COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Petroleum Search Subsidy Acts

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Exmouth Gulf Marine Seismic Survey Western Australia, 1961

BY

WEST AUSTRALIAN PETROLEUM PTY LIMITED

Issued under the Authority of the Hon. David Fairbairn
Minister for National Development

1965

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

MINISTER: THE HON. DAVID FAIRBAIRN, D.F.C., M.P.

SECRETARY: SIR HAROLD RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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FOREWORD

In 1959 the Commonwealth Government enacted the Petroleum Search Subsidy Act 1959. This Act enables companies that drill for new stratigraphic information, or carry out geophysical or bore-hole surveys in search of petroleum, to be subsidized for the cost of the operation, provided the operation is approved by the Minister for National Development.

The Bureau of Mineral Resources, Geology and Geophysics is required, on behalf of the Department of National Development, to examine the applications, maintain surveillance of the operations and in due course publish the results.

A reconnaissance marine reflection seismic survey was carried out under the Petroleum Search Subsidy Act 1959 by Seismograph Service Limited for West Australian Petroleum Pty Limited. The survey took place over an area within the Carnarvon Basin, Western Australia.

This Publication deals with this survey, and contains information furnished by West Australian Petroleum Pty Limited and edited in the Petroleum Exploration Branch of the Bureau of Mineral Resources. The final report was written by D.N. Smith, West Australian Petroleum Pty Limited, and R.D. Lugg, Seismograph Service Limited. The methods employed in the seismic survey and the results obtained are presented in detail.

J.M. RAYNER
Director

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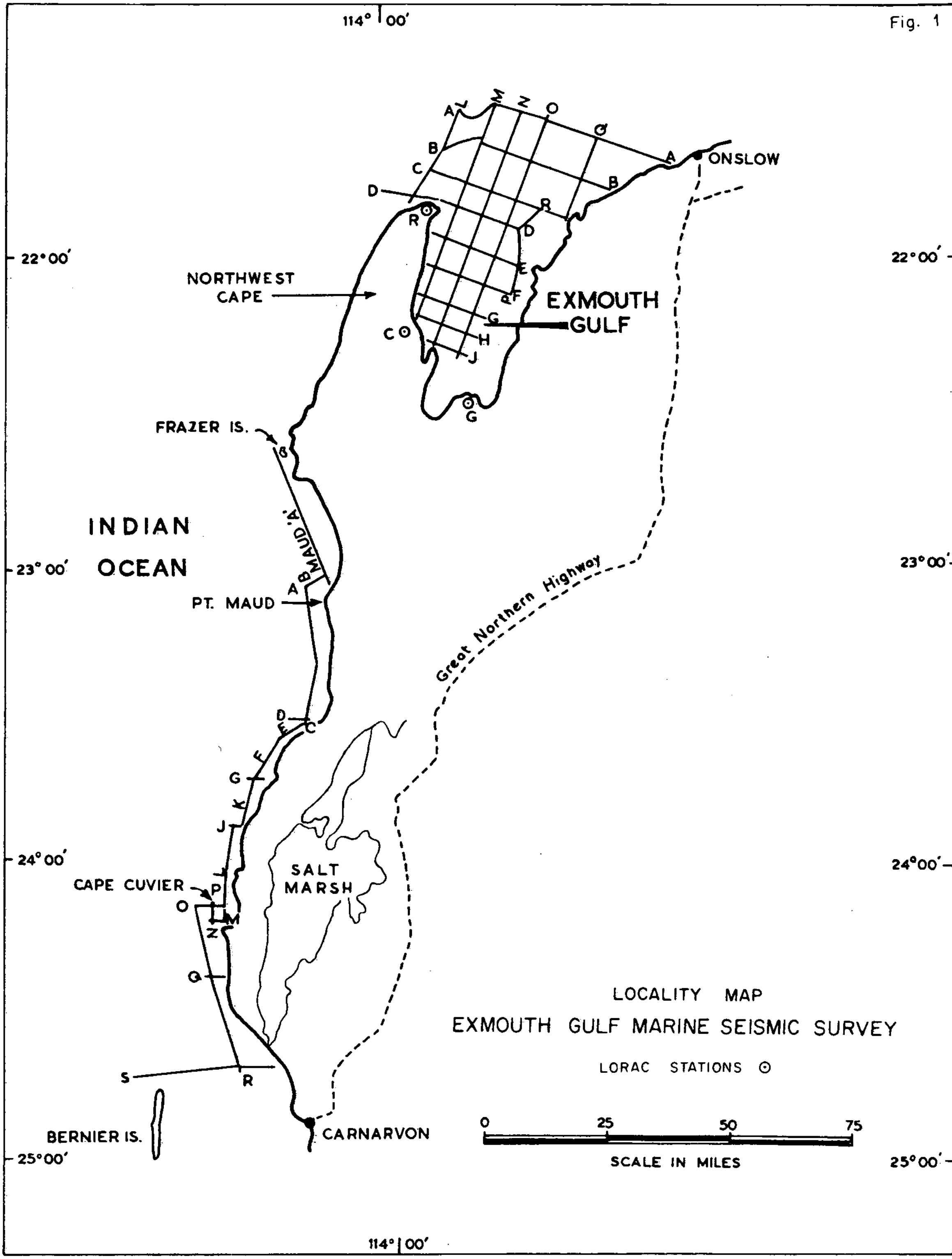


Fig. 1
114° 00'
22°00'
23°00'
24°00'
25°00'
ONSLOW
NORTHWEST CAPE
EXMOUTH GULF
FRAZER IS.
INDIAN OCEAN
MAUD 'A'
PT. MAUD
Great Northern Highway
CAPE CUVIER
SALT MARSH
BERNIER IS.
CARNARVON
LOCALITY MAP
EXMOUTH GULF MARINE SEISMIC SURVEY
LORAC STATIONS ⊙
0 25 50 75
SCALE IN MILES

SUMMARY

A reconnaissance marine reflection seismic survey was conducted in Exmouth Gulf and the open coastal waters along the west coast of Western Australia from Frazer Island to Bernier Island (see Fig. 1).

The survey was a two-boat operation. The survey in the Exmouth Gulf area was controlled by a Lorac radio navigational system, and along the west coast positioning was determined by sextant angle measurements to shore beacons and landmarks. All shots were recorded on magnetic tapes which were processed into variable area record sections.

The following maps were constructed:

(i) On a Horizon "A" within the Upper Cretaceous Korojon Calcarenite (Exmouth Gulf area only);

(ii) On a Horizon "B" near the Basal Cretaceous unconformity;

(iii) On pre-Cretaceous structure;

(iv) Time interval between Horizons "A" and "B" (Exmouth Gulf area only);

(v) Depth of water.

The Exmouth marine survey indicated that Exmouth Gulf is essentially synclinal in character in the Cretaceous and Tertiary sediments. Several major pre-Cretaceous fault trends which had already been mapped on land with the seismograph were followed beneath the Gulf. The pre-Cretaceous axis of the Cape Range Anticline was located both to the north and to the south of the surface expression of the structure. The chain of islands to the north-east of the Cape Range are aligned on a structural trend.

To the south of Point Maud, the Cuvier marine survey provided a much-needed tie between the Rough Range-Cape Range area and the structurally complex area around the Salt Marsh. Some structural leads were found in this southern area and the trend of major faults was established.

INTRODUCTION

West Australian Petroleum Pty Limited conducted two marine seismic projects during July and August, 1961, in the waters off-shore Western Australia. A total of 753 miles of traverse was shot by Seismic Party No. 169G of Seismograph Service Limited.

The project areas fall within West Australian Petroleum Pty Limited's Permit to Explore 28H and include parts of Licences to Prospect 52H (Learmonth), 83H (Cape Cuvier), 86H (Cape Range North), 51H (Yanrey), and 63H (Rough Range).

The Exmouth Marine Project (No. 74) covered Exmouth Gulf and open coastal waters between Frazer Island and Point Maud (see Fig. 1). The Cuvier Marine Project (No. 75) extended along the coast from Point Maud to Bernier Island.

The seismic operation is discussed in the first section of this report, the account of which was taken from an operational report written by R.D. Lugg of Seismograph Service Limited. The interpretation of the data is discussed in the next section, which was written by D.N. Smith of West Australian Petroleum Pty Limited. The accompanying maps were compiled by D.N. Smith and P.A. Hoelscher of West Australian Petroleum Pty Limited.

The purpose of the Exmouth Marine Project was to obtain, by economical methods, information on the regional geology of the North West Cape area with particular attention to mapping the structure of the Cretaceous, Jurassic, and Carboniferous-Devonian formations.

It was hoped that the Exmouth Marine Project would provide information on extensions of the Rough Range and Learmonth Trends into the Exmouth Gulf area, and on the south-western extension of the Cape Range Anticline, Dingo Syncline, and Rough Range structure in the Frazer Island-Point Maud area. Information was also sought on the nature of the pre-Cretaceous-post-Palaeozoic faulting.

The purpose of the Cuvier Marine Project was to obtain further regional assessment of structural conditions in this part of the Carnarvon Basin, with particular attention to the off-shore portion of the Cape Cuvier anomaly where a gravity maximum trend coincides with a surface anticline. Devonian strata were encountered here at -1126 feet in Cape Cuvier No. 1 Well.

SEISMIC OPERATIONS

General

The marine reflection seismic survey described in this report was conducted as a two-boat operation using the 35-ton barge M.V. "Tamona" as recording boat and the 45-foot launch "Necede" as shooting boat. The 300-ton fishing vessel M.V. "Laakanuki" was used as a mother-ship from 22nd July onwards to reduce the travel time on the programme remote from the Learmonth Base Camp.

The positioning of the survey within and to the north of Exmouth Gulf was controlled by a Lorac radio navigational system. The remainder of the survey was related to shore beacons from which the position of the ship was determined by sextant angle measurements.

All shots were recorded on magnetic tapes which were played back in the Learmonth Base Camp to give variable area record sections corrected both for dynamic step-out and water depth. The interpretation was made from these. No conventional records were taken but a density modulated display unit gave an instantaneous dynamically-corrected time-section on board ship.

The reflection quality within the Fxmouth Gulf was fair to good in general although record quality deteriorated towards the north where reverberations due to multiple reflections from the sea bed obscured genuine reflection events. On the west coast lines the shallow reflections were good but the deeper reflection quality was poor and not continuous.

The method of locating the shot points will be described first, followed by descriptions of recording and shooting operations, record play-back and computing, and data quality. Operational statistics and details about the equipment are given in Appendix 1.

Locating Shot Points

Exmouth Gulf Area:

(i) Setting up the Lorac Network

Shot points in Exmouth Gulf were located by a Lorac radio navigation network. The Lorac land stations were sited (see Fig. 1) from considerations of programme coverage and accessibility; some loss of control was accepted for the small portion of the prospect area to the west of the Red baseline and north of the Red station because of lane expansion and the obliqueness of lane intersections. Thus Line L and those parts of Lines A, B, C and D to the west of Line M, which lie outside the zone of good Lorac accuracy, were positioned on the map by dead reckoning, with the Lorac readings used only to maintain control of line intersections.

All the Lorac ground stations were erected before the survey commenced and were not moved until they were dismantled at the termination of the survey. Permanent markers consisting of iron stakes set in concrete were placed at each mast position.

The co-ordinates of the three Lorac stations were determined by a triangulation survey and used to calculate the co-ordinates of the intersections of two families of hyperbolae. Lorac charts were drawn from these intersections. Pre-plots for every shot point were also computed which gave the Lorac and grid co-ordinates of points spaced at intervals of 1320 feet along the proposed lines of traverse.

The basic theory of the Lorac positioning system is given in Appendix 2. The co-ordinates of the Lorac transmitters and reference beacons are given in Appendix 3.

(ii) Land survey to locate Lorac transmitters and reference beacons

The grid co-ordinates of the Lorac transmitter masts and the reference beacons were determined between 18th and 27th May, prior to the commencement of the seismic survey. This work was based on the results of a first order geodetic triangulation survey carried out by Captain Doran for West Australian Petroleum Pty Limited in 1955.

Lorac Green and Centre stations were sited within the area covered by the Doran scheme; Lorac Green was fixed by observations from Giralia triangulation point and Lorac Centre from observations at South Base and Old Camp points.

Lorac Red station on North West Cape was outside the Doran scheme and triangulation was carried out to obtain co-ordinates for this station. The original field observations of Doran showed a computational error in the co-ordinates of Badjir triangulation point. The co-ordinates for Crestal point and revised co-ordinates for Badjir point were used for the Red station survey.

Three shore reference beacons were sited directly at the Doran points Sandy, North Base and Old Camp; a fourth beacon, Edna, was established by observations from these three points to provide an additional check on the sextant angle fix in the reference area at the commencement of the survey.

(iii) Determining position within the Lorac network

At the start of operations, the recording ship's position was fixed by sextant angles from the four shore reference beacons. The phase-meters on board ship were then set to the Lorac readings corresponding to that position and a run was then made to a particular position against the Learmonth jetty in order to establish a fixed Lorac reference point ashore. From this point, the Lorac signal was carried over the network. Anchored buoys were dropped at the end of each day's work to act as a known reference point for the beginning of the next day; this was necessary because the signal could not be held through the night. The buoy positions were used only to set the whole lane number; the phase-meters take up the correct interlane position automatically.

The ship's position, that is the position of the Lorac receiving antenna on the mast head, is fixed by noting the phase-meter readings at each shot on the mobile Lorac receiver and plotting these readings on the Lorac charts. The ship was navigated to bring the phase-meter readings as near as possible to the pre-plotted values, thus maintaining the correct shot point spacing along the line.

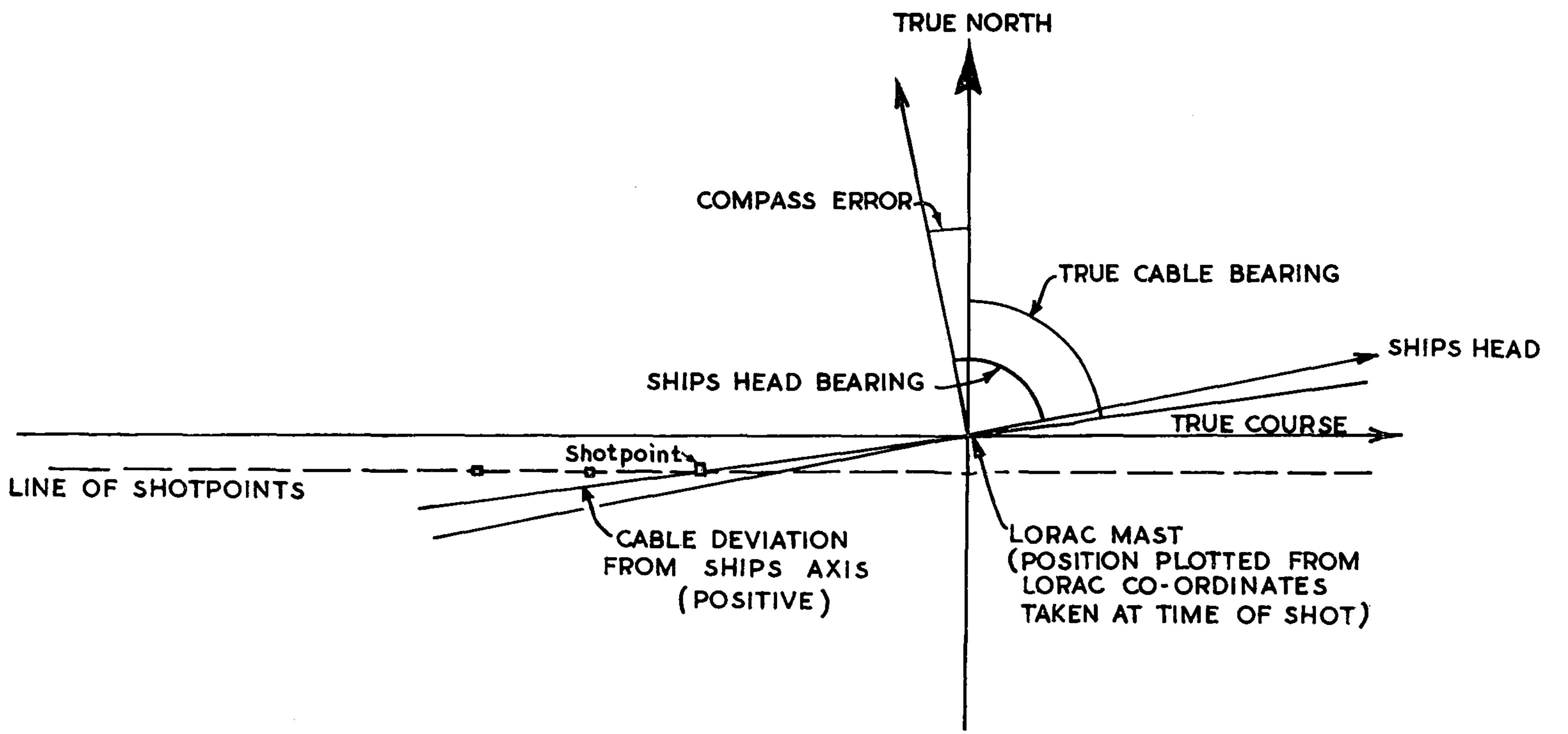
At each shot, the ship's position, heading, water depth, and cable deviation were tabulated. Cable deviation was read by sighting the cable from the ship's stern by alidade and measuring the angle between the cable and the line of the ship's head. (Clockwise deviation of the cable from dead astern was considered positive). The shot point was plotted on the location map 1615 feet behind the ship's position along the line of the true cable bearing (see Fig. 2).

The line of shot points relative to the ship's course varied continually, depending on currents, winds and tides.

Point Maud Area:

Ship's positions along the west coast were fixed by sextant observations on to shore beacons. It would have been uneconomical to move the Lorac system repeatedly for the reconnaissance lines outside the Exmouth Gulf Lorac network.

Fig. 2



SHOTPOINT LOCATION WITH RESPECT TO SHIP LOCATION

A triangulation scheme existed in the Point Maud area which had been carried out by H.M.A.S. Warrego and six beacons were sited at Warrego points. Four beacons north of the Warrego survey were established by triangulation carried out from 25th June to 6th July, using the Warrego-Lund Hill and Doublet Hill points as the base line. In addition, observations were made to establish co-ordinates for the Frazer and Ningaloo light houses.

Sextant angles to the shore beacons were observed from the ship "Laakanuki" which provided a more stable platform than the recording boat and could be stopped when necessary without interfering with the progress of the recording and shooting boats. The "Laakanuki" was normally positioned opposite the recording boat and about 250 feet away.

Sextant angles were observed approximately every five shot points. The recording ship's position was plotted allowing for the 250 feet offset between the "Laakanuki" and the recording boat. The shot point was then plotted 1615 feet astern of the recording ship's position along the line of the true cable bearing.

The location of the Maud Line A is considered reliable.

South of Point Maud:

No survey control was available in the remaining area and it was not possible to undertake an extensive survey of the remaining 114 miles of coastline before the seismic survey.

Beacons were set up in groups of three at intervals of about 20 miles along the coastline and the Cuvier lines were shot without the beacons being accurately surveyed in. A total of 19 beacons was used. All beacon positions were marked with a stake and tag bearing the beacon number.

(i) Beacons 11-14 and 21-29 were tied to permanent gravity stations by observing magnetic bearings and stadia distances. However the geographical grid and the coastline on the gravity maps do not agree with the locations based on aerial photographs, and the plotted positions of certain beacons fell in the sea. The error in the gravity station co-ordinates was not realized at the time of erection of the beacons.

(ii) Beacons A, 15, 18, 20 and Bulbarli well were positioned from 1 inch to 1 mile aerial photographs.

(iii) Beacons 16 and 17 were positioned by secondary survey from Beacon 15.

(iv) Beacon 19 was positioned by observations from Beacons 18 and 20.

(v) Beacons 17 and 20 were both sited at Government tellurometer traverse points but co-ordinates were not available (the survey was still in progress).

(vi) From Bulbarli well south to Beacon 19, no survey control existed and no permanent gravity stations were located.

The co-ordinates used for plotting the beacons on the location map are listed in Appendix 3. However, inasmuch as these beacon positions were not based on accurate data, the co-ordinates are unreliable.

Although sextant angles were observed on to the shore beacons whenever possible, the positions obtained from these observations were irregular and in disagreement with observations made by taking bearings with the ship's compass on to prominent topographical features and with dead reckoning computations.

It was felt that shot point positions would be more reliable if topographical features and coastline taken from aerial photographs were used rather than the beacon sights.

Hence positions for the Cuvier lines were plotted as follows:

(i) The east-west lines were positioned first since they were sited in areas of good topographical relief and their positions could be more reliably established by bearing observations (e.g., Line Q on Quobba Homestead, Line D on Bulbarli well).

(ii) The north-south lines were plotted using bearing observations together with dead reckoning (using the ship's compass course and speed) to obtain the best possible fix.

(iii) The position of the line intersections was controlled by dropping buoys (except for the intersection of Line L with Lines M and O).

(iv) The shot point interval was maintained as closely as possible to 1320 feet by controlling the time between shots; alterations of the timing were made whenever a reliable fix of the ship's position was obtained.

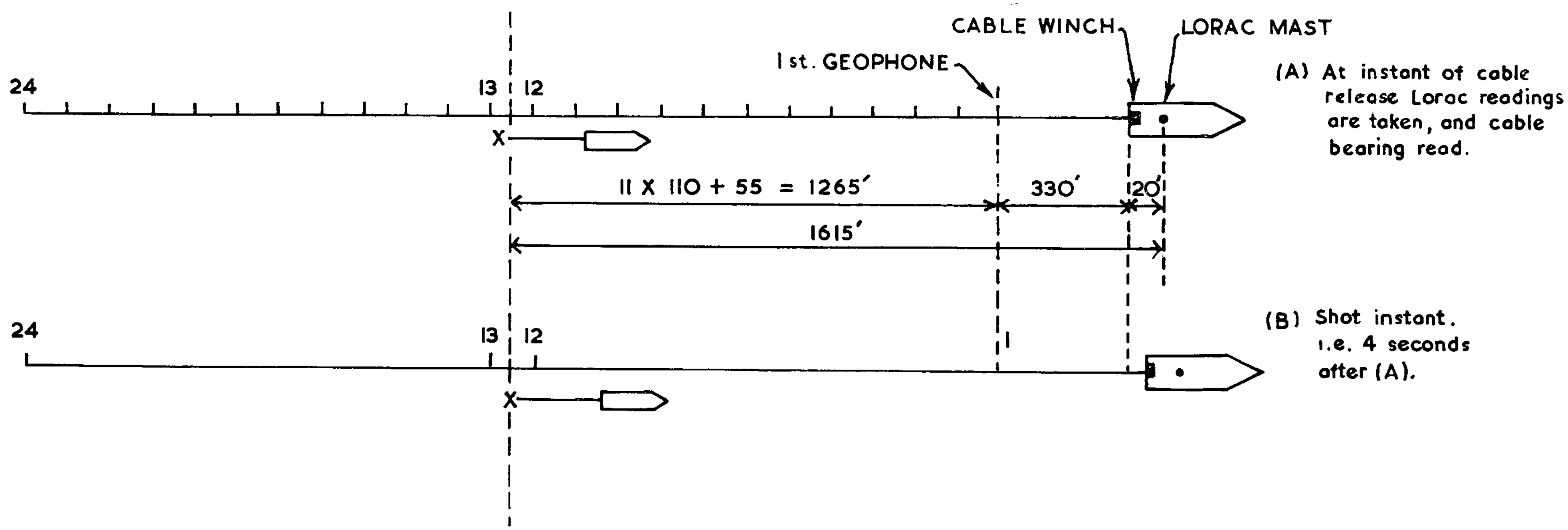
The position of the Cuvier lines is not considered reliable.

Recording Operation

Details of the recording system are given in Appendix 1.

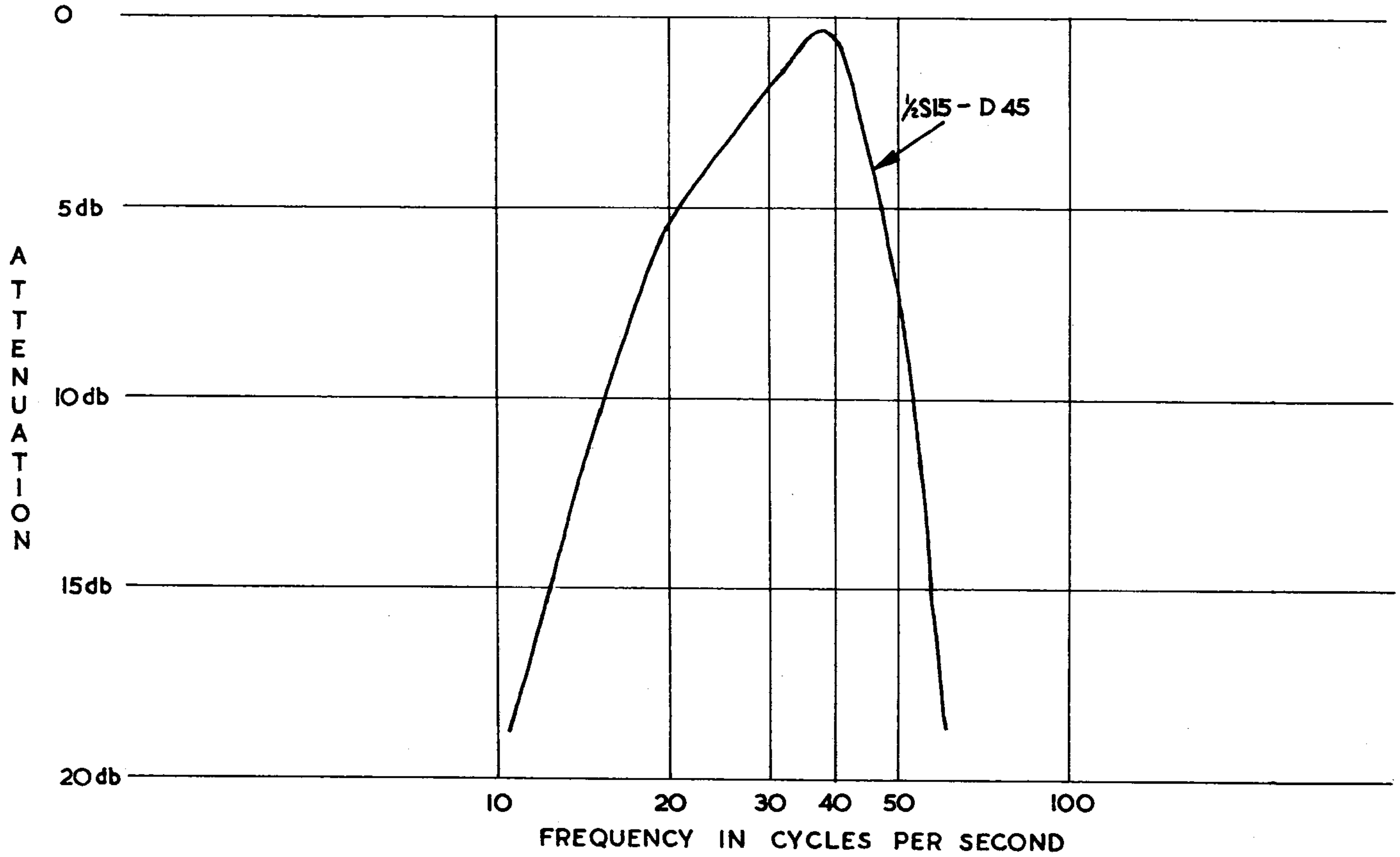
A straddle spread consisting of 24 Gulf pressure hydrophones equally spaced at 110-foot intervals was employed. The hydrophones were suspended 10 feet below the surface of the water from a buoyant stress member to which the conductor cable was attached. The charge was detonated from a separate firing line between stations 12 and 13.

In order to eliminate extraneous noise arising from the motion of the hydrophones through the water, the recording cable was released a few seconds before the shot, the ship's position being fixed at the instant of release (see Fig. 3). Freeing the recording cable also allowed the hydrophones to sink to their operational depth. Five seconds after the shot, the cable was wound in and held ready for the next shooting cycle. The whole cycle of events was performed automatically by a remote control unit triggered by the Lorac operator. The time between shots varied from 2 to 5 minutes according to the strength and direction of currents and winds.



POSITION OF CABLE AT TIME OF RELEASE AND AT TIME OF SHOT

Fig. 4



COMBINED RECORD AND PLAYBACK

FILTER RESPONSE CURVES FOR EXMOUTH AND CUVIER

MARINE PROJECTS

The energy from the hydrophones is fed into 24 model AAZ amplifiers with filter settings 15 to 65 cps. The amplifier output was split between an Electro-Tech DS-8 Magnetic Tape Recorder and a Density Modulated Display Unit (filtered 17-55 cps.). The low pass filter setting of 65 cps. partially compensates for the response curve of the pressure geophone which increases with frequency, so that the combination hydrophone and amplifier response is flat to frequencies higher than 100 cps. (see Fig. 4).

The DS-8 Magnetic Tape Recorder has 27 recording heads which were employed as follows:

Heads 1-24:	Hydrophone signals (Head No. 1 recording the signal from the geophone nearest the ship);
Head 25 :	100 cps. timing signal;
Head 26 :	Time break;
Head 27 :	Trigger pulse for play-back.

Continuous rolls of tape were used, up to 500 feet in length. The tape speed was 7 1/2 inches per second; about 4 1/2 seconds of seismic information after the time break was recorded.

A set of monitoring heads on the DS-8 recorder fed 15 transistorized amplifiers whose outputs fed a Visual Display Unit. This provided a check on the magnetic recording. Time break, trigger pulse, timing signal and the signal from tracks 1-12 (or alternately 13-24) were displayed on a perspex screen.

The DMD Unit gave a corrected 'time section' with about 4 1/2 seconds of information immediately. Alternate channels only were displayed. These records were used only to observe the progress of the survey (they were not permanent).

Shooting Operation

The shooting launch steamed parallel with the geophone cable opposite and approximately 100 feet away from a marker buoy on the cable; this launch towed a 150-foot firing line with a cone buoy supporting its free end. The explosive charges (16-2/3 lb. of Seismex or 10 or 20 lb. of Geophex) were slung on rings which slid down the insulated firing line to the cone buoy. A section of the firing line near the cone buoy was not insulated and thus a circuit was made from the blaster through the shooting cable to the charge, the sea water being used for the return to the ship's hull and blaster. The capacitative blaster put out 1500-2000 volts, sufficient to overcome the leakage and detonate the shot.

The shot was fired remotely by the interruption of a radio oscillator signal transmitted from the recording boat. Prior to the shot, this signal was demodulated and rectified by the shooter's radio and used to 'hold off' the blaster. A constant 2-millisecond delay was involved between the recorder time break and the shot detonation.

When a charge is detonated under water, a pocket of gas is formed which alternately expands and contracts as it rises in the water until it breaks the surface. It is the aim in marine seismic work to position the charge at such a depth that the first expansion will have been completed just as the 'bubble' breaks the surface. For normal charges this depth is four to five feet. If the charge is shallower than this a portion of the energy will be wasted at the surface and an 'air-shot' results; if the charge is deeper, successive expansions and contractions of the gas pocket will produce impulses which result in one or more sets of 'first breaks' appearing down the record, i.e., a 'bubble' shot.

Great difficulty was experienced in towing the 20 lb. charges of Geophex through the water at the optimum depth in the rough seas encountered off the West Coast; this resulted in a high percentage of 'air-shots' and 'bubble-shots'. Seismex did not present the same difficulty because of its symmetrical shape and constant drag but sufficient Seismex was not available and hence Geophex was used from 5th August onwards.

Playback

Variable Area Sections (VAX) were produced in the Learmonth Base Camp by playback from an Electro-Tech DS-7 magnetic recorder through a second set of 24 AAZ amplifiers using half-section 15 cps. high pass filters and double section 45 cps. low pass filters. All traces were played back unmixed.

When the tape was recorded the time break was fed to two heads on the DS-8 recorder. No. 26 was in line with the signal heads and No. 27 was displaced a distance equivalent to 240 milliseconds. On playback the pulse from trace 27 produced a pulse for triggering the VAX 240 milliseconds before the time break which ensured that the time break and first breaks appeared on the VAX sections.

Corrections were made for the 2-millisecond time break delay and for depth of water to reduce the data to a sea level datum. The water depth correction in milliseconds is:

$$\frac{2z-15}{4.95} - \frac{2z}{7.88}$$

where z is the water depth in feet. This correction assumes a charge depth of 5 feet, a hydrophone depth of 10 feet, a water velocity of 4950 feet per second (corresponding to a sea temperature of 63°F and a salinity of 33,000 ppm.) and a replacement formation velocity of 7880 feet per second. This correction was applied to all traces unless consecutive shot-point corrections differed by more than 2 milliseconds, in which case the correction difference was distributed across the intervening traces.

A single dynamic correction was employed throughout the prospect (see Figs 5 and 6). This correction approximates that given by the G.S.I. velocity function based on surveys in the Rough Range Nos 1 and 9 Wells.

Quality of Data

The reflection quality in the Exmouth Gulf area was generally fair. North of the Gulf itself the quality deteriorated and in the deeper waters strong water bottom reverberations obscured genuine reflection events in many cases.

Along the West Coast, the shallow reflections showed fair continuity but the deeper events were of poor quality and were not continuous.

Fig. 5

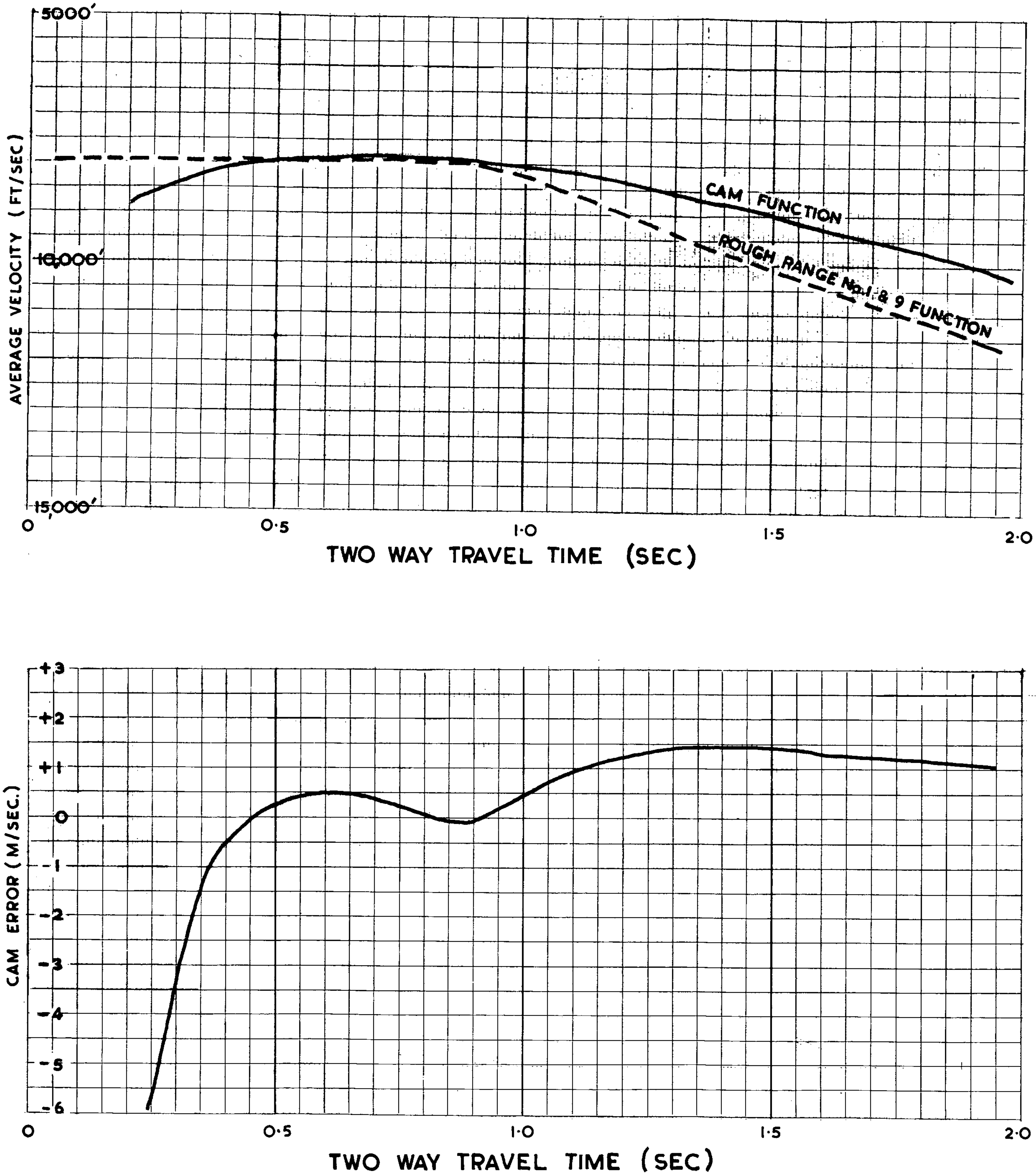
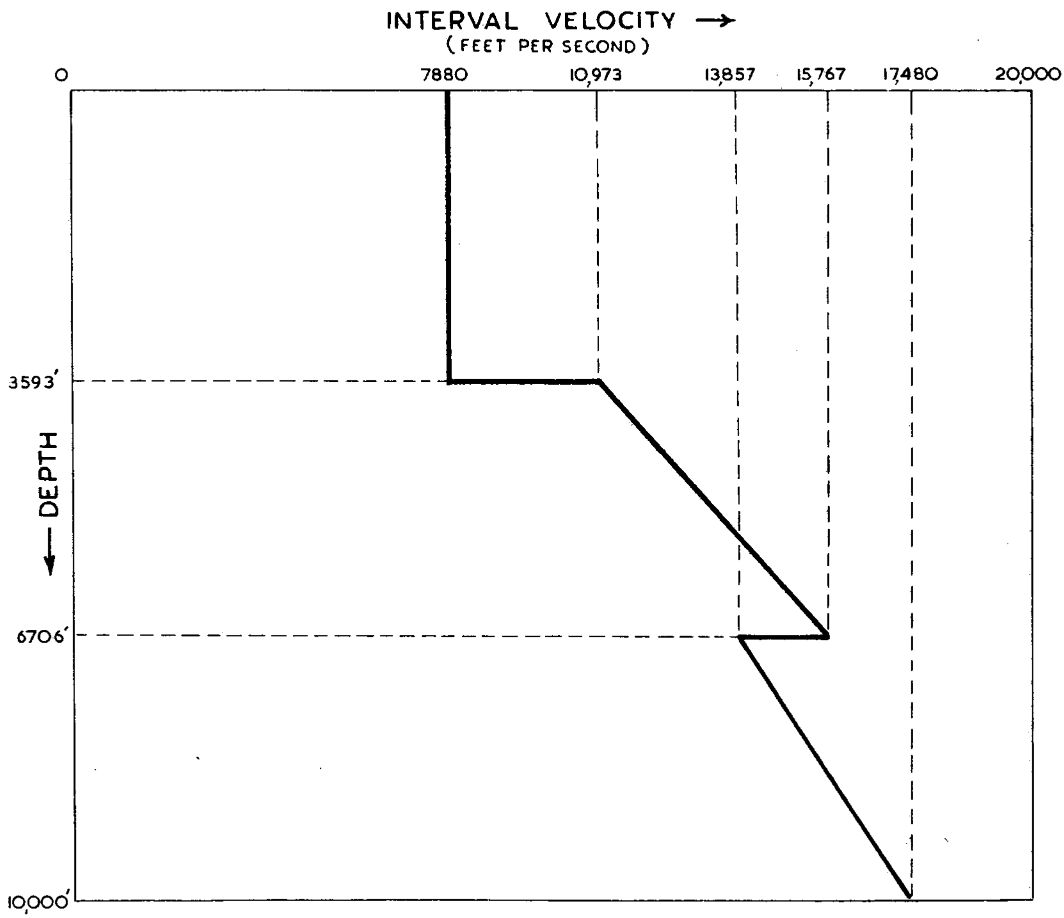

5000'
10,000'
15,000'
AVERAGE VELOCITY (FT/SEC)
CAM FUNCTION
ROUGH RANGE No. 1 & 9 FUNCTION
0
0·5
1·0
1·5
2·0
TWO WAY TRAVEL TIME (SEC)
+3
+2
+1
0
-1
-2
-3
-4
-5
-6
CAM ERROR (M/SEC.)
0
0·5
1·0
1·5
2·0
TWO WAY TRAVEL TIME (SEC)

Fig. 6



G.S.I. COMPOSITE VELOCITY FUNCTION
BASED ON ROUGH RANGE Nos. 1 & 9

The majority of the records shot in water deeper than 30 fathoms are characterized by very strong evenly spaced multiple reflections from the sea bed. Where the water depth is shallow, water bottom multiple reflections coalesce to produce a continuous sinusoidal waveform which is called ringing. The amplitude of ringing depends on the velocity contrast at the sea bed and on the water depth and energy frequency. Little ringing was observed within the Gulf proper, possibly because the sea bed is covered with silt which provided a smooth velocity transition for the seismic pulse and consequently a low reflection coefficient. Some of the Cuvier records show ringing, notably between SP's 2507-2514 on Cuvier Line K. This ringing is recognized by the characterless appearance of the records and by considerable curvature (because of the low average velocity of the multiple path).

INTERPRETATION

Previous Work

Geological and geophysical data have demonstrated to a fair degree the geological structure and history of the Carnarvon Basin and shown that oil source sequences, reservoir beds, impervious cover beds, and structural areas of interest exist.

The Bureau of Mineral Resources commenced detailed geological surveys of the Carnarvon Basin in 1948 (Condon et al., 1955, 1956). Reconnaissance seismic and gravity surveys followed in 1950 (Thyer, 1951; Francis, 1951). West Australian Petroleum Pty Limited commenced seismic work in the area in 1952 (Johnstone, 1953; Watson, 1953) and the BMR did a limited detailed gravity survey of Rough Range (Dooley and Everingham, 1956). Exploratory drilling commenced in 1953, oil being discovered in the Cretaceous at Rough Range No. 1 Well. Subsequently a number of other tests were drilled in the North West Cape area. In 1956 West Australian Petroleum Pty Limited ran a reconnaissance gravity survey over most of the Carnarvon Basin and the Bureau of Mineral Resources flew an aeromagnetic survey (Garrett, 1956). Gravity traverses over Cape Range were made in 1958 (Garrett, 1958). West Australian Petroleum Pty Limited conducted seismic work in the North West Cape area from 1955 to 1957 and in 1961 (Linehan, 1958; Anderson and Johnstone, 1957 a, b, c, d, e; Hoelscher and Rempel 1961 a, b; and Hoelscher and Linehan, 1958).

In the North West Cape area four structural trends were delineated; the Cape Range, west flank of the Dingo Syncline (the Learmonth Trend), Rough Range and Giralia Range trends. The Rough Range and Learmonth trends were investigated by wells and with disappointing results. The rugged limestone topography of Cape Range hindered the extension of seismic coverage. However, the Rough Range-Cape Range area has been rated as one of the most prospective areas for commercial oil accumulation in the Carnarvon Basin. The subject survey was conducted in order to obtain regional information about the structure and stratigraphy, especially in a regional sense, and to map the extensions of the trends which have been defined on land.

Exmouth Gulf Area

Three structure maps have been made of the Exmouth Gulf area. The best defined of these is the "B" Horizon which is believed to approximate the Basal Cretaceous unconformity. The "A" Horizon is frequently a reasonably strong reflector and is believed to be within the Upper Cretaceous Korojon Calcarenite. The pre-Cretaceous map consists of phantoms in various areas which are not related to each other. The time intervals between these three structure maps have also been mapped.

All of the mapping has been done in seismic time. Approximate depths corresponding to the seismic travel time can be obtained from the velocity surveys run in the Rough Range Nos 1 and 9 Wells (see Fig. 7).

Horizon "A" - within the Upper Cretaceous Korojon Calcarenite (Plate 1)

The Horizon "A" map is based on a persistent reflection band which is readily identifiable on most of the variable area record sections. Correlations to previous land surveys (e.g., G.S.I. Line 39 and S.S.L. Line A-12) suggest that this band of reflections represents a horizon from within the Upper Cretaceous Korojon Calcarenite. The structure at Horizon "A" depth is a subdued representation of the deeper Horizon "B" structure.

A closed syncline (northern extension of Dingo Syncline) immediately east of Cape Range reaches a maximum depth of one second (approximately 4000 feet) on Exmouth Line E. The axis of this syncline continues north and passes to the west of a closed anticlinal structure (Anomaly A) near the Muiron Islands. A closure of 25 milliseconds (150 feet) is possible at a depth of -2700 feet.

Data to the north-west are unusable because of reverberations from the sea bottom. To the east of Anomaly A regional west dip was mapped.

A possible west-dipping fault (Fault N) cuts this horizon at shot point G-9. This fault may be the northern continuation of the Paterson Fault.

Seismic loops were closed without difficulty and the map is considered reliable.

Horizon "B" - Basal Cretaceous Unconformity (Plate 2)

The variable area record sections (especially dip lines, such as Exmouth Line J) show a marked angular unconformity at a time of about one second (about 4000 feet). Horizon "B" was carried on a persistent reflection band which occurs immediately above this unconformity evidence. For the most part, this band of reflections is continuous and of fairly distinctive character. However, where water depths exceed 20 to 30 fathoms (as in the north-west part of Exmouth Gulf) low frequency reverberations from the sea bottom mask the reflection. A higher frequency ringing (showing excess normal moveout) sometimes masks the reflection in shallow water.

Correlation to previous land surveys - such as G.S.I. Line 39 and S.S.L. Line A-12, and recent seismic work in the Cashen area (Hoelscher and Rempel, 1961b) - suggests that this reflection band represents the unconformity at the base of the Cretaceous. At the same time it is believed to represent closely the structural picture of the Lower Cretaceous Birdrong Formation.

The main structural feature of this map is a closed syncline which is parallel to and immediately east of the Cape Range structure. On Exmouth Line G the axis of the syncline reaches a depth of approximately -7000 feet or 1400 milliseconds. To the south, it continues into the Dingo Syncline. To the north it separates two anticlinal structures.

These anticlinal structures are the north-plunging Cape Range Anticline and a south-plunging anticline near the Muiron Islands (Anomaly A). The former shows 200 milli-
2 seconds of reversal on Exmouth Line D while the latter, controlled by Exmouth Lines B, C and

D, shows a maximum of 60 milliseconds of reversal on Line B. Unfortunately, north of Line B the data are unusable because of water reverberation from the sea bottom. However strong north dip on the northern part of Line O suggests that Anomaly A may close to the north.

The area east of the Muiron Islands shows regional west dip on this horizon. Minor folding appears to be superimposed on this regional west dip and small structural anomalies may exist which this reconnaissance work has not defined.

Apart from the extreme north and north-western part of the area, closures around the seismic loops were good and this map is considered a reliable presentation of regional structure.

Pre-Cretaceous Structure (Plate 3)

Reflection quality beneath Horizon "B" is fair to poor, containing semi-continuous reflection bands which cannot always be correlated, especially where faulting is evident. Structural relief is great and any single reflection band soon becomes either too deep or lost at the Basal Cretaceous unconformity. Pre-Cretaceous structure in the Exmouth area is therefore represented by a composite map of three different horizons, phantoms "C", "D", and "E".

Three structural "highs" are evident in the pre-Cretaceous section:

Anomaly B is a large structure at approximately -10,000 feet controlled by 330 milliseconds (about 2000 feet) of faulted reversal (Fault L) on Exmouth Line B. Closure to the north-west is inferred because of the unusable data, but the assumption is reasonable in view of regional north-west dip.

Anomaly C is a small closure up-plunge from Anomaly B. It is controlled by Line C and may rise to 1500 milliseconds (about -7500 feet).

Anomaly D is a possible closure at -2400 milliseconds (about -16,000 feet) on a north-east plunging anticlinal axis which is closely associated with Fault J in the south-west part of the area. A possible extension of the Rough Range Fault was mapped from Line J to Line E. Subsidiary faults are labelled H and K.

The Cape Range Anticline on Exmouth Line D has 240 milliseconds of reversal (2000 feet) at Phantom "C" depth. Plunge appears to be south.

Apart from the Cape Range axis, there is little co-incidence between Cretaceous and pre-Cretaceous structure.

Time Interval between Horizons "A" and "B" (Plate 4)

This map of the time interval between Horizons "A" and "B" shows that in the area to the north of Exmouth Gulf, i.e., between the Muiron Islands and Onslow, there is little thickening or thinning in the Cretaceous. However, within the Gulf proper there is a regional divergence to the west. The rate of this divergence decreases in the syncline which was mapped at both horizons. The result is an apparent thinning in the axial region of the syncline. Previous work on land has shown that the Rough Range Fault has normal movement (west block down) in the Palaeozoic with possible reverse movement in the Mesozoic section. The effect of the latter movement on the Mesozoic section is sometimes thinning on the hanging wall and thickening on the footwall. Hence, the anomalous thinning in the axial region may be associated with the Rough Range Fault which underlies the east flank of the syncline.

Thinning occurs over both the Cape Range Anticline and Anomaly A.

There was insufficient reliable data for construction of a time interval map to illustrate thinning within the pre-Cretaceous section. There are, however, no striking time interval anomalies other than apparent thinning over structural "highs".

Coastal Area (Frazer Island-Point Maud-Bernier Island)

Horizon "B" - Basal Cretaceous Unconformity (Plate 2)

Maud Line A is not tied to any previous work but an angular unconformity occurs at a time comparable to that of the Basal Cretaceous unconformity mapped on G.S.I. Lines 15 to 33 in the Point Cloates area. The band of reflections immediately above the unconformity on Maud Line A is therefore believed to be correlatable to the "B" Horizon band of the Exmouth Gulf area.

Maud Line A shows that moderate folding has imposed a relief of up to 540 milliseconds (approximately 2000 feet) on this horizon. A syncline through shot point 2102 and an anticline through shot point 2120 are believed to be the south-western extension of the Dingo Syncline and Rough Range Anticline respectively. The plunge of these structures is unknown without dip-strike control, but 165 milliseconds of west dip was mapped at Horizon "B" depth on Cuvier Line A. The contouring on Maud Line A therefore implies west plunge.

Phantom Horizon "B" was carried south to the Cuvier lines from Maud Line A. The controlling reflection band is of fair quality although semi-continuous as far south as Cuvier Line J. Data on Line K are extremely poor and the mapping has been carried to Lines L, M, N, O and P in the Cape Cuvier area by character correlations.

Unusable data occur on Line R (shot points 2799-2817). However, the unconformity and its overlying reflection band are easily recognizable beyond this zone, especially on Line S (Line S shot points 2120-2937).

The structure between Point Maud and Red Bluff is gently undulating. Plunge to the west is suggested on Cuvier Lines D, G and J.

At Cape Cuvier a broad north-plunging syncline is faulted on its east flank by Fault P.

Phantom Horizon "B" is at approximately -2200 feet, west of Fault P while the base of the Cretaceous was encountered at -1055 feet to the east in Cape Cuvier No. 1. Displacement therefore is down-to-the-west. Tertiary and Cretaceous folding in the Salt Marsh area of the Carnarvon Basin is commonly due to reverse movement along pre-existing Palaeozoic normal faults and therefore it is believed that the down-to-the-west displacement of Horizon "B" may be due to reverse movement along an east-dipping Palaeozoic fault. Fault P was not identified south of Line Q.

A south-west plunging anticlinal structure occurs near the intersection of Lines R and S. Line S to the west of this intersection is featureless except west of Bernier Island where there is 100 milliseconds of east dip.

Pre-Cretaceous Structure (Plate 3)

The Cape Range and Rough Range anticlines were clearly mapped by Maud Line A. Both axes may be faulted. Although the record quality is generally poor, a semi-continuous phantom was constructed in order to estimate the possible size of the anticlinal dip reversals.

The Cape Range axis is opposite Frazer Island, six miles north of Point Cloates. At a time of 1300 milliseconds (about -6000 feet) the probable north-west dip is 80 milliseconds (about 1000 feet), and the south-east dip is about 150 milliseconds (1400 feet) but it may be as much as 350 milliseconds (3000 feet). There is a minor, probably faulted, anticlinal axis opposite Point Cloates.

The record section across the Rough Range Anticline has the characteristic steep south-east flank that has been frequently mapped on land. At a time of 1300 milliseconds the south-east flank has 190 milliseconds (about 1600 feet) of dip. The north-west flank has a four-mile wide zone of almost no reflections which indicates possible faulting. The total recorded north-west dip into the Dingo Syncline is about 300 milliseconds (2500 feet).

Pre-Cretaceous reflections south of Point Maud are generally poor. This coastal traverse is parallel to the regional north-south strike of the surface Tertiary folding (at least) and the small amount of pre-Cretaceous folding suggests that this series of coastal lines may also be along the pre-Cretaceous strike.

Anticlinal reversals were recorded near Cape Cuvier and Cape Farquhar. Although the reflections are very poor in the Cape Cuvier area a tied loop slightly increases the certainty of the interpretation shown of a small anticline which could have 20 milliseconds (about 200 feet) of closure over about one square mile. Lines M and O have anomalously steep dips at their eastern ends caused by Fault M which has been interpreted as a small reverse fault that is responsible for the folding (at the surface) of the Cuvier Anticline.

The possible anticlinal axis off Cape Farquhar has fair north-east dip (200 milliseconds plus) but the validity of the south-west dip of 110 milliseconds is doubtful because of the increasing water depth and the poor character of the reflections on this flank.

Conclusions

Horizons "A" and "B" are essentially conformable in the Exmouth Gulf area, the main structural feature being a syncline immediately east of the Cape Range Anticline. A closed anticlinal structure may exist in the vicinity of the Muiron Islands. The only other large reversal mapped was the northern extension of the Cape Range Anticline. The interval map between Horizons "A" and "B" shows regional westward thickening with moderate thinning over the structural "highs".

Unlike the Cretaceous and Tertiary sediments, the pre-Cretaceous section is displaced by a series of down-to-the-west faults, one of which is the Rough Range Fault. Three anticlinal anomalies were mapped, the largest having 2000 feet of reversal. The interval map suggests thinning over the anomalies.

Along the coast Horizon "B" is generally featureless except for a prominent syncline (Dingo Syncline?) and the probable south-western extension of the Rough Range Anticline.

The Cape Range and Rough Range anticlines were each clearly mapped in the pre-Cretaceous section. A possible closed anticline was mapped near Cape Cuvier.

REFERENCES

ANDERSON, R.C., and JOHNSTONE, M.H.,	1957a:	Yardie Creek refraction profiles A and B. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).
ANDERSON, R.C., and JOHNSTONE, M.H.,	1957b:	A reflection and refraction seismograph survey - Yanrey North Prospect. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).
ANDERSON, R.C., and JOHNSTONE, M.H.,	1957c:	Refraction profile A - Yanrey North Prospect. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).
ANDERSON, R.C., and JOHNSTONE, M.H.,	1957d:	Rough Range Prospect refraction profile C. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).
ANDERSON, R.C., and JOHNSTONE, M.H.,	1957e:	Rough Range refraction profiles A and B. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).
CONDON, M.A., JOHNSTONE, D., PERRY, W.J., and CRESPIN, I.,	1955:	The Cape Range Structure, Western Australia. Bur. Min. Resour. Aust. Bull. 21.
CONDON, M.A., JOHNSTONE, D., PRICHARD, C.E., and JOHNSTONE, M.H.,	1956:	The Giralia and Marrilla Anticlines, North-West Division, Western Australia. Bur. Min. Resour. Aust. Bull. 25.
DOOLEY, J.C., and EVERINGHAM, I.B.,	1956:	Detailed gravity survey of Rough Range Anticline near Learmonth, Western Australia. Bur. Min. Resour. Aust. Rep. 43.

FRANCIS, G.F., 1951: North-West Basin area, W.A. Report on field conditions and gravity and seismic work up to October, 1951. Report for West Australian Petroleum Pty Limited (Unpubl.).

GARRETT, M.J., 1956: Bureau of Mineral Resources aeromagnetic survey (416) of selected areas in the Carnarvon Basin. Report for West Australian Petroleum Pty Limited (Unpubl.).

GARRETT, M.J., 1958: Gravity survey of the Cape Range. Report for West Australian Petroleum Pty Limited. (Unpubl.).

HOELSCHER, P.A., and LINEHAN, A.L., 1958: Rough Range refraction profile D. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).

HOELSCHER, P.A., and REMPEL, A., 1961a: Seismograph survey - Paterson Project. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).

HOELSCHER, P.A., and REMPEL, A., 1961b: Seismograph survey - Cashen and Ranger Projects. Report for G.S.I. and West Australian Petroleum Pty Limited (Unpubl.).

JOHNSTONE, W.E., 1953: Field report on reflection survey of Rough Range - Exmouth Gulf area. S.S.L. Report for West Australian Petroleum Pty Limited (Unpubl.).

LINEHAN, A.L., 1958: Seismograph survey, the North-West Cape area. G.S.I. Report for West Australian Petroleum Pty Limited (Unpubl.).

THYER, R.F., 1951: Gravity reconnaissance (1950), North-West Basin, Western Australia. Bur. Min. Resour. Aust. Rec. 1951/69 (Unpubl.).

WATSON, S.J., 1953: Field report on reflection survey, Rough Range, Exmouth Gulf Area, Western Australia. S.S.L. Report for West Australian Petroleum Pty Limited (Unpubl.).

APPENDIX 1

FIELD OPERATIONS

General Data

Operator:	West Australian Petroleum Pty Limited, 251 Adelaide Terrace, Perth, W.A.
Contractor:	Seismograph Service Limited, Keston, Kent, England.
Location:	Exmouth Gulf and offshore from Frazer Island to Bernier Island, Western Australia.
Basin:	Carnarvon
Tenement Holder:	West Australian Petroleum Pty Limited
Details of Petroleum Tenement:	Permit to Explore 28H
Date survey commenced:	15th July, 1961
Date survey completed:	20th August, 1961

Statistics

	Exmouth 74 Project	Cuvier 75 Project	Total
No. of days on survey	28	9	37
No. of days shooting	23	7 1/2	30 1/2
No. of days travelling	1	1	2
No. of days lost because of bad weather	2	1/2	2 1/2
No. of days lost because of repairs to craft	2	-	2
Coverage in miles	539	214	753
No. of shots fired	2171	858	3029
No. of shots fired per shooting day	94.4	114.4	99.3 (average)
Total hours worked	237 1/2	83-2/3	321-1/6
Hours Lorac	217	-	217
Hours recording	124-2/3	47-1/12	171 3/4
Hours travelling	74-1/6	27-1/3	101 1/2
Hours cable-handling	23 1/2	7 3/4	31 1/4
Hours referencing	12-1/6	-	12-1/6
Hours loading explosives	3	1	4
Hours lost	5-1/3	3/4	6-1/12
No. of shots fired	2171	858	3029
No. of misfires	35	16	51
No. of premature shots	4	0	4
Boosters used	1749	-	1749
Boosters jettisoned	-	51	51
Detonators used	2181	877	3058
Detonators jettisoned	-	8	8
Geophex used (pounds)	8620	12370	20990
Seismex used (pounds)	30000	-	30000

Personnel

Seismic: (Seismograph Service Limited)

Party Chief:	R.D. Lugg
Chief Computer:	F. Muir
Computer/Playback Operator:	N.J. Delaney
Observer:	E.J. Bassett
Observer:	A.R. Edgington
Assistant Observer:	R.N. Briggs
Surveyor:	J.E. Rogers
Shooter:	R.A. Hennings
Shooter:	R.Kilby

Lorac:

Network Chief:	H.W. Gayfer
Operator:	P.J. Lambe
Operator:	I.C.A. Harris
Operator:	L.R. Coussens
Operator:	J.N. Murtagh
Operator:	P.A. Watson

West Australian Petroleum Pty Limited Representatives:

D. Johnstone
D.N. Smith
P.A. Hoelscher

Vessels used

M.V. "Tamona" - landing craft type barge, 35 tons, 2 x 5-cylinder Gardner diesel engines, draught 4 feet - used as recording boat.

M.V. "Necede" - 45-foot launch, 1 x 6-cylinder Gray Marine diesel engine, draught 5 feet - used as shooting boat.

M.V. "Laakanuki" - 300 tons, 120 feet length, draught 8 1/2 feet, fishing vessel - used as mother ship from 22nd July to accommodate and mess personnel.

Prior to chartering the M.V. "Laakanuki", a fast speed boat was used to reduce travel time. This craft proved unsuitable as it was unable to maintain speed except under the calmest of conditions.

Recording Equipment

AAZ Amplifiers:

Gain of 120 dB from 500 ohm input to output plate.

Frequency range from 25 to 105 cps. filtered, and from 3.5 cps. in the refraction position.

High pass filters of 25, 35, 45, 65 cps.

High pass slope selection: 18 and 34 dB/octave with OUT and REFRACTION positions.

Low pass filters of 35, 45, 65, 85, 105 cps.

Low pass slope selection: 21 and 38 dB/octave.

A.G.C. threshold of 1 microvolt.

A.G.C. range of 54 dB for 6 dB output variation.

Maximum input signal of 5 millivolts for no visible distortion.

Short and normal A.G.C. speeds.

Suppression of 50 dB by one master control.

G.C.F. Gulf Pressure Geophones:

Frequency response (at a depth of 2 feet), rising with frequency at the rate of 6 dB/octave.

Output of 104 dB below 1 volt per dyne per square centimetre at 125 cycles per second.

Electro-Tech DS-7 Tape Recorder:

Signal to noise ratio greater than 46 dB rms. to rms. at peak magnetization, 30 cps.

Static time correction of $\pm$ 50 milliseconds.

Maximum dynamic time correction of 100 milliseconds.

Maximum correction rate of 300 milliseconds per second.

Overall timing accuracy of $\pm$ 0.5 millisecond.

Head spacing of 0.250 inch.

Track width of 0.140 inch.

Tape speed of 7 1/2 inches per second.

Tape width of 7 1/2 inches.

Electro-Tech DS-8 Tape Recorder:

Similar to the DS-7 recorder, but lacking facilities for static and dynamic time corrections.

Variable Area Cross-Section Recorder:

24 variable area traces at a time on 9 1/2" film.

Image width of all 24 traces is 2/3".

Timing marks at 0.1 second intervals are recorded before and after each section.

APPENDIX 2

LORAC POSITIONING SYSTEM

The Lorac radio navigation system depends upon phase angle measurements taken in the interference pattern produced by two continuous wave transmitters. Two transmitters produce an interference pattern of hyperbolic form with the two stations as foci. The addition of a third station produces a second set of hyperbolae and the three stations are positioned so as to form a grid across the working area.

The frequencies of Red, Centre, and Green stations (although controlled within close limits) are free running. The frequencies of the three stations are separated by audio frequencies, Red and Centre 240 cps., Green and Centre 600 cps. A fourth station, known as Reference, receives a signal from all three stations and transmits a reference signal on a separate channel. Because the Reference receiver remains at a fixed position the reference signal remains steady except for frequency variations at one of the stations. The mobile receiver aboard ship receives signals from both the Reference transmitter (Reference signal) and from the C.W. stations (Position signal). These signals are applied to two phase meters which compare the variable Position signal to the virtually constant Reference signal and take up a position which indicates the position of the Mobile receiver within a lane. Slight variations at one of the C.W. Stations will be reproduced in both the Reference and the Position signal and will, therefore, cancel.

A counter in the phase-meter adds or subtracts lanes as the ship moves through the network, thus keeping count of changes in the ship's position. When operations commence from a point with known Lorac (hyperbolic) co-ordinates, the counters continually give the ship's position.

Lorac is capable of high accuracy. At the frequencies used, (just under two megacycles) a wavelength is about 500 feet and therefore, lane separation on the baseline is 250 feet. The lanes expand away from base lines. A repeatability of approximately 20 feet can be achieved. Accuracy depends on the accuracy of the station co-ordinates as well as on correct lane count.

APPENDIX 3

LAND REFERENCE POINTS

(Grid Co-ordinates are Australian Mapping Grid in Yards)

Lorac Points

Lorac Transmitters:	Eastings	Northings
Lorac Green	192,817.0	2,278,316.9
Lorac Centre	181,433.6	2,226,302.5
Lorac Red	208,971.9	2,200,329.4
Lorac Reference Beacons:		
Sandy	183,391.1	2,232,102.8
North Base	183,743.6	2,229,466.0
Edna	184,959.1	2,227,719.4
Old Camp	185,934.2	2,226,343.1
Lorac Reference at Learmonth Jetty:	185,571.9	2,227,327.9

Beacons along West Coast

Maud Area (Fixed by triangulation):		
No. 1	147,969	2,161,963
No. 2	150,188	2,155,459
No. 3	152,319	2,150,262
No. 4	153,690	2,144,637
No. 5	155,747	2,139,049
No. 6	156,155	2,133,604
No. 7	155,623	2,123,431
No. 8	153,442	2,118,805
No. 9	150,747	2,116,778
No. 10	150,673	2,112,733
Cuvier Area (Unreliable):		
No. 11	150,558	2,108,008
No. 12	152,931	2,096,421

APPENDIX 3 (Cont'd)

	Eastings	Northings
No. 13	153,108	2,093,327
No. 14	154,080	2,088,018
Bulbarli Well	149,120	2,067,450
No. 15	132,110	2,051,000
No. 16	131,770	2,048,020
No. 17	129,850	2,043,000
A	117,940	2,021,250
No. 18	117,830	2,013,100
No. 19	117,150	2,009,150
No. 20	114,200	2,005,120
No. 21	116,321	1,990,109
No. 22	113,707	1,985,056
No. 23	110,127	1,982,785
No. 24	111,919	1,965,379
No. 25	112,508	1,961,413
No. 26	112,462	1,957,462
No. 27	117,225	1,944,208
No. 28	121,646	1,940,674
No. 29	124,901	1,936,747

APPENDIX 4

LINES SHOT

Shotpoints	Project 74 Exmouth Line	Date Shot	
5- 59	G	July	15
61- 131	H		16
133- 154	G		17
155- 173	N		17
174- 201	N		18
202- 253	J		18
257- 277	O		18
279- 332	O		19
333- 358	F		19
389- 411	E		20
412- 440	O		20
442- 503	F		21
504- 557	M		21
558- 566	N		22
567- 684	N		23
685- 753	N		24
754- 777	A		24
779- 838	O		24
840- 922	O		25
923- 988	E		25
989-1073	M		26
1074-1094	C		26
1095-1110	C		27
1111-1146	L		27
1147-1190	D		30
1191-1263	D		31
1264-1292	R		31

Shotpoints	Project 74 Exmouth Line	Date Shot	
1294-1318	C		31
1320-1366	R	August	1
1367-1399	C		1
1402-1438	C		2
1439-1480	M		2
1481-1520	B		2
1521-1607	B		4
1608-1629	Q		4
1630-1694	Q		5
1695-1774	A		5
1776-1849	A		6
1850-1890	M		6
1891-1930	B		7
1931-1970	L		7
1971-2011	A		7
2012-2050	L		9
	Maud		
2051-2176	A		11

APPENDIX 4 (Cont'd)

Project 75

Shotpoints	Cuvier Line		Date Shot
2177-2195	A	August	12
2196-2269	B		12
2270-2322	C		12
2323-2342	D		13
2343-2375	E		13
2376-2423	F		14
2424-2438	G		14
2439-2490	H		15
2491-2506	J		15
2507-2552	K		15
2553-2610	L		16
2611-2632	M		16
2633-2657	N		16
2658-2678	O		16
2679-2704	O		17
2705-2776	P		17
2777-2798	Q		17
2799-2889	R		18
2890-3034	S		19

APPENDIX 5

ADDITIONAL DATA FILED IN THE

BUREAU OF MINERAL RESOURCES

The following additional data relating to the Exmouth Gulf Marine Seismic Survey have been filed in the Bureau of Mineral Resources, Canberra, and are available for reference:

(i) Map C-2758-D6: Depth of water, Exmouth Marine (74) and Cuvier Marine (75) Projects.

(ii) Record sections consisting of the following:

Exmouth Lines A to R;

Maud Line A;

Cuvier Lines A to S.

(iii) Lorac pre-plot co-ordinates

(iv) Lorac computation data sheets

(v) Observer's reports.

Plate 1
ONSLOW
SALT MARSH
ANOMALY 'A'
CUVIER Nº1
BERNIER ISLAND
CARNARVON
SHARK BAY
TIME V. DEPTH
BASED ON ROUGH RANGE No. 1 & 9 VELOCITY FUNCTION
MILLISECS
FEET
ONLY EVERY FIFTH SHOTPOINT SHOWN ON MARINE SEISMIC LINES
SEISMIC LEGEND
LOCALITY
TOPOGRAPHICAL SYMBOLS
GRAVITY AND AEROMAGNETIC LEGEND
MISCELLANEOUS
SCALE IN MILES
REVISIONS
WEST AUSTRALIAN PETROLEUM PTY. LIMITED
SEISMOGRAPH SERVICE LIMITED
SEISMIC MAP
EXMOUTH MARINE (74) PROJECT
ISOCHRON MAP
HORIZON 'A'
? UPPER CRETACEOUS KOROJON CALCARENITE
PARTY CHIEF.......... R. LUGG
GEOL-GEOPHYS......D.N.SMITH
CONTOUR INTERVAL 25 MILLISECS.
14 NOV. 1961
DR.BY F.B.
TR.BY F.B.
CH.BY
DATE
26 SEP 61
C-2758-D1
TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL MAPPING GRID

Plate 2
ANOMALY 'A'
ONSLOW
SALT MARSH
CARNARVON
BERNIER ISLAND
SHARK BAY
CUVIER Nº1
TIME V DEPTH
BASED ON ROUGH RANGE Nº 1 & 9
VELOCITY FUNCTION
MILLISECS FEET
SCALE IN MILES
WEST AUSTRALIAN PETROLEUM PTY. LIMITED
SEISMOGRAPH SERVICE LIMITED
SEISMIC MAP
EXMOUTH MARINE (74) & CUVIER MARINE (75) PROJECTS
ISOCHRON MAP
HORIZON 'B'
?BASAL CRETACEOUS UNCONFORMITY
PARTY CHIEF: R. LUGG
GEOL. GEOPHYS.: D.N. SMITH
CONTOUR INTERVAL 25 MILLISECS
1 SEP 61
DATE 26 SEP 61
C-2758-D2
TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL MAPPING GRID
ONLY EVERY FIFTH SHOTPOINT SHOWN ON MARINE SEISMIC LINES
SEISMIC LEGEND
GRAVITY AND AEROMAGNETIC LEGEND
MISCELLANEOUS
LOCALITY
TOPOGRAPHICAL SYMBOLS

REVISIONS	WEST AUSTRALIAN PETROLEUM PTY. LIMITED

SEISMOGRAPH SERVICE LIMITED

SEISMIC MAP

EXMOUTH MARINE (74) & CUVIER MARINE (75) PROJECTS

ISOCHRON MAP

HORIZONS 'C','D' AND 'E'

PRE-CRETACEOUS

PARTY CHIEF.........R. LUGG
GEOL-GEOPHYS.......R.A. HOELSCHER
CONTOUR INTERVAL ·050· SECS.
14 NOV. 1961

DR. BY F.B.	DATE		
TR. BY F.B.	26 SEP 61		C-2758-D3
CH. BY			

TRANSVERSE MERCATOR PROJECTION — AUSTRALIAN NATIONAL MAPPING GRID

Plate 4
ONSLOW
SALT MARSH
CARNARVON
BERNIER ISLAND
SHARK BAY
TIME V. DEPTH
MILLISECS
FEET
SCALE IN MILES
ONLY EVERY FIFTH SHOTPOINT SHOWN ON MARINE SEISMIC LINES
SEISMIC LEGEND
FAULT SYMBOLS
GRAVITY AND AEROMAGNETIC LEGEND
MISCELLANEOUS
LOCALITY
TOPOGRAPHICAL SYMBOLS
REVISIONS
WEST AUSTRALIAN PETROLEUM PTY. LIMITED
SEISMOGRAPH SERVICE LIMITED
SEISMIC MAP
EXMOUTH MARINE (74) PROJECT
TIME INTERVAL MAP
HORIZON 'A' – 'B'
PARTY CHIEF........ R. LUGG
GEOL-GEOPHYS.... D.N.SMITH
CONTOUR INTERVAL 25 MILLISECS.
17 NOV 61.
DR.BY F.B.
TR.BY F.B.
CH.BY
DATE
26 SEP 61
C - 2758 - D4
TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL MAPPING GRID