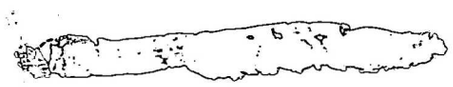

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES.
GEOLOGY AND GEOPHYSICS

RECORDS 1957, No. 37

SEISMIC REFRACTION TRAVERSE IN THE CHRISTMAS CREEK AREA, KIMBERLEY DIVISION, W.A.

by

E. R. SMITH

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CONTENTS

ILLUSTRATIONS

ABSTRACT

A seismic refraction survey was conducted by the Bureau of Mineral Resources in the Christmas Creek area of the Fitzroy Basin, Western Australia, during June, 1955. An earlier refraction survey had been carried out in the nearby Nerrima area in 1952. In these areas the upper part of the geological section could be expected to be reasonably similar.

The velocities recorded at Christmas Creek appear to be similar to those recorded at Nerrima, but when correlated through known geological formations, they are in general less than their Nerrima equivalents. This could be accounted for either by the shallower depths of the corresponding refractors, caused by the thinning of the Poole Sandstone from Nerrima to Christmas Creek, or by minor facies changes.

The deepest refractor recorded (velocity 15,130 ft/sec.) was at a calculated depth of 7100 feet. This refractor is unconformable with those recorded above it, and is interpreted as being immediately below the base of the Permian formations.

1. INTRODUCTION

This report describes a seismic refraction survey which was carried out in the Christmas Creek area of the Fitzroy Basin, Western Australia, during June 1955 (Plate 1). It was considered that velocity information obtained from refraction shooting might be useful in indicating the type of rocks present beneath the Permian section in this area, and also enable a comparison to be made with the section at Nerrima, where seismic velocities were measured in 1952 (Vale et al., 1953).

The refraction traverse was at right angles to traverse "A" of the seismic survey carried out by the Bureau in 1953 (Smith, 1955), and passed through S.P.37 of that traverse (see Plate 2). One mile of reflection shooting was done between S.P.500 and S.P.503, to provide information on angles of dip and so assist in the interpretation of results.

The camp for the party was set up near Dusty Outcamp on Christmas Creek Station, about one mile north-east of the main Fitzroy Crossing - Hall's Creek Road. The party consisted of E.R. Smith (party leader) and M.J. Goodspeed, geophysicist, one radio technician, surveyor, drilling supervisor and driller, mechanic, shooter, cook and 11 assistants. The recording equipment used was a 24-channel seismograph manufactured by the Technical Instrument Company of Houston, Texas. The party was equipped with a Failing "750" Drill, three 700-gallon water tenders and several other vehicles. The duration of the survey was three weeks.

2. GEOLOGY

A comprehensive report on the geology of the Fitzroy Basin is given by Guppy (1953). The report by Smith (1955) includes notes from Guppy's report which pertain more particularly to the Christmas Creek Area. Since these reports were written, however, two deep holes have been drilled in the Fitzroy Basin. West Australian Petroleum Pty. Ltd. completed Grant Range No. 1 at a depth of 11,500 feet. This bore revealed that the thickness of the Grant Formation, which is of Permian age, is of the order of 7000 to 8000 feet. It also proved the existence of at least 5,000 feet of sedimentary rocks of Carboniferous age, beneath the Grant Formation. Associated Freney Oil Company's No. 1 Well on Nerrima Dome confirmed the large thickness of the Grant Formation.

The present traverse is situated on Quaternary sands and alluvium overlying the Noonkanbah Formation (Permian). Assuming the Noonkanbah Formation to be conformable with the phantom horizon of the reflection cross-section of traverse "A" of the 1953 survey, it is estimated that there is 600 feet of this formation below S.P.37. It is probable that there is about 200 feet of Poole Sandstone, and this overlies the Grant Formation. If the unconformity at 8000 feet, shown by the reflection cross-section along traverse "A", is at the base of the Grant Formation, then this formation is approximately 7000 feet thick in this area also. Below the Grant Formation, Carboniferous sediments can be expected, and the unconformity at 13000 feet, shown by the reflection section, is now interpreted as the Devonian/Carboniferous contact. The following table summarises the geological section expected beneath S.P.37 :-

...2

TABLE 1.

Age	Formation	Depth
	(Noonkanbah Formation	0
Permian	(Poole Sandstone	600'
	(Grant Formation	800'
----------Unconformity----------		8000'
Carboniferous ?		
----------Unconformity----------		13000'
Devonian		

3. USE OF REFRACTION METHOD FOR MEASUREMENT OF VELOCITIES

The purpose of the survey was to measure the velocities and depths of the refractors present in the geological section. To measure the velocities accurately it is necessary to shoot in-line profiles of the refractor in both directions; a dipping refractor will alter the slope of the time-distance curve from the reciprocal of the true velocity to the reciprocal of an "apparent velocity", and thus shooting in one direction would serve to measure only this apparent velocity. If V_U is the apparent velocity measured when shooting "up-dip", V_D the apparent velocity measured when shooting "down-dip" and θ the angle of dip, the true velocity (V) is given by :-

$$V = \frac{2 \cos \theta}{\frac{1}{V_U} + \frac{1}{V_D}}$$

As the dip of the refractor is likely to vary along the traverse, it is important that the refractions recorded in both directions come from the same section of the refractor. As the rays arrive at the surface at an angle, the section of the refractor they have emerged from is not vertically below the detectors, but is off-set a distance "x" towards the shot point. This offset distance varies with the depth and dip of the refractor. In choosing geophone locations, an estimate of this offset distance must be made in advance, and the geophones placed so that the rays come from the desired section of the refractor. An ideal set-up of shot points and geophones is shown in Fig. 1.

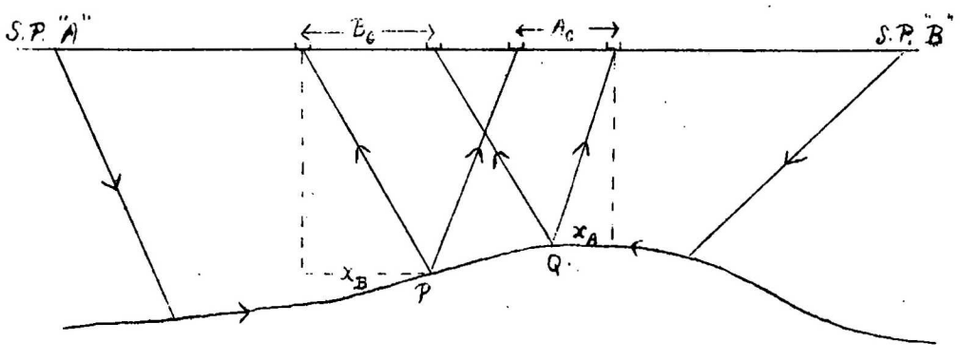


Fig. 1.

...3

This figure shows that when shooting from shot point "A", the geophone spread AG would record from the section PQ of the refractor, which is offset a distance ^{x}A towards shot point "A". When shooting in the reverse direction, from shot point "B", the geophone spread BG is required to be as shown in order to record from the same section (PQ) of the refractor, the offset distance in this instance being ^{x}B. If the refractor were horizontal, the offset distances ^{x}A and ^{x}B would be equal.

In the present survey an attempt was made to record the refractors from those parts of them lying vertically below S.P.500 to S.P.503. The approximate offset distances for the shallow refractors were obtained from the refraction survey carried out in this area during 1953 (Smith, 1955). For deeper refractors it was only possible to make use of the general relation that an increase in the distance between shot point and geophones increases the depth of penetration and hence the offset distance. Thus, as shot points were moved further out, the geophones were moved in the opposite direction away from the section S.P.500 to S.P.503. As no estimate of dip could be made in advance, the shot point and geophone locations were spaced symmetrically about this section of the traverse.

4. RESULTS

A. Reflection shooting.

Reflection profiles were shot from S.P.500 to S.P.503; the resultant cross-section is shown on Plate 3.

The angular unconformities shown by the reflection cross-section along traverse "A" (Smith, 1955) are not obvious on Plate 3, but the same zones of reflections are apparent, i.e. from 3000 feet to 8000 feet, from 8000 feet to 13000 feet, and from 13000 feet to 20000 feet. Table 2 shows the component dips measured along traverse A (1953), traverse θ (1955) and the calculated resultants.

TABLE 2.

ZONE	DIP (magnitude and direction)		
	Trav. "A" (1953)	Trav. "θ" (1955)	Resultant
3000' to 8000'	2° N25°E	$1\frac{1}{2}$° N115°E	$2\frac{1}{2}$° N62°E
8000' to 13000'	$5\frac{1}{2}$° N25°E	3° N115°E	$6\frac{1}{4}$° N54°E
13000' to 20000'	1° N25°E	$4\frac{1}{2}$° N115°E	$4\frac{3}{4}$° N102°E

B. Refraction traverse.

The reflection profiles enabled a calculation to

...4

be made of the depth of the weathered layer between S.Ps.500 and 503. Information on the weathering along the other sections of the traverse where recordings were made, was obtained by shooting special "weathering" spreads with geophones closely spaced. It was possible, therefore, to correct the refraction times from shot point to geophone for the delays due to the low velocity weathered layer under the geophone spreads. Weathering corrections are not needed at the shot points as the shot was fired below the weathered layer. Corrections were also applied to all the times, except those which were due to refractions through the immediate sub-weathered layer, to allow for variations in the elevations of the shot points and geophones. These elevation corrections were made to a datum level of 450 feet above sea level.

The time-distance curves obtained from the refraction shooting are plotted on Plate 4. The times fall nicely on straight lines and should give reliable values for the velocities of the refractors. This is in contrast with the refraction survey at Nerrima, where many discontinuities and abrupt changes of slope were shown by the time-distance curves, and it was difficult to obtain reliable values for the velocities. A discussion of the refractors which were recorded follows, and a summary of the results is given in Table 3.

V1 = 9,100 ft/sec. This velocity is from the immediate sub-weathering refractor, and has been calculated from the average of the initial velocity recorded from S.P.503 (9290 ft/sec.) and the initial velocity recorded from S.P.500 (8900 ft/sec). The value of 9100 ft/sec. is similar to the 9075 ft/sec. obtained in the 1953 survey by the refraction work along Traverse "A" (Smith, 1955, p. 8), and also to the average value of 9000 ft/sec. obtained for the subweathering velocity from the initial refraction breaks on the reflection records along Traverse "A" (Smith, 1955, p.4).

This velocity represents the Noonkanbah Formation, which is known to be present near the surface along the traverse. Of the two refractors recorded from within the Noonkanbah Formation at Nerrima, i.e. 8450 ft/sec. (sub-weathering) and 9700 ft/sec. at 200 to 400 feet (Vale et al, 1953, p.6), the former would not be expected along Traverse θ as the top 600 feet of the formation has been eroded away. Thus the velocity of 9100 ft/sec. obtained in the present survey probably correlates with that of 9700 ft/sec. at Nerrima.

V2a = 11160 ft/sec. This velocity is best calculated from recordings from S.Ps. 527 and 505, because these are from a common section of the refractor between S.P.502 and S.P.501. The time-distance curves yielded the following information :-

$V2a_U$ = 11120 ft/sec.) V2a = 11160 ft/sec; depth = 600 ft;

$V2a_D$ = 11200 ft/sec.) component of dip = $\frac{1}{4}^o$ NW.

In the 1953 survey the velocity of this refractor was measured as 10850 ft/sec. and its depth as 650 ft. As the depth of the Poole Sandstone is known to be 600 feet, velocity V2a probably represents the top of this formation and should therefore be correlated with the refractor of velocity 11550 ft/sec. recorded at Nerrima.

...5

V2b = 11125 ft/sec. The time-distance curve from S.P.505 shows a sudden increase in time at a distance of 4000 feet from the shot point. The record for this section gives the normal appearance of a new refraction taking the place of the one recorded up to that point. However, the slope of the time-distance curve remains the same thereafter. It appeared likely, therefore, that this feature might be associated with a fault or discontinuity in the refractor. However, when shooting from S.P.506, the same increase occurs at the same distance from the shot point, i.e. it has moved horizontally with the shot point. Also, when shooting in the reverse direction from S.P.528, a similar increase in time is observed, whereas, if it were associated with a fault, a decrease in time should be apparent. It appears certain therefore, that a new refractor is present. The recordings from this refractor do not come from the same subsurface section. However, as the dips of the refractors above and below this one are small between S.Ps. 500 and 503, the following results obtained from the time-distance curves of S.P.506 and 528 should be fairly reliable :-

$V2b_U$ = 11100 ft/sec.) V2b = 11125 ft/sec; depth = 850 ft;
)
$V2b_D$ = 11150 ft/sec.) component of dip = $\frac{1}{4}^{o}$ NW.

This velocity is lower than V2a, whereas in general each successive velocity recorded is higher than the previous one. However, the difference between the two is well within the limit of error of the refraction method. It is possible that the true value of V2a is lower than 11,160 ft/sec. (the value obtained in the 1953 survey was 10850 ft/sec.) and/or that V2b is higher than the calculated value of 11125 ft/sec.

The thickness of the Poole Sandstone is 200 feet in this area, so it is likely that V2b is recorded from the top of the Grant Formation, in which case it should be correlated with the velocity of 12650 ft/sec. recorded at Nerrima.

V3 = 12550 ft/sec. Recordings from this refractor were obtained from S.P.534 with the geophones from S.P.37A to S.P.505, and from S.P.512 with geophones from S.P.37A to S.P.527. The offset distance was calculated as 1850 feet, so the recordings covered a common section of the refractor from midway between S.Ps..500 and 501 to midway between S.Ps. 502 and 503. The velocity calculation should therefore be accurate.

The results obtained are as follows :-

$V3_U$ = 12600) V3 = 12550 ft/sec; depth = 1600 ft;
)
$V3_D$ = 12500) component of dip = $\frac{1}{4}^{o}$ SE.

V4 = 13660 ft/sec. This refractor was recorded from S.Ps. 534, 538, 542 and 547 when shooting to the north-west and from S.Ps. 512, 516 and 520, when shooting to the south-east. The off-set distance is approximately half-a-mile, so the best pair of refractions to use for the velocity calculation are those from S.Ps.534 and 512, as these are from a common section between S.Ps. 500 and 503. This pair gives :-

$V4_U$ = 13920 ft/sec) V4 = 13660 ft/sec; depth = 2400 ft;
)
$V4_D$ = 13420 ft/sec) component of dip = 1^{o}SE.

...6

This refractor is 1550 feet below the top of the Grant Formation and consequently correlates with the refractor of velocity 14500 ft/sec which was recorded at Nerrima 1500 feet below the top of the Grant Formation. In the 1953 survey at Christmas Creek, the velocity of this refractor was calculated as 14300 ft/sec. and its depth as 2650 feet.

V5 = 15130 ft/sec. To record the next refractor below V5, it was necessary to set up the geophones 7 miles from the shot point when shooting to the south-east and 9 miles from the shot point when shooting to the north-west. As the calculated offset distance is 8800 feet, the only recording made from this refractor to the north-west, i.e. from S.P.555, comes from approximately the same subsurface section of the refractor as the recording from S.P.525. The result from this pair is :-

$V5_U$ = 14200 ft/sec.) V5 = 15130 ft/sec; depth = 7100 feet;
$V5_D$ = 16660 ft/sec.) component of dip = 9° NW.

This velocity has not been correlated with the velocity of 16000 ft/sec. recorded at Nerrima; the reasons for this are discussed below.

TABLE 3.

Geological Formation	Christmas Creek (S.P.37)				Nerrima	
	Depth from Geological and Reflection Data (ft.)	Velocity (ft/sec)	Depth (ft)	Component of dip	Velocity (ft/sec)	Depth (ft.)
Noonkanbah Formation	0	9100	0		9700	300
Poole Sandstone	600	11160	600	¼°NW	11550	1000
Grant Formation	800	11125	850	¼°NW	12650	2500
Layer within Grant Formation	-	12550	1600	¼°SE	Not recorded	
Layer within Grant Formation	-	13660	2400	1°SE	14500	4000
Layer within Grant Formation					16000	7000
Base of Grant, Carboniferous	8000	15130	7100	9°NW		

5. CONCLUSIONS

(1) The velocities recorded at Christmas Creek in this survey constitute a similar set to those recorded previously at Nerrima. However, when correlating them with the Nerrima velocities, with the aid of known geology, they are found to be lower than their Nerrima equivalents. With the exception of V5, this may be due to the respective formations being shallower at Christmas Creek, but may also be due to minor facies differences in the Permian.

(2) The refractor of velocity 15130 ft/sec. at a depth of 7100 feet is interpreted as representing a formation underlying the Grant Formation, and which is unconformable with the overlying Permian formations. It probably represents the top of the Carboniferous sediments. Its depth, 7100 feet, agrees reasonably well with the unconformity at about 8000 feet shown by the reflection cross-section in the Christmas Creek area, especially as inspection of that cross-section under S.P.37 shows that the unconformity could be as shallow as 7000 feet at that point.

The dip component of 9°NW, calculated from the refraction work, does not agree with the dip component of 3°SE calculated from the reflection cross-section. The explanation of this is probably that the refraction is from the top of the formation, at the unconformity, and consequently measures the dip of the old erosional surface, whereas the reflections are from within the formation and indicate the attitude of the bedding.

(3) As the bore recently drilled on the Nerrima structure was still in the Grant Formation at 7000 feet, the refractor of velocity 16000 ft/sec measured at Nerrima is apparently within the Grant Formation and is not the equivalent of the refractor of velocity 15130 ft/sec. recorded at Christmas Creek. By analogy with the other refractors recorded from the Permian at both Nerrima and Christmas Creek, the refractor of velocity 16000 ft/sec. which was recorded at Nerrima should have been recorded at Christmas Creek with a velocity of approximately 15000 ft/sec., at a depth of 5400 feet. No such refractor was recorded however, and it is considered that its velocity has probably decreased to such an extent that it was not recorded as a first arrival.

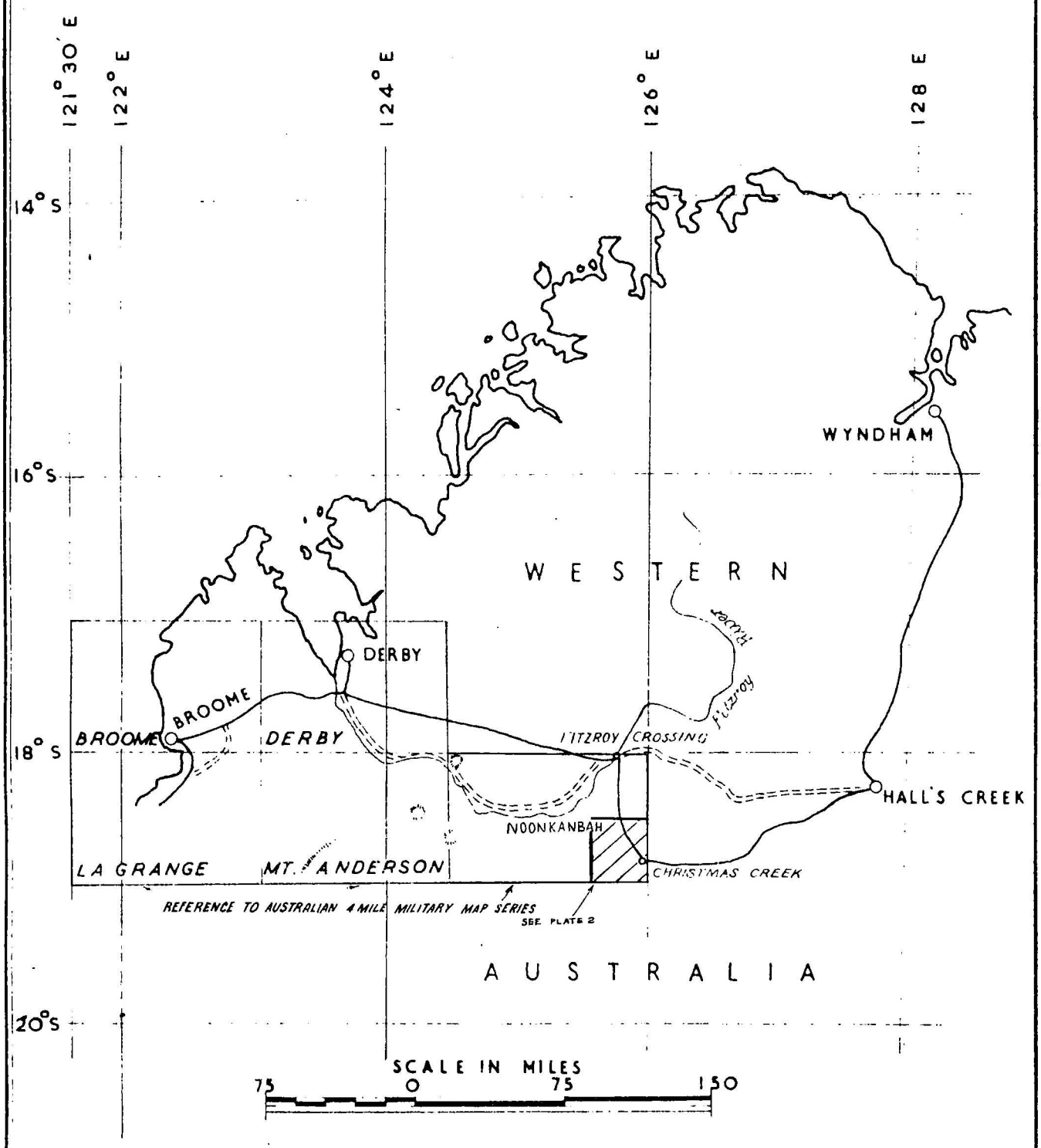
6. REFERENCES

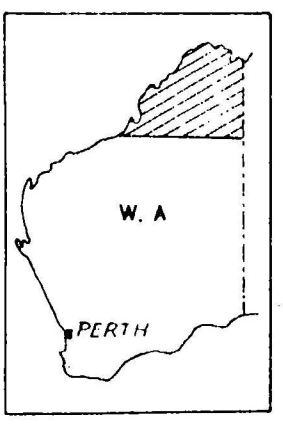
Vale, K.R., Smith, E.R., and Garrett, M.J., 1953 - Seismic Survey of the Nerrima Dome, Kimberley Division, W.A. Bur. Min. Res. Geol. and Geophys., Records 1953 No. 72.

Smith, E.R., 1955 - Progress Report on a Seismic Survey of the Poole Range - Price's Creek Area, Kimberley Division, W.A., Bur. Min. Res. Geol. and Geophys., Records 1955 No. 35.

Guppy, D.J., 1953 - Preliminary Report on the Geology of the Fitzroy Basin, Kimberley Division, W.A., Bur. Min. Res. Geol. and Geophys., Records 1953, No. 146.

PLATE I





SEISMIC REFRACTION TRAVERSE
IN THE CHRISTMAS CREEK AREA,
KIMBERLEY DIVISION, W.A.

LOCALITY MAP

PLATE 2

SCALE IN MILES

2 0 2 4 6

SEISMIC REFRACTION TRAVERSE
IN THE CHRISTMAS CREEK AREA,
KIMBERLEY DIVISION, W.A.

SEISMIC TRAVERSE "θ"

IN RELATION TO 1953 SEISMIC TRAVERSES
AND SURFACE GEOLOGY
(GEOLOGY AFTER GUPPY 1953)

LEGEND

Quaternary	Qrb	RESIDUAL BLACK SOIL
	Qrr	OTHER RESIDUAL SOILS
	Qra	ALLUVIUM
	Qrc	CALICHE
	Q s	SAND, SAND-DUNES
Permian	P l	LIVERINGA GROUP
	P n	NOONKANBAH FORMATION
	P p	POOLE SANDSTONE
	P g	GRANT FORMATION
Upper Devonian	Dub	BUGLE GAP LIMESTONE
	Dup	MT. PIERRE GROUP
	Duj	J & CONGLOMERATE
	Dud	SADDLER BEDS
Mid. Devonian	Dmp	PILLARA FORMATION
Ordovician	O g	GAP CREEK DOLOMITE } PRICE'S CREEK GROUP
	O e	EMANUEL LIMESTONE } PRICE'S CREEK GROUP

GEOLOGICAL BOUNDARIES

- ESTABLISHED BOUNDARY — ACCURATE
- ESTABLISHED BOUNDARY — APPROX
- INFERRED BOUNDARY
- ESTABLISHED BOUNDARY — CONCEALED
- INFERRED BOUNDARY — CONCEALED

FOLDS

- ESTABLISHED ANTICLINAL CREST
- ESTABLISHED SYNCLINAL TROUGH
- ANTICLINAL CREST — APPROX.
- SYNCLINAL TROUGH — APPROX.

BORES

- B • BORE
- A • ARTESIAN
- S A • SUB-ARTESIAN
- S • SPRING
- Ⓢ • HOTSPRING
- W • WELL
- T ■ TANK (EARTH)

FAULTS

- U/D ESTABLISHED FAULT — ACCURATE WITH RELATIVE MOVEMENT
- ESTABLISHED FAULT — APPROX
- INFERRED FAULT
- INFERRED FAULT — CONCEALED
- ESTABLISHED FAULT — CONCEALED

TOPOGRAPHIC SYMBOLS

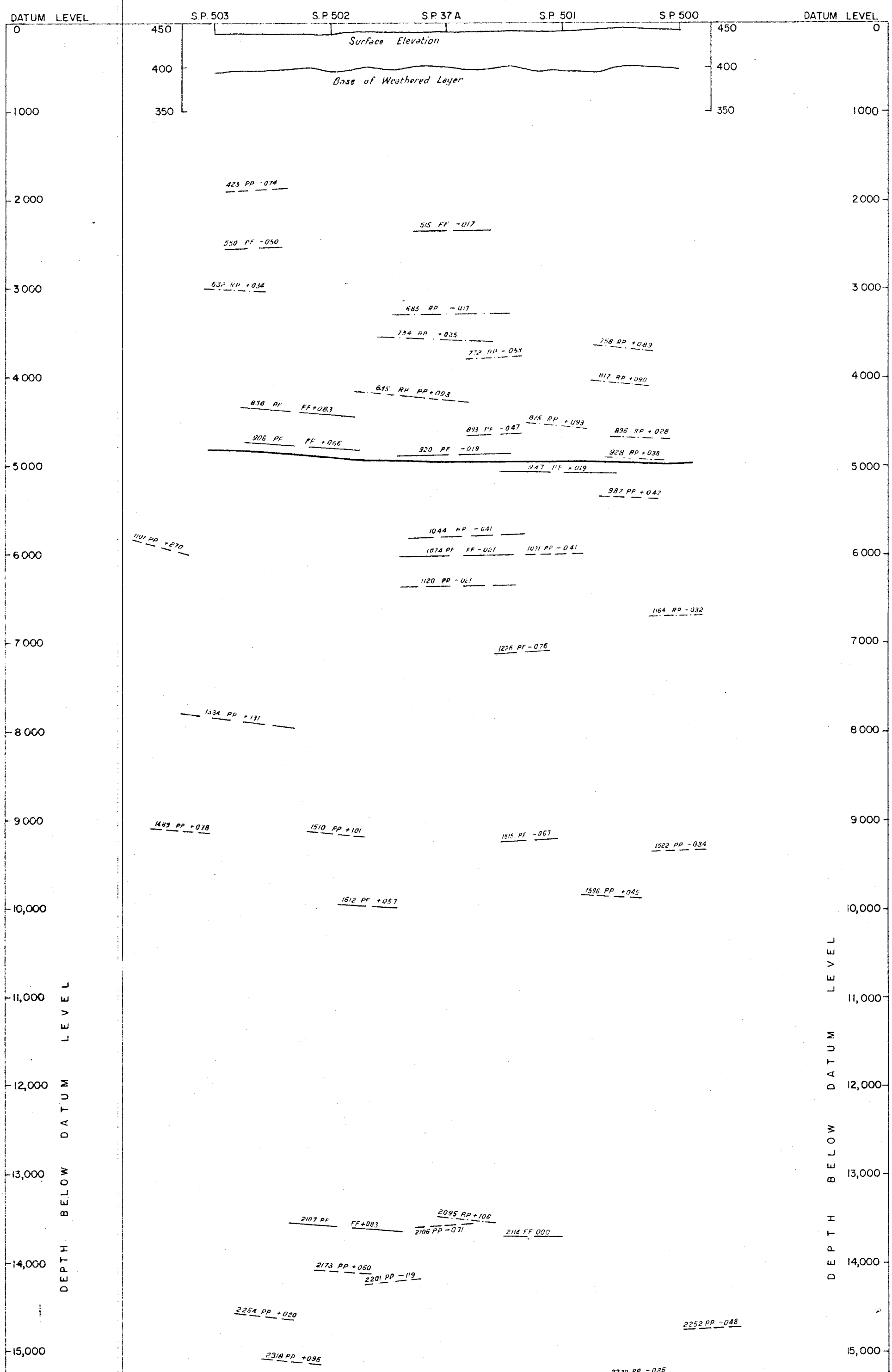
- MAIN ROAD
- TRACK
- FENCE
- TELEPHONE LINE
- ■ HOMESTEAD
- ⊞ YARD
- ⊙ HILL

E. R. Smith.
Geophysicist

G 149-12

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

PLATE 3



SEISMIC REFRACTION TRAVERSE IN THE CHRISTMAS CREEK AREA,
KIMBERLEY DIVISION, W. A.

REFLECTION CROSS-SECTION

OF CENTRE MILE OF REFRACTION TRAVERSE θ

HORIZONTAL AND VERTICAL SCALES IN FEET

1000 0 1000 2000 3000

GEOPHYSICIST

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics. G 149-13

PLATE 4

SEISMIC REFRACTION TRAVERSE
IN THE CHRISTMAS CREEK AREA
KIMBERLEY DIVISION, WA

REFRACTION PROFILES ALONG TRAVERSE "θ"

SCALE
HORIZONTAL 1000 0 1000 2000 FEET
VERTICAL 0·2 0 0·2 0·4 SEC.

G149-17