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GEOPHYSICAL REPORT

LEGUNE SEISMIC & GRAVITY SURVEY

NORTHERN TERRITORY, AUSTRALIA

P.R. 64/15

for

AUSTRALIAN AQUITAINE PETROLEUM PTY. LTD.

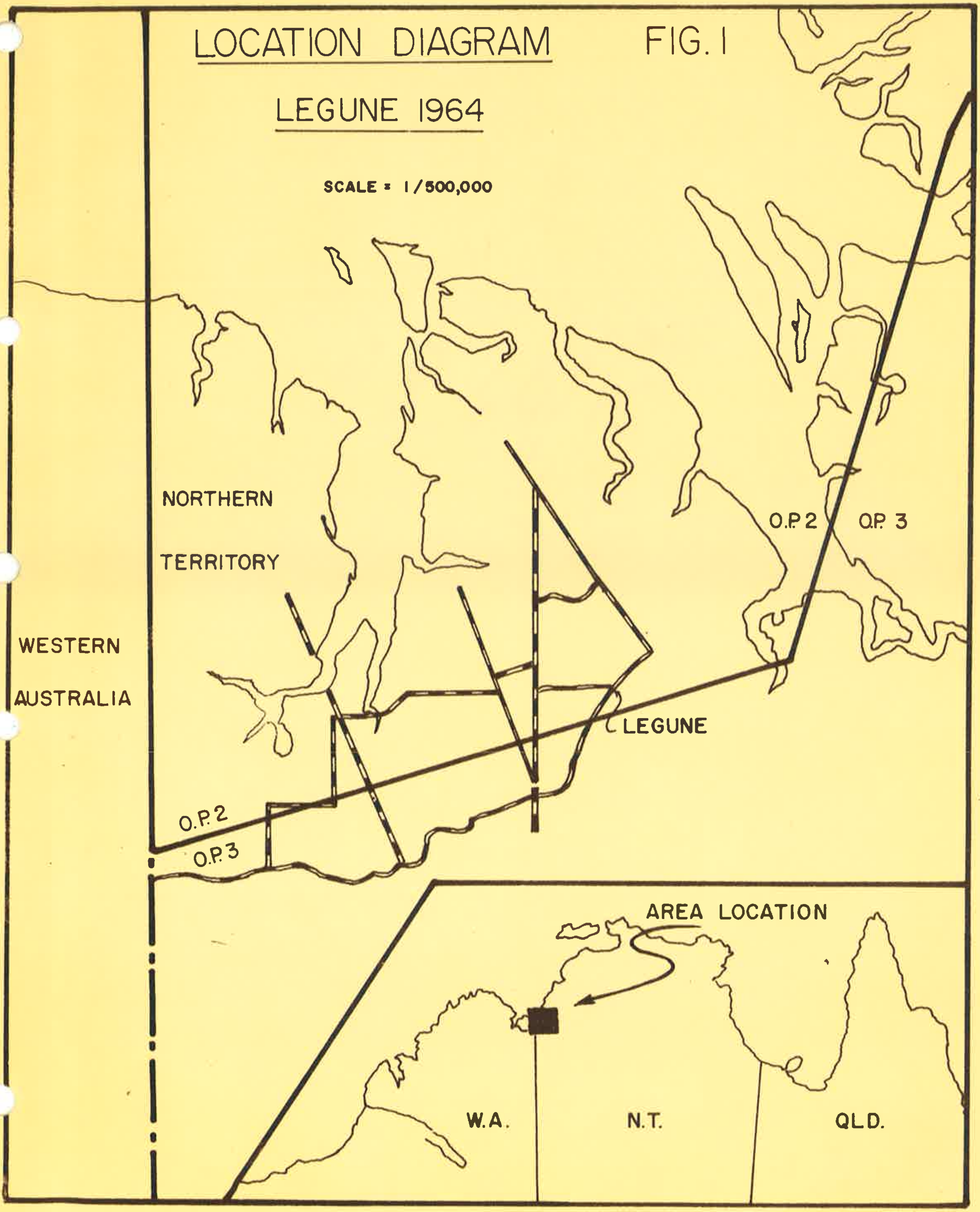
Brisbane, Queensland

by

Petty Geophysical Engineering Company

San Antonio, Texas

U.S.A.



LOCATION DIAGRAM
FIG. 1
LEGUNE 1964
SCALE = 1/500,000
NORTHERN
TERRITORY
WESTERN
AUSTRALIA
O.P. 2
O.P. 3
O.P. 2
O.P. 3
LEGUNE
AREA LOCATION
W.A.
N.T.
QLD.

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SUMMARY:

A seismic and gravity reconnaissance survey was conducted by Petty Geophysical Engineering Company, Party 30A, for the account of Australian Aquitaine Petroleum Pty. Ltd. in the Keep River Area of the Northern Territory of Australia, in permit number O.P. 2.

The prospect and subsidy name is "LEGUNE SEISMIC AND GRAVITY SURVEY". The subsidy number is 64-4541.

Reflection and refraction work was done covering eighteen (18) miles of refraction line and 38.28 miles of reflection line. Eleven and one third (11-1/3) miles of the refraction was shot on reflection lines.

The gravity line network covers 141 miles and readings were taken along all refraction and reflection lines with the exception of 4.67 miles along Line 10 north of the Keep River.

After the former seismic survey, it was thought that a deep basin extended below the Legune Area, separated from the Proterozoic outcrops by a major fault with a northwestern downthrow. It was thought that the high velocity marker followed by refraction represented the Burt Range limestones. However, after the present survey, a thin sedimentary section of this nature was interpreted with thickening to the north towards the Bonaparte Gulf.

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INTRODUCTION:

An agreement for the performance of seismic and gravity work was established between Australian Aquitaine Petroleum Pty. Ltd. and Petty Geophysical Engineering Company to conduct seismic and gravity work in petroleum concession area O.P.2.

Twenty-three (23) men formed the total number of personnel on the field crew not including tractor personnel.

The estimated date of the beginning of the work was July 15, 1964, but actual drilling did not start until July 23, 1964, and shooting on July 24, 1964.

The duration of the work was from July 23, 1964 through September 26, 1964, for the reflection and refraction survey. The last gravity meter reading was taken on October 14, 1964.

Crew operations started under the direction of John Schuyler Thompson as Party Chief. Walter O. Weber replaced him as of August 10, 1964.

Petty's field supervisor was Mr. E. Bartel.

CHAPTER I

GEOLOGICAL AND GEOPHYSICAL DATA

1. Geological Data

Mud flats and Cainozoic sediments predominantly cover the Keep River Area. Some lower Permian outcrops have been found in the Keep Inlet. The thickness of the Permian sediments is not known.

In the southeastern part of the Keep River, some Carboniferous sediments outcrop in isolated hills along the Eastern Bonaparte Gulf Basin Margin. These are comparable to those exposed in the southern part of the basin, where a thick Paleozoic section exists, limited on the east by a major fault system.

The section in the southern part of the Bonaparte Basin is as follows:

AGE	LITHOLOGY	THICKNESS
Permian	Sandstones, shales and limestones Regional unconformity	1,500 feet
Upper Carboniferous	Conglomerates, sandstones Regional unconformity	2,700 feet
Lower Carboniferous	Sandstones, limestones, siltstones Regional unconformity (Intra-Visean)	2,700 feet
	Shales, limestones, sandstones, siltstones	4,500 feet
Upper Devonian	Sandstones, limestones Unconformity-transgression	6,000 feet
Cambrian-Lower Ordovician	Sandstones and limestones, shales, sandstones Unconformity	0'-4/5,000 feet
Cambrian (?)	Basalts, volcanic agglomerates, tuffs	80'-3,000 feet

AGE	LITHOLOGY	THICKNESS
Upper Proterozoic	Sandstones, shales, dolomite Unconformity	12,000 feet
Lower Proterozoic	Metamorphic complex - granite	Basement

2. Geophysical Data

2.1. Gravity

Some gravity lines were surveyed by a Minad crew in 1955 and 1957, and a B.M.R. crew in 1956. The results of these surveys show the Keep River Area as a gravity low which indicates the possible presence of a sedimentary basin.

The Keep River low is separated from the Port Keats low by the Queen's Channel high. The intention of the Legune Gravity Survey is to establish if the Keep River low and the Port Keats low are two separate basins.

2.2 Seismic

In 1962, seismic reflection and refraction work was carried out by G.S.I. under the supervision of Minad, for Associated Australian Oilfields.

The survey showed that fair reflection quality was obtained in the southern part of the permit, but in spite of some experiments, only very poor records were obtained in the northern part of the area. Due to the impossibility of obtaining reliable reflection results, the G.S.I. crew changed to refraction work and followed a marker with a velocity of 18,500 feet per second, which was tentatively considered as Devonian.

The main structural feature drawn from the survey was general sedimentary dip to the northwest, with a rapid thickening of the sedimentary section.

CHAPTER II

OBJECTIVES AND PROGRAMME

1. Objectives

1.1 To carry out seismic reflection experiments in order to determine an adequate technique yielding data suitable for structural investigation.

1.2 To apply the seismic method in order to obtain structural information regarding the general attitude of the sediments, especially in the northern part of the area.

1.3. To check if gravity data is directly related to the structural shape of the basin.

1.4 Eventually to locate a suitable drilling site.

2. Programme

2.1 The programme planned to meet the objectives stated, made use of the seismic reflection and refraction methods as well as the gravity technique. Reflection work consisted of three (3) traverses oriented NNW-SSE perpendicular to the eastern border of the basin.

A gravity station was located at each shotpoint and an additional gravity line network was set up.

2.2 Shortly after the commencement of the survey, while working on the southern end of traverse L8 (located on the Proterozoic outcrop), it appeared that the velocity of the marker given by the first breaks of the reflection records was the same velocity as that recorded by refraction during the former campaign. This was attributed to a formation younger than the Burt Range. This observation, if confirmed, meant that the sedimentary section over the area was very thin. Therefore, it was necessary to prove that the Proterozoic marker recorded on the southern end of the traverse L8 was the same marker as the one recorded with the same velocity in the north of the basin. Because of this the programme was altered from reflection to refraction so as to tie the Proterozoic outcrop marker with the markers formerly recorded in the basin.

3. Programme Time Table

Information regarding weather conditions revealed that rains might start anytime after September 15. The time table was set to complete the work before the rainy season.

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CHAPTER III

TECHNIQUE AND OPERATIONS:

1. Technique

Reflection shooting was conducted making use of the reflection spread hole pattern and geophone pattern as illustrated in Figure 2.

Refraction continuous profiling and refraction probes with 290 foot trace intervals were used in refraction programme.

Gravity measurements were conducted along all seismic reflections and refraction traverses plus an interlaced grid system. The irregularity of the grid network was caused by topographic features that were inaccessible.

2. Operations

Operations were conducted from a tent camp with sleeping, messing, shop and office facilities for the entire crew. This main camp was moved or fly camps established when necessary to facilitate working conditions. Great distances to supply centers, difficult terrain and scarcity of water hampered the work considerably. Long water hauls limited the production of the drills and therefore reduced the output of the seismic crew.

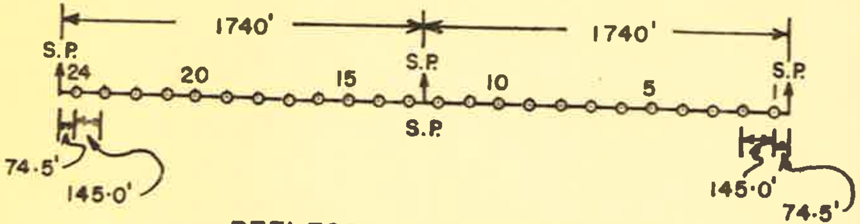
AAP

Reflection Spread, Hole Pattern, Geophone Pattern DIAGRAM

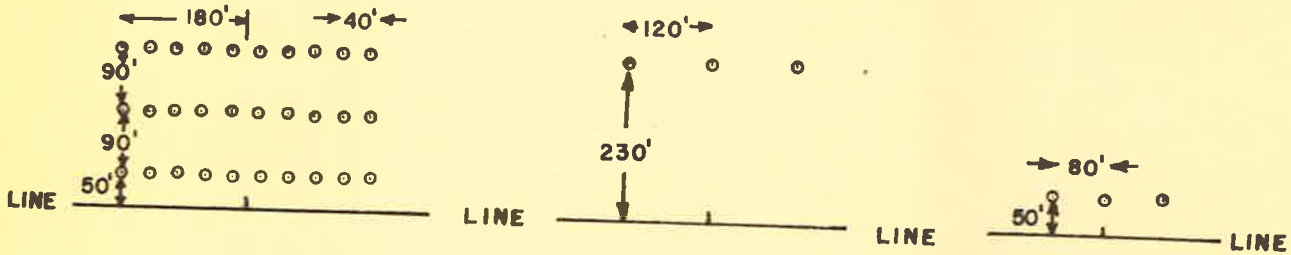
Petty

LEGUNE 1964

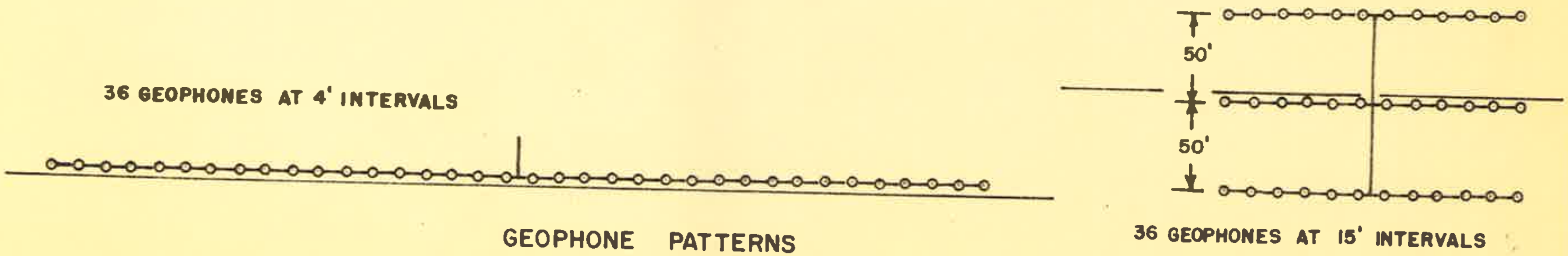
FIG.2



REFLECTION SPREAD



HOLE PATTERNS



GEOPHONE PATTERNS

CHAPTER IV

RESULTS:

1. Gravity Results

The results of the gravity survey are shown on Plate VI-A in the form of a Bouguer Anomaly Map. The anomaly values are based on the observed gravity value of Mines Administration gravity station number 317 (AAP gravity station number SR67), which was calculated using an assumed theoretical observed gravity value at (border survey) peg number 60 MN of 978.40920 gals.

The results of the Mines Administration Keep River Gravity Survey have been adjusted to the Legune Gravity Survey and are incorporated in this survey.

An extensive gradient trends northeast across the area surveyed. The amplitude of this trend is in excess of 18 mgals. with values decreasing towards the northwest. The majority of the Bouguer values obtained are positive (greater than 0.00 mgals.) because the average elevation of the survey is seventy-eight (78) feet.

In the southwest part of the area the +1 to +5 mgal. contours show a swing towards the northwest, while the +6 to +10 mgal. contours initially continue southwest an additional ten (10) miles before swinging north and then northwest. A gravity low of about 1 mgal. centered near station G149 is largely enclosed by the swing in the +6 mgal. contour. A swing to the northwest by the +4 to +7 mgal. contours is indicated in the northeastern portion of survey area. A gravity ridge extends northeast through station G73 towards station S12 and to the south of this ridge the gravity values decrease.

Several local irregular gravity features superimposed on the gravity ridge and gradient were investigated by means of residual gravity analysis. As a mathematical residual analysis was not possible due to the large gaps in the available gravity information, it was decided to attempt a graphical method of residual analysis. in which the regional gravity contours were sketched in by eye. The results indicated that two (2) gravity highs were superimposed on the gravity gradient. The larger high had $2\frac{1}{2}$ mgals. amplitude and was centered on station S85. A smaller residual gravity high with an amplitude of about 1 mgal. was centered on station S25.

Two (2) gravity lows were superimposed on the gravity gradient. The larger, with amplitude of about 5 mgals. was centered near station G147 and the smaller, with an amplitude of 4 mgals. was centered near station G87.

No residual analysis was made on the irregular features superimposed on the gravity ridge as the lack of detailed information in this area did not permit a satisfactory regional gravity contour pattern to be drawn.

2. Reflection and Refraction Results

Interpretation of seismic profiles indicate a very thin sedimentary section in the southeastern portion of the survey with a rapid rate of dip to the northwest.

Control was not adequate to delineate any possible anomalies.

CHAPTER V

DISCUSSION OF RESULTS AND INTERPRETATION:

The interpretation has been divided into two (2) sections.

1. The Gravity Interpretation

2. The Seismic Reflection and Refraction Interpretation

The seismic reflection and refraction interpretation makes use of the gravity interpretation as far as direction of dip is concerned.

Seismic reflection and refraction interpretation was derived from field playbacks only. No corrected playback section was used for the purpose.

1. Gravity Interpretation

If it is assumed that the major gravity anomalies present in the survey area are produced by variations in the thickness of the underlying sedimentary section, then the results of the gravity survey indicate that the sedimentary section is thinnest in the southeast of the survey area - in the area of the gravity ridge, and that it thickens towards the northwest.

The increase in the sedimentary section towards the northwest may be calculated by means of the two layer formulae.

$$GZ = 12.77\ OH$$

Where "O" = the density contrast between upper and lower layers

AND

Where "H" = the thickness of the upper layer in Kilofeet

The known decrease in gravity values towards the northwest in 18 mgals. and assuming a density contract of 0.3 G/CM^3, this would indicate an increase of about 4,500 feet in the sedimentary thickness in this direction.

The density contrast assumed is reasonable for a section in which Palaeozoic sediments overlie a basement of Metamorphosed sediments. However, confirmation or adjustment of this figure by means of density determinations on rock samples would lead to a more accurate calculation of the increase in sedimentary section.

In both the west and northeast of the survey area the gravity contours show a northwesterly trend and this may indicate the southwestern and northeastern limits of the indicated area with thick sediments lying to the northwest of the survey area.

The gravity ridge may be regarded as being produced by a basement ridge and the presence of local features superimposed on this gravity ridge is indicative of local irregularities on the basement ridge surface. The ridge appears to be at its most shallow depth between stations G34 and S63. This high area on the basement ridge extends northwards as a spur or nose cutting out from the ridge, producing the gravity feature which was isolated as a residual gravity high centered near station S85.

The small residual gravity high centered near station S25 is probably produced by a similar, but smaller, spur extending northwards from the basement ridge.

The larger residual gravity low centered near station G147 is probably produced by the presence of locally thick sediments, forming an extension of the area of thick sediments indicated further to the north.

The smaller residual gravity low centered near station G87 may also represent a local "pocket" of thicker sediments. However, it would seem more probable that this low is produced by an intra-basement intrusion perhaps of the granite kind.

The above gravity interpretation is shown on plates IV, V, VI, VI-A, VII, VII-A and VII-B.

2. Reflection and Refraction Interpretation

This interpretation is presented on the following five (5) contour maps:

A. Plate XVI Horizon "A" (Ordovician?)

B. Plate XVII Horizon "B" (Proterozoic?)

C. Plate XVIII Horizon "C" (Basement?)

D. Plate IXX Isochron "A - B" Horizons (Ordovician - Proterozoic?)

E. Plate XX Isochron "B - C" Horizons (Proterozoic - Basement?)

A very thin sedimentary section has been interpreted. To the southeast, reflection Line 8 and reflection Line 5R indicate the outcropping or the near outcropping of the basement.

To the northwest on shotpoint 68 of Line 9 the deepest point of the basement has been interpreted. Its depth is -6,140 feet.

Two (2) reversed faults with thrusts to the northwest are shown on Line 10 and make this line shallower than Line 9. The most eastern Line 8 is the shallowest and thus Line 9 appears to be located on a basement syncline.

Since no seismic loop line network exists Lines 8, 5R, 9 and 10 were interpreted as separate entities, using gravity information available for the approximate direction of the sedimentary and basement dip.

Line 8 shows two (2) normal tension faults downthrown to the south-east. The first fault has a throw of 330 feet and is located at shotpoint 41.

The second tension fault on this line is at shotpoint 49 and has a throw of 700 feet. This fault probably cuts Line 9 at shotpoint 77, while the first fault probably dies out to the southwest.

From refraction data another normal minor down to the southeast fault on Line 5R between shotpoint 105/1 and 105/13 exists. Its throw is 120 feet.

On Line 10 two (2) thrust faults with their thrusts to the northwest have been interpreted. The first one of these thrust faults is at shotpoint 124 and has a thrust of 2,660 feet.

The second thrust fault is at shotpoint 138 and has a thrust of 900 feet.

All normal tension faults, as well as thrust faults, are basement faults.

Basement to the northwest is probably of different lithology than to the east. It is thought that to the northwest basement is of a meta-morphic nature while to the east it is probably of the igneous basalt type. The Legune Homestead attempted to drill a water well and hit a very hard black rock type formation at a depth of fifty (50) feet. It continued to 360 feet depth where it was abandoned. Samples of this black type of rock looked like basalt to the writer. Also a very much higher basement refraction velocity is interpreted to the east than to the west. To the west the basement velocity is believed to be 16,500 feet per second while to the east an 18,000 feet per second basement velocity has been interpreted. The 16,500 feet per second basement velocity to the west appears to be somewhat low for a basement velocity and the question arises if no further sedimentary section underlies this refractor.

All three (3) mapped horizons, Horizon "A", Horizon "B" and Horizon "C" show rapid dip to the northwest.

The horizons have tentatively been identified as follows, but their identification is highly questioned:

Horizon "A"	=	Lower Ordovician
Horizon "B"	=	Upper Proterozoic
Horizon "C"	=	Basement

The isochrons show a rapid thickening of the sedimentary section to the northwest.

On Line 10 Horizons "A" and "B" are thought to be eroded to the northwest of shotpoint 125 where Horizon "C" rises up to a depth of 1,460 feet on the thrust side of the fault at shotpoint 124.

No closures could be interpreted without a seismic line loop network.

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CHAPTER VI

ACHIEVEMENT OF OBJECTIVES:

1. The marker beds are poorly identifiable from refraction depth probes.

2. A poor inventory of the marker beds could be obtained from the refraction depth probes.

3. The relative effectiveness of both the seismic reflection and refraction methods is poor due to the poor data obtained in the area by the methods employed.

4. Gravity data is directly related to the structural shape of the basin.

5. Further exploration would be needed before a suitable drilling site could be located.

Respectfully submitted,

PETTY GEOPHYSICAL ENGINEERING COMPANY

Stanley W. Hall

for W. O. Weber
Party Chief-Party 30A

APPENDICES

APPENDIX I

PERSONNEL

1. Basic Seismic Party

One (1) Party Chief
One (1) Chief Computer
One (1) Computer
One (1) Surveyor
Two (2) Surveyor Helpers
One (1) Observer
One (1) Junior Observer
Five (5) Linemen
One (1) Shooter
Two (2) Drillers
Two (2) Drill Helpers
One (1) Cook
One (1) Mechanic

Total: 20 men

2. Complementary Personnel

One (1) Gravity Meter Operator

3. Tractor Personnel

Two (2) Operators
One (1) Supporting Vehicle Driver/Mechanic

Total: 3 men

The above twenty-four (24) men plus a gravity computer and a cook's helper, who were not specified in the contract, formed the total personnel employed in the field operation.

4. Illness

Crew personnel suffered from Infectious Hepatitis beginning September 4, 1964. A total of fourteen (14) men were hospitalized and the crew's productivity was adversely affected.

APPENDIX II

EQUIPMENT

Equipment used on the crew was as follows:

1. Vehicles

One (1)	Party Chief Land Rover	Basic
One (1)	Survey Unit Land Rover	Basic
One (1)	4 x 4 B-120 International Recording Truck	Basic
One (1)	4 x 4 Chevrolet Blitz Shooting Truck	Basic
One (1)	4 x 4 Chevrolet Supply Truck	Basic
One (1)	Recording Personnel Carrier Land Rover	Basic
One (1)	Geophone and Cable Carrier Land Rover	Basic
One (1)	Drill Tender, Personnel Carrier Land Rover	Basic
Two (2)	T-850 Ford 6 x 4 Drill Trucks	Basic
Two (2)	T-750 Ford 6 x 4 Water Trucks	Basic
One (1)	R-190 International 6 x 4 Water Trucks (replacement for one of the above Fords)	Basic
One (1)	Toyota Gravity Meter Operator Vehicle	Complementary
One (1)	Toyota Client Representative Vehicle	Complementary

2. Camp

One (1)	Kitchen-Dining Room-Shower Combination
One (1)	Caravan mounted on A-160 International Tractor Truck
Four (4)	Billy Huts - Office
One (1)	Billy Hut - Sleeping Quarters
Six (6)	12' x 12' Sleeping Tents
One (1)	12' x 12' Food Supply Tent
One (1)	16' x 16' Repair Shop Tent

3. Special Equipment

3.1 Surveying Instruments

One (1) Hilger and Watts Survey Theodolite
One (1) Keuffel and Esser Transit
One (1) Survey Chain
Two (2) Stadia Rods
One (1) Range Pole

APPENDIX II (CONTD.)

3.2 Drilling Equipment

Two (2) Mayhew 1000 drills equipped with $4\frac{1}{2}$ x 6 Gardner Denver mud pumps and WXN 1003 100 PSI air compressors, mounted on the two (2) Ford T-850 6 x 4 trucks and power driven by the truck engines.
One (1) Griffith 1500 gal. water tank mounted on a T-750 6 x 4 Ford truck.
One (1) Griffith 1000 gal. water tank mounted on a T-750 6 x 4 Ford truck.
One (1) Griffith 1000 gal. water tank mounted on an R-190 International 6 x 4 truck. (To replace above Ford when broken down)

3.3 Recording Equipment

One (1) twenty-four (24) channel SIE MS-15 FM magnetic tape recording instruments.
One (1) electrical stylus for playback

3.4 Geophones

492 HS-30 cycle reflection geophones in strings of twelve (12) and eight (8) single spares (basic)
400 HS-30 cycle reflection geophones (complimentary)
Thirty (30) EVS $7\frac{1}{2}$ cycle refraction geophones

3.5 Cables

Five (5) seventeen hundred and sixty foot, 13 takeout, Vector cables used for reflection and refraction

3.6 Blasters

Two (2) SIE automatic 2000 volt blasters

3.7 Gravity Meter

One (1) Worden gravity meter

APPENDIX II (CONTD.)

3.8 Radios

Three (3) Eilco transceivers equipped for time break transmission

3.9 Engineering

Two (2) TD-18 International Hydraulic Blade Bulldozers
One (1) Dodge power wagon tractor supporting vehicle

APPENDIX III

HISTORY AND STATISTICS

1. History

July 15th was the planned commencement date but drilling actually started July 23rd and shooting commenced on July 24th.

Drilling was completed on September 24th and shooting was finished September 26th.

October 14th was final day for the gravity meter operation.

2. Statistics

2.1 Reflection Statistics

A total of 382¼ hours were expended in the reflection programme. Seventy-two and three quarters (72¾) of these hours were used in driving and 309½ hours of these were actual field working time. The following was accomplished:

a. 38 miles of reflection profiles
b. 4 replaced spreads
c. 29 weathering shots
d. 11 refraction shots on reflection spreads

Long water hauls during the entire programme and then a Hepatitis epidemic in September limited production.

2.2 Refraction Statistics

Twenty-eight and three quarters (28¾) hours were used in driving and 121¾ hours in production. Eighteen and one third (18.1/3) miles refraction profile was shot and the thirteen (13) bases were shot from an average of five (5) or six (6) different shotpoints.

2.3 Drilling Statistics

Three thousand six hundred and seventy-two (3,672) shot holes or 142 shotpoints were drilled for a total footage of 73,072 feet. One hundred and sixty-eight and three quarters (168¾) hours were used travelling and 657 hours were expended in the field.

Scarcity of water and illness reduced the effectiveness of the drilling very greatly.

2.4 Dozing Statistics

Two (2) International Harvester TD - 18 bulldozers were employed to clear lines. They worked a total of 655 hours and of this total, 161 hours were spent moving and 494 were spent clearing lines.

2.5 Consumable Stores Statistics

A total of 98 insert bits, insert blades and roller bits were used for the drilling.

Twelve thousand pounds of Nitramon, (12,000) 11,060 primers, 2,250 shields and 5,135 detonators were used in shooting.

2.6 Gravity Statistics

The gravity operator worked 193½ hours and completed 451 new stations, 151 repeat (base) stations and 10 re-run stations. Production was curtailed because of the lack of a full time surveyor.

APPENDIX IV

EXPERIMENTAL WORK

1. Objectives

The objective was to find a shothole pattern and geophone array that would produce reliable data and stay within the limits of economical possibilities.

2. Programme

Comparisons between hole patterns on Line 8, shotpoints 12 to 15, and Line 5, shotpoints 63 to 67, indicated that the 30 hole pattern, holes 19½ feet deep and loaded with one pound of explosive each, would give reasonable record quality. (See figure 2)

Experiments on Line 8 began with 36 geophones in line at 4 feet intervals. Later three rows of geophones 50 feet apart with individual geophones at 15 feet intervals were used. (See figure 2) The latter method was continued throughout the survey.

3. Results

Experimental work was done in an area where basement is very near the surface; however, the method selected gave reasonable results in the northern part of the area where more sedimentary section was present.

APPENDIX V

TECHNIQUE

1. Reflection

The continuous split reflection shooting technique was used. Shot-point intervals were 1,740 feet. The inside traces were 72.5 feet from the shotpoint and center trace intervals were 145 feet constant, thus making a spread layout configuration of 1667.5'-0-1675.5'. This layout was kept constant throughout the prospect. Other reflection shooting techniques are described under Appendix VI.

2. Refraction

2.1 Refraction Probes

Refraction probes were conducted on Line 8R and Line 10R to draw up an inventory of marker beds. (See Plates 9 and 10)

2.2 Continuous Refraction Profiling

This method was applied on Line 5R. Plate 8 demonstrates this in an exploitation diagram.

3. Gravity

All gravity measurements were conducted along a network of loops consisting of all seismic reflection and refraction traverses and an interlaced irregular grid system. The irregularity in the grid network was caused by topographic inaccessibility over portions of the area.

Gravity loop bases were set at intervals which permitted repeat readings within a maximum time limit of two (2) hours. All loops were vectorially closed to within 0.27 mgals. All gravity stations were placed approximately at one third (1/3) mile intervals.

APPENDIX VI

FIELD OPERATIONS

1. Natural Conditions

The terrain is flat except where outcroppings exist. Very rough black soil surface conditions limit a vehicle's travel speed to four (4) miles per hour. To the east of the prospect bulldusty conditions prevail with bulldust depths up to two (2) feet. Between the Keep River road crossing and Alligator Springs a fine sandy surface area exists, that makes travelling without four wheel drive vehicles impossible.

In the rainy season the area is partially submerged. The Legune Homestead stocks up on supplies at the beginning of September and carries several weeks supplies of food. Although the Legune Homestead ground has an airstrip, the strip is not serviceable sometimes during November and December when the area has its heaviest rainfall.

2. Camp

Two (2) main camp locations existed. The first being between Line 8 and Line 5R at the southeast corner of the Legune Airstrip. Line 5R, Line 8, 8R and Line 9 were shot out of this camp. The travel time was thus cut to a minimum. The second main camp was placed at the Keep River road crossing. Line 10 was shot out of this camp and other gravity lines were worked out of it. Basically the camp was placed at this location to eliminate a water supply problem.

A fly camp was set up on the north bank of the Keep River on Line 10. This was necessary to finish shooting reflection and refraction on Line 10 after a heavy storm with $1\frac{1}{2}$ inches of rain in 20 minutes struck the Keep River camp on September 20. The rain shorted out the electric generator and rendered it useless. Because the generator was unserviceable and no light or refrigeration could be obtained without it, it was decided to finish shooting the rest of the programme out of a fly camp.

Another fly camp was later set up at Alligator Springs for the completion of gravity meter readings, the taking of solar declination observations and the making of other horizontal survey ties.

APPENDIX VI (CONTD.)

3. Logistics

3.1 Water Supply

Only three (3) fresh water sources are known. Alligator Springs at TBM 1, a water pond at TBM 2/3 and the upper Keep River. Drinking, cooking and drilling water was obtained from these sources.

Access to salt water sources was treacherous due to tidal muds and it was preferred not to use salt water due to a corrosion and contamination likeliness in the water injection systems of the drills. Roundtrip water hauls took up to six (6) hours due to the very rough access road conditions to the shotpoints and the water sources. Drilling operations were greatly affected due to this and not enough drilling water transport.

3.2 Food Supplies

During July and August, perishable food had to be flown in from Darwin to Kununurra where it was picked up every Tuesday. A roundtrip from the Legune Camp to and from Kununurra took ten (10) hours. The distance is seventy (70) miles one way. As of September 1, an Ord River Co-operative Store opened in Kununurra, carrying many of the necessary items. Reliability of obtaining perishables from Kununurra or Wyndham was vague and it was considered safer and more reliable to make use of the Darwin "fly-in" system.

3.3 Fuels and Lubricants

Fuels and lubricants were first being supplied from Wyndham. After August 15, fuels were being purchased in Kununurra. Transport of fuels was difficult and deliveries were late on several occasions. On numerous instances it required sending a crew vehicle to pick up a few drums of petrol to carry us over until the fuel truck arrived.

3.4 Spare Parts

Spare parts were ordered by telegraph from either Darwin, Brisbane or Perth. The flying in of heavy items caused delays of up to and over two (2) weeks.

3.5 Explosives

Dupont Nitramon and primers were used. Transport of explosives is also difficult and the nearest purchasing source is either Alice Springs or Perth. Detonators were obtained from a company who had an excessive stock after the completion of a seismic survey to the west of the Legune Area.

4. Communications

4.1 Radio

The Royal Flying Doctor Service radio communications on the 5300 KC/SEC frequency were established with the Wyndham Station. Telegrams could be sent and received through this service four (4) times daily except on Sundays. On Saturdays the service shut down at 1.00 PM after its third session. Also emergency medical calls and advice could be made through this station.

4.2 Mail Service

Mail arrived in Kununurra twice per week via air mail from Brisbane or Darwin, on Tuesdays and on Fridays and from Perth also via air mail on Tuesdays and on Thursdays. The sending of mail was through Kununurra and the departure days were Tuesdays and Fridays.

4.3 Air Service

Regular air service facilities were available twice per week to or from either Perth or Darwin from Kununurra on Tuesdays and on Fridays.

4.3 (1) Regular Line

The only regular airline servicing Kununurra on the above days is Mac Robertson Miller Airlines (MMA).

4.3 (2) Chartered Planes

Air charters could be arranged with either John Cox of Wyndham or Muir (Muirav) Darwin. The two (2) charter

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4.3 (2) Chartered Planes (contd)

possibilities could be arranged with the Flying Doctor Radio station in Wyndham or directly via telegram with Muirav - Darwin. Air charter facilities were possible either through Kununurra or the Legune Homestead airstrip.

5. Surveying Operations

5.1 Alignment and Pegging

A Hilger and Watts theodolite was used for the placing and orientation of the lines in the desired bearings. The lines were started with the theodolite and continued by simple range pole alignment. When later levelling with the theodolite took place the straightness and bearings of the lines were checked. The bearings were oriented on magnetic readings. A declination of 4^{o}E was taken into consideration for this. Later magnetic solar declination observations taken on Line 10, Line 9, Line 5R and Line 8, averaged to 4^{o} 39' 45" E. Individual observations reading sets ranged from 4^{o} 29' E to 4^{o} 32' E.

The pegging was performed using a chain. Stadia distance readings were taken when levelling took place. On the reflection pegging on Line 10 various wrong distances between shotpoints were chained out.

Between shotpoints 118 and 127 one (1) chainman alone was used when these mistakes occurred and while he used the method of pushing a spike in the ground through the eye of the chain end, the ground was too soft for the firm holding of the chain in its place. The actual distances obtained from stadia distance readings were used in this case. Stadia distances across the Keep River on Line 10 were used for the mapping of the line.

5.2 Levelling

Levelling was done using the Hilger and Watts theodolite. Readings were taken at each shotpoint and gravity station or at topographic irregularities. Readings were taken to the

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nearest tenths of a foot markings of the levelling rod. Where no vertical ties could be made lines were double run. A levelling accuracy expressed in feet, of 0.5 M (where "M" equals number of miles in the traverse) was maintained.

5.3 Documents Used

Emphasis was laid on a Mines Administration map of the area but the Inch to Four Mile Series map was also used.

5.4 Tie of the Survey

5.4 (1) Horizontal Ties

To the east the survey was horizontally tied to the LA 21 astronomical station. To the west horizontal ties were made to Western Australia-Northern Territory border Public Works Department bench marks and other not positively identified Mines Administration gravity stations.

5.4 (2) Elevation Tie

An assumed base takeoff elevation of 75.0 feet at the Legune airstrip wind sock was used and all lines were tied to this elevation by either actual back ties or double runs of lines.

5.5 Permanent Markers

A list of permanent markers, their latitudes, longitudes and elevations is attached. These permanent markers (as shotpoint locations) were placed at approximately five (5) mile intervals along all seismic, refraction or gravity lines. Line intersections were preferred. A permanent marker is a two (2) inch pipe 20-21 feet long planted 4-5 feet into the ground and sticking 15-16 feet up into the air. Some permanent markers have a brass plate 4" x 2" welded at eye level height. 1/8" punch stencil type identification markings are engraved on these brass plates. On permanent markers which do not possess a brass plate such engravings were made directly into the steel pipe at eye level height. A typical identification engraving is as follows:

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AAP - PETTY
Line L8 SP 12
October 1964

Approximately two (2) feet of the top of the permanent markers, as well as approximately two (2) feet over the identification engravings were painted with white weatherproof paint.

The marker set at SP 28 on Line 8 is erroneously marked SP 27.

5.6 Engineering (Bulldozing)

The two (2) International Harvester TD-18 hydraulic bulldozers were used to make access trails and clear line from vegetation and other surface obstacles. Care was taken in preserving the hard crust ground surface for two reasons. The immediate hard crust underlaying formation turned into a bulldust after vehicles made use of the trails two or three times. In other places, and where a hard crust black soil surface exists, one or two inch surface earth cuttings resulted in removing a grass root interlaced chunk of earth which produced approximately one (1) foot deep holes, thus making a very rough access track. Although the surface, as it is, is very rough the cutting of it would only have made it worse.

6. Drilling Operations

Drilling production was enormously affected due to the water supply problem as explained above under Appendix VI 3.1 Water Supply. All drilling required 100% water from the top to the bottom of the kelly deep, 19½ feet, holes. A sticky wet mud was encountered at five (5) feet depths throughout the area. No hard drilling type of formations were encountered except on holes close to outcroppings, namely on the south end of Line 8, the south end of Line 9 and on the south bank of the Keep River on Line 10. In these areas roller type rock bits were used. Otherwise kelly starter bits, insert type bits or replacement blades were used. Approximately 60% of the drilling time was spent waiting on water. In September only one (1) drill could be supplied with water.

7. Shooting Operations

7.1 Reflection shooting was conducted using one (1) 2,000 volt SIE automatic blaster. Multiple hole charges were connected in series hook ups. Since the holes did not stay

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open charges were loaded immediately after a hole was drilled, charges were one (1) Dupont Primer (1 lb.) per hole.

7.2 Refraction shooting made the use of two (2) shooting teams. One on each side of the base. Two (2) 2,000 volt SIE automatic blasters were used plus three (3) Eilco transceiver radios for the transmitting and receiving of the time breaks. Each shooting team was equipped with one (1) of these radios and the recording truck with the third set. Charges were exploded on the surface or in craters resulting from previous charge explosions. Charges ranged from five (5) pounds per shot for short offset shots to 1,350 pounds for long offset shots. Explosives used were Dupont Nitramon and primers.

8. Recording Operations

8.1 Reflection

Reflection recording made use of the continuous split reflection profile techniques. Shotpoint spacing was 1,740 feet and actual spread layout center trace distances were 145 feet. Overall surface spread coverage was 1,667.5 feet with twelve (12) traces per spread and 36 seismometers per trace in a linear layout parallel to the line. Linear geophone spacing was fifteen (15) feet and perpendicular spacing between rows of twelve (12) geophones was fifty (50) feet. Hole patterns were three (3) rows of ten (10) holes each, parallel to the line, with the first row offset fifty (50) feet perpendicular to the line and the second and third rows spaced ninety (90) feet apart and parallel to the first row. (See Figure 2)

All shots were recorded on SIE magnetic tape. The instruments were set on a medium automatic Gain Control, 100% gain and a low 20 and high 90 cycle cutoff filter was used.

8.2 Refraction

Two (2) shooting teams equipped with Eilco radios and a third Eilco radio at the recording unit conducted the refraction survey. Trace interval was 290 feet one (1) 7½ cycle EVS Electro-Tech refraction geophone per trace and twenty-four (24) traces were recorded for a surface coverage of

6,670 feet per base. Bases tied to each other with two (2) overlapping end traces. Example: Trace 24 of base 104 = trace 2 of base 105 and trace 23 of base 104 = trace 1 of base 105.

Recording settings were as follows:

No Automatic Gain Control
Filters - Out
Attenuation - 10% - 40% (according to noise level)
Modulation - 20%

8.3 Special Recording (Weathering Shots)

Weathering shots were taken on Line 8R, Line 5R, Line 9, Line 10 and Line 10R. Trace intervals varied from fifteen (15) feet to sixty (60) feet. Six hundred and seventy (670) feet was the longest spread length. One (1) pound explosive charges were detonated on the surface at each end of the spread with inline offsets up to forty-five (45) feet from the end geophones. No filtering and no Automatic Gain Control was used in recording. Single $7\frac{1}{2}$ cycle EVS refraction geophones were used on each trace.

9. Playback Operations

9.1 Reflection

Field playbacks were made medium A.G.C., no mixing and filter selections were low 20 - high 90 and low 20 - high 47.

9.2 Refraction

Refraction records were played back with low filter - 0, high filter - 35, A.G.C. in refraction position with gain settings from 50% to 100%.

9.3 Special Playbacks (Weathering Shots)

These playbacks were made with low filter - 0, high - 25, A.G.C. in refraction position, 20% attenuation and 20% modulation.

10. Gravity

The gravity section of the crew initially was a meter operator/ computer. Later an additional man was added to do the computing which allowed the operator freedom to concentrate solely on meter reading and laying out of stations.

Local (Darwin) time was recorded for all readings. Production could have been improved greatly with a full time surveyor.

A 4 x 4 Toyota Land Cruiser was used for the operator's transportation and his instrument was a Worden Gravity Meter, Number 286. This meter was calibrated for use in Australia by occupying the two (2) pendulum stations in Brisbane prior to the commencement of the survey. Prior to calibration in Brisbane, the factor for the meter in the U.S. was 0.09374. After calibration the factor was 0.9334.

APPENDIX VII

REDUCTION AND PRESENTATION OF DATA

1. Reflection Computations and Depth Cross Sections

Since all kelly deep shots were shot in the weathering the following intercept method from first arrival plots was used:

$$W_c \text{ at shotpoint} = D_2\left(\frac{1}{V_{wz}} - \frac{1}{V_c}\right)$$

Where D_2 is the distance from the bottom of the charge to the base of the weathering and is obtained as follows:

$$D_2 = \tfrac{1}{2}\left(\frac{1}{\cos i} - t_s\right) V_{wz} - \frac{a}{2}$$

$$W_c \text{ at geophone} = D_1\left(\frac{1}{V_{wz}} - \frac{1}{V_c}\right),$$

$$D_1 = D_2 + a = \tfrac{1}{2}\left(\frac{1}{\cos i} - t_s\right) V_{wz} + \frac{a}{2}$$

(See Figure No. 3)

Elevation correction at shotpoint is $Ec = \dfrac{Esp - dmax - Edp}{Vc}$

Elevation correction at geophone is $Ecg = \dfrac{Eg - dmin - Edp}{Vc}$

Total surface correction

$$\Sigma T = (Ec + Wc + Ecg + Wcg + ts)$$

Migrated depth cross sections were made and are presented in Plates XIII, XIV, and XV.

Velocity information for the migration was computed from Plate XI average normal move-out curve and Plate XII average velocity function depth curve.

The angles of the dip were obtained using the following formulae:

$$\text{Sin of Dip} = \frac{\text{Avg } V \ \Delta T}{2X}$$

X = spread length

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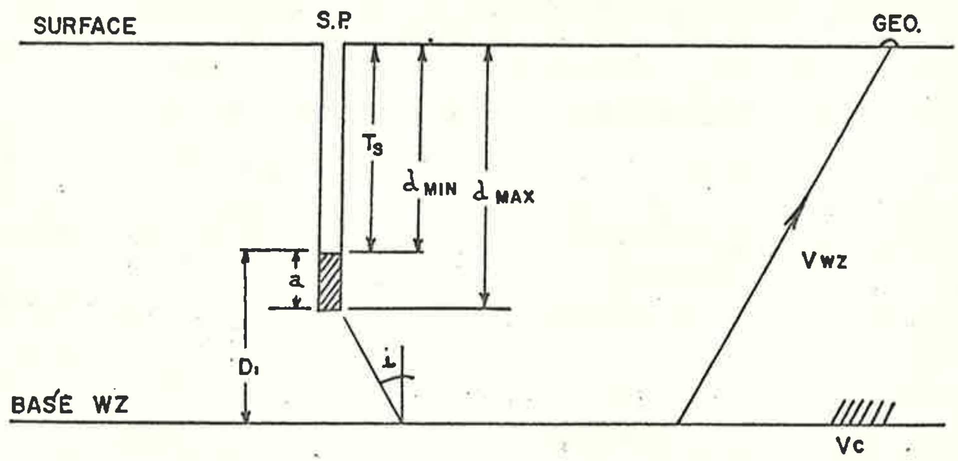
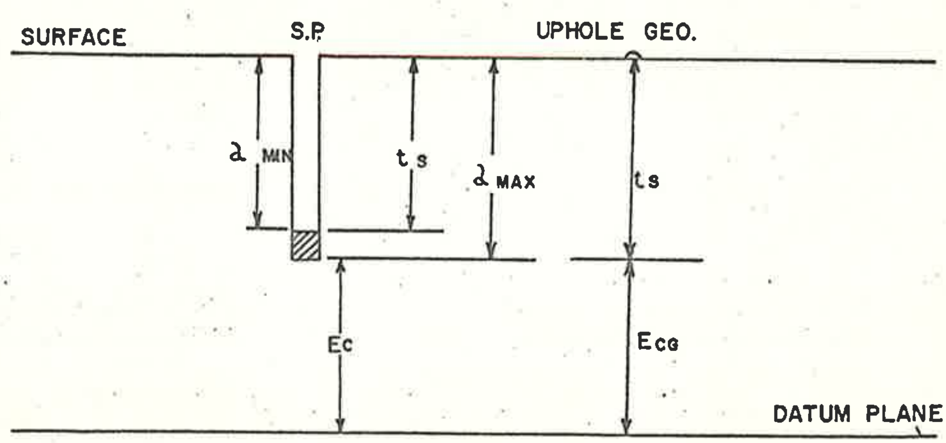
Figure 3



WEATHERING



ELEVATION

SITUATION

1. GEOPHONE NEAR S.P.
2. WZ CORRECTION MADE

The velocity function used as obtained from the normal move-out curve and average velocity function depth curve is:

$$Vi = 9500 \text{ ft. per sec.} + 0.40\, Z$$

1.1 Average Normal Move-Out Curve

Plate XI shows the average normal move-out curve obtained from normal move-out readings off records from Line 8, Line 9 and Line 10. Normal move-out readings are at record times counted from the time break.

1.2 Average Velocity Function Depth Curve

On Plate XII the average velocity function depth curve is represented. It was computed by using the NMO or T values from the average normal move-out curve. The velocity function obtained using Miller's Method is:

$$Vi = 9500 \text{ ft. per sec.} + 0.40\, Z$$

2. Refraction Exploitations, Computations and Cross Sections

Refraction exploitations of Lines 5R, 8R and 10R are schematically represented on Plates VIII, IX and X.

The refraction computations for Lines 8R and 10R are taken from reflection data on these lines. All refraction breaks are corrected to the sea level datum plane.

Refraction computations for Line 5R were effected using the weathering shots. The total corrections applied to the refraction times were obtained as follows:

$$\Sigma T = (Ec + Wc + Ecg + Wcg)$$

All refraction breaks were also corrected to the sea level datum plane.

The refractors were obtained using the Baumgarte Wave Front Method as shown on the sections.

Refraction cross sections are illustrated on Plates VIII-A, IX-A and X-A.

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3. Gravity Computations

Elevation corrections to sea level were made for an overburdened density of 2.0 GMS/CM^3. The density factor applied (0.06854 MGLS/FT for a density of 2.0 GMS/CM^3) permitted the simultaneous correction of both free air and Bouguer effect.

Latitude corrections were based on the international formulae for expected variations on a triaxial spheroid.

The frequency and close spacing of base stations minimised diurnal drift in the repeat reading.

Some drift did occur, however, and when this drift amounted to 0.11 mgals. or more, it was distributed on a linear time scale.

Drift of 0.10 mgals. or less was adjusted by averaging the applicable repeat readings, and applying this average to the computation of the observed gravity value for the respective bases.

Tidal corrections were so small that they were not applied.

APPENDIX VIII

LIST OF PERMANENT MARKERS

Line	SP or G Station	Longitude	Latitude	Elevation
L - 8	12	129° 28.18'	S 15° 11.88'	71.8 feet
L - 8	Note: Marker is 28 erroneously marked 27	129° 25.35'	S 15° 08.25'	68.6 "
L - 8	50	129° 21.81'	S 15° 02.91'	70.8 "
L - 8	61	129° 20.03'	S 15° 00.30'	69.8 "
L - 9	90	129° 19.84'	S 15° 14.10'	75.6 "
L - 10	109	129° 12.34'	S 15° 18.91'	74.4 "
L - 10	122	129° 10.90'	S 15° 15.47'	75.9 "
L - 10	127	129° 10.33'	S 15° 14.17'	69.4 "
L - 10	128	129° 07.96'	S 15° 08.75'	53.4 "
L-10	140	129° 09.30'	S 15° 11.90'	51.1 "
L - 5R	109/12	129° 22.02'	S 15° 21.94'	105.7 "
L - 5R	107/1	129° 21.95'	S 15° 19.23'	93.9 "
L - 5R	106/24	129° 21.94'	S 15° 19.08'	95.5 "
L - 5R	102/13	129° 21.91'	S 15° 14.15'	73.8 "
L - 5R	"A"	129° 21.90'	S 15° 08.91'	70.1 "
Gravity	G - 230	129° 23.73'	S 15° 08.93'	71.9 "
Gravity	G -15	129° 23.25'	S 15° 13.85'	73.3 "
Gravity	Legune Wind Sock	129° 26.74'	S 15° 13.09'	76.0 "
Gravity	G -34	129° 24.67'	S 15° 16.02'	77.0 "
Gravity	G -53	129° 21.20'	S 15° 20.02'	81.9 "
Gravity	TBM/P30/1	129° 23.68'	S 15° 18.62	79.2 "
Gravity	TBM/P30/2-3	129° 14.38'	S 15° 23.55	94.8 "
Gravity	G - 210	129° 14.60'	S 15° 14.09	76.9 "
Gravity	G - 248	129° 03.32'	S 15° 24.49	98.4 "
Gravity	G - 258	129° 00.93'	S 15° 24.23	113.2 "