DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

1976/73

GRAVITY SURVEY ALONG SEISMIC TRAVERSES IN THE NORTHEASTERN PART OF THE EROMANGA BASIN, QUEENSLAND, 1967

by

M.D. WATTS AND F.W. BROWN

1976/73

GRAVITY SURVEY ALONG SEISMIC TRAVERSES IN THE NORTHEASTERN PART OF THE EROMANGA BASIN, QUEENSLAND, 1967

by

M.D. WATTS AND F.W. BROWN

CONTENTS

ILLUSTRATIONS

F. D. ATKINSON, Commonwealth Government Printer

Plate 13. Relation of Bouguer anomalies to seismic structure between Thunderbolt No. 1 and Lake Galilee No. 1 wells

Plate 14. Diagramatic elevation misclosures and adjustments in north and southeast of survey area

FOREWORD

This report was written mainly by Mr Watts prior to 1970; thus the subject matter is not up to date. For a more comprehensive discussion of the geology and geophysical information in the northeastern Eromanga Basin reference can be made to reports by Harrison, Anfiloff & Moss (1975), Harrison & Bauer (1975), and Senior, Harrison & Mond (in press).

Some usages in the report are not those presently in use by the Bureau of Mineral Resources, in particular the appearance of non-metric units on some illustrations which are common to earlier reports.

SUMMARY

Between May and August 1967, 2700 gravity readings were made at seismic shot-points in the northeastern Eromanga Basin. The shot-points were spaced at about 1 km intervals along lines 10 to 20 km apart which formed an irregular grid over parts of six 1:250 000 sheet areas. The gravity data were analysed using a 'stripping' technique to remove the gravity effect of the Mesozoic section so that the gravity expressions of pre-Mesozoic structures could be examined.

The survey results, combined with seismic evidence, show that sedimentary structures in the northeastern Eromanga Basin cannot be predicted by analysis of Bouguer anomalies alone, because no consistent correlation between Bouguer anomalies and pre-Mesozoic sediment thicknesses can be demonstrated. The densities of both the pre-Mesozoic sediments and the underlying basement probably vary over the survey area.

INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics (BMR) took 2700 gravity readings at seismic shot-points in the northeastern Eromanga Basin between May and August 1967. The shot-points were surveyed on a series of reflection seismic surveys conducted by Amerada Petroleum Corporation between September 1965 and September 1967. They were spaced at intervals of about 1 km along lines about 10-20 km apart which formed an irregular grid over TANGORIN*, MUTTABURRA, and the adjacent parts of HUGHENDEN, MANUKA, BUCHANAN, and GALILEE (Plates 1 and 2).

The main objective of the gravity survey was to test the applicability of the gravity method in delineating the structure of the pre-Mesozoic sediments. Survey operations were facilitated by the availability of precise elevation control at seismic shot-points, the presence of access tracks constructed for the seismic survey, and low topographic relief throughout the survey area.

For the analysis of the data it was proposed to employ the stripping technique of Falcon & Tarrant (1951) to remove the effect of the Mesozoic section and then to establish correlation with geological structure where this was clearly evidenced in the seismic results.

GEOLOGY

The survey area includes the outcropping zones of three overlapping basins; the Drummond, Galilee, and Eromanga Basins (Plate 3). Basement is represented by Devonian metamorphics, volcanics, and granite of the Anakie Complex, all of which crop out to the east of the Drummond Basin. Crystalline rocks encountered in exploratory boreholes farther west are probably volcanics of the Drummond sequence.

The Anakie Complex is a north-northwest trending basement ridge consisting of the Anakie Metamorphics (intermediate volcanics and sediments metamorphosed in the mid-Devonian), the Ukalunda Beds (Middle Devonian volcanics and sediments), and Upper Devonian intrusive granite (Olgers, 1972).

The Drummond Basin is a structural remnant of a large intermontane depositional basin that developed in the Tasman Geosyncline after the late Middle Devonian Tabberabberan Orogeny. It received up to 12 000 m of predominantly fluviatile sediments which were transported into the basin by a generally north-flowing river system. Sedimentation was terminated during the Middle Carboniferous Kanimblan Orogeny, when the sequence was folded and uplifted to form a structural high shedding detrital material into the Bowen and Galilee Basins (Olgers, op. cit.).

The Galilee Basin overlies the western part of the Drummond Basin, obscuring its western margin. Brown, Campbell & Crook (1968) consider that sedimentation commenced in the Late Carboniferous, with the deposition of glacial and fluvioglacial sediments, followed by discontinuous terrestrial sedimentation until upper Triassic times. Up to 2700 m of pre-Jurassic sedimentary section is believed to exist in the Galilee Basin. Mild folding took place at the end of the Triassic, followed by erosion and subsidence during the Early Jurassic when the Eromanga Basin began to form.

---

* The names of 1:250 000 Sheet areas are printed in capital letters to distinguish them from place names.

The Eromanga Basin obscures the western margin of the Galilee Basin, and is itself masked by Quaternary cover. It contains up to 1100 m of largely marine Cretaceous and Jurassic sediments, which dip gently and uniformly towards the centre of the basin.

Four oil exploration wells have been drilled in the survey area. Their stratigraphy is summarized by Olgers (op.cit.). Brookwood No. 1 (Exoil, 1962c), Thunderbolt No. 1 (Amerada, 1966a) and Tower Hill No. 1 (Amoco, 1967) all bottomed in acid volcanic rocks now believed to be of Middle Devonian age. Lake Galilee No. 1 (Exoil, 1964) drilled 565 m of sediments of Middle to Late Devonian age below the Galilee Basin sequence; Drummond Basin sediments were not encountered.

PREVIOUS GEOPHYSICS

Gravity surveys

A reconnaissance gravity survey covering the detailed survey area and its surrounds was made by BMR in 1963 (Gibb, 1968). Of the gravity features delineated in the vicinity of the present survey area, only two, the Aramac Gravity Platform and the Tangorin Gravity Depression, are of relevance to this study. Gibb (op. cit.), interpreted the Aramac Gravity Platform from aeromagnetic and seismic evidence as representing a basement swell, with not more than about 1200 m of sedimentary cover. Borehole data from Brookwood No. 1 (Exoil 1962c) and Thunderbolt No. 1 (Amerada 1966a) wells indicate slightly greater basement depths, since granitic rocks were encountered at 1460 m and 1600 m respectively in the wells. Gibb (op. cit.) considered that the Tangorin Gravity Depression was caused by a buried sedimentary trough, but information from subsequent seismic surveys and a borehole have shown this interpretation to be incorrect. Basement was encountered in the Tower Hill No. 1 well (Amoco, 1967) at 1460 m, the same depth as in Brookwood No. 1 which is on the Aramac Gravity Platform.

Darby (1965) made gravity readings at the shot-points of the Torrens Creek seismic survey (Exoil, 1962a) in east TANGORIN. The results confirm the regional gravity contours which delineate a broad gravity spur in this area. Local irregularities in the gravity contours were correlated with northwest trending structures mapped by the seismic survey.

Aeromagnetic surveys

An aeromagnetic survey was carried out over the eastern part of the survey area for Exoil (1962b). The interpretation providing basement depth contours (Plate 5) is of doubtful quality, and the interpreted magnetic basement depths were not confirmed by subsequent seismic results.

Seismic surveys

Surveys for the Artesian Basin Oil Company and for Exoil N.L. were reviewed by Jones (1970). Extensive surveys for Amerada (1965, 1966a, 1966b) linked up previous surveys and mapped the 'P' horizon on TANGORIN, MUTTABURRA and the adjacent parts of HUGHENDEN, GALILEE, BUCHANAN, and MANUKA. The 'P' horizon, a strong, persistent event

believed to originate near the top of the Permian, was traced throughout the area by conventional reflection techniques using explosives as energy sources. Events below the 'P' horizon were generally poor or non-existent. Subsequently, a weight-dropping survey was undertaken by Ray Geophysics for Amerada (1966c) with the primary objective of delineating sub-'P' reflectors. The survey was successful; events as deep as 3.5 s reflection time were recorded. The basement depth was estimated to reach 6100 m (Plate 6).

The seismic surveys showed that the 'P' horizon is gently undulating. Elongate domal structures and minor faulting of the horizon have two important trends: a pronounced northeast trend in the south of the area, and a less pronounced northwest trend in the north. The quality of 'P' horizon events is good, and they are thus considered reliable for mapping structures at this level. Lower horizons delineated by the Ray Geophysics surveys are fairly reliable, but some events are discontinuous (Plate 7).

DENSITY DATA

Density values obtained from surface rock samples are not representative of the same rocks at depth because of the effects of near-surface weathering. Densities obtained from subsurface samples from wells are therefore desirable, but the scarcity and poor distribution of wells militate against obtaining in-situ samples below the surface. Within the survey area, only four stratigraphic boreholes, Tower Hill A-1, Brookwood No. 1, Thunderbolt No. 1 and Lake Galilee No. 1, have been drilled (Plate 3). Continuous formation-density gamma-gamma logging has been carried out in the Tower Hill A-1 and Thunderbolt No. 1 bores, but in the other two bores density information was obtained only from measurements on irregularly-spaced core samples. In Table 1, densities derived from gamma-gamma logs and core samples from Thunderbolt No. 1 well are compared. The results show that densities derived from gamma-gamma measurements are in excellent agreement with those obtained from the cores.

A comparison of average densities for the same formation in different boreholes shows that a variation of about 0.1 tm^{-3} occurs (Plates 8 and 9). This is probably due to lateral density variations in the formation, non-representative core sampling, and unreliable picking of stratigraphic boundaries. The following density contrasts between stratigraphic sequences and basement, obtained from analysis of all available data, have been adopted for quantitative interpretation of gravity results:

Eromanga Basin sequence:	-0.17 tm^{-3}
Upper Galilee Basin sequence:	-0.10 tm^{-3}
Lower Galilee Basin sequence:	-0.04 tm^{-3}
Drummond Basin sequence:	+0.04 tm^{-3}
Granitic basement:	0.00 tm^{-3}

Evidence cited later suggests that considerable density variations occur within the basement.

RESULTS AND INTERPRETATION

The method of Falcon & Tarrant (1951) was used to eliminate the gravity effect of known structures, as defined by the 'P' horizon, from the reconnaissance gravity contours, prior to the commencement of the survey. The resultant 'stripped' map, in which the Bouguer anomaly contours reflect only sub-'P' mass variations, is shown in Plate 10. It is essentially identical to the original Bouguer anomaly contour map; thus on a regional scale, sedimentary structures above the 'P' horizon do not appear to cause any appreciable gravity variations. The correlations between several Bouguer anomaly features of the survey and the corresponding seismic sections have been examined and are presented in Plates 11 and 12. No consistent correlation appears to exist, so it is not possible to use information from detailed gravity surveys to predict structures at the 'P' horizon level.

The relation between Bouguer anomalies and sub-'P' structure has been examined on a seismic traverse (Amerada, 1966c) between Thunderbolt No. 1 and the Galilee No. 1 wells (Plates 7 and 13). This traverse crosses the eastern edge of the Eromanga Basin and the western edge of the Drummond Basin; the sedimentary section increases from about 2000 m at the western end of the traverse to about 5000 m in the east. Gravity data shown in these plates have been projected from a parallel seismic traverse approximately 5 km north of the Amerada line, and aeromagnetic data have been taken from a report by Exoil (1962b).

The simulated gravity profile for the structural model between Thunderbolt No. 1 and Galilee No. 1 wells (Plate 13) bears little resemblance to the observed profile. Undulations in the western half of the observed profile have no obvious cause and may reflect either sedimentary structures not detected by the seismic survey, or basement density variations. The gradual rise in the computed Bouguer anomaly profile towards the eastern end of the traverse cannot be wholly attributed to thinning of the post-Permian section and thickening of the Drummond Basin. Either some model parameters are substantially incorrect or a regional easterly density increase occurs beneath the sedimentary basins. The absence of any major gravity feature over the Drummond Basin boundary tends to confirm that the pre-Mesozoic sediments have no significant density contrast with the underlying basement and that the main gravity effect may be attributed to basement density variations.

CONCLUSIONS

The gravity survey results, combined with seismic evidence, show that sedimentary structures cannot be detected by analysis of Bouguer anomalies within this area. No consistent correlation between Bouguer anomaly variations and pre-Mesozoic sediment thicknesses was demonstrated.

TABLE 1 Comparison of gamma-gamma densities and core sample density measurements for Thunderbolt No. 1 well (after Amerada, 1966a).

Sample No.	Depth m	Lithology	Density tm^{-3}	Density (core) tm^{-3}	Difference tm^{-3}
2	913	sst	2.43	2.42	+ 0.01
3	1011	shl/slt	2.41	2.53	- 0.12
6	1144	sst	2.40	2.40	0
7	1241	shl	2.53	2.58	- 0.05
8	1384	sst	2.42	2.46	- 0.04
8	1385	sst	2.47	2.49	- 0.02
8	1387	sst/slt	2.48	2.49	- 0.01
9	1540	shl	2.64	2.69	- 0.05
10	1608	dac	2.52	2.52	0
				Mean =	- 0.03

sst - sandstone
shl - shale
slt - siltstone
dac - dacite

REFERENCES

AMERADA PETROLEUM CORP., 1965 - Bowen Downs seismic survey, ATP 76P, Queensland. Petrol. Search Subs. Act Rep. 65/11034 (unpubl.).

AMERADA PETROLEUM CORP., 1966a - Thunderbolt seismic survey, ATP 76P, Queensland. Petrol. Search Subs. Act Rep. 66/11128 (unpubl.).

AMERADA PETROLEUM CORP., 1966b - Yarrowglen seismic survey, ATP 76P, Queensland. Petrol. Search Subs. Act Rep. 66/11133 (unpubl.).

AMERADA PETROLEUM CORP., 1966c - Tower Hill seismic survey, ATP 76P, Queensland. Petrol. Search Subs. Act Rep. 66/11136 (unpubl.).

AMERADA PETROLEUM CORP., 1967 - Well completion report for Thunderbolt No. 1, Qld. Petrol. Search Subs. Act Rep. 67/4245 (unpubl.).

AMOCO PETROLEUM AUST. LTD, 1967 - Well completion report for Tower Hill No. A-1, Qld. Petrol. Search Subs. Act Rep. 67/4271 (unpubl.).

BROWN, D.A., CAMPBELL, K.S.W., & CROOK, K.A.W., 1968 - The Geological Evolution of Australia and New Zealand. Permagon Press, Oxford.

DARBY, F., 1965 - Gravity readings along seismic traverses, central and southern Queensland. Bur. Miner. Resour. Aust. Rec. 1965/91 (umpubl.).

EXOIL N.L., 1962a - Torrens Creek seismic survey. Petrol. Search Subs. Act Rep. 62/1647 (unpubl.).

EXOIL, N.L., 1962b - An airborne magnetometer survey of the Aramac-Mt Coolon area. Petrol. Search Subs. Act Rep. 62/1716 (unpubl.).

EXOIL, N.L., 1962c - Well completion report for Brookwood No. 1. Petrol. Search Subs. Act Rep. 62/1122 (unpubl.).

EXOIL, N.L., 1964 - Well completion report for Lake Galilee No. 1. Petrol. Search Subs. Act Rep. 64/4076 (unpubl.).

FALCON, N.L. & TARRANT, L.H., 1951 - The gravitational and magnetic exploration of parts of the Mesozoic-covered areas of south-central England. Quart. J. Geol. Soc. Lond. 106 pp 141-170.

GIBB, R.A., 1968 - North Eromanga and Drummond Basins gravity surveys, Queensland 1959-1963. Bur. Miner. Resour. Aust. Rep. 131.

HARRISON, P.L., ANFILOFF, W., & MOSS, F.J., 1975 - Galilee Basin seismic and gravity survey, Queenslamd, 1971. Bur. Miner. Resour. Aust. Rep. 175.

HARRISON, P.L., & BAUER, J.A., 1975 - Galilee Basin seismic survey, Queensland, 1975 - Presurvey Report. Bur. Miner. Resour. Aust. Rec. 1975/131 (unpubl.).

JONES, P., 1970 - Flinders River seismic survey, Queensland. Bur. Miner. Resour. Aust. Rec. 1970/52.

OLGERS, F., 1972 - The geology of the Drummond Basin. Bur. Miner. Resour. Aust. Bull. 132.

SENIOR, B.R., HARRISON, P.L., & MOND, A., in press - Notes on the geology of the northern part of the Eromanga Basin. Bur. Miner. Resour. Aust. Bull. 167A.

APPENDIX 1. : Survey Accuracy

Accuracy of elevations

Shot-point elevations used in the computation of Bouguer anomalies, were taken from several seismic surveys carried out independently by different contractors. Some of the surveys were not tied to elevation control points so that large misclosures occur at some line intersections. Ties for elevation control were mainly to oil wells.

The largest misclosures were observed in the northern and south-eastern parts of the survey area. The large misclosures were plotted on gravity traverse maps (Plates 14 and 15) and adjustments to individual legs of the network were made by hand, to improve the quality of the elevation data in these areas. The adjustments were made to reduce height values along poorly-controlled seismic lines to the same bench-mark datum used in the 1963 Reconnaissance Helicopter Gravity Survey and the well-controlled seismic surveys. The following information indicates the magnitudes of the adjustments to legs in the network:

Number of legs adjusted	30
Approx. average length of adjusted legs	24 km
Total range of adjustments	10.7 m
Maximum adjustment in a single leg	5.8 m
Mean of adjustments	2.0 m

The mean of adjustments can be taken as a measure of the average elevation error although the relative errors between individual stations on each traverse would be much smaller. The general accuracy of elevations in well-controlled areas is probably better than 1 m.

Accuracy of observed gravities

The gravity network was adjusted to gravity base stations at Hughenden and Torrens Creek and to base stations of previous reconnaissance surveys. Drift control was maintained by ties to previously established gravity stations, thus obviating the need to take frequent repeat readings. The accuracy of observed gravity measurements is estimated to be $\pm$0.2 mGal.

Accuracy of Bouguer anomalies

From the average elevation and observed gravity errors, the average Bouguer anomaly error is calculated to be $\pm$0.6 mGal. In areas of poor elevation control, the error may exceed $\pm$1 mGal.

APPENDIX 2 : Survey Statistics

Commencement Date: 26/5/1967

Date of last reading: 11/8/1967

Personnel:

Geophysicist:	M.D. Watts
Technical Assistant:	K.W. Kirby
Field Assistant:	M. Dando

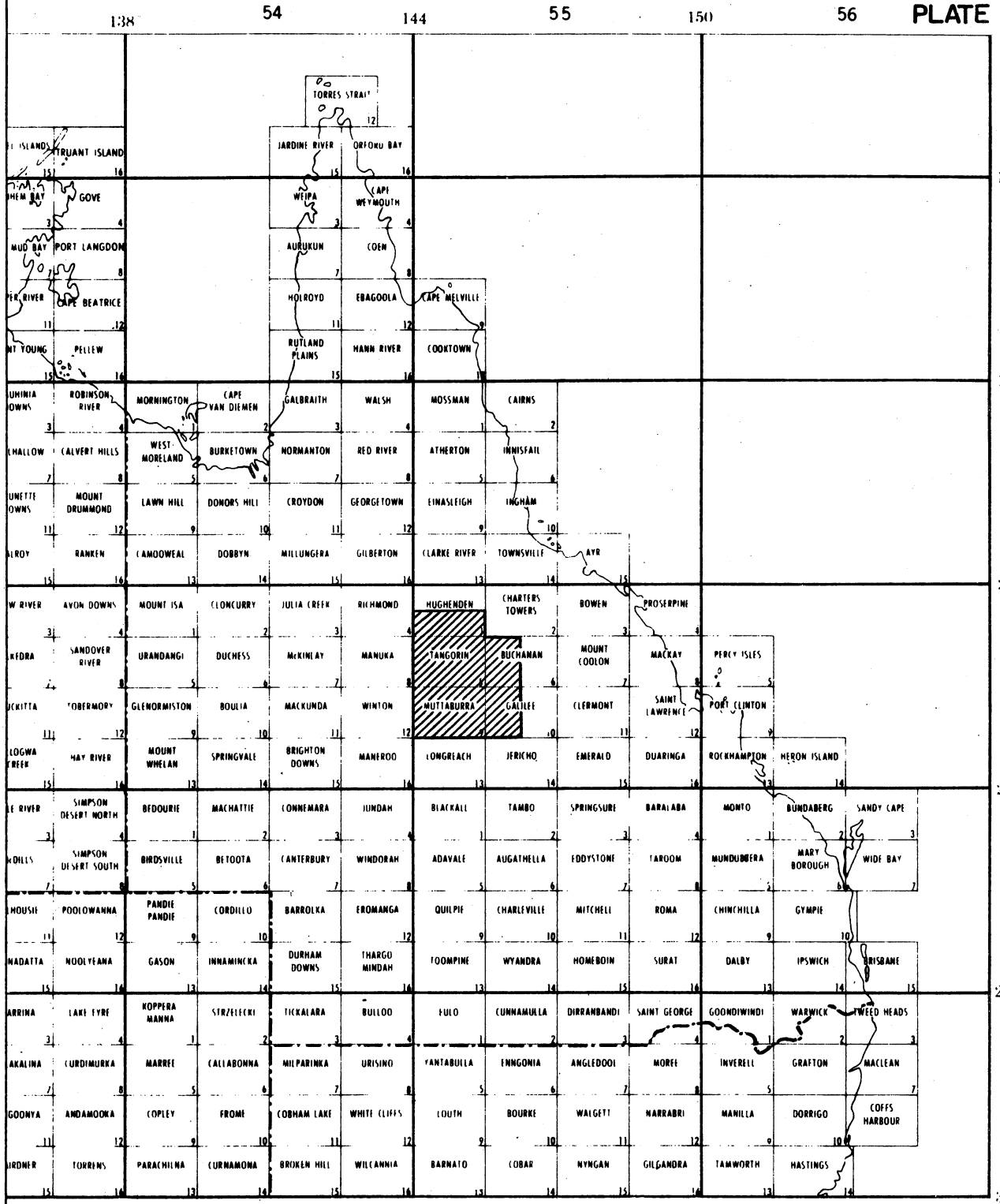
Vehicles: SWB Land-rover (fitted with vehicle tripod) - ZSM 410
International 1 ton 4 x 4 ZSU 179

Gravity meter: Worden 61; calibration factor 0.09067 mGal per scale div.
(Calibrated at Townsville 22/5/1967)

Number of readings: 2700

Number of new stations: 2534

PLATE 1



Survey area

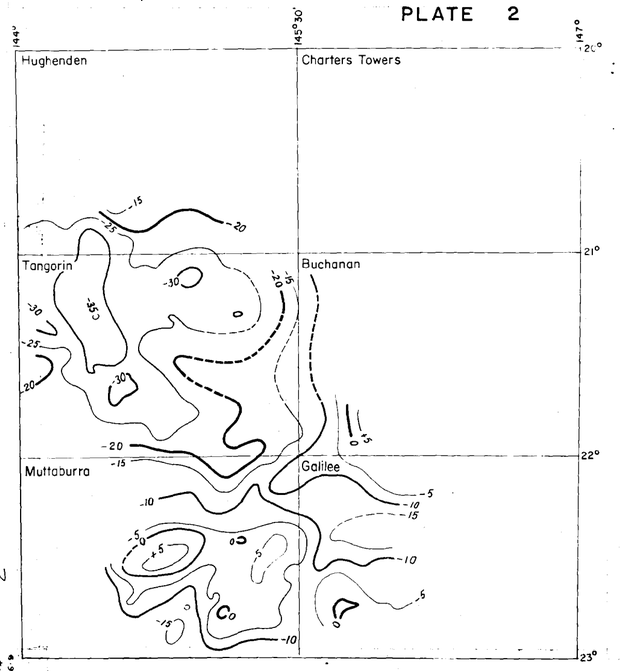
KILOMETRES 200 0 200 400 600 800 1000 1200 KILOMETRES

LOCALITY MAP

Record No. 1976/73

F55/B2-61A

PLATE 2



20° 30'

21° 00'

22° 00'

23° 00'

144° 00'

145° 30'

146° 15'

HUGHENDEN

TANGORIN

MUTTABURRA

BUCHANAN

GALILEE

TORRENS CREEK

TOWER HILL No. 1

THUNDERBOLT No. 1

LAKE GALILEE No. 1

MUTTABURRA

ARAMAC

BOUGUER ANOMALY CONTOURS

For the calculation of Bouguer anomalies, 1·9 tm^{-3} has been adopted as an average rock density

Profile (See Plates 7 and 13)

10 0 20 40 Kilometres

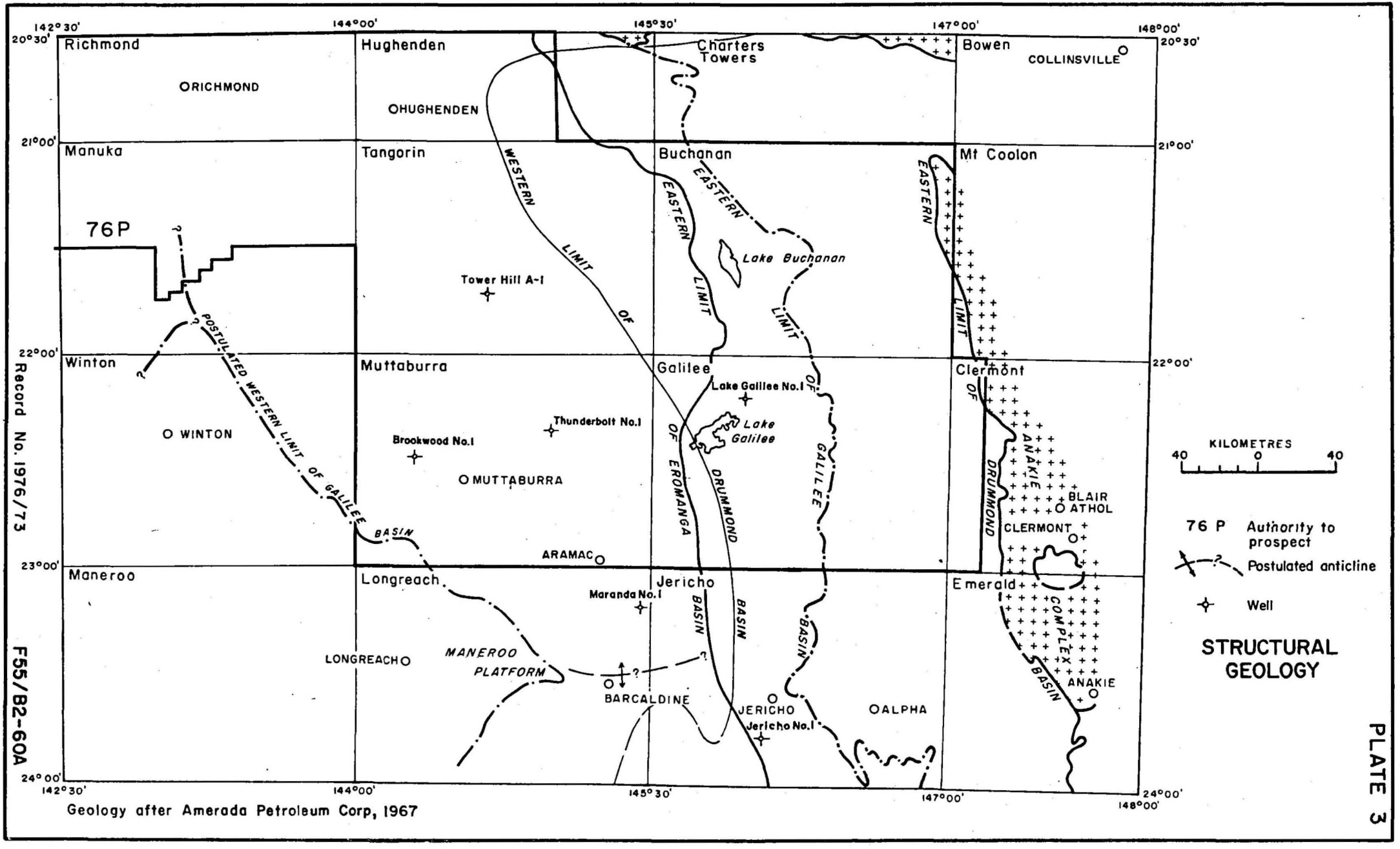
•1881 −3·2 Gravity station with number and Bouguer anomaly value

Isogal gravity stations

Bore hole

Record No. 1976/73

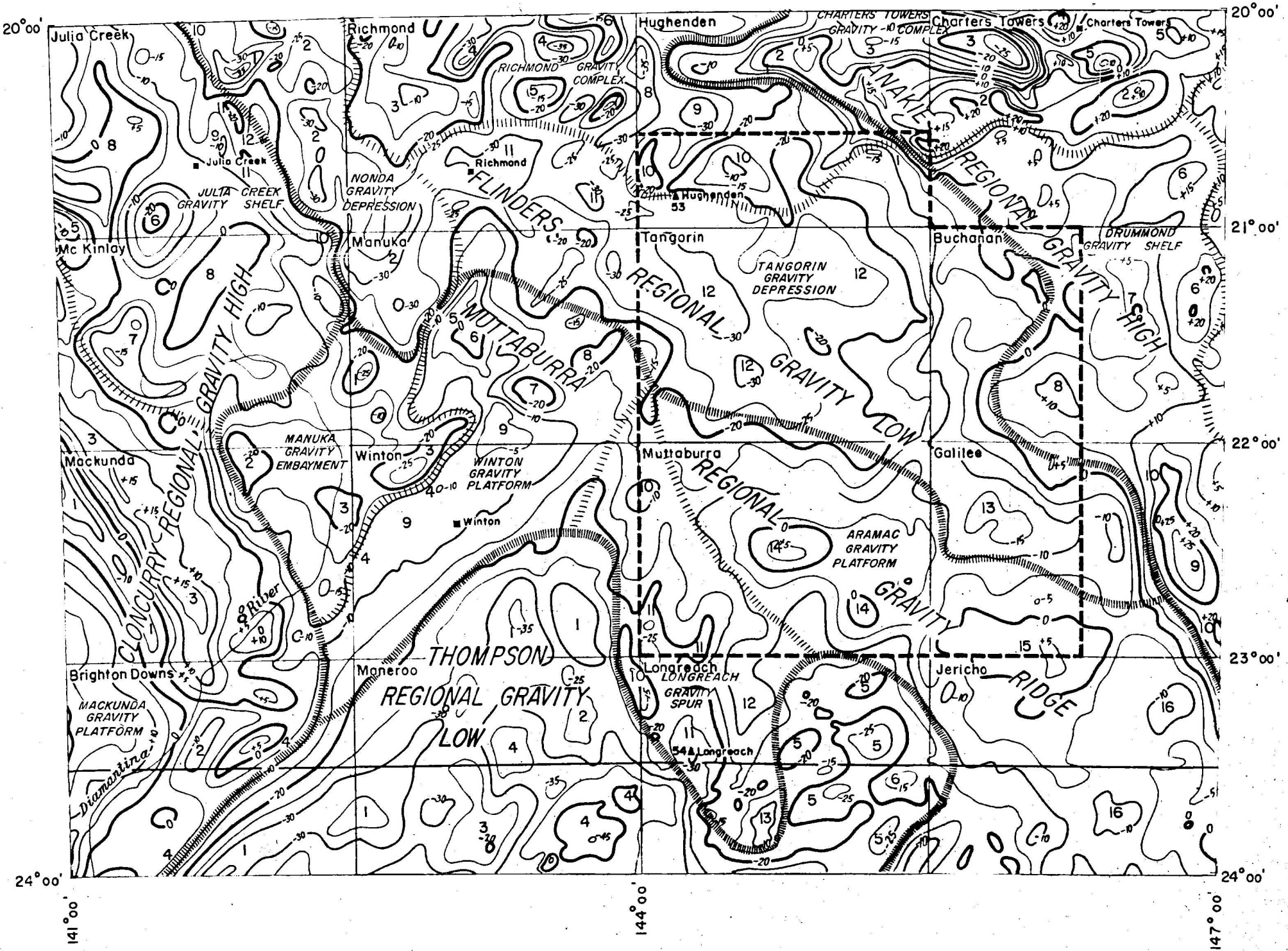
F55/B2–62



Record No. 1976/73

F55/B2-60A

PLATE 3



Isogals, values in milligals

▲ 53 BMR gravity pendulum station

Winton 1:250 000 map area

Survey area

Gravity province boundary

Gravity unit boundary

15 Gravity sub-unit

40 0 80 160 KILOMETRES

Bouguer anomalies are based on the observed gravity values at BMR pendulum stations:

No. 50	Clermont	978,776·1 milligals
No. 51	Townsville	978,624·0 "
No. 53	Hughenden	978,604·3 "
No. 54	Longreach	978,790·3 "
No. 55	Cloncurry	978,651·9 "
No. 56	Boulia	978,793·9 "
No. 57	Birdsville	979,004·1 "

For the calculation of Bouguer anomalies $1{\cdot}9\ tm^{-3}$ has been adopted as an average rock density

Elevation datum – Queensland State

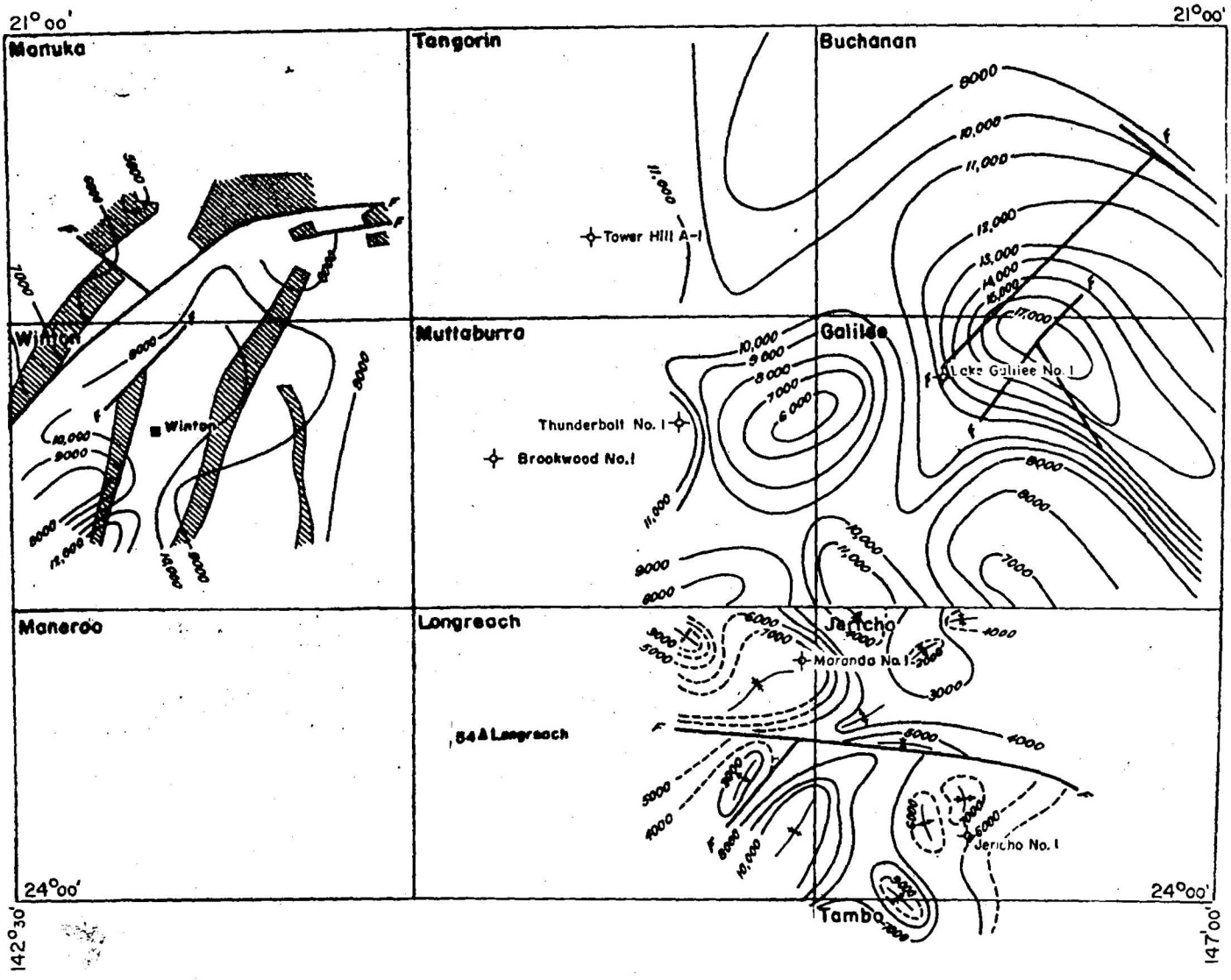
BOUGUER ANOMALIES AND GRAVITY PROVINCES

Contour interval 5 milligals

Record No. 1976/73

After Gibb, 1968

F 54/B2-43-4



LEGEND

- Anticlinal axis
- Synclinal axis
- —5000— Depth to basement in feet
- "Basic mass"
- —F— Fault

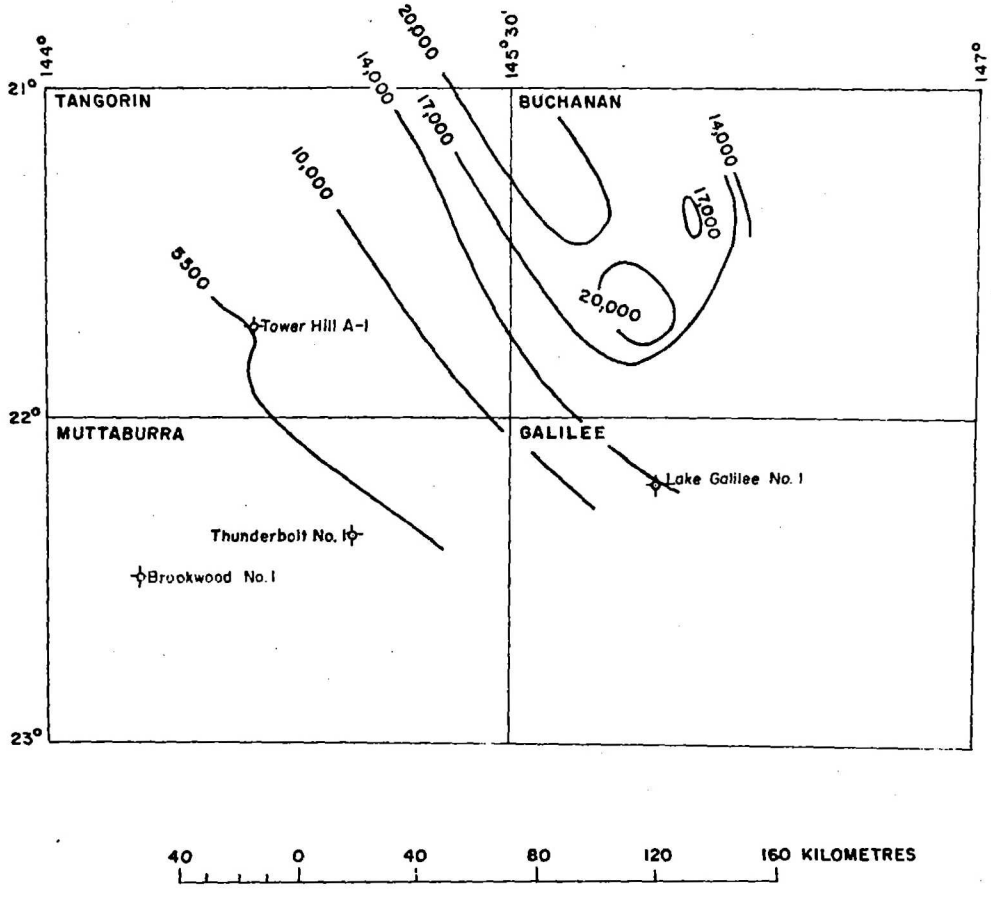
Compiled from interpretations by Magellan Petroleum Corp and Exoil N.L. and based on Plate 12 of Gibb, 1968

AEROMAGNETIC INTERPRETATION
MAGNETIC BASEMENT CONTOURS

40 0 80 160 KILOMETRES

Record No. 1976/73

PLATE 6



CONTOUR VALUES ARE IN FEET BELOW +700FT DATUM

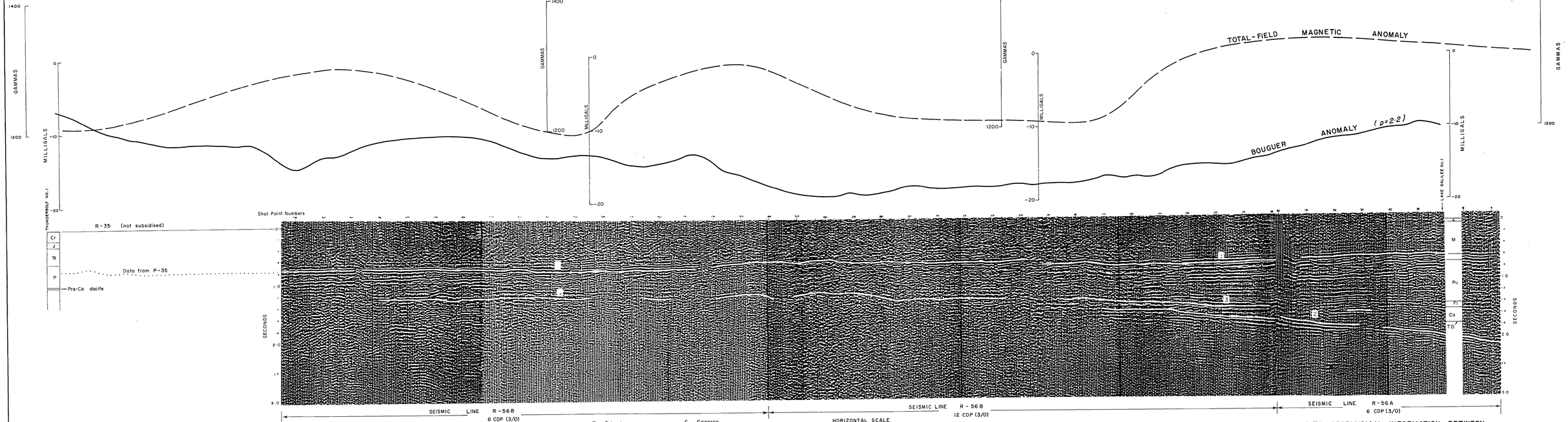
APPROXIMATE BASEMENT CONTOURS DERIVED FROM ISOLATED SEISMIC REFLECTION PROFILES OF THE TOWER HILL SEISMIC SURVEY

(BY AMERADA PETROLEUM CORP. OF AUSTRALIA LTD)

Record No. 1976/73

F55/B2-66A

PLATE 7



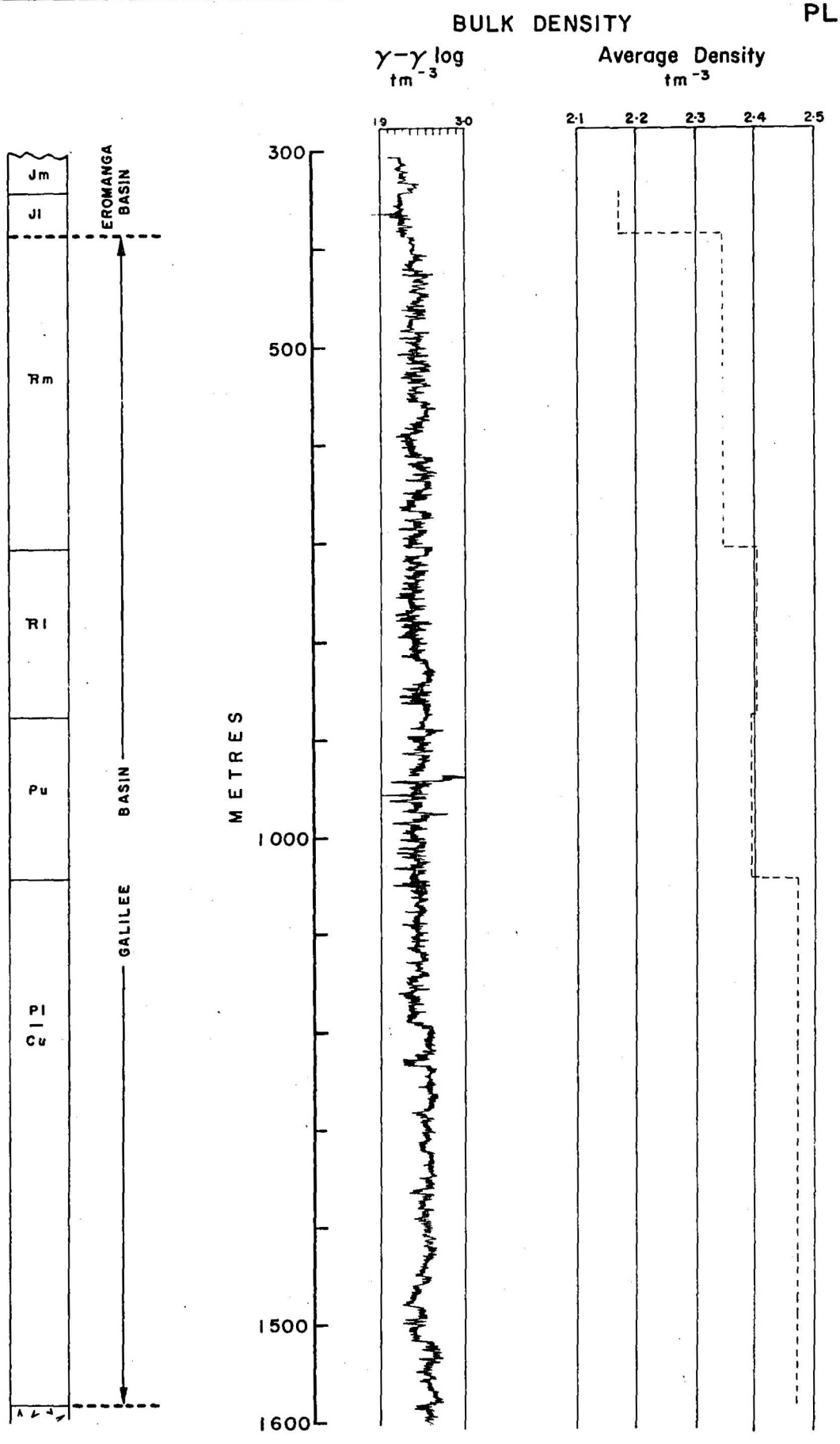
After Amerada, 1966

COMPOSITE GEOPHYSICAL INFORMATION BETWEEN THUNDERBOLT NO.1 AND LAKE GALILEE NO.1 WELLS

Record No. 1976/73

F55/B2-72-1

PLATE 8

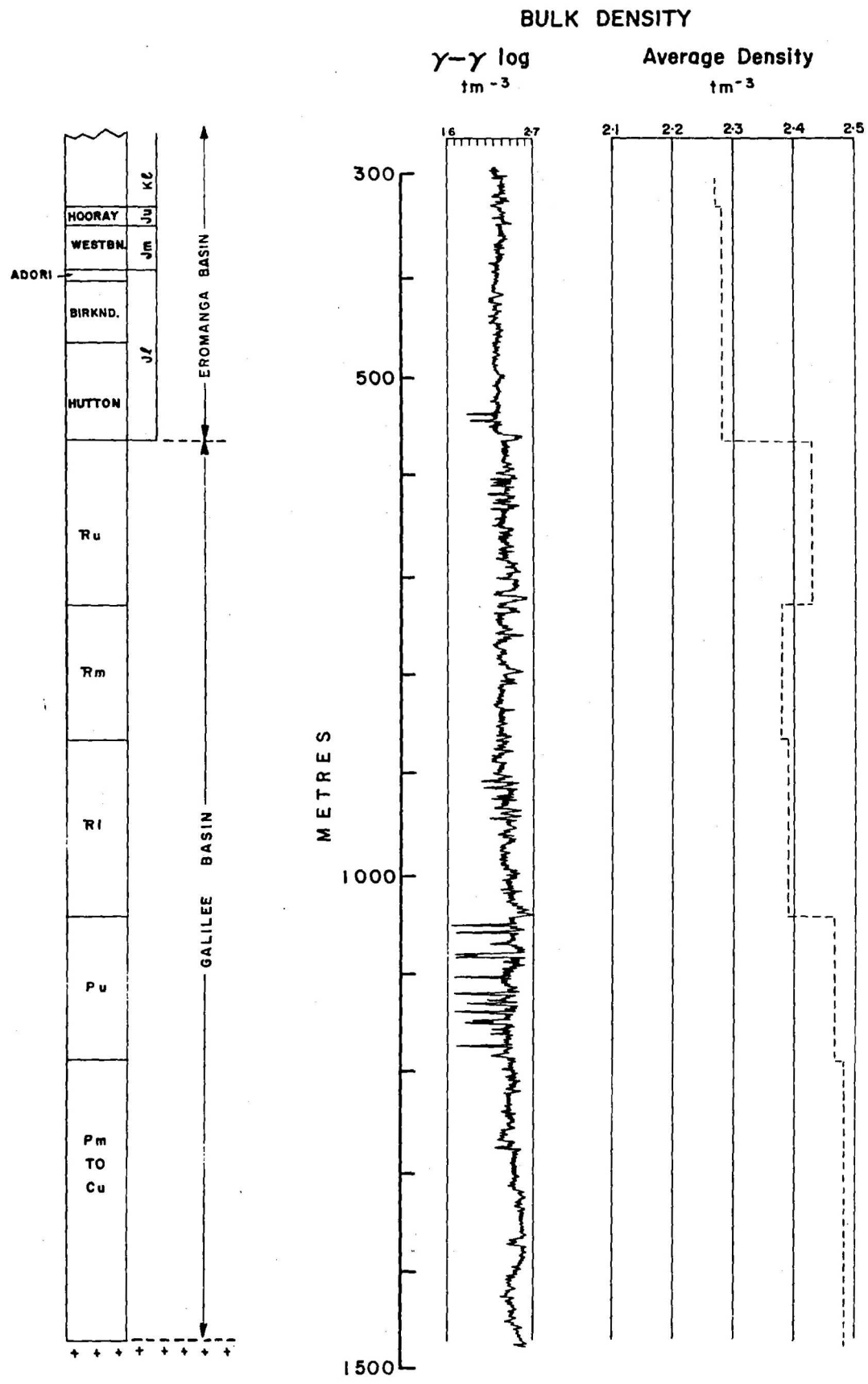


THUNDERBOLT No. 1 WELL

STRATIGRAPHIC AND FORMATION DENSITY LOGS

Record No. 1976/73

F55/B6-100A



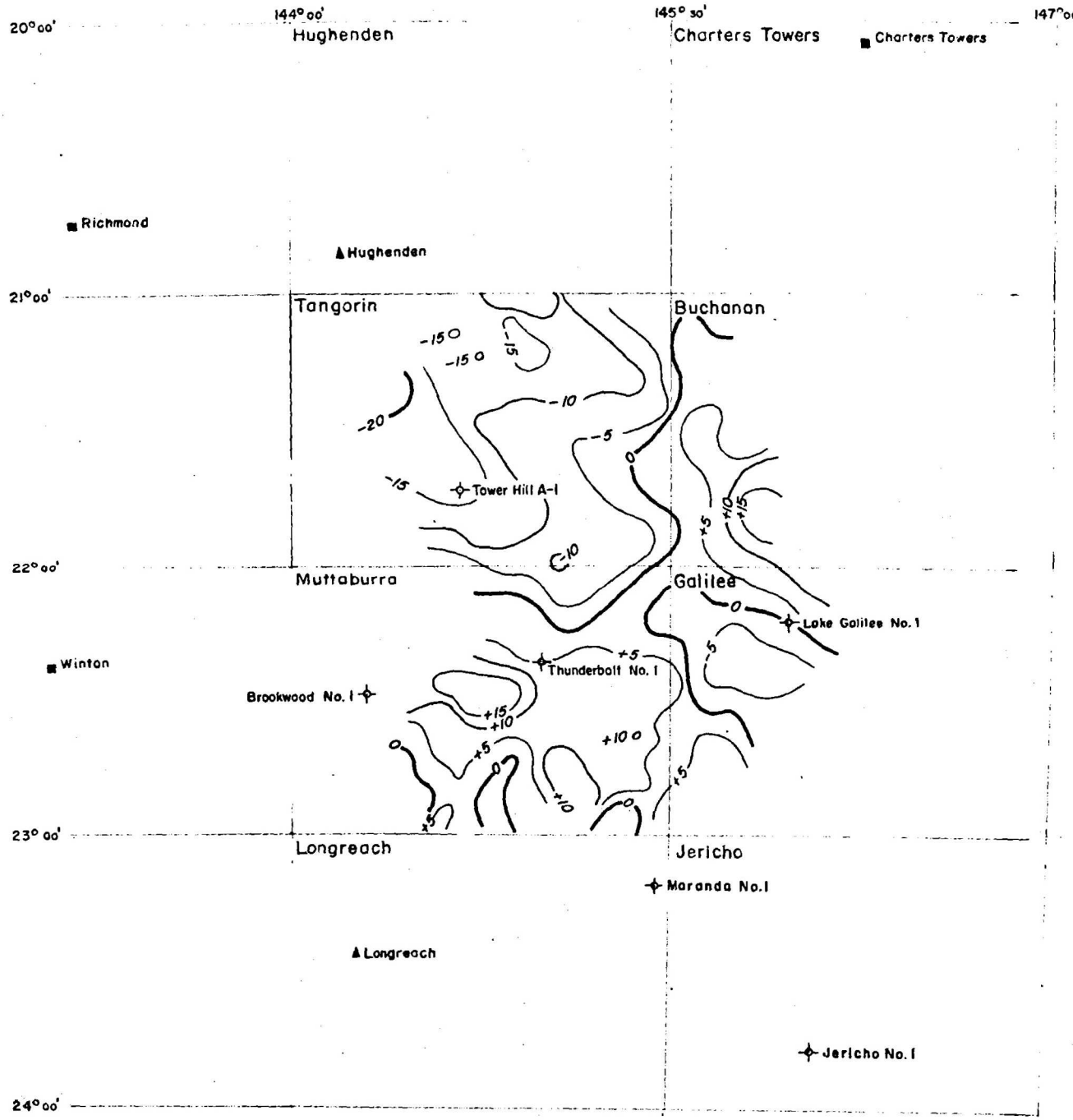
TOWER HILL No. A1 WELL

STRATIGRAPHIC AND FORMATION DENSITY LOGS

Record No. 1976/73

F55/B6-101A

PLATE 10



▲ Isogal gravity station

-5 Contour in milligals

Well

40 0 80 160 Kilometres

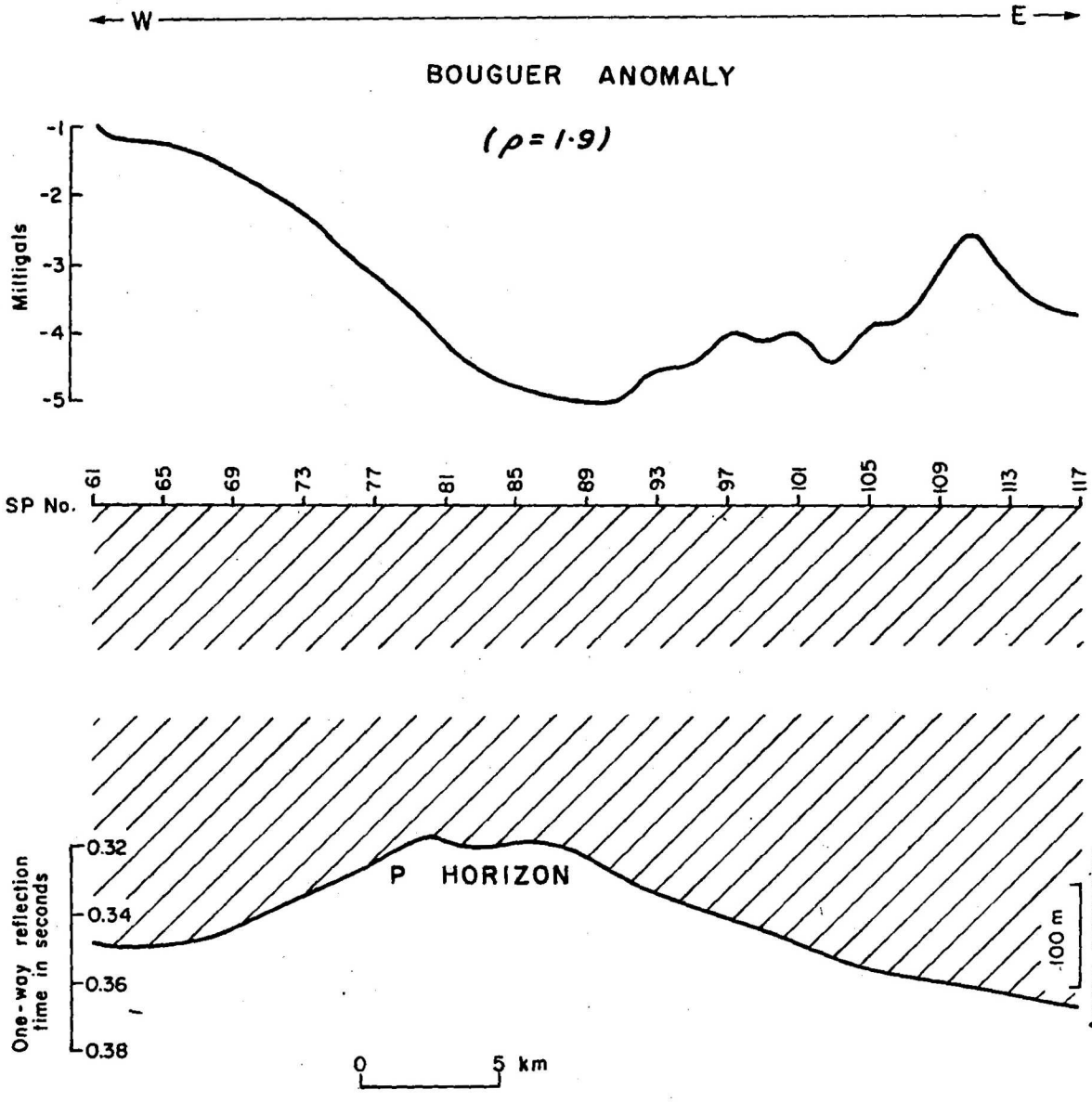
RESIDUAL BOUGUER ANOMALIES

AFTER CORRECTION FOR MESOZOIC EFFECT

Record No. 1976/73

F55/B2-58A

PLATE II

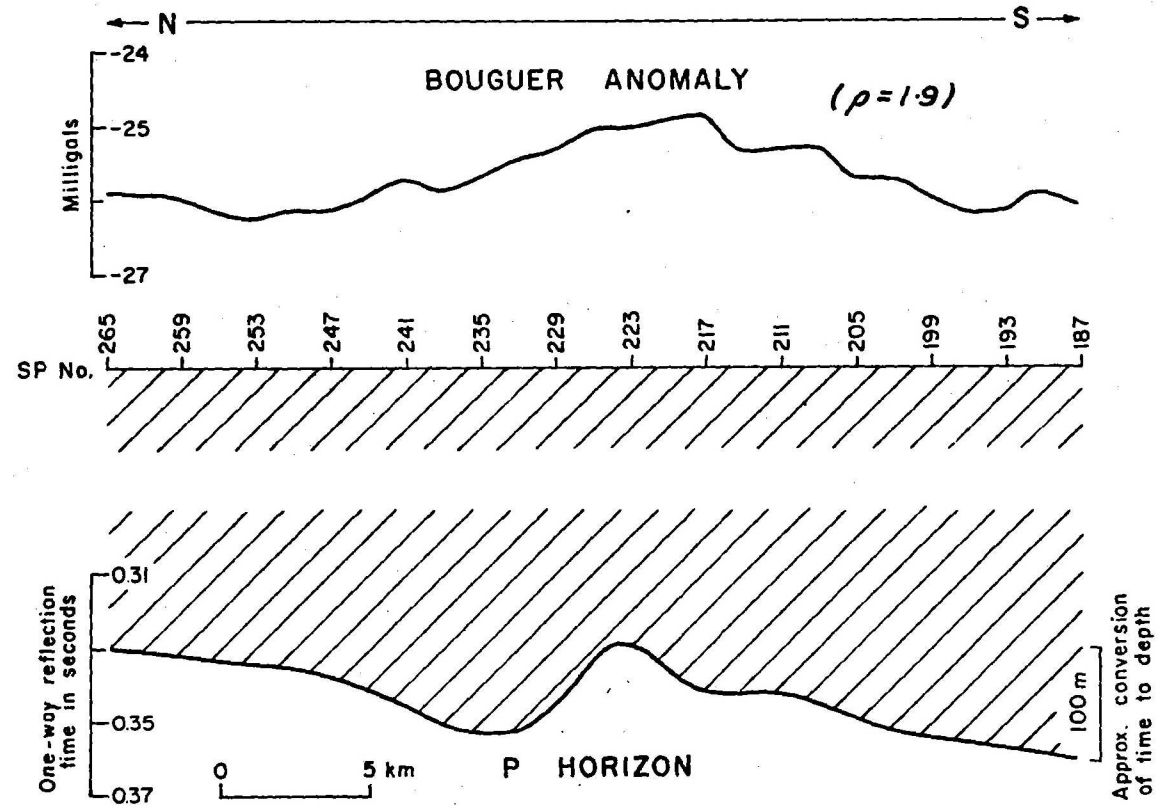


STRUCTURE C, Muttaburra sheet, Seismic Line P-1, centred at 22°23·6'S, 145°20·9'E

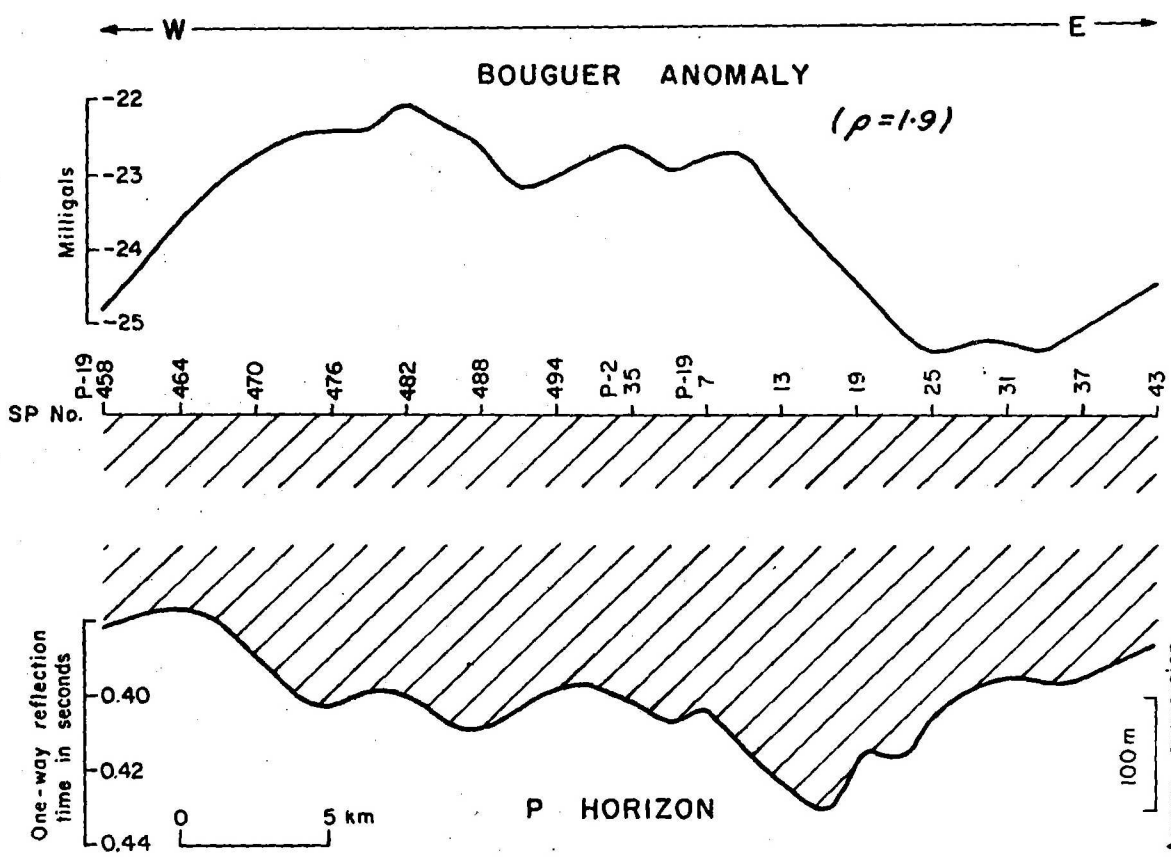
RELATION OF BOUGUER ANOMALIES TO 'P'-HORIZON STRUCTURE, SEISMIC LINE P-1, SP 61-117

Record No. 1976/73 F55/82-68A

PLATE 12



STRUCTURE A, Tangorin sheet on Seismic Line N-2, centred at 21°16·1'S, 144°38·0'E



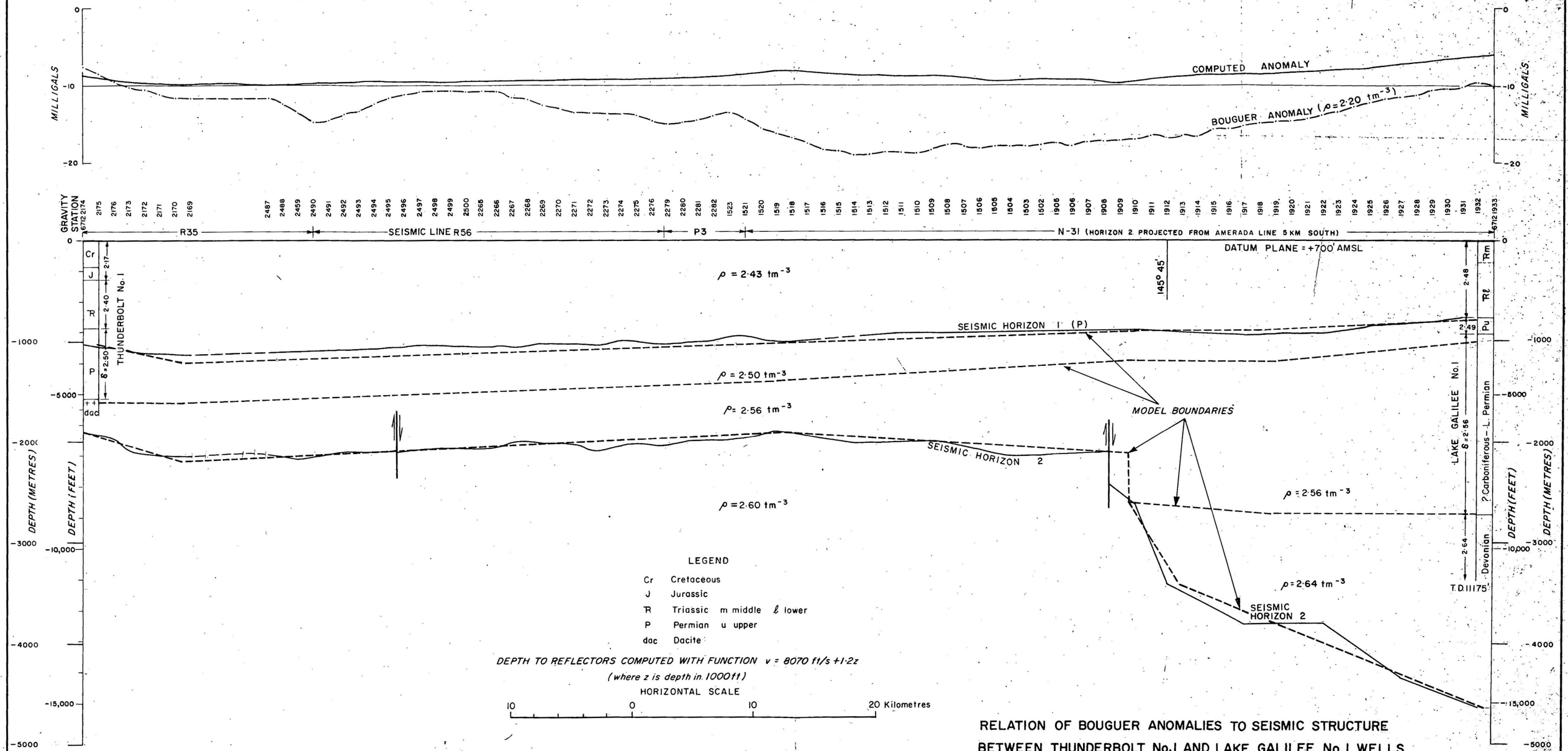
STRUCTURE B, Tangorin sheet, Line P-19, centred at 21°55·0'S, 144°42·1'E

RELATION OF BOUGUER ANOMALIES TO 'P' - HORIZON STRUCTURE, SEISMIC LINE N-2, SP265-187 AND SEISMIC LINE P-19, SP458-494 AND SP7-43

Record No. 1976/73

F55/B2-69A

PLATE 13

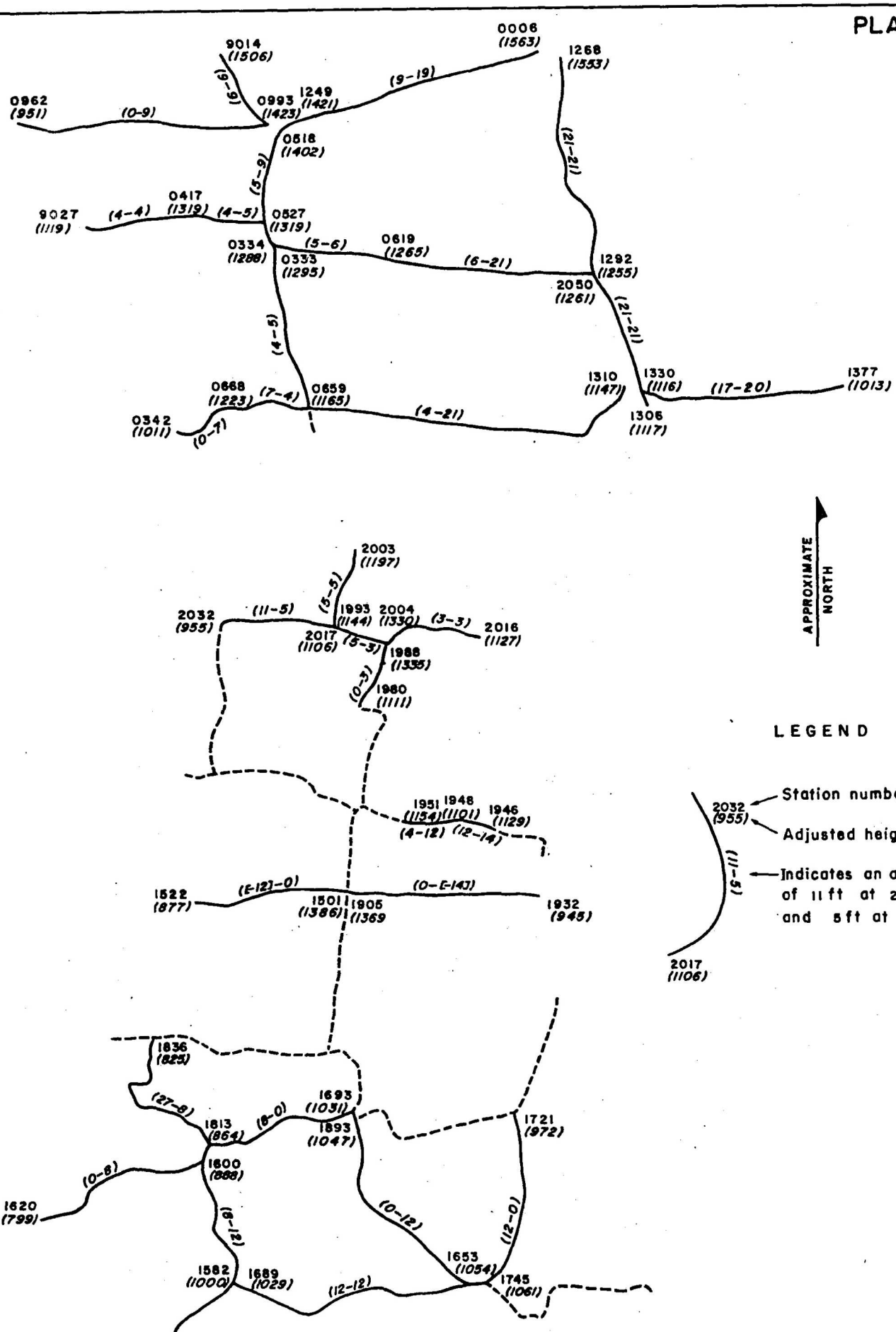


RELATION OF BOUGUER ANOMALIES TO SEISMIC STRUCTURE
BETWEEN THUNDERBOLT No.1 AND LAKE GALILEE No.1 WELLS

Record No. 1976/73

F55/B2-65

PLATE 14



LEGEND

2032 (955) — Station number; Adjusted height (feet)

(11-5) — Indicates an adjustment of 11 ft at 2032 and 5 ft at 2017

DIAGRAMMATIC ELEVATION MISCLOSURES AND ADJUSTMENTS IN NORTH AND SOUTHEAST OF SURVEY AREA

Record No. 1976/73

F55/B2-82A