COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1964/73

WESTBOURNE SEISMIC SURVEY SOUTH OF TAMBO, QUEENSLAND 1961

by

A.L. BIGG-WITHER and J.S. DAVIES

RECORD No. 1964/73

WESTBOURNE SEISMIC SURVEY SOUTH OF TAMBO, QUEENSLAND 1961

by

A.L. BIGG-WITHER and J.S. DAVIES

CONTENTS

ILLUSTRATIONS

SUMMARY

Aeromagnetic and gravity surveys were made in the Tambo-Augathella area by Magellan Petroleum Corporation in 1959 and 1960 respectively. A probable fault shown in the magnetic interpretation is almost coincident with a zone of steep gravity gradients which was interpreted as indicative of a fault or of steeply dipping strata. However, the normal gravity interpretation would indicate a deeper cross-section to the south-east of this zone, whereas the magnetic interpretation suggests that the fault is downthrown to the north-west.

The present survey was undertaken by the Bureau of Mineral Resources to find out which interpretation was the more probable. A reflection seismic traverse was shot at right angles to the closed gravity 'high' and across the zone of steep gravity gradients. Results show that the closed gravity 'high' is the expression of an anticline and that the zone of steep gravity gradients is caused by steep dip to the south-east on the flank of the anticline.

The gravity interpretation is therefore found to be more representative of actual conditions.

1. INTRODUCTION

A seismic survey was undertaken by the Bureau of Mineral Resources during 1961 in the Westbourne area to the south of Tambo, Qld. The area lies in the northern half of the area covered by the Augathella sheet of the 1:250,000 map series. It is in the north-eastern portion of the Eromanga Basin which forms the western portion of the Great Artesian Basin.

Aeromagnetic and gravity surveys were made under the Commonwealth Petroleum Search Subsidy Act 1959 in the Tambo-Augathella area by Magellan Petroleum Corporation in 1959 and 1960 respectively (Magellan, in press). There was little agreement between the magnetic and gravity interpretation. The object of this seismic survey was to try to find which interpretation was the more representative of actual conditions. It was planned to use both refraction and reflection methods of seismic exploration to provide structural information across a steep gravity gradient coincident with, but in the opposite sense to, a fault interpreted from the magnetic results.

2. GEOLOGY

In the area surveyed the surface rocks are largely Tertiary sediments. Along the eastern edge of the prospect, sandstones of Cretaceous-Jurassic age (Blythesdale Group) crop out and dip gently westward into the Eromanga Basin. These rocks overlie Triassic and Permo-Carboniferous rocks which crop out 45 miles and 90 miles north-east at Playfair and Mantuan Downs respectively. The Permo-Carboniferous rocks unconformably overlie Devonian rocks which are the oldest rocks in the area and which crop out some 95 miles north-east at Echo Hills.

Numerous water bores have been drilled in the area and the stratigraphic sequence to the depth of the artesian aquifers is well known. A depth-to-basement map (compiled from water-bore data) and a structure contour map of the first significant aquifer (probably Jurassic) have been compiled by Magellan (in press). However, very few wells have reached basement and in the area south of Tambo little is known of the rocks below the aquifer for no deep wells have been drilled in this area. The nearest deep well is South Pacific Pty Ltd No.1 (Birkhead) which was drilled as a wildcat for oil about 25 miles north of Tambo township. Continental facies of Permian lying on highly tilted, indurated Palaeozoic rocks of possible Carboniferous age were encountered below the artesian sequence.

Magellan (in press) shows the tectonic elements in the area and a composite stratigraphical column, taken from various sources, in which each formation is shown at its maximum thickness in the general area. A stratigraphic cross-section from Birkhead No. 1 to Mitchell bore is also given. At Mitchell the Mesozoic rocks are seen to lie directly on metamorphic rocks.

3. GEOPHYSICS

The results of the surveys made by Magellan (in press) are displayed in Plate 2 in the form of Bouguer anomaly contours and magnetic basement depths. The interpretation given below is essentially that presented in the Magellan report.

One interpretation of the Bouguer anomaly map is that there is a synclinal feature near Oxford Downs with an anticlinal ridge north-west of this syncline near Westbourne; on the other hand, the magnetic interpretation indicates a shelf area of 3000 to 5000 ft of sediments in the south-eastern part of the area (including the Oxford Downs area) deepening to about 8000 ft in the area north-west of this shelf (including the Westbourne area). There is a strong gravity gradient between the suggested synclinal and anticlinal features of the gravity interpretation and this gradient is in part coincident with a 'probable fault' which forms the north-western margin of the shelf area of the magnetic interpretation. In general, however, there is no agreement between the interpretations of the gravity and magnetic results, particularly as to the direction of the displacement across the 'fault'.

In the magnetic interpretation most of the inferred structures were presumed to exist in or at the surface of the basement. It was pointed out that the possible presence of igneous rocks such as volcanic flows within the sedimentary cross-section, sub-basement facies changes in the crystalline rocks, or the inclusion of metamorphic Palaeozoic rocks with unmetamorphosed Palaeozoic rocks may all make the magnetic interpretation indefinite. The gravity interpretation was based on the assumption that gravity maxima are indications of structural uplifts. Density changes in the basement rocks or a negative density contrast between Palaeozoic and pre-Palaeozoic rocks, however, would make the gravity interpretation indefinite or even incorrect.

It is clear from the above that structural investigations by drilling or by other geophysical methods were needed to help in the interpretation of the magnetic and gravity data. Therefore it was planned to shoot a continuous reflection seismic traverse in a north-westerly direction across the area of steep gravity gradients between the relative gravity 'low' 25 miles south of Tambo and the relative gravity 'high' north-west near Westbourne. The position of the traverse is shown in Plate 2. There is a total change of 7 mgal along the seismic traverse and it was expected that enough structural detail would be obtained to explain the gravity anomaly. It was also planned to shoot two refraction traverses on each side of the steep gravity gradient; however, this part of the programme was not completed. Only one refraction shot was fired from the north-eastern end of Traverse B (Plate 2) and a short reflection traverse was shot where this traverse crossed Traverse A.

4. RESULTS AND INTERPRETATION

Reflection

Record cross-sections from Traverses A and B are shown in Plate 4.

At a time of 1.04 sec under Shot-point 2 there is a strong reflection of good quality and character that can be accurately correlated from Shot-point 2 to Shot-point 35. Several reflections were recorded above this reflection and a few of them are correlatable across many records. These upper reflections are of generally poor quality although they can be followed with fair certainty from shot-point to shot-point. The amplitude of the deeper reflection suggests

a substantial change in elastic properties of the rocks and this deep reflector probably represents the base of the Mesozoic formations. All reflections down to and including the strong reflection at about 1 sec appear to be conformable.

A depth cross-section (Plate 3) has been plotted from the record cross-section, using the average velocity shown on Plate 5, which was calculated from a $t:\Delta t$ analysis. This clearly shows an anticlinal structure with its crest under Shot-point 13.

There is a gentle westerly dip (one to two degrees) on the western flank of anticline, and also a gentle easterly dip (one to two degrees) between Shot-points 13 and 29. On the eastern flank at Shot-point 28, however, there is a sudden change in dip from two degrees to 13 degrees and this dip persists to Shot-point 33 where it levels off. It is apparent then that the Mesozoic sediments between Shot-points 28 and 33 increase in thickness by about 1300 ft.

Refraction

Heavy rain prevented completion of the refraction programme. One refraction shot was fired from Shot-point 134 with spread arranged between Shot-points 104 and 108 on Traverse B. A velocity of 18,200 ft/sec was measured from first-arrival times (Plate 6). Second-arrival times indicate a shallower refractor in which the velocity is 13,400 ft/sec.

A depth of 5050 ft was calculated for the 18,200 ft/sec refractor. Although shooting was done in one direction only, this depth is considered reasonably realistic since dips of less than one degree were indicated for the deep reflection, which probably represents the refractor, along Traverse B (Shot-points 104 to 107).

A second event of velocity 13,400 ft/sec was recorded but no depth could be calculated as it was not possible to find where the first onset of the event was. It is likely that the 18,200-ft/sec refractor is related to the deepest reflection horizon which is possibly the base of the Mesozoic rocks.

It was intended to locate a second refraction traverse on the south-west side of the structure in order to confirm that the Mesozoic strata thicken to the west as indicated by reflection results. The reflection results are so clear, however, that confirmation by refraction methods does not appear to be necessary.

5. GRAVITY INTERPRETATION

Qualitative

The gravity 'high', Anomaly 2A (Plate 2) corresponds to the anticlinal structure indicated by the seismic reflection cross-section (Plates 3 and 4). The crest of the anticline (under Shot-point 13) coincides with the highest gravity value. The relatively steep gravity gradient between Shot-points 28 and 33 corresponds to a substantial increase in thickness of the Mesozoic strata as shown by the seismic cross-section. The increase in thickness, viz. 1300 ft, is consistent with the observed gravity decrease of about 7 mgal if a density contrast of about 0.43 g/cm^3 is assumed.

From the above it is clear that there is good qualitative correlation between the seismic cross-section and the observed Bouguer anomaly profile.

Quantitative

The sudden increase in dip east of Shot-point 28 may be regarded as a low-dipping fault for the purpose of the gravity interpretation. The middle of this 'fault' coincides with the point of inflection of the Bouguer anomaly curve. The half-width of this curve is 5000 ft (i.e. 6200 ft below datum of 1200 ft above MSL). This is 550 ft greater than the estimate from seismic work of the depth (5650 ft) of the block producing the anomaly. Since the fault is low-dipping and not vertical, the depth given by the half-width of the Bouguer anomaly is expected to be over-estimated. The correlation between the seismic work and the gravity work is thus fairly good.

The effect of the 'fault' was calculated using an integration chart assuming that the surfaces on either side of the 'fault' were horizontal and that the depth to the upthrown side of the faulted block was 5000 ft. The effect of the strata above 5000 ft was neglected for this purpose. It was found that over the significant region of the fault the calculated curve fits the observed curve closely (Plate 3). The Bouguer anomaly due to the 'fault' as calculated above was then removed from the observed Bouguer anomaly and the residuals plotted. The residuals should be the Bouguer anomaly due to the structure above 5000 ft (Plate 3).

It is seen that under Shot-point 28 the depth to the deep reflector is 5000 ft and under Shot-point 13 (the crest) it is 4575 ft. The residual Bouguer gravity anomaly is 2.3 mgal which once again suggests a density contrast of about 0.43 g/cm^3. However, between Shot-points 2 and 13 the gravity and seismic results do not appear to correlate. The difference in depth between Shot-points 2 and 13 is 425 ft, whereas the difference in the Bouguer values is $4\frac{1}{2}$ mgal; this suggests a density contrast of approximately 1.00 g/cm^3. The reason for this apparent discrepancy is most likely due to a mass deficiency west of Shot-point 2. There is good correlation between the seismic and gravity results from Shot-points 13 to 33 after removal of the effect of the Bouguer curve caused by the mass deficiency due to the 'fault'. Between Shot-points 2 and 13 no apparent correlation exists between the seismic and Bouguer profiles. The gravity contour map shows that north-west of Shot-point 2 the value falls to as low as -27 mgal on the north-western end of Anomaly 2A (Plate 2). This is the same value as that on the eastern end of the traverse and it is quite likely that the Mesozoic cross-section increases in thickness to the west by as much as it does to the east (i.e. 1300 ft).

6. CONCLUSIONS

The following conclusions are made from this seismic survey:

(a) the seismic traverse crosses an anticlinal structure with its crest below Shot-point 13 and with steep dips (13 degrees) on its south-eastern flank between Shot-points 29 and 32,

(b) there is good qualitative agreement between the structure indicated by the seismic results and the gravity profile interpreted normally. In particular, the steep gravity gradient correlates with the steep dips on the south-eastern flank of the anticline. The agreement is good quantitatively if a density contrast of 0.43 g/cm^3 is assumed at the level of the main reflecting horizon,

(c) the magnetic interpretation does not agree with the results of the seismic survey.

7. REFERENCE

MAGELLAN 1963 Tambo-Augathella aeromagnetic and gravity surveys, Queensland 1959. PSSA Publ. 31 (in press).

APPENDIX A

STAFF AND EQUIPMENT

STAFF

Party leader	:	A.L. Bigg-Wither
Geophysicist	:	J.S. Davies
Clerk	:	W.E. Rossendell
Observer	:	R. Krege
Shooter	:	E.H. Cherry
Drilling supervisor	:	B.G. Findlay
Drillers	:	K. Suehle, F. Reith, P. O'Brien
Surveyors	:	J. Ransom, R. Wenholz (Department of the Interior)
Mechanics	:	T. Clark J. Maxwell
Wages hands	:	11 - 12

EQUIPMENT

Magnetic recorder	:	Electro-Tech DS7
Seismic amplifiers	:	TIC type 621
Oscillograph	:	TIC 50-trace (24 mixed traces) with Electro-Tech Seismod attached
Geophones	:	(a) TIC, 20 c/s, in groups of 6 at 22-ft intervals (approx. 430) (b) TIC, 6 c/s (approx. 80) (c) EBF 2B, 20 c/s, in groups of 6 at 22-ft intervals (approx. 450)
Cables	:	Vector, portable, 1500 ft, with 13 take-outs at 110-ft intervals.
Transceivers	:	SIE CT-100D (3) and Traeger 51-ma.
Drill	:	Carey

APPENDIX B

TABLE OF OPERATIONS

Sedimentary Basin	:	Eromanga
Area	:	Tambo-Augathella
Party accommodation	:	Royal Carringata Hotel, Tambo
Surveying commenced	:	29.11.61
Drilling commenced	:	30.11.61
Shooting commenced	:	30.11.61
Miles surveyed	:	11
Topographic survey control	:	Land maps and gravity stations by Magellan Pet. Corp.
Total footage drilled	:	3332
Explosives used	:	2400 lb
Datum level for corrections	:	1200 ft
Weathering velocity	:	2000 ft/sec
Sub-weathering velocity	:	8000 ft/sec
Source of velocity distribution	:	t: Δt analysis

REFLECTION SHOOTING DATA

Shot-point interval	:	1320 ft
Geophone group	:	6
Geophone-group interval	:	22 ft
Holes shot	:	39
Miles traversed	:	$9\frac{3}{4}$
Common shooting depths	:	80 ft
Usual recording filter	:	L2H3 (23 to 78 c/s)
Usual playback filter	:	L2H3 (23 to 78 c/s)
Common charge sizes	:	15 lb - 20 lb

REFRACTION SHOOTING DATA

Geophone group	:	2
Geophone-group interval	:	Close together
Hole shot	:	1

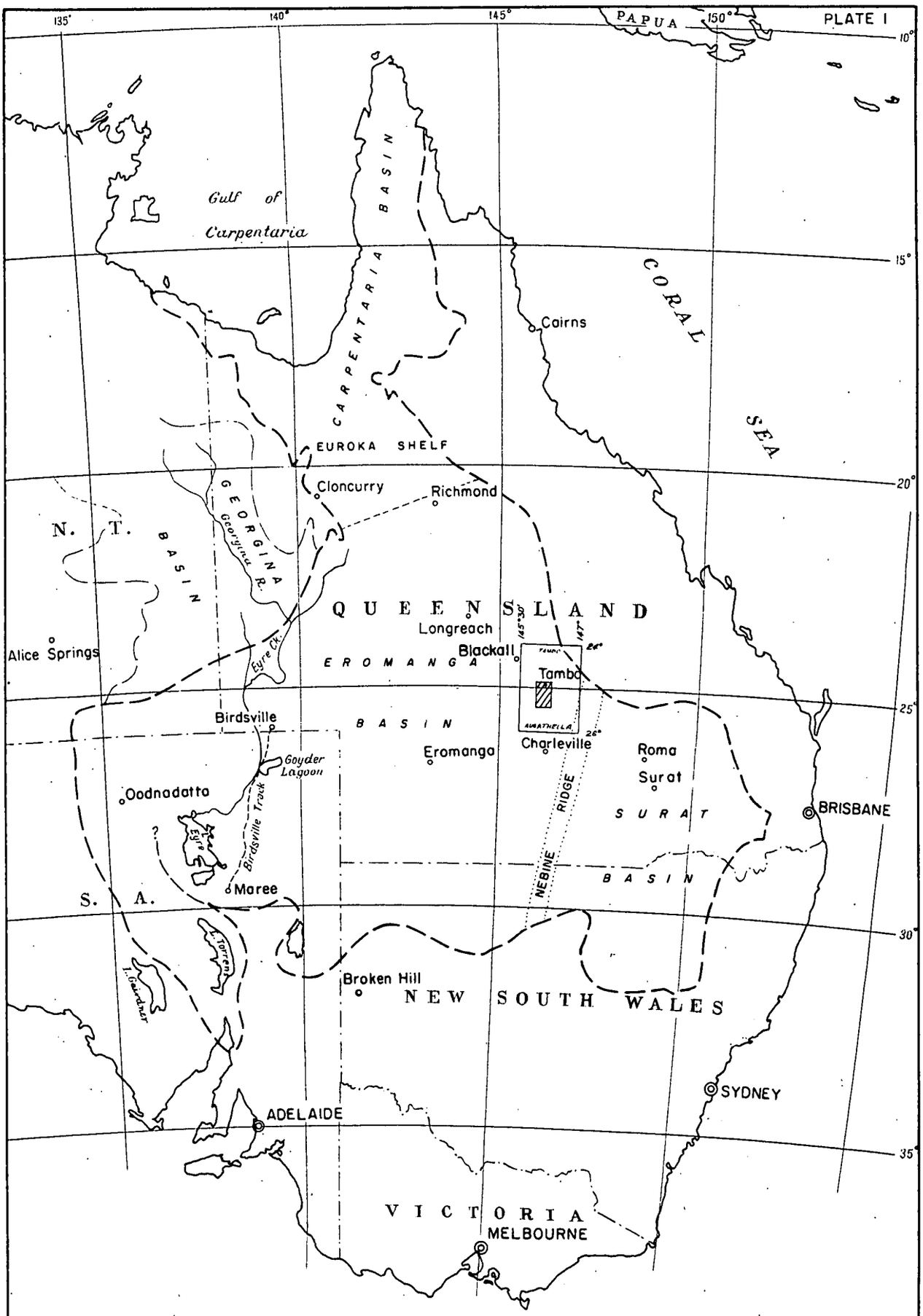
APPENDIX B (CONT.)

Usual recording filter	:	LOH3 (8 to 75 c/s)
Number of refraction traverses	:	1
Charge size	:	370 lb
Max. shot/geophone distance	:	$6\frac{1}{2}$ miles
Weathering Control	:	Reflection shooting

APPENDIX C

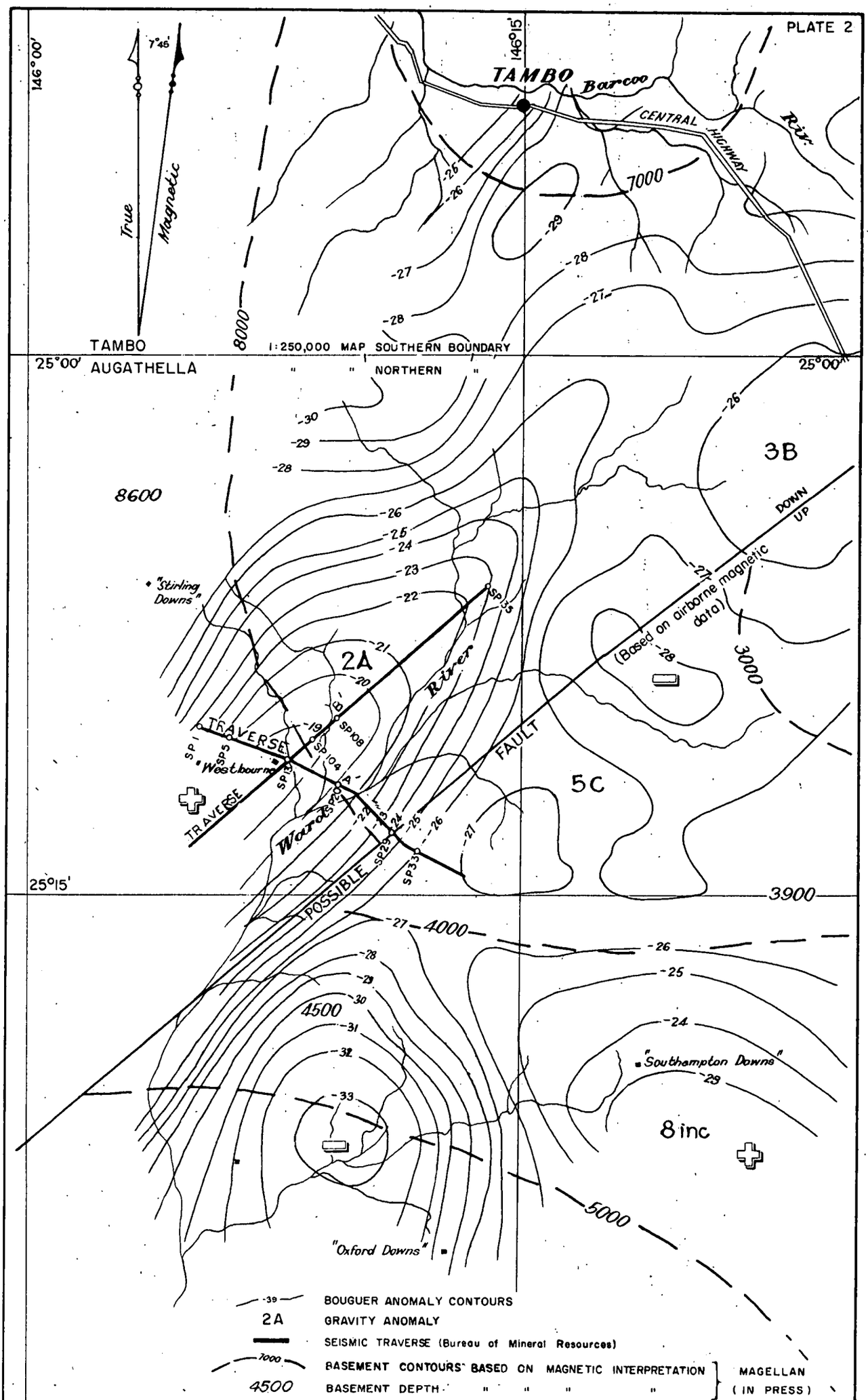
SEISMIC SHOT-HOLE DRILLING STATISTICS

Total footage drilled	:	3332
No. of holes drilled	:	44
Average depth of holes	:	75.7 ft
Deepest hole drilled	:	153 ft
Travelling time and rigging up	:	32.5 hr
Time lost, waiting on water	:	Nil
" " repairs to drill	:	12¼ hr
" " because of rain	:	Nil
" " repairs to rig engine	:	Nil
" " waiting on surveyors	:	Nil
" " public holidays	:	Nil
Drilling time	:	81 hr
No. of shifts worked	:	18
Maintenance to drill	:	14½ hr
Bentonite used	:	Nil
Fishing job	:	10 hr
Drilling rate	:	81.1 ft/hr
Loading holes	:	1¼ hr



WESTBOURNE AREA

PLATE 2



-39- BOUGUER ANOMALY CONTOURS

2A GRAVITY ANOMALY

SEISMIC TRAVERSE (Bureau of Mineral Resources)

7000 BASEMENT CONTOURS BASED ON MAGNETIC INTERPRETATION } MAGELLAN (IN PRESS)

4500 BASEMENT DEPTH " " " " }

WESTBOURNE AREA
TRAVERSE LOCATION, BASEMENT CONTOURS, AND BOUGUER ANOMALY CONTOURS

SCALE IN MILES

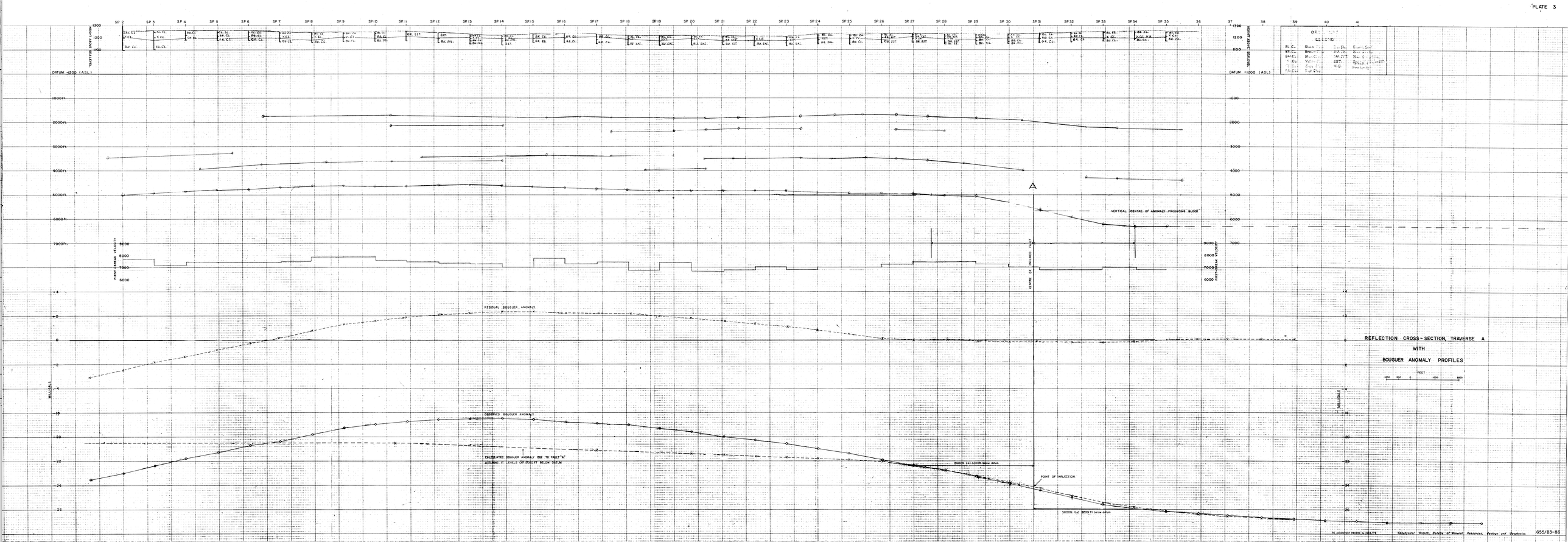
4 0 4 8 12

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

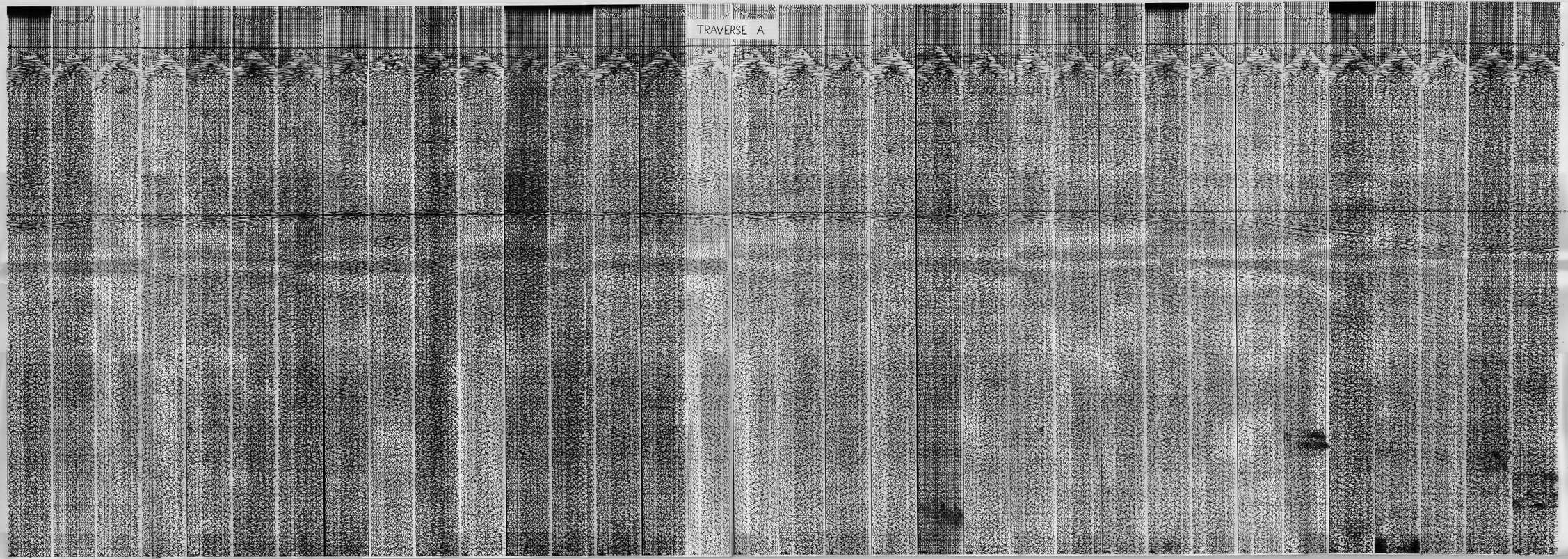
G55/B3-41

TO ACCOMPANY RECORD No. 1964/73

Westbourne Seismic Survey South of Tambo Q'land


DATUM +1200 (ASL)
HEIGHT ABOVE DATUM
FIRST-BREAK VELOCITY
POST-STACK VELOCITY
VERTICAL CENTRE OF ANOMALY PRODUCING BLOCK
CENTRE OF INCLINED FAULT
RESIDUAL BOUGUER ANOMALY
OBSERVED BOUGUER ANOMALY
CALCULATED BOUGUER ANOMALY DUE TO FAULT "A" ASSUMING IT LEVELS OFF 8500 FT BELOW DATUM
8500ft (±) 4200m below datum
POINT OF INFLECTION
5600ft (±) 3800ft below datum
MILLIGALS
FEET
REFLECTION CROSS-SECTION, TRAVERSE A
WITH
BOUGUER ANOMALY PROFILES

G55/83-86



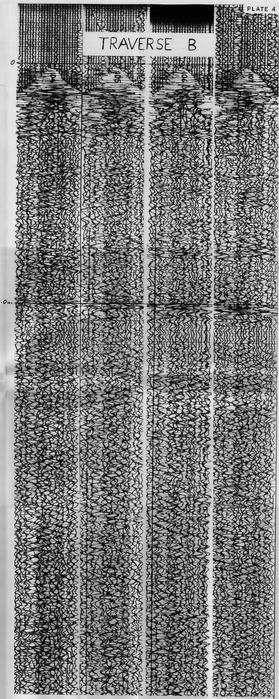


PLATE 2

WESTBOURNE SEISMIC SURVEY

TAMBO-AUGATHELLA

RECORD CROSS-SECTIONS

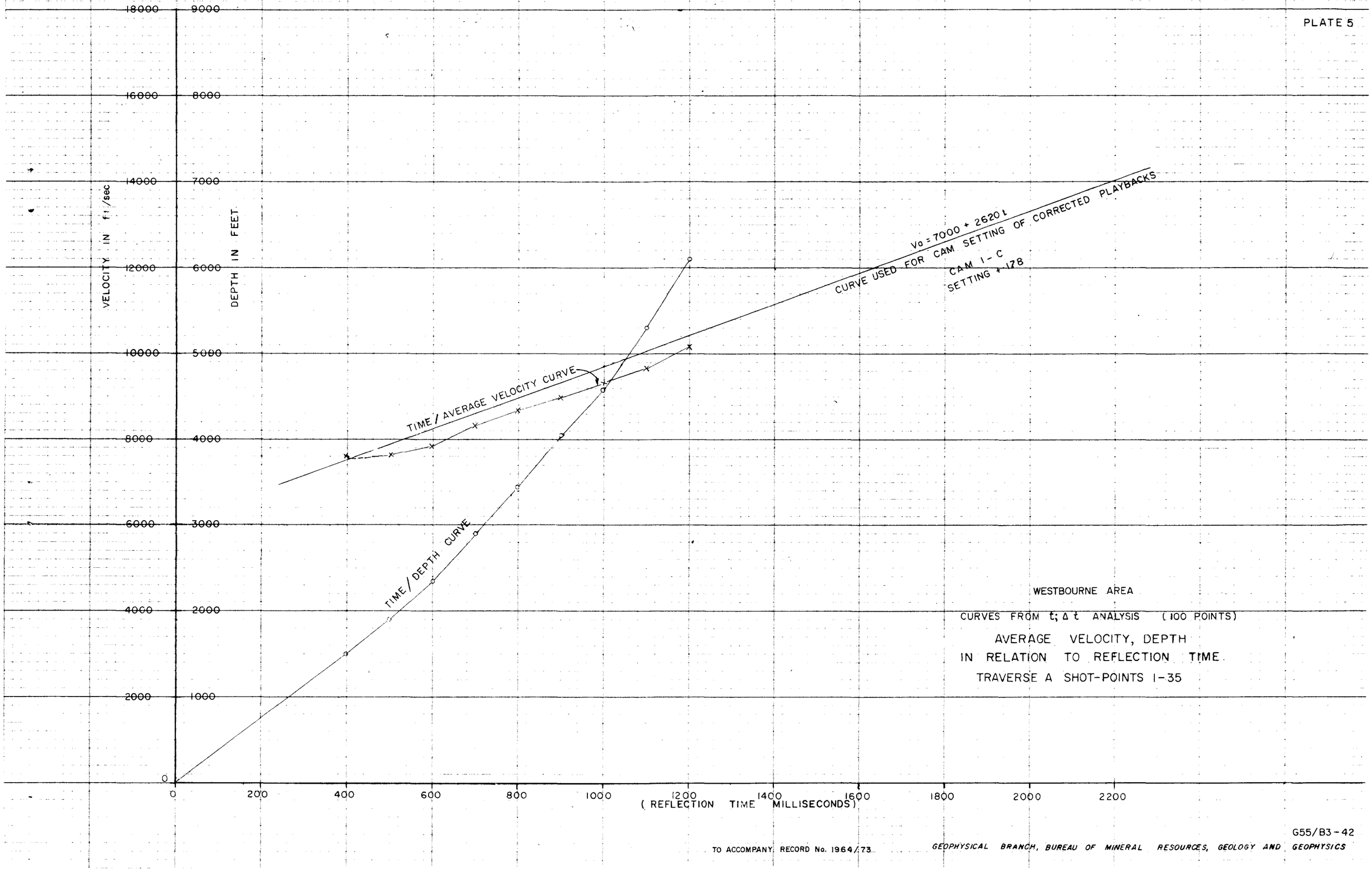
TRAVERSES A AND B

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

055/83-87

(Ex 9409-5)

PLATE 5



WESTBOURNE AREA

CURVES FROM $t; \Delta t$ ANALYSIS (100 POINTS)

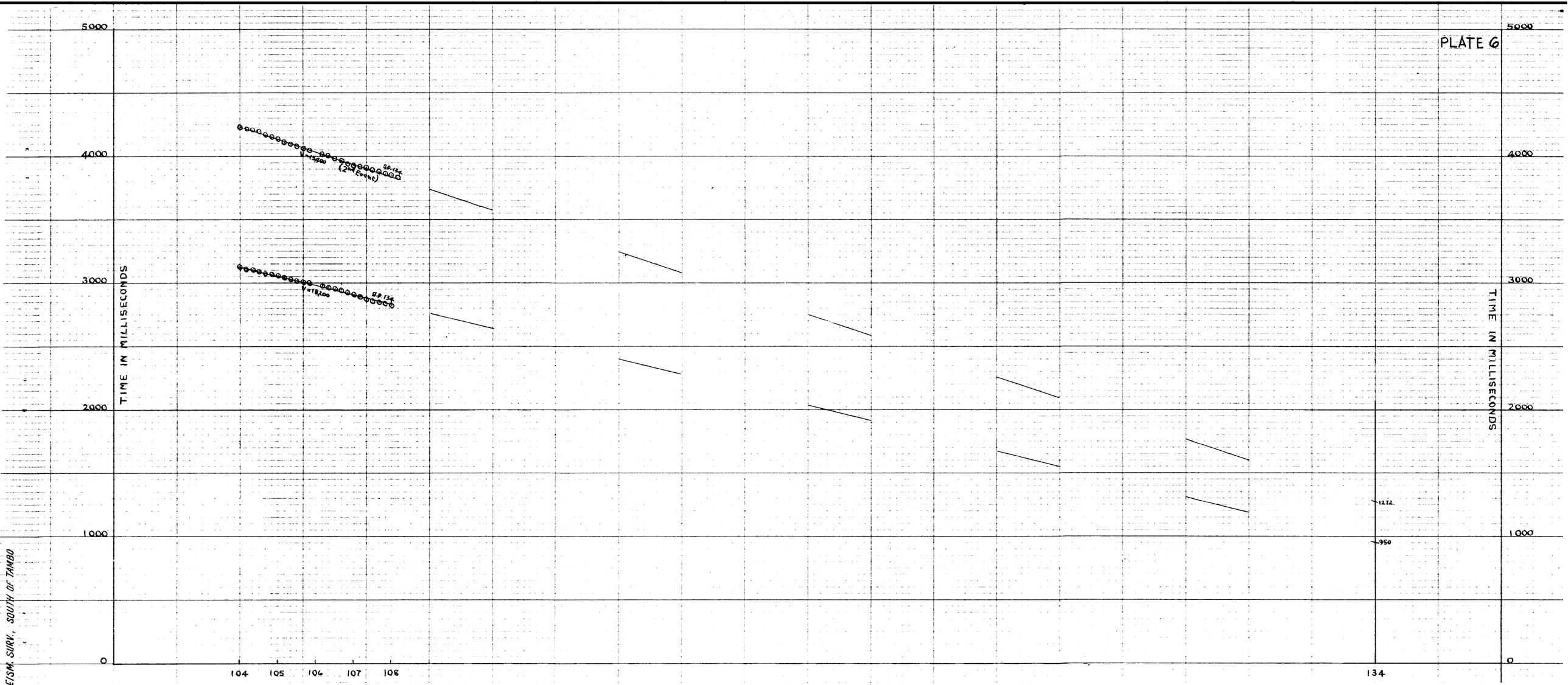
AVERAGE VELOCITY, DEPTH
IN RELATION TO REFLECTION TIME
TRAVERSE A SHOT-POINTS 1-35

G55/B3-42

TO ACCOMPANY RECORD No. 1964/73

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PLATE 6



VELOCITY OF FIRST EVENT = 18200 FT/SEC

ESTIMATED DEPTH OF REFRACTOR UNDER SHOT-POINT 106 = 5050 FEET

SEISMIC REFRACTION RESULTS

TRAVERSE B

HORIZONTAL SCALE

2640 1320 0 2200 4400 FEET

G55/83-43

WEST BOURKE SEISM. SURV., SOUTH OF TAMBO

TO ACCOMPANY RECORD No. 1964/73

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics