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AUSTRALIAN AQUITAINE PETROLEUM PTY. LTD.

LONE HILL

SEISMIC & GRAVITY SURVEY
AUGUST - OCTOBER, 1969

COMPAGNIE GENERALE DE GEOPHYSIQUE
AUSTRALIAN AQUITAINE PETROLEUM PTY. LTD.

LONE HILL SEISMIC AND GRAVITY SURVEY

August - October 1969.

OPEN FILE

By

COMPAGNIE GENERALE DE GEOPHYSIQUE

NORTHERN TERRITORY GEOLOGICAL SURVEY

R 69/12 A
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</tr>
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<td>Misclosure Sketch &quot;Y&quot;</td>
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ABSTRACT

During the period of 2nd. of August to the 9th of October 1969, COMPAGNIE GENERALE DE GEOPHYSIQUE carried out a seismic and gravity survey on Permit OP 162 (Northern Territory) on behalf of AUSTRALIAN AQUITAINE PETROLEUM PTY. LTD.

Different seismic techniques were used, namely: Seismic Refraction and Gravity on the KEEP RIVER AREA and three-fold coverage Seismic Reflection on the KULSHILL AREA.

The main results obtained during this survey are:

KEEP RIVER AREA

The seismic refraction survey achieved the delineation of the approximate extension of marker M'1 (NINGBING LIMESTONE) towards the south of KEEP RIVER No. 1 well, as well as the addition of new information regarding the attitude of marker M2 (MILLIGAN BEDS IV).

The high velocity refractor M1 (V = 5700 m/s) probably related to the economic basement (PROTEROZOIC) could be mapped on the southern part of the Permit.

KULSHILL AREA

- Providence Hill Structure: Better delineation of the prospect has been obtained during this survey. This subcircular anticline appears
structurally closed and is separated from the major KULSHILL structure by a slight syncline axis.

- Tree Point Prospect: The additional seismic work carried out on this area did not confirm the structural closure of the higher anomaly previously delineated.

Additional gravity meter readings were taken on the KEEP RIVER area. The Bouguer Anomaly map adds information to the general feature of the surveyed area.
INTRODUCTION

A seismic and gravity survey, the subject of the present report, was carried out by COMPAGNIE GÉNÉRALE DE GÉOPHYSIQUE on behalf of AUSTRALIAN AQUITAINE PETROLEUM PTY. LTD. on Permit OP 162 in the Northern Territory.

This survey, called the "LONE HILL SEISMIC AND GRAVITY SURVEY", included two working areas:

- The "KEEP RIVER AREA" where the investigation was done using the seismic refraction and gravity methods. Also some experimental reflection tests were carried out in this region.

- The "KULSHILL AREA" where the seismic reflection method (300% coverage) was used on two prospects called "Providence Hill" and "Tree Point".

One bulldozer was hired for making access roads and clearing seismic traverses and shot point patterns.

Drilling started on the 28th. July 1969. When the drilling operations ended on the 8th. October 1969, 12,558 holes totalling 222,460 feet had been drilled.

Seismic operations were carried out between the 2nd. August and 9th. October 1969. 21 seismic refraction spreads and 203 three-fold CDP spreads were recorded.
Gravity readings commenced on the 10th. of October and finished on the 15th. of October 1969.

C. ROYANT headed the party which was supervised from Brisbane and in the field by R. WEBER of Australian Aquitaine Petroleum Pty. Ltd. and M. ALTMEYER of Compagnie Generale de Geophysique.
CHAPTER I

GENERAL INFORMATION

1. GEOGRAPHICAL AND WEATHER CONDITIONS

1-1. GEOGRAPHICAL LOCATION

The first part of the survey (Fig. 1a) was carried out south of the Joseph Bonaparte Gulf, mainly on the western side of the Keep River.

The second part (Fig. 1b) was located on the mid-east coast area of the Joseph Bonaparte Gulf, particularly east of Pearce Point (Providence Hill Structure) and south of Hyland Bay (Tree Point Anomaly).

1-2. WEATHER

The weather was mostly fine throughout the survey becoming hot and wet from September onwards.

2. GEOLOGICAL DATA (Information supplied by A. A. P.)

Generally speaking, the Paleozoic Bonaparte Gulf basin is bounded by two Proterozoic Blocks, the KIMBERLEY Block in the west and the VICTORIA RIVER Block in the east.

The onshore part of the Bonaparte Gulf basin is divided into two areas by the Queen's Channel, the Keep River area, and the Port Keats area.
KEEP RIVER AREA
SCHEMATIC LOCATION MAP

SCALE: 1/250 000

1967 REFLECTION
1967 REFRACTION
1969 REFRACTION

N

W A N T Q L D

15° 00' 129° 00'

129° 15'

WESTERN AUSTRALIA
NORTHERN TERRITORY

RLH 2

KEEP RIVER 1

OC 4

OC 3

OC 1

1st CAMP

KEEP RIVER

L I M I T O P 1 6 2
The Keep River area is situated in the southern area where the main outcrops range from Lower Cambrian to Permian as follows, while the Port Keats area shows only Permo-Triassic outcrops capped by Mesozoic veneer. (Figs. 2 and 3).

**STRATIGRAPHIC NOMENCLATURE OF THE BONAPARTE GULF BASIN**

Established by D. M. Traves and later modified by J. Veevers et al., (B. M. R.) and by Australian Aquitaine Petroleum.

<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesozoic</td>
<td>No stratigraphic name applied</td>
</tr>
<tr>
<td>UNCONFORMITY</td>
<td>Kummowaitch Fmn,</td>
</tr>
<tr>
<td></td>
<td>Hyland Bay Fmn,</td>
</tr>
<tr>
<td>TRIASSIC TO</td>
<td>PORT KEATS GROUP</td>
</tr>
<tr>
<td>LOWER PERMIAN</td>
<td>Fossil Heads Fmn,</td>
</tr>
<tr>
<td></td>
<td>Kulshill Fmn,</td>
</tr>
<tr>
<td>UNCONFORMITY</td>
<td>BORDER CREEK FORMATION</td>
</tr>
<tr>
<td></td>
<td>POINT SPRING SANDSTONE</td>
</tr>
<tr>
<td>LOWER</td>
<td>TANMURRA FORMATION</td>
</tr>
<tr>
<td></td>
<td>MILLIGAN FORMATION (divided in 4 members)</td>
</tr>
<tr>
<td>UNCONFORMITY</td>
<td>ZIMMERMANN FORMATION</td>
</tr>
<tr>
<td>CARBONIFEROUS</td>
<td>LOCAL UNCONFORMITY</td>
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<tr>
<td></td>
<td>SEPTIMUS FORMATION</td>
</tr>
<tr>
<td></td>
<td>ENGA FORMATION</td>
</tr>
<tr>
<td></td>
<td>LOCAL UNCONFORMITY</td>
</tr>
<tr>
<td>UNCONFORMITY</td>
<td>BURT RANGE FORMATION</td>
</tr>
</tbody>
</table>

Continued
GEOLOGICAL SKETCH
KULSHILL AREA
Scale 1:1,000,000

LEGEND

Klm  Cretaceous
R   Triassic
Pk  Permian
Clp-z  Visean
Clp-b  Tournaisian
Duc  Upper Devonian
Pu  Upper Proterozoic
Pl  Sedimentary Rock (Middle Proterozoic)
Pg  Granite (Proterozoic)
An  Archean

Map supplied by Australian Aquitaine Petroleum
The outcropping sedimentary sequences of the Cambrian - Lower Ordovician and Upper Devonian - Lower Carboniferous are of the same sort and were deposited in a shallow sea: sandstone in response to uplift of the Pre-Cambrian source area in the south, and limestone by biogenous deposition at the end of periods of uplift.

A different style of deposition started with the Lower Permian, a fluvio deltaic conglomeratic quartz sandstone succeeded by glacial sediments.

In broad structural terms, folds are virtually unknown in the Bonaparte Gulf basin, and the main movements have been effected by step and block-
faulting, tilting and epeirogeny.

According to all these above considerations and interpretations of previous seismic, gravity and airmag surveys (in conjunction with sedimentologic data), it appears that the onshore part of the Bonaparte Gulf basin might be sub-divided into two Paleozoic Ante-Permian sub-basins: the Port Keats and Ningbing sub-basins, separated by a high zone which, in this area, would be located westwards of the Keep River, on the extension of the Pincombe Range. These sub-basins are filled with fine clastic sediments like those found in Kulshill I and Bonaparte I, while the Keep River high zone shows coarse clastic and carbonated sediments (Ningbing reef limestone of the Upper Devonian).

But the thickness of Paleozoic sediments is much greater in Keep River, due to an enlarged section of Lower Carboniferous rocks, and, unlike Bonaparte I and Kulshill I, the whole Tournaisian sequence of the Burt Range sub-basin was encountered in Keep River No. 1 (Fig. 4).

This sequence which pinches out towards the east and west of the basin must very likely do the same towards the south, because of the Pincombe Range High and the high zone separating the Keep River area from the Burt Range sub-basin.

3. GEOPHYSICAL DATA

3-1. PREVIOUS GEOPHYSICAL WORK

Several seismic surveys were carried out in or in close vicinity of the
KEEP RIVER and KULSHILL areas:

- 1960 Port Keats Seismic Survey by Austral Geo. Prospectors for Minad,

- 1962 Keep River Seismic Survey by G. S. I. for A. A. P.

- 1963 Pearce Point Seismic Survey by C. G. G. for A. A. P.

- 1964 Kulshill Seismic and Gravity Survey by C. G. G.
  Legune Seismic and Gravity Survey by Petty G. E. C.

- 1965 Skull Creek Seismic Survey by Petty G. E. C.

- 1966 Moyle River Seismic and Gravity Survey by C. G. G.
  Velocity Survey and Sonic Calibration of Kulshill No. 1 by C. G. G.

- 1967 Oakes Creek Seismic and Gravity Survey by C. G. G.

3-2. NEW DATA

Apart from the subject survey, the only new geophysical data available in the area is from the drilling of the KEEP RIVER No. 1 well, situated on an anticlinal structure delineated during the Oakes Creek Seismic and Gravity Survey.

The velocity survey brought forward the following new information:

3-2-1. Seismic Reflection: (Correlation with geological units)
3-2-2. **Seismic Refraction**

On refraction Line OCR1, which is situated approximately 3 km south of Keep River No. 1, the following refraction markers were recorded:

- Marker M'1 \( V = 6,050 \text{ m/s} \)
- Marker M2 \( V = 4,550 \text{ m/s} \)
- Marker M3 \( V = 4,075 \text{ m/s} \)

On the other hand, the elastic characteristics of the sediments intersected by the well can be sketched out as follows:

<table>
<thead>
<tr>
<th>HORIZONS Oakes Creek Surv.</th>
<th>TIME</th>
<th>DEPTH</th>
<th>CORRELATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, A, P.</td>
<td>C, G, G.</td>
<td>T, W.</td>
<td>K, B.</td>
</tr>
<tr>
<td>A</td>
<td>280? ms</td>
<td>1642'</td>
<td>Approximate base of the Lower Permian or Top of the TANMURRA Formation, Lower Carboniferous.</td>
</tr>
<tr>
<td>B</td>
<td>H1</td>
<td>1040 ms</td>
<td>6272'</td>
</tr>
<tr>
<td>C</td>
<td>1290 ms</td>
<td>7952'</td>
<td>Approximate Milligan IV Lower Member</td>
</tr>
<tr>
<td>D</td>
<td>H2</td>
<td>1490 ms</td>
<td>9272'</td>
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From the above, it appears quite obvious that marker M₃ is related to the TANMURRA formation, delay values, velocity of the marker and formation velocity are in good accordance. This TANMURRA formation which in the Keep River area is of little interest to the exploration has an unfortunate "screening effect" for the underlying M₂ refractor, making its exploitation difficult.

To locate marker M₂ in the Keep River No. 1 sedimentary column is more difficult. It was assumed that this refraction is related to the member IV of the MILLIGAN Beds.
Marker M'1 is obviously related to the NINGBING LIMESTONE which were encountered at a depth of 12,180' in Keep River No. 1.

4. OBJECTIVES OF THE SURVEY AND PROGRAMME

4-1. KEEP RIVER AREA

4-1-1. Objectives

The drilling of the Keep River No. 1 well achieved the definition of two main petroleum objectives:

- the Lower Carboniferous which contained a number of gas bearing reservoirs.
- the Ningbing Limestone (Devonian) which were encountered with poor reservoir qualities but remains a potential objective for hydrocarbons.

The gas bearing CARBONIFEROUS section is approximately contained within the interval between marker M2 (4550 m/s) and marker M'1 (6000 m/s), the latter being probably generated by the high velocity contrast given by the NINGBING LIMESTONE.

Therefore, in this area, the main objective of the LONE HILL SEISMIC REFRACTION SURVEY can be summarized as follows:

Exploration Objectives

- Investigation of the geographical extension of markers M1,
M'1 and M2 south of Keep River No. 1 (evolution of M'1 - M2 and/or M1 - M2 intervals, approximate zone of pinch out ...)

- Study and localization of possible changes in horizontal velocity of the high velocity markers (M1 - M'1).
- Delineation of structural features.
- Reconnaissance of the geomorphological anomaly situated in the bend of the Keep River.
- Investigation with seismic refraction of the "poor reflection results" area, adjacent to OC2 area, assumed to represent an uplifted fault block (?).
- Tie of both M'1 and M2 markers to Keep River No. 1 for geological correlations.

**Tests of Seismic Techniques**

Before any further drilling, subsurface mapping would be required on structural features delineated by seismic refraction. The previous seismic surveys encountered major difficulties in obtaining reliable results in some large areas although common depth point technique was used. Limited seismic reflection tests were carried out in two areas of poor seismic response, in an attempt to enhance the results with the use of improved shooting patterns, greater depth of detonation and increase of the geophone pattern.

For the same "mapping" purpose, limited tests were made at the end of the refraction work in order to check whether the required
"conditions" for eventual "wide angle" reflection profiling are met in this area.

4-1-2. **Programme**

**Seismic Reflection Tests**

Two test areas were selected along line OC4.

- **Zone A**: OC4, SP 260 to 240 approximately, with the following tests:
  - upheole shooting
  - noise analysis
  - shot hole pattern experiments
  - geophone arrays experiment.

- **Zone B**: OC4, SP 204 to 225 approximately. Here it was suggested that the WZ be investigated by shallow refraction and the parameters, found as the most suitable in Zone A, be tested again.

**Wide Angle Seismic Reflection**

The location of this test had to be decided during the course of the survey when more refraction data were available.

**Seismic Refraction**

**(a) Line RLH1**: North - South: 35 km representing 12 refraction bases.

**Objective of the Line**:

- tie of both markers M'1 and M2 to Keep River No. 1 for
geological correlation,
- investigation through the fault area,
- investigation of the geomorphological anomaly,
- reconnaissance of the southern part of the permit.

(b) Line RLH2: East-West: 26 km representing 9 refraction bases.

Objective of the Line:
- reconnaissance of the east bank of the Keep River.
- investigation of the geomorphological anomaly.
- reconnaissance of the western border of Permit OP 162.

4-2. KULSHILL AREA

4-2-1. "Providence Hill" Prospect

Experiments: The following tests were carried out:
- noise analysis
- shot hole pattern
- re-shooting of a previously recorded shot point.

Details on the "Providence Hill" structure

This structure was delineated by the KULSHILL CREEK SEISMIC SURVEY in 1964, but prior to the implantation of an exploration well, the northern closure of the anticline had to be confirmed and additional information about the "fault pattern" had to be obtained.

The TANMURRA Formation (Lower Carboniferous) represents here the main petroleum objective. From the geophysical point of view, the mapping of
Horizon B (C. G. G. Horizon "3") had to be achieved, together with reliable data on Horizon C (C. G. G. Horizon "4"). At Kulshill No. 1 and No. 2 wells, Horizon B was correlated to the top of the TANMURRA Formation but in this area, the top of this formation being also affected by an unconformity surface, it was not known whether Horizon B was mainly generated by this surface or by velocity contrasts at the top of the TANMURRA. The confirmation of a structural closure at any deeper horizon would greatly ascertain the closure of the TANMURRA Formation.

The programme included 4 reflection lines (2 northwest - southeast and 2 northeast - southwest) of approximately 34 km. Their actual location depending upon surface conditions, tectonics and results of previous surveys.

4-2-2. Details on the "Tree Point Anomaly"

Previous KULSHILL and MOYLE RIVER surveys, together with offshore seismic surveys suggested the possibility of a "high" anomaly located between Line K20 and Line K24. In this northern area of the prospect, the Permian series are probably increased at the top of adjunction of younger sections of Upper Permian age, thus increasing the chances of existence of suitable cap-rocks above the reservoirs of the Lower Permian. The complementary seismic work planned here aimed to confirm the existence or not of a "closed" structure.

The programme included 2 lines oriented north - south and east - west, totalling approximately 15 km, and located on the possible structure.
4-3. **GRAVITY SURVEY (KEEP RIVER AREA)**

Complementary gravity measurements were carried out only in the Keep River area. The gravity measurements were made mainly on points surveyed by the surveyor. The spacing was basically as follows:

- refraction traverse: 1 reading on every second trace (480 m), every offset shot point.
- on surveyed access roads (when topographical control was available) at a spacing ranging from 500 m to 1,000 m.

The gravity measurements were tied with the OAKES CREEK GRAVITY network. The density used for the computation was 2.0

5. **TECHNIQUES USED** (cf. Fig. 5)

5-1. **REFRACTION (KEEP RIVER AREA)**

The field procedures used were designed in order to enable the interpretation of the refraction records by the "Gardner-Layat" method.

**Refraction base:** \( L = 2,640 \) metres.

Consisted of 12 traces regularly spaced at 240 metres.

**Refraction trace:**

Consisted of an array of 12 Hall Sears refraction geophones, 215 ohms, 4.5 c.p.s., laid out perpendicular to the line, 20 metres between geophone
REFRACTION SPREAD

GEOPHONE PATTERN
12 GEOPHONES 4.5 Hz PER TRACE

SHOT POINT PATTERN
DIRECT
REVERSE
S.P.
NORTH
strings, 10 metres between detectors.

**Shot Point pattern:**

Consisted of several holes in one or two lines perpendicular to the refraction traverse. Charge size depended upon the shooting distance and the noise level.

At each refraction shot, 24 channels of information were recorded through a C.G.G. AS 604 R amplifier on an SIE camera. All the shots were magnetically recorded with a PMR unit.

Two consecutive bases were recorded successively from several shot points on either side of the spreads (direct shots – reverse shots). When the programmed profiles were completed, the 12 traces of the first base were shifted forward, leaving 12 traces in common between two consecutive profiles. Shooting orders and time break signals were transmitted by radio. A "tie trace" was connected at trace 24 of every preceding spread.

5-2. **REFLECTION (KULSHILL AREA) (cf. Fig. 6)**

All the lines were shot using three fold coverage. Sections of 15 pairs seismic reflection cables were connected to give a total spread of 1,440 metres (24 traces, 60 metres apart).

**Geophone Patterns**

Consisted of an array of 48 Hall Sears Junior geophones 245 ohms, 20 c. p. s., laid in two lines of 24, parallel to the traverse and 20 metres apart. The
REFLECTION SPREAD

1300 m

trace 24

GEOPHONE PATTERN
48 GEOPHONES PER TRACE

LINE

60 m

20 m

5 m

SHOT POINT PATTERN

LINE

1300 m

20 m

10 m

FIG. 6
first line of geophones was laid along the edge of the line cut by the bulldozer. On each line the geophones were 5 metres apart.

**Shot Point pattern**

Two shot patterns were used depending upon the response of the subsurface:

- 3 lines of 13 holes, or  
  drilled 15 feet deep, 10 or 20 metres between holes and 20 metres between lines.

- 3 lines of 20 holes

The centre of the shot pattern was 130 metres from the line and located between traces 4 and 5 or between traces 20 and 21. Shot points were spaced 240 metres (4 traces) apart.

The charge of explosives used ranged from 120 to 240 lb. per shot point. All the detonators were connected in series.

The crossing of several swamps required off-end shot points to ensure the continuity of subsurface coverage.

Time break was transmitted by radio.

After each shot, four traces were disconnected at the rear-end of the spread and four new traces connected at the front-end using a roll-along switch box.

---

5-3. **GRAVITY (KEEP RIVER AREA)**

The Worden No. 437 gravity meter was used for the survey. Gravity readings were made every second trace on refraction lines RLH1 and RLH2. The new survey was tied to the previous gravity bases of OAKES CREEK.
SEISMIC AND GRAVITY SURVEY.

Before starting the operations and at the end of the survey the gravity meter (Worden) was calibrated in Brisbane between the bases of Mount Coo-Tha and the University of Queensland.
CHAPTER II

PERFORMANCE

1. ACCESSIBILITY

1-1. KEEP RIVER AREA

From Kununurra, the Legune Station road could be used by all heavy vehicles. At the Keep River yard, 40 miles from Kununurra, a track led to the C, G, G, camp, located 20 miles to the north at the previous Petty and C, G, G, camp sites. The Oakes Creek crossing had to be smoothed in order to allow the passage of heavy vehicles.

All seismic lines and shot point patterns were cleared by the bulldozer except the northern part of Line RLH1 located in tidal mud flats which could only be crossed during a short period of neap tides. For the northern most shot points, surveyors and shooters had to walk through the mud area.

Major difficulties were encountered where Line RLH2 crossed the Keep River. At this point the Keep River is 240 metres wide and strong currents occur during the ebb and flow of the tide.

In order to reach the line on the right bank of the river an upstream detour of 40 miles to the Keep yard fords was necessary. A dinghy was used for the transport of personnel across the river. Despite a steel cable stretched between the river banks to support the seismic refraction cable, this cable could not resist the strain of the current and broke several times.
Fuel and explosive dumps were set up on the eastern bank of the river. Two more creek crossings had to be improved by the bulldozer at the eastern end of Line RLH2, but the fords were destroyed during high tide and they became difficult to cross. At this point one rig was bogged for a full day obstructing the passage of a shooting truck.

PROVIDENCE HILL AND TREE POINT AREAS

After completion of the Keep River area, the crew moved to Port Keats (approximately 700 miles by roads and tracks). The road from Daly River to Port Keats was improved by the Civil Engineering crew, especially at the crossings of running creeks. However, this road remained quite rough and could only be passable with 4-wheel drive vehicles. Consequently, supply trucks were unable to reach the camp site and commodities had to be reloaded onto C. G. G. vehicles.

The fuel had been sent previously by barge from Darwin to Port Keats and unloaded at Chindi Beach.

Since the area is heavily timbered, accesses to the camp and to the lines were cleared by the bulldozer and several swamps had to be detoured.

Upon completion of the survey on the Providence Hill prospect, the crew moved to the Tree Point area. After clearing by 'dozer, some previous seismic lines could be used as access roads. Two fords were built to cross creeks with running water by using logs laid on the bottom. Constant maintenance was necessary, particularly when the creeks were swollen by rainfalls.
The road between Port Keats and Daly River was still usable when the crew moved out of the Permit.

2. PARTY COMPOSITION (Figs. 7 and 8).

2-1. RECORDING

Fig. 7 shows the composition of the party equipment and personnel.

2-2. DRILLING AND BULLDOZING

Fig. 8 shows the composition of the drilling and bulldozing teams.

2-3. CAMPS

Three main camps were established during the survey in order to reduce travelling time. Their locations are indicated on Figs. 1a and 1b.

- The first camp was situated approximately in the middle of the Keep River prospect.
- The second one was established 12 miles southwest of the Port Keats Catholic Mission (Providence Hill prospect), on the previous Line PP8.
- The last one was located 14 miles northeast of the Port Keats Catholic Mission (Tree Point prospect), on the previous Line K19.

All camp sites had to be cleared by the bulldozer as well as dump sites.
In Kulshill Area: they were supplied by the Shell depot in Darwin and shipped by barge to Chindi Beach where a dump was set up with the help of the natives of the Port Keats Catholic Mission.

**Dynamite and Detonators**

In Keep River Area: they were delivered at the camp site by hired trucks from Alice Springs or Darwin.

The remainder was transported to Providence Hill area by C. G. G. vehicles.

In Kulshill Area: they were delivered by hired truck from Darwin.

Two kinds of explosives were used:

- The first, mainly used for refraction shooting, manufactured by IMPERIAL CHEMICAL INDUSTRIES, Melbourne and denominated GEOPHEX POLAR, 10 lb cartridges, size 2' x 3''.

- The second, manufactured by DUPONT FAR EAST INC., and denominated PRIMERS and NITRAMON "S", 1 lb. tins.

These explosives were detonated by NOBEL ELECTRIC 60 foot wire detonators.

The explosives left after the completion of the survey were destroyed (2,080 lb. of Nitramon and 330 detonators).

**3-2. COMMUNICATIONS**

Communications were good through Kununurra for mail and air transport.
# PARTY COMPOSITION

## DRILLING & BULLDOZING

### DRILLING

<table>
<thead>
<tr>
<th>PERSONNEL</th>
<th>EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BASIC</strong></td>
<td></td>
</tr>
<tr>
<td>4 Drillers</td>
<td>4 International R190 with Mayhew 1000</td>
</tr>
<tr>
<td>4 Drillers Helpers</td>
<td>4 International AB160 Water Truck</td>
</tr>
<tr>
<td>4 Drillers</td>
<td>1 Bedford 4 x 4</td>
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</table>

<table>
<thead>
<tr>
<th><strong>ADDITIONAL FACILITIES</strong></th>
<th><strong>EQUIPMENT</strong></th>
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</thead>
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<tr>
<td></td>
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</tbody>
</table>

### BULLDOZER

<table>
<thead>
<tr>
<th>PERSONNEL</th>
<th>EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Operator</td>
<td>1 D6C Bulldozer</td>
</tr>
<tr>
<td>1 Operator Mechanic</td>
<td>1 Landrover</td>
</tr>
</tbody>
</table>
for fuel and explosives storage. The living conditions were rather unpleasant due to the presence of "bulldust", mosquitoes, March-flies and flies.

3. LOGISTICS

3-1. SUPPLIES

Food

In Keep River Area: fresh and packaged food-stuffs were brought into the camp by C.G.G. vehicles as often as necessary from Kununurra and Wyndham where a good supply was available.

In Kulshill Area: perishable provisions were airfreighted weekly from Darwin. Canned goods were transported from Darwin by truck via Daly River at the beginning of the survey.

Water Supply

In Keep River Area: water was available from a windmill well belonging to the Homestead, 5 miles south from the camp.

In Kulshill Area: water could be found in many creeks within a radius of 5 miles from the camps.

Fuel and Lubricants

In Keep River Area: they were supplied by the Shell depot in Kununurra and transported to the camp by C.G.G. vehicles.
services. In addition, the Keep River airstrip was used for chartered planes from Darwin to transport personnel and equipment at the beginning of the survey. Regular flights and/or chartered planes brought the mail to Port Keats from Darwin.

Several radio schedules per day for telegrams and medical advice were arranged with the "Royal Flying Doctor" service based in Wyndham.

Direct contact with Darwin was possible from Providence Hill and Tree Point areas.

One SSB transmitter/receiver was used for daily communications with Australian Aquitaine Petroleum's office in Brisbane.

At the end of the survey and probably due to bad meteorological conditions, the radio communications turned out to be rather difficult.

4. STATISTICS (Fig. 9)

Refraction: 60.48 km were shot in 184.25 production hours, consequently an average of 0.328 km per production hour was maintained.

Reflection: 50.44 km were shot in 212.50 production hours, an average of 0.238 km per production hour was maintained.

Consumption of Explosives and Detonators:

Refraction: 29,989 lb. of Geophex, 9,685 of Nitramon with 1,334
60 foot length detonators.

**Reflection**: 11 lb. of geophex, 36,285 of Nitramon with 12,136 60-foot length detonators

5. **TECHNICAL CONDITIONS**

5-1. **BULLDOZING**

One Caterpillar D6 C owned by C. Patterson (Berrimah - Northern Territory) was used during the whole survey to clear traverses and shot point patterns, to open access roads and to prepare camp sites.

- For refraction work, lines were 'dozed' at one blade width and shot points consisted of one or two cuts at right angles to the main line.

- For reflection work, four parallel lines, one blade in width, were dozed: the first for the spread, recording site and movement of vehicle, the other three for the shot points.

These lines were continuous since each shot point was 200 metres in length and 50 metres apart.

The bulldozer worked permanently under the surveyor's supervision in order to avoid any deviation of the line.

Production was sufficient during the refraction survey but the bulldozer had to work 12 hours per day, 7 days a week, during the reflection survey in order not to slow down drilling and seismic operations.
During the survey, the bulldozer crew worked 817 hours including actual
dozing on the lines, travelling from line to line and area to area and
opening of access tracks. An average of 1.4 dozing hours per recording
hour were necessary.

5-2. SURVEYING (Fig. 10)

The area in general is mildly undulated with light to medium coverage of
eucalyptus and acacia trees.

The traverses were surveyed using a WILD TO theodolite and a steel cable.
Shot points and trace positions were marked with wire pegs labelled with
coloured plastic tape.

**Levelling** (Pls. 5, 6 and 7)

All traverses were closed to form loops which were later adjusted for the
final location. All the coordinates and elevations were calculated in metric
system.

Closures were assured by tying to a number of permanent markers of the
previous surveys.

The misclosure diagrams and the final coordinate values show that they are
within the standard of:

\[ F = 10 \sqrt{D} \]

when F is the misclosure value in centimetres for elevation, in metres
for planimetry and D the loop length in km.
| **REFERENCE DOCUMENTS** | Aerial Photomosaics (scale 1/50,000) - A.A.P.  
Australian National Mapping - AUVERGNE - PORT KEATS (scale 1/250,000)  
A.A.P. Accessibility Map (scale 1/50,000) |
|-------------------------|---------------------------------------------------------------------|
| **PROJECTION SYSTEM**   | UTM Australian National Spheroid on Keep River Area.  
ATM Clarke 1858 Spheroid on Kulshill Area. |
| **REFERENCE DATA**      | Closure on previous surveys: Oakes Creek (Keep River area)  
Kulshill and Pearce Point (Providence Hill Prospect)  
Moyle River and Kulshill (Tree Point Prospect) |
| **MAGNETIC DECLINATION**| Made on sun and stars observations.  
Keep River area : 4° 03  
Providence Hill Project : 3° 40  
Tree Point Project : 4° 02 |
| **CLOSURES**            | Better than $F = 10 \sqrt{D}$ when $F$ is the misclosure value in centimetres and $D$ the loop length in km. |
| **ELEVATION**           | Better than $F = 10 \sqrt{D}$ when $F$ is the misclosure value in metres and $D$ the loop length in km. |
| **PLANEIMETRY**         | Keep River Area (scale 1/50,000)  
Kulshill Area (scale 1/100,000)  
Providence Project (scale 1/50,000)  
Tree Point Project (scale 1/50,000) |
Coordinates were computed in the Universal Transverse Mercator Australian National Spheroid System for the Keep River area and in Australian Transverse Mercator Clarke 1858 Spheroid System for the Providence Hill and Tree Point prospects as the previous surveys in these different areas were using these respective systems.

Maximum and average misclosures were:

- 25 m and 11 m in X
- 29 m and 8 m in Y
- 0.37 m and 0.15 m in Z

**Permanent Markers**

Permanent markers (11 ft. lengths of 2" diameter galvanized iron pipe driven 3 ft. into the ground) were placed every two refraction bases, at each end of lines, at crossings of new reflection lines or at convenient points between intersections.

A list of these permanent markers and those of previous surveys used for closure, with corresponding elevations and coordinates, is given in the Appendix.

Figures 11 and 12 show the different values of magnetic declination based on sun and stars observations. The adopted values are:

- Keep River area: $4^\circ 03$
- Providence Hill prospect: $3^\circ 40$
- Tree Point prospect: $4^\circ 02$
Reference

The following reference documents were used:

- Aerial Photomosaics (scale 1/50,000) (A. A. P.)
- Australian National Mapping Auvergne (scale 1/250,000)
- Australian National Mapping Port Keats (scale 1/250,000)
- A. A. P. Location Maps (scales 1/50,000 and 1/100,000)
- A. A. P. Accessibility Map (scale 1/50,000).

5-3. DRILLING

The crew started the survey with four conventional Mayhew 1000 rotary drills adapted for air or water drilling. After one rig was destroyed by fire on August 17th, three day shifts and one night shift were assured on the remaining rigs in the Keep River area.

The production was sufficient to allow full utilization of the recording crew when using refraction method.

During the moving of the crew to Port Keats another rig had engine breakdown and was unserviceable for twelve days. As soon as it was repaired, a fifth shift was added to increase drilling output.

Most drilling was done by air. Water drilling was used for some deep holes and in low areas close to swamps or rivers. Drilling was not possible in mud flats as the holes caved in immediately. An auger drill was tried but without any success.
In some sandy formations a number of holes collapsed before loading.

The production varied depending upon the formation encountered. It was low in gravel layers or hard outcrops, especially during the experiments on Line OC4 and refraction on Line RLH1. Better production was obtained in Providence Hill and Tree Point areas.

Samples were collected from the bottom of a deep hole for A. A. P.'s geological laboratory.

5–4. RECORDING

The particulars of the recording equipment (refraction and reflection) are shown on Fig. 13. Spreads and shooting patterns used by the crew in either refraction or reflection are sketched on Figs. 5 and 6.

Unforeseen Circumstances

On the 9th. August a Bedford supply truck carrying explosives was destroyed by fire, subsequently a bush fire activated by strong winds spread over the survey area. Two cables and two jumpers were burnt out although the line was carefully watched by crew members.

A few other cables were chewed by cattle or dingoes, even during daylight. In some places the whole spread had to be picked up at night to avoid damages.
KEEP RIVER AREA
MAGNETIC DECLINATION MAP
SCALE 1:250,000

15° 00' 129° 00' 129° 15'

W. A. N. T.

15° 15'

RLH 2

107 108 106 105 104 103 102 101 100

RLH 1

110 109 108

111

CAMP

STARS CAMP RLH1 RLH2

α CETI 4° 09'
α GENTAURI 4° 11'
α ERIDANI 4° 06'
SUN 4° 09'
SUN 4° 05'
SUN 111/11 3° 59'
SUN 110/6 3° 59'

STATIONS

102/11 4° 07'
<table>
<thead>
<tr>
<th><strong>RECORDING</strong></th>
<th></th>
</tr>
</thead>
</table>
| **RECORDING SYSTEM** | **Reflection : AS 604 R recorder + PMR20 magnetic recorder + SIE 50/60 TR camera**  
**Refraction : AS 626 recorder + PMR20 magnetic recorder SIE 50/60 TR camera** |
| **CHARACTERISTICS OF AMPLIFIERS** | **Reflection : AS 626 X : Dynamic range 60dB. This zone (60dB range) can be moved up to 50dB with steps of 5dB by choice of "Common gain sill" from 0.1 microvolts to 32 millivolts. All amplifiers have the same gain (after the initial gain is released). Controlled by arithmetic average of either 24 traces or per groups of 12, gain is recorded in logarithmic form and allows to know the gain level at any time and for each trace. Individual AVC circuits, from 0 to 40dB (by steps of 5dB) can be put out of use by switch on each amplifier. Noise level 0.5 microvolts with a line of 500 ohms. Either 18 or 36dB per octave slopes for low cut filters and 18db per octave for high cut filters.** |
| **CABLES** | **Reflection : 27 refraction cables (length 270m, one take out per cable)**  
**WZ : 2 cables (length 240m)**  
**Reflection : 15 x 3 traces reflection cables** |
| **GEOPHONES** | **Reflection : 300 Refraction Hall sears 4.5Hz 215 ohms**  
(3 per string, 10m spacing)  
**WZ : 24 Refraction Hall sears 4.5Hz**  
**Reflection : 1728 Reflection Hall sears junior, 20Hz, 245 ohms** |
| **PERIODIC TESTS** | **Recorder : daily** |
| **RECORDING INSTRUMENT SETTING** | **Filters**  
Common gain level 14 - 80  
Common gain level 0.56 to 1.8  
Initial gain -30 to -55dB  
Common AGC final gain Max  
Delay 200 to 550ms  
Individual AGC gain -30dB to Max (according to the distance of the trace)  
Delay 200 to 550ms  
Traces, gains ranging -3 to 33dB according to the shot point, to the spread distances and noise conditions.  
Filters out -28
CHAPTER I

TESTS

The programmed tests were carried out on two different areas of Line OC4: (cf. Fig. 14).

- **Zone A**: from SP 260 to 240 approximately, where the results are fair from SP 240 to 243 and poor to nil from SP 243 to 260.

- **Zone B**: from SP 204 to 225 approximately, where the results are roughly from poor to nil.

1. **ZONE A**

1-1. **SURVEY OF THE WEATHERED ZONE**

**Aims**: determination of the depth of the weathered layers, thence determination of the minimum depth of the seismic shot hole.

**Means**: **Up Hole Shooting** (Fig. 15)

Located at the crossing of the previous reflection lines OC4 with OC2, this hole was drilled at a depth of 200'. Shots were recorded at the following depths: 200' - 180' - 160' - 100' - 60' - 40' - 30' - 20' and 10'.

**Results**:

- from 0 to a depth of 56' vertical velocity = 2900 ft/sec or 900 m/sec.

- from 56 to a depth of 120' vertical velocity = 6700 ft/sec or 2040 m/sec.
below 120' vertical velocity = 10,000 ft/sec. or
3,050 m/sec.

During the drilling operations the water table level was met at approximately ~ 50 feet.

1-2. **SHOT HOLE PATTERN EXPERIMENTS**

Different patterns were compared with the following geophone set up:
24 traces - 48 geophones/trace in 2 parallel lines of 24 each - 5 metres between geophones.

1-2-1. **Group A** (Pl. 8)

Located on Line OC4 between SP 259 and 260 where the previous results are very poor.

- **Previous parameters**: (PT 700 Recording Unit)
  
  3 holes x 20 lb. = 60 lb. depth 55'

- **New parameters**: (AS 626 Recording Unit)
  
  (I) 60 holes x 3 lb. = 180 lb. depth 20' (end shot)
  (II) 60 holes x 2 lb. = 120 lb. depth 20'
  (III) 18 holes x 5 lb. = 90 lb. depth 75'

The best results are obtained by the pattern shot with 18 holes at a 75' depth.
The general feature of the record is improved and is good with a reasonable signal/noise ratio. A larger number of organized energy arrivals are visible and confirmed by the gain control curve. This gain control curve
shows a better consistency in the energy level (approximately +12 dB) all along the record for shot (III) than for shots (I) and (II).

\[(\text{III}) > (\text{I}) \text{ and } (\text{II})\]

In conclusion, improvement of the recorded data is achieved when compared to the previous Oakes Creek Survey results.

1-2-2. Group B (Pl. 9)

Located on Line OC4 at the crossing with Line OC2 where the previous results are very poor.

- **Previous parameters**: (PT 700 Recording Unit)
  
  3 holes x 25 lb. = 75 lb. depth 55'  

- **New parameters**: (AS 626 Recording Unit)
  
  (I) 8 holes x 10 lb. = 80 lb. depth 135'  
  (II) 8 holes x 10 lb. = 80 lb. depth 100' (end shot)  
  (III) 2 holes x 40 lb. = 80 lb. depth 100'

Considering the results obtained on the previous Group A parameters the present results are of poorer quality. However, results given by the pattern shot with 8 holes at a 135' depth are better. In general the quality of this record is acceptable and the gain control curve shows a higher energy level (approximately +8 dB at the beginning of the record).

\[(\text{I}) > (\text{II}) \text{ and } (\text{III})\]
Here again, when compared to the Oakes Creek data, the records are slightly improved.

1-2-3. **Group C** : (Pl. 10)

Located on Line OC4 between SP 247 and 248. (Split spread - end shot).

- **Previous parameters** : (PT 700 Recording Unit)
  
  3 holes x 20 lb. 60 lb. depth 55'

- **New parameters** : (AS 626 Recording Unit)

(I) 4 holes x 20 lb. = 80 lb. depth 75' (end shot)

(II) 18 holes x 5 lb. = 90 lb. depth 75'

Although these two records have only a limited subsurface coverage in common, the noise level on shot (I) appears lower than on shot (II), and

(I) > (II)

1-3. **GEOPHONE ARRAYS EXPERIMENT** (Pl. 10)

A "Fold Back Spread" lay-out located on Group C was used for this experiment with the following geophone arrays :

- 24 geophones per trace, spread over 115 metres.
- 48 geophones per trace, spread over 2 parallel lines of 24 geophones each (length : 115 metres).

The best results are obtained with 48 geophones per trace.
The general quality is slightly improved and the energy level higher (+ 4 dB) from 2 sec. two way time.

2. ZONE B

2-1. SURVEY OF THE WEATHERED ZONE

Aims: investigation of the weathered zone by shallow refraction.

Means: WZ Shooting (Figs. 16a - 16b)
Two WZ refraction analyses were effected:

- WZ 1: located on SP 209 of Line OC4.
- WZ 2: located on SP 220 of the same line.

The lay-out was composed of two cables of 240 metres each with 1 geophone per trace and 12 traces per cable. A centred shot and 2 end shots were respectively effect on both WZ spreads.

Results:
The horizontal velocity of the consolidated medium varies from 2,500 m/s on WZ 1 to 3,500 m/s on WZ 2. The thickness of the weathered layer is about the same, 18 m for WZ 1 and 23 m for WZ 2.

2-2. NOISE ANALYSIS

An initial noise test, located on reflection Line OC4 between SP 241 and 252 (Zone A) was interrupted due to lack of results. (Very weak energy level of organized noises necessitating the use of too large charges). Therefore only three bases of the six planned were recorded.
This lack of results may be explained by the fact that the shots were effected nearby the Keep river in a blue clay area. A second attempt was made on this same line between SP 209 and 221 on a less favourable area where surface conditions were more average, mainly composed of sand and laterite.

2-2-1 **Field Procedure**

- Recording from 200 to 1,580 metres.
- 6 bases of 24 traces with 10 m between traces.
- 12 bunched geophones per trace.
- 1 tie trace (trace 24 = trace 1).

All shots were effected using 20' deep holes with the following charges:

<table>
<thead>
<tr>
<th>Base</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base I</td>
<td>3 lb.</td>
</tr>
<tr>
<td>Base II</td>
<td>5 lb.</td>
</tr>
<tr>
<td>Base III</td>
<td>10 lb.</td>
</tr>
<tr>
<td>Base IV</td>
<td>40 lb.</td>
</tr>
<tr>
<td>Base V</td>
<td>40 lb.</td>
</tr>
<tr>
<td>Base VI</td>
<td>80 lb.</td>
</tr>
</tbody>
</table>

Setting of the AS 626 recorder as follows:

<table>
<thead>
<tr>
<th>Filters</th>
<th>14 - 160</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common gain &quot;sill&quot;</td>
<td>1, 0</td>
</tr>
<tr>
<td>Initial gain</td>
<td>Bases I and II - 30 dB</td>
</tr>
<tr>
<td></td>
<td>Bases III and IV - 25 dB</td>
</tr>
<tr>
<td></td>
<td>Bases V and VI - 20 dB</td>
</tr>
<tr>
<td>Individual gain</td>
<td>Nil.</td>
</tr>
</tbody>
</table>
2-2-2. **Results**: (Pl. 11)

Looking at the organized energy arrivals three possible noise patterns were selected:

**Noise A**: well characterized on bases I and II, disappears on base III.

**Noise B**: visible on bases I and II, disappears on base III.

**Noise C**: important, since it only disappears on base V.

---

**Exploitation Diagram**: (Pl. 12)

Characteristics of the noises and reflected signal.

<table>
<thead>
<tr>
<th>Noise</th>
<th>Average velocity</th>
<th>Wave length $\lambda$</th>
<th>Frequency f</th>
<th>Frequency K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise A</td>
<td>550 m/sec.</td>
<td>31 to 33 metres.</td>
<td>17 to 18 c/sec.</td>
<td>30 to 32 c/sec/metre.</td>
</tr>
<tr>
<td>Noise B</td>
<td>920 m/sec.</td>
<td>37 to 43 metres.</td>
<td>21 to 25 c/sec.</td>
<td>23 to 27 c/sec/metre.</td>
</tr>
<tr>
<td>Noise C</td>
<td>1300 to 1450 m/sec.</td>
<td>74 to 83 metres.</td>
<td>16 to 19 c/sec.</td>
<td>12 to 13 c/sec/metre.</td>
</tr>
</tbody>
</table>
Signal $S$ : average velocity 3900 m/sec.
wave length $\lambda$ 230 metres.
frequency $f$ 17 c/sec.

- Choice of Geophone Pattern

The use of Smith's formulae gives, for a most suitable geophone pattern, the following result:

Maximum length of the geophone group such as:

$$Nh = 0.45 \lambda S$$

with $N =$ total number of geophones per trace in line, and $h =$ spacing between geophones

$$\lambda S = \frac{v S_{\text{minimum}}}{fH}$$

$V S$ : smallest value of the apparent horizontal velocity of the reflected signal $\approx 3900$ m/s for signal $S$,

$fH$ : highest frequency needed to save the character of the signal $\approx 40$ c/sec.

$$\lambda S = 98 \text{ metres}$$

$$Nh = 44 \text{ metres}.$$

- Use of the Cancellation Curves (Fig. 17)

$e/\lambda$ tabulation

<table>
<thead>
<tr>
<th>n</th>
<th>Noises A</th>
<th>Noises B</th>
<th>Noises C</th>
<th>Signal S</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.284 - 0.267</td>
<td>0.238 - 0.204</td>
<td>0.119 - 0.106</td>
<td>0.038</td>
</tr>
<tr>
<td>12</td>
<td>0.129 - 0.121</td>
<td>0.108 - 0.093</td>
<td>0.054 - 0.048</td>
<td>0.018</td>
</tr>
<tr>
<td>24</td>
<td>0.062 - 0.058</td>
<td>0.052 - 0.044</td>
<td>0.026 - 0.022</td>
<td>0.008</td>
</tr>
</tbody>
</table>
\[ A = \frac{\sin n \pi e/\lambda}{n \sin \pi e/\lambda} \]

- \( n \) = number of geophones per line
- \( e \) = spacing between geophones

Graph showing the relationship between \( e/\lambda \) and \( A \) for different values of \( n \): 8, 12, and 24.
KEEP RIVER AREA
The noises A, B, C and signal S have been reported in abscissa with the following values of e/λ:

1. 92 metres with 24 geophones
2. 4 metres with 12 geophones
3. 8.80 metres with 6 geophones

In applying the cancellation curves for geophone groups consisting of six, twelve and twenty-four geophones per line it appears that:

- with 24 geophones the amplitude of the signal S is reduced of 5% when all noises are practically grouped and their amplitudes reduced of 50%.
- with 12 geophones the amplitude of the signal S is reduced of 8% when the amplitude of noises are respectively reduced of 42% for (C), 75% for (B) and 82% for (A).

In conclusion, if 12 geophones and 24 geophones in line give a similar light cancellation of signal, 12 geophones are more effective concerning the noises, mainly (A) which is the most persistent. In this last case the signal/noise ratio is considerably increased.

2-3. SHOT HOLE PATTERN EXPERIMENTS

Some more patterns were compared with the geophone set up previously used on Zone A.

2-3-1. Group F (Pl. 13)

Located on Line OC4 (SP 229).

- Previous parameters: (PT 700 Recording Unit)

3 holes x 20 lb. = 60 lb. depth 55′
Present parameters: (AS 626 Recording Unit)

(I) 8 holes x 20 lb. = 160 lb. depth 135' (end shot)
(II) 8 holes x 20 lb. = 160 lb. depth 130'
(III) 17 holes x 5 lb. = 85 lb. depth 60'

The gain control curve on records (II) and (III) shows that the energy level is consistent and quite comparable along both records. On the common part, traces 1 to 12, the characteristics are identical whereas a visible improvement is observed on traces 13 to 24 of record (III).

(III) > (II)

With regard to the previous Oakes Creek Survey records, the results are similar down to 2 seconds (two way time) and slightly improved below. However, multiple reflections also seem to occur.

2-3-2. Group G (Pl. 14)

Located on Line OC4 between SP 223 and 224.

Previous parameters: (PT 700 Recording Unit)
3 holes x 20 lb. = 60 lb. depth 55'

New parameters: (AS 626 Recording Unit)

(I) 3 holes x 25 lb. = 75 lb. depth 60'
(II) 3 holes x 25 lb. = 75 lb. depth 90'
(III) 21 holes x 5 lb. = 105 lb. depth 90'
The pattern (I) shot at a 60' depth is very noisy with its energy level decreasing rapidly (charge in or at the verge of the weathered zone).

The gain control curve on records (II) and (III) (charge approximately 20' below the water table) shows that the energy level is quite similar and well conserved all along both records. However, a better quality is apparent on record (III), mainly from traces 13 to 24.

\[
(\text{III}) \geq (\text{II}) > (\text{I})
\]

With regard to the Oakes Creek Survey records the existence of a better signal/noise ratio has to be noted.

3. CONCLUSION

Although the responses of the shots are different from one location to another, it can be assumed that the best results are given with patterns shot at 90' depths. The use of a multiple hole pattern at Kelly depth did not bring any improvement.

The parameter "depth" seems very important and for further reflection work in such an area all charges should be put approximately 20' below the water table. The recommended pattern would be:

- 18 holes;
- 80 - 90 lb. charge;
- 20' below the water table in depth with a geophone pattern of 1 or 2 parallel lines of 12 geophones.

However, from the experience of the Oakes Creek and present surveys,
the main difficulties to be expected in the future will be encountered by the drilling (i.e. one and a half days were necessary for the drilling units to complete one 18 hole pattern at a 90' depth).
CHAPTER II

SEISMIC REFRACTION

1. OPERATIONS - FIELD TECHNIQUE

A geophone spread being laid along the traverse, shots were recorded from both in-line directions. One is called direct and the other is the reverse shot. The shooting distances are selected so that energy arrivals from the desired marker be recorded on as many traces as possible. On each successive move, spreads and shot points are shifted along the traverse with the same constant distance in the same direction. This distance is called a base and the length of the base is the stepping distance. It is selected so that with two successive shots from the same direction, energy refracted from the same marker is recorded with a number of common geophones.

2. PRINCIPLES OF THE GARDNER-LAYAT METHOD (Figs. 18a - 18b)

2-1. VERIFICATIONS

A first set of verifications is based upon reciprocal time checks between couples of surface locations occupied by shot points and geophones during direct and reverse shooting:

\[ \text{travel time } SABG = \text{travel time } S'BAG' \] (cf. Fig. 18a)

Next, the difference of travel time to the same geophone locations \( G, H, \ldots \) from different shot points \( S_1, S_2 \) and along the same marker \( M \) must be
REFRACTION Method GARDNER-LAYAT
Method GARDNER - LAYAT

![Diagram of direct and reverse shots with markers and intercept curves]

- Direct Shots
- Reverse Shots

Markers M, M₁, M₂

Ir. G₁, Ir. G₂, Ir. G₃

Direct Relative Intercept Curve
Average Curve
Reverse Relative Intercept Curve
a constant (Fig. 18a).

\[ t(S_2A_2CH) - t(S_1A_1CH) = t(S_2A_2BG) - t(S_1A_1BG) = t(S_2A_2A_1) - t(S_1A_1) \]

In other words: the time-distance curves relative to a given marker are parallel.

2-2. CONSTRUCTION OF RELATIVE INTERCEPT CURVES

What is true for travel times is still true for intercept times: \( I = t - \frac{X}{V} \), where \( X \) is the shot point to geophone distance and \( V \) is the horizontal velocity along the marker. So, by shifting in time, segments of intercept curves obtained from successive shot points, it is possible to get a single continuous intercept curve as if energy refracted from this marker had been recorded all along the traverse from the same shot point. This shifting is made separately for direct shots and reverse shots. The result is two "Relative Intercept curves", each one relative to a definite shot point.

By definition, the intercept time is the sum of the two delay times corresponding to the shot point and the geophone under consideration.

For example, along the wave path \( S_1A_1BG \) (Fig. 18a):

\[ I = t(S_1A_1BG) - \frac{S_1G}{V} = d_{S_1} + d_G \]

So, a relative intercept curve is actually a delay curve on which to each geophone delay value the delay at the origin shot point has been added.
2-3. **CONSTRUCTING THE DELAY CURVE**

An advantage of the method is that it allows computation of intercept curves with a velocity \( V \). Practically, the computation is made using a velocity as close as possible to the assumed true velocity of the marker. The two relative curves so plotted are parallel only when and if the velocity used for the computations is exactly the true velocity of the marker. If not, the curves either converge or diverge and the amount of convergence allows a posteriori determination of the true velocity.

Before being compared for convergence, the relative curves must be shifted towards the shot point. The distance of shift is the "offset". For example, the information obtained in \( G \) from shot point \( S_1 \) and in \( g \) from shot point \( s \) are both relative to the same point \( B \) on the marker. The intercept curve relative to a shot point on the left must be shifted towards the left and the amount of the shift is the offset \( Gb \). The intercept curve relative to a shot point on the right must be shifted a quantity \( gb \) to the right.

With the two relative offset curves in "OFFSET" position, an "Average curve" can be drawn. This curve does not depend on the velocity used for the computation of the intercepts (see next paragraph 3-4). When properly positioned in the time scale, it represents the delay curve of the Marker \( M \), (Calibration).

The formula relating delays to travel times being of the form \( d = 1/2 \ I = \frac{1}{2} \ (t - X/V) \), the delays depend on the velocity of the marker. The time positioning cannot be made without knowledge of this true velocity. This is derived, as indicated below, from the convergence of the relative curves.
3. ANALYSIS OF VARIOUS PHASES OF THE GARDNER-LAYAT METHOD

3-1. DELAY COMPUTING WHEN THE ACTUAL MARKER VELOCITY IS KNOWN (Fig. 18b)

If a shot point S and a geophone G are considered, the intercept is:

\[ I_G = t - \frac{SG}{V} = d_S + d_G \]  

where:
- \( t \) = travel time
- \( V \) = marker M horizontal velocity
- \( d_S \) and \( d_G \) = delay times at points S and G.

If the origin shot point of the relative intercept curve is not S but G, the relative intercept \( I_{rG} \) can be obtained by \( I_{rG} = I_G + C \) (2), C being a constant applied to all intercepts computed with the shot point S. This constant is zero for the origin shot point and then, is calculated for each shot point of the traverse, comparing the intercepts.

Considering the traces G and H recorded from a given shot point:

If \( I_{rG} \) and \( I_{rH} \) are the relative intercepts, applying the formula (1), then:

\[ I_{rH} - I_{rG} = d_H - d_G \]  

and, from (1) and (2):

\[ I_{rG} - C = d_S + d_G \]  

Adding (3) and (4):

\[ I_{rH} - C = d_H + d_S \]

The delays \( d_H \) and \( d_S \) are relative to the same point B of the marker M.
Therefore, the delay to one point B of the marker is the difference between the relative intercept plotted at an offset distance a, and the constant relative to the shot point located on the other side, at the same distance a. The formula (5) has been used for computing all delays plotted on the average curve of the different markers.

3-2. DELAY CORRECTION WHEN THE COMPUTATION VELOCITY IS NOT THE ACTUAL VELOCITY

\[ V = \text{actual marker velocity} \]
\[ V_m = \text{approximate marker velocity}. \]

In this case the computed intercept is:
\[ I = t - \frac{X}{V_m} \]
(6)

Considering the same shot point S and geophone G, it must follow:
\[ d_S + d_G = t - \frac{S}{V} \]

The formula (6) gives:
\[ t = I_G + \frac{S}{V_m}, \quad t = I_{RG} - C + \frac{S}{V_m}, \]

Then:
\[ d_S + d_G = I_{RG} - C - S_G. \quad (1/V - 1/V_m) \] (7)

Applying this formula to the geophones G and H shot from the same shot point the result will be:
\[ d_H - d_G = I_{RH} - I_{RG} - S_H. \quad (1/V - 1/V_m) \] (8)

Adding (7) and (8):
\[ d_S + d_H = I_{RH} - C - S_H (1/V - 1/V_m), \]
but $d_S = d_H = d_B$ and $SH = 2a$:

$$d_B = \frac{1}{2} (I_{rH} - C) - a. (1/V - 1/Vm) \quad (9)$$

Comparing (9) and the above formula (5), it appears that the correction to be applied to delays calculated with $V_m$ instead of $V$ is the expression $a. (1/V - 1/V_m)$. Then, the actual delay curve is but the translated provisory delay curve.

The values chosen for $V_m$ for markers M1 - M'1, M2 and M3 were 6000 m/s, 4500 m/s and 4170 m/s respectively. The corrections $a (\frac{1}{V} - \frac{1}{V_m})$ were applied after determination of the actual marker velocities $V$.

3-3. DETERMINATION OF THE MARKER'S ACTUAL VELOCITY

The formula (8) indicates that the delay curve : points $d_H$, $d_G$, ..., is not parallel to the relative intercept curve : points $I_{rH}$, $I_{rG}$, ....

There is a convergence :

$$(d_H - I_{rH}) - (d_G - I_{rG}) = GH. (1/V - 1/V_m) = K$$

The convergence by unit of length is : $K/L = 1/V - 1/V_m \quad (10)$

The computation of the convergence allows the determination of the actual marker velocity:

$$1/V = K/L + 1/V_m.$$  

Changes of the convergence $K$ indicate changes of the marker velocity $V$. 

as long as the same approximate computation velocity $V_m$ has been used.

3-4. **THE AVERAGE CURVE IS PARALLEL TO THE DELAY CURVE**

It was stated previously that an advantage of the Gardner-Layat method was the determining of intercepts using any velocity $V_m$.

Let us suppose that energy from $M_1$ and $M_2$, points within Marker $M$, has been recorded by geophones $G_1$ and $G_2$ (direct shots), $g_1$ and $g_2$ (reverse shots). Direct shot points are supposed to be on the left side and reverse shot points on the right side: see Fig. 18b.

Distances are considered positive in the direction from shot point towards geophone.

$x_1$, $x_2$, $x_1$, $x_2$, being the abscissae of geophones $G_1$, $G_2$, $g_1$, $g_2$ and $K_d$, $K_r$ the direct and reverse convergence, it follows:

$$K_d = (x_2 - x_1) \cdot (1/V - 1/V_m)$$

$$K_r = (x_1 - x_2) \cdot (1/V - 1/V_m)$$

The couples of geophones are chosen so that $g_1 G_1 = g_2 G_2 = 2a$:

$$x_1 - x_1 = 2a \text{ and } x_2 - x_2 = 2a$$

Then:

$$K_d = -K_r$$
Applying the formula (8) to the couples of geophones $G_1$, $G_2$ and $g_1$, $g_2$:

\[
\begin{align*}
    d_{G_1} - d_{G_2} &= I_{rG_1} - I_{rG_2} - K_d \quad (11) \\
    d_{g1} - d_{g2} &= I_{rg1} - I_{rg2} - K_r \quad (12)
\end{align*}
\]

But $d_{G_1} = d_{g1} = d_{M1}$ and $d_{G_2} = d_{g2} = d_{M2}$ then adding (11) and (12):

\[
2d_{M1} - 2d_{M2} = I_{rG1} + I_{rg1} - I_{rG2} - I_{rg2}
\]

Therefore, when the curve $I = \frac{1}{2}(I_{rG} + I_{rg})$ is drawn, an average curve parallel to the actual delay curve is thus obtained.

Practically, a deviation curve is plotted representing the time interval between the relative intercept curves in marker position. Its slope is double that of the convergence used for the marker's velocity determination. The average curve is then transformed into a delay curve by plotting a limited number of calculated and corrected delay values.

4. **CORRECTIONS**

The datum plane was chosen at sea level.

The elevation correction was carried out on every shot point and every trace with a replacement velocity of 2000 m/s ($\frac{V}{\cos \theta} = 2100$ m/s).

The weathering depth was determined by plotting first breaks on every
weathering record.

All the velocities of the weathering zone were taken into account for the computation of the weathering correction (CWZ).

5. ANALYSIS OF THE RESULTS

5-1. GENERAL - RECORD SAMPLES (LINE RLH1)

- **Marker M1 (Figs. 19 - 20).**

The velocity of this marker is approximately 5700 m/s. The "breaking zone" in reverse (cf. Fig. 20) is characterized by a phenomenon of "beat" (high amplitudes on several traces where the energy arrivals relative to markers M'1 and M1 are interfering). In direct (cf. Fig. 19) a phenomenon of loss of phase occurs in the transition zone and the amplitude then rapidly decreases.

- **Marker M'1 (Figs. 19 - 20 - 21 - 22).**

The velocity of this marker is approximately 6400 m/s. The signal is characterized by a rather low frequency. On the record sample, represented on Fig. 21, its energy arrivals are weak but, however, well conserved all along the record.

- **Marker M2 (Figs. 22 - 23).**

The velocity of this marker is variable from 4500 to 4700 m/s. Its energy arrivals can be easily identified and occasionally followed in late arrivals.
Markers M3 and M'3 (Figs. 22 - 23).

Their velocities are 4100 m/s for marker M3 and 4400 m/s for marker M'3. The character of their signals are quite similar and very often they disappear by phenomenon of loss of phase.
LINE RLH1

5-2. LINE RLH1 (Fig. 24)

This line oriented north-south is composed of 12 bases numbered from 100 to 111.

5-2-1. Statistical Diagram (Pl. 15)

5-2-2. Interpretation Diagram (Pl. 16)

Markers M'1 and M1:

- **Direct**: Their separation is well defined and characterized by a phenomenon of loss of phase (cf. Figs 19 and 25). The deepening towards the north of marker M1 occurs abruptly on base 108 and is well observed on all the records shot on bases 107 - 108.

The energy level of the arrivals relative to marker M1 is more conserved along the records than the one relative to marker M'1 (weak and interfered signal).

- **Reverse**: Their respective arrivals of energy are very difficult to discriminate since from base 103 to base 105 they are characterized by abnormally high amplitudes and large periods. The phenomenon of "beat" appears maximum on bases 103 - 104 and it may correspond there to the transition M'1 - M1 (cf. Figs. 20 - 25). It has to be noted that on the northern end of the line the energy level is very weak and not conserved. Although large charges of explosives were used on this part of the line the refraction signal remained very weak, therefore rendering interpretation...
KEEP RIVER AREA
SCHEMATIC LINE LOCATION RLH1

SCALE: 1/250 000

1967 REFLECTION
1967 REFRACTION
1969 REFRACTION

WA N.T QLD

15°00' 129°00'

129°15'

15°15'

RLH1

KEEP RIVER 1

OC3

OC1

OC4

RLH2

WESTERN AUSTRALIA
NORTHERN TERRITORY

LIMIT OP 162

CAMP

FIG. 24
and timing difficult (cf. Fig. 21).

In conclusion two different markers with close horizontal velocity, are visible on the records: marker M1 on the southern part of the line and M'1 on the northern part. On this last part marker M1 is no longer visible, but replaced by marker M'1, which occurs with a higher horizontal velocity.

**Marker M2**

This marker is accurately followed in first arrival on the northern part of the line but disappears on its southern part (cf. Figs. 26, 27 and 28). On the northern part in direct and reverse its break with marker M3 is often not well defined. Their respective arrivals of energy in this area are very difficult to discriminate on the records as no apparent velocity break or change of signal shape seem to occur.

In conclusion this marker, gradually thins out towards the south and it disappears in the vicinity of base 111 in direct and bases 107 - 108 in reverse. This feature is more defined on the direct than on the reverse records.

**Markers M3 - M'3** (cf. Fig. 29)

This shallow refractor was recorded from a shooting distance of 5 km. onwards. The seismic signal appears weak, heavily interfered and is decreasing very rapidly with distance. Nevertheless, a change, or evolution, of apparent velocity towards the south is clearly visible on the records.

Furthermore, a remarkable loss of phase occurs on bases 103 - 105 in
direct and bases 102 - 103 in reverse, but no definite break or change
of signal shape is visible on these records.

In conclusion, for the exploitation by the Gardner-Layat method, two
denominations, M3 and M'3 were used for the arrivals of energy occurring
north and south of this phenomenon of loss of phase. However, taking into
account the weak energy level and the quality of the records it would be
difficult to ascertain that two different markers are present.

5-2-3. Interpretation Plates:

- Markers M'1 and M1. (Pl. 17)

Two different markers were computed. Their respective velocities as
measured on the convergence curve are 5700 m/s for marker M1 (south
part of line) and 6400 m/s for marker M'1.

3, 120 and 4, 800 metre offset values were used for markers M1 and M'1.
These offsets were graphically determined from the intercept curves.

No major difficulties have been encountered during the exploitation of these
markers, even between bases 109 to 111 in reverse, where the records are
very weak.

A doubtful zone exists on bases 105 - 106 in subsurface position where the
true horizontal velocity relative to markers M1 and M'1 are not well defined.
In fact, a velocity of 6000 m/s is made apparent by the convergence curve
which may correspond to an average of the velocities of M1 and M'1
(phenomenon of "beat" where the arrivals of energy relative to the two
markers interfere). In this area the delay curves of these markers have been extrapolated with the 6000 m/s velocity (reverse intercept curve for marker M1 and direct intercept curve for marker M'1).

It has to be noted that the velocity change in direct and reverse does not occur in the same subsurface position and that, in such a case, a larger offset, approximately 5700 metres should have been necessary. However, this solution was not taken into account since the theoretical offset calculated at the KR No. 1 well is of 3,000 metres.

In conclusion, from the difference of the extrapolated delay values relative to both markers, it can be assumed that marker M'1 is relatively thin on bases 106 - 107 becoming thicker in the vicinity of base 105 towards the north (see sketch below).

- Marker M2: (Pl. 18)

Several exploitations with different offset values were attempted and finally,
an offset distance of 3,120 metres was chosen as being suitable over all of line RLH2. (The theoretical offset calculated at KR No. 1 well is approximately 2,800 metres).

A good comparison of the "gradients" has been assured. A large number of delay values were calculated and the delay curve is reliable.

The scattering on the convergence curve is reasonably good and two velocity changes are made apparent (4690 m/s on the northern part and 4575 m/s on the southern part).

Marker M3 (Pl. 19)

For this shallow marker the offset distance value was considered negligible. The theoretical value at KR No. 1 well, where the refractor is at its deepest, is around 500 metres.

The exploitation of this marker was rendered difficult by a phenomenon of loss of energy and phase often occurring on the records. Consequently the continuity of the exploitation was delicate and sometimes uncertain. However, the comparison between the "gradients", whenever possible, did not show an important drift and the calibration on the delay curve is satisfactory.

Towards the south several velocities (4410 - 4120 - 4070 and 3960) are made apparent on the convergence curve. The most important velocity change (4410 - 4000 m/s) appears on base 103, from this limit the exploitation was effected considering two different markers, called M'3 in the north and M3 in the south. However, it has to be noted that the records in this area are
very weak and no break or change of signal shape seems to occur. It is possible that this change in velocity is due to a change of facies of the same marker M3.

5-2-4. Delay Curves (Pl. 20)

Markers M'1 - M1:
The delay curve of marker M'1 rises towards the south. The rising is steeper on base 102 and a general monocline shape is noticeable to the further extension of the delay curve.

The delay curve of marker M1 also rises towards the south. In the common part, (bases 105 - 106) where both markers have been exploited, their relative delay curves show that marker M'1 thins towards the south and may disappear in the vicinity of base 107. On the end of base 105, towards the north, marker M1 abruptly deepens and could not be recorded further.

Marker M2:
The delay curve of this marker shows a general smooth sub-horizontal configuration where two depressions, located at the end of base 102 and beginning of base 104, are noticeable. An important depression is observed on base 109 but remains doubtful as on this part the delay curve has been extrapolated.

A general convergence occurs between marker M2 and markers M1 - M'1.

Markers M'3 - M3:
The delay curve of marker M'3 gently rises towards the south. The delay
curve of marker M3 forms a general sub-horizontal configuration with a large depression located at bases 105 - 106. At this location an unconformity exists between markers M2 and M3 though elsewhere a general agreement occurs between these two markers.

**Conclusion**

Markers M1 and M'1 have been satisfactorily followed. The deepening of marker M1 becomes too large at base 104 and the fact that its velocity is inferior to the velocity of M'1 rendered impossible the extension of its study further north. On bases 105 - 106 marker M'1 is very thin and may disappear towards the south in the vicinity of base 107.

Marker M2 has been followed from base 101 to base 109 and a general convergence exists with markers M1, M'1 and M2.

Markers M3 - M'3 are generally in agreement except at bases 105 - 106 where an unconformity appears.
5-3. **LINE RLH2 (Fig. 30)**

This line, oriented east-west, is composed of 9 bases numbered from 100 to 108.

5-3-1. **Statistical Diagram (Pl. 21)**

5-3-2. **Interpretation Diagram (Pl. 22)**

- **Marker M1** (cf. Fig. 31)

In direct, an apparent velocity change is observed at bases 103 - 104 with the highest velocity occurring on the western part of the line. In reverse, a very high velocity, approximately 7500 m/s, is observed at base 100. Moreover, this phenomenon of velocity change is generally characterized by a high frequency signal and a weak but constant energy level on the records. Obviously, from bases 100 to 103, an important dip exists on the marker.

A probable fault A affects this marker on base 106/12 in direct and base 104/8 in reverse. Another probable fault B is observed, only in reverse, at base 107/6 since no data are available in direct.

- **Marker M2**

This marker is followed in first arrivals on bases 105 - 106 in direct, bases 102 - 103 in reverse and in second arrivals on base 104 in direct and base 101 in reverse. On the eastern part these latter arrivals were used to extend the study of the marker. However, between bases 104 in direct and 107 in
reverse it seems to have disappeared. This marker is accurately followed and characterized by a good and constant energy level with distance.

- **Marker M3** (cf. Fig. 32)

As observed on line RLH1, the investigation of this marker is rendered difficult by the persistent phenomenon of loss of energy and phase. However, a probable fault C is seen at base 105 on both direct and reverse records (no offset). A characterized loss of energy occurs between bases 103 and 104 in direct, which may indicate the presence of an accident D?

5-3-3. Interpretation Plates

- **Marker M1** (Pl. 23)

The major difficulty encountered here is the choice of a suitable offset, consequently two tentatives were effected with:

**Offset 3, 120 metres.** This offset is similar to the one previously used for the exploitation of line RLH1. It has to be noted that the use of such an offset only ensures a good fit of the direct and reverse intercept curves on the eastern part of the line (velocity - 6400 m/s). Thereafter, towards the west, the curve does not fit very well and a 5650 m/s velocity is made apparent with an important step located at the beginning of base 106. This last step may correspond to the fault A previously observed on the records.

**Offset 5, 760 metres.** This offset was graphically determined and ensures the best fit of the shifted intercept curves all along the line. On the eastern part the 6400 m/s velocity remains the same but a velocity of 6000 m/s now
appears on the western part.

In conclusion, although the delay curve using either offset values shows good similarity, the attempt made with a 3,120 metre offset was adopted, mainly because fault A is located on the same subsurface position on both direct and reverse intercept curves.

- **Marker M2** (Pl. 24)

One offset distance of 3,120 metres was used for the exploitation of this marker and seems suitable since it ensures a good fit of the intercept curve when shifted. A velocity of 4490 m/s is made apparent on the convergence curve. Due to the fact that this marker appears on a limited number of records (bases 102 - 105), four delay values only could be calculated, giving however, a reasonable calibration of the curve. The fault A encountered on marker M1 still exists and is located at the end of base 105.

- **Marker M3** (Pl. 25)

As on line RLH1 no offset was used for the whole line. Good calibration of the delay curve was assured. Two different velocities are made apparent on the convergence curve, 3820 m/s from bases 100 to 101 and 4040 m/s from bases 102 to 106. On the western most part, in direct (bases 105 - 106), the records were too weak and did not permit the continuity to be ensured and the delay curve is extrapolated only from the reverse intercept curve. The probable fault A, encountered on markers M1 and M2, still exists on M3. Considering the delay values obtained on base 106 it can be assumed that marker M3 is outcropping further towards the west.
5-3-4. Delay Curves (Pl. 26)

Marker M1

Two faulted areas A and B are located respectively at the end of base 105 and at base 108/5. An important bend occurs on base 103 where the delay curve indicates a very steep rising towards the east. This rising persists all along the eastern part from base 102 to 100 and it can be assumed that a fault exists at this point with eventually a change of facies of the marker towards the east.

Marker M2

The fault A encountered on marker M1 still exists. The delay curve of this marker forms a slight depression located at base 103/7 with its eastern flank showing a relatively steep rising in agreement with marker M1.

Marker M3

The fault A encountered on markers M1 and M2 still exists at this level. The delay curve shows a gentle smooth configuration where two minimum and a top have to be noted. Base 104/11 and base 102/9 for the minimum and base 104/4 for the high. The marker appears almost outcropping towards both ends of the line.

Conclusion

Markers M1 and M2 have been reasonably well followed. A fault A can be seen affecting either markers M1, M2 and M3. An important flexure, suggesting a fault is visible on base 103 for marker M1. Then, towards
the east, a steep rising persists and an eventual change of facies may occur.

Marker M2 has been followed from base 102 to base 105 and a general agreement exists with marker M1.

The delay curve of marker M3 gives a reasonable idea of the general configuration of a shallow layer.

5-4. GEOLOGICAL IDENTIFICATION OF THE REFRACTION MARKERS

To identify the possible refracting interfaces on line RLH1 in the geological series intersected by the Keep River No. 1 well, two different approaches were used:

- Firstly, a qualitative approach, consisting of the search for agreement between the actual velocity of the marker and measured interval velocities of the series, situated at a reasonable depth, allowing of course for a slight percentage of anisotropy.

- Secondly, by a more quantitative approach, consisting of the comparison between the actual recorded delay times and the theoretical delay times calculated at the Keep River No. 1 well.

At the intersection with Keep River No. 1 well the following refraction markers were recorded:

<table>
<thead>
<tr>
<th>Marker</th>
<th>( V \approx )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker M'1</td>
<td>6400 m/s</td>
</tr>
<tr>
<td>Marker M2</td>
<td>4700 m/s</td>
</tr>
<tr>
<td>Marker M3</td>
<td>4400 m/s</td>
</tr>
</tbody>
</table>
Comparison Delay Time Gardner with Theoretical Delay

(a) **Marker M3:** Results given by Keep River No. 1

- Average velocity: 3330 m/s
- Vertical velocity: 4270 m/s
- Depth: 451 metres
- Horizontal velocity Gardner: 4410 m/s

Theoretical delay time = \[\frac{\text{depth} \times \cos \theta}{\text{average velocity}}\]

\[= \frac{451 \times 0.655}{3330} = 89 \text{ ms.}\]

Recorded delay time = 107 ms.

(b) **Marker M2:** For this marker, as for the deeper marker M'1 the sonic log of Keep River No. 1 well was reduced in a limited succession of layers, having plane and parallel boundaries and yielding a constant velocity, the average of the formation. Doing this the "screening effect" of the TANMURRA formation (high vertical velocity) will be taken into account.

The theoretical delay time associated with this succession overlying the "marker" can be obtained by the relation:

\[D = \sum_{J=1}^{n} Z_J \sqrt{\left( \frac{V_M^2 - V_J^2}{V_J^2} \right)} / V_J V_M\]

Theoretical delay time = 287 ms

Recorded delay time = 271 ms
## DELAY TIMES CROSSINGS

<table>
<thead>
<tr>
<th></th>
<th>RLH 2</th>
<th>RLH 2</th>
<th>OCR 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>RLH 1</td>
<td>d = 51</td>
<td>d = 57</td>
<td>d = 64</td>
</tr>
<tr>
<td></td>
<td>v = 4070</td>
<td>v = 4040</td>
<td>v = 4120</td>
</tr>
<tr>
<td></td>
<td>a = 0</td>
<td>a = 0</td>
<td>a = 0</td>
</tr>
<tr>
<td></td>
<td>v1 = 4000</td>
<td>v1 = 4000</td>
<td>v1 = 4000</td>
</tr>
<tr>
<td></td>
<td>d1 = 51</td>
<td>d1 = 57</td>
<td>d1 = 64</td>
</tr>
<tr>
<td>M3</td>
<td>d = 216</td>
<td>d = 204</td>
<td>d = 274</td>
</tr>
<tr>
<td></td>
<td>v = 4575</td>
<td>v = 4490</td>
<td>v = 4690</td>
</tr>
<tr>
<td></td>
<td>a = 3120</td>
<td>a = 3120</td>
<td>a = 3120</td>
</tr>
<tr>
<td></td>
<td>v1 = 4500</td>
<td>v1 = 4500</td>
<td>v1 = 4500</td>
</tr>
<tr>
<td></td>
<td>d1 = 216 - 11 / 205 = 204 + 2 / 206</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RLH 1</td>
<td>d = 245</td>
<td>d = 274</td>
<td>d = 245</td>
</tr>
<tr>
<td>M2</td>
<td>v = 4690</td>
<td>v = 4550</td>
<td>v = 4550</td>
</tr>
<tr>
<td></td>
<td>a = 1440</td>
<td>a = 1440</td>
<td>a = 1440</td>
</tr>
<tr>
<td></td>
<td>v1 = 4500</td>
<td>v1 = 4500</td>
<td>v1 = 4500</td>
</tr>
<tr>
<td></td>
<td>d1 = 245 - 2 / 24 8 = 243</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RLH 1</td>
<td>d = 4575</td>
<td>d = 443</td>
<td>d = 4575</td>
</tr>
<tr>
<td>M1</td>
<td>v = 4500</td>
<td>v = 4500</td>
<td>v = 4500</td>
</tr>
<tr>
<td></td>
<td>a = 3120</td>
<td>a = 3120</td>
<td>a = 3120</td>
</tr>
<tr>
<td></td>
<td>v1 = 6000</td>
<td>v1 = 6000</td>
<td>v1 = 6000</td>
</tr>
<tr>
<td></td>
<td>d1 = 471 + 27 / 498 = 504</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RLH 1</td>
<td>d = 64</td>
<td>d = 601</td>
<td>d = 601</td>
</tr>
<tr>
<td>M1 1</td>
<td>v = 6050</td>
<td>v = 6050</td>
<td>v = 6050</td>
</tr>
<tr>
<td></td>
<td>a = 4600</td>
<td>a = 4600</td>
<td>a = 4600</td>
</tr>
<tr>
<td></td>
<td>v1 = 6400</td>
<td>v1 = 6400</td>
<td>v1 = 6400</td>
</tr>
<tr>
<td></td>
<td>d1 = 677</td>
<td>d1 = 677</td>
<td>d1 = 677</td>
</tr>
<tr>
<td></td>
<td>d1 = 601 + 56 / 657</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND:**
- $d =$ delay times
- $v =$ real velocity
- $a =$ offset
- $v_1 =$ adopted fictitious velocity, $d_1 = \frac{a g d}{l}$
(c) Marker M'1

Theoretical delay time = 728 ms

Recorded delay time = 725 ms

Results

From the above, it appears that the velocity of the markers and delay values are in good accordance.

<table>
<thead>
<tr>
<th>Marker</th>
<th>Velocity (m/s)</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>M'1</td>
<td>6400</td>
<td>NINGBING LIMESTONE (Devonian)</td>
</tr>
<tr>
<td>M2</td>
<td>4500 - 4700</td>
<td>MILLIGAN BEDS IV (Lower Carboniferous)</td>
</tr>
<tr>
<td>M3</td>
<td>4400</td>
<td>TANMURRA FORMATION (Lower Carboniferous)</td>
</tr>
</tbody>
</table>

Concerning the other marker called M1 encountered on line RLH1 south of Keep River No. 1 well and exploited by Gardner-Layat method, it can now be assumed to correspond to the BASEMENT (Proterozoic).

It has to be noted that its velocity is lower than that of marker M'1 (NINGBING LIMESTONE).

<table>
<thead>
<tr>
<th>Marker</th>
<th>Velocity (m/s)</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>5700</td>
<td>BASEMENT (Proterozoic).</td>
</tr>
</tbody>
</table>

5-5. TENTATIVE DELAY TIME CONTOUR MAP (cf. Pl. 27)

The two markers M'1 (NINGBING LIMESTONE) and M1 (BASEMENT - Proterozoic) were mapped. In order to have homogeneous time values,
the same constant velocity of 6000 m/s was used for these two markers.

The delay time contours are drawn every 10 ms and indicated every 50 ms. Data obtained from previous line OCR-1 (Oakes Creek Seismic Survey) were included in this tentative interpretation.

The zone of transition between markers M'1 and M1, located slightly north of Line RLH2, appears to extend towards the northeast on Line OCR-1 where fault f has been observed. This fault, the direction of which is north - south is also suggested by the Gravity results.

On the southern part marker M1, which is probably the basement, features the approximate edge of the basin.

On the northern part marker M'1 presents a gentle northwest dip towards the Timor Sea.
CHAPTER III

WIDE ANGLE SHOOTING TEST

1. METHOD

In some areas the wide angle shooting may provide a convenient and often economical method for subsurface mapping.

Field Procedure

The shot points and geophone spreads are laid out along parallel lines.

The distance between each line of shots and the geophone line is chosen so that it will be the same as the double offset distance or slightly greater. In this way the sought for refracted event will be received as a late arrival.

When this spacing is used, the refracting point associated with the shot will be very close to that associated with the detector and each delay time will be approximately half the intercept time. A single depth point (based on half the intercept time) is then plotted midway between shot and receiver. All depth points are thus placed along the "control line" which is located half way between the shooting and the receiving lines.

A longitudinal spread is added occasionally to permit the identification of the marker.

2. TEST (Fig. 34)

2-1. LOCATION
This test was located on bases 105 - 106 of Line RLH2 since wide angle reflected signals were identified in this area (cf. Fig. 35).

On the refraction record 105 - 106 shot from 107/12 these wide angle arrivals are very well characterized and appear approximately within a shooting distance of 3,800 and 6,000 metres. Consequently a 6,000 metre double offset shooting distance was used for the wide angle test.

2-2. **RESULTS** (Figs. 36 - 37)

2-2-1. Comparison of the Depth Given by Wide Angle Slant Time with Recorded Delay Time at the same Depth Point (Base 106 between Traces 11 and 12).

Average vertical velocity \( (V_a) = 3990 \text{ m/s} \) (Keep River No. 1).

- **Wide Angle**:

![Diagram of wide angle test setup](attachment:image.png)
Single slant time \( (T) = \frac{1991}{2} = 996 \text{ ms} \).

Depth \( (D) = \sqrt{\frac{V_a}{T^2} - \frac{x^2}{4}} = \sqrt{\frac{3990^2}{x} \times 0.996^2 - \frac{6000^2}{4}} \approx 2,610 \text{ metres} \)

- **Refraction:**

Recorded delay time = 464 ms.

Depth = \( \frac{V_a \times \text{delay time}}{\cos \theta} \) with \( \sin \theta = \frac{3990}{6000} = 0.666 \)

and \( \cos \theta = 0.747 \)

\( \frac{3990 \times 0.464}{0.747} \approx 2,480 \text{ metres} \)

2-2-2. **Comparison of the Depth Given by Wide Angle Slant Time with Recorded Delay Time at the same Depth Point (Base 104, between traces 10 and 11).**

- **Wide angle:**

Single slant time \( (T) = \frac{2088}{2} = 1,044 \text{ ms} \).

\( \text{depth} \approx 2,880 \text{ metres} \).

- **Refraction:**

Recorded delay time = 504 ms.

\( \text{depth} \approx 2,700 \text{ metres} \).

From the above, it appears quite obvious that the results given by the wide
angle test are in total accordance with the refraction exploitation. Consequently the same marker has been followed by both methods.

Obviously the dip towards the east is also confirmed by both methods and is in accordance with the apparent velocities obtained on the longitudinal records. (7050 m/s in reverse and 4900 m/s in direct).

3. CONCLUSION

The wide angle technique seems to give acceptable results in this area and may be recommended for aerial mapping if the reflection method failed to give any reliable data.

However, it has to be understood that the presence of important dips in this area would necessitate a sophisticated field procedure (variable distance of shooting) as well as complicate the interpretation.
CHAPTER IV

GRAVITY

1. GENERAL

Gravity observations were tied to the previous gravity bases of OAKES CREEK SEISMIC AND GRAVITY SURVEY. The Worden No. 437 gravity meter was used for the survey. The calibration of the instrument is shown on Figs. 38 and 39.

The maximum loop misclosure was 0.09 mgal. Some repeated readings effected on the field give a quadratic mean of ± 0.05 mgal.

Nevertheless, when tracing the Bouguer Anomaly map a constant difference appeared with the values of the former survey. The difference resulted from the change of projection system where the central meridians are different:

- Australian Transverse Mercator Clarke 1858 Spheroid for the OAKES CREEK SEISMIC AND GRAVITY SURVEY
- Universal Transverse Mercator Australian National Spheroid for the present survey.

All the Oakes Creek values had to be corrected by +0.37 mgal in order to be transferred on the new projection.

2. RESULTS (cf. Pl. 28)

The overall features of the present map are the same as those obtained during the OAKES CREEK survey. The Bouguer Anomaly values pro-
GRAVITY METER CALIBRATION

WORDEN · PIONEER Nº 437

BRISBANE UNIVERSITY

MOUNT COOTHA

Calibration coefficient = 58.26 = 0.9025

54.55
GRAVITY METER CALIBRATION

WORDEN PIONEER No 437

November 5th 1969

BRISBANE UNIVERSITY

0400

MOUNT COOT-THA

15 PM

16 PM

%G = 0.0108

A = 6650

AG = 5824

K = 0.9035
gressively decrease towards the north. A long negative axis, approximately oriented north-south, appears east of the Keep river. A second trend, oriented east-west, extends slightly north of Line OC1.
KULSHILL AREA

(PROVIDENCE HILL PROSPECT)

(TREE POINT PROSPECT)
CHAPTER I

TESTS

1. NOISE ANALYSIS

This experiment is located on reflection Line PH2 between SP 17 and 22 (cf. Fig. 40).

Field Procedure

- Recording from 200 to 1,350 metres.
- 5 bases of 24 traces with 10 metres between traces.
- 12 bunched geophones per trace.
- 1 tie trace (trace 24 = trace 1).

All shots were effected using 20’ depth holes with the following charges:

<table>
<thead>
<tr>
<th>Base</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base I</td>
<td>2 lb.</td>
</tr>
<tr>
<td>Bases II and III</td>
<td>4 lb.</td>
</tr>
<tr>
<td>Base IV</td>
<td>20 lb.</td>
</tr>
<tr>
<td>Base V</td>
<td>30 lb.</td>
</tr>
</tbody>
</table>

Setting of the AS 626 recorder:

- Filters: 14 - 160
- Common gain "sill": 1.0
- Initial gain:
  - Bases I and II: -45 dB
  - Bases III and IV: -40 dB
  - Base V: -35 dB
- Individual gain: Nil,
PROVIDENCE HILL AND TREE POINT AREA TEST LOCATION MAP

SCALE: 1/50,000

PROVIDENCE HILL
Results (Pl. 29)

The records displayed on Plate 29 show two groups of noise:

Noise A: powerful on bases I and II; disappears on base IV.

Noise B: important on base II; disappears at the end of base III.

Exploitation Diagram (Pl. 30)

Characteristics of the noises and reflected signal:

Noise A:
- Velocity: 500 to 650 m/s
- Wave length $\lambda$: 25 to 37 metres
- Frequency $f$: 17 to 22 c/sec.
- Frequency $K$: 25 to 40 c/sec/metre.

Noise B:
- Velocity: 900 to 1,600 m/s.
- Wave length $\lambda$: 35 to 65 metres.
- Frequency $f$: 21 to 33 c/sec.
- Frequency $K$: 15 to 29 c/sec/metre.

Signal S:
- Velocity: 2,900 m/s
- Wave length $\lambda$: 132 metres
- Frequency $f$: 22 c/sec.
- Frequency $K$: 8 c/sec/metre.
Choice of Geophone Pattern

The Smith's formulae give the following results:

\[ \lambda_s = \frac{V_s}{\beta H} = \frac{2900 \text{ m/s}}{40 \text{ c/sec}} = 73 \text{ metres.} \]

\[ Nh = 0.45 \lambda_s = 0.45 \times 73 \text{ m} = 33 \text{ metres.} \]

Use of Cancellation Curves (Fig. 41)

\[ \frac{e}{\lambda} \text{ Tabulation} \]

<table>
<thead>
<tr>
<th>n</th>
<th>Noises</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>6</td>
<td>0.264 - 0.178</td>
<td>0.189 - 0.101</td>
</tr>
<tr>
<td>12</td>
<td>0.120 - 0.081</td>
<td>0.086 - 0.046</td>
</tr>
<tr>
<td>24</td>
<td>0.060 - 0.040</td>
<td>0.043 - 0.023</td>
</tr>
</tbody>
</table>

Noises A and B and signal S have been plotted in abscissa with the following tabulated values of \( \frac{e}{\lambda} \):

- 1.92 m with \( n = 24 \) geophones
- 4 m with \( n = 12 \) geophones
- 8.80 m with \( n = 6 \) geophones.

The resulting cancellation ratios can be read in ordinate.

Since the pattern used was 24 geophones in line with 5 metres between
$A = \frac{\sin \frac{n \pi e}{\lambda}}{n \sin \frac{\pi e}{\lambda}}$

$n =$ number of geophones in line
$e =$ spacing between geophones

$100\%$

$50\%$
geophones, the effective filtering can be summarized as follows:

\[
\frac{5}{\lambda} \quad \text{Tabulation}
\]

<table>
<thead>
<tr>
<th>n</th>
<th>Noises</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>0.200 - 0.135</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>0.143 - 0.077</td>
<td></td>
</tr>
</tbody>
</table>

The plot of these different values on the cancellation curve \( n = 24 \) shows that the amplitude of signal \( S \) is attenuated of approximately 8 dB, while the amplitudes of noises \( A \) and \( B \) are reduced of 20 dB and 18 dB. These theoretical calculations put the emphasis upon the drastic and harmful effect of the noise encountered in this area.

**Choice of the Shooting Distance**

On the diagram, the first organized signal which may represent a seismic event (reflection) appears at the end of Base I (approximate distance 430 m) and at a depth of 600 - 700 ms (two way time). On the other hand the noise is well identified and can be troublesome within 0 to 450 metres.

The best way to cancel the noise should have been to shoot with a 450 m offset so that only the reflected signal should have been recorded.

Unfortunately, the remotum distance becomes very important (1,830 metres) and on a certain number of traces the reflected signal will interfere with refracted arrivals. Such arrivals can already be seen on base V very
close to the reflection event (Horizon 2 culminates at 350 ms).

An intermediary solution was adopted with the centre of the shot pattern located at 130 metres from the line and projected between traces 4 and 5 or 20 and 21 of each spread.

The following sketch shows the noisy area depending upon the shot point location.

![Noisy Area Sketch]

2. **SHOT HOLE PATTERN EXPERIMENTS** (Pl. 31)

Located on Line PH2 (SP 13) three different patterns were compared with the following parameters.

(I) 30 holes x 4 lb. = 120 lb depth 15'

(II) 59 holes x 2 lb. = 118 lb (4/ lines) depth 15'

(III) 60 holes x 2 lb. = 120 lb (3/lines) depth 15'
Results obtained on record (II) are rather noisy with rapid loss of energy. Records (I) and (III) are quite similar (same aspect and relatively good conservation of the energy level). However, some organized energy arrivals are seen on record (III) at approximately 2, 3 seconds which cannot be noticed on record (I).

\[
\begin{array}{ccc}
\text{(III)} & > & \text{(I)} & > & \text{(II)}
\end{array}
\]

3. **RESHOOTING OF A PREVIOUSLY RECORDED SHOT POINT**

This shot was effected on Line K33 (SP 753 - Kulshill Seismic and Gravity Survey) with an identical spread in order to check the recording instrument and the pattern; results were similar.

4. **CONCLUSION**

For the reflection exploitation on Kulshill area the following parameters were adopted.

- **Geophone pattern**: 48 geophones in 2 parallel lines of 24 with 20 m. between lines and 5 m. between geophones.

- **Shot point pattern**: 3 lines of 13 or 20 holes with 20 m. between lines and 10 or 20 m. between holes.

The centre of the shot pattern was 130 metres from the line and projected between traces 4 and 5 or 20 and 21.
CHAPTER II

SEISMIC REFLECTION

1. CORRECTIONS

Datum:

All readings are reduced to a sea level datum, using a 2000 m/s velocity.

Static

The corrections were computed using WZ shots every 3 shot points (720 metres). The velocities adopted for WZ corrections were 500 m/s and 1200 m/s.

Between the WZ measurements the correction at each trace has been determined by the "Methode des indicatrices" when possible and by "Altimetry" when the reflection events were too poor to be picked.

Dynamic

Initially, the velocities given by the Kulshill No. 1 well were used for NMO corrections. This velocity law was suitable for the Providence Hill area (cf. Velocity analysis, Pl. 32 - 33), but appeared unsuitable for the Tree Point area. During the processing GSI carried out additional velocity analyses on line TP1 (Pl. 34) and the new function was applied to the Tree Point sections (TP1 - TP2). The respective velocity laws used are shown on the label of the sections.
2. PROCESSING

The processing was carried out by the GSI processing centre in Sydney (Australia). The field analog records were digitalized before processing.

Display "Wiggle + variable area".

Scales: distance: 1/14400
        time: 100 ms = 19.1 ms
Homogeneous velocity: 2750 m/s

A filter analysis was carried out on line PH1 during the processing (Pl. 35) to determine the filtering to apply to the final three-fold stacked section. The band pass digital filter chosen was 15 to 47 Hz.

In order to harmonize the static corrections before final display a "3-fold common depth point gather" has been done for each line (manual statics).

Digital Processing Sequence (Sample rate 4ms.)

- Analog to digital transcription
- Normal move out
- Trace equalization
- Static corrections
- 3-fold common depth point gather
- 3-fold common depth point stack
- 3-fold common depth point mix
- Final display.
3. **CROSS SECTIONS**

The variable area cross sections are included in this report (Pls. 36 to 39 for the Providence Hill prospect and Pls. 43 - 44 for the Tree Point prospect) and show the horizons picked.

3-1. **PROVIDENCE HILL PROSPECT**

With regard to the previous data obtained in this area the present results show an important improvement of quality. The results are good on lines PH1 - PH4 and range from good - fair - poor on lines PH2 and PH3, depending upon the horizon taken into consideration.

- **Horizon "2"** which is the same as Horizon "2" of the previous Kulshill and Pearce-Point surveys. Its character is quite constant on all lines but correlation remains rather difficult on Line PH2 across the faulted area.

- **Horizon "4"** is the same as Horizon "4" picked and mapped on the previous Moyle River survey. Its picking on the present section is based on good to fair reflections on Lines PH1 and PH4 and fair to poor reflections on Lines PH2 and PH3. As mentioned for Horizon "2" correlation across the faulted area, mainly on Lines PH2 and PH3, remains questionable.

- **Horizon "3"** is the same as A. A. P.'s Horizon "B" (cf. supplement to the C. G. G. Moyle River final report - July 1967).

Its picking is based on good reflections on Line PH1, fair reflections on
Line PH4 and generally poor and questionable reflections on Lines PH2 and PH3.

3-2. **TREE POINT PROSPECT**

As observed for Providence Hill prospect the quality of the data is generally better than that obtained on the previous survey (MOYLE RIVER SEISMIC SURVEY).

The present results are good for Horizon "2" and fair for Horizon "4" on both Lines TP1 and TP2.

Two horizons were picked on this area:

Horizon "2" and Horizon "4", which are the same as Horizons "2" and "4" of the previous surveys.

Although this data are of rather good quality the picking was sometimes rendered difficult by several frequency changes and loss of phase.

4. **IDENTIFICATION OF HORIZONS**

4-1. **PROVIDENCE HILL PROSPECT**

The identification of the horizons was effected with the lines intersected by the Kulshill No. 1 and Kulshill No. 2 wells. The calibration is given by the following tabulation:
Port Keat - Moyle River Area

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Place of Datation</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGG</td>
<td>AAP</td>
<td></td>
</tr>
<tr>
<td>2 A</td>
<td>Kulshill No. 1 and Kulshill No. 2</td>
<td>TOP MICROCONGLOMERATIC SHALE MEMBER, LOWER PERMIAN</td>
</tr>
<tr>
<td>3 B</td>
<td>Kulshill No. 1 and Kulshill No. 2</td>
<td>BASE UNNAMED BEDS FORMATIONS (BASE LOWER PERMIAN - TOP LOWER CARBONIFEROUS)</td>
</tr>
<tr>
<td>4 C</td>
<td>Kulshill No. 1</td>
<td>CALCAREOUS SANDSTONES UPPER VISEAN/MIDDLE VISEAN</td>
</tr>
</tbody>
</table>

4-2. TREE POINT PROSPECT

The two horizons may reasonably correspond to Horizons "2" and "4" picked and mapped for the Providence Hill prospect, but since a poor to nil results area (F7) exists between the two prospects, their correlation remains questionable.

5. CONTOUR MAPS

Horizons "2", "3" and "4" (Providence Hill prospect) and Horizons "2" and "4" (Tree Point prospect) were mapped. Data obtained from previous traverses were included in this interpretation. Additional data of the present survey permitted a 10 ms (one way time) contour interval to be used for contouring these maps. As expected, the general features of
the maps established from the previous survey remain unchanged.

5-1. PROVIDENCE HILL PROSPECT

5-1-1: Horizon "2" (Pl. 40)

A major faulting system (F2 - f2 - f'2) crosses the surveyed area in a northeast - southwest direction. Fault F2 is well seen on Line PH2 and disturbs a large area on the section (SP 15 to 21). Southwards, two faults f2 and f'2 seem to be diverging from F2 before crossing Line K15. Where the seismic results are disturbed (SP 302 to 305) the data on the section are of very poor quality but still definable. Another fault F8? may exist, crossing Lines K33 and PH3. The actual location of this fault, where Line PH3 crosses a swamp, is questionable on the section. Off-end shooting was necessary but the obtained results are disappointing.

In short, it appears that the main fault F2 with the subsidiary faults f2, f'2 and f8? divide the survey area into four compartments. The correlation across f8? is easy but remains doubtful between faults f2 and f'2.

The major feature of the map is a structure which seems to be closed, in all directions, and affected by a system of radiating faults.

Previously, this structure was outlined but from the present additional results it appears that two culminations can be noted:

- culmination A at 330 ms located beside fault F3 in the vicinity of the crossing of Line PH2 with Line PH3.
- culmination B at approximately 400 ms or less south of
fault F2.

East of F2 a depression C extends, separating the PROVIDENCE HILL structure from the KULSHILL structure.

5-1-2. **Horizon "3"** (Pl. 41)

This map shows the same overall features as that of Horizon 2 with, however, increased faulting. South of the main fault F2, a new radiating fault F'2 may exist. On the other hand, no data are available between faults f'2 and f2 and an attempt of correlation between these faults indicates an highly complicated area. Structurally, the culminations A and B, as well as the depression C, still exist at this level.

5-1-3. **Horizon "4"** (Pl. 42)

Here again, the overall features are quite comparable. Culminations A and B still exist respectively at 1000 ms and 990 ms. The faulting system is similar to the one encountered for Horizon "3" and correlation between faults f2 and f'2 is still not possible. South of F2 the quality of the data is very poor and no contours were drawn across the loop K13 - K17 and PP7.

5-2. **TREE POINT PROSPECT**

5-2-1. **Horizon "2"** (Pl. 45)

The map mainly shows a regular dip from fault F6 towards the west, except near the line crossing of SM2 - TP1 where a minor culmination appears structurally as high, if not higher, than the border of fault F6. A slight
syncline axis exists along the western part of Line K24.

5-2-2. **Horizon "4"** (Pl. 46)

Starting from the border of fault F6 this map shows mainly a regular dip towards the west. A fault has been correlated crossing Lines TP1 and TP2 and seems to disappear before reaching Line K19.

A depression which seems to take shape on the western end of Line TP1 has to be noted. A doubtful culmination appears between the northern parts of Lines SM4 and K19.

A general unconformity exists between Horizons "2" and "4" (different dip).
CONCLUSION

During this survey, more information was added to the results of the OAKES CREEK survey (Refraction - KEEP RIVER AREA) and MOYLE RIVER SURVEY (Reflection - KULSHILL AREA).

On the KEEP RIVER area, an approximate delineation of markers M'1 (NINGBING LIMESTONE), M1 (BASEMENT - PROTEROZOIC) and M2 (MILLIGAN BEDS IV) was achieved. The zone of transition between M1 and M'1 being approximately located on the beginning of base 107 (Line RLH1).

On the KULSHILL area, a better delineation has been obtained on the PROVIDENCE HILL structure during the survey. This structure seems to be closed, in all directions, and affected by a system of radiating faults. Two culminations have been made apparent:

- Culmination A, located near the crossing of Lines PH2 with PH3.

- Culmination B, located south of fault F2.

On the TREE POINT prospect, the additional seismic work did not confirm the structural closure of the higher anomaly previously delineated.

Several reflection tests (noise analysis - shot hole patterns - wide angle shooting) were carried out on the KEEP RIVER area and their results can be summarized as follows:
- Recommended shot pattern: 18 holes, 80 - 90 lb. charge, depth 20' below the water table.

- Recommended geophone pattern: 1 or 2 lines of 12 geophones with 5 metres between geophones.

- Wide angle shooting: this method seems to give acceptable results in this area and may be recommended for aerial mapping if the reflection method failed to give any reliable data.

Respectfully submitted,

Party Chief
C. ROYANT

J-M. CUNIN
Australian Branch Manager.
# LIST OF PERMANENT MARKERS 1969

**ATM COORDINATES**

(KULSHILL AREA)

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### Previous Permanent Markers Used During the Survey

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### List of Permanent Markers 1969

**UTM Coordinates**

(keep river area)

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continued:
### Previous Permanent Markers Used During the Survey

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II. REFLECTION TESTS - KEEP RIVER AREA

Plate 8 Records Group A
Plate 9 Records Group B
Plate 10 Records Group C
Plate 11 Noise Test: Records
Plate 12 Noise Test: Interpretation Diagram
Plate 13 Records Group F
Plate 14 Records Group G

III. REFRACTION - KEEP RIVER AREA

Plate 15 Line RLH1 - Statistical Diagram
Plate 16 - Interpretation Diagram
Plate 17 - Interpretation Plate Markers M'1 - M1
Plate 18 - Interpretation Plate Marker M2
Plate 19 - Interpretation Plate Markers M'3 - M3
Plate 20 - Delay Plate
Plate 21 Line RLH2 - Statistical Diagram
Plate 22 - Interpretation Diagram
Plate 23 - Interpretation Plate Marker M1
Plate 24 - Interpretation Plate Marker M2
Plate 25 - Interpretation Plate Marker M3
Plate 26 - Delay Plate
Plate 27 Contour Map Markers M'1 - M1

IV. GRAVITY - KEEP RIVER AREA

Plate 28 Bouguer Anomaly Map
Plate 28B Gravity Base Network