COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS



RECORD No. 1966/131

# BMR 12 (COCKROACH) WELL VELOCITY SURVEY,

## NORTHERN TERRITORY 1964

*by*

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*(Geophysicist, Institut Francais du Petrole, Bureau des Etudes Geologiques, Paris)*

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ILLUSTRATIONS

## SUMMARY

In November 1964, the Bureau of Mineral Resources Seismic Party No. 1 carried out a velocity survey in BMR 12 (Cockroach) well, Northern Territory, which had been drilled to 4000 feet and logged using sonic and other logging methods. The time/depth values obtained in the velocity survey were in good agreement with those obtained by integration of the sonic log. A curve showing the variation with time of the coefficient of reflection calculated from the sonic log showed an outstanding feature, which appeared to correlate with the best reflection recorded on an experimental seismic traverse nearby. According to the geological interpretation of the well log, this reflection arises from velocity changes near the boundary of the Arrinthrunga Formation and the Marqua Beds at a depth of 2,721 feet.

## 1. INTRODUCTION

Since 1956, the Bureau of Mineral Resources (BMR) has carried out reconnaissance geological and geophysical investigations of the Georgina Basin in Queensland and the Northern Territory. These investigations included a programme of stratigraphic drilling by the Geological Branch and seismic surveys by the Geophysical Branch in 1963 and 1964.

As part of this programme, BMR 12 (Cockroach) Well was drilled to 4000 feet near Cockroach Waterhole in the south-west of the Georgina Basin, Northern Territory, in 1964 (Plate 1).

The following velocity measurements were made in this well:

(1) A sonic log was carried out by Schlumberger Seaco Inc. and was made in two runs: the first run from 69 to 800 feet on 13th September 1964 and the second from 700 to 3993 feet on 19th November 1964.

(2) A well velocity survey, to calibrate the results from the sonic log, was carried out in November 1964 by the BMR Seismic Party No. 1, which was in the area to make a brief experimental seismic survey (Chenon, 1966).

This report describes the well velocity survey and discusses the results of the sonic logs and the velocity survey in relation to each other.

## 2. SURFACE VELOCITIES

Measurements made during the well velocity survey yielded estimates of the surface velocities. The accuracy of the observed times cannot be better than 1 millisecond. Therefore, high accuracy for the computed velocities cannot be expected. Nevertheless, because of the number of records obtained, the statistical accuracy is satisfactory.

### Vertical velocities (Plate 2)

The mean value for the vertical velocity of the first fast layer is about 11,000 ft/s. Since all the holes were shot below the first low velocity layer, it is difficult to obtain a precise estimate of its vertical velocity. However, the values obtained indicate that the velocity is less than 3000 ft/s.

### Horizontal velocities

An idea of the horizontal velocity in the first fast layer may be obtained from the first breaks recorded from the geophones located near the well (Plate 3). The observed values from the different records are in agreement and no horizontal anisotropy is observed. Slight differences between the observed values of first-break times result from variations in the weathered-zone thickness, which may be computed from first-break and uphole times.

For times of about 10 to 20 milliseconds, the accuracy cannot be better than 10% because of the error of about 1 millisecond in reading the times. The value for the horizontal velocity of the first fast layer is about 15,000 ft/s. It is similar to that found during the seismic survey in this area.

The approximate thicknesses of the weathered layer at the various shot-points near BMR 12 were computed as :

Shot-points 1 and 2 : 20 feet
Shot-point 3 : 21 feet
Shot-point 4 : 20 feet

## 3. WELL VELOCITY SURVEY

The main purpose of the well velocity survey was to supply time values for calibration in absolute time of all the relative times computed from the sonic log. The field operation was very simple and took only a few hours.

### Shothole details

The layout of shot-holes is shown in Plate 3. One hole to a depth of 150 feet and three holes to depths of 30 feet were sufficient.

It was necessary to have an uphole time measured from 150 feet in order to know the vertical travel-time near the surface, over an interval in which the sonic log was incomplete. Knowing the direct travel-time from 150 feet to the surface it was possible to tie the time/depth values derived from integration of the sonic log to the surface.

A shot depth of 30 feet was chosen so that all shots would be below the weathered zone.

The shot-points were placed close to the well head to avoid the need for move-out corrections. In this case the move-out corrections were less than 0.5%, the distance from the well head being 50 or 100 feet.

In order to detect any travel-time variation resulting from different paths through the near-surface layers, one shot-hole (shot-point 4) was drilled 100 feet from the well head symmetrically opposite the main group of shot-holes (Plate 3).

### Charge

The first charge used was 2½lb. This proved to be insufficient and the charge had to be increased to 20 lb, which is unusually heavy for this type of measurement. The well was very 'noisy'; the Schlumberger pulley was placed very high on the rig because of the length of the sonic log/gamma ray instrument. The wind in the cable increased the noise.

### Geophone layout

In addition to the well geophone, six field geophones were used on the surface as indicated on the layout diagram (Plate 3). Their object was to detect the existence of any horizontal anisotropy and to provide values for the surface velocity computations. The uphole geophone was placed at the shot-hole used.

Results from the geophone placed at the well are erroneous because the area was covered by dry mud.

### Recording

Eight parameters were recorded on thirteen traces. In particular, the well geophone response was recorded with three different gains. The time break was also recorded on three traces, two of them on the top of the record and one at the bottom, in order to check the error of the time lines. This error is negligible - less than 1 millisecond.

### Shooting

The well velocity survey was carried out between 7 a.m. and 1 p.m. The first shot was at 9.35 a.m. Eleven shots were recorded for six measurements. Ten of them are usable, of which one is questionable, and one is not usable.

Surface corrections

All the well geophone times were corrected to the surface elevation of 721 feet. The weathered zone was theoretically replaced by a layer with a velocity of 11,000 ft/s (see Plate 2). This was done by correcting each uphole time to the velocity curve (Plate 2) and by subtracting 5 milliseconds from the values obtained to bring the velocity curve back to the origin. The charge length was neglected.

The depths given by the Schlumberger operator are considered to be accurate. The depth correction used results from the elevation of the rotary table above ground surface (8 feet).

Computation

The computations were done in a conventional way and are shown in Plate 3. No move-out correction was made. The corrected times are plotted in Plate 4.

4. SONIC LOG

Evaluation of the accuracy of the measurements

Before using the results of the sonic log (Plate 6), a careful study of the calibration of the instrument was made with the following results :

Run 1. Here, the errors seem very small for the values yielded by the integrator and for the velocity values. All depth values were corrected to the surface elevation. It is unfortunate that the calibration was done for a level of 100 microseconds when most of the values are about 50 microseconds. The manual integration of the function 1/V yields less than a 2% error with respect to the mechanical integration.

Run 2. Here, the calibration for the velocities seems correct, but a 4% error appears on the time values given by the integration for a time of 50 microseconds. The calibration for 100 microseconds yields an error of less than 1%. It was, therefore, necessary to correct the time values yielded by the integration by +4% most of these values being in the 50-microsecond band. The manual integration of the function 1/V yields an error of 3% with respect to the integrator. Since this second check was less precise than the first one, an adjustment of 4% was used for the computation.

The comparison between the two runs showed two other errors:

(1) The lag on the depth value is about 3 feet. This error is negligible.

(2) The lag on the velocity value, when the curves are matched, is considerable, i.e. about 5 microseconds/foot. This difference introduced an error in the integrated value. Thus it is necessary to use the corrected integrator values to compute the velocity, not the values read on the curve 1/V.

Computations from the sonic log

The computations were made according to standard practice. The corrections mentioned above were used. A time/depth curve and a velocity/depth curve were plotted (Plate 4) and the reflection coefficient was plotted against time (Plate 5).

The time/depth curve is calibrated with the values obtained from the well velocity survey. The agreement between these is reasonable. The differences between the values from the sonic log and from the conventional velocity survey are always less than 2 milliseconds, less than the error in measurements. Only the 1000-ft value is very doubtful, but here the record quality is poor and the reading of the time is questionable.

The coefficient of reflection R was computed from the formula:

$$R = (V_2-V_1)/(V_2+V_1)$$

It was plotted at the same scale as the seismic records in two-way time for two different sampling times. A sampling interval of 5 milliseconds one-way time yielded a curve effectively filtered with a low-pass filter of 100 c/s. A sampling interval of 10 milliseconds one-way time yielded a curve effectively filtered with a low-pass filter of 50 c/s.

After ignoring the first 200 milliseconds, where any reflected events on the field seismic records are overshadowed by refracted arrivals and hole noise, the following events are observed on the coefficient of reflection plots (Plate 5):

1. A strong, good reflection at 0.35 second. It has a wide frequency spectrum since it can be observed as well with the 50-c/s filter as with the 100-c/s filter. The power of resolution of the 100-c/s filter is much greater. The corresponding velocity contrast can be seen on the sonic log starting at 2720 feet. According to the geological interpretation of the well log, this event comes from the top of the Marqua Beds. It is interesting to note the difference in character of the velocity variations above and below the interface between the Arrinthrunga Formation and the Marqua Beds. The event can be recognised on the reflection seismogram shot near the well (Plate 5).

2. A series of oscillations between 200 and 270 milliseconds observed with the 100-c/s filter becomes only one oscillation with the 50-c/s filter (10-millisecond sampling interval).

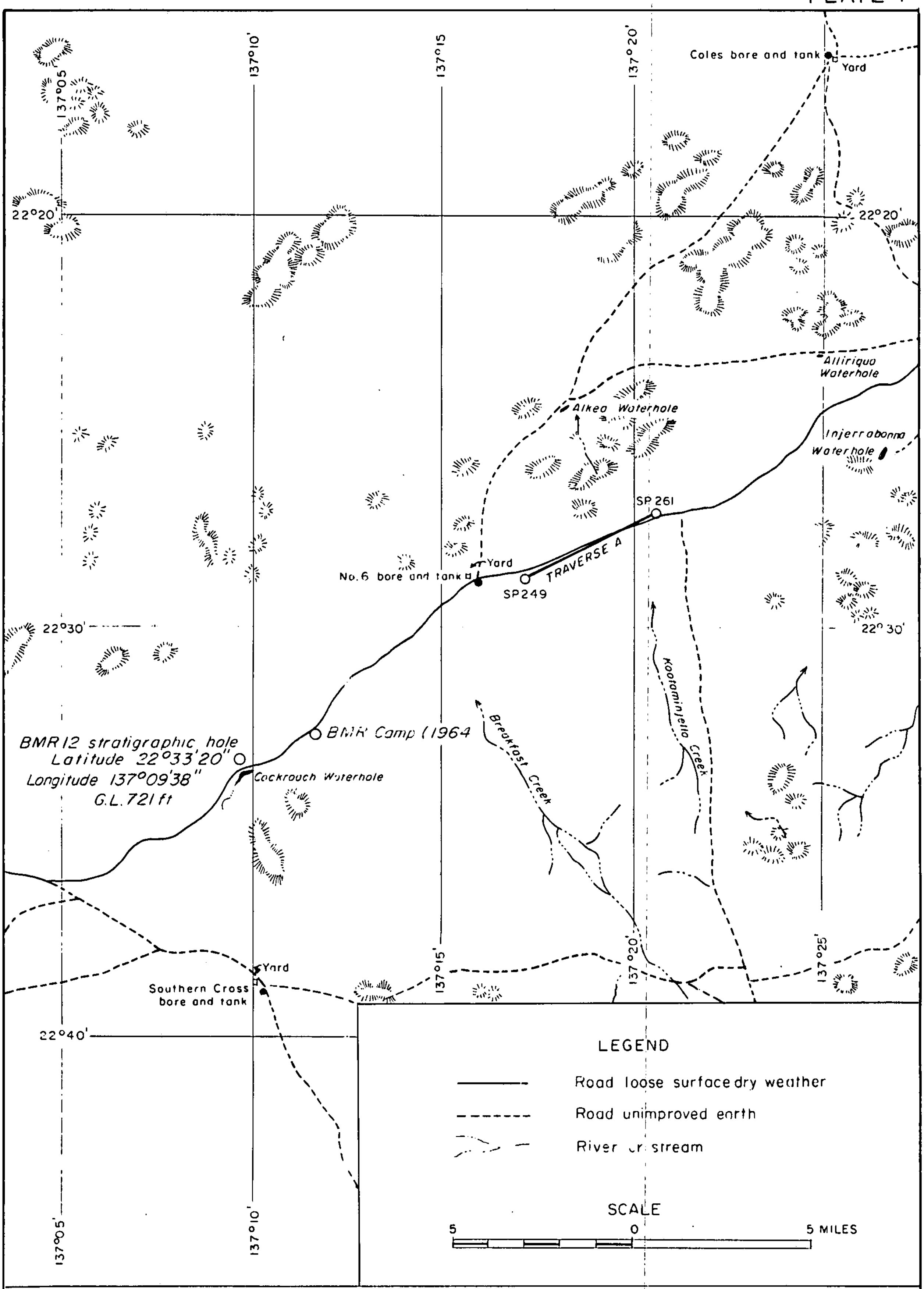
## 5. CONCLUSION

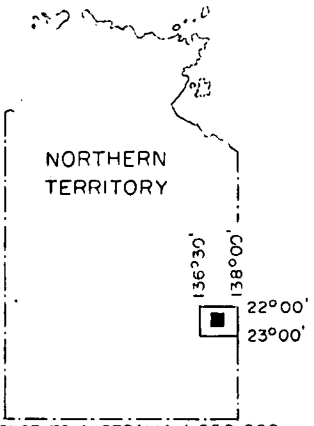
The velocity study in BMR 12 is complete. It comprises a conventional well velocity survey and a sonic log. The agreement between the results is satisfactory considering the errors found (and subsequently corrected) in the sonic log. The computation of the reflection coefficient leads to the prediction of a good reflection at 2700 feet, which should be found on field seismograms near BMR 12.

## 6. REFERENCE

CHENON, C., 1966 Cockroach Waterhole area, experimental seismic survey, NT 1964. Bur. Min. Resour. Aust. Rec. 1966/75.

PLATE I




REFERENCE TO AUSTRALIA 1:250,000
STANDARD MAP SERIES : TOBERMORY

BMR 12 (COCKROACH)

WELL VELOCITY SURVEY

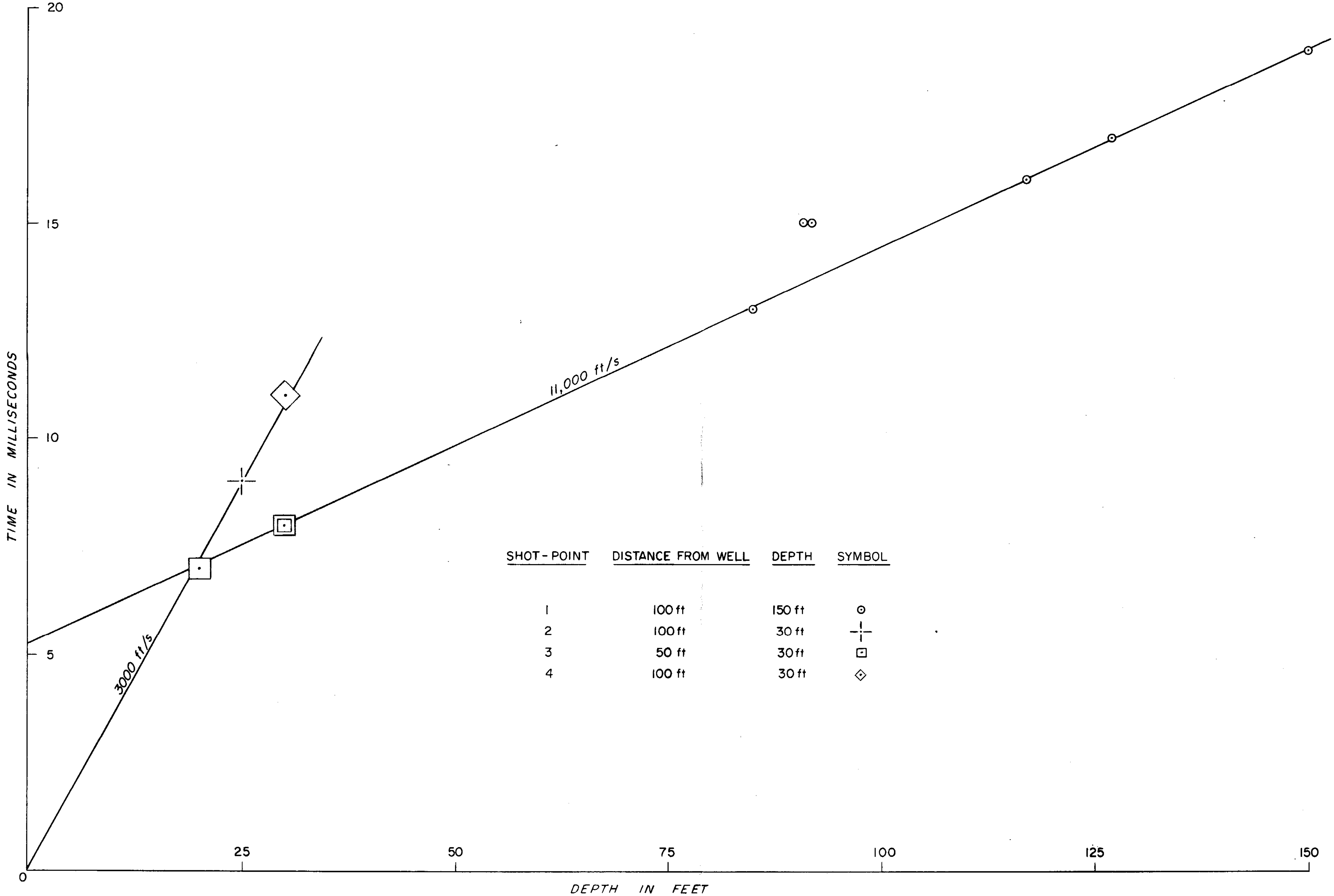
# LOCALITY PLAN

*Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics*

F53 / B3 - 113

TO ACCOMPANY RECORD No. 1966/131

PLATE 2




# UPHOLE TIMES

TO ACCOMPANY RECORD No. 1966/131

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F53/B3-112

# WELL VELOCITY SURVEY DATA SHEET

WELL NAME BMR 12 — OWNER BMR — WELL LOGGING CONTRACTOR SCHLUMBERGER SEACO INC

LOCALITY COCKROACH, NT — ADDRESS 203 COLLINS ST MELBOURNE — ADDRESS

COORDINATES 22° 33' 20" S, 137° 09' 38" E — DRILLING CONTRACTOR W.L. SIDES — TYPE AND NUMBER OF LOGGING UNIT

DATE OF SURVEY 20TH NOVEMBER 1964 — ADDRESS 422 COLLINS ST MELBOURNE — LOGGING UNIT OPERATOR J ABSIL

ORGANIZATION SUPERVISING VELOCITY SURVEY BMR — SEISMIC INSTRUMENTS MAKE TEXAS INSTRUMENTS, TYPE 7000B — WELL GEOPHONE MAKE TIC, TYPE 1 COMPONENT, No — B.M.R. REPRESENTATIVE — DATA CALCULATION J S DAVIES

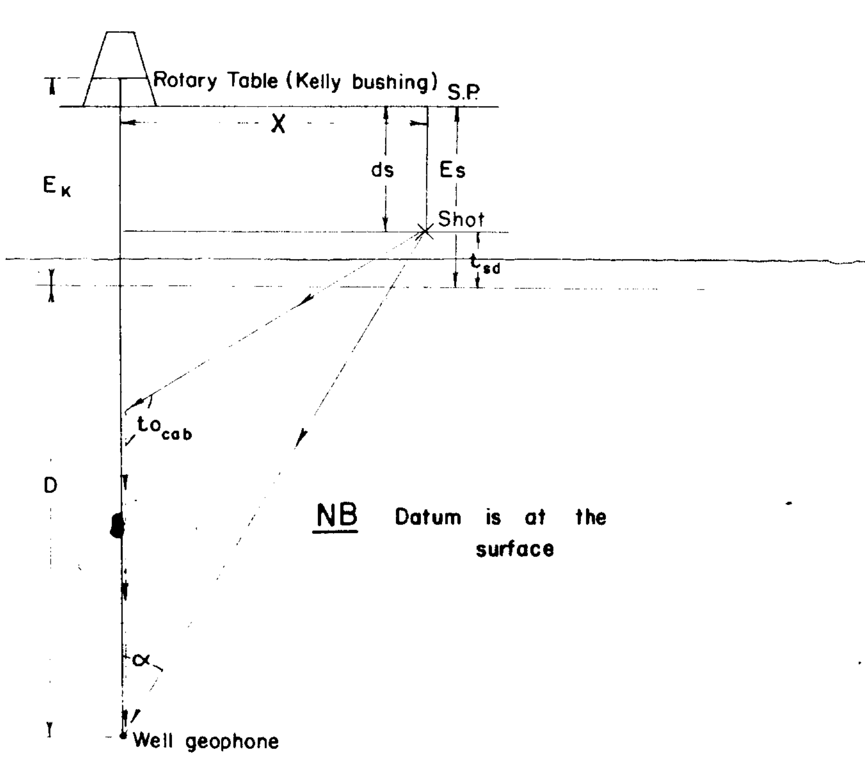
ADDRESS 203 COLLINS ST MELBOURNE

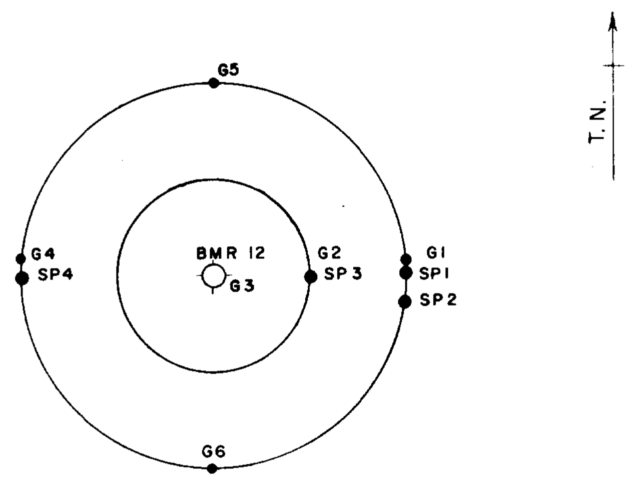
SURVEY SUPERVISOR C CHENON (I.F.P.)

$E_K$ = 8ft  Vo =  Ve = 11,000 ft/s  Do = 722 ft  $\rho m$ =  B.H.T. or Tm =  Vcab (Manufacturer) = 11,100 ft/s, (Test) =  Cable Depth Accuracy =

| SHOT No. | $E_K$+D | D | S.P. | X | chge | Es | ds | $t_{sd}$ | α | $tv_1$. Gr. | $tv_2$. Gr. | $tha_1$. Gr. | $tha_2$. Gr | $thb_1$. Gr. | $thb_2$. Gr. | $t_{RG}$ or $to_R$ | Gr. | $\Delta t_{RG}$ or $\Delta to_R$ | $t_{cab}$ | $to_{cab}$ Gr. | $t_o$ or $t_o - \frac{t_{sd}}{\cos\alpha}$ | Cos. α | tc | Va | ΔD | Δtc | Vi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2B | 500 | 492 | 3 | 50 | 2½ | 0 | 30 | −3 | 6° 10' | 38 | | | | | | | | | | | 38 | ·994 | 41 | 12000 | | | |
| 9F | 1000 | 992 | 1 | 100 | 20 | 0 | 90 | −8 | 6°20' | 50 | | | | | | | | | | | 50 | ·994 | 58 | 17100 | 500 | 17 | 29400 |
| 8E | 2000 | 1992 | 1 | 100 | 20 | 0 | 97 | −9 | 3°01' | 122 | | | | | | | | | | | 122 | ·998 | 131 | 15200 | 1000 | 73 | 13700 |
| 3A | 2600 | 2592 | 1 | 100 | 5 | 0 | 150 | −14 | 2°21' | 155 | | | | | | | | | | | 155 | ·999 | 169 | 15350 | 600 | 38 | 15800 |
| 7D | 3000 | 2992 | 1 | 100 | 20 | 0 | 98 | −9 | 1°59' | 180 | | | | | | | | | | | 180 | ·999 | 189 | 15850 | 400 | 20 | 20000 |
| 6A | 3990 | 3982 | 4 | 100 | 10 | 0 | 30 | −3 | 1° 27' | 245 | | | | | | | | | | | 245 | ·999 | 248 | 16100 | 990 | 59 | 16800 |

REMARKS:




LAYOUT OF WELL SHOT-POINTS AND GEOPHONES (G)

SCALE IN FEET




DEFINITIONS OF SYMBOLS AND COLUMN HEADINGS:

- $E_K$+D — Depth of well geophone below rotary table Kelly bushing
- Do — Elevation of Datum above sea level
- $E_K$ — Elevation of rotary table Kelly bushing referred to datum plane
- D — Depth of well geophone below datum plane
- ΔD — Difference between depths of well geophone for two shots
- S.P. — Shot-point
- X — Distance of shot-point from centre of well
- chge — Pounds weight of explosive fired
- Es — Elevation of shot-point referred to datum plane
- ds — Depth of shot below surface
- Vo — Weathering velocity
- Ve — Subweathering velocity
- $t_{sd}$ — Vertical time from shot to datum plane. Normally = $\frac{Es-ds}{Ve}$
- α — Vertical angle subtended by straight line from shot to well geophone = $\tan^{-1}\frac{X}{D+Es-ds}$
- $tv_1$ — Vertical component first break time for well geophone
- $tv_2$ — Vertical component first trough time for well geophone
- $tha_1$ — Horizontal component A first break time for well geophone
- $tha_2$ — Horizontal component A first trough time for well geophone
- $thb_1$ — Horizontal component B first break time for well geophone
- $thb_2$ — Horizontal component B first trough time for well geophone
- RG — Reference geophone
- $t_{RG}$ — Reference geophone time
- $\Delta t_{RG}$ — Reference geophone correction time. In general practice $tv_1 - \Delta t_{RG}$ is best estimate of $t_o$
- $to_R$ — Reference reflection time
- $\Delta to_R$ — Reference reflection correction time. In general practice $tv_1 - \Delta to_R$ is best estimate of $t_o - \frac{t_{sd}}{\cos\alpha}$
- $t_{cab}$ — Calculated cable break time
- $to_{cab}$ — Observed vertical component cable break time
- $\Delta to_{cab}$ — Difference between $to_{cab}$ corresponding to well geophone depth difference ΔD
- $t_o$ — Accepted time for straight line ray from shot to well geophone. In idealized case $t_o$ would equal $tv_1$, $tha_1$ and $thb_1$
- tc — Vertical time from datum plane to well geophone = $t_o \cos\alpha - t_{sd}$
- Va — Average vertical velocity between datum plane and well geophone = $\frac{D}{tc}$
- Δtc — Difference between tc corresponding to well geophone depth difference ΔD
- Vi — Interval velocity over depth difference ΔD $\left(= \frac{\Delta D}{\Delta tc}\right)$
- Vcab — Logging cable velocity = $\frac{\Delta D}{\Delta to_{cab}}$
- T.D. — Total depth of well referred to rotary table Kelly bushing
- $\rho m$ — Density of mud in well
- Tm — Temperature of mud returns when circulating in hole
- B.H.T. — Bottom hole temperature i.e. temperature at T.D.
- Gr. — Grading of certainty and accuracy of time:
  - 1st grade: G means: Certain that true formation break selected; P " :Some doubt " " " "
  - 2nd grade: G " :Accuracy less than ± ·001 seconds; F " : " " " ± ·003 "; P " : " " " ± ·005 "
  - ? grade means very doubtful certainty or time

FIELD INSTRUCTIONS:

1. Do not use outer sheath of cable or other neutral lead as geophone lead.
2. Before running geophone in well, shoot buried detonator under well geophone or do tap test to check all connexions and polarity.
3. While running geophone into well fasten small geophone and a clamp to cable and strike a vertical blow on the clamp to check manufacturer's figure for cable velocity.
4. As soon as cable and shallow formation velocities are sufficiently well known, and before survey proceeds, construct calculated cable break curves for all shot-point offsets.
5. Do complete calculation as survey progresses and watch for cable breaks.
6. Where possible obtain copies of C.V.L., electric and lithologic logs and fill in all information required on this sheet.

AFTER G 85 − 113

F53/B3-99

PLATE 3

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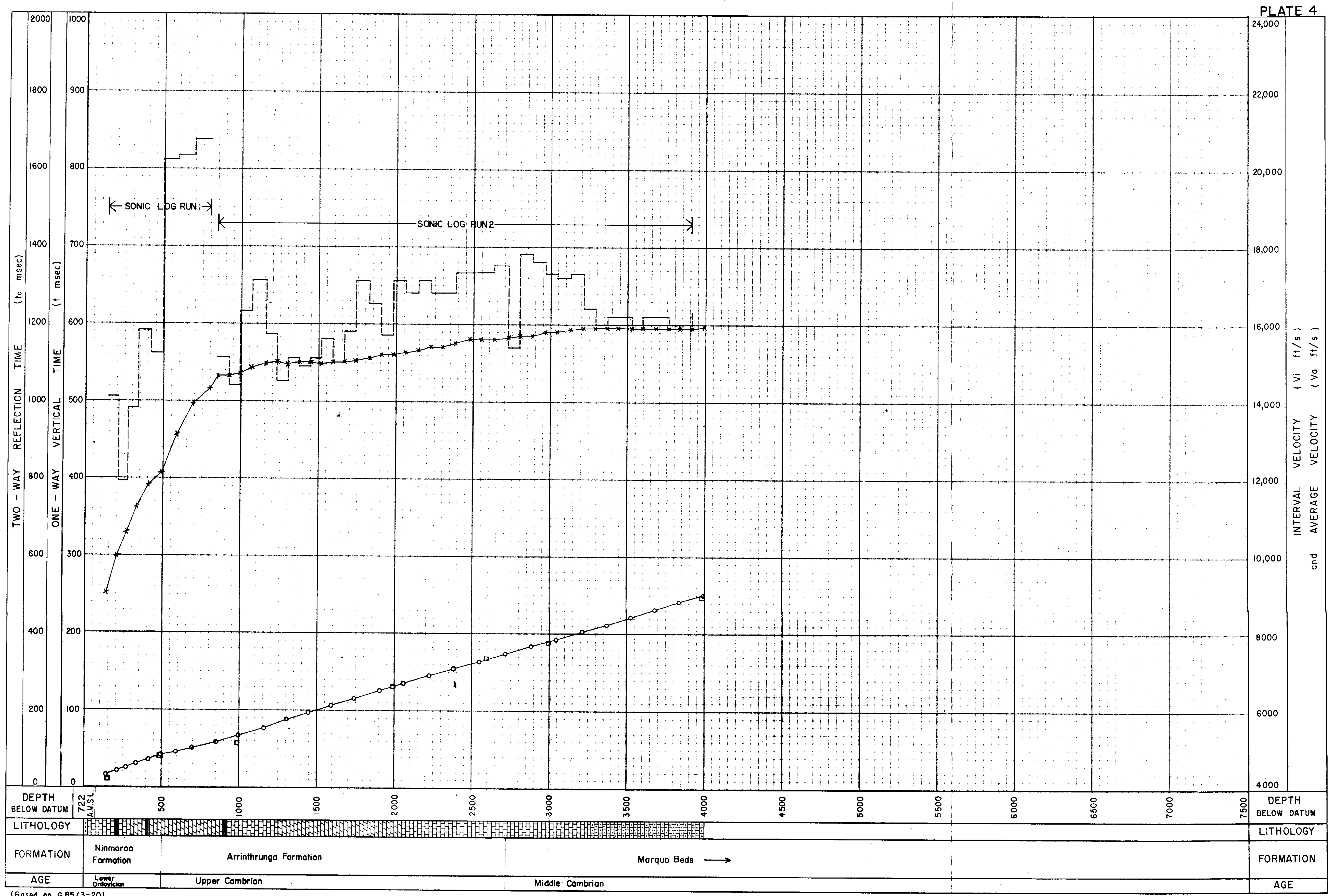
TO ACCOMPANY RECORD No. 1966/131

PLATE 4




(Based on G 85/3-20)

□ Time / depth from well velocity survey
—o— Time / depth curve from sonic log
Interval velocity (Vi)
—x— Average velocity (Va)

LITHOLOGY

Sandstone
Siltstone
Shale
Limestone
Dolomite
Sandy limestone and calc. sandstone

# VELOCITY AND TIME VERSUS DEPTH

AREA BMR 12(COCKROACH) WELL, GEORGINA BASIN

Basis SONIC LOG AND WELL VELOCITY SURVEY 1964

TO ACCOMPANY RECORD No. 1966/131

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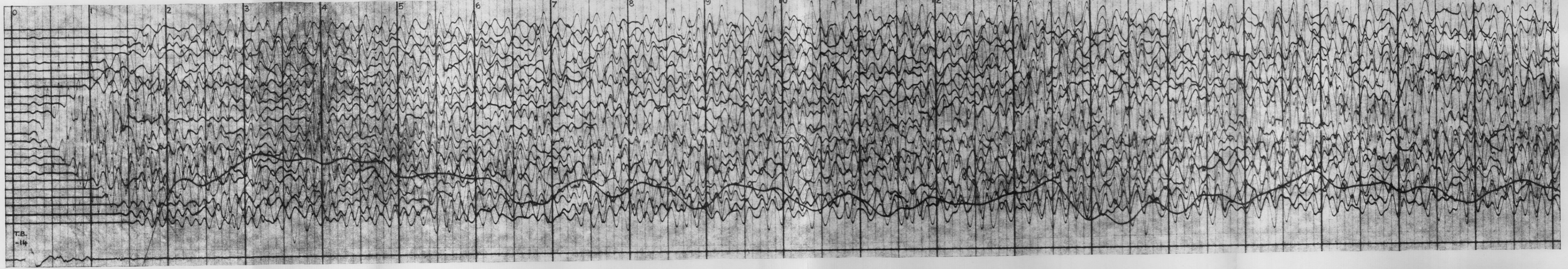
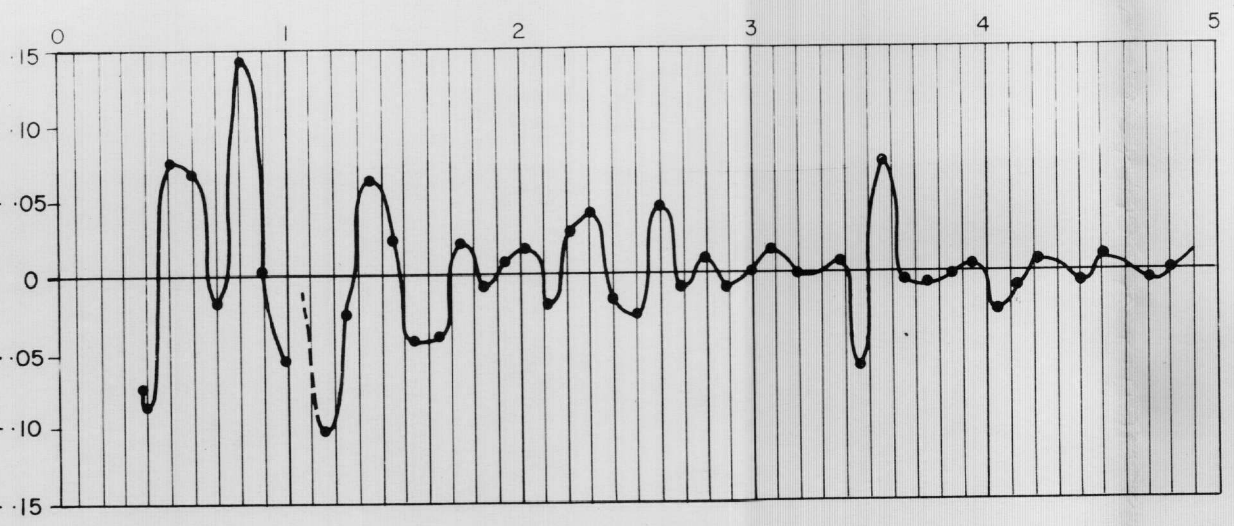
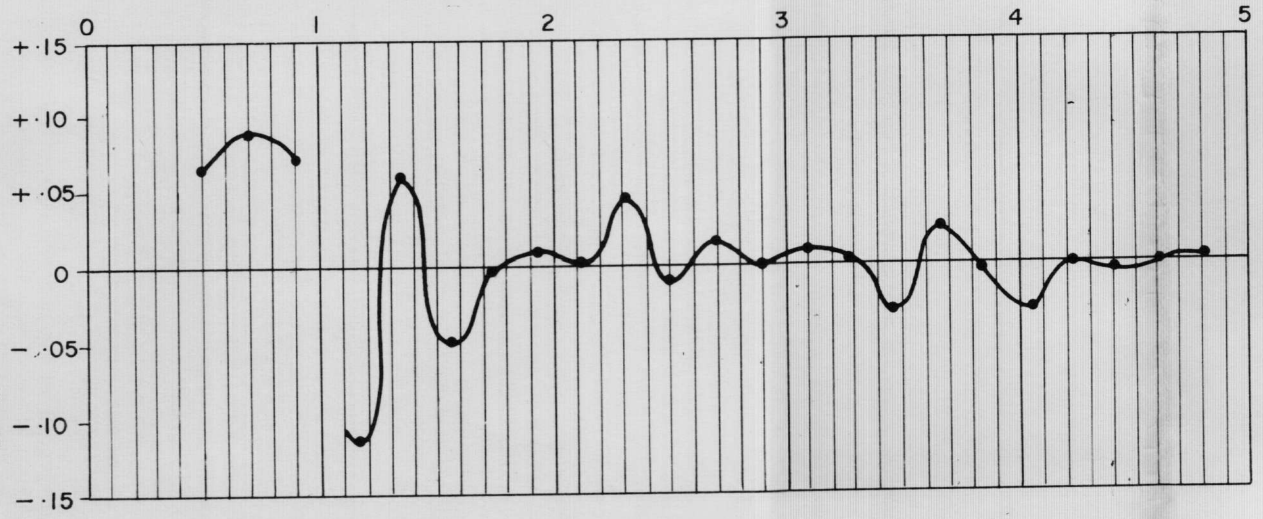
SEISMIC RECORD






Time in milliseconds x 100




## COMPARISON BETWEEN SEISMIC RECORD AND COEFFICIENT OF REFLECTION DERIVED FROM SONIC LOG OF BMR 12 (COCKROACH) WELL

SEISMIC RECORD : SP 256

20 holes 30′ deep in 4 rows of 5 parallel to traverse
32 geophones/trace in 4 rows of 8 parallel to traverse
Original filters : K24—K120 Playback filters : K36—K92

COEFFICIENT OF REFLECTION

Computed from sonic log using sampling intervals of 5 and 10 milliseconds and formula $R = \frac{V_2 - V_1}{V_2 + V_1}$

PLATE 6



BMR 12 (COCKROACH) WELL

## SONIC LOG

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F53/B3-111