COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

B

RECORD No. 1962/107

ROCKINGHAM/MUNDIJONG SEISMIC SURVEY, WESTERN AUSTRALIA 1956

by

F. J. MOSS

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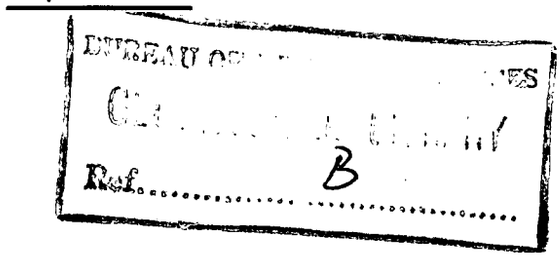

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CONTENTS

ILLUSTRATIONS

Plate 5 has not been scanned due to poor quality.
Hard copy is available for viewing in the library.

SUMMARY

A seismic reflection traverse was surveyed across the Perth Basin, Western Australia, between the townships of Rockingham and Mundijong. It was planned in order to give information regarding the depth of the Basin and its structure adjacent to the Darling Scarp.

Seismic refraction traverses were surveyed to give the longitudinal velocities in the near-surface granitic gneisses on the Precambrian Shield, and in the Cardup Series (Proterozoic) abutting the Darling Scarp.

At least 14,000 ft of sediments are indicated in the deepest part of the Basin but there is no clear seismic evidence of what a maximum thickness might be.

Seismic reflection results indicate that the sediments on the west of the Darling Scarp abut the older rocks on a plane that dips at about 60 degrees to the west and that cuts the surface some distance in front of the present position of the scarp. This suggests that the Darling Scarp at Mundijong is the surface expression of a normal fault. However, the presence of reflection alignments east of this postulated fault plane, and thus apparently arising within the granitic gneisses, is contrary to the fault hypothesis. The true nature of the tectonic features is thus unresolved. Seismic results indicate that faulting occurred within the Basin and such faulting may have completed closure of possible oil traps. Further seismic investigation of the faults and associated structures is recommended.

1. INTRODUCTION

Gravity surveys of the Perth Basin (Thyer and Everingham, 1956; Neumann and Flavelle, 1961) showed the presence of a considerable thickness of sediments in the Basin, and steep Bouguer anomaly gradients in the vicinity of the Darling Scarp.

Seismic reflection traverses were planned at several locations to confirm the thickness of sediments and to give additional information regarding the structure of the Basin near the Darling Scarp. In 1955 the Bureau of Mineral Resources seismic party surveyed traverses at Gingin (Vale, 1956), 45 miles north of Perth, and at Cookernup (Vale and Moss, 1962), 75 miles south of Perth. The results obtained from these preliminary seismic surveys confirmed the existence of a considerable thickness of sediments in the Basin, and major faulting in the vicinity of the Darling Scarp.

In 1956 the Bureau seismic party carried out additional work at Cookernup, completed a seismic reflection traverse from Quindalup through Busselton to Donnybrook in the south of the Perth Basin (Lodwick, 1962), and shot a seismic reflection traverse from Rockingham to Mundijong, 25 miles south of Perth. Two refraction traverses were also shot near Mundijong to determine the seismic velocities in the Precambrian granitic gneisses and in the Precambrian Cardup Series.

The results of the seismic survey in the Rockingham/ Mundijong area are presented in this Record.

2. GEOLOGY

General discussions of the known geology of the Perth Basin are given by Fairbridge (1949), McWhae, Playford, Lindner, Glenister, and Balme (1958), and Playford and Johnstone (1959).

The Basin is approximately 400 miles long and its maximum width on land is 55 miles. Outcrops are mostly of Mesozoic to Recent age, but in the north of the Basin, Palaeozoic sediments (Permian as well as probably-Ordovician and Silurian) are known. Except in the extreme north and south, the western boundary of the Basin is not yet defined; in the east the Basin is bounded by the Precambrian Western Australian Shield at the Darling Scarp.

The Perth Basin, so far as it is known, is defined by the Bouguer anomaly map (Plate 1) which shows steep gradients coinciding with the Darling Fault. From the intensity and magnitude of the anomalies, Thyer and Everingham (1956) have postulated that very large thicknesses of sediments must exist. This was confirmed by seismic surveys at Gingin (Vale, 1956), and at Cookernup (Vale and Moss, 1962). The thickest sediments appear to be west of Watheroo where the thickness may be as much as 35,000 ft of sediments.

Aeromagnetic surveys results indicate the presence of a narrow sub-surface basement ridge (Beagle Ridge), approximately 4500 ft deep, trending north in the northern part of the Basin at about 40 miles south of Dongarra. Bores BMR 10 and 10A were drilled for the Bureau on Beagle Ridge (see Plate 1). Bore BMR 10, which was abandoned at 3910 ft in Permian sediments, is discussed by McTavish (1960). BMR 10A penetrated the Permian sequence and struck granitic gneiss basement at approximately 4790 ft (Jewell and Jackson, 1961). These bores confirmed the presence of sediments ranging from Pleistocene through Jurassic-Triassic into the Permian. The most important discovery was that a marine sequence existed in the Triassic and that possible reservoir beds and cap-rocks existed in the Permian. Condon (1955) suggests the possibility of a marine sequence ranging from Cambrian to Permian in the deeper parts of the Basin.

The Cardup Series of presumed Proterozoic age consists of shale, slate, and sandstone and appears in outcrop at Gosnells, Armadale, Cardup and Mundijong.

At Cardup this series, considered to be at least 2300 ft thick, overlies Precambrian granite and gneiss unconformably; it dips at about 60 degrees to the west. Dolerite dykes are known to intrude the Cardup Series. At Cookernup the Darling Fault is fairly clearly defined but at Yandanooka and Cardup a thick sequence of west-dipping sediments overlies the Fault and confuses the picture.

3. FIELD WORK

Personnel, equipment, and general statistics are shown in Appendices A and B.

Traverses were laid, wherever possible, within road reserves that were consistent with the laying of straight quarter-mile spreads. Several shorter spreads were laid, however, to allow for bends in the road.

Between Shot-points 1 and 25, near the coast, the drill penetrated several bands of calcareous sandstone, in which circulation of drilling fluids was lost. Twelve holes caved in but were not redrilled because adjacent shot-points gave only a few poor reflections.

Neither the time available nor the seismic equipment being used permitted further experimentation with either multiple holes or multiple geophones.

4. VELOCITY DISTRIBUTION

A t : ∆ t analysis made on fair-quality reflections recorded along the Rockingham/Mundijong traverses shows that the velocity distribution in the sediments closely approximates that found at Gingin and Cookernup.

A velocity distribution was found by Miller's method (Dix, 1952). The function calculated for Rockingham/ Mundijong was $v_1 = 7500 + 0.36d$.

Migrated sections were plotted by the curved path technique, using a Sinclair Dip Plotter. The velocity distribution is probably substantially in error for reflections from deep Palaeozoic or Proterozoic sediments, and more particularly for alignments recorded apparently from within the granite complex of the Darling Scarp.

A nomogram relating reflection time, depth, average velocity, and spread correction is shown on Plate 3.

5. RESULTS

Individual traverses

Traverse A (Plate 5). Reflections were of fair to poor quality.

West of Shot-point24, in the coastal limestone area, record quality is very poor due to excessive ground roll and, possibly, to poor energy propagation. Dip information is not reliable but the weight of evidence suggests horizontal bedding.

A 36-hole pattern shot with hole spacings of 50 ft and depths 20 ft was shot at Shot-point 4. The charges were connected in parallel and did not fire simultaneously. However the experiment indicated that improvements could be expected from properly conducted experiments.

East of Shot-point 24, reflections with good continuity were recorded down to depths of roughly 7000 ft, but only scattered reflections were recorded below 7000 ft. Three phantoms have been drawn in the interval 0 - 7000 ft. Phantom A has been drawn to represent the mean dip of the near-surface sediments in Zone A. Phantoms B and C have been drawn to represent the mean dip of reflections within Zones B and C respectively. There is angular unconformity between Zones A and B, with Zone A wedging out towards the west. The mean dip of reflections within Zone B is generally the same as that in Zone C. Below Zone C, information is too scanty for a reasonable dip estimate to be made.

Two faults are postulated. The displacement of the zones and phantoms across the no-reflection area under Shot-points 35 to 37 has been made after study of the reflection character on records from Shot-points 31 to 35 and 37 to 41. This has resulted in a fault being postulated under Shot-point 35, with an estimated throw of 1800 ft, and down-thrown to the west. A similar fault is postulated under Shot-point 48. Phantom horizons are not shown on the east side of this fault, since the reflections are not sufficiently characteristic to make a reasonable estimate of the reflection correlation and the fault throw.

The westernmost line of steeply-west-dipping reflections when produced to the surface cuts it just east of Shot-point 63. This may represent the interface between the Cardup Series and younger sediments. The more easterly line of steeply-west-dipping reflections (below Shot-point 63) when produced to the surface cuts it about 4500 ft east of Shot-point 63. This may represent the interface between the Cardup Series and the Archaean.

The more easterly of the steeply-west-dipping reflections are probably not plotted in their true position as the velocity distribution was calculated for the younger sediments. However, this does not alter the above hypotheses which are in agreement with the known geology.

Reflections are recorded to the east of the Darling Fault. These are discussed in the general discussion.

Traverse B (Plate 5). The few reflections recorded were of poor quality. The deepest ones suggest steep dips to the east. The shallower sediments (0 - 1000 ft) show no dip component.

Traverse D (Plate 6). The same comments apply as for the eastern end of Traverse A. The records from Traverse D are presented on Plate 8.

Traverse E (Plate 7). This traverse was placed on Precambrian granitic gneiss outcrops. The refraction velocity in the granitic gneiss was found to be 16,000 ft/sec.

Traverse C (Plate 7). This traverse was placed on Cardup Series outcrops, about 1000 ft west of the surface expression of the Darling Scarp. The velocity recorded for the Cardup Series was 13,200 ft/sec. The drillers' logs report rubble in Shot-point 3, so the 10,700-ft/sec velocity recorded near Shot-point 3 may be associated with granite wash.

The 19,500-ft/sec velocity is tentatively considered not to be associated with the Cardup sediments.

General Discussion

The most satisfactory explanation made to fit the seismic and gravity results at Cookernup (Vale and Moss, 1962) was that the Darling Scarp was the surface expression of a normal fault in the basement, which was down-thrown to the west by approximately 16,000 ft.

The seismic results at Mundijong show a very similar cross-section although the dips are much flatter at the eastern end and indicate that the basement is down-thrown to the west by approximately 14,000 ft. It is suggested that the basement displacement continued during deposition, with a hinge line some undefined distance to the west, resulting in the present east dip of the sediments, with thinning of the cross-section towards the west, and possible faulting in the basement and sediments west of the Scarp under Shot-points 35 and 48.

The fault under Shot-point 35 is particularly significant as it is associated with relatively steep east dips and could provide a barrier to oil migrating from the east.

The Cardup Series is known to crop out east of Shot-point 63. West dips of about 60 degrees are measured at the surface, and the seismic indication, based on one doubtful alignment, is that they are at about 40 degrees at 10,000 ft below Shot-point 55.

Seismic events apparently arising from east of the supposed Darling Fault were recorded. Two possible theories are advanced to explain their existence:

(a) The Archaean granite and gneiss east of the fault may contain a number of shear and fault zones. Organised seismic events may be recorded from some of these shear planes. This hypothesis is not unreasonable when it is noted that somewhat similar events were recorded at Busselton (Lodwick, 1962), under circumstances that leave little doubt that they originated within the granite complex.

(b) The reflections may be multiple reflections originating within the Cardup Series.

The first explanation is considered the more likely one.

6. RECOMMENDATIONS

Further seismic investigation in the Rockingham/Mandijong area is desirable for the following reasons:

(a) West of Shot-point 24 present seismic reflection results do not provide any clear indication of structure in the sediments, the Basin structure, or the depth to basement. Further reflection shooting, using multiple-hole patterns and multiple-geophone arrangements, probably could give much of the required information.

(b) The relation between the Archaean rocks, the Cardup Series, and the younger sediments in the vicinity of the Darling Scarp is not yet clearly defined. Further refraction seismic surveying, parallel with and to the west of the Darling Scarp (near Shot-point 63) may determine the presence and thickness of the Cardup Series at depth and so contribute to the information about this relation.

(c) Two faults have been postulated in the sediments, under Shot-points 35 and 48. They could have considerable importance for oil accumulation. Refraction depth-probes east and west of the postulated faults should confirm their existence and give measures of their throws.

(d) If the fault below Shot-point 35 is confirmed, further reflection work to determine the location for a drill site for a stratigraphic test on the eastern side should follow, and a bore down to say 10,000 ft would be warranted.

7. REFERENCES

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VALE, K.R.	1960	A discussion on corrections for weathering and elevation in exploration seismic work 1959. Bur. Min. Resour. Aust. Record 1960/13.
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APPENDIX A

STAFF AND EQUIPMENT

STAFF:

Party Leader	-	M.J. Goodspeed
Geophysicist	-	K.B. Lodwick
Surveyor	-	W.A. Dawson (Department of the Interior)
Clerk	-	S. Butkus
Observer	-	R.O. Franklin
Shooter	-	C.A. Fogarty
Drillers	-	L. Sprynskyj, A.J. McCrae, B.G. Findlay (Petroleum Technology Section, B.M.R.)
Mechanic	-	G.C. Bennett

Ten assistants including cooks, drill helpers, surveyors' assistants, etc., were employed.

EQUIPMENT:

Seismic Amplifiers	-	TIC model 521 - (Plate 4 shows filter curves)
Seismic Oscillograph	-	TIC 24-trace 6 in.
Geophones	-	TIC 20 cycle
Drills	-	2 Failing-750 (with 4½ in. x 5 in. mud pumps) Drills supplied by the Petroleum Technology Section of the Bureau.
Water Tankers	-	3 x 700-gallon, vacuum-filling
Shooting truck	-	1 x 700 " , " "

A workshop truck, 4 Land Rovers, a 15-cwt utility truck, a number of trailers, and camping equipment completed the party equipment; not all the vehicles were continuously employed.

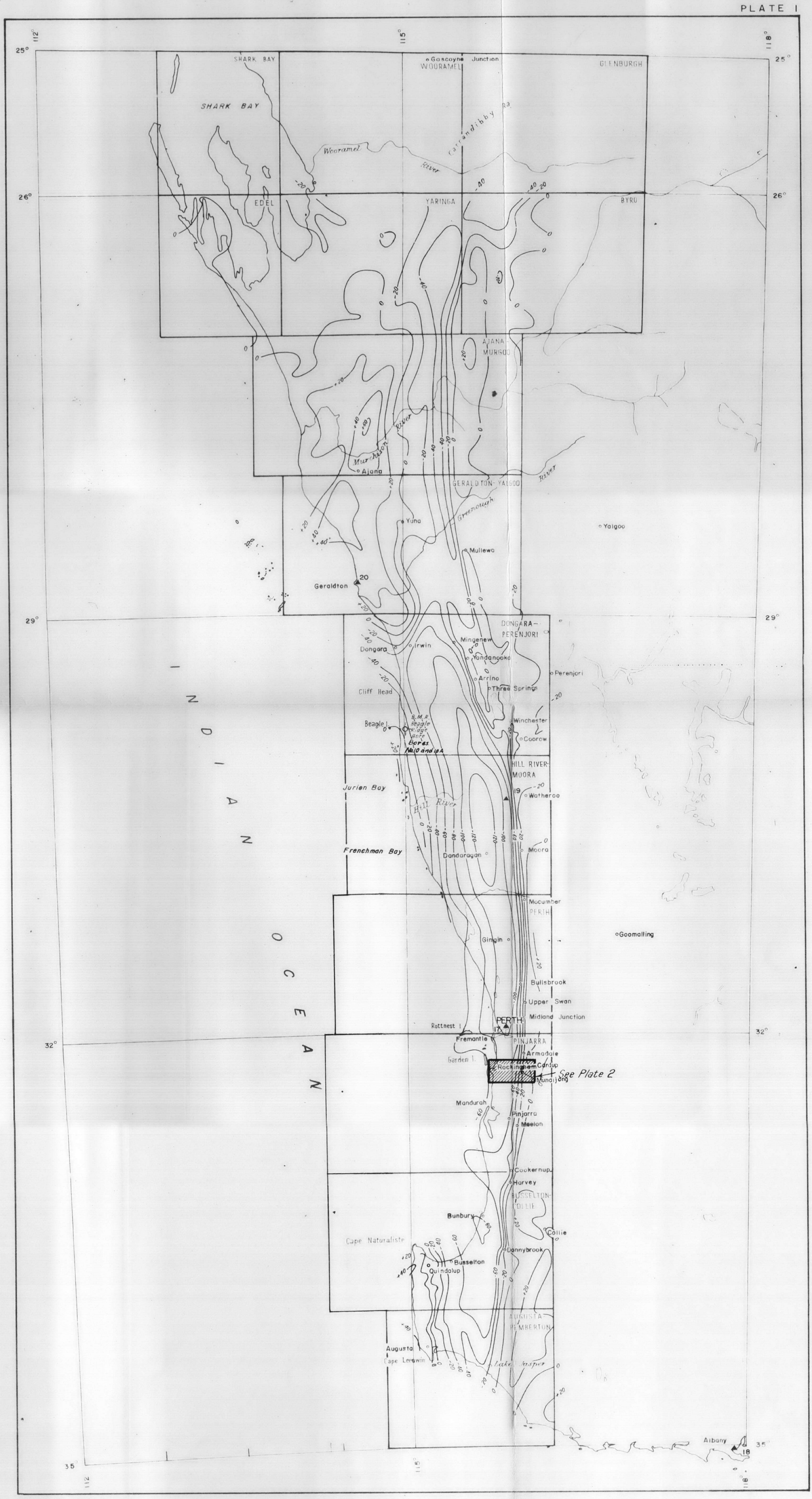
APPENDIX B

TABLE OF OPERATIONS

Sedimentary Basin:	Perth Basin, W.A.
Area:	Rockingham/Mundijong
Camp Site:	2 miles from Rockingham on Mundijong road
Date camp established:	1-3-56
Date surveying commenced:	2-3-56
Date drilling commenced:	5-3-56
Date shooting commenced:	6-3-56
Date operations concluded:	3-4-56
Miles surveyed:	20½ miles approximately
Topographic survey control:	Low water mark - Fremantle
No. of holes drilled:	111, including a 36-hole pattern, and 9 redrills
Total footage:	6770 ft
Common hole depth:	75 ft
Deepest hole:	202 ft
Datum level for corrections:	Low water mark Fremantle + 50 ft
Weathering velocities:	1850 ft/sec approx
Sub-weathering velocities:	6000 - 7000 ft/sec
Source of velocity distribution:	See under 'Computing Methods'

Shooting Data

Shot-point interval:	1320 ft
Geophone group:	4 per trace, 5 ft apart in line
Geophone group interval:	110 ft
Holes shot:	99
Explosives used:	1313 lb
Usual recording filter:	L_3H_4
Common charge sizes:	10-15 lb
Weathering corrections:	After Vale (1960)
Grading system:	After Gaby (1947)



LEGEND

- Isogals (values in milligals)
- Gravity high anomaly
- " low "
- B.M.R. gravity pendulum station
- " gravity and aeromagnetic area (Scale 1" = 4 Mile)

COMPILED AUGUST 1960

ROCKINGHAM-MUNDIJONG SEISMIC SURVEY,

PERTH BASIN, W.A., 1956

LOCALITY MAP AND BOUGUER ANOMALIES

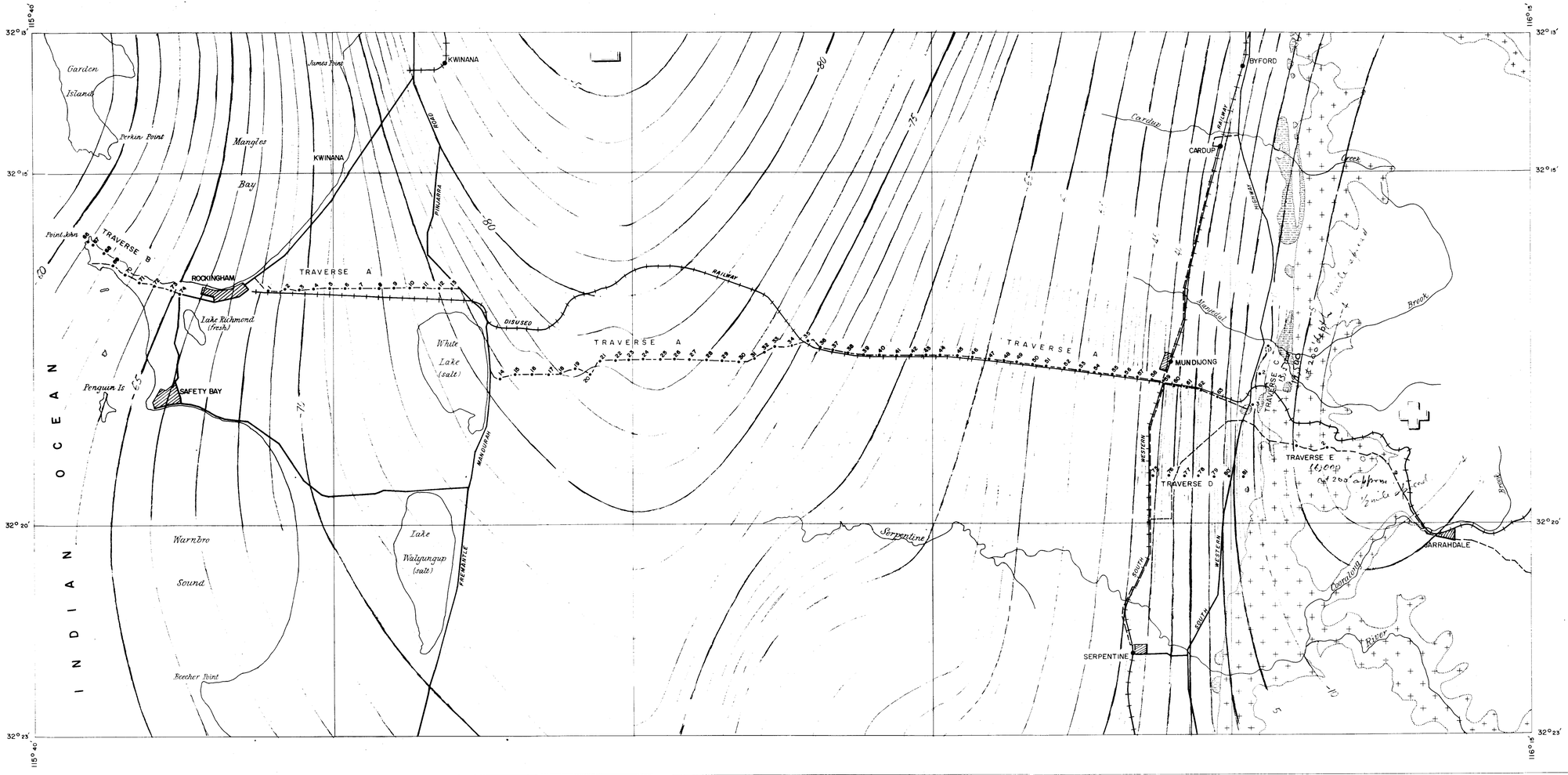
SCALE IN MILES

40 0 40 80 120

Reference - W.A. Mines Dep't 1950 geological sketch map

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G193-47-1

To Accompany Record No 1962/107



LOCATION

MAP DATA

PROJECTION : TRANSVERSE MERCATOR, AUSTRALIAN SERIES

CONTROL : ROYAL AUSTRALIAN SURVEY CORPS 1 MILE TO 1 INCH MAPS – FREMANTLE, KELMSCOTT, ROCKINGHAM AND JARRAHDALE

DETAIL : PLANIMETRY FROM RASC 1 MILE GRAVITY MAPS
GRAVITY VALUES FROM FIELD SURVEY ALONG B.M.R. SEISMIC TRAVERSE

RELIABILITY : GRAVITY - SEMI-DETAILED RECONNAISSANCE

EXPLANATION

RELATIVE BOUGUER ANOMALIES ARE BASED ON THE OBSERVED GRAVITY VALUE OF 979,394·3 MILLIGALS AT B.M.R. No 17 PENDULUM STATION, PERTH, W.A.

FOR THE CALCULATION OF BOUGUER ANOMALIES 2·2 GR/CM^3 HAS BEEN ADOPTED AS AN AVERAGE ROCK DENSITY

ELEVATION DATUM – M.S.L. FREMANTLE, W.A.

LEGEND

TOPOGRAPHY
- ROADS
- RAILWAY
- WATERCOURSE (NON-PERENNIAL)
- TOWNSHIP

GRAVITY
- SEISMIC SHOT POINT
- ISOGALS
- HIGH ANOMALY
- LOW ANOMALY

GEOLOGY
- GRANITE AND GRANITIC GNEISS
- SHALES OF LOWER CARDUP SERIES

PRE-CAMBRIAN

SCALE IN MILES

1 0 1 2 3 4

CONTOUR INTERVAL 1 MILLIGAL

Reference : W.A. Geological map Perth and Environs, 1 mile to 1 inch

ROCKINGHAM - MUNDIJONG SEISMIC SURVEY PERTH BASIN, W.A. 1956

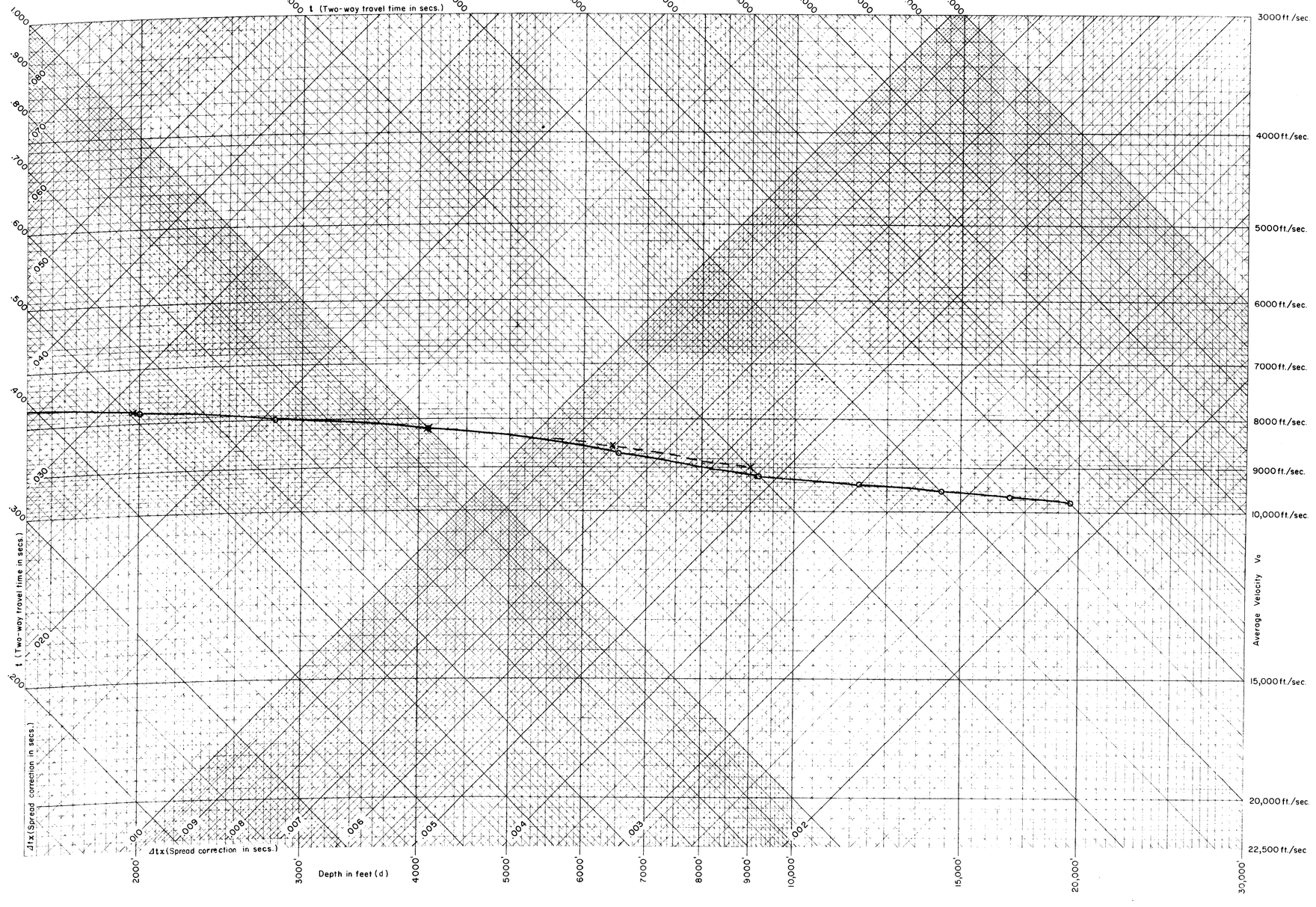
SEISMIC TRAVERSES, GEOLOGY AND BOUGUER ANOMALIES

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

COMPILED FEBRUARY 1961

G 193-62

To Accompany Record No 1962/167



NOMOGRAM

TIME - DEPTH - AVERAGE VELOCITY - SPREAD CORRECTION

$x = 1320'$

In use, this nomogram will provide a single point for any two of the four parameters defined below. From this point, the values of the other two parameters may be read off directly.

BASIC EQUATIONS

$$\Delta t_x = t \left[\left(\frac{x^2}{4d^2} + 1 \right)^{\frac{1}{2}} - 1 \right] \quad \text{①}$$

$$d = \frac{1}{2} V_a t \quad \text{②}$$

PARAMETERS

t_o = Two-way vertical travel time to horizontal reflecting surface

x = Distance from shotpoint to geophone

Δt_x = Spread correction at distance x from shotpoint

d = Depth of horizontal reflecting interface

V_a = Average Velocity

—⊖— Velocity curve from $t, \Delta t$ Analysis

–X– Velocity curve ($V_a = 7500 + 0.36d$) - used for dip plotting

ROCKINGHAM-MUNDIJONG SEISMIC SURVEY

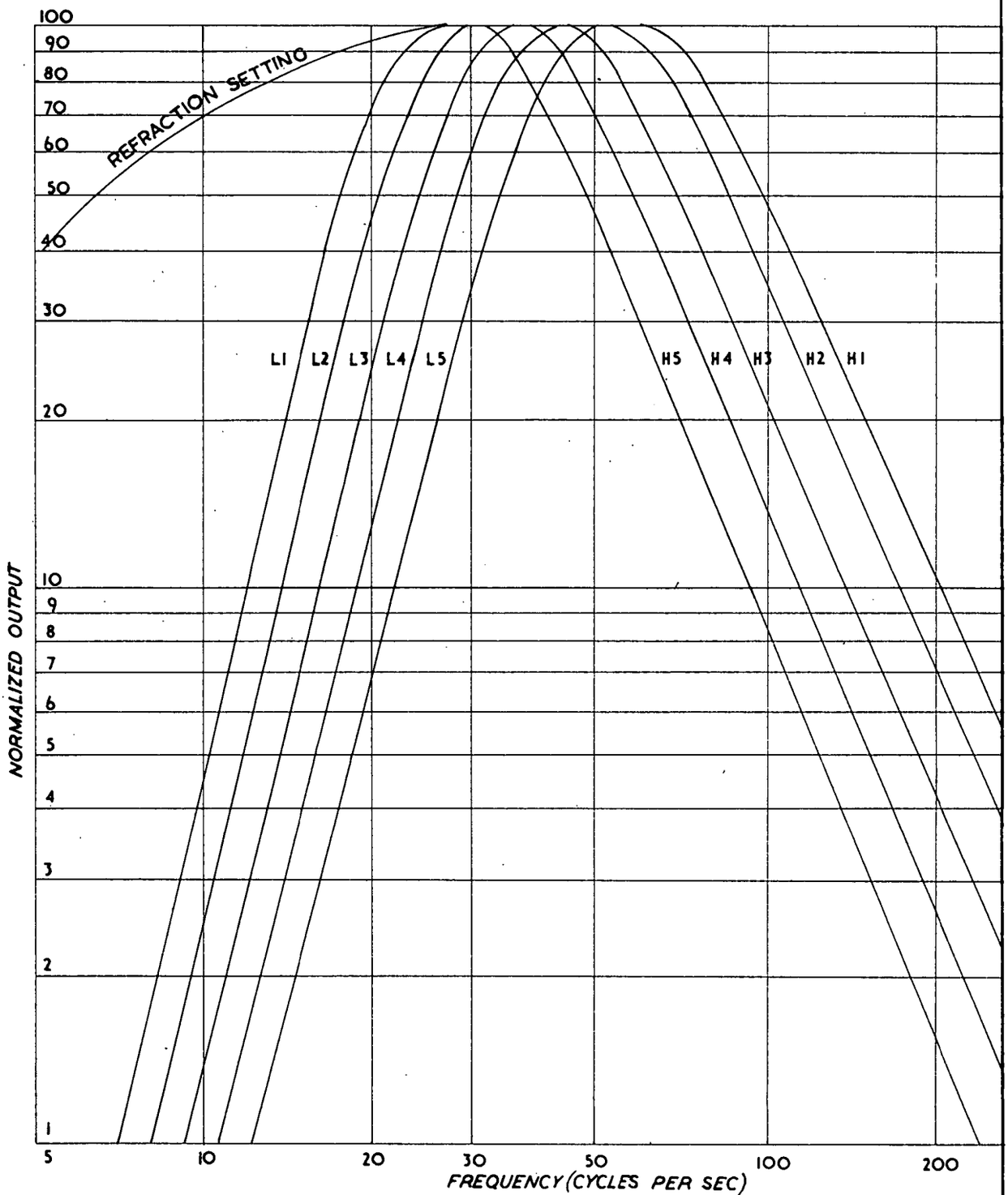
PERTH BASIN, W.A. 1956

(AFTER G 85-115)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G193-53

To Accompany Record No 1962/107

PLATE 4



FILTER CURVES

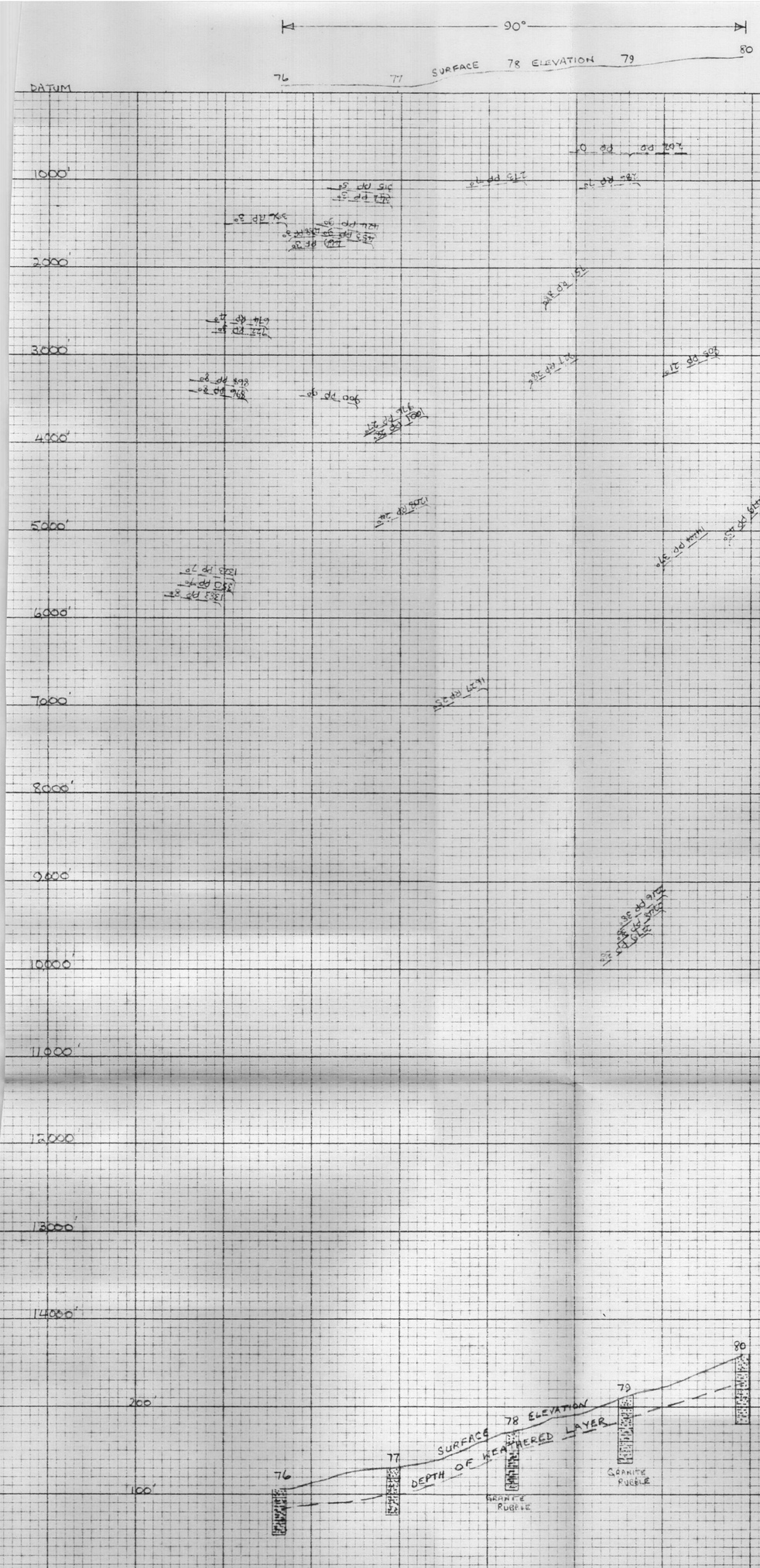
T. I. Co AMPLIFIER BAND PASS TYPE 521

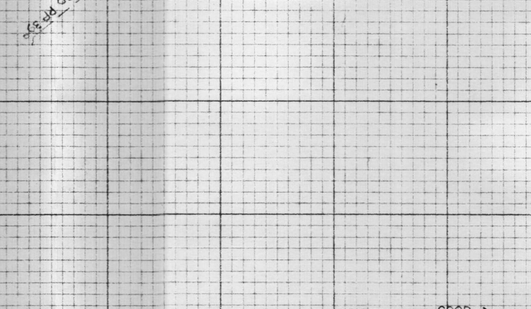
G 193-31

ROCKINGHAM

TO ACCOMPANY RECORDS No 1962/107

PLATE 6





REFLECTION CROSS-SECTION

TRAVERSE D

REFLECTIONS MIGRATED BY CURVED PATH TECHNIQUE

VELOCITY FUNCTION $V_d = 7500 + 36\,d$

HORIZONTAL AND VERTICAL SCALES IN FEET

1000 0 1000 2000 3000 4000

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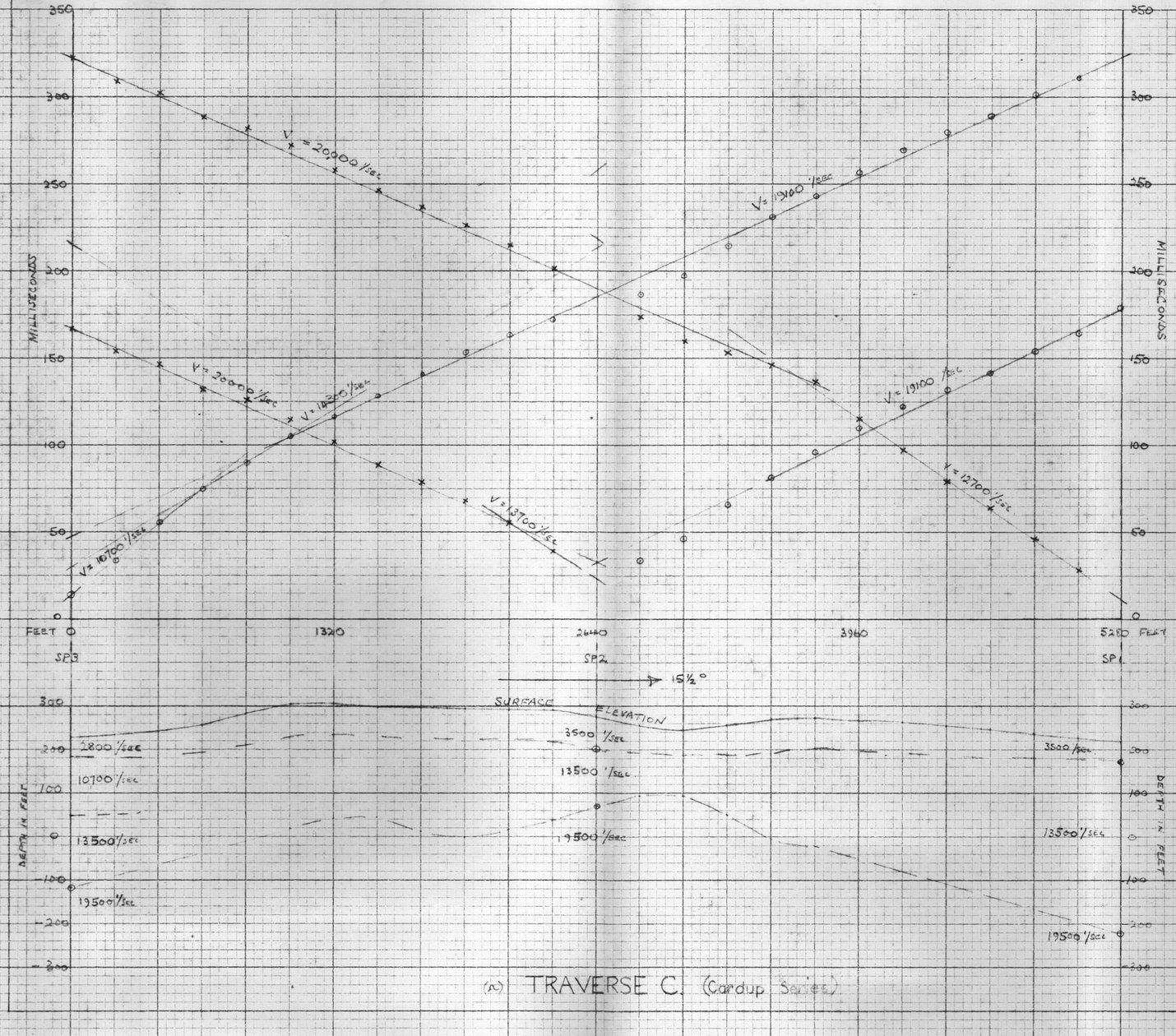
G193-52

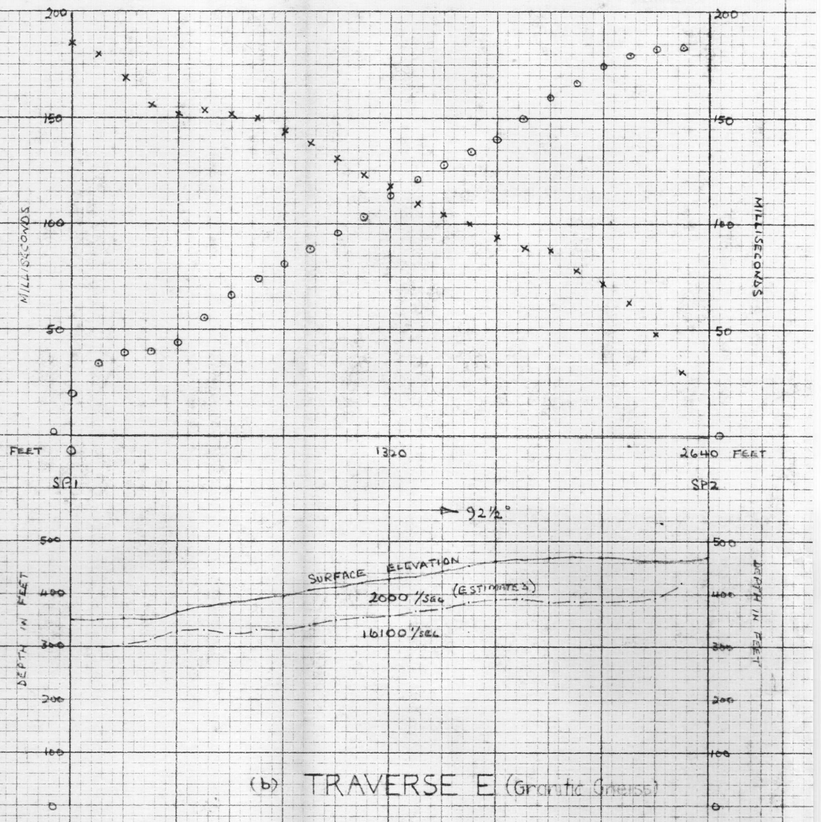
To Accompany Record No. 1962/107

ROCKINGHAM-MUNDIJONG. W.A. 1956.

PLATE 7



(a) TRAVERSE C. (Cardup Series)



(b) TRAVERSE E (Granitic Gneiss)

REFRACTION TIME DISTANCE CURVES AND INTERPRETATION

ROCKINGHAM — MUNDIJONG, W.A. 1956

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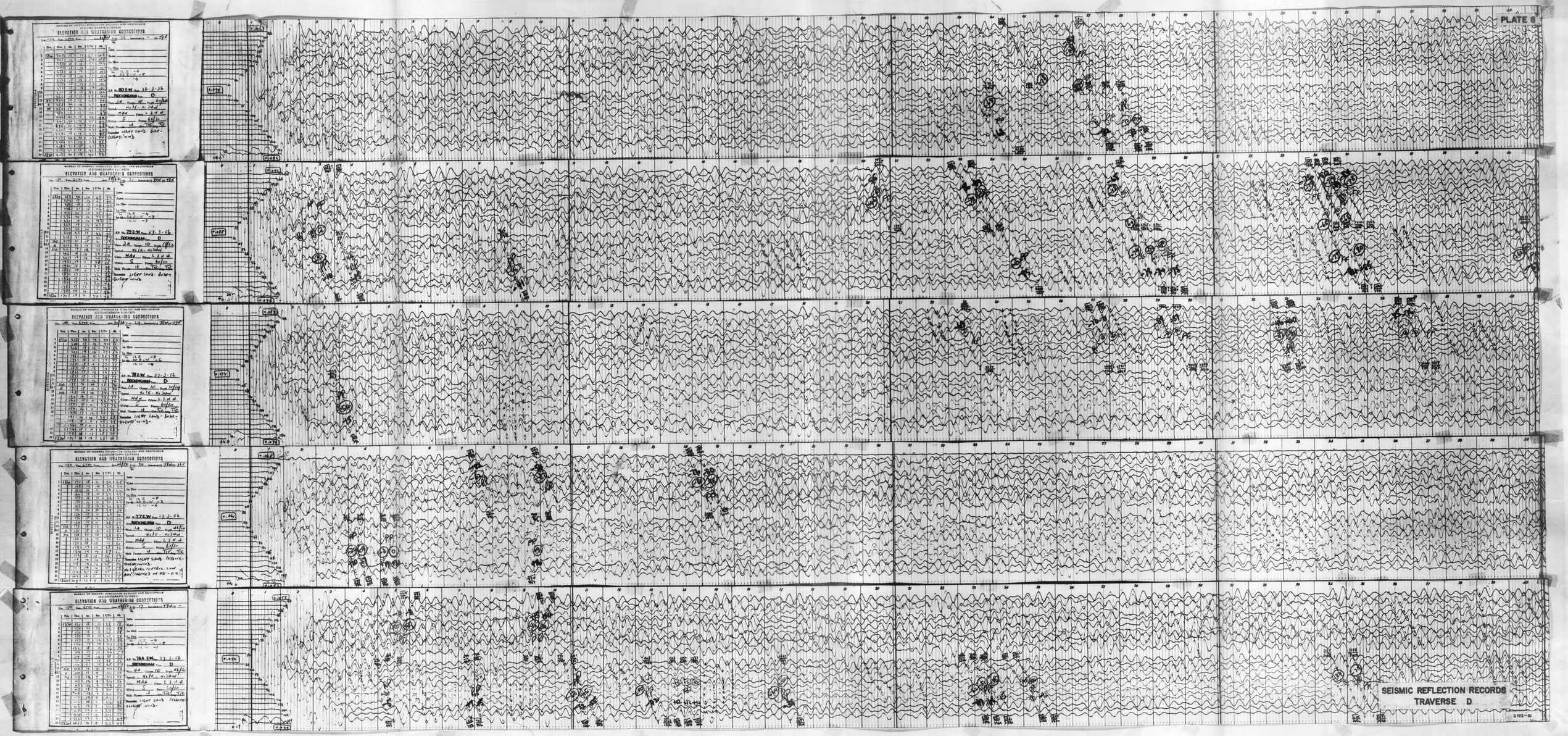
To Accompany Record No 1962/107

PLATE 6



SEISMIC REFLECTION RECORDS
TRAVERSE D

GPO 5-60