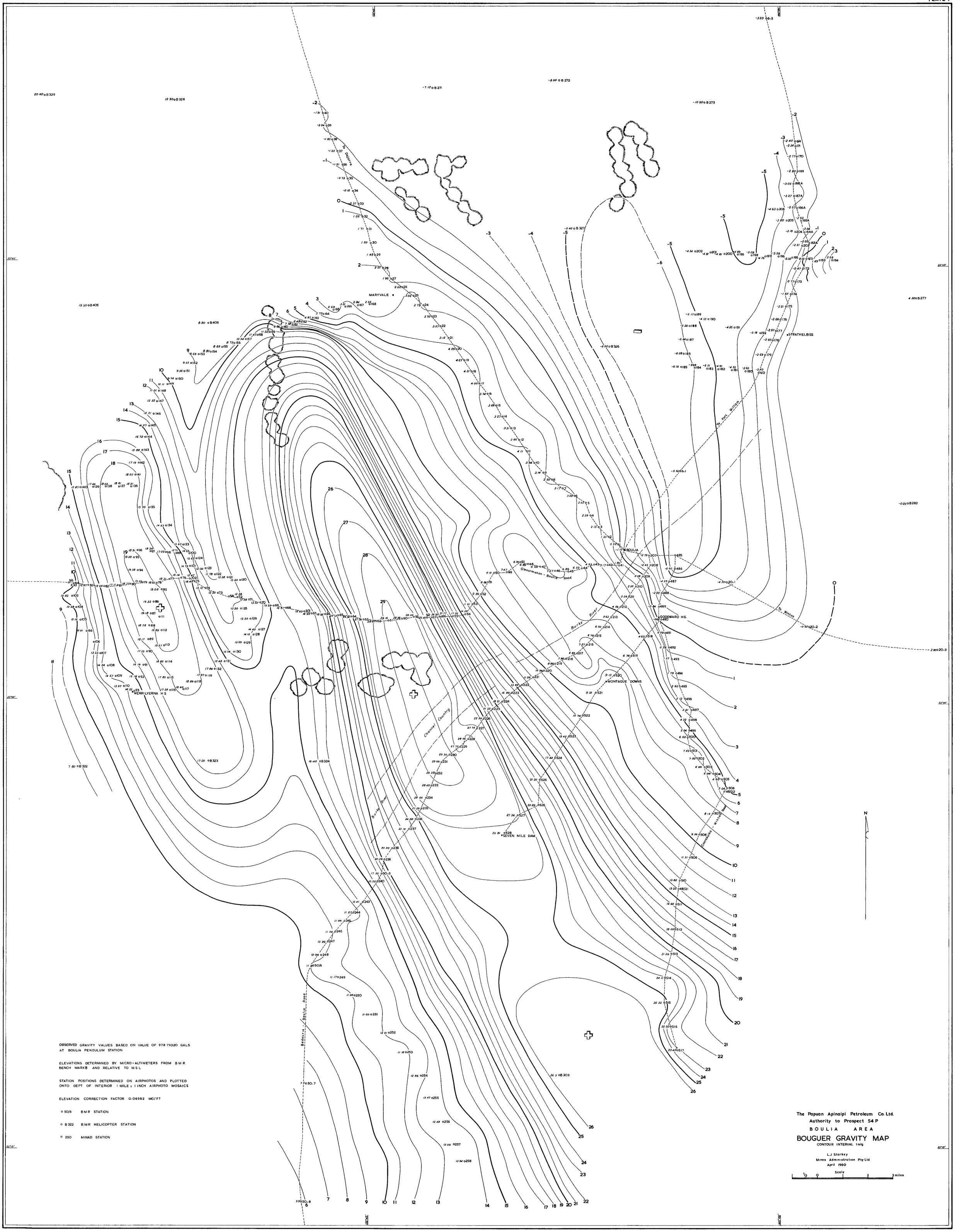
CONTOUR INTERVAL 1 mlg

L J Starkey
Mines Administration Pty Ltd
April 1960

Scale
1 1/2 0 2 3 miles

N

PLATE 4



OBSERVED GRAVITY VALUES BASED ON VALUE OF 978 79320 GALS AT BOULIA PENDULUM STATION

ELEVATIONS DETERMINED BY MICRO-ALTIMETERS FROM B.M.R. BENCH MARKS AND RELATIVE TO M.S.L.

STATION POSITIONS DETERMINED ON AIRPHOTOS AND PLOTTED ONTO DEPT OF INTERIOR 1 MILE = 1 INCH AIRPHOTO MOSAICS

ELEVATION CORRECTION FACTOR 0·06982 MG/FT

o 50/6 B.M.R. STATION

o B 322 B.M.R. HELICOPTER STATION

o 250 MINAD STATION

The Papuan Apinaipi Petroleum Co. Ltd.
Authority to Prospect 54 P

BOULIA AREA

BOUGUER GRAVITY MAP

CONTOUR INTERVAL 1 mlg

L.J. Starkey
Mines Administration Pty Ltd
April 1960

Scale
1/2 0 1 2 3 miles

OBSERVED GRAVITY VALUES BASED ON VALUE OF 978 79320 GALS AT BOULIA PENDULUM STATION

ELEVATIONS DETERMINED BY MICRO-ALTIMETERS FROM B M R BENCH MARKS AND RELATIVE TO M S L

STATION POSITIONS DETERMINED ON AIRPHOTOS AND PLOTTED ONTO DEPT OF INTERIOR 1 MILE = 1 INCH AIRPHOTO MOSAICS

ELEVATION CORRECTION FACTOR 0 06982 MG/FT

o 10-1 B.M.R. STATION

o B 351 B M R HELICOPTER STATION

o 154 MINAD STATION

The Papuan Apinaipi Petroleum Co. Ltd.
Authority to Prospect 54 P
GLENORMISTON AREA
BOUGUER GRAVITY MAP

CONTOUR INTERVAL 1 mlg

L. J. Starkey
Mines Administration Pty. Ltd
April 1960

Scale
1 ½ 0 1 2 3 miles

N

138°45'

139°00'

23°00'

23°15'

23°30'

GLENORMISTON

PEALUNGRA

KENDALLS CAMP

TWENTY MILE BORE

PLATE 6

23°30'

23°45'

SAND DUNES

GIBBER PLAINS

GIBBER PLAINS

ISOLATED SANDHILLS

FAIRVIEW BORE

LOOBS BORE

KIDMANS BORE

DUCK POINT W.H.

MOUTARA W.H.

PLUCHEA W.H.

FIELDS BORE

No.3 BORE
to Brocklebank

Mulligan River

Sylvester Creek

OBSERVED GRAVITY VALUES BASED ON VALUE OF 978·79320 GALS AT BOULIA PENDULUM STATION

ELEVATIONS DETERMINED BY MICRO-ALTIMETERS FROM B.M.R BENCH MARKS AND RELATIVE TO M.S.L

STATION POSITIONS DETERMINED ON AIRPHOTOS AND PLOTTED ONTO DEPT OF INTERIOR 1 MILE = 1 INCH AIRPHOTO MOSAICS

ELEVATION CORRECTION FACTOR 0·06982 MG/FT

○ 10-22 B.M.R STATION

○ 224 MINAD STATION

N

The Papuan Apinaipi Petroleum Co Ltd.
Authority to Prospect 54 P

DUCK POINT

BOUGUER GRAVITY MAP

CONTOUR INTERVAL 1 mlg.

L.J Starkey
Mines Administration Pty Ltd
April 1960

Scale
1 ½ 0 1 2 3 miles

OBSERVED GRAVITY VALUES BASED ON VALUE OF 978·79320 GALS AT BOULIA PENDULUM STATION.

ELEVATIONS DETERMINED BY MICRO-ALTIMETERS FROM B.M.R. BENCH MARKS AND RELATIVE TO M.S.L.

STATION POSITIONS DETERMINED ON AIRPHOTOS AND PLOTTED ONTO DEPT. OF INTERIOR 1 MILE : 1 INCH AIRPHOTO MOSAICS.

ELEVATION CORRECTION FACTOR 0·06982 MG/FT.

o 50/16 B.M.R. STATION

o B438 B.M.R. HELICOPTER STATION

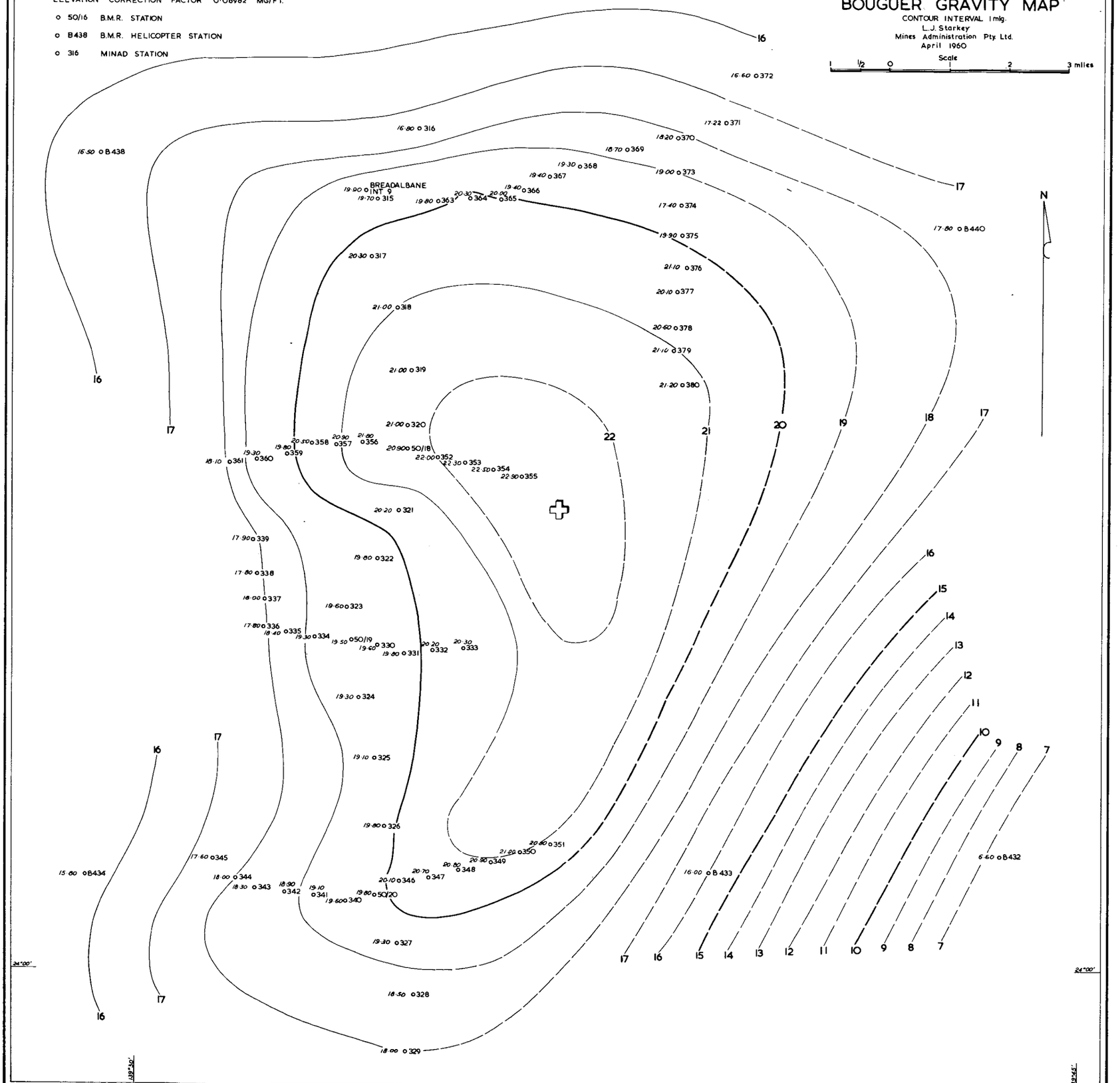
o 316 MINAD STATION

The Papuan Apinaipi Petroleum Co. Ltd.
Authority to Prospect 54 P
BREADALBANE

BOUGUER GRAVITY MAP

CONTOUR INTERVAL 1 mlg.
L.J. Starkey
Mines Administration Pty. Ltd.
April 1960

Scale
1 ½ 0 2 3 miles



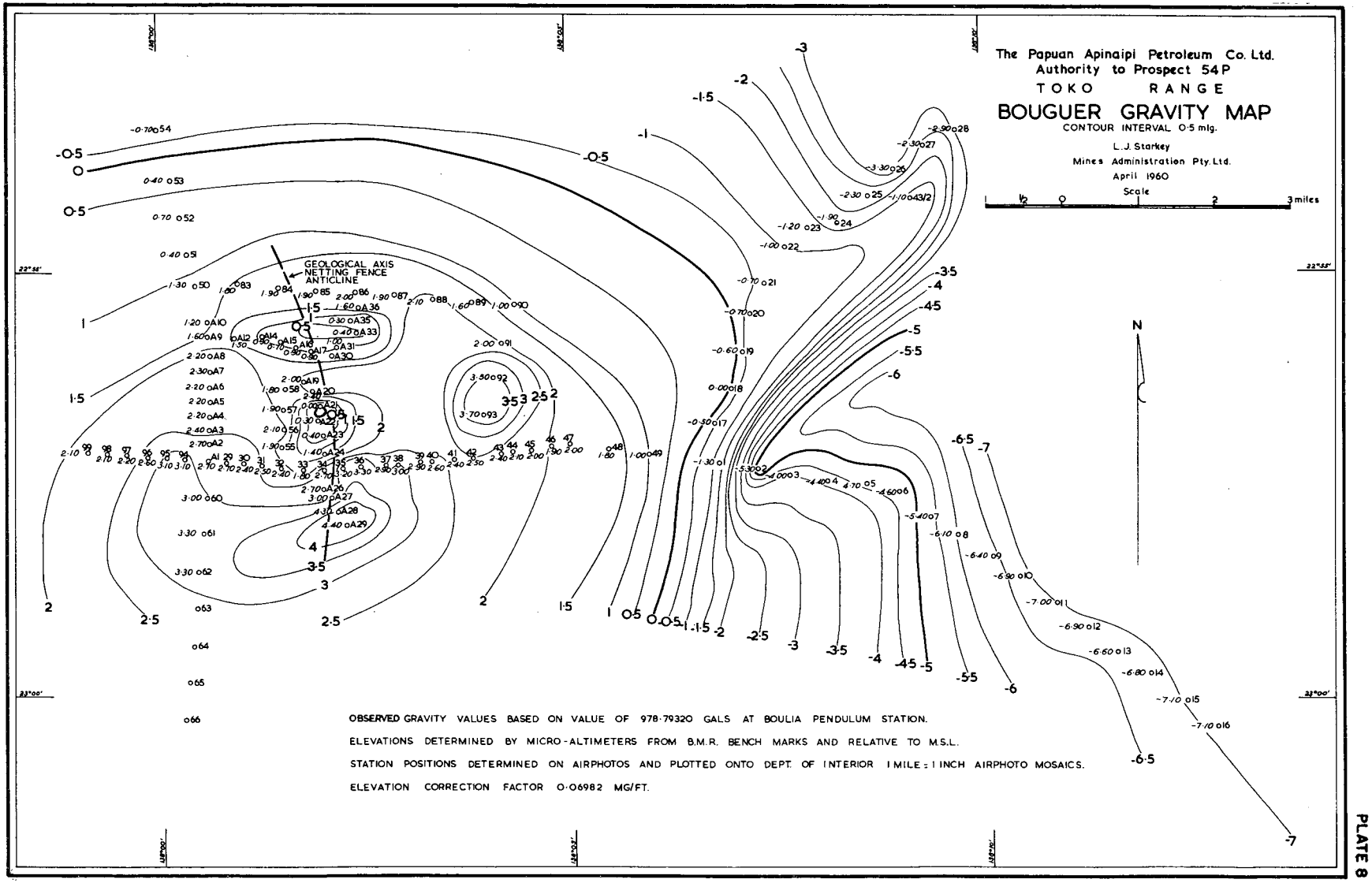
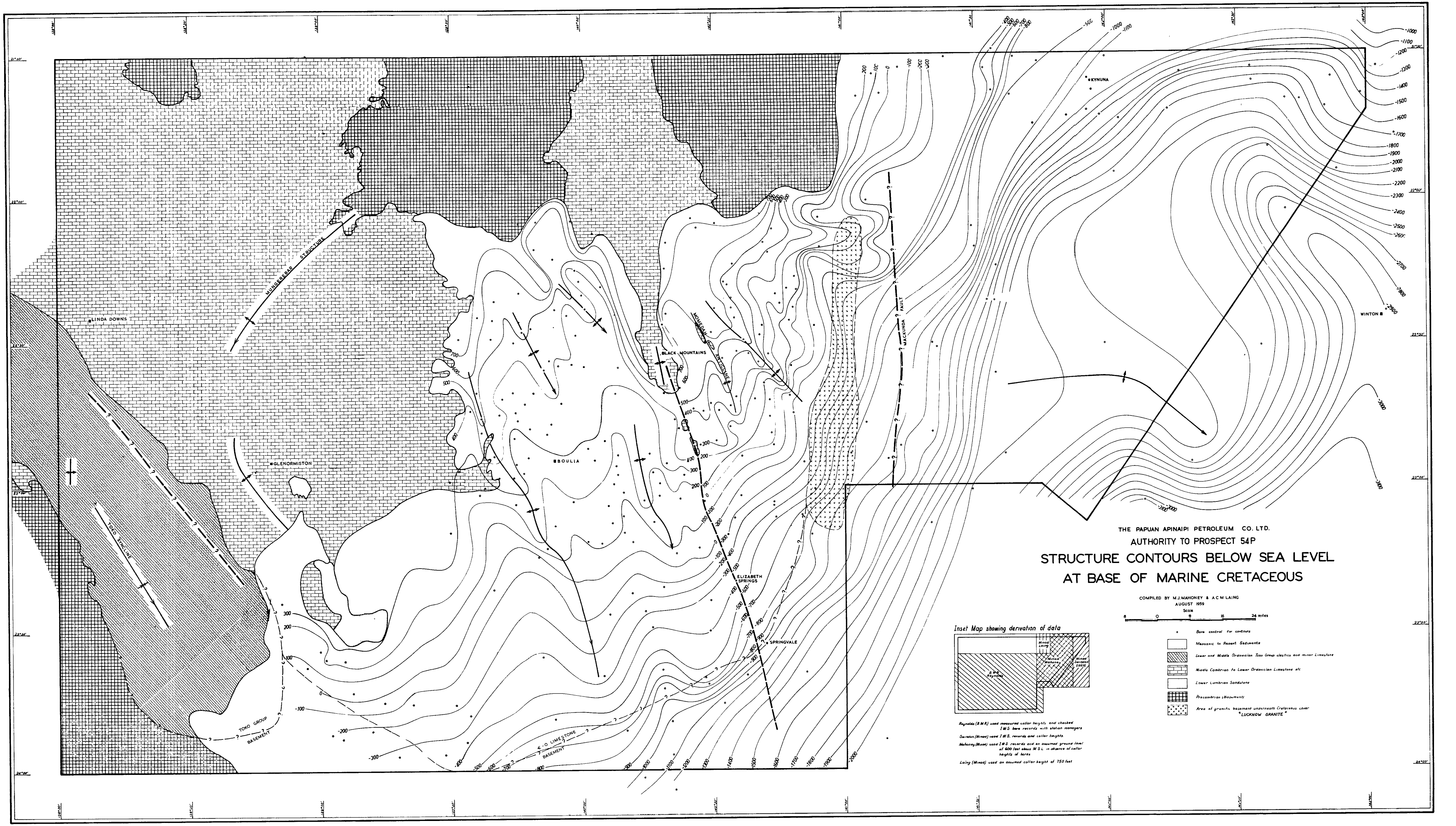

The Papuan Apinaipi Petroleum Co. Ltd.
Authority to Prospect 54P
TOKO RANGE
BOUGUER GRAVITY MAP
CONTOUR INTERVAL 0·5 mlg.
L.J. Starkey
Mines Administration Pty. Ltd.
April 1960
Scale
1 ½ 0 1 2 3 miles
GEOLOGICAL AXIS
NETTING FENCE
ANTICLINE
N
22°54'
23°00'
OBSERVED GRAVITY VALUES BASED ON VALUE OF 978·79320 GALS AT BOULIA PENDULUM STATION.
ELEVATIONS DETERMINED BY MICRO-ALTIMETERS FROM B.M.R. BENCH MARKS AND RELATIVE TO M.S.L.
STATION POSITIONS DETERMINED ON AIRPHOTOS AND PLOTTED ONTO DEPT. OF INTERIOR 1 MILE = 1 INCH AIRPHOTO MOSAICS.
ELEVATION CORRECTION FACTOR 0·06982 MG/FT.

PLATE 8


THE PAPUAN APINAIPI PETROLEUM CO. LTD.
AUTHORITY TO PROSPECT 54P
STRUCTURE CONTOURS BELOW SEA LEVEL
AT BASE OF MARINE CRETACEOUS
COMPILED BY M.J. MAHONEY & A.C.M. LAING
AUGUST 1959
Scale
8 0 8 16 24 miles
Bore control for contours
Mesozoic to Recent Sediments
Lower and Middle Ordovician Toko Group clastics and minor Limestone
Middle Cambrian to Lower Ordovician Limestone etc
Lower Cambrian Sandstone
Precambrian (Basement)
Area of granitic basement underneath Cretaceous cover
"LUCKNOW GRANITE"
Inset Map showing derivation of data
Minad Laing
Minad Mahoney
Minad Swindon (1959)
B.M.R. Reynolds
Reynolds (B.M.R.) used measured collar heights and checked I.W.S. bore records with station managers
Swindon (Minad) used I.W.S. records and collar heights.
Mahoney (Minad) used I.W.S. records and an assumed ground level of 600 feet above M.S.L. in absence of collar heights of bores
Laing (Minad) used an assumed collar height of 750 feet
KYNUNA
WINTON
LINDA DOWNS
GLENORMISTON
BOULIA
BLACK MOUNTAINS
ELIZABETH SPRINGS
SPRINGVALE
MUNGERIBAR STRUCTURE
TOKO SYNCLINE
MACKUNDA FAULT
TOKO GROUP BASEMENT
Є-O LIMESTONE BASEMENT