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DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1973/62

OFFICER BASIN SEISMIC SURVEY, W.A., 1972

OPERATIONAL REPORT

by

P.L. Harrison

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ILLUSTRATIONS

SUMMARY

A seismic survey was made in the southwest part of the Officer Basin, Western Australia, by the Bureau of Mineral Resources from mid-July to early December 1972.

Geological mapping in the basin has given an incomplete picture of the structure because the area is largely covered by flat-lying Permian fluvioglacials and Cretaceous rocks. Proterozoic outcrops are sparse and widely scattered so that the structure and composition of much of the sedimentary sequence are unknown. The only reliable shallow subsurface information available from geophysical and well data is along the northern part of the basin near Warburton Mission.

The survey comprised a series of combined reflection and refraction probes along a northeast line roughly following the Warburton Range Road between the northeast and southwest edges of the basin, where Precambrian basement rocks crop out.

Seismic operations were difficult because of extensive sand dunes and thick scrub and the lack of shallow bore-water which necessitated fetching water from up to 300 kilometres away. The area was a difficult one in which to record good seismic data. The main problem was coherent noise generated by shots within the generally thick weathered layer. It would have been uneconomical to drill all shot-holes below this layer.

36 kilometres of single and multiple coverage and 71 kilometres of reversed refraction profiles were obtained. Single-coverage reflection yielded data of quality varying from good to poor; the quality was generally improved using 6 and 12-fold CDP multiple-coverage probes. First arrivals on the refraction profiles were strong and clearly recorded, but later arrivals were generally weak.

Preliminary interpretation indicates that the basin sediments, probably largely Proterozoic, are about 10 000 metres thick near the centre of the basin; this is about 4000 metres thicker than suggested from previous geophysical work. The basin sediments dip gently northeast over most of the area surveyed and the sedimentary section appears to thin significantly near Lake Throssell about 30 kilometres northeast of Precambrian basement outcrops. The Lower Cambrian Table Hill Volcanics formerly named Officer Volcanics (M.J. Jackson, pers. comm.), which were intersected in Hunt Oil Co. Yowalga No. 2 well at a depth of 730 metres were intersected at 30 m in a shallow seismic shot-hole about 150 k lometres southwest of the well. A fair-quality reflection recorded at a depth of about 1000 metres near the centre of the basin between the two drill locations has been correlated with the Volcanics on the basis of reflection quality, refractor velocity, and dip.

1. INTRODUCTION

A seismic survey across the southwest part of the Officer Basin, W.A. was conducted by the Bureau of Mineral Resources (BMR) during July to December 1972 as part of an integrated geological and geophysical investigation conducted by BMR and the Geological Survey of Western Australia (GSWA), which commenced with geological mapping in 1970. Pinchin & Mathur (1972) have made a review of previous geological and geophysical investigations and have prepared a comprehensive list of references and selected bibliography.

The geology of the area, based on the recent geological mapping, is shown in Plate 1. Earlier geophysical data indicated that the basin was an elongated and asymmetrical structural depression, aligned NW-SE with the deeper part closer to the northeast flank. In Western Australia this depression is filled with a Proterozoic sequence about 5500 m thick overlain by a layer of Phanerozoic sediments about 450 m thick.

The Officer Basin, in W.A. has been covered by a reconnaissance helicopter gravity survey by BMR, by a land gravity survey by Hunt Oil Co., and by an aeromagnetic survey for Hunt Oil Co. with a flight-line spacing of 48 kilometres. Aeromagnetic data suggested depths to basement varying from about 6000 m in the northeast to about 2000 m and shallower towards the southwest. Basement depths interpreted from the gravity data agreed with the magnetic depths in the northeast and central parts, but were deeper by about 2000 m in the southwest. Seismic surveys made in the north and northeast near Warburton Mission (Plate 1) verified the basement depth in this area as interpreted from the gravity and magnetic results and defined the nature and structure of the northeastern margin of the basin. However, the seismic surveys south and southwest of Warburton Mission provided little information about the sediments deeper than a good seismic reflector, Horizon A, which corresponds to a basalt layer, the Table Hill Volcanics, which have been recently dated as Lower Cambrian (M.J. Jackson, pers. comm.).

The subsurface information about the sediments and basin structure in the central and southwest parts of the basin was poor. The interpretations were inconsistent and warranted a more precise determination of the nature and structure of the sediments by seismic surveys.

The BMR seismic survey was a combined reflection and refraction operation along a roughly northeast line following the Warburton Range Road between the Cosmo-Newberry and Warburton Missions. This line was chosen because operations and logistics would be easiest along the road and the resulting data would provide subsurface coverage across the basin between its northeast and southwest edges where Precambrian basement rocks outcrop.

A detailed gravity survey was made in the area by BMR concurrently with the seismic survey. Gravity observations were made along the Warburton Range Road, on short cross-traverses intersecting the road, and on the main seismic lines. Zadoroznyj (in prep.) will present details of the gravity operations and preliminary results.

This report presents details of the operations and preliminary results and conclusions at the end of the seismic field survey. Further data processing and detailed analysis of the seismic and gravity data will be required before a final interpretative report is completed.

2. OBJECTIVES AND PROGRAM

Objectives

The aim of the seismic survey was to obtain subsurface information along a northeast line across the Officer Basin, W.A., between its margins south of Lake Throssell, where the basement rocks are exposed, and west of Warburton Mission, where substantial geological and geophysical information has enabled the partial definition of the northeast margin of the basin. The specific objectives were:

1. To define the southwest margin of the basin where seismic work has not previously been attempted and to further define the northeast margin of the basin.
2. To obtain a reliable configuration of the basement of the basin.
3. To determine the structure, thickness, and seismic velocity of sedimentary layers in the basin.

Program as proposed

It was planned to start operations near the centre of the basin and to record:

1. Noise test, uphole shoot, and expanded spread to determine optimum shooting and recording parameters and subsurface velocity distribution. Previous surveys required the use of large arrays of geophones and shot-holes to attenuate coherent noise. (Pinchin and Mathur, 1972). It was anticipated that this would also be the case on the 1972 survey.
2. CDP reflection coverage and a reversed refraction profile to record horizons down to and including basement.

Similar reflection and refraction probes were planned farther southwest. The locations of subsequent probes were to depend on the assessment of results as the survey progressed. The recording parameters were to be reviewed throughout the survey. It was planned to tie-in the results to those from the Hunt Oil Company seismic surveys in the north-eastern part of the basin.

Program as carried out

The general location of the seismic lines surveyed is shown in Plate 1 and the details of their layout are shown in Plate 2. A list of the data recorded is given in Table 1. The seismic program as carried out is summarized below:

Experimentation. An uphole shoot and noise test were conducted near the centre of the basin as planned. Single coverage was then recorded at SPs 601-597 to determine the best recording and spread parameters: records shot with different geophone and shot-hole patterns, shot-depths, and geophone station intervals were compared. A further two uphole shoots were recorded at SPs 399 and 377 to determine the best shooting depth and near-surface velocity and weathering information in different areas.

Reflection and refraction probes. The first probe was recorded near the centre of the basin as planned. 6-fold CDP coverage was recorded at SPs $610^{10}/12$-607 and a reversed refraction profile was recorded between SPs 612 and 551. The second probe was placed with its northeast end about 90 km southwest of SP 612. Continuous 6-fold CDP and some 12-fold CDP coverage was recorded at SPs 379-369 and at SPs 339-336. A reversed refraction profile was recorded between SPs 375 and 332. Seven short reflection and/or refraction probes were recorded farther southwest between SPs 304 and 100 to obtain information on the southwest margin of the basin.

It would have been preferable to have recorded some reflection coverage along one or more of the Hunt Oil Co. lines west of Warburton Mission to enable direct comparison of reflection data, but time did not allow this.

Vertical velocity determination. Three expanded spreads were recorded, centred at SPs 610, 375, and 263, to determine the vertical velocity distribution and to identify primary and multiple reflections.

Deep crustal recording. Shots fired at Mount Fitton, S.A. and Kunanalling, W.A. were recorded on two perpendicular spreads at SP 375 to obtain deep crustal refraction data as part of an Australia-wide deep crustal survey. Deep crustal reflection shots were later fired at the refraction recording location to obtain supplementary reflection data.

Geoflex comparison shots. Three geoflex shots using different geoflex arrays and one dynamite shot were recorded at SPs 614-613 to determine whether geoflex shooting would be advantageous. The tests were limited because of the lack of a suitable vehicle to tow the geoflex plough. Party trucks were used initially but were committed to other tasks. The results of the tests are inconclusive.

3. RESULTS AND CONCLUSIONS

RESULTS

Reflection

Preliminary reflection single-coverage and multiple-coverage record sections are presented in Plate 3. Reflection quality was generally variable over the area surveyed and appeared to depend greatly on variations in surface conditions; the quality was good to fair over dry salt lakes, fair to poor over lateritized Cretaceous outcrops, and very poor over sand dunes or sandy country.

The area had three major characteristics which reduced the quality of reflection data. These were:

1. Coherent noise. A widespread, thick weathered layer, over 100 m thick in places, was present in the area. Shots had to be fired within this layer because it would have been uneconomical to drill all shot-holes below the layer. Serious coherent noise was generated by these shots as shown by the noise test. Large patterns of geophones and shot-holes were therefore needed to attenuate this noise. The selected geophone pattern which gave satisfactory noise attenuation was 48 geophones per trace, in 3 rows of 16 geophones spaced 6 m apart in line and 14 m between rows. At SPs 610^{10}/12-607 a pattern of 25 holes, of depth 4.5 m in a square with holes spaced 20 m, was considerably better in cancelling noise than 3 or 5 holes of depth 30 m. The situation was reversed at SPs 379-369; 30 m holes were satisfactory for the remainder of the reflection recording.

2. Variable weathered layer. Large variations in the thickness of the weathered layer over short distances made reflections appear discontinuous in some places. The effectiveness of CDP stacking was reduced because of the lack of reliable weathering information. It was often difficult to record first arrivals from the sub-weathering refractor owing to the presence of near-

surface high-velocity 'stringers' and because of high attenuation of first breaks. In many locations first breaks from reflection shots provide the only weathering information since time did not permit special weathering shots. The latter could be recorded with high gain to improve first breaks whereas on the reflection shots the gain had to be lower to avoid loss of shallow reflection information by saturation of the amplifiers.

3. <u>Basalt layer</u>. A strong shallow reflection recorded between SPs 614 and 587 appears to correlate with a reflection, recorded on previous seismic surveys west of Warburton Mission, which is associated with a basalt layer, the Table Hill Volcanics. Later reflections were weak, possibly because of reduced energy transmission through the strongly-reflecting layer. At SPs 399, 397, and 392-391 single-coverage records over basalt subcrop were very poor. CDP multiple coverage at SPs $610^{10}/12$-607 improved the quality deep reflections; multiple coverage was not attempted over basalt subcrop, however, as the low quality of the single-coverage records suggested that significant improvement would be unlikely.

CDP recording generally improved the quality of data. At the northeastern end of the area surveyed, the quality of the seismic results with 6-fold CDP from SPs $610^{10}/12$-607 compared favourably with the good-quality seismic data obtained west of Warburton Mission by Hunt Oil Co. using weight-dropping techniques. 1-12 fold CDP at SPs 379-$368^{10}/12$ was of lower quality, and good-quality reflections were only obtained over 1620 m, about 20% of the subsurface coverage. At SPs 339-336 the 1-12 fold CDP was of very low quality. Single-coverage recording at SPs 303-301 and 268-261 over dry salt lakes and at SPs 256-251 and 249-244 near Lake Throssell was of fair quality.

Reflections were present on the records up to 3.5 s two-way time. It is difficult to correlate reflections over the area surveyed because of the variability in record quality and limited reliable information on interval velicities. For ease of operation most lines were placed along straight sections of the Warburton Range Road, and the bearings of the lines vary by as much as 50°. This makes correlation of dipping events difficult. Reflections at SPs 610 and 375 have dips of about 5° northeast, but between SPs 304 and 236 dips are up to 25° northeast.

<u>Refraction</u>

Reversed refraction depth probes were recorded as follows:

<u>SPs 612-551</u>. A refractor of velocity 5400 m/s was recorded as a strong first arrival up to the maximum offset of 32 km. From previous seismic and well information it appears to be associated with a basalt layer, the Table Hill Volcanics. Its depth decreased from 1000 m at SP 612 to 300 m at SP 551. A single weak later arrival was recorded from a refractor with velocity 6250 m/s. The depth to the refractor at SP 612 was 6700 m and at SP 551 was 5500 m.

The initial association of the 5400 m/s refractor with a basalt layer was confirmed when basalt with this velocity was intersected at SP 399 in a drillhole at 30 m. By extrapolation using its dip at SPs 612-551, the 5400 m/s refractor was expected to become shallow near SP 399.

<u>SPs 375-332</u>. A refractor of velocity 6100 m/s was recorded as a first arrival out to the maximum offset of 23 km. Its depth decreased from 800 m at SP 375 to 600 m at SP 332. A single weak later arrival was recorded only on spreads to the northeast. The refractor had an apparent one-way velocity of 6450 m/s and its apparent depth at SP 332 was 2500 m.

<u>SPs 304-201</u>. A shallow high-velocity refractor was recorded on each of four short refraction probes in this area. Events with velocities varying from 6000°-6200 m/s were recorded from refractors at depths varying from 200-300 m.

CONCLUSIONS

The following conclusions are based on the field results.

1. A sequence of sediments, probably largely Proterozoic, is about 10 000 metres thick at SP 610, has a gentle northeast dip over most of the area surveyed, and may thin significantly between SPs 249 and 201.

2. A fair-quality reflection event at a depth of about 1000 m near the centre of the basin is tentatively correlated on the basis of reflection quality, refractor velocity, and dip with the Lower Cambrian Table Hill Volcanics, which were intersected in Yowalga No. 2 well at 730 metres and in a shallow seismic shot-hole about 100 kilometres north-east of Precambrian basement outcrops near Lake Throssell.

4. REFERENCES

PINCHIN, J., & MATHUR, S.P., 1972 - Presurvey report on Officer Basin Seismic Survey, W.A. 1972. Bur. Miner. Resour. Aust. Rec. 1972/95 (unpubl.).

ZADOROZNYJ, I., (in prep.) - Officer Basin gravity survey, W.A. - Operational Report. Bur. Miner. Resour. Aust. Rec.

TABLE 1. RECORDING SUMMARY

Recording	Technique	Shot-points	Remarks
Uphole shoot	Reflection	600	First recording of survey
		599	Hole, depth 100 m, recorded because hole at SP 600 collapsed to 50 m
Noise test	Reflection	599 8/12	
Uphole shoot	Reflection	399	First recording in new area. Basalt encountered at 30 m.
		377	To determine if basalt present, and near-surface information. Basalt not found to maximum depth 94 m.
Multiple coverage	Reflection	610^{10}/12-607	6-fold CDP coverage
		379-368 10/12	Up to 12-fold CDP coverage
		339-336	Up to 12-fold CDP coverage
		268-261	1-2 fold CDP coverage
		255-251	" " " "
		249-244	1-3 " " "
		205-201	1-2 " " "
Single coverage	Reflection	601-597	Experiments with various recording, geophone, shot-hole, and spread parameters
		610, 589	Test of record quality
		397, 392-391 377-375	Test record quality with several recording and shot-hole parameters.
		303-301 236-235	Preview of recording conditions and record quality
Refraction depth probe	Refraction	612-551	
		304-300	Preview recording
		240-234	Preview recording
		375-332	
		205-201	
		270-262	
		107-100	Recorded to obtain refractor velocity of shallow basement

Recording	Technique	Shot-points	Remarks
Expanded spread	Reflection	615-605 379-371 267-259	
Cross-traverse	Reflection	610, 375 and 302	To obtain true dip information
Deep crustal	Reflection	375	Two perpendicular spreads, charges 3600 and 4200 kg, 24 s of data recorded
	Refraction	375	Two perpendicular spreads recorded shots from Mt Fitton, SA and Kunanalling, WA
Geoflex tests	Reflection	614-613	Comparison of several spread and geoflex arrays and dynamite shot.

APPENDIX 1

STAFF AND EQUIPMENT

Staff

Party Leader	P.L. Harrison
Geophysicists	J. Pinchin E.J. Riesz (11.7.72 - 30.8.72) A.R. Fraser (10.9.72 - 17.10.72) R.A.P. Garnett (14.10.72 - 29.11.72)
Observer	L.E. Hemphill (11.7.72 - 16.8.72) A.F. Martindale (from 17.8.72)
Assistant Observer	A.F. Martindale (11.7.72 - 16.8.72) J.R. Walker (1.9.72 - 29.11.72)
Shooters	R.D.E. Cherry S.J. Wilcox
Surveyors	P. Gunnel (11.7.72 - 15.8 and 8.10.72 - 24.10.72) T. Rooney (16.8.72 - 7.10.72) J. Ritchie (25.10.72 - 29.11.72) (all from Department of the Interior, Perth)
Toolpusher	E.H. Cherry
Driller	E.D. Lodwick
Drill Assistant	E. Reid
Mechanic	E.C. McIntosh
Clerk	I.C. Betts
Field Hands	Seventeen

Equipment

Recorder	Seismic Amplifiers SIE PT-700 Oscillograph SIE TRO-6 Magnetic Recorder (FM) SIE PMR-20
Geophones	Hall Sears HS-J, 14 Hz Refraction, 4.5 Hz and 20 Hz
Drilling Rigs	Mayhew 1000 (1) Foxmobile (2)

Other vehicles, camping and miscellaneous equipment

APPENDIX 2

OPERATIONAL STATISTICS

Detailed statistical information is given in the Seismic Operations Chart in Plate 4.

Sedimentary Basin	Southwest Officer Basin
Camp Sites	Manunda Rockhole (11.7.72 - 6.9.72) Terhan Rockhole (7.9.72 - 5.11.72) Nullye Soak (6.11.72 - 29.11.72) (nearest named feature)
Survey commenced	14 July 1972
Survey completed	28 November 1972
Kilometres of reflection traverse	36
Kilometres of reversed refraction traverse	71
Topographic survey control	Department of the Interior benchmarks
Total number of holes drilled	2687
Total depth drilled in metres	33 606
Explosives used	22 700 kg Anzite blue 30 300 kg Ammonium nitrate
Shot-point interval	540 metres
Geophone station interval	
reflection	45 metres
refraction	90 and 180 metres
Geophone group	
Reflection	48, in 3 lines of 16 parallel to traverse, spacing in line 6 metres, spacing between lines 14 metres.
Refraction	4, in one line perpendicular to traverse, spacing in line 6 metres.
Common hole patterns	25, in 5 lines of 5 parallel to traverse, spacing in line and spacing between lines 20 metres. 3, in one line parallel to traverse, spacing in line 40 metres. Single hole.

Common hole depths	4.5 metres 30 metres
Charge sizes	
reflection	1-55 kg
refraction	7-1800 kg
Normal tamping	Solid
Recording mode	Automatic gain control Programmed gain
Normal recording filters	L16-KK100
Datum for corrections	400 metres A.S.L.
Weathering velocity	1100-1700 m/s
Sub-weathering	2000-3200 m/s

PLATE I

SURFACE GEOLOGY AND LOCATION MAP

(BASED ON G51/B0-26)

To accompany Record No. 1973/62

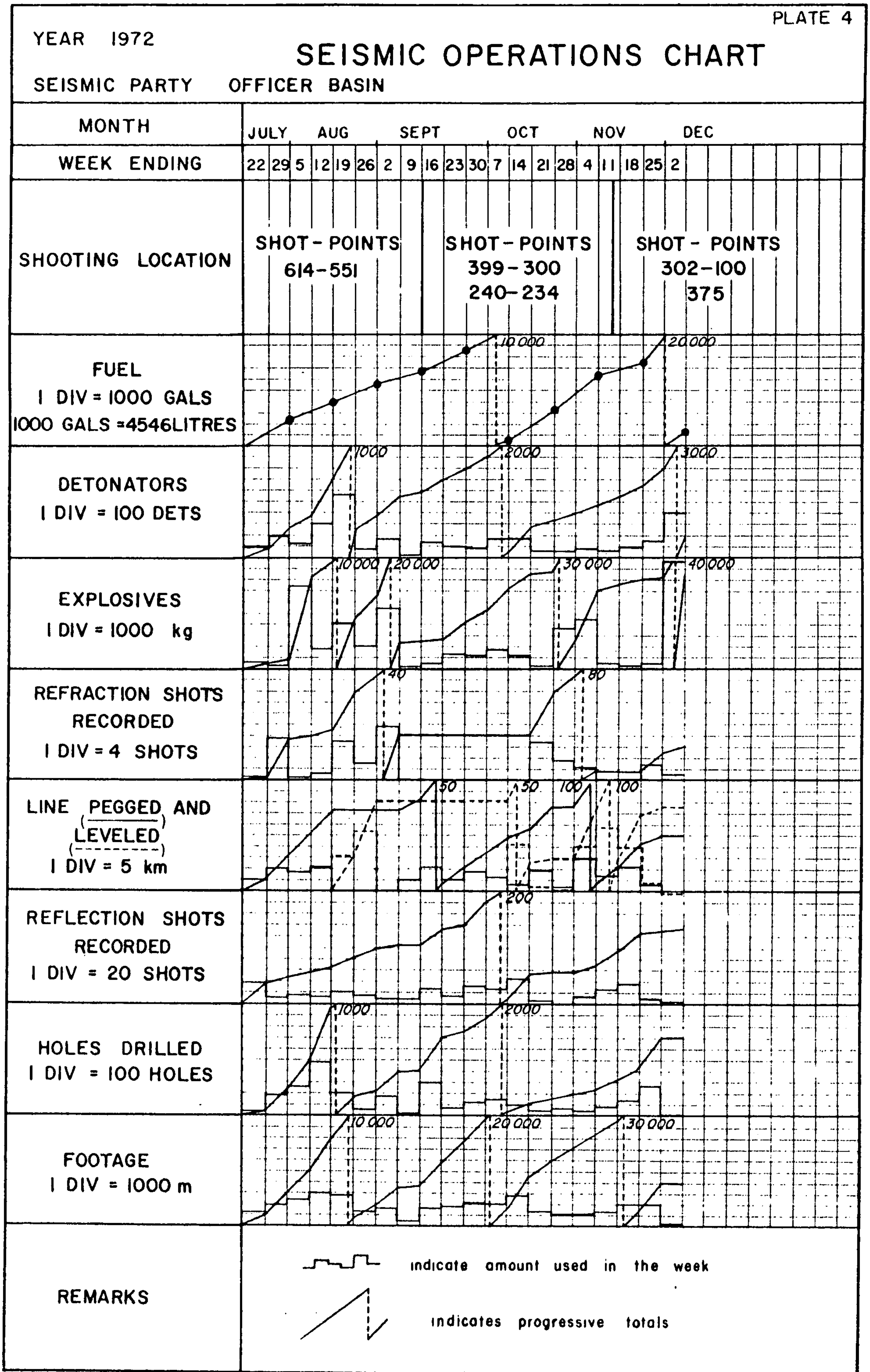
G51/B3-44


PLATE 2
WA
PERTH
ROBERT
YOWALGA
THROSSELL
WESTWOOD
RASON
NEALE
KILOMETRES
THROSSEL
WESTWOOD
LAKE
THROSSELL
WARBURTON RANGE ROAD
WARBURTON RANGE ROAD
YOWALGA
RASON
"Yamarna"
SP 100
SP 107
SP 201
SP 205
SP 234
SP 240
SP 244
SP 249
SP 332
SP 336
SP 339
SP 369
SP 375
SP 379
SP 391
SP 397
SP 399
SP 551
SP 589
SP 597
SP 601
SP 607
SP 610
SP 613
LEGEND
SP 300
Shot-point number
Refraction shot-point
Reflection coverage
Seismic line
Road or track
WESTWOOD
1 : 250 000 map sheet
Note: Some shot-points referred to in the text such as 610 10/12 indicate that shots were fired at closer spacing than the basic 540m. interval. These shot-points have not been shown on this traverse plan.
SEISMIC TRAVERSE PLAN
To accompany Record No. 1973/62
G51/B3-45

To accompany Record No. 1973/62

G51/B3-46

OFFICER BASIN SEISMIC SURVEY 1972
PRELIMINARY REFLECTION RECORD SECTIONS



(Based on G85/3-128) *To accompany Record No 1973/62* G51/B3-43A