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RECORD No. 1964/21

LAKE GEORGE GRAVITY SURVEY, NSW 1963

by

L. KEVI

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CONTENTS

ILLUSTRATIONS

SUMMARY

This Record describes a gravity survey designed to investigate the controversial fault at the western margin of Lake George, NSW.

Results show a roughly elliptical gravity 'high' of about 24 mgal probably due to amphibolite. This 'high', superimposed on the detailed gravity pattern, obscures the minor gravity features. However, analysis of the gravity pattern indicates a fault, possibly overthrust, west of Lake George, with a possible vertical downthrow of 3000 to 5000 ft to the east.

1. INTRODUCTION

There has been much controversy about the origin of Lake George situated in New South Wales about 140 miles south-west of Sydney and about 8 miles north of the north-eastern corner of the Australian Capital Territory. The main point in the controversy is whether a submeridional fault runs along the western margin of the lake. The object of the gravity survey described in this Record was to investigate the existence of such a fault by the gravity method.

The survey was undertaken by the Geophysical Branch of the Bureau of Mineral Resources, Geology and Geophysics at the request of the Geological Branch. The locations of the gravity stations were determined by using one-mile military maps (Goulburn, Lake George, Lake Bathurst, Canberra, and Braidwood sheets).

The geophysical party consisted of L. Kevi (party leader), J.P. Pigott (geophysical assistant), and one field assistant supplied by the Geological Branch. The survey was made during December 1962 and January 1963.

2. GEOLOGY

The following description of the geology of the area is based on Garretty (1936a, b, & c). Part of Garretty's geological map is reproduced on Plate 2. Geological cross-sections are shown on Plate 3. Cross-sections A and B are based on Garretty's map; C and D are based on the more-recent 4-mile geological series (Sheet I55-16).

Stratigraphy

The oldest rocks in the area are Upper Ordovician metamorphic rocks, viz. schist, phyllite, slate, and shale.

The Silurian rocks comprise chiefly shale, but phyllite, sandstone, and limestone also occur. The rocks referred to on Garretty's map as of 'doubtful age' consist mainly of argillaceous sediments and are probably also Silurian.

The Devonian is represented by red sandstone, conglomerate, and quartzite. Tertiary and Quaternary lake deposits and alluvium are located mainly south and east of Lake George.

Igneous rocks

Amphibolite, a metamorphosed pre-Upper Silurian intrusive, forms considerable outcrop between Collector and Tarago. The southern continuation of this outcrop seems to be covered by Tertiary and Recent deposits. The granites of the area consist of biotite-hornblende granites and quartz-felspar porphyries. Some granites may be Ordovician but most of them are probably Upper Silurian.

Geological structures

The Ordovician and Silurian rocks are folded along meridional axes. Garretty suggests asymmetrical folding with axial planes dipping to the west. Some controversy exists about the origin of the escarpment on the western margin of Lake George. Taylor (1907) suggested that it is a fault scarp, whereas Garretty (1936b) regarded it as an erosional feature.

3. METHODS

Gravity

The gravity observations were made with Worden gravity meter No. 61. The calibration factor of the instrument is 0.09047 mgal/scale division. This was obtained by a test on the Melbourne Calibration Range on 24th October 1962. The interval adopted for the Calibration Range was 53.04 mgal; the measured gravity interval was 586.3 scale divisions.

Gravity readings were observed at 246 stations. The gravity stations were placed at about one-mile intervals along the roads and tracks around Lake George except in the vicinity of the assumed fault where they were placed at half-mile intervals.

The gravity traverses were arranged so that they formed a closed network (Plate 5). The closing errors in the loops of the network were calculated and distributed. The closing errors were generally small, the greatest being 0.17 mgal.

The survey was tied to BMR regional gravity station No. EA-140. The value adopted for this base station is shown in the appendix.

Elevation

The elevations of gravity stations were obtained by barometric levelling. Two 'Mechanism' microbarometers, Serial No. 317/62 and 318/62, were used. These instruments can be read to an accuracy of 0.02 mb pressure, which is approximately equivalent to 0.6-ft elevation.

Three trigonometrical stations were used as fixed points. The levelling traverses formed a closed network. The precision of the barometric levelling was estimated by computing the heights of 21 stations by following different paths. The standard deviation is estimated as about 4 ft.

Elevation Correction

The gravity values were reduced to the 1800-ft-above-MSL datum. The combined elevation correction factor is a combination of the free-air correction and the Bouguer correction. The latter is directly proportional to the density of near-surface rocks. To obtain this density, and hence the appropriate elevation correction factor, two statistical methods were used. The first is based on the assumption that the density which gives zero correlation between Bouguer-anomaly and the elevation of stations is the correct density.

The second method, which was developed by Siegert (1942), determines the elevation correction factor in a manner that makes the corrected gravity profile as smooth as possible. The methods indicated specific gravities of 3.05 and 2.76 respectively. The mean of the specific gravities obtained by the two methods was 2.9 and this value was used in the elevation correction factor (0.0571 mgal/ft).

Terrain correction

Most of the gravity stations were placed at points where the terrain effect was small. The presence of an escarpment along the assumed fault, however, caused considerable terrain effect for 30 stations. As the escarpment was essentially a 'two-dimensional' feature the method of terrain correction published by Hubbert (1948) was applied.

The terrain corrections were computed by using the contours of the one-mile military map series:

Terrain correction (mgal)	Number of stations
Zero to 0.49	5
0.50 to 0.99	5
1.00 to 1.49	5
1.50 to 1.99	6
2.00 to 2.49	4
2.50 to 2.99	3
3.00 to 3.49	2

Latitude correction

Latitude correction was applied taking the latitude 35°15' as arbitrary zero. The value of theoretical gravity on the international ellipsoid at this latitude is 979,667.7 mgal.

4. ACCURACY

The accuracy of Bouguer anomalies is affected by:

(a) error in observed gravity (Δg),

(b) error in elevation (Δh),

(c) error in latitude (Δl),

(d) error in terrain correction (Δt), and

(e) error in specific gravity (Δd).

The estimated errors are given below :

Estimated error		Bouguer anomaly (mgal)
Δg		$\pm$ 0.05
Δh	$\pm$ 4 ft	$\pm$ 0.23
Δl	$\pm$ 0.2 miles	$\pm$ 0.25
Δt		$\pm$ 0.20

Computing the square root of the sum of the squares gives the random error in Bouguer anomalies as $\sqrt{\Delta g^2 + \Delta h^2 + \Delta l^2 + \Delta t^2}$ which was found to be $\pm$ 0.42 mgal.

In addition to the random errors listed above a systematic error is introduced by the error in specific gravity used in the elevation correction. The magnitude of this systematic error equals:

$2\pi G.h.\ (\pm \Delta d)$ in which G is gravity constant,

h is the elevation, and Δd is the error in specific gravity.

For $\Delta d = \pm\ 0.1$, this systematic error equals $\pm$0.00128 mgal/ft.

For the maximum elevation difference of 1122 ft observed for stations in the area this amounts to $\pm$ 1.44 mgal.

5. RESULTS

The contour plan of Bouguer anomalies is shown on Plates 1 and 5. The 24-mgal contour encloses a large gravity 'high' north-east of Lake George which, superimposed on the geological map, coincides approximately with the area in which high-density amphibolite crops out. This gravity 'high' probably obscures smaller gravity features but the contour plan suggests that the gravity 'high' is superimposed on a gravity 'low' east of line PQ.

Representative gravity profiles, A, B, C, and D, based on the contour plan are shown in Plate 3. Residual profiles are shown for C and D; these were obtained by subtracting the assumed effect of the amphibolite from the gravity values. The gradients on the western parts of the profiles are consistent with the existence of a fault or shear zone. The steepest gradients are observed close to the intersection of PQ with the profiles. An alternative estimate for the effect of the amphibolite on Profile C is shown in Plate 4. This illustrates that the maximum gravity gradient due to the fault or shear zone alone may be located east of PQ, and indicates the difficulty of isolating the fault anomaly with any accuracy.

Profile A shows a difference of 13 mgal from K to L. After subtracting the estimated gravity influence of the amphibolite mass on Profiles C and D, the lowering of gravity value by the supposed fault is 7 mgal or more. Uncertainty exists because of the extrapolation required on Profile D.

Assuming that the specific gravity of the older metamorphic rocks west of the assumed fault is about 2.8 to 2.9, and that of the shale, sandstone, and granite (excluding the amphibolite mass) east of PQ is 2.6 to 2.7, the specific gravity contrast would be about 0.2. The gravity effect of a fault can be approximated by the gravity anomaly due to a semi-infinite horizontal slab. Using this approximation it can be shown that for unit specific gravity contrast, 1-mgal gravity effect corresponds to a vertical throw of 78 ft. (Nettleton, 1940). For a contrast of 0.2 and a gravity effect of 13 mgal a throw of $(78 \times 13)/0.2 = 5070$ ft is obtained; for a gravity effect of 7 mgal the throw will be 2730 ft. Thus, if the above gravity differences are caused by faulting, the total vertical throw of the fault can be estimated at 3000 to 5000 ft.

In the above estimates regional gravity trends were ignored because the survey was too-restricted in area to make any conclusion about regional trends. From the contour map of Bouguer anomalies for Australia and New Guinea (Dooley, 1959, Plate 4) the regional gradient appears to be small in this area.

6. CONCLUSIONS

The gravity results suggest there is a fault along PQ or east of PQ. The approximate coincidence of this suggested fault with the escarpment on the western edge of Lake George suggests a relation between the escarpment and the fault. If the fault anomaly is centred west of the escarpment, this would imply an overthrust fault; if centred east of the escarpment, the anomaly would imply a normal fault. However this cannot be resolved from the present survey. The topographical features further indicate that faulting continued until Recent times; if this were not so the topographical features would have been eroded down. The gravity values suggest that the block east of the fault may be downthrown about 3000 to 5000 ft.

The large gravity anomaly (closure about 26 mgal) north-east of Lake George is probably caused by basic intrusives, that have been metamorphosed to amphibolite.

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APPENDIX

Data of some gravity stations in Lake George area

Station No.	EA - 140	23	36	75	97	152	156	181
Latitude (S)	34°54'50"	35°15'30"	35°10'11"	35°01'20"	35°05'45"	34°47'25"	34°48'20"	34°46'43"
Longitude (E)	149°26'25"	149°26'50"	149°17'50"	149°16'05"	149°36'45"	149°29'25"	149°36'30"	149°16'15"
Elevation (ft above MSL)	2310	2295	2228	1878	2461	2304	2270	1861
Observed gravity (mgal)	979567.03	592.37	593.51	601.25	567.89	547.04	555.16	583.88
Latitude correction (mgal)	28.58	-0.64	6.83	19.31	13.17	38.83	37.67	39.74
Elevation correction (mgal)	29.10	28.24	24.42	4.45	37.71	28.76	26.82	3.48
Bouguer anomaly (reduced to 1800 ft above MSL)	979624.71	619.97	624.76	625.01	618.77	614.63	619.65	627.10

Elevation correction factor = 0.05706 mgal/ft.

Location descriptions:

Station EA - 140 : Intersection of Federal Highway and Collector - Breadalbane Road, at signpost.

Station 23 : Platform of Bugendore Railway Station, north-eastern corner of office building.

Station 36 : On Federal Highway at milestone C16 - G43.

Station 75 : Junction of Gundaroo - Gunning and Gundaroo - Collector road, at signpost.

Station 97 : Junction of Bugendore - Tarago and Collector - Tarago road, at trig. point SSM 1981.

Station 152 : Platform of Breadalbane Railway Station, north-western corner of office building.

Station 156 : Federal Highway and Hume Highway junction, at signpost on northern side of the road.

Station 181 : Junction of Hume Highway and Gunning-Collector road, at signpost.

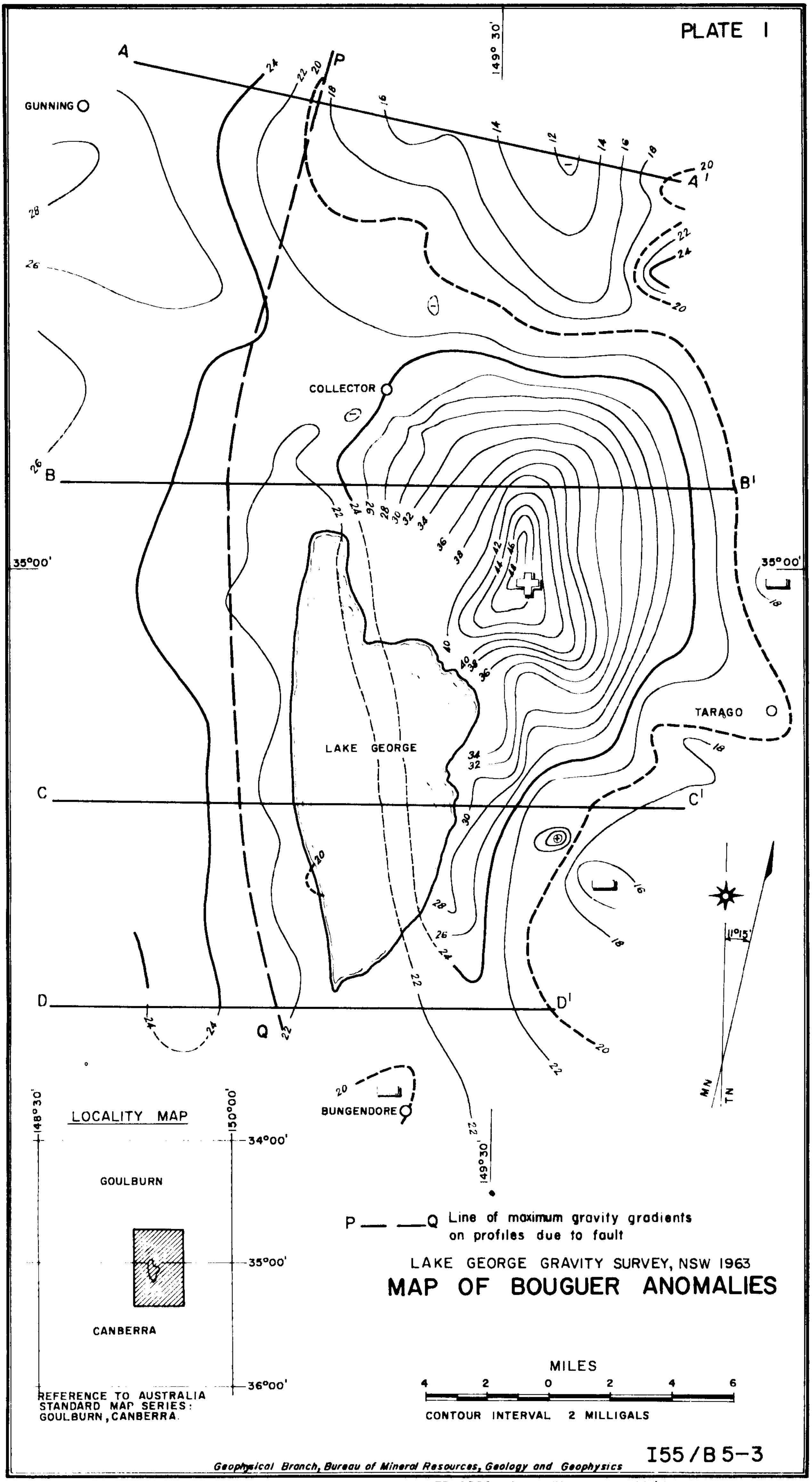

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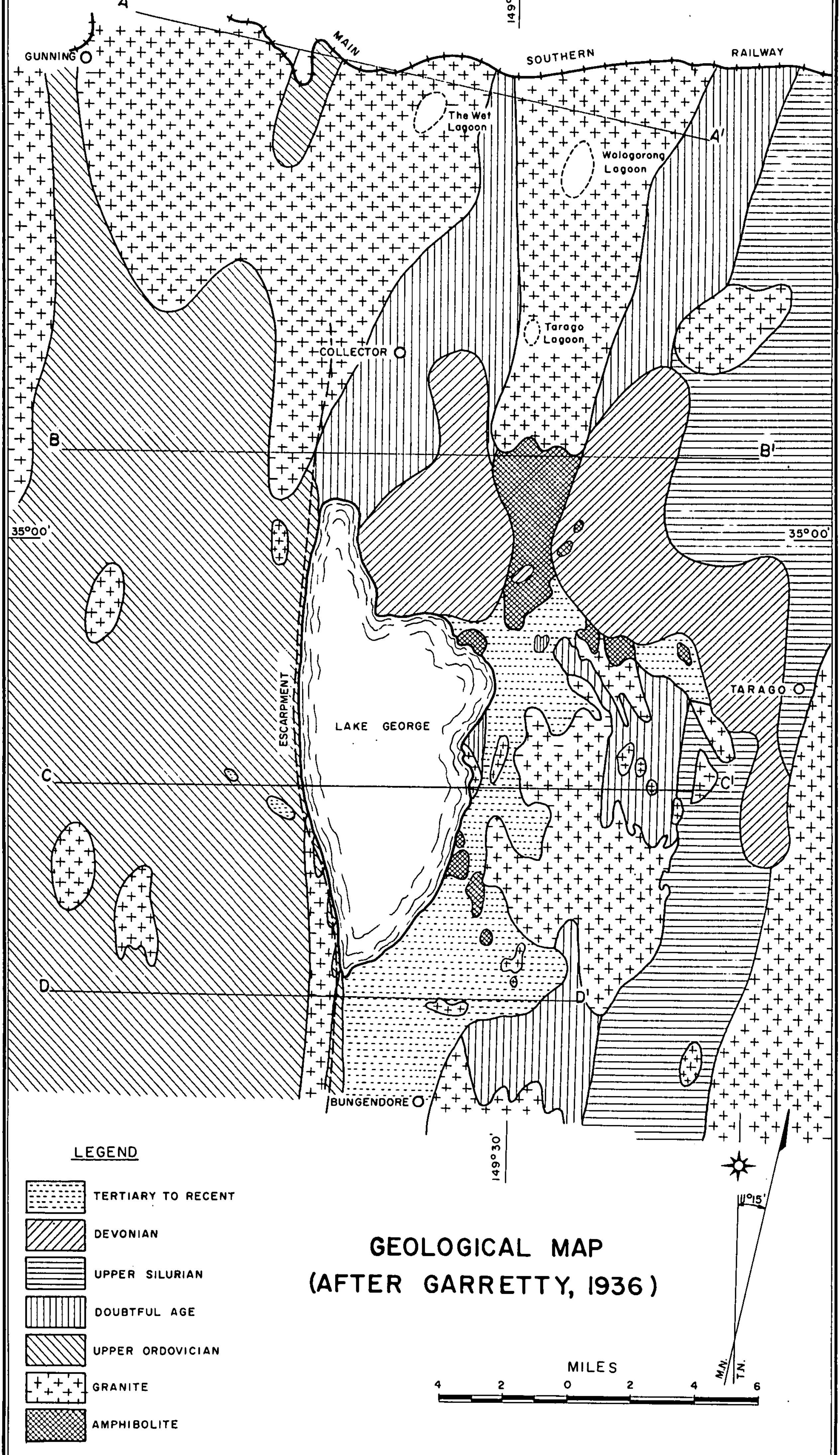
PLATE 2



GEOLOGICAL MAP
(AFTER GARRETTY, 1936)

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GRAVITY EFFECTS ALONG PROFILE C DUE TO FAULT AND TO AMPHIBOLITE

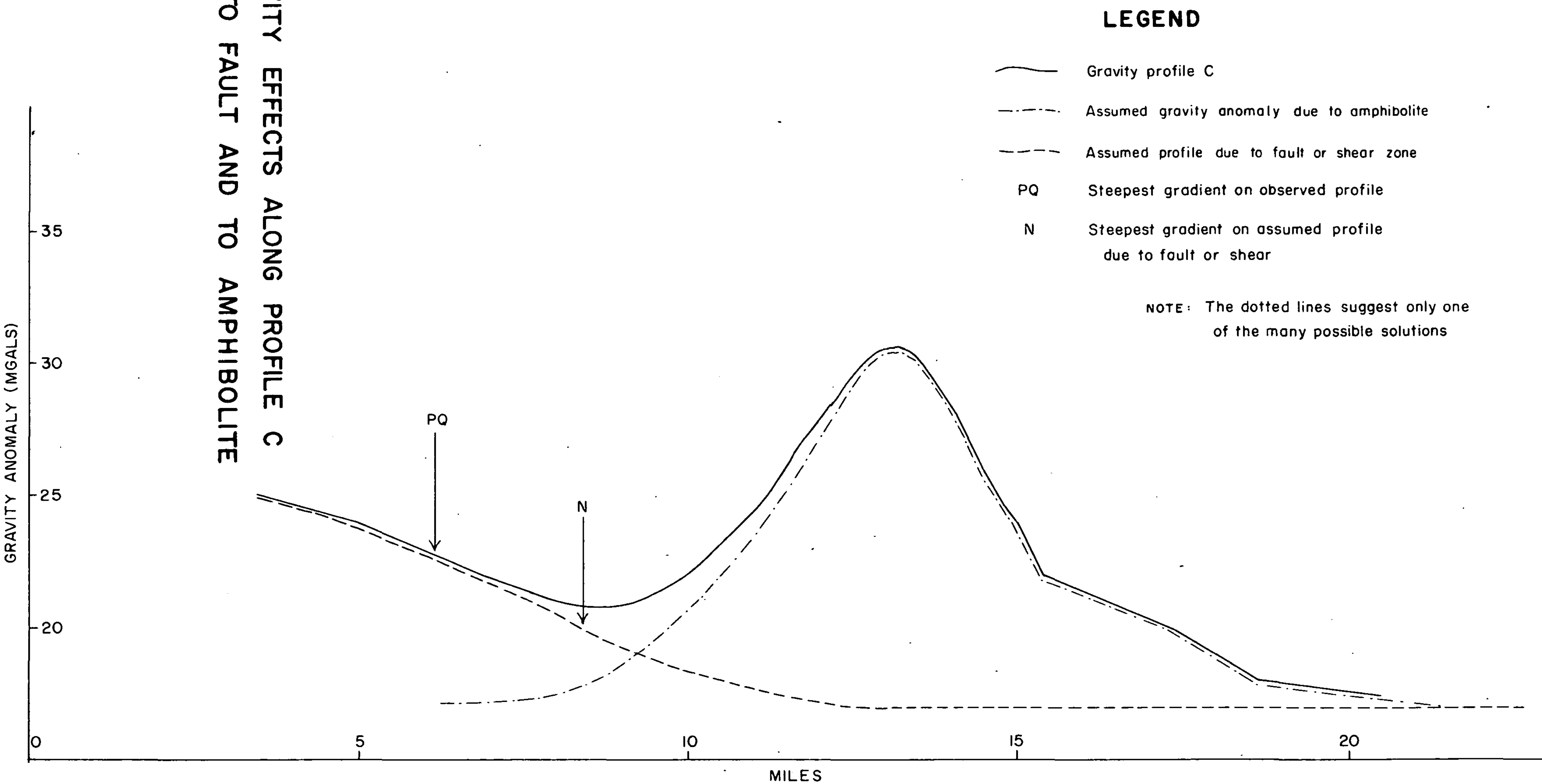

PLATE 4

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
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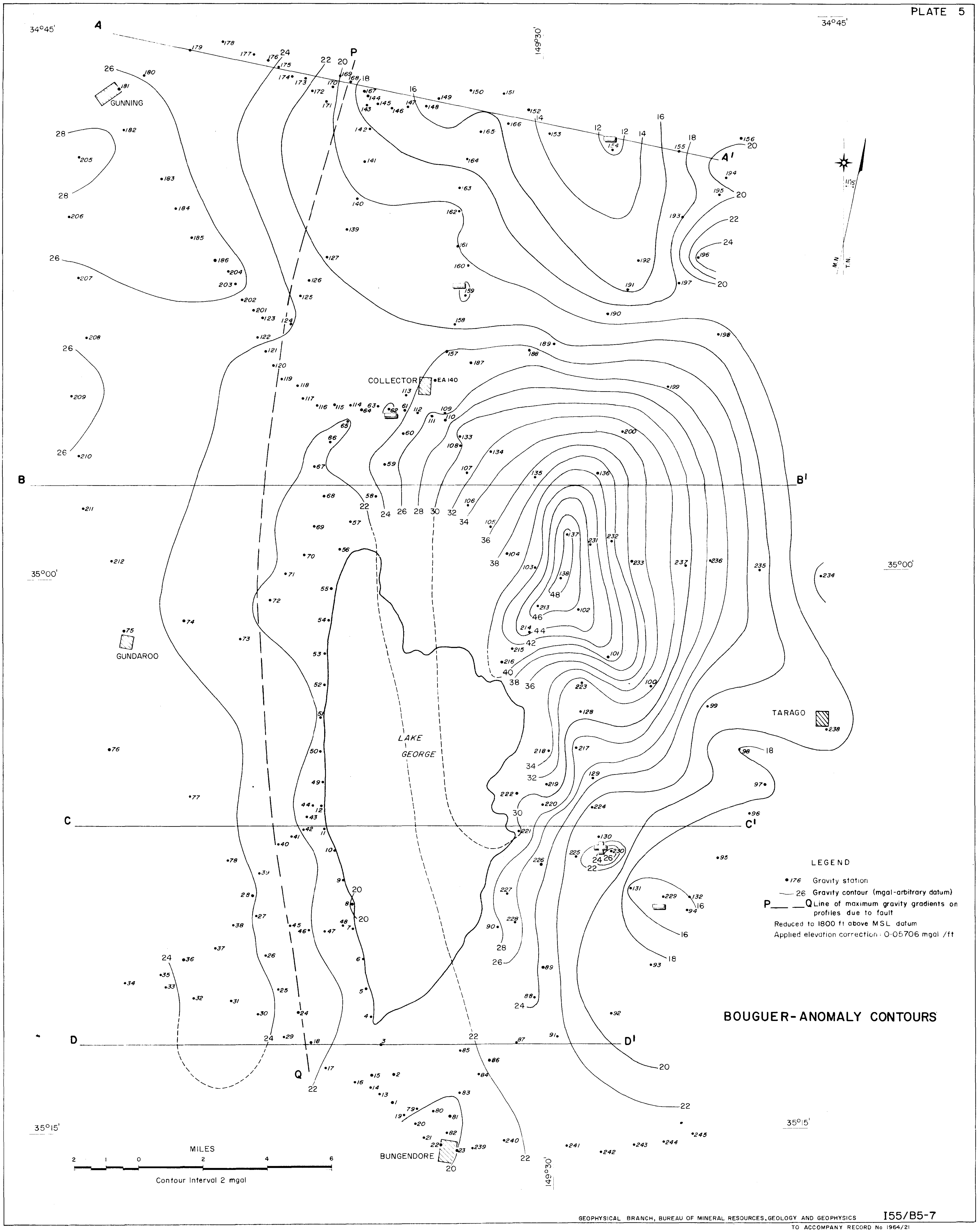
PLATE 5



BOUGUER-ANOMALY CONTOURS

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LAKE GEORGE, NSW
GRAVITY SURVEY, 1963