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REPORT 7200-P-5

14 FEB

DETAILED GRAVITY SURVEYS IN MT. SALT - MT. SCHANK, SUMMER HILL AND TANTANOOLA AREAS OF GAMBIER SUNKLANDS SOUTH AUSTRALIA

by

K. A. Richards

Frome-Broken Hill Co. Pty. Ltd.

Melbourne

20th December, 1957

ABSTRACT

Three separate detailed gravity surveys were carried out in the Gambier Sunklands, over previously noted geological structures.

Observations were made with good accuracy.

The results did little to confirm the presence of many of the geological structures at depth. However, interesting features, especially in regard to faulting, were noted. It was postulated that many of the known faults in the area have been subject to reverse movement. One interesting feature, a gravity high Northwest of Mt.Schank, was located and a structural feature has been inferred.

Seismic work has been recommended to outline accurately some of the proposed features.

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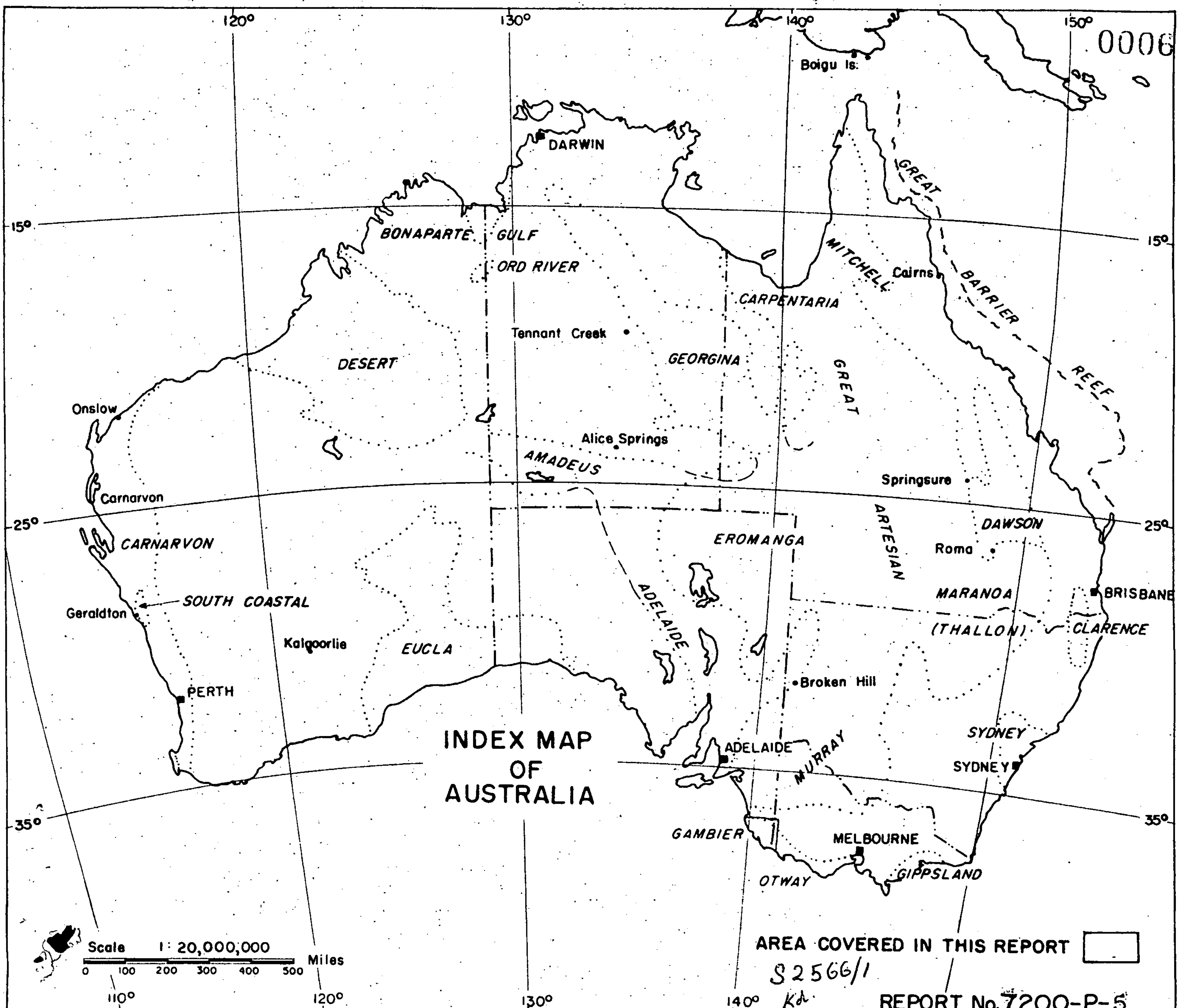
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Boigu Is.
DARWIN
BONAPARTE GULF
ORD RIVER
Tennant Creek
DESERT
GEORGINA
CARPENTARIA
MITCHELL
Cairns
GREAT BARRIER REEF
GREAT ARTESIAN
Onslow
Alice Springs
AMADEUS
Springsure
Carnarvon
CARNARVON
DAWSON
EROMANGA
Roma
ADELAIDE
MARANOA
BRISBANE
SOUTH COASTAL
Geraldton
(THALLON)
CLARENCE
Kalgoorlie
EUCLA
Broken Hill
PERTH
SYDNEY
INDEX MAP OF AUSTRALIA
ADELAIDE
MURRAY
SYDNEY
GAMBIER
MELBOURNE
OTWAY
GIPPSLAND
Scale 1: 20,000,000
0 100 200 300 400 500 Miles
AREA COVERED IN THIS REPORT
S2566/1
Kd
REPORT No. 7200-P-5
120° 130° 140° 150°
15° 25° 35°
110° 120° 130° 140°

FRONTPIECE

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0007

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1. INTRODUCTION

(a) Location

Three separate gravity surveys were carried out. The largest, covering about 110 sq. miles, was in the Mt. Salt-Mt. Schank area, just to the southwest of Mt. Gambier, South Australia (Plate 1). Another was situated just southeast of Tantanoola, South Australia (Plate 1) and covered approximately 6 square miles. The third was made some months later in the Summer Hill area just west of Nelson (Plate 1) and covered approximately 13 square miles in South Australia and Victoria.

(b) Objective

The objective of the gravity work was to confirm if possible the continuation at depth of geological structures inferred by Dixon (1 & 2) and O'Mara (3); and to ascertain the likelihood of any closure on the structures.

(c) Instruments

The gravity meter used was Worden Meter No. 274. Closures for drift were made at least every two hours, and an average drift of from 1 to 2 scale divisions for this period was obtained. Reading conditions for at least half the time were bad, beam movement being so pronounced that at times reading was not attempted. This may have been due to the strong winds experienced or small shock waves caused by large offshore atmospheric disturbances. The makers' scale factor of 0.10262 mg/scale div. was used in the first two surveys. However, a check was made on this figure before the Summer Hill work commenced and a new scale factor of 0.10141 mg/scale div. was used in this survey.

The alidale used was a Hilger and Watts and levelling was done with two Kern type levels.

(d) Acknoweldgements

The surveying work in the Mt. Salt-Mt. Schank and Tantanoola area, consisting of accurate levelling with some plane-tabling, was carried out by Kevin Turner assisted for some time by Brian Turner and Hans Meisinger. Hans Meisinger was responsible for all levelling in the Summer Hill survey.

2. MT. SALT-MT. SCHANK SURVEY

(a) Field Work

The fieldwork in the Mt.Salt-Mt. Schank area was carried out between 30th April and 11th June with the exception of the first week in June which was devoted to the Tantanoola Survey. During the survey, 554 gravity stations were read, levelled, and positioned.

The gravity values were tied to the Bureau of Mineral Resources, Mt. Gambier Pendulum Station. The stations, for the most part, were set out at $\frac{1}{4}$ mile intervals, on an approximate 1 mile grid, along the many roads, tracks and fences in the area. A number of traverses had to be walked, but in the main vehicles were used. Much of this area had been planetable surveyed by geological parties, and this information was supplemented by additional survey work, especially near Kongorong. Each gravity station was levelled accurately using Kern levels,and was placed far enough away from any hills to make the terrain effect negligible.

A net work of 13 base stations was first set out, each station being read at least twice. The survey was then adjusted to these bases. In most cases closure errors were small enough to be negligible but on occasions errors of up to 0.02 mg. per station occured. This was almost certainly due to the meter not being read accurately enough because of the previously mentioned beam movement. Where too large a closure error resulted the traverse was repeated.

(b) Elevation Correction

All levelling was accurate, closure errors never exceeding 0.25 ft. Elevation datum was taken from road-railway crossings at Mt. Gambier. The railway levels used have their datum at Adelaide and this is 100 ft. below Mean Sea Level. However, 100 feet has been subtracted from all the final gravity station elevations.

Density determinations were carried out by the Bureau of Mineral Resources on a selected number of core samples from the Nelson bore. The samples were dry due to their long exposure to air. The results are as follows;-

Rock Type	Depth	Stratigraphic unit		Density gm/cc	
Limestone	Surface	Gambier Formation		1.26	= 1.79 wet
Marl	474	"	"	1.63	2.03 wet
Limestone	578	"	"	1.95	
Sandstone	1281	Knight Group		1.92	
"	2828	"	"	2.57	2.62 wet
Siltstone	3080	"	"	2.18	
Sandstone	6294	"	"	2.45	
Siltstone	6485	"	"	2.46	
Sandstone	6751	"	"	2.46	

Combining these into groups. The average density of the Gambier Formation is 1.61 and the Knight Group 2.34. The density factor used was 2.25 and this was calculated from the 1 : 8 ratio of Gambier Formation to Knight Group in the Nelson bore. This gave an elevation correction factor of 0.065 mg/ft.

2.02
2.47
2.42
.063

(c) Latitude Correction

A base map, scale 1" = 1000 ft. was prepared using as a basis plane table sheets drawn up by K. Turner during Dixon's (2) previous field work. To this was added plane table data from O'Mara's (3) map of the Mt. Salt area. The resulting map included most of the gravity traverses undertaken, and traverses in other areas were surveyed by plane table and the gravity lines plotted on the base map.

Where new plane table work was undertaken the gravity stations were positioned in accordance with the plane table survey. The stations on the majority of the remaining north south traverses and the walking traverses, were positioned by finding their distances apart whilst levelling or by chaining. On the remainder of the traverses the positions were found by taking accurate speedometer readings for each station, between the two closest appopriate fixed points on the base map. This distance was then divided in the ratio of the speedometer readings between each of the stations. No distance to be divided ever exceeded 1 mile and the number of stations was generally four. This method was first checked by chaining and it was found that an error for each station of between 50 - 100 feet was introduced. Since most of these traverses were in an east west direction it was thought that this method was quite accurate enough.

The latitude of a fixed point on the base map was determinded from the South Australian Mines Department 1 mile to the inch Geological Sheet and the theoretical gravity value determined for that point. The latitude corrections were made using a transparent overlay of scale 1.267 mg/mile. It was estimated that the error in the latitude correction was ± 0.03 mg.

(d) Results

The Bouguer gravity contours are plotted on Plate 2a. They are most irregular especially to the south. The irregularity may be due to two causes. Firstly there may be nonsedimentary rocks at reasonably shallow depth, or secondly there may be near surface density changes in the Gambier limestone due to underground cavities. The former is not supported by either aerogmagnetic or available geological information. However, the limestone contains many visible sink holes and caves and their extension underground would create sufficiently large anomalies to affect the final values to a noticeable degree.

Assuming the latter to be correct, an attempt was made to either filter out these irregularities or to localise them by over-emphasis, with the use of residual and second derivative maps. However, although several different methods were tried, none was successful to any marked degree. Perhaps the best result, Plate 2a, was obtained by using T. A. Elkins (4) formulae.

$$\frac{\partial^2 G}{\partial Z^2} = \frac{1}{62k^2r^2} \left\{ 44H(0) - 16H(S) - 12H(S\sqrt{2}) - 48H(S\sqrt{5}) \right\}$$

with a $\frac{1}{2}$ mile grid spacing. This map over-emphasises some of the features of the Bouguer contours, but little additional information has been gained.

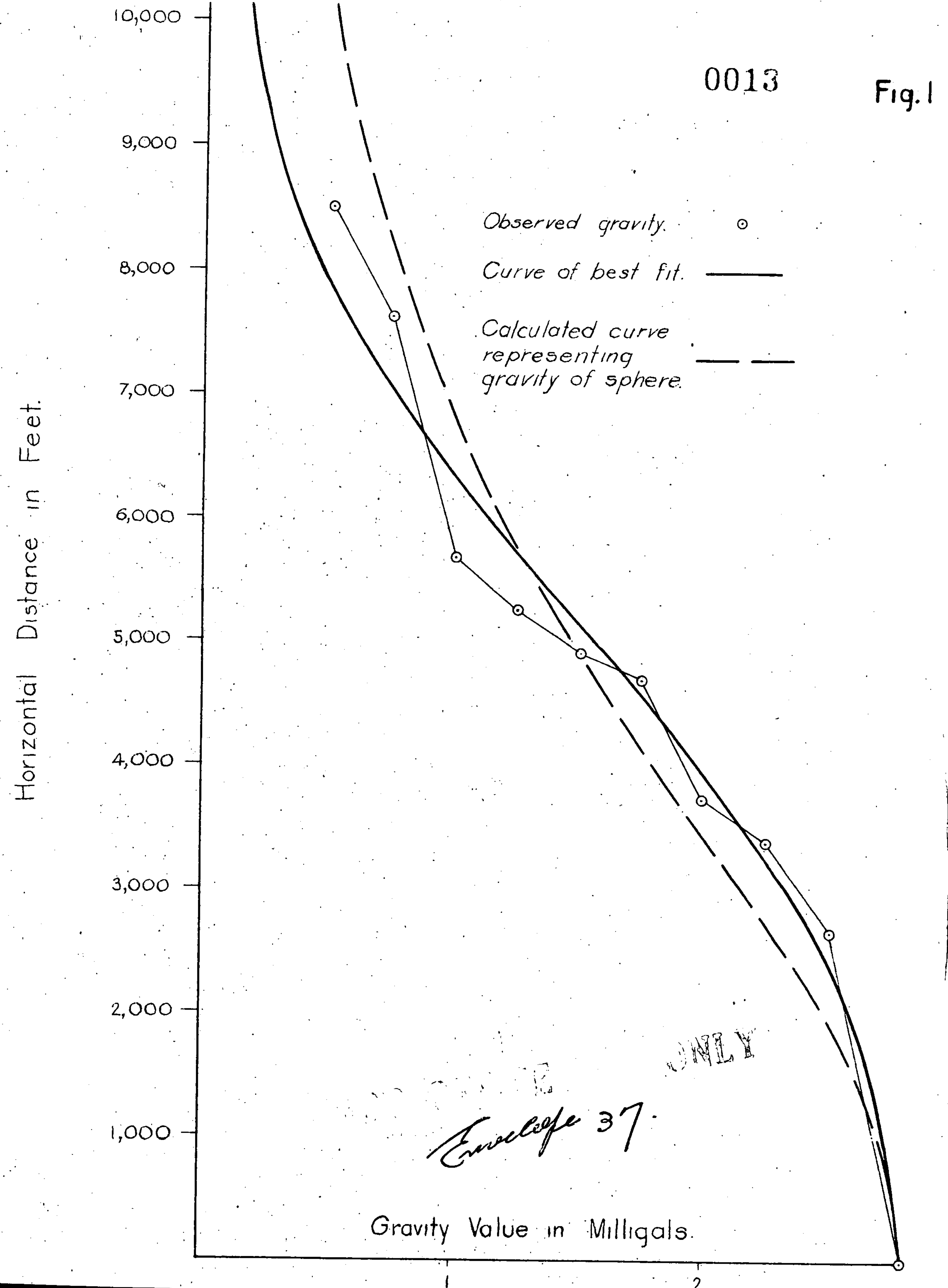
(e) Interpretation

(i) General

This interpretation will be restricted to the Bouguer map except where the second derivative has additional information to offer. Also it is important to remeber that since the density contrast between the Gambier and Knight Groups is 0.73, any structure which has affected both should be shown up on the gravity map.

On comparison of the gravity results with Dixon and O'Mara's surface geology, it is apparent that little agreement is present. In a regional sense there is general agreement with O'Mara's conclusions. The prominent gravity maximum in the north of the area covers what he concluded to be a structurally high area and the negatives directly south coincide with his low areas. However, the individual

Fig. 1



0013
Observed gravity.
Curve of best fit.
Calculated curve representing gravity of sphere.
Horizontal Distance in Feet.
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
Gravity Value in Milligals.
1
2
Envelope 37.

features are not apparent. With some exceptions, the structures mapped by Dixon do not show up on the gravity, contour map. The strong gradients on the east and south east flank of the gravity maximum probably represent a northerly extension of Dixon's Allendale fault, although these gravity features are not noted south of Mt. Schank. The fact that the higher gravity values are to the south of the proposed fault are discussed in section 5. The positive nosing to the south east of the gravity maximum may represent a small offshoot of the inferred structure (see below) and could have surface representation in Dixon's MacDonnell anticline. There is also a slight possibility that the nosing of the contours in the south west corner of the map reflects the Mt. Schank anticline.

The gravity maximum to the north could represent a structural feature and if so appears reasonably deepseated. The anomaly could be caused by doming in the pre-Tertiary beds alone, but from geological evidence the doming persists in the Tertiary rocks. There is evidence that the structural feature is faulted on the north south and east and it could well be of a horst nature. The second derivative map shows the gravity high to be much smaller and this may be a more accurate representation of the extent of the structural feature in the Tertiary beds. (O'Mara's structural high) There is the possibility that the gravity maximum is caused by a sill or volcanic neck, but the gravity gradient appears too small to account for such a feature unless it is deepseated.

The gravity high near station 246 could well represent a buried ash or cone or basalt, although the sparsity of data doesn't permit any definite interpretation.

The only other salient feature is that the regional trend is an increase in gravity value to the south and this could mean a thinning of the sedimentary section in that direction.

(ii) Quantitative

An attempt was made to determine the approximate depth to the feature causing the gravity maximum. Several profiles were drawn across the contours where it was thought the anomaly could be best represented by the gravity effect of a sphere. Calculations were then made based on a theory put forward by Nettleton (5). Two sets of calculations were made for two separate assumptions. Firstly the anomaly was assumed to be caused by a flexure of the Gambier Formation/Knight Group unconformity alone, using the known density contrast of 0.73. Secondly it was assumed to be caused by a flexure of the hypothetical Knight Group/Jurassic unconformity. Outcropping Jurassic sandstones are reported to have densities up to 2.35, so a value of 2.5 was assumed at depth, giving a density contrast of 0.25 at the latter unconfirmity. Values were then calculated for the depth to the two undonformities. The results covered a wide range depending on the profiles used. However, additional control was available from the log of Knight's Dome No.2, a well situated approximately 3½ miles to the north of the gravity maximum. Only 175 feet of Gambier formation was present and the well bottomed at 2013 feet, still in Knight Group. The gravity calculations of the depth of the Gambier Formation were absurd, but the depth to the Knight Group/Jurassic unconformity ranged from 2,300 to 5,000 feet. The best theoretical fit was obtained for profile A-B (fig.1). This profile gave a depth of 2,900 feet to the Jurassic beds. d

While the above calculations are very assumptive, it is thought they emphasize the fact, that if the gravity anomaly is caused by a flexure, it is at a reasonable depth, at least affecting the immediate pre-Tertiary beds, as well as the Tertiary itself.

3. TANTANOOLA SURVEY

0016

(a) Field Work

The field work took place during the first week of June, 60 gravity stations being established. The gravity values were tied to the Mt. Gambier Pendulum Station. The traverses were somewhat irregular depending on the tracks available, and the stations were approximately ¼ mile apart. Three gravity base stations were established and the gravity observations adjusted to them. Closure errors were very small. No terrain correction was applied as the stations were placed well away from any hills in the area.

(b) Elevation Correction

All stations were levelled accurately, datum being as before and closure errors of better than 0.25 ft. being obtained. The elevation correction factor was again 0.065 mg./ft.

(c) Latitude Correction

Each station was positioned by planetabling and was accurate to at least 50'. The latitude of a point on the map was obtained from the South Australian Lands Department and absolute corrections made, using an overlay of scale 1.265 mg./mile.

(d) Results and Interpretation

The results of the gravity survey are shown on plate 3 of Bouguer gravity map of the Tantanoola survey.

It has been postulated from previous geological work that there is a small anticline in the area with a north west- south east axis, approximately coincident with the road on which stations 36 to 40 are situated. Some, notably O'Mara (3), consider that the anticline is faulted parallel to the road and just to the east of it.

The gravity results support the existence of an east dip, as there is a consistent decreasing gradient to the east of, and with approximately parallel strike to, the above road.

The gravity contours also indicate the existence of the small fault as suggested by O'Mara, however again the higher values are on the southwestern side, which is indicated by the geology to be down-thrown (see section 5).

There is also slight evidence for the existence of an anticline, with some closure to the south, the axis however being some 1000 odd feet west of the road. More work would be required to the south and west, however, before any definite feature could be determined from gravity results. It is thought that the presence of basalt,(O'Mara 3) in the western portion of the area covered has had some effect on the gravity readings causing irregularities in the gravity contours.

4. SUMMER HILL SURVEY

(a) Field Work

The Summer Hill survey was carried out from the 8th to 10th August in conjunction with a larger survey in south west Victoria. 104 gravity stations were established at approximately 800 feet intervals along the available roads and tracks in the area. Five gravity base stations were established and the observations adjusted to them. The values were tied to the Mt. Gambier Pendulum Station. A number of traverses could not be closed, but those that were gave very small closure errors.

(b) Elevation Correction

For this survey no accurate elevation datum could be located in the near proximity, and the time was not available to run a long accurate levelling traverse to the nearest bench mark. An estimate was made of Mean Sea Level at the Glenelg River bridge at

Nelson and this used as datum. A discrepancy, the magnitude of which is probably not very great, thus exists between the elevation correction of the surveys. However, unless it is wished to compare accurately the actual Bouguer values of the three separate surveys, then this discrepancy is not very important. The same elevation correction 0.065 mg./ft. was used as in the other surveys and the height of each station is considered accurate to 0.25 ft.

(c) Latitude Correction

A plane table sheet, scale 1" = 1000 ft. drawn up during Dixon's (2) field work, was used as a base map. For the most part stations could be placed along roads at identifiable points, such as corners or intersections. Where this was not possible the distance between stations was taken whilst levelling. The stations are considered to be positioned to within 50-100ft. The latitude of the Nelson Bore shown on Dixon's map was known, and absolute latitude corrections were then made using a scale of 1.267 mg./mile.

(d) Terrain Corrections

Since it was necessary to place stations on or near hills and near the steep banks of the Glenelg River, a terrain correction was made for the appropriate stations, using the contours on the plane table sheet. The largest correction was 0.14 mg. but the majority range from 0.01 to 0.04 mg.

(e) Results and Interpretation

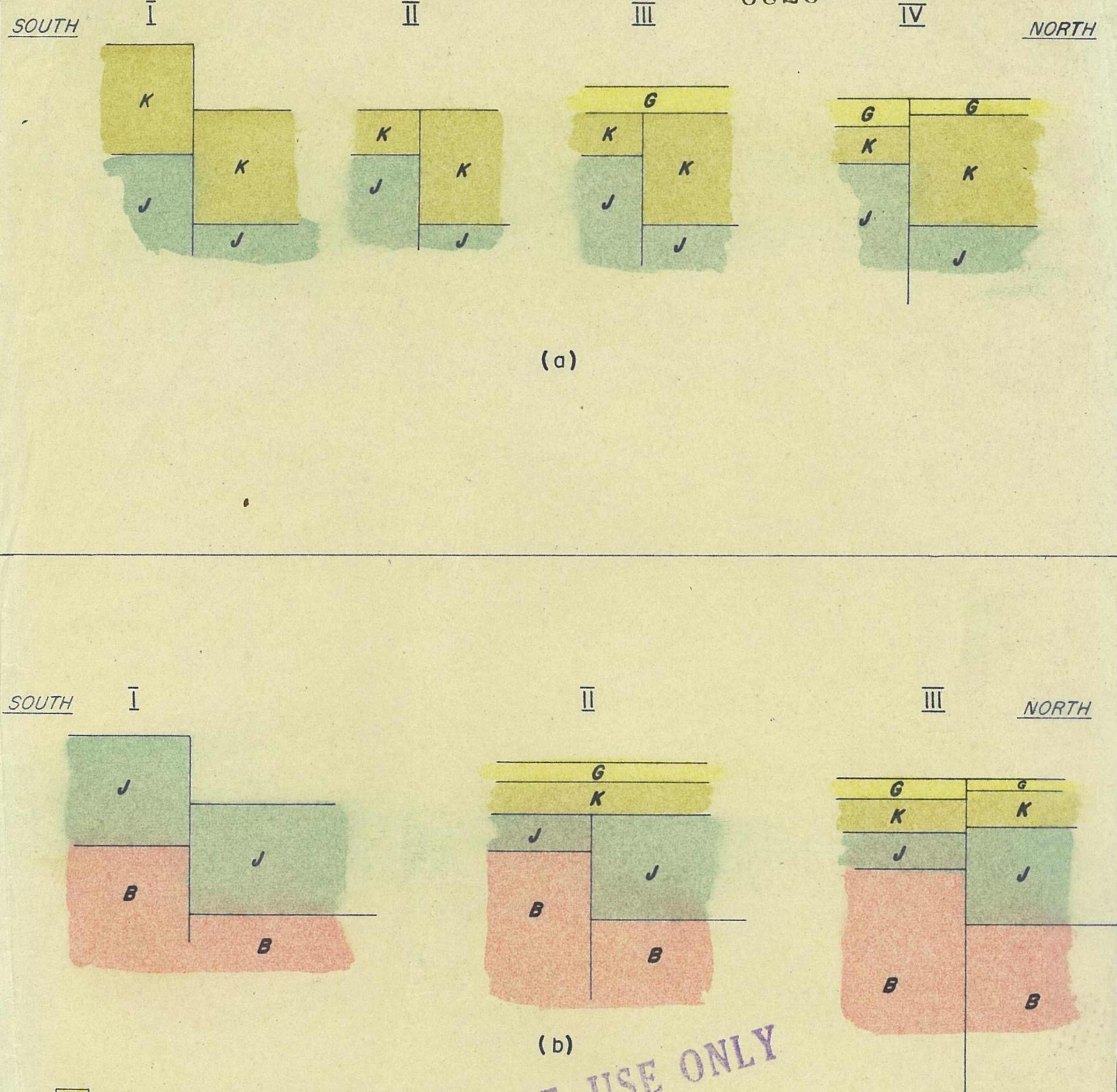
The observed Bouguer gravity values contoured at an interval of 0.25 mg. are shown on Plate (4). A strong regional effect is known to exist in this area, from both South Australian Mines Department and Bureau of Mineral Resources reconnaissance gravity surveys. An attempt was made to eliminate it by smoothing and fitting together the gravity profiles along a network of intersecting lines. Smooth contours were then drawn using these profiles and values interpolated from them for each station. These values were then subtracted from the observed Bouguer values to give the residual. The residual values and contours are shown on Plate 4(a).

The direct pupose of this survey was to ascertain whether the "Summer Hill Anticline" as reported by Dixon (2) existed at depth and if so whether there was any closure on the south eastern end. Both the observed and residual contours give no indication of an anticline. It seems certain that the structure exists only in the Gambier formation and does not extend to the unconformity between the Gambier Formation and Knight Group.

However, there is confirmation of the Nelson fault as mapped by Dixon, although its possible extension to the northwest does not show up. The faulting is more apparent on the Bouguer map and can be noted running almost parallel to the road from Stations N41 to N9. Rather than simply extending to the northwest from Station N41 the contours suggest that the faulting may be a step system perhaps with enechelon continuation further to the south. Again it should be noted that the higher gravity values are on what is considered to be the downthrown side of the fault (see section 5).

The small high on the residual map near Station N89 could be due to structures as mapped by Dixon or possibly a slight doming of the Gambier Formation/Knight Group unconformity.

0020



G Gambier Formation.

K Knight Group.

J Jurassic.

B Basement. (pre-Jurassic.)

FIG. 2

Possible Geological Explanations of Gravity Anomalies over Faults in Gambier Sunklands.

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5. CONCLUSIONS

0021

The following points can be made upon reviewing the gravity results and considering their bearing on the general concept of the area.

Structures existing in the Gambier limestone cannot be relied upon to continue with depth. The generally accepted theory that the main Tertiary features are faults rather than folds is strongly supported by the gravity data. The Allendale and Nelson faults are upheld as two of the main Tertiary structures.

There is however some difficulty in explaining the higher gravity values being on what geologists regard as the downthrow side of the Nelson, Allendale and Tantanoola faults. This anomaly cannot be explained as a regional effect since its removal in the first two cases does not alter the relative position. The density column into the Jurassic also provides no answer. Two possible situations are put forward to explain the gravity results and both are dependant on the fact that reverse movement has occurred along the fault zones. They are illustrated in fig.2 (a) and (b), the diagrams being purely illustrative and not to any scale. Reversal has been suggested already by Boutakoff and Sprigg (6) and the gravity results have strongly supported their deductions. From the fact that the gravity drop over the faults is not very large it appears that the various movements have almost nullified themselves as far as the gravity effect is concerned. Since the Tertiary downthrow is considered to be several hundreds of feet in each case, then the deeper and original faulting must have been very considerable for its gravity effect to over compensate what would be a large anomaly caused by a displacement of the relatively shallow Gambier Formation/Knight Group unconformity.

It is suggested that to obtain a clear picture of any reversal, seismic data across several of the major faults, must be obtained.

B I B L I O G R A P H Y 0022

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(5) Nettleton, L. L. - Gravity & Magnetic Calculations - Geophysics Vol. 7, p.293-310, 1942.

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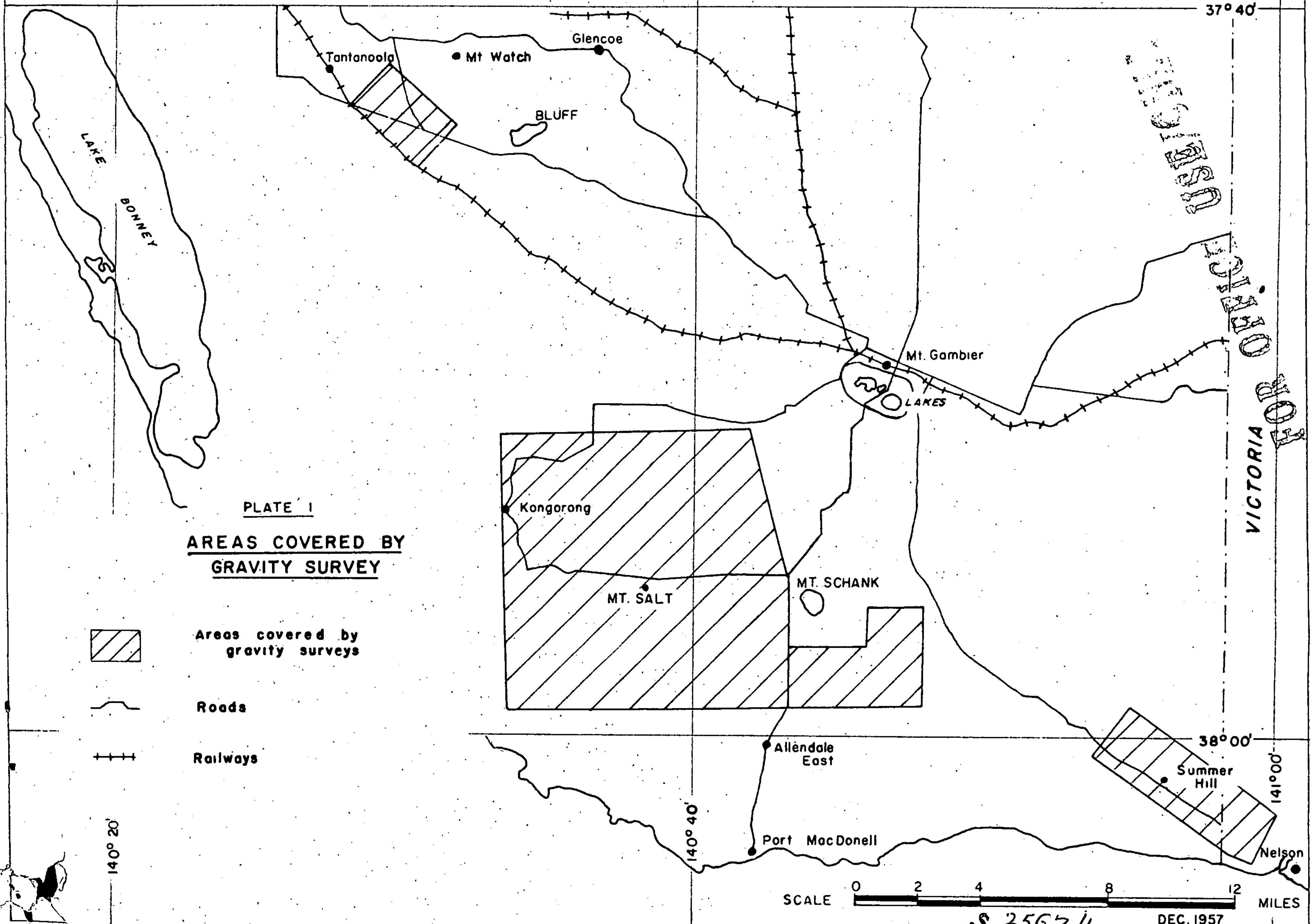

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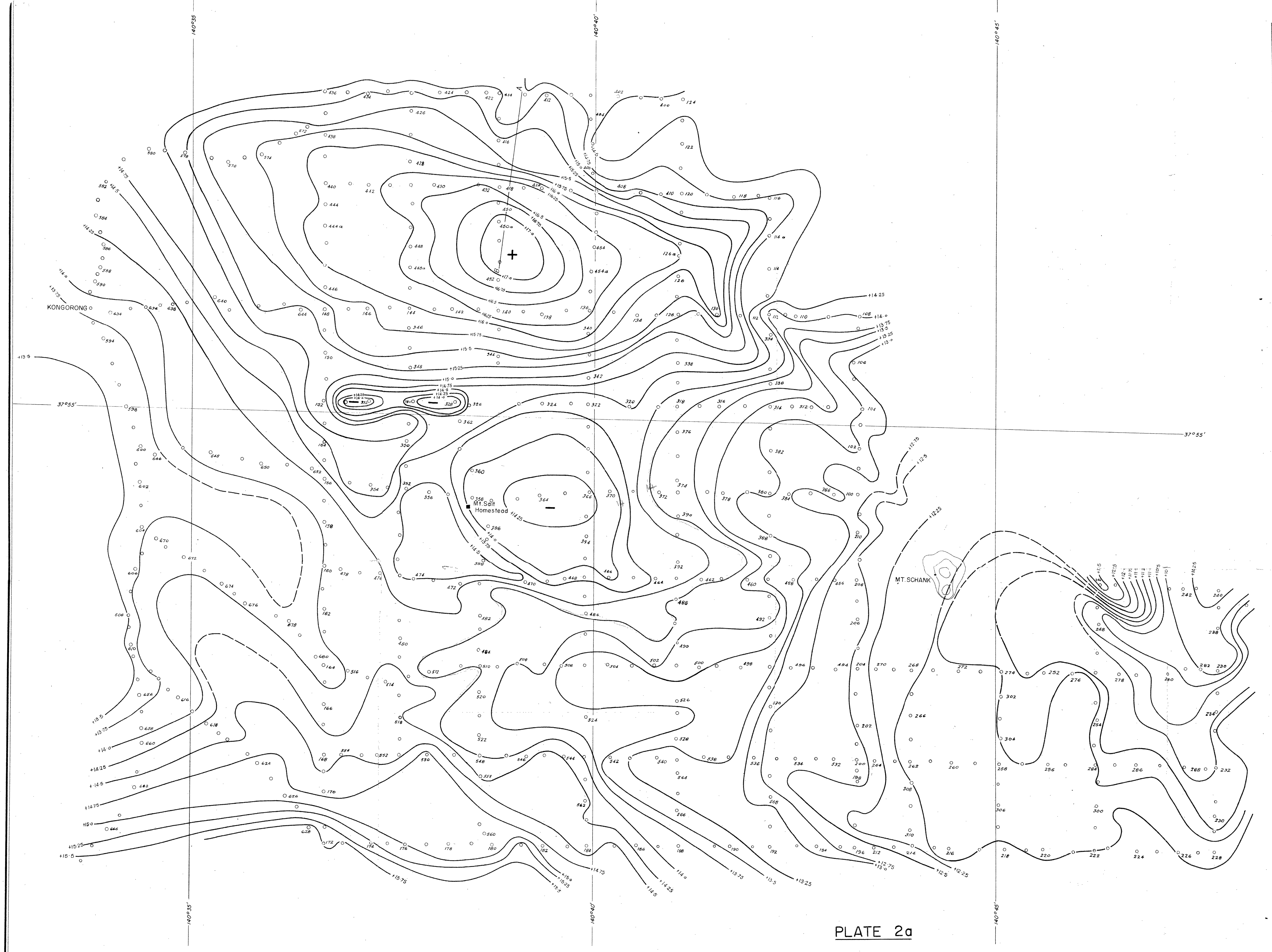

PLATE 2a

Contour Interval. 0·25 Mg.
Gravity Station. ○ 532

Note:- All co-ordinates are approximate.

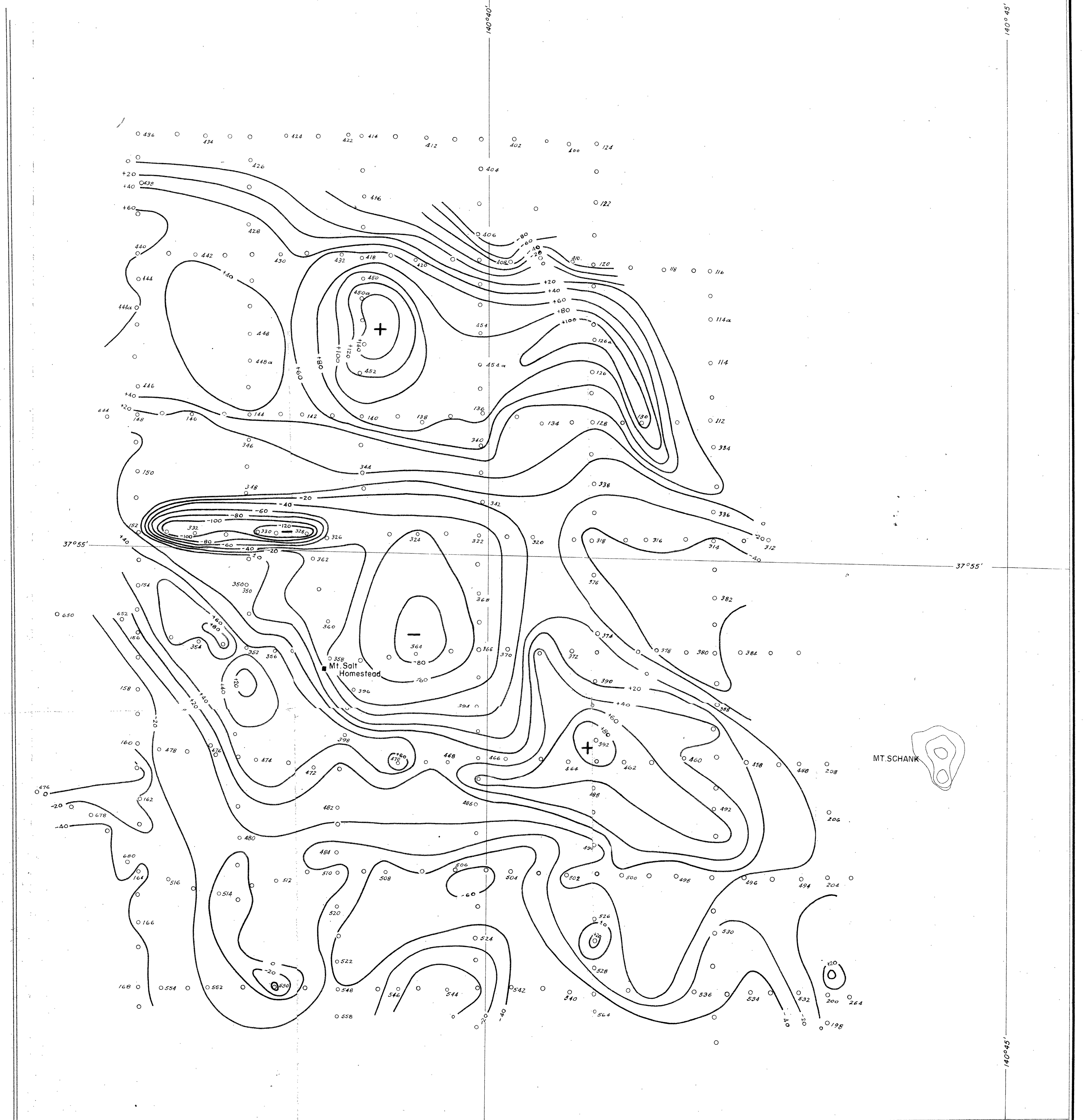

PLATE 2b

Calculated from formula $\frac{\delta^2 G}{\delta z^2} = \frac{1}{62k^2r^2}\ 44H(o) + 16\overline{H}(S) - 12\overline{H}(S\sqrt{2}) - 48\overline{H}(S\sqrt{5})$ *with ½ mile grid spacing.*
Contour Interval. 20×10^{-15} *cgs. units.*
Gravity Station. ○ 122

Compiled: R. Walker.
Checked: [signature]

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Exploration Department

Plate 2a. BOUGUER GRAVITY MAP MT. SALT–MT. SCHANK AREA

Plate 2b. SECOND DERIVATIVE GRAVITY MAP MT. SALT–MT. SCHANK AREA

PLATE 2

FROME REPORT: Detailed Gravity Surveys in the Mt. Salt–Mt. Schank, Summer Hill and Tantanoola Areas of the Gambier Sunklands. By K.A. RICHARDS.

SCALE: 2 INCHES = 1 MILE.
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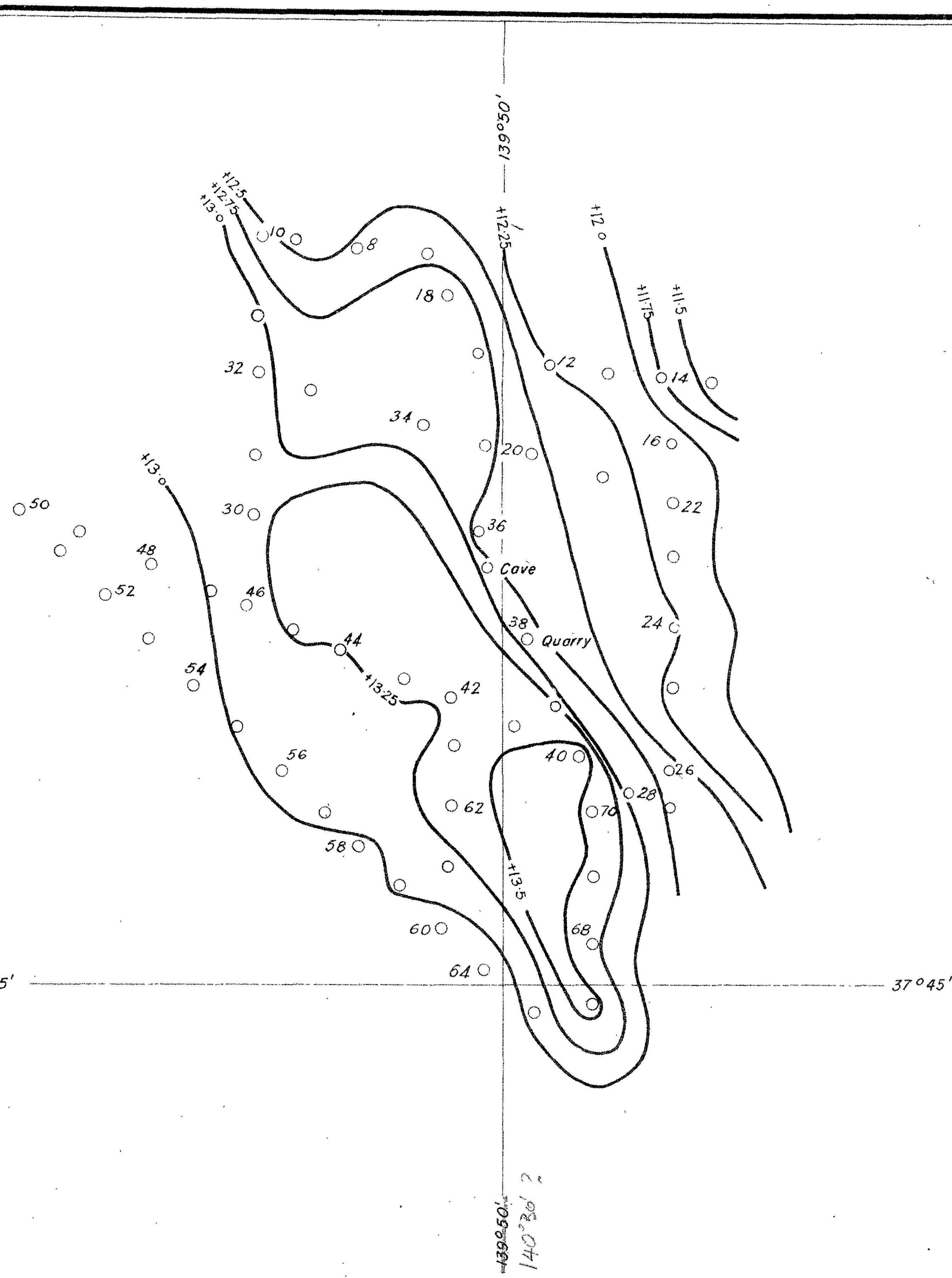

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BOUGUER GRAVITY MAP
TANTANOOLA AREA

PLATE 3

FROME REPORT: Detailed Gravity Surveys in the Mt.Salt-Mt.Schank, Summer Hill and Tantanoola Areas of the Gambier Sunklands.
By K.A.RICHARDS

SCALE: 2 INCHES = 1 MILE

½ 0 1 1½ MILES

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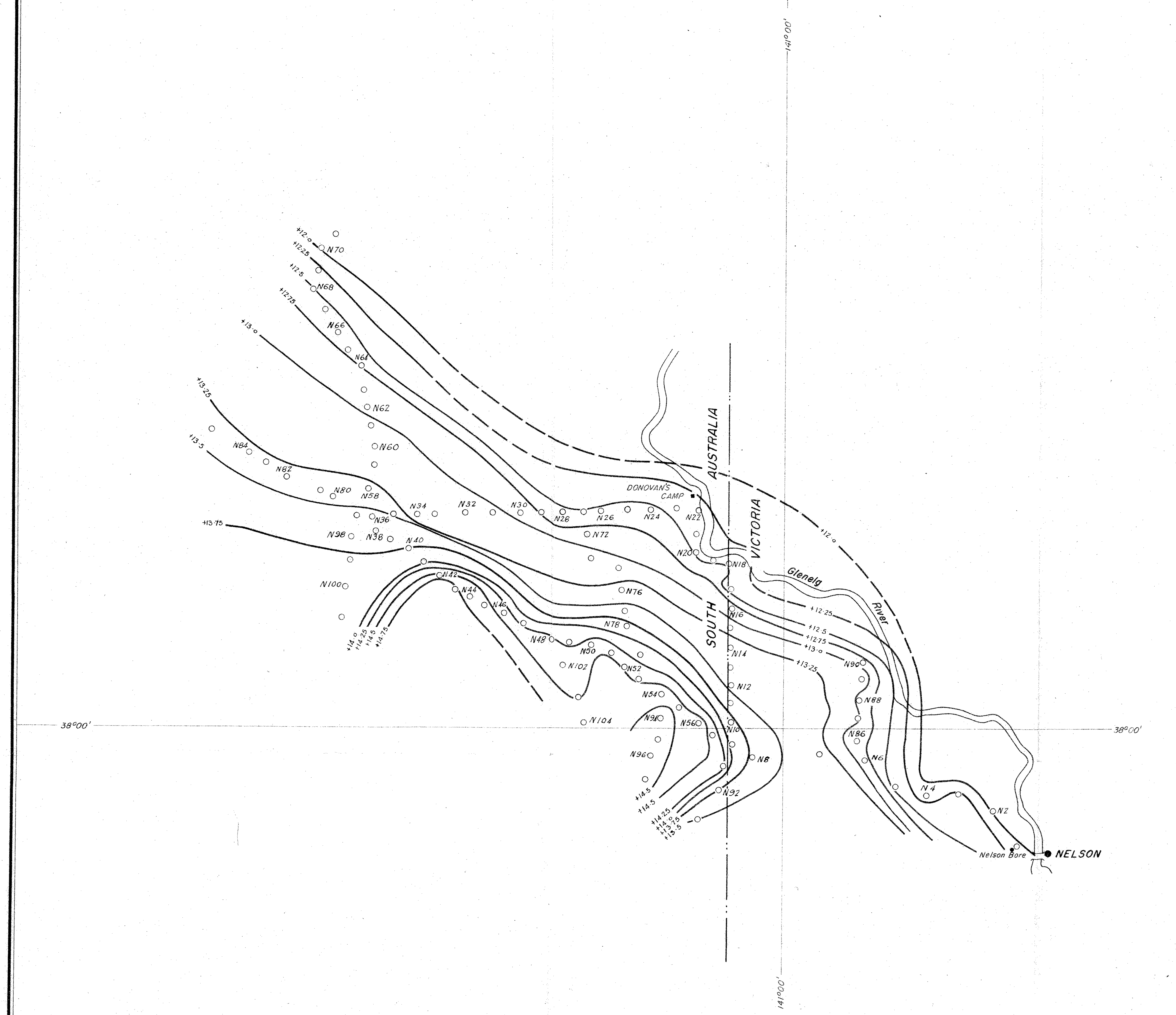

PLATE 4a

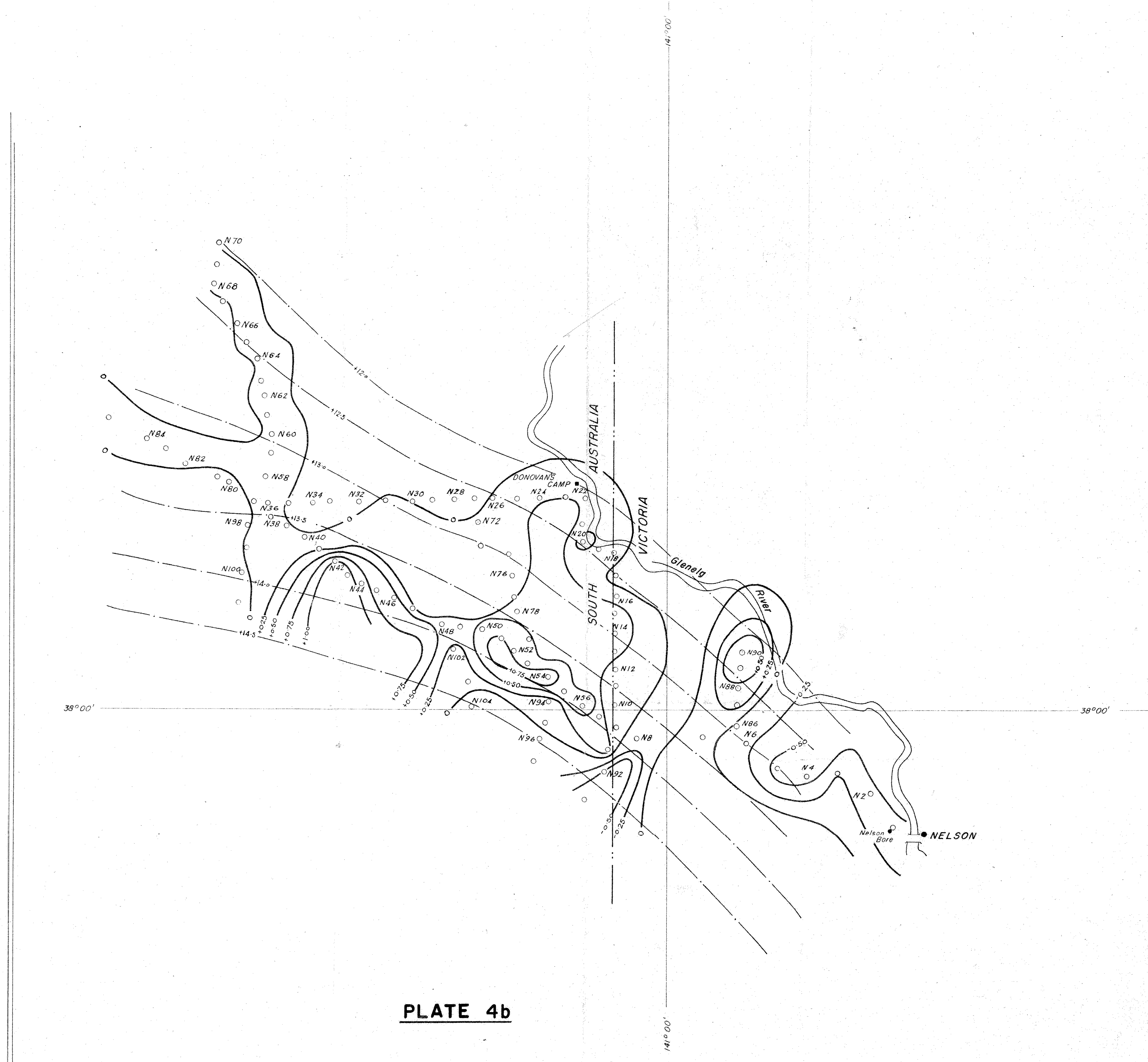

PLATE 4b

Contour Interval. 0·25 Mg.
Gravity Station. ○ N56

Contour Interval. 0·25 Mg.
Gravity Station. ○ N2
Residual Gravity Contours.
Regional Gravity Contours.

Note - All co-ordinates are approximate.

Compiled: R. Walker.
Checked:

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Exploration Department

Plate 4a. **BOUGUER GRAVITY MAP SUMMER HILL AREA**

Plate 4b. **RESIDUAL GRAVITY MAP SUMMER HILL AREA**

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PLATE 4

FROME REPORT: Detailed Gravity Surveys in the Mt. Salt - Mt. Schank, Summer Hill and Tantanoola Areas of the Gambier Sunklands.
By K.A. RICHARDS.

SCALE: 2 INCHES = 1 MILE.

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