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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1962/108

BUSSELTON SEISMIC REFLECTION SURVEY,

WESTERN AUSTRALIA 1956

by

K. B. LODWICK

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SUMMARY

Following a gravity survey of the Perth Basin in 1951-52 (Thyer and Everingham, 1956), in which it was indicated that a sedimentary thickness of about 35,000 ft was probably present in the Perth Basin, several seismic traverses were surveyed across the Basin. This Record deals with one such reflection traverse which was surveyed between Quindalup and Donnybrook. The purposes of the survey were to find the thickness and dip of the sediments and to discover any faulting or folding within them.

Results of the survey were inconclusive regarding the depth to basement but indications are that it is at least 8000 ft in the deepest part of the Basin along this traverse. The sediments appear to be folded and faulted. There is evidence for the existence of a major fault east of the Dunsborough Fault, and the existence of the Whicher Fault was tentatively confirmed.

1. INTRODUCTION

In January and February 1956 a seismic party from the Bureau of Mineral Resources did a reflection survey along a roughly easterly line through Busselton, Western Australia. (Plate 1). The line is across the Perth Basin towards its southern limit. A regional gravity survey of the whole of the Basin in 1951-52 (Thyer and Everingham, 1956) disclosed a large negative Bouguer anomaly (Plate 2) in the Basin. The area covered by the Bouguer anomaly (Plate 2) is roughly that which includes the Mesozoic to Quaternary formations west of the Darling Fault (Plate 1). Thyer and Everingham concluded that much of the Bouguer anomaly was due to a great thickness of sediments, in places probably as great as 35,000 ft. In the Busselton area metamorphic, gneissic, and granitic rocks are known to crop out along the coastline between Cape Naturaliste and Cape Leeuwin as well as to the east of the Darling Fault (Plate 1). The negative Bouguer anomaly was confined between these two blocks of basement rocks. The seismic line was planned to cross the Bouguer anomaly from basement outcrop to basement outcrop.

The aims of the seismic survey were:

(a) to determine the thickness of sedimentary rocks in the Busselton area, thereby testing the interpretation of the gravity data

(b) to provide structural information regarding the sediments and perhaps the basement.

2. GEOLOGY

The geology of the Perth Basin has been described by Fairbridge (1949); McWhae, Playford, Lindner, Glenister and Balme (1958), and Playford and Johnstone (1959). Thyer and Everingham (1956) presented a general outline of the geology with reference to the report by Fairbridge. A geological map of the southern part of the Perth Basin (after Fairbridge, 1949) is shown on Plate 1.

The Perth Basin extends along the coast of Western Australia from Augusta to Geraldton. The north-trending Darling Fault forms the eastern boundary of the Basin, separating mainly the Precambrian gneiss, granite, and metamorphic rocks of the Western Australian Shield from the sediments of the Basin. Upper Precambrian and Lower Palaeozoic sediments crop out in places on the eastern side of the fault. Generally the western margin of the Basin is concealed below the Indian Ocean, but in the Busselton area the Perth Basin appears to be formed in a graben-like structure between the Darling Fault and another block of Precambrian gneiss, granite, and metamorphic rocks that crop out from Cape Naturaliste to Cape Leeuwin. The Dunsborough Fault forms the boundary between the sediments and these Precambrian rocks on the western side of the Basin.

The Perth Basin is clearly defined by the Bouguer anomaly map (compare Plates 1 and 2), which shows steep gradients coinciding with the locations of the Darling and Dunsborough Faults. From the intensity of the anomaly, Thyer and Everingham (1956) have postulated that very great thicknesses of sediments must exist in the Perth Basin, the thickest part probably being west of Watheroo where there may be as much as 35,000 ft of sediments. They have also suggested that the Perth Basin should be divided into two main structural units, the Dandaragan Trough in the north and the Bunbury Trough in the south. It is postulated that these two units join to form a saddle-like feature west of Harvey (Plate 2). The seismic line passes slightly south of the deepest part of the Bunbury

Trough. On the basis of the gravity results, the thickest sediments, probably about 15,000 to 20,000 ft in thickness, may be expected adjacent to the Darling Fault. The sedimentary cross-section then thins to the west until it is terminated by the Dunsborough Fault.

On physiographical evidence, Fairbridge (1949) has postulated the Whicher Fault, curving from the Darling Fault east of Bunbury to the Dunsborough Fault about 20 miles south of Cape Naturaliste (Plate 1). This fault divides the Perth Sunkland (to the north of the fault), which is covered mainly by Quaternary sand and limestone, from the Donnybrook Block (to the south of the fault), where Mesozoic rocks are exposed. There is little evidence in the Bouguer anomaly map to confirm the existence of the Whicher Fault (Thyer and Everingham, 1956). However the gravity results indicate that there is a fault about 10 to 12 miles east of the Dunsborough Fault (<u>op. cit.</u>). This fault would be downthrown to the east, and its position has been shown on Plate 2.

The formations that are exposed on the surface over which the seismic survey was done are shown on Plate 1. In some places basalts of Tertiary or Cretaceous (McWhae <u>et al</u>, 1958 p. 101) age are exposed and have been observed at Shot-point 109 and between Shot-points 204 and 207 (Plate 3). The formations beneath those exposed on the surface, (Quaternary, Tertiary, and upper Jurassic or lower Cretaceous Capel River Group) are unknown. The Capel River Group, of which the Donnybrook Formation comprises the top unit, is about 3000 ft thick; it consists of sandstone, shale, some conglomerate, and lignitic beds. In the north of the Basin, however, Palaeozoic sediments (probably Permian as well as Ordovician and Silurian) are known. The possibility of the existence of similar formation beneath the Capel River Group should be appreciated particularly as the gravity results indicate a possible thickness of 15,000 to 20,000 ft of sediments in the Basin near Busselton. In a bore drilled at Beagle Ridge, 150 miles north of Perth, sequences of Pleistocene, Mesozoic, and Permian strata were penetrated before basement rocks were reached at approximately 4790 ft (Jewell and Jackson, 1961)

3. <u>FIELD DATA</u>

The personnel attached to the seismic party and the equipment used during the survey, are listed in Appendix A. The Table of Operations (Appendix B) gives a summary of the surveying, drilling, and recording data.

The seismic line can conveniently be divided into three parts as follows:

Traverse A, west of Busselton (Shot-points 1 - 51)

Traverse B, from Busselton eastward to Cartis (Shot-points 53 - 109)

Traverse C, beside the Capel-Donnybrook road (Shot-points 201 - 251).

A plan of the traverses with the position of each shot-point is shown on Plate 3. The traverses were surveyed beside railways and roads so that access was generally easy, but this meant that it was necessary in places to bend the traverses. However, the general direction of the traverses is east. Major changes in direction are indicated on the seismic reflection cross-sections (Plates 4, 5, and 6); the details of the direction changes may be obtained from Plate 3.

Drilling throughout most of the area was generally easy. In some places, however, there were difficulties in maintaining circulation, and bentonite was used. Samples were taken from each shot-hole and were sent to the Bureau's Geological Branch for examination. The drill logs of each shot-hole are shown on the seismic reflection cross-sections (Plates 4, 5, and 6).

Throughout the survey, single shot-holes were used, and charges ranged between 5 and 25 lb.

4. RESULTS

Velocity information in the weathered and sub-weathering layers was derived from short refraction spreads, up-hole times, and first-arrival times on each record. The thickness of the weathered layer is plotted below the elevation profile of the traverses on Plates 4, 5, and 6. Velocities recorded for the sub-weathering layer at each shot-point are also shown.

As the quality of reflections recorded in the Busselton area was poor, it was not possible to obtain reliable vertical velocity information from a $t: \Delta t$ analysis of reflections. The time-depth relation for the area was assumed to be the same as at Gingin (Vale, 1956). A velocity function $V_i = 7500 + 0.36d$ was used in depth (d) and dip calculations.

Reflection quality at Busselton ranged from poor to very poor. A high noise level is believed to be the main factor causing the records to be poor; even though reflected energy can be recognised on almost all records, it is generally difficult to follow reflections clearly across a record. The signal-to-noise ratio was so low that few reflections had sufficient elevation and envelope to be graded as F or G (Gaby, 1949). Reliable dip information could not be obtained from the reflections recorded.

Migrated seismic reflection cross-sections along Traverses A, B, and C are shown on Plates 4, 5, and 6. The cross-sections have been plotted on a natural scale of 1000 ft to 1 in. using a Sinclair Dip Plotter. To facilitate the interpretation of the results, phantom horizons have been drawn on the cross-sections by correlating reflections, where possible, and by averaging dip information where there were insufficient data for correlation. Owing to the poor reflection quality it has not been possible to correlate these horizons across faults or across gaps between traverses; consequently the phantom horizons do not necessarily refer to the same geological horizon throughout the three traverses.

5. INTERPRETATION

Traverse A (Plate 4)

From Shot-points 47 to 51, at the western end of Traverse A, first-break velocities of the order of 16,500 ft/sec were recorded. Shot-point 52 (which was not drilled) is actually close to outcropping granite, and it seems probable that the granite is at shallow depth as far as the vicinity of Shot-point 47; this would account for the high first-break velocities. This suggests that the Dunsborough Fault is probably located near or east of Shot-point 47. However, the records from Shot-points 47 to 51 show reflections at times as great as 8 seconds, mostly with strong east dip. Owing to the great depth from which they appear to come, only a few could be plotted on the cross-section. When migrated according to their east dip, they appear to come from within the basement complex to the west of the Dunsborough Fault.

The recording of apparent reflections at times as great as 8 seconds, generally showing steep, often erratic dips, was quite common in this area. It appears unreasonable to interpret these energy alignments as reflections within sedimentary rocks, particularly as some were from shot-points almost certainly above a shallow basement. It is thought that some of these reflections could be associated with faulting in the basement. Also, it is known that the outcropping basement rocks are a complex of granitic, gneissic, and metamorphic rocks, which presumably may have interfaces within them that could give rise to reflections.

On Traverse A, steeply-east-dipping reflections at a depth of about 10,000 ft beneath Shot-point 51 (recorded from Shot-points 47 and 48), may be associated with the Dunsborough Fault, although they appear to be displaced too far to the west, if the positioning of the fault from the first-break velocities is correct. Along the rest of the traverse, reflections were often recorded from a zone 8000 ft to 16,000 ft deep. Generally their dips are erratic and quite often steep. As indicated above, it is very unlikely that they indicate sedimentary layering, and, in general, no reasonable interpretation of them can be given in terms of basement structure. Exceptions to this are:

(a) the steep east-dipping reflections recorded below Shot-points 22 to 19, which may be associated with faulting in the shallower layers below Shot-point 24.

(b) the steep east-dipping reflections recorded below Shot-points 13 to 8, which may be associated with faulting in the shallower layers below Shot-point 13.

(c) the steep west-dipping reflections at Shot-points 6 and 7, which may be associated with faulting in the shallower layers below Shot-point 4.

The shallower reflections, although of poor quality, are consistent in their dips, and they might be expected to represent sedimentary layers. It seems likely that the thickness of sediments between Shot-points 14 and 49 is at least 3000 ft but not greater than 5000 ft. The phantom horizons drawn in this zone appear to show an anticlinal structure at Shot-point 28. Beneath Shot-point 25, reflections indicate that faulting may have taken place, but there is no indication of any significant thickening of sediments on the eastern (down-thrown) side. Between Shot-points 14 and 11 a zone of faulting is indicated by the reflections; sediments appear to thicken from probably less than 4000 ft on the west, to at least 6500 ft at Shot-points 8 and 9. This fault corresponds closely in position to the fault indicated by gravity results (Plate 2). Beneath Shot-points 4 and 5, a possible fault is indicated by steep dips recorded from 4500 ft and by the disturbance in the configuration of the phantom horizons shown on the cross-section.

Traverse B (Plate 5)

Along this traverse, reflections indicate that the sediments are at least 6000 to 7000 ft thick. Reflections were recorded fairly consistently from this zone and they do not show abnormal dips. From below this depth there are a fair number of reasonably consistent reflections, particularly east of Shot-point 72, which may be associated with sedimentary rocks down to 15,000 ft, but because of the poor quality of the reflections, this inference is very doubtful. Amongst these deeper reflections, there are a few steeply-dipping ones that are obviously not from normal layering in the sediments. An interpretation of these is not attempted.

Two phantom horizons have been drawn in the zone above 7000 ft. These apparently demonstrate an anticlinal structure, but as there is a substantial bend in the line at Shot-point 78, the apparent east and west dips could both be components of a southerly dip. At Shot-point 89 the reflections give strong evidence of faulting in the second horizon. Variable dips in the first horizon support this.

Traverse C (Plate 6)

On Traverse C, conformable reflections were recorded to a depth of about 8000 ft and these can probably be associated with sediments. A few odd reflections were recorded from below this depth down to about 12,000 ft, but they are too rare to suggest further sediments.

Reflections were of poorer quality than on Traverses A and B, and this may be associated with the considerable variation in elevation and thickness of the weathered layer along this traverse. The failure to record reflections from beneath Shot-points 205 to 208 may be explained by the presence of basalt near the surface. Basalt was observed in a creek bed nearby.

The attitude of reflections in the upper layers indicates faulting beneath Shot-point 217. This fault corresponds closely with the position of the Whicher Fault suggested by Fairbridge (1949). A change in elevation along Traverse C near Shot-point 215 indicated evidence on which Fairbridge based his suggestion of faulting.

At the eastern end of Traverse C no indication is given by the reflection cross-section of the proximity of the Darling Fault. Granitic boulders and rubble were recovered from the shot-hole at Shot-points 249. The cross-section indicates that sediments dip slightly more to the east as the Darling Fault is approached. The anticline suggested at Shot-point 242 is based on very poor data on its western flank, and the reversal may not be real.

A seismic reflection traverse recorded across the Perth Basin near Cookernup (Vale and Moss, 1962) also showed that the sediments continue to dip to the east as the Darling Fault is approached. However, along that traverse the fault itself was strongly indicated by steep west-dipping reflections that were obviously associated with the fault zone. No such reflections were recorded on Traverse C.

6. CONCLUSIONS

Owing to the poor quality of the seismic results it is not possible to make any definite estimate of the thickness of sediments in this part of the Perth Basin. It seems probable that between 3000 and 5000 ft of sediments occur immediately east of the Dunsborough Fault at about Shot-point 47; thus the throw of this fault appears to be at least 3000 ft. A further increase in thickness of sediments is indicated east of Shot-point 12, and this may also be associated with a fault which in the basement would be down-thrown to the east by about 2000 to 3000 ft. This is in agreement with gravity results. Between this fault and the Darling Fault, the sediments probably attain a thickness of at least 8000 ft. It is impossible to say from the seismic results whether the sediments continue below this depth. There is no direct recorded seismic evidence of the presence of the Darling Fault.

APPENDIX A

STAFF AND EQUIPMENT

STAFF

Party Leader	M.J. Goodspeed	
Geophysicists	K.B. Lodwick	
	F.J. Moss	
Surveyors	A.N. Rochefort	)
	W.A. Dawson	) Dept. of the Interior
Chainman	J. Cahill	)
Observer	R.O. Franklin	
Shooter	C.A. Fogarty	
Drillers	L. Sprynskyj	
	B.G. Findlay	
	A.J. McRae	
Mechanic	G.C. Bennett	
Field Assistants	Eight	

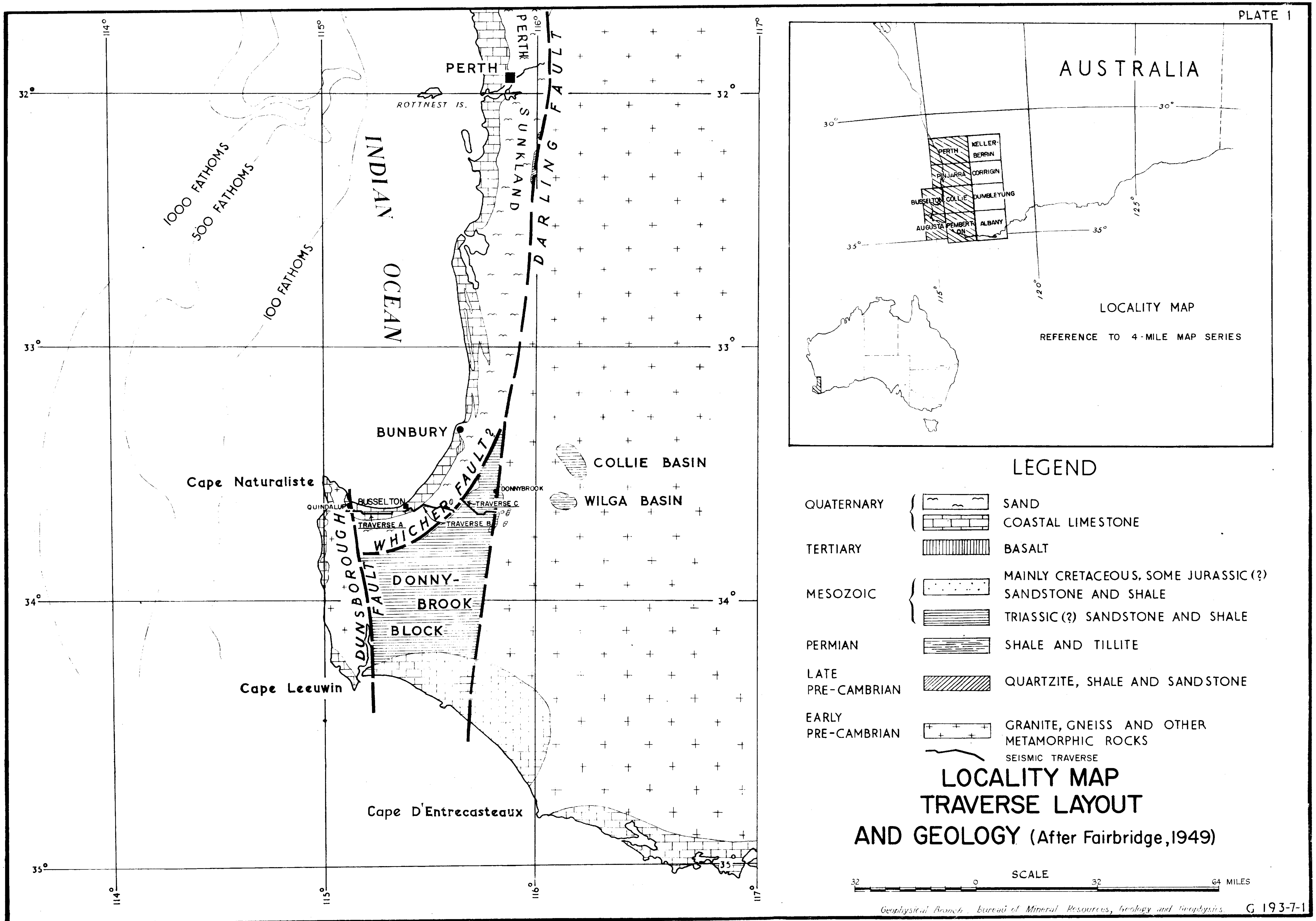
EQUIPMENT

Seismic amplifiers	TIC Model 521 (24)
" camera	TIC 6-in. 25-trace
Geophones	TIC 20 c/s
Drills	Two, Failing 750

APPENDIX B

TABLE OF OPERATIONS

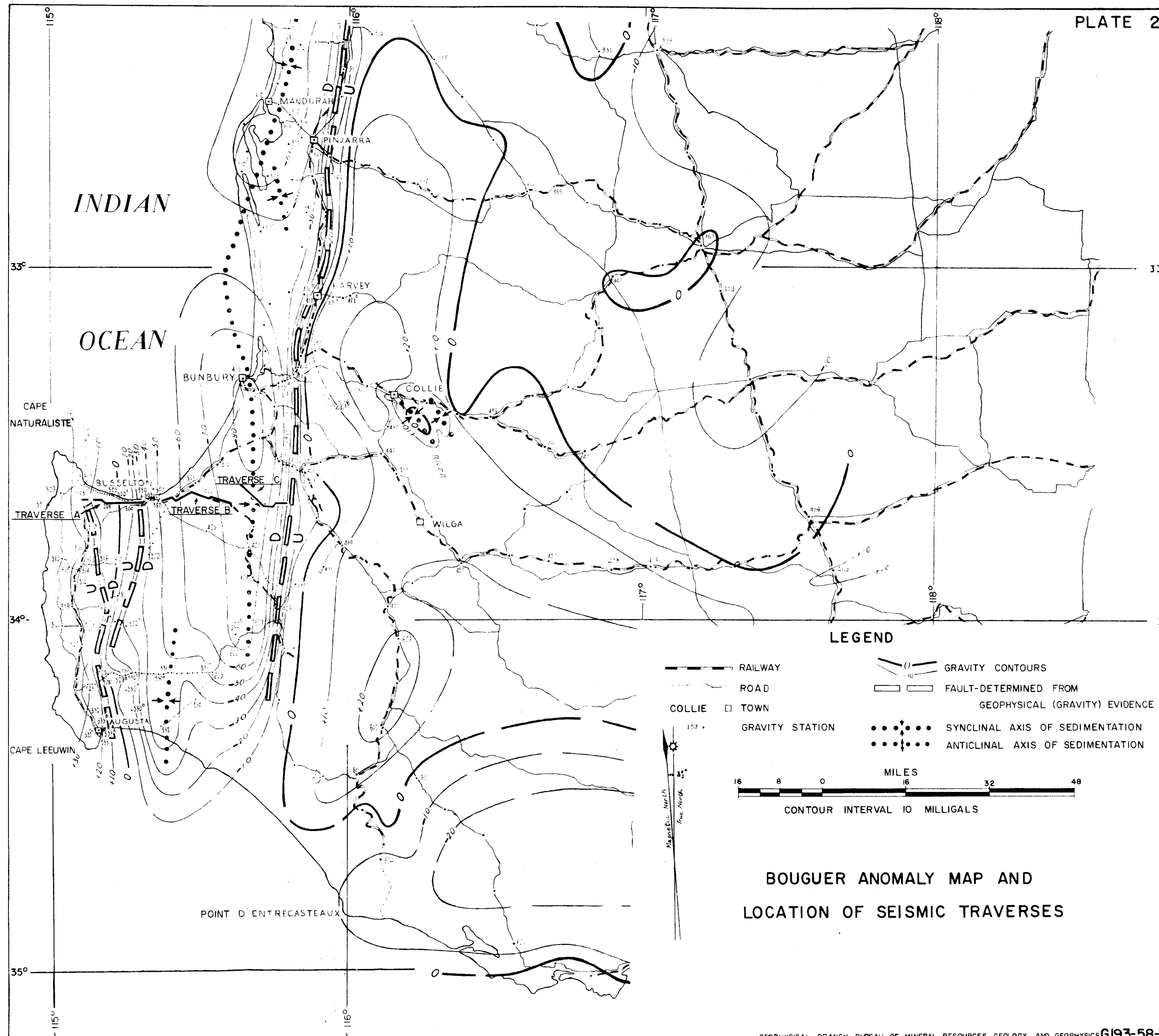
Sedimentary basin	Perth Basin, Western Australia
Area	Quindalup-Busselton-Donnybrook
Survey commenced	18th January 1956
Survey completed	29th February 1956
Camp sites	Busselton aerodrome and farm-house on Capel-Donnybrook road
Miles surveyed	40
Topographic survey control	Land maps and 1 inch = 1 mile military series
Levels	Mean sea level at Bunbury, (from Railway)
Datum level for corrections	50 ft below M.S.L.
Total footage drilled	13,646 ft
No. of holes drilled	154
Source of velocity distribution	Gingin area (Vale, 1956)
Shot-point interval	1320 ft (see cross-sections for short and long spreads)
Geophone group	4 geophones at 5-ft intervals
Geophone group spacing	110 ft
Holes shot	154
Common shooting depths	65 and 100 ft
Common charge sizes	5 and 10 lb
Grading system	After Gaby (1947)
Weathering corrections	After Vale (1960)



LOCALITY MAP
TRAVERSE LAYOUT
AND GEOLOGY (After Fairbridge, 1949)

PERTH BASIN W.A. 1962

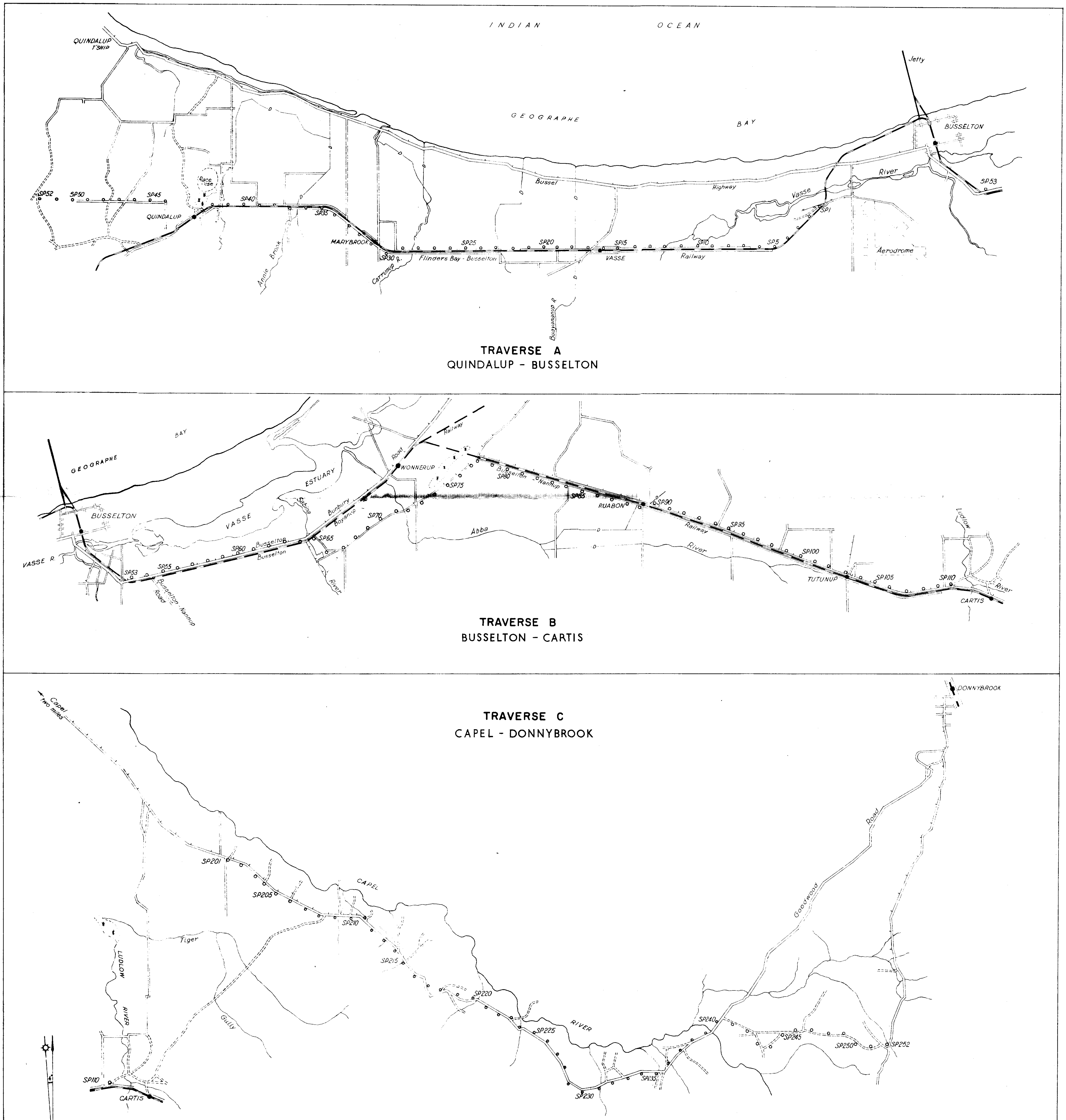
To Accompany Record No 1962/108



BOUGUER ANOMALY MAP AND LOCATION OF SEISMIC TRAVERSES

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G193-58-1

To Accompany Record No 1962/108



LEGEND

- Swamp or marsh
- Drain
- Railway
- Telephone or telegraph line
- Electric transmission line
- Unfenced earthen road
- Shot-point

LOCATION OF SEISMIC TRAVERSES

SCALE IN MILES

1 0 1 2 3 4

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

G251-2

TO ACCOMPANY RECORD No 1962/108

BUSSELTON - PERTH BASIN, W.A.

E
SE
W
BRITISH MAID "ALLIANCE"
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
FEET ABOVE M.S.L.
100
0
-50
V=16300
V=16600
V=16600
5900
10700
16700
Vc=5750
Vc=5005
Vc=5920
Vc=5980
Vc=5940
Vc=6110
Vc=6140
Vc=6250
Vc=6150
Vc=6110
Vc=6180
Vc=6150
Vc=6120
Vc=6220
Vc=6380
Vc=6140
V1=6280
V1=7760
Vc=6160
V1=8680

SEISMIC REFLECTION CROSS - SECTION

TRAVERSE A

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G 103-54
TO ACCOMPANY RECORD 1962/108

NE
SE
NE
55
56
57
58
59
60
61
62
63
64
67
68
69
70
71
72
73
74
75
78
79
80
1000
2000
3000
4000
5000
6000
7000
8000
9000
10 000
11000
12000
13000
15000
17000
FEET ABOVE MSL

PLATE 5

SEISMIC REFLECTION CROSS-SECTION

TRAVERSE B

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G 193-55

TO ACCOMPANY RECORD No 1962/108


SE
202 203 204 205 206 207 208 209 212 213 214 215 216 217 218 219 220 221 223 224 225 226 227
FEET BELOW DATUM OF SOFT M.S.L.
?F
FEET ABOVE M.S.L.
ELEVATION
WEATHERED LAYER
Ve = 7100 FT/SEC
Ve = 7000
Ve = 6500
Ve = 5900
V₁ = 10,210
Ve = 6010
V₁ = 10300
Ve = 5940
V₁ = 7040
Ve = 6110
Ve = 5410
V₁ = 7530
Ve = 5950
Ve = 6100
V₁ = 10,120
Ve = 5810
Ve = 5850
Ve = 5320
Ve = 6350
Ve = 6050
Ve = 5500
V₁ = 7250
Ve = 5540
V₁ = 7520
Ve = 6040
Ve = 6020
Ve = 6300
Ve = 5660
V₁ = 6400
Ve = 6080
Ve = 6300
Ve = 6130
Ve = 6490
Ve = 6820
Ve = 5870

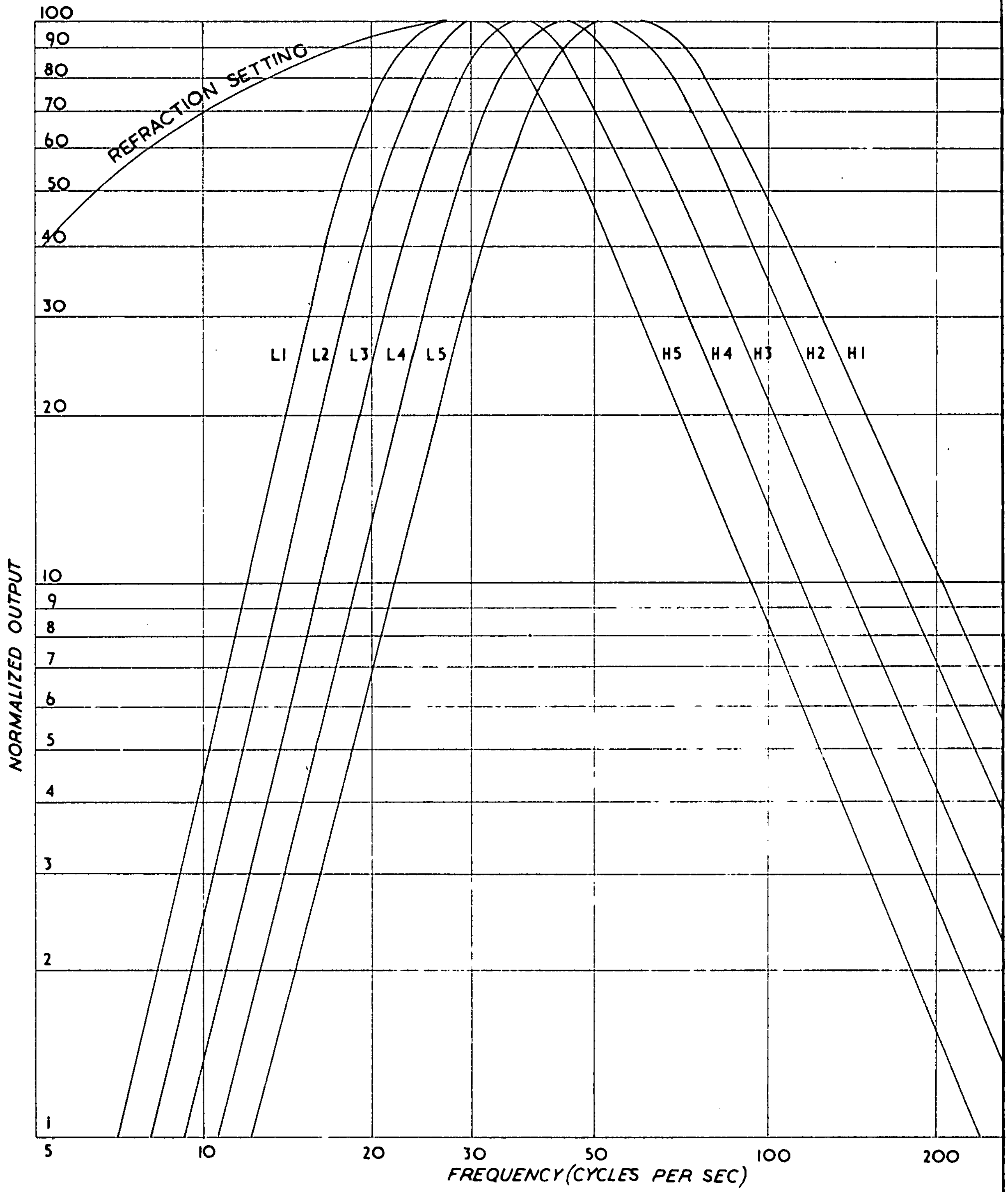
PLATE 6

SEISMIC REFLECTION CROSS-SECTION

TRAVERSE C

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS. G193-56

TO ACCOMPANY RECORD No 1962/108



FILTER CURVES

T. I. Co. AMPLIFIER BAND PASS TYPE 521

G193-72

To Accompany Record No 1962/108