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MISSIONARY PLAIN
SEISMIC AND GRAVITY SURVEY
OIL PERMITS 43 AND 56 NORTHERN TERRITORY

for

MAGELLAN PETROLEUM (N.T.) PTY. LTD.
Bowman House, Edward and Adelaide Streets,
Brisbane, Queensland.

by

GEOPHYSICAL ASSOCIATES PTY. LTD.
85 Eagle Street, Brisbane, Queensland.

December, 1965.

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I ABSTRACT

Magellan Petroleum (N.T.) Pty. Ltd. conducted an integrated programme of seismic, gravity and surface geological work over the Missionary Plain Area of the Amadeus Basin, Northern Territory, Australia from June 1 to November 27, 1965. The survey proceeded on a continuous work basis and resulted in 467 miles of seismic coverage, 2547 gravity stations and surface geological ties at 21 different sites. Initial programming called for continuous cross-basin reconnaissance profiles tied to outcrops by projection, with correlation of seismic events between lines.

The programme was altered somewhat as the work progressed to permit evaluation of reconnaissance leads in an attempt to define drillable prospects. This reduced the extent of the area covered but resulted in sufficient detail control to define four potential test locations and contributed some knowledge to a fifth.

Interpretation of data has disclosed two arcuate sub-basins separated by an ancestral ridge trending northeast through Gosse's Bluff to Tyler anticline and probably eastward to Glen Helen. Décollement adjustments with small thrust faults deep in the basins are common in the upper Proterozoic section. Diapirism and imbricate thrusting in Precambrian, Cambrian and Ordovician systems are shown by seismic profiles at Tyler and West Waterhouse and by gravity anomalies at West Waterhouse and West Carmichael - Deering Creek.

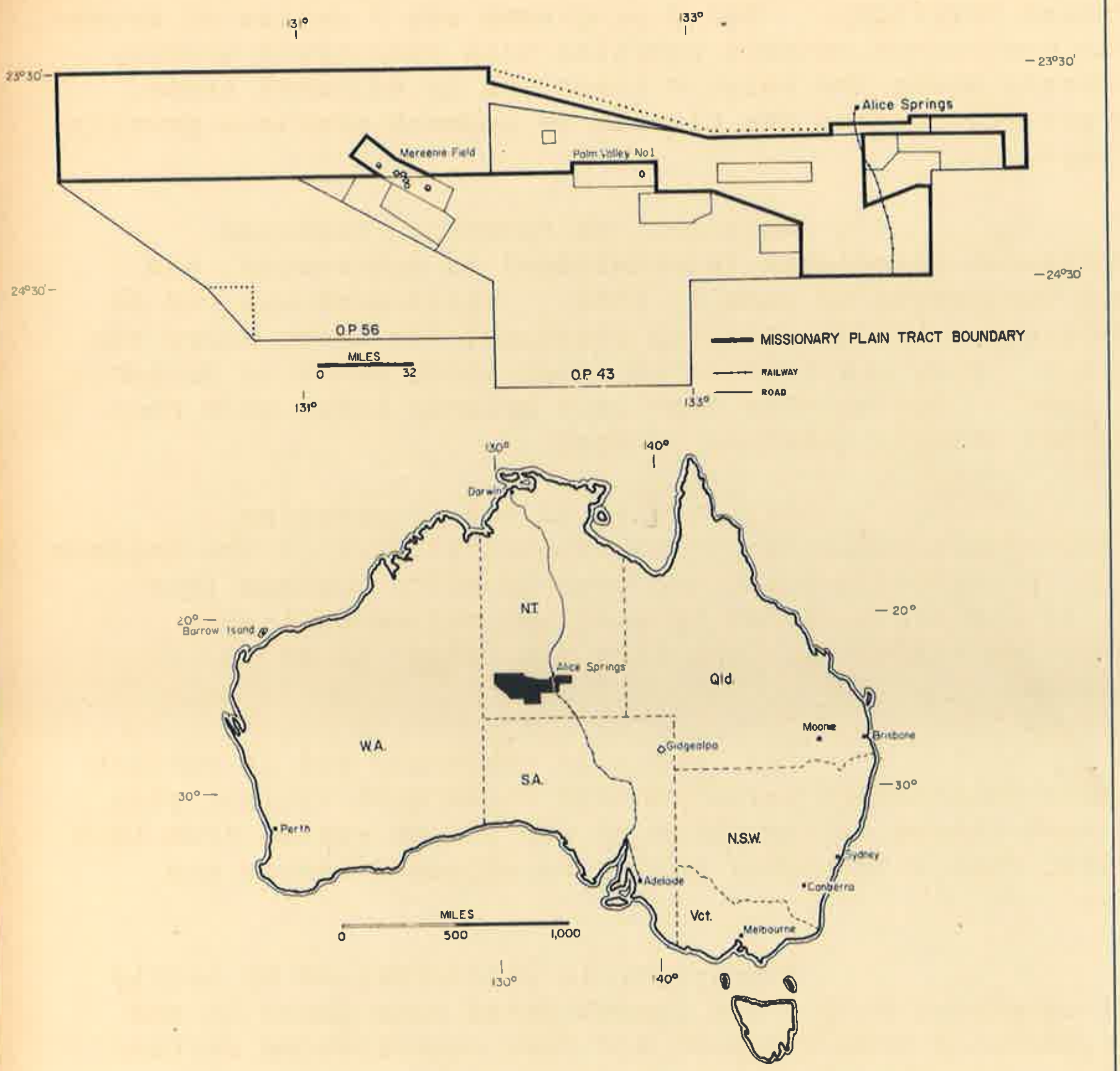


FIG. 1

LOCATION MAP

II INTRODUCTION

Early in 1965 a geophysical survey was undertaken in the Northern parts of Oil Permits 43 and 56, (see Fig. 1) held respectively by Magellan Petroleum (N.T.) Pty. Ltd. and United Canso (N.T.) Pty. Ltd. in the Northern Territory. Basic programme was a series of cross-basin continuous seismic profiles with concurrent gravity traverses along the seismic lines and in adjacent areas. The gravity control was planned to augment previous gravity surveys.

Magellan, as operator, selected Geophysical Associates International as contractor, and field work began on June 1, 1965. Field work was run on a continuous basis, rotating personnel for leave every six weeks. Work was terminated after 1830¼ hours on November 27, 1965. During this time 1403 seismic holes were shot and 2547 gravity stations metered.

Oil Permits 43 and 56 comprise 19,696 square miles in the north-central part of the Amadeus Basin, principally south and west of Alice Springs (see Fig. 1) and are enclosed by geographical co-ordinates $129^{o}45'$ to $134^{o}45'$ E. Longitude and $23^{o}30'$ to 25^{o} S. Latitude.

The region is semi-arid and is subject to wide temperature variation and occasional violent rain and dust storms. Elevation of the plains varies from 1800 to 2600 feet with higher points on adjacent ranges and peaks.

Topography is characterized by gently rolling plains with a few consolidated sand dunes in the east becoming more frequent and less consolidated farther west. Steep-sided gibber terraces occur mainly in the northern plains where they merge into steeper foothills of the MacDonnell Ranges. Drainage pattern is largely dendritic over the alluvial plains but is influenced by lithology and geologic structure near outcrops. Principal channels are Finke River, Ellery Rudalls, Deering and Carmichael Creeks. Crossings are usually wide and sandy in the plains but often become narrow and steep with boulders and gravel where the beds are confined by terraces or bedrock areas.

Vegetation varies greatly in type and density. Gibber areas can be spinifex covered, densely brush-covered or open. Sandy areas are densely covered when low-lying and usually sparsely covered when high. Dune areas frequently appear park-like with scattered desert oak trees and a minimum of undergrowth.

Traverse is difficult to good with all-wheel drive units and sand tyres. Track-making was necessary to carry straight lines and decrease travelling time.

Seismic data were recorded on tape and playback records immediately worked in the field office and in Alice Springs. Conversion to fully corrected play-back sections was done in Brisbane.

Gravity data were taken with a standard La Coste-Romberg meter. An extra portable meter was held in reserve. The gravity report is included in Appendix V .

Magellan supplied geological field parties which operated during the survey to tie the ends of seismic lines to measured outcrop sections.

III GEOLOGY

REGIONAL GEOLOGY

The Amadeus Basin is an eastwest trending miogeosyncline occupying some 80,000 sq. miles in central Australia between the Arunta craton on the north and the Musgrave craton on the south, both of Archaean age. Continuous deposition from Late Proterozoic to Middle Palaeozoic has been demonstrated, and within these systems there occur source beds, reservoir and cap rocks favourable for petroleum generation and accumulation (Fig. 2 and Fig.3).

This survey (Fig. 1 and 2), was confined to the north central flank of the basin, south of the steeply-dipping MacDonnell Ranges and westerly projection of their trend. This northern flank is considered to have received the greatest thickness of sediments, estimated to be in excess of 25,000 feet. These estimates are largely based on measured sections in outcrop, partly on sparse well control, and on local and regional seismic and gravity surveys.

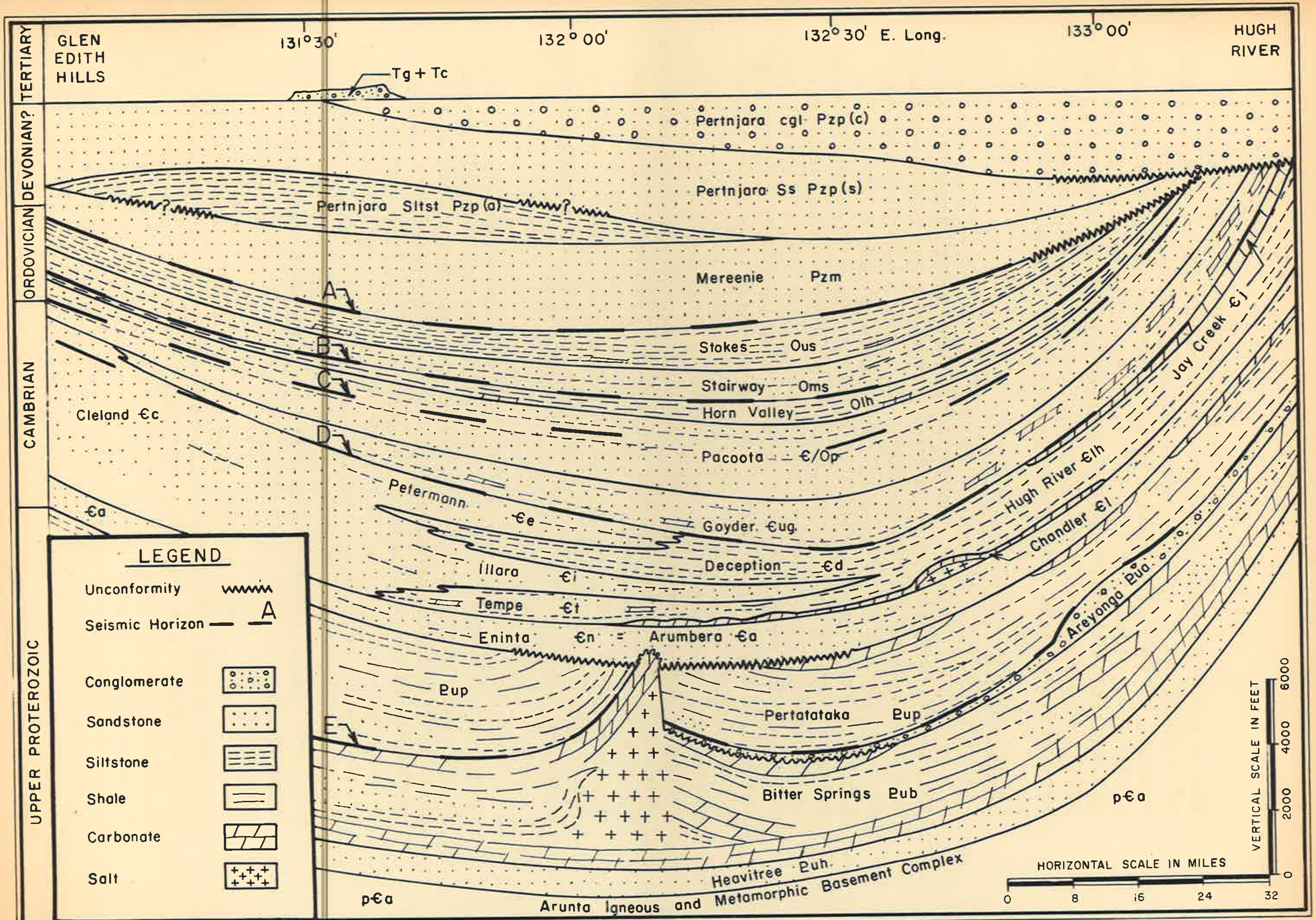
Extensive surface mapping has defined a number of large east-trending anticlines, principally south of the area of this survey; i.e. the Watson, Glen Edith, Gardiner, and James Ranges, and the localised Mereenie, Palm Valley, Johnny's Creek and Ochre Hill structures (Fig.2). The Mereenie and Palm Valley anticlines have proved to be productive of hydrocarbons and appear to have economically significant gas reserves.

The Missionary Plain is situated between the MacDonnells on the north and the anticlinorium complex on the south. Much of this area is lacking in outcrop and surface expression of structure. Gosse's Bluff and the Waterhouse Range are notable exceptions. The surface cover of the plain is principally Quaternary sands, gravels, and alluvium with some conglomerates exposed near major structural features and in local washes. The seismic survey has shown that a thick section of Proterozoic and Lower Palaeozoic rocks is present beneath the Missionary Plain, and that the structure is mainly asymmetric synclines with narrow anticlines and uplifts complicated by thrust faults and diapirism.

Tectonically the area appears to have been quite stable, (with the exception of concurrent diapirism), from upper Proterozoic to Middle Devonian, subsiding sufficiently to maintain a shallow-water mainly marine environment for deposition of widespread sands, evaporites, limes and shales (see Stratigraphic Column, Fig. 2 and Fig. 3). It is likely that basic structural trends such as Gardiner - Gosse's Bluff - Tyler uplift and the Deering Creek - Carmichael - Goyder Pass trend were developed by diapiric and décollement adjustments which began during this long period of loading.

At some time following Mereenie deposition, (possibly concurrent with the Tabberabberan orogeny of Middle Devonian (?) age) the basin was subjected to regional orogeny which resulted in the growth of the anticlinal ranges on the south and the tilting and overthrusting of the MacDonnell Ranges on the north ("Alice Springs Orogeny", Forman 1965) which obscured ancestral structural trends. Late Palaeozoic and Mesozoic were either times of non-deposition or the sediments have since been stripped. Post Mesozoic (?) epeirogenic adjustment has raised the area to about 2,000 feet above sea level.

Geologic - Geophysical Integration - The Amadeus Basin has been recently mapped at a scale of 1 inch to four miles by the B.M.R. and the regional surface geology is thoroughly discussed in their several reports (B.M.R. Rep. Nos. 61, 85, 86, 88, 87, 103 - 1962/66). A programme of detailed surface geologic mapping and section measurement by Magellan was carried out concurrently with the 1965 Geophysical programme. The chief purpose was to locate precisely the shot points on the aerial photographs, transfer them to photo-compilation base maps, and tie the seismic lines to surface geology and measured sections by plane-table mapping. A good tie was effected between existing well control, surface geology and some seismic profiles. Cross-sections were constructed where surface ties were not across major faults or tectonic discontinuities.



RELATIONSHIP OF ROCK UNITS, MISSIONARY PLAIN. Showing Generalized Stratigraphy.

Fig. 3.

Surface outcrops of each seismic horizon mapped were transferred from published B.M.R. maps at a scale of 1 : 250,000, modified by detailed surface mapping of Magellan geologists, and plotted on 1 : 120,000 scale base maps. The chief sources of data for isopachous values are published measured sections of the B.M.R. (1962-1965) supplemented and modified by field work, measured sections and well data by Magellan geologists.

LOCAL GEOLOGY

A complete succession from Arunta (Basement) Complex to Pertnjara crops out in the MacDonnell homocline north of the survey area, and a nearly complete section from Bitter Springs to Pertnjara crops out in the folded ranges to the south (Fig.3.). On a regional basis, seismic results indicate that the stratigraphic succession is remarkably consistent, and more than a dozen reflecting bands can be carried with considerable accuracy across the basin and correlated with reasonable certainty into the outcrop (Fig. 3). Most of the measured surface sections correlate well with the indicated thicknesses on the seismic isochron maps; however the interval from D to E appears far thicker in the subsurface than would be expected from surface data. This could be because a seismic horizon is miscorrelated or it could reflect additional section (evaporites ?) in the subsurface which is not present on the outcrop.

In general, the Devonian (?) Pertnjara formation thickens northward towards the MacDonnell mountain front, with prominent thick areas in the troughs of synclines. The thickness of the Ordovician Larapinta group and the Mereenie formation is generally uniform across the area, with no distinct regional pattern. Prominent locally thick areas occur near Stokes Pass and Tyler Pass, south of the Tyler structure and north of Waterhouse (Plates X and XI), and local thins are situated coincident with each prospect.

The Upper Ordovician thins and is beveled by the sub-Mereenie unconformity in the vicinity of Waterhouse. The Lower Ordovician to Cambrian sequence is remarkably uniform in thickness with no discernible regional pattern (Plate XII). The Cambrian to Upper Proterozoic section, however, thickens gradually and uniformly to the southwest (Plate XIII) with local thick wedges in the faulted and diapiric cores of West Waterhouse and Carmichael structures. Details of local stratigraphy are discussed with the individual prospects.

Strata along the north flank of the Plain strike generally west-northwest and dip homoclinally southward, but are vertical to overturned across much of the central front of the MacDonnell Ranges. There is a profound structural discontinuity between the Proterozoic Bitter Springs formation and the overlying succession. This has been ascribed by Forman (1965) to overthrusting from the north accompanied by a décollement along a detachment plane in the Bitter Springs and by the formation of local nappe structures (Ormiston, Blatherskite, etc.). The small amount of shooting along line 2-2.7 near Glen Helen on the Finke River tends to support Forman's concept that overthrusting from the north has produced deep-seated blind thrusts and related fold structures which are concealed beneath the Pertnjara conglomerate foothills and the MacDonnell Ranges outcrops. The Tyler - Glen Helen structure and the Goyder Pass - Carmichael - Deering Creek uplift appear to be subparallel tectonic welts related to the MacDonnell orogeny, localized or modified by diapirism within the cores of the uplifts.

The main central portion of the Missionary Plain is a remarkably uniform broad syncline whose near symmetry is disturbed by the Waterhouse uplift on the east, and by the ancestral Gardiner - Tyler uplift on the west (Plates V - IX). The syncline apparently terminates as a structural entity with the convergence of the Gardiner Range and Deering Creek - Carmichael anticlines. Details of the local structure are discussed with the individual prospects.

IV OBJECTIVES OF SURVEY

The presence of hydrocarbons in both Upper Proterozoic (Ooraminna No. 1), and Lower Palaeozoic (Alice No. 1, Palm Valley No. 1, and the Mereenie wells), offers proof of occurrence sufficient to justify further exploration. Well-defined surface structures are mapped along the south border and to a lesser extent, within the Missionary Plain. Between outcrops large sand-covered tracts exist which could be synclinal in sub-crop or could conceal anticlinal structures. The latter, if present, would be of considerable producing potential in the known sections of Cambrian and Ordovician age and also could have accumulation in the Mereenie sandstone of Devonian (?) age, as well as in the Proterozoic.

The objectives of this survey were:

1. To determine structural attitudes in the inter-outcrop areas which could lead to new drill-sites and subsequent production;

2. To define the north flank of the Palm Valley structure and also to obtain data which could indicate possible west closure;

3. To further evaluate several structural anomalies: i.e. West Waterhouse, Gosse's Bluff and Carmichael; and also several photo anomalies which could indicate structural leads.

4. To investigate and determine by stratigraphic mapping coupled with surface geology, the possibilities for stratigraphic traps for hydrocarbons.

It was the objective of the gravity survey to refine previous coverage, principally that by the B.M.R. and Century, (Ref. 7 and 20) with and ahead of the seismic survey in hope that this control could pick up structural leads that could be investigated by seismic shooting. It was also thought that gravity profiles along seismic lines could assist in evaluation of local diapirism that might not be readily apparent on the seismic profiles.

V PREVIOUS GEOPHYSICAL WORK

(See Appendix VII, Selected References)

Geophysical work began with the regional gravity surveys by Marshall and Narrain in 1951. In 1957 the B.M.R. extended this north-south line of control from Alice Springs to Giles, W.A. Further gravity control was added by the B.M.R. in 1959 and 1960 and an air magnetometer profile was flown from Alice Springs to Giles. A local gravity survey of Gosse's Bluff was run by Frome-Broken Hill Co. Pty. Ltd. 1958. In 1960 and 1961 further local surveys were carried out at Ooraminna structure, Alice Prospect and Mereenie anticline. Magellan ran several long traverses in 1961 along various tracks south and west of Alice Springs, 1261 stations, and results incorporated previous local work by Frome-Broken Hill. A major contribution came with the B.M.R. helicopter survey in 1961-62 on a seven mile grid (See Langron, 1962, and Lonsdale and Flavelle, 1963).

First known seismic work was done by the B.M.R. in May-August 1961 (F.J. Moss) Amadeus Basin (Southern Margin) Seismic Survey, N.T. 1961, Record 1962/167 followed in November by Palm Valley - Hermannsburg Seismic Survey Amadeus Basin, N.T. 1962, Record 1963/5. Namco Geophysical Co. shot over the Alice, Ooraminna and Mereenie Prospects for Exoil in 1962, and the B.M.R. shot a cross-basin profile from the Gardiner Range through Gosse's Bluff into the MacDonnell Ranges, Record No. 1964/66.

In 1964 Magellan shot additional seismic control around the northwest half of Mereenie anticline.

VI OPERATIONS

A. Access and Clearing

(See Plate I)

Access within the survey area is by a graded road from Alice Springs to Hermannsburg Mission, a distance of 84 miles, then 35 miles west to Gosse's Bluff junction. From here tracks go 20 miles southwest to Katapata Gap, west through Undandita to Carmichael, and north through Tyler Pass to Haast's Bluff.

The Haast's Bluff road was used for access to the westernmost work, lines 1-3 and 0-4. The Hermannsburg - Glen Helen track was used for access to the northeastern portion of the Tyler area.

Seismic lines and access tracks were cleared by an Allis-Chalmers crawler tractor which pulled a V-shaped dozer blade. A substantial tree-pusher mounted on the front protected the crawler and up-rooted all but the larger trees. The vehicle operated very well in the normal plains country but was handicapped in boulder washes or on steep sided hills. Its speed, both in cutting track and in travelling between traverses (with blade raised), made it superior to a normal dozer. Steep-sided ravines and gullies could not be filled easily with the pull-blade, so some detouring was necessary.

This tractor also served as a prime mover for a 2,000 gallon water trailer when necessary.

B. Surveying

(See Plates I and II)

All lines were surveyed with K & E transits. Elevation control was established from Bench Mark 75-34 (four miles north of Gosse's Bluff). Horizontal and vertical ties were checked at intersections with previous B.M.R. seismic and Century Geophysical Co. gravity work.

Horizontal control was established from Gosse's Bluff triangulation station and true bearing from Gosse's Bluff to Tyler Pass station. Horizontal plate angles were carried for approximately one month; subsequently magnetic bearings were used to expedite the surveying. A magnetic declination of 4°30' east was used. All lines not included in closed loops were double run. Vertical miss-ties did not exceed 2 ft.

Steel fence posts with the shot point and gravity station numbers stamped on metal tags were set out at four mile intervals and at most line intersections to mark these locations permanently.

C. <u>Drilling</u>

Sandstones of varying degrees of hardness were air-drilled with little difficulty to depths of 90 to 160 feet in most areas.

Exceptional conditions which adversely affected drilling rates were:

1. Damp sand, which hindered air drilling and required water injection for approximately 30 holes in the western-most portion of the survey on lines 1-3 and 0-4.

2. Loose sand and gravel, which necessitated water drilling for two holes in the Finke River Valley near Palm Valley No. 1.

3. Surface and near-surface gravel, boulders and bedrock slowed the drilling rate in both north and south extremities of the survey.

4. Extremely hard drilling in the Pertnjara conglomerate, which caused high consumption of rock-bits and low production in the Tyler area. Hole depths were decreased in this area in order to obtain maximum coverage. In general, record quality did not suffer unduly.

A hydrological map showing those holes thought capable of producing water, depth to water sand and estimated flow has been prepared. Copies are

EXPERIMENTAL

SHOT HOLE AND CABLE LAYOUT

LINE 2-3

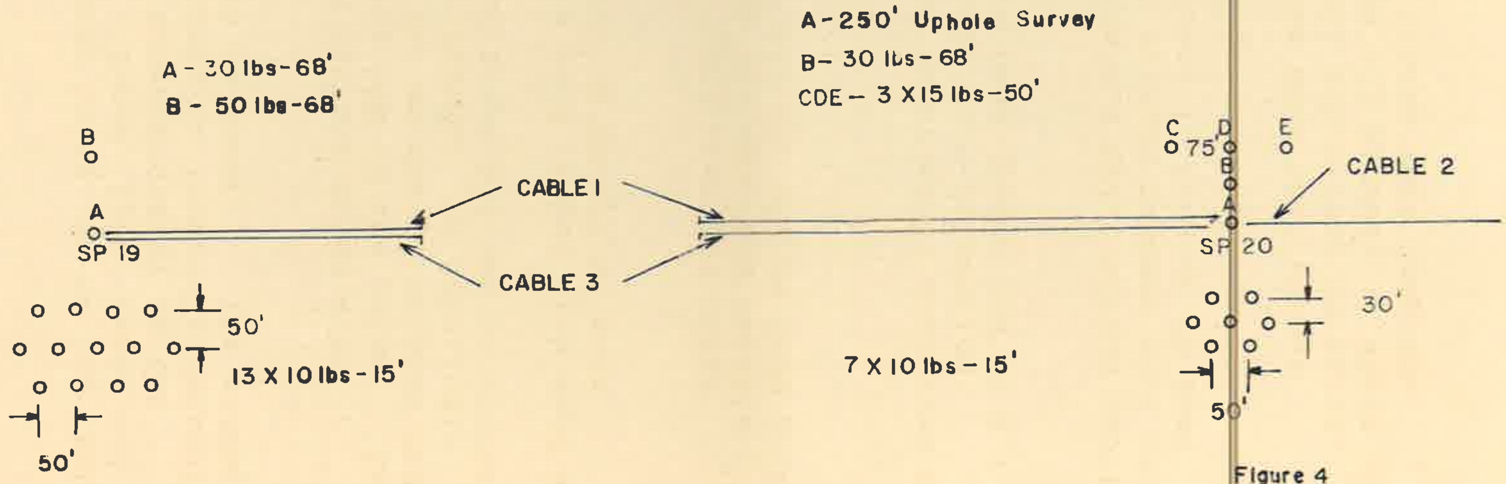


Figure 4

not included in this report but have been sent to the B.M.R. and the Northern Territory Water Resources Branch.

D. Shooting

Single deep holes, 90 to 160 feet, were drilled almost exclusively. Three, five, seven and thirteen hole patterns were shot experimentally at the beginning of the survey and at irregular intervals thereafter. (See Fig. 4). Large charges were necessary. The average shot was 100 lbs.

Ammonium nitrate mixed with dieseline was used in approximately 50% of the holes. Large nitrate charges were primed with two sticks of Geophex near the top and bottom of the nitrate column. A relatively small number of holes were too wet to permit use of nitrate.

All holes were tamped with sand so that second shots were rarely possible except at much shallower levels.

Several holes blew gas after shooting. These are indicated on the maps and details given in Appendix IV. (See Appendix IV, GAS IN SHOT HOLES)

E. Recording

Recording instruments used were a new set of Dynatronics FM 80 reflection - refraction amplifiers, Dynatronics TR-8 AM/FM tape system and an S.I.E. RO-22 oscillograph.

The continuous split-spread profile technique was used with 1760 feet spacing between shot points. Six S.I.E. S-16 geophones were spread in line at 25 foot intervals (Fig. 5).

End traces were laid across adjacent shot points to obtain full subsurface coverage. Trace spacing was kept constant on all spreads. Where it was necessary to shorten spread, traces were dropped.

EXPERIMENTAL

REFLECTION SPREAD DIAGRAM

LINE 2-3

12 Geophones per trace

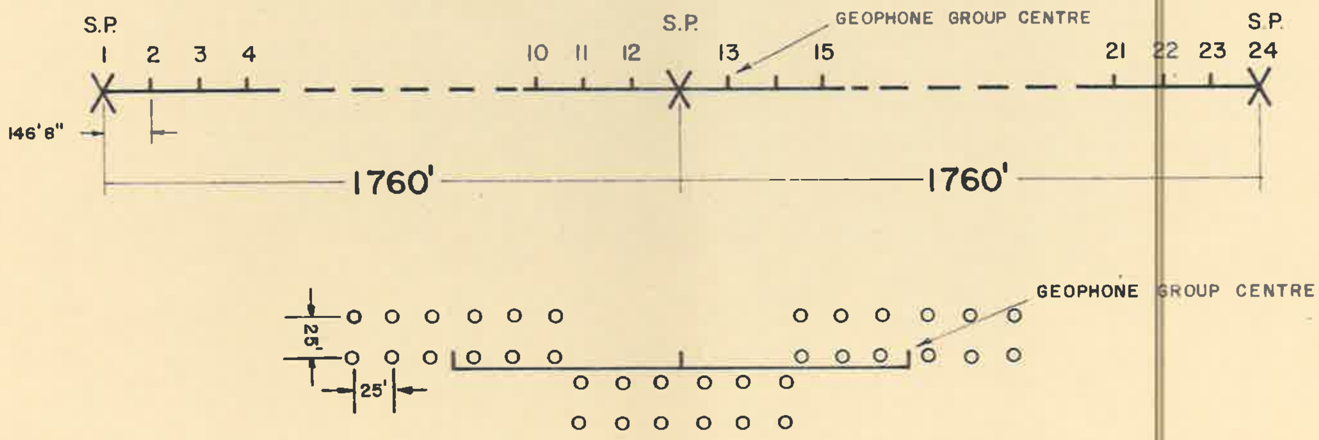


Figure 6

REFLECTION SPREAD DIAGRAM

6 Geophones per trace

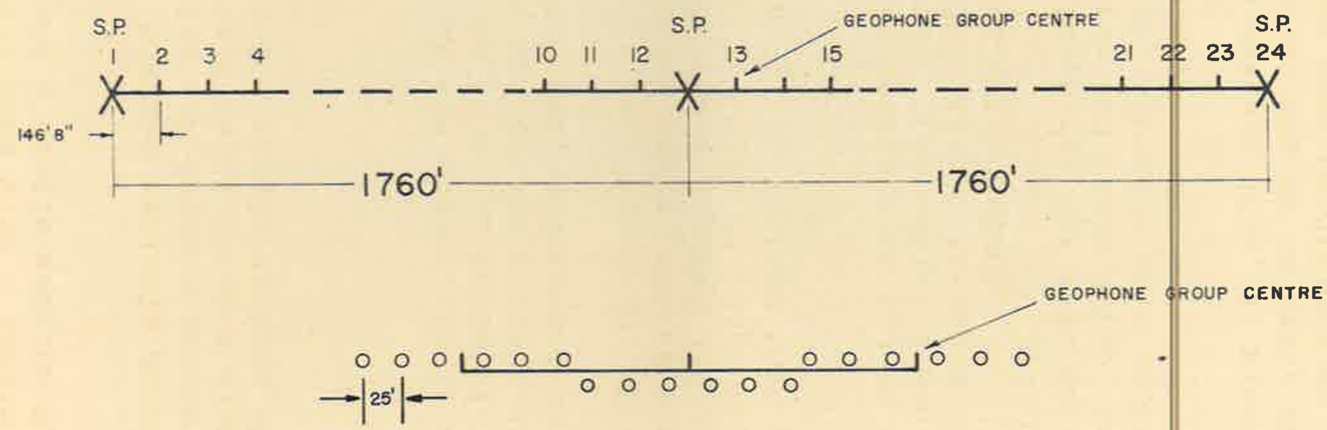


Figure 5.

Tapes and co-incident monitors were initially recorded with single section 16 to 150 cps filters. During the first months operation, excessive wind noise and some ground roll required a change to filter settings of 21 to 110 cps. All shots were taken using slow AVC. Field playbacks were made with a single section 21 cps high pass filter and a single section 61 cps low pass filter.

Unmixed variable density galvo record sections with static and dynamic corrections applied were prepared from the field tapes using a single section 27 cps high pass filter and a single section 65 cps low pass filter.

F. Experimental

At the outset, tests were conducted at shot points 19 and 20 on line 2-3 to determine optimum size and depth of charge, number and pattern of shot holes, number and spacing of geophones, and recording procedure.

At Shot Point 20, three cables were laid out, cable 2 to the north, cables 1 and 3 to the south. Six geophones per trace, spaced 25' apart, in line, were used on cables 1 and 2, while 12 geophones per trace were used on cable 3 (Fig. 6). Testing then proceeded as follows:

1. A single 30 lb charge with top at 68 feet was shot into cables 1 and 2, and recorded using a 16-150 filter and programmed gain control.

2. A single 50 lb charge was shot using the same filter and cable array, but recorded using automatic gain control on slow recovery.

3. A three-hole pattern (Fig. 4) with 15 lbs per hole, top at 50 feet, was shot under the same conditions as shot 2, but with fast recovery automatic gain control.

MISSIONARY PLAINS UPHOLE VELOCITY SURVEY

LINE 2-3

SHOT POINT ELEVATION - 2030' A.S.L.

S.P. 20.

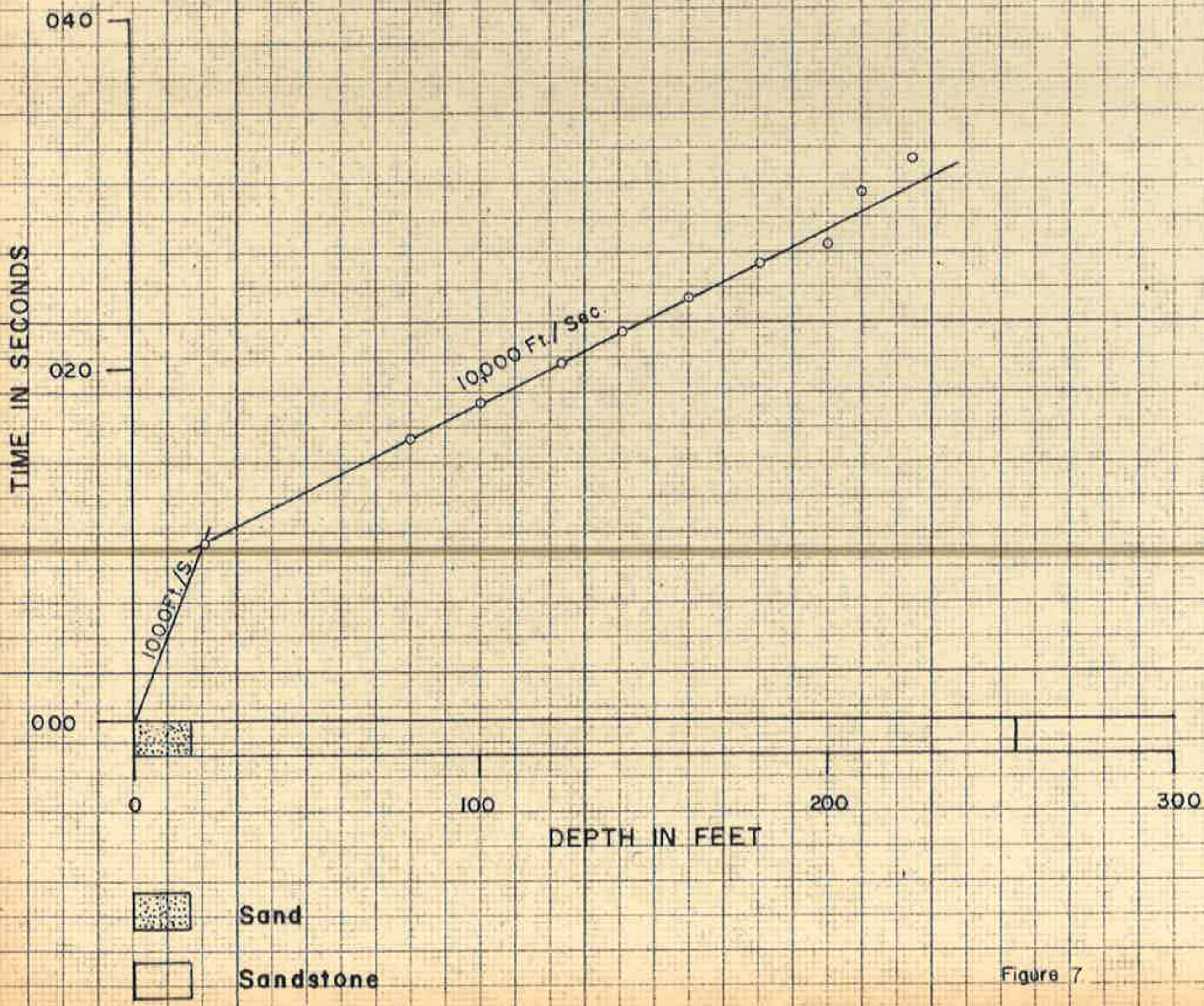


Figure 7

4. A seven hole pattern (Fig. 4) with 10 lbs per hole was shot into cables 1 and 3, to afford a comparison between 6 geophones per trace and 12 geophones per trace. Other conditions were as in shot 3.

Three shots were fired at shot point 19, using a standard split-spread with 6 geophones per trace, to compare results obtained from a single hole, versus a 13 hole pattern, (Fig. 4) and to compare results from recording with programme gain control and automatic gain control.

Study of the filtered playbacks indicated that best results would be obtained by shooting a large charge in a single deep hole, recording with A.G.C. rather than P.G.C., and that a 12 geophone array gave no substantial improvement over the results obtained using a 6 geophone array.

In various areas where record quality deteriorated, or extremely hard drilling made it desirable to decrease hole depth, pattern holes were compared with single holes. Results from pattern shots were generally inferior to the single shots.

G. Computation

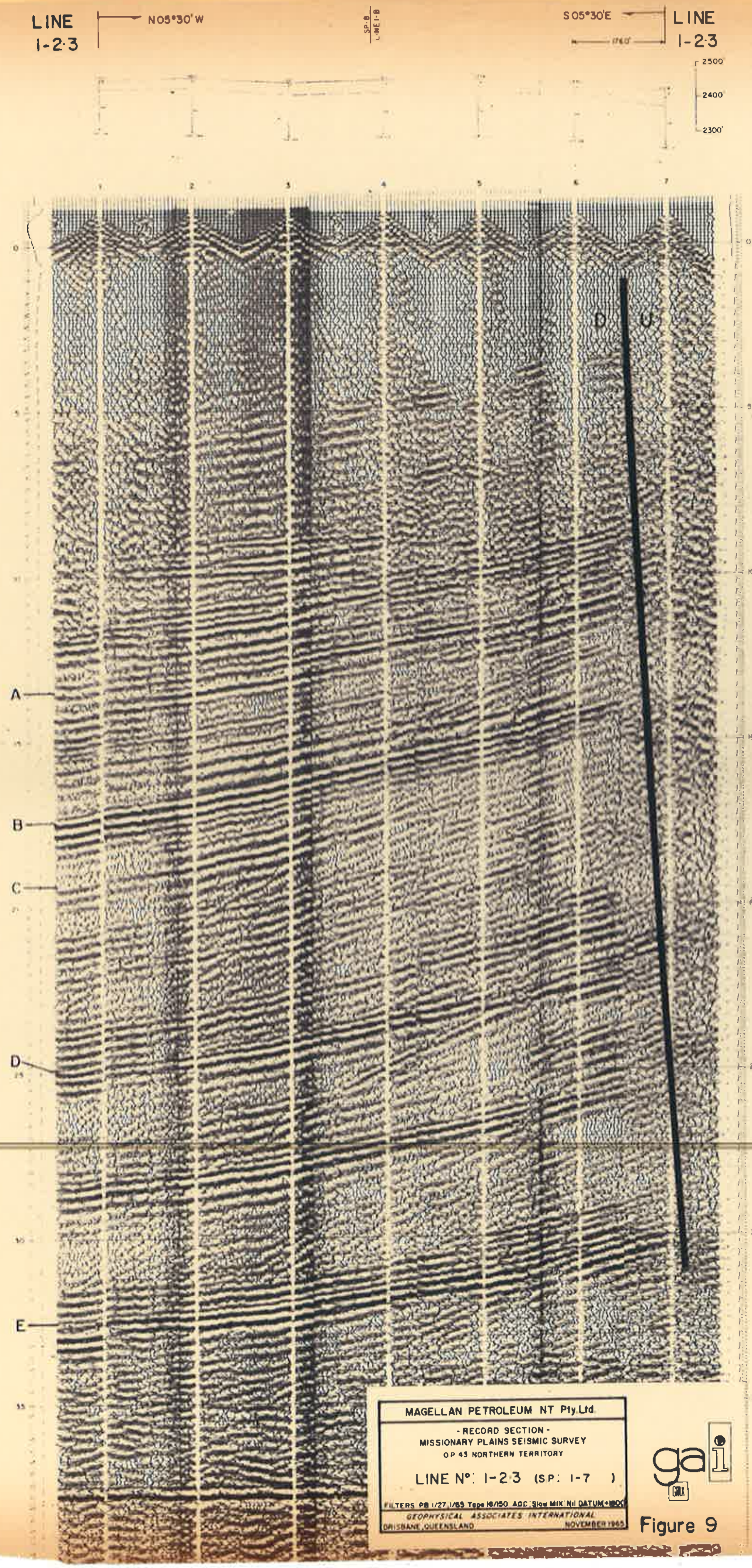
1. Seismic

The reflection seismograms were corrected to a datum of 1800 feet above sea level by the standard uphole method. A datum velocity of 10,000 ft/sec. was used in the formula: (See Fig.7, Uphole Velocity Survey).

$$Tc = -\left[\frac{2\,(Es - W - D)}{V} + TUH\right]$$

where:-

Tc - Total correction
Es - Surface elevation
W - Depth of top of charge
D - Datum plane elevation
V - Velocity to datum (10,000 ft/sec)
TUH - Uphole time


LINE 1-2·3
N05°30'W
SP-8 LINE 1-B
S05°30'E
1760'
LINE 1-2·3
2500'
2400'
2300'
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MAGELLAN PETROLEUM NT Pty.Ltd.
- RECORD SECTION -
MISSIONARY PLAINS SEISMIC SURVEY
O P 43 NORTHERN TERRITORY
LINE N°: 1-2·3 (SP: 1-7)
GEOPHYSICAL ASSOCIATES INTERNATIONAL
BRISBANE, QUEENSLAND
NOVEMBER 1965
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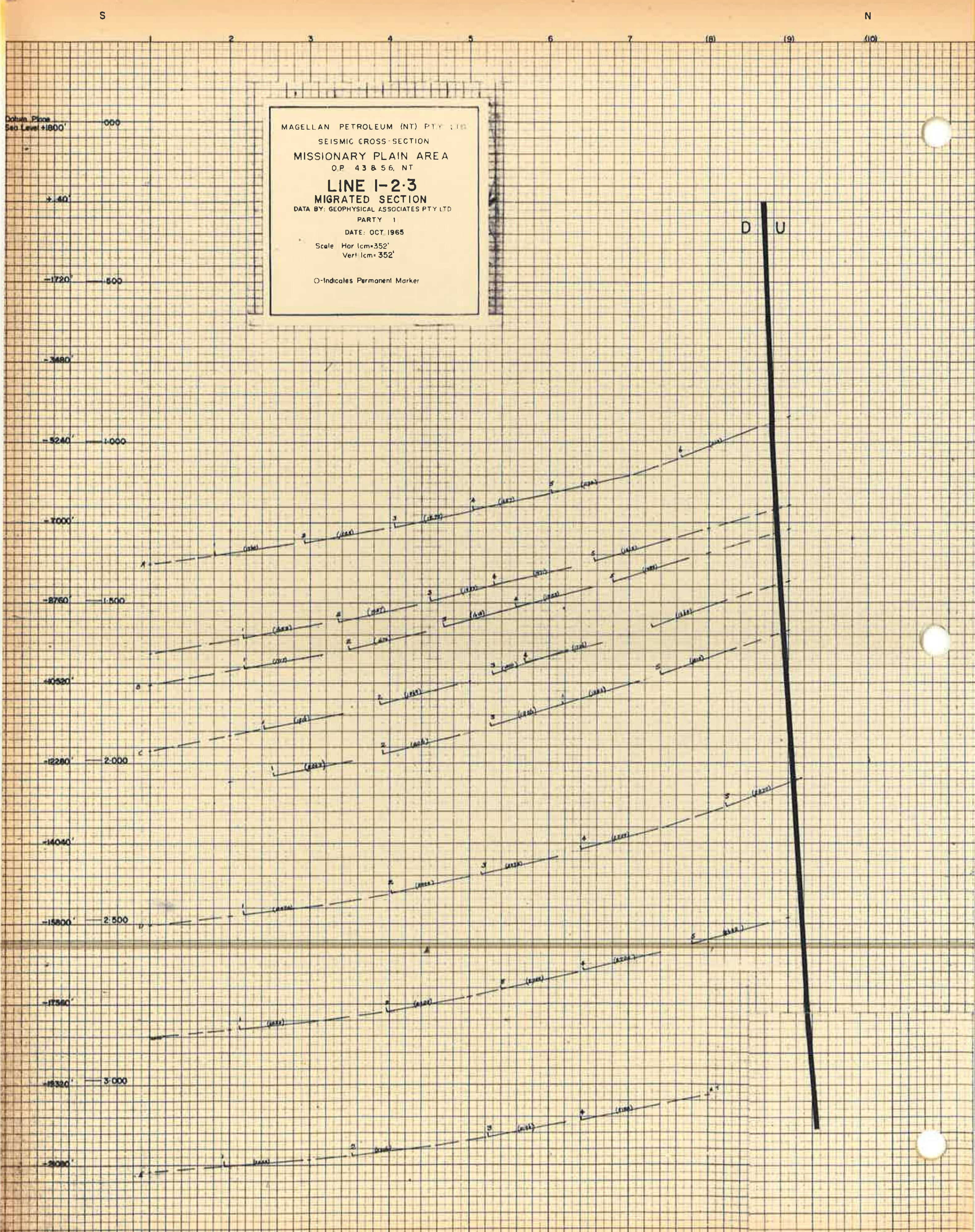
Figure 9



MAGELLAN PETROLEUM (NT) PTY LTD
SEISMIC CROSS-SECTION
MISSIONARY PLAIN AREA
O.P. 43 & 56, NT
LINE 1-2-3
MIGRATED SECTION
DATA BY: GEOPHYSICAL ASSOCIATES PTY LTD
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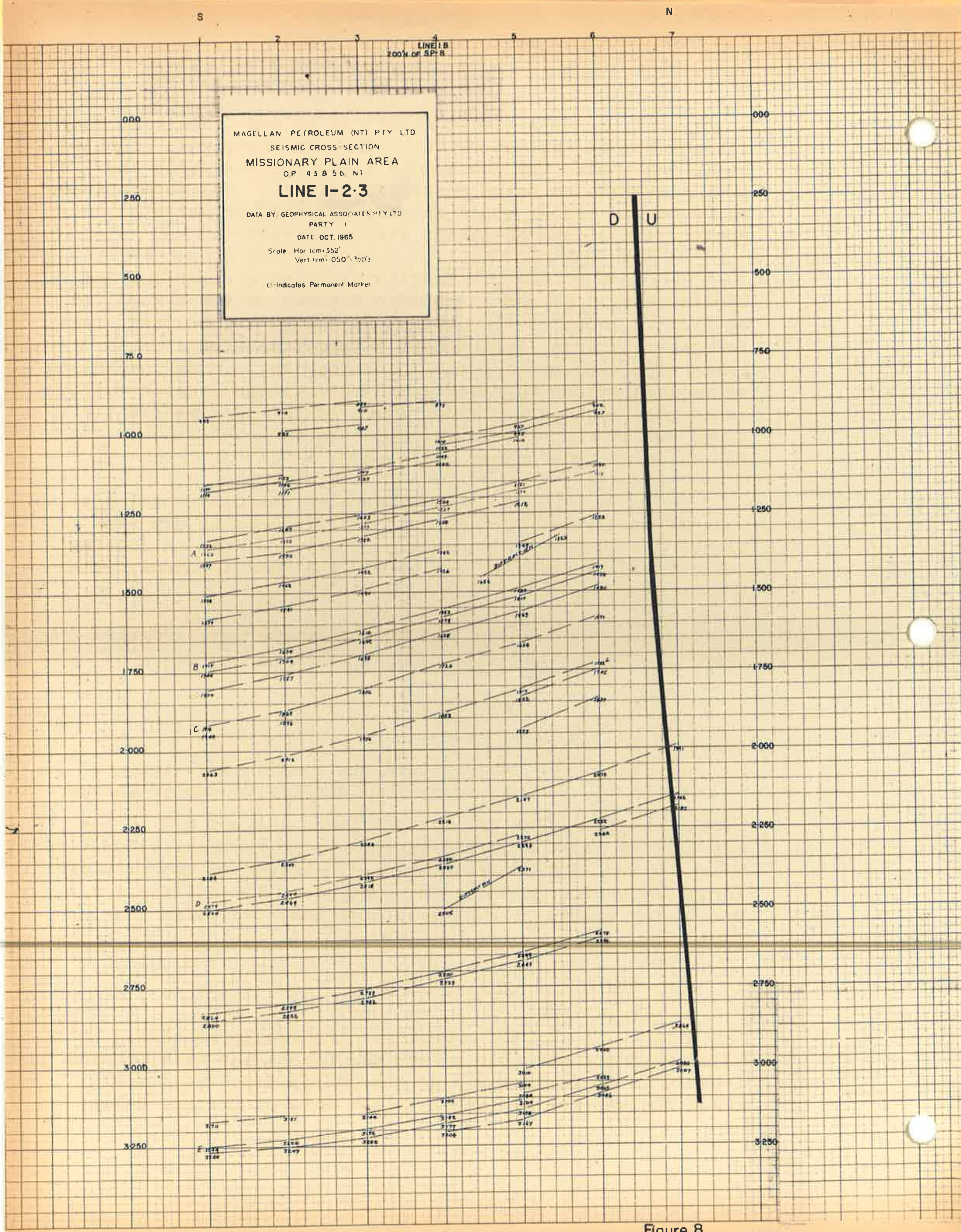
Figure 10



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MAGELLAN PETROLEUM (NT) PTY LTD
SEISMIC CROSS SECTION
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O.P. 43 8 56 NT
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PARTY I
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D
E
000
250
500
750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250

Figure 8

Corrections to end trace time ties for the common spreads between adjacent shots were computed by interchanging the two uphole times and averaging the shot elevation to datum correction times. The common travel paths of end traces could thus be adjusted to datum by application of the resultant static correction.

Individual trace corrections for record section presentation were entered on forms supplied by Pacific Magnetic Reductions, Brisbane. Corrected times for centre traces, relative to a zero time break, were taken from the computed field seismograms. From inspection of several strong representative reflections, static corrections were applied to traces which exhibited consistently lower or higher irregularities caused by weathering or elevation changes across the spread.

Steep dips in the Carmichael area were migrated when more than 10 milliseconds of dip per spread was recorded. (See Figs. 8, 9 and 10) A constant velocity of 14,000 feet per second was used in constructing a wave front chart.

Weathering depths were computed using the formula:

$$Wx = \frac{10\ Tuh - W}{4}$$

where:

Tuh = Observed uphole time in milliseconds
W = Distance from surface to top of charge

over the entire area, except for lines 1-3 and 0-4 in the far western portion of the survey, where vertical velocities on the order of 8,000 ft/sec were indicated by the plot of an uphole survey conducted at shot point 107 on line 1-3. Weathering depths in this area were computed using the formula:

$$Wx = \frac{8\ Tuh - W}{3}$$

Depth of the weathered zone, calculated for all shot points throughout the area, ranged from 20 to 50 feet. Top of the charge was always well below the weathering except in the case of pattern holes, infrequent cases of holes blocking off at shallow depth and in the north portion of the area where extremely hard drilling required shallow holes in the interests of production and economy.

Sample first arrival plats, made initially in each area, and occasionally thereafter as a check, indicated horizontal velocities on the order of 12,000 feet - 14,000 ft/sec over most of the area. In the western portion of the survey horizontal velocities of 7,500 - 9,000 ft/sec were encountered.

2. Gravity

Meter readings were first converted to milligal values by applying the instrument calibration factor. Tidal corrections were included with the corrections for instrumental drift since both are time dependent. Station gravity values were further reduced by applying the appropriate latitude correction and an elevation factor of .068, corresponding to a density of 2.05. The established datum of the Alice Springs pendulum base was used. The results were plotted as the Bouguer gravity anomaly values.

All progress maps during the course of the survey were based on this .068 elevation factor. Subsequent analysis of data (Nettleton, 1966) indicates that an elevation factor of .063 (density 2.42) gives a smoother profile and the final Bouguer map, Plate III, is based on the re-computed values.

For interpretational study, selected Bouguer values also have been plotted in profile form. The interpretation is discussed by Dr. L.L. Nettleton in the gravity results section of this report (see Appendix V).

H. Progress Reports

Reports covering operations and results were submitted semi-monthly to Magellan and to the B.M.R. Fully corrected playback record sections were prepared and two copies of each section were forwarded as received to the B.M.R. Several sections have been reduced, overprinted with seismic and geologic horizons and included with this report for illustrative purposes. (See Plates XIV to XVIII). All of the playback sections should be considered a part of this report although they are not included herewith.

It is noted that the final Bouguer Map, Plate III is slightly different from the progress maps due to changing the elevation factor from .068 mgs/ft. to .063 mgs/ft.

VII INTERPRETATION

A. Seismic

Interpretation began with the field crew using monitor and filtered play-back records. A second set of play-backs was sent into Magellan's Alice Springs office every several days. Corrected centre times were plotted vertically on millimeter paper at a scale of 1 cm = 352 feet horizontally vs. 1 cm = .050 seconds vertically. At an average velocity of 14,000 feet per second this gave a nearly true-scale plot. Copies of plotted sections were sent to Magellan as they progressed.

Preliminary reflection time maps were constructed from the sections and sometimes directly from the seismograms both in the field and independently at Magellan's office. Horizon identification was made with line 2-2, the tie line into the Palm Valley well. Those horizon correlations below total depth of the well were based on calculations from nearest measured surface sections. A synthetic seismogram prepared from the Palm Valley CVL confirmed the mid-Pacoota reflection but did not directly assist in shallower identifications except as used for interval velocities.

The corrected playback sections in galvo-variable-density mode were an additional aid to interpretation. The B.M.R. Gosse's Bluff and Hermannsburg shooting in variable area sections and also from playbacks made from transfer tapes also materially assisted the interpretation.

From velocity surveys at East Mereenie No. 2 and Palm Valley No. 1 it was known that the Devonian to Ordovician formations penetrated presented considerable variation in velocity. As this survey was to cover a large area with very little known about the thickness of basin fill and virtually nothing about velocity gradients, it was decided to carry all maps in time of reflection. In this form they would be more amenable to conversion to depth and correction for velocity gradients when such information became available.

Migration of the steeper dips was done principally in the Carmichael area. Based on the Mereenie and Palm Valley velocity surveys a constant velocity of 14,000 feet per second was chosen for construction of a wave-front chart. Plotting results showed good line-up of reflections. (See Fig. 10).

Strong local diffractions were first noted at the north end of line 2-3 and were thought to originate from faulting north of the end of the line. Other diffractions were noted at the north of line 2-4 when it was shot. As both lines had been run to the base of the Pertnjara conglomerate hills, no attempt to enter this rough terrain was made at this time.

Subsequently, strong diffracted energy was found to be associated with most faults in the area. Some occur high in the section where the high velocity Upper Stairway is probably in fault contact with the lower velocity Mereenie formation, whereas many other diffractions originate at faults in the deep Cambrian and Proterozoic section.

As the seismic lines approached outcrop areas, geological parties located end points on photos and made plane table maps and measured sections extending into the outcrops. (See Plates XIV to XVIII). These surface ties assisted and generally confirmed identification of zones of energy. Disparity of agreement between the seismic interpretation and the projection of surface geology first indicated the presence of an anomalous condition at the north end of line 2-5. Subsequent shooting defined the Tyler structure.

B. Gravity

Progress maps of Bouguer gravity values were submitted periodically and checked for local anomalies to assist in lay-out of additional seismic lines. Computation was based on an elevation factor of .068 mgs/ft. which was derived from the several density profiles previously run by Century Geophysical Company. Several stations were placed in a north-south line over the Palm Valley Anticline by helicopter and levelled by surveying altimeter.

These data were the first to indicate a possible coincidence of gravity and topography which ultimately led to re-computation of all values for a .063 mgs/ft. elevation factor.

Local high intensity anomalies were first found at West Waterhouse which indicated confirmation of faulting and probable shallow diapirism. Similar gradients were subsequently noted at Carmichael and westward along the Deering Creek fault and fold axis. Bouguer plots on lines 1-3 and 0-4 also showed rapid local changes in the places where seismic data were virtually absent. Slow surveying and difficulty of movement generally, in this area, resulted in limited coverage which restricts interpretive efforts. It is presumed that the rapid changes of gradients are due to near-surface effects of subcrop truncation of the several layers of different densities. Steep subcrop dips with possible faulting and a generally highly deformed section would account for the very poor seismic results and satisfy the observed gravity.

A detailed treatment of gravity results and interpretation has been made by G.A.I. Houston office under Dr. L.L. Nettleton. This is given in full in Appendix V.

VIII RESULTS OF SEISMIC SURVEY

A. General

Briefly, the survey confirmed the basic concept of a broad syncline containing more than 25,000 feet of Proterozoic and Lower Palaeozoic rocks beneath the central Missionary Plain. On the basis of limited shooting the north flank appears to reflect extensive décollement adjustment with associated thrust faulting related to tectonic movements of the MacDonnell Ranges. The south flank of the syncline either dips gently from the flanks of the bordering anticlines as at the James and Palm Valley structures, or is abruptly dislocated as along the Gardiner fault and the Watson Range. Two major subsurface uplifts with one completely unsuspected closed anticlinal structure were defined by the survey.

Seismic data have shown that a profound angular unconformity between the Pertnjara and older formations is present under at least the northern part of the plain. It is concluded that the Pertnjara synorogenic conglomerate along the MacDonnell Ranges front can mask significant pre-Pertnjara structures.

Semi-detail shooting defined or provided new information on five major structures: Tyler anticline; Northeast Gardiner terrace; West Waterhouse anticlinal nose; Carmichael - Deering Creek faulted anticlinal trend; and Gosse's Bluff uplift (See Appendix VI).

B. Regional Features

Well-defined surface structures border the area of seismic survey. They indicate a long east-west trough from Waterhouse Range to the east-pitching synclinal axis between the Deering Creek outcrops and the northwest extension of Gardiner Range. Gosse's Bluff is the only interruption of note in this distance of over 100 miles. This survey has in part compromised a simple interpretation of this Missionary Plain area.

Results in the east-central portion, (east of Gosse's Bluff and north of Hermannsburg) show a simple, asymmetrical basin, arcuate to the southeast and southwest, following the general conformation of the Palm

Valley anticline and its western extension. North slopes into the basin are very regular in Ordovician, Cambrian and Proterozoic sections as mapped, but become gentler to the west as the Gardiner Range fault is approached. The north side of the basin is much steeper with faults cutting all horizons below Mereenie.

To the east the basin shallows then bifurcates around the west extension of Waterhouse Range, the north branch in apparent en echelon position as it again pitches eastward. The southern branch forms the syncline separating Waterhouse from the James Range series of anticlines and is considerably shallower in all horizons.

The west end of this central basin is forced into a south-west trend by the arcuate ancestral ridge connecting NE Gardiner, Gosse's Bluff and Tyler. (It is postulated that this ridge may continue eastward through or under Glen Helen and may be tectonically connected to the northwest trending Waterhouse axis.)

A second major basin lies to the west and north of this ridge. Again the arcuate trend is apparent from near the west end of Gardiner Range outcrops to the lowest point mapped north of Tyler anticline. Southern slope of the basin is similar to the central basin i.e. more gently dipping as the Gardiner Fault is approached, and more steeply dipping north of Tyler. The north flank of the basin is seen only partially at Carmichael where it is steep. Eastward from here the Carmichael thrust apparently transgresses the synclinal axis until, north of Tyler, only the south flank of the basin can be shown. It is postulated that the fault and the south flank continue eastwards under the MacDonnell Ranges where they are folded and crop out on the surface at Goyder Pass, presenting a cross section of this structure.

West of Carmichael only sparse seismic control was obtained on lines 1-3 and O-4. Very poor to NR data were recorded except for a segment of line 1-3 (28 to 41), which indicates a syncline between the Glen Edith Hills and the Watson Range. This syncline is considerably shallower on all horizons than that between Mereenie and Gardiner Range, which, in turn, is shallower than both the central and west basins of the Missionary Plain.

Regional variations in stratigraphic thicknesses have been investigated by means of the isochronous interval maps presented herewith. (Plates X to XIII). Some trends are quite apparent, but in much of the area mapped local influences, such as faulting with diapirism, have modified and distorted the regional pattern. The most complex of these is the area north of West Waterhouse.

In general, the Ordovician represented by the A-B and B-C isochrons (Plates X and XI) shows a gradual thickening westward into the deeper western basin. The Northeast Gardiner - Gosse's Bluff - Tyler ancestral ridge is defined as a prominent depositional thin, stretching in an arc from Katapata Gap towards Glen Helen. The thickest section of Ordovician lies northwest of Tyler structure where contemporaneous movement along the Carmichael fault probably contributed to the increase in sedimentation. Southward regional thinning though not great, is sufficient to indicate the Palm Valley anticline to have been a slightly positive area.

The Upper Cambrian section, represented by the C to D Isochron, (Plate XII), indicates a very quiescent period in the synclinal areas and only slight positive influences over the Northeast Gardiner - Gosse's Bluff - Tyler arc. Differential movement along the Carmichael fault is shown by abrupt local thickness changes. Other local and sharp changes at West Waterhouse and Carmichael structures firmly suggest later diapiric injection of Cambrian salts or other evaporites. A local thin paralleling the Gardiner thrust suggests that this was a positive trend during Cambrian deposition.

The Lower Cambrian - Upper Proterozoic (D to E) Isochron (Plate XIII) shows a general and quite pronounced thickening to the west and south in the central basin, while a north-westward thickening is apparent in the western basin. The ancestral Northeast Gardiner - Gosse's Bluff - Tyler ridge is still shown, but it is now secondary to a thin parallel ridge immediately to the northwest. This feature runs directly into Goyder Pass diapir, indicating a very early ancestral positive trend - possibly a salt swell of Bitter Springs evaporites caused by Pertatataka and or Arumbera loading.

Trends eastward from the central basin indicate an early origin of the West Waterhouse positive by the bifurcation of the axial thin. Drastic local changes at West Waterhouse attest to severe diapirism combined with complex thrust faulting.

The localized thin and thick areas at Tyler and at Carmichael are believed to be the direct result of tectonic and associated diapiric deformation rather than depositional patterns. One exception may be the westward thickening over the axial trend of Tyler.

C. Horizons Mapped

Five horizons have been mapped over most of the survey area on nearly continuous events; three lie within the Ordovician section, one in the Cambrian and one in the Proterozoic. Identifications of shallow horizons have been tentatively established through a tie to the Palm Valley No. 1 well for which there is a velocity survey, acoustic log, and synthetic seismogram, and supported in part by projection of the horizons into areas of outcrop.

It is specifically pointed out, however, that data at and north of the Palm Valley well are very poor (S.P. 1-7 line 2-2), having been recorded in the Finke River canyon, and these horizon ties could be considerably in error by either mis-correlation or faulting or both.

All maps are contoured in reflection time from a datum of 1,800 feet a.s.l.

Isochronous interval maps between these horizons have been prepared and, together with the structure maps, are enclosed in the separate map folio of this report.

The maps are identified as follows:

Horizon A, Approx. Base of Mereenie (Plate V)
Horizon B, Approx. Horn Valley (Plate VI)
Horizon C, Approx. Mid-Pacoota (Plate VII)
Horizon D, Approx. Hugh River-Jay Creek (Plate VIII)

Horizon E,	Approx.	Areyonga-Bitter Springs	(Plate IX)
Isochron A-B	Approx.	Base of Mereenie to Horn Valley	(Plate X)
Isochron B-C	Approx.	Horn Valley to Mid-Pacoota	(Plate XI)
Isochron C-D	Approx.	Mid-Pacoota to Hugh River-Jay Creek	(Plate XII)
Isochron D-E	Approx.	Hugh River-Jay Creek to	
	Approx.	Areyonga-Bitter Springs	(Plate XIII)

a. Horizon A Approximate Base of Mereenie (Plate V)

This map is based on a good continuous reflection over most of the area. Energy and character go out in shallow zones as outcrops or structural highs are approached. All major structural features found in the course of the survey are represented on this horizon. Major faulting cuts through the Mereenie although many of the local imbricate thrusts representing décollement adjustments are confined to deeper horizons.

b. Horizon B Approximate Horn Valley (Plate VI)

This map is also based on a good continuous event over all but the structurally highest areas. Character is good and correlation certain except in the area northwest of Waterhouse, (where depositional changes, erosion and probable minor faulting change character of the reflection resulting in uncertain correlation). This, in turn, affects the apparent validity of both isochrons, A-B and B-C. Some of the small thrusts in the Tyler area displace the B horizon. Local radial and/or peripheral faults in the Gosse's Bluff area also show displacement at this depth.

c. Horizon C, Approximate Mid-Pacoota (Plate VII)

This horizon is the one best identified in its tie into the Palm Valley well. The reflection is part of a narrow band with usually less energy than events above and below but with very consistent frequency and amplitude. The resultant map is considered the most reliable of the five horizons. One weakness is its precise position within the Pacoota as this formation varies in thickness from 1,500 to 2,500 feet over the area. At

Palm Valley well, the tie places the C horizon about 600 feet below the Pacoota top. Total thickness is about 2,000 feet. It is believed that this reflection is probably representative of changes in the Upper Pacoota and that isochronous changes below include the increased Pacoota section where it is thicker.

Evidence of multiple fault cuts of this horizon at Tyler, Gosse's Bluff and Waterhouse indicate that rocks both above and below have flowed in diapiric adjustment with the competent Pacoota broken and locally repeated through over-thrusts.

This Mid-Pacoota reflection ties to a good event on the synthetic seismogram made from the Palm Valley sonic log.

d. Horizon D, Approximate Hugh River-Jay Creek (Plate VIII)

This map is thought to be representative of the Hugh River and the Jay Creek formations of lower Cambrian age. It is based on a good narrow band of energy that is consistent but, in places changes character through phase shifts. These could introduce an error of twenty to thirty milliseconds, possibly in the Northeast Gardiner area. Correlations are considered reliable elsewhere. The tie to Palm Valley well is by projection of thickness measurements from surface outcrops below the total depth of the hole. It cannot be determined whether the reflection as followed to the east represents the Hugh River-Jay Creek contact or remains representative of the Goyder-Jay Creek contact (See Fig.3). There is also some doubt of what it represents west of Carmichael where the Hugh River becomes more sandy until it merges into the Cleland. The energy and sequence correlation to Line 1-3 is relatively good, however, so it is believed that the reflection probably represents a base of Goyder-Hugh River contact similar, at least in acoustic response, to that found in the central part of the area.

Major faulting cuts this horizon but it is interesting to note that the smaller thrusts that so disrupt the Pacoota on the Tyler structure apparently do not affect the Hugh River-Jay Creek. This reflection carries continuously over the crest on lines 2-4.8, 2-4.4, and 2-4 extension once the major fault on the south flank is crossed.

e. Horizon E, Approximate Areyonga-Bitter Springs (Plate IX)

This map is based on the deepest conformable band of energy and is identified by projection below the Palm Valley well. It is believed to correlate with the lower Areyonga or the upper carbonate section of the Bitter Springs formation. The many fault breaks coupled with good evidence of deeper plastic movement support identification with the competent upper part of the Bitter Springs. The horizon is readily correlated even where it is repeated on the same record. Character is very consistent but there is a possibility of mis-correlation when frequency becomes high. Maximum error would be twenty to thirty milliseconds.

The most complex area shown is the West Waterhouse feature. The interpretation made is believed to be basically correct, but probably over-simplified. (See Plate XV, reduced copy of line 3-4). Several faults displacing the horizon cannot be adequately shown on the map, because they are hidden below others; the imbricate repetition would require two sets of contours.

Data below this horizon are quite independent, sometimes conforming and sometimes showing great discontinuity. In many areas strong bands of diffraction energy are clearly seen. It is postulated that many of these diffractions originate with probable faulting within the Pre-Heavitree section, presumably the Arunta Complex.

D. Conclusions and Recommendations

The unusually good seismic data recorded over most of the area recommend the reflection method for exploration. The wealth of data recovered presents a challenge to the interpreter. As more direct knowledge of the section is gained through additional drilling it will probably be possible to map unconformities and section changes within very close limits.

Identification of energy bands and individual reflections is not as firm as desired due mainly to poor data on the tie line to Palm Valley well and to the limited depth of penetration of the well. The possibility of a fault in the poor data zone to the north is a recognized hazard which could cause some misinterpretation. Tie-in to surface outcrops by projection, however has been quite close in a sufficient number of cases to obviate the possibility of gross error.

This survey with its projected continuation should provide a basis for reasonably conclusive understanding of tectonics and depositional patterns over a large part of the concealed Northern Amadeus basin.

E. Prospects

Semi-detail shooting defined or provided new information on five major prospects: Tyler anticline; Northeast Gardiner terrace; West Waterhouse anticlinal nose; Carmichael faulted anticline; Gosse's Bluff uplift. They are discussed in detail in Appendix VI.

EDWARD A. KRIEG AND ASSOCIATES — GEOPHYSICAL ASSOCIATES PTY. LTD.

E.A. Krieg

E.A. Krieg

J.H.B. Campbell

J.H.B. Campbell

APPENDIX I

EQUIPMENT

Automotive

7 F-750 Fords, 4 or 6 wheel drive, equipped with winch
5 Toyotas and 1 Land Rover, with 4 wheel drive

Recording

1 Recording truck with air conditioned instrument cab
1 Cable Toyota with 'Squirter' cable handler and geophone storage
1 Set Dynatronics fully transistorised TA-8 AM or FM amplifiers
1 SIE RO-22A Recording Camera
450 SIE S-16, 18 cps Reflection Geophones
3 Vector standard reflection cables 1800' each
1 SIE SCD-2000 BA Multicap Blaster
1 SIE PCB-12B Portable Blaster
2 Vector Portable Cables 1320' each

Shooting

1 F-750 Ford Truck

Drilling

2 Mayhew 1000 air-water combination drills
2 Water trucks mounted with a stake sided flat bed 1000 gallon tank
1 Land Rover Service Unit

Surveying

2 Toyotas (1 supplied by Magellan)
2 K & E Transits

Supply

Contract hired large trucks for large loads, Party Chief's Toyota for smaller loads

Office

1 Trailer complete with office equipment and printer
1 Auxiliary trailer for gravity office, also used as radio shack. (Trailer and Radio supplied by Magellan)

Camp

1 Kitchen trailer with attached dining tent
1 Utility trailer with shower, wash facilities and 4 bunks
2 Sleeping trailers with 8 bunks each
1 Workshop trailer mounted on an F-750 Ford with electric and acetylene welders and a complete set of hand and power tools
2 Diesel generators, trailer mounted 15 kw each
3 Six man sleeping tents with beds etc.

Gravity Equipment

1 Toyota

1 La Coste Romberg land meter

1 La Coste Romberg reserve portable meter

Track Vehicle

(Under Sub-contract)

1 Allis-Chalmers crawler-tractor with dozer blade and 2000 gallon water trailer

APPENDIX II

PERSONNEL

Party Chief	J.D. Fellows
Party Manager	B.T. Ford
Seismologist	R.D. Graves
Computers	J. Allender, J. Lockhart D.K. Smith
Observer	K. Pelegrin
Junior Observer	E.C. Geyer
Surveyors	L. Bear, W. Dodds, G. Seals, G. Kenway
Drillers	G.E. Thompson J. Tarbet C.T. Hogbin H. Malone
Gravity Computer	J. Aston
Meter Operator	S.A. Harris

The basic crew comprised 24 men.

In addition to the key personnel listed above 13 men were employed as:

Shooter	1
Rodmen	2
Recording Helpers	4
Drilling Helpers	2
Cook	1
Cook's Helper	1
Mechanic	1
Mechanic's Helper	1

<u>APPENDIX III</u>

<u>STATISTICS</u>

Starting Date		June 1st, 1965
Completion Date		November 27th, 1965
Total Hours		1830¼
Recording Hours (Field)		1392½
Travel Hours		259¾
Weather Hours - 23¾ less 12¼ made-up		11½
Camp Move Hours		126½
Wait on Crawler Hours		30
Holiday Hours		10
Days Worked		172
No. of Shot Holes		1403
Total Shots		1448
Miles Traversed		467
Pounds Geophex Used		79,440
Pounds Nitrate Used		66,715
Average Charge Size		100.9
Detonators Used		2438
Drill No. 1	Holes Drilled	757
	Total Footage	86,926
	Hours Drilling	1476½
	Travelling	280½
	Other	120
	Total Hours	1877
	Average Penetration	58.9 ft/hr
Drill No. 2	Holes Drilled	735
	Total Footage	85,587
	Hours Drilling	1435½
	Travelling	283
	Other	133½
	Total Hours	1852
	Average Penetration	59.6 ft/hr
Crawler Operating Hours		1187
Gravity Crew Hours		1795
Gravity Stations		2547
Bits Used:	4¼" Rock	61
	4¼" Insert	209
	4½" Rock	168
	4½" Insert	406
	4½" Blade	60
	4¾" Rock	49
	4¾" Insert	33
	4¾" Blade	7
	4 5/8" Rock	4
	4 5/8" Starter	42
	6¼" Rock	6
	6¼" Starter	3
	6¾" Starter	4
	7" Starter	4

APPENDIX IV

GAS IN SEISMIC SHOT HOLES

Gas was encountered in a total of 19 shot holes in the course of the survey (see Plates 1-5). Of these, 8 ignited and burned, whereas the remainder either would not support combustion or flows were too small. The holes were drilled into Pertnjara sandstone or conglomerate bedrock to depths of 80 to 120 feet with no sign of gas during drilling, and were shot with 10 to 100 pounds of Geophex and 60 to 70 pounds of nitrate. Gas blew for periods varying from a few seconds to over 18 hours. All had some odour, variously described as similar to coal gas, naptha, hydrogen sulfide or unrecognizable. Eight samples were caught by holding a plastic container over the blowing hole. The analyses were predominantly air and products of the explosion, but all contained small percentages of hydrocarbon gases. Gas chromatographic analyses were made by Australia Mineral Development Laboratories in Adelaide, and are on file in the Magellan office. Despite the crude sampling procedure and improper containers (which are permeable to hydrocarbon gases and which had collapsed), Methane, Ethane, Propane, i-Butane, n-Butane and higher hydrocarbons were identified in quantities ranging from a trace to more than 5% (4.45% in S.P. 62, line 2-6; 5.02% in S.P. 01 line 2-2.7). In addition to the hydrocarbons, the following gases were present in order of abundance: Nitrogen, Oxygen, Carbon Dioxide, Carbon Monoxide, Water Vapour, Hydrogen, Helium and Hydrogen Sulfide (4% in S.P.54 line 2-6).

It is difficult to assess the significance of the gaseous hydrocarbons in near surface beds of tight Pertnjara sandstone and conglomerate. The distribution of the gas is concentrated around structures, many of which are known to be faulted. It therefore seems most probable that the gas is seeping from deeper sources and is being trapped in local near surface pockets from which it is liberated by detonation of the shots. The Gosse's Bluff well, in fact, yielded gas from fractured Stairway sandstones at 3,090'.

APPENDIX V

GRAVITY

SUMMARY

The Missionary Plain seismic operation was accompanied by an abbreviated gravity crew for the primary purpose of making gravity observations at shot points. In addition, gravity stations were made along roads and on other connecting lines which gave somewhat more coverage than that of the seismic survey.

The gravity results show strong anomalies, and it is obvious that there are strong density contrasts among the sedimentary rocks of the Missionary Plain. These contrasts have been partially evaluated by a study of the velocity logs in the Palm Valley and East Mereenie No. 2 wells and from two gravity traverses which cross outcrops of the MacDonnell Range.

The regional gravity pattern shows a westward plunging regional minimal axis corresponding approximately with the Missionary Plain. A Residual Map shows several local features of probable structural significance which are discussed in some detail. Correlation of gravity and seismic results is definite on some features and obscure on others. It appears that some of the gravity expression must come from density contrasts which are quite shallow and in the early time zone of the seismic records where reflections are obscure or not recognizable.

GRAVITY

CONTENTS

INTRODUCTION

This report covers the operations and results of a gravity survey conducted together with the seismograph operation in the Missionary Plain area. As originally planned, the gravity survey was to provide values at each seismic shot point at three stations per mile along all the seismic traverses. In addition, gravity stations were observed, at the same spacing, along roads or trails and in other places between seismic lines so that the coverage by the gravity survey is somewhat more complete than that of the seismic operation.

The gravity party consisted of only four men added to the seismic crew. These were the surveyor, rodman, meter operator, and computer. During the period June 5 to December 2, 1965, a total of 2547 stations were observed.

Details of the gravity operations are given on pages 49-51.

PREVIOUS GRAVITY SURVEYS

A survey in 1961 by Century Geophysical Company for Magellan consisted of widely spaced reconnaissance lines some of which are in the Missionary Plain area. A local survey in the Gosse's Bluff area was made by Frome-Broken Hill Co. Pty. Ltd. These older surveys have been used to a very limited extent where they have given useful additions to the control.

The general Missionary Plain area is included in the B.M.R. helicopter gravity survey of the Amadeus Basin with approximately seven-mile station spacing and mapped at scale 1 : 250,000. The Bouguer correction was for a density of 2.20. This map shows the Missionary Plain as in a flat minimal zone plunging to the west with gravity decreasing from about -115 mg at the east end of the present survey (longitude 133°15') to -135 mg at the west edge of the available maps (longitude 132°). The north flank of the minimum shows an extremely strong gravity rise of about 180 mg to an apex of +50 at about latitude 23°10', longitude 132°45'. This maximum is approximately in the centre of the belt of Archaean rocks between the Amadeus Basin and the Ngalia trough to the north.

GEOLOGICAL BACKGROUND

The Missionary Plain survey is within the deeper part of the Amadeus Basin. Below the cover of recent alluvium and Tertiary, the area is covered by the Pertnjara formation (Devonian ?) which crops out over the northern and southeasterly parts of the Plain. To the north the Plain is bounded by the nearly vertical beds of the MacDonnell Range which extend westward from Alice Springs to the western part of the surveyed area. The very steep gravity rise to the north, as shown by the B.M.R. regional survey, is quite closely parallel with the MacDonnell Range but the steepest part of this rise, which must be over the central part of a profound density contrast, is considerably north of the MacDonnell Range and is in the area of Archaean outcrops. This had led to a B.M.R. interpretation that the MacDonnell Range is the forefront of a large overthrust and that the Amadeus Basin sediments extended northward under this overthrust into the zone of the steep northward gravity increase.

The southwesterly part of the Missionary Plain is interrupted by the outcrops of the Gardiner Range with southwest dip and bounded on the northeast by a large fault. These beds show the same sequence as that of the MacDonnell Range to the north. The Missionary Plain is underlain by a very thick section of Palaeozoic and Precambrian sediments. A measured section (B.M.R. Report No. 61) shows some 7000 ft of sediments from the Upper Cambrian to the base of the Pertnjara with that formation having a total thickness of 10,000 ft and also some 10,000 ft of Cambrian and Precambrian sediments. As will be pointed out in the section on densities, the Pertnjara is a relatively heavy formation which led to some correlation of Bouguer gravity values with a lower elevation factor (0.063, density 2.44) rather than the factor used in the original reduction (0.068, density 2.05). The densities of the underlying rocks which crop out in the MacDonnell Range are variable as shown by steep gravity changes in the traverses which cross the Range.

DENSITIES

It is apparent, from the sharp gravity changes, that there are substantial density differences among the rocks of the Amadeus Basin. Considerable variation in density is to be expected from the lithology of the rocks. More quantitative evidence has been derived from density profiles of gravity stations and from the continuous velocity logs of the Palm Valley and East Mereenie No. 2 gas wells.

The Century Geophysical Company's gravity operation in 1962 reported three elevation factor profiles. As we interpret these results, the line on the Arumbera formation some 50 miles east of the present survey gave a factor of .065 mgs/ft corresponding to a density of 2.26; one north of Gosse's Bluff on the Pertnjara gave a factor of .062 (density of 2.51), and one north of Glen Helen Tourist Camp on the Bitter Springs gave a factor of .068 (density of 2.05).

During the GAPL operation in 1965 three profiles were run. No. 1 is about nine miles north-northwest of the Hermannsburg Mission on an east-west line through station 631 and gave a factor of .064 (density 2.36). From the geologic map this appears to be on alluvium, but this could be very thin and the effective formation probably is Pertnjara. Profiles Nos. 2 and 3 are on east-west lines through shot points 55 and 59, respectively on seismic line 2-5, and about 10 miles northeast of Gosse's Bluff. These gave values of .072 and .071 corresponding to densities of 1.73 and 1.80, respectively. The surface formation is mapped as Pertnjara conglomerate but, according to Dr. McNaughton, this is in an area of very highly disturbed surface geology, so these values probably are not typical of that formation. (See Footnote 1 at end of Appendix V). These locations must be rather near the Century profile on the Pertnjara located only as "on Haast Bluff road, north of Gosse's Bluff" which suggests that there may be rapid local variations in Pertnjara density.

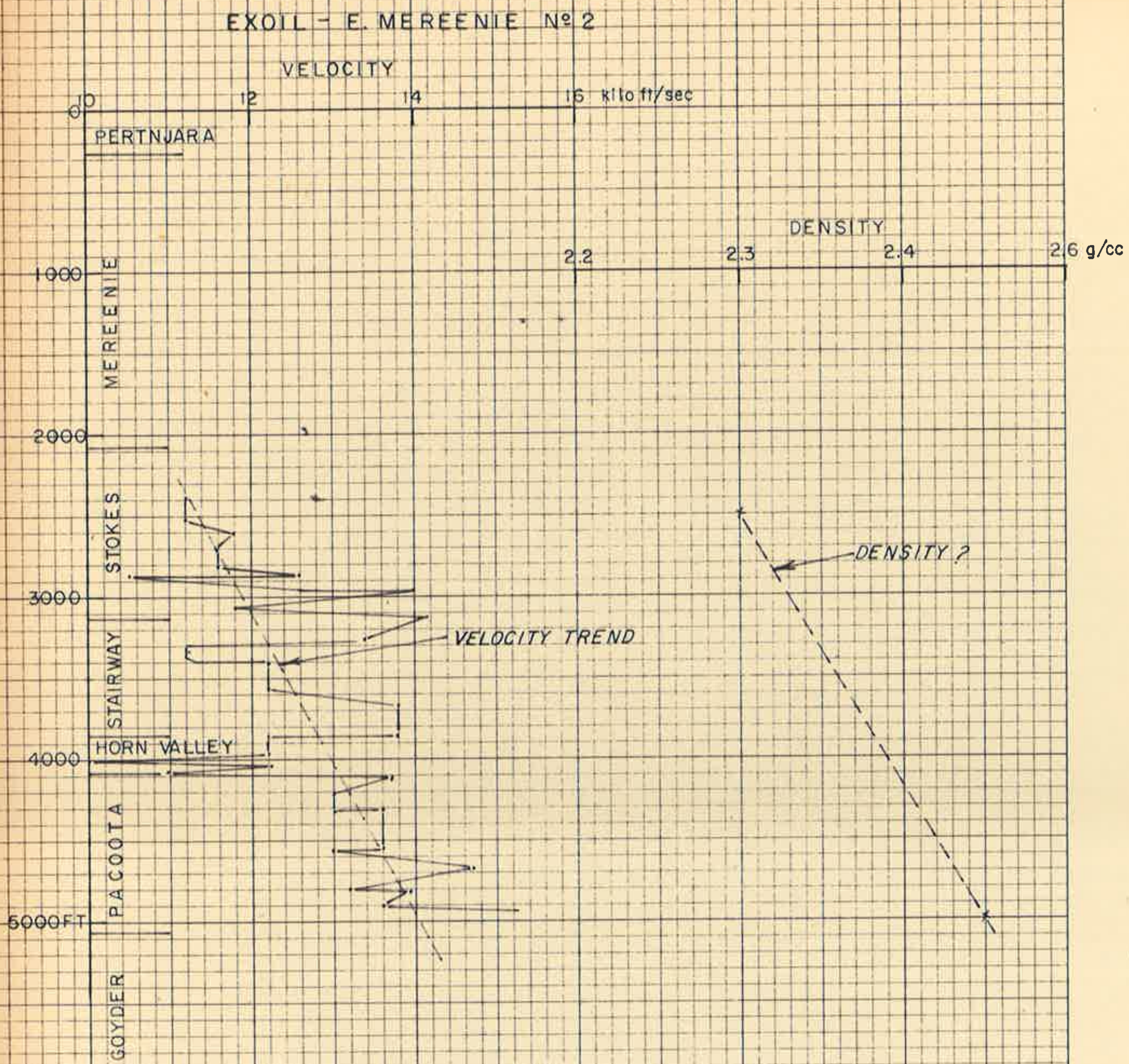

FIGURE 2

EXOIL E. MEREENIE Nº 2

VELOCITY DATA

FROM

SCHLUMBERGER CONTINUOUS VELOCITY LOG, 2380-4990 FT

AND

POSSIBLE AVERAGE DENSITIES

GAPL HOUSTON, TEXAS 25 JAN 1966

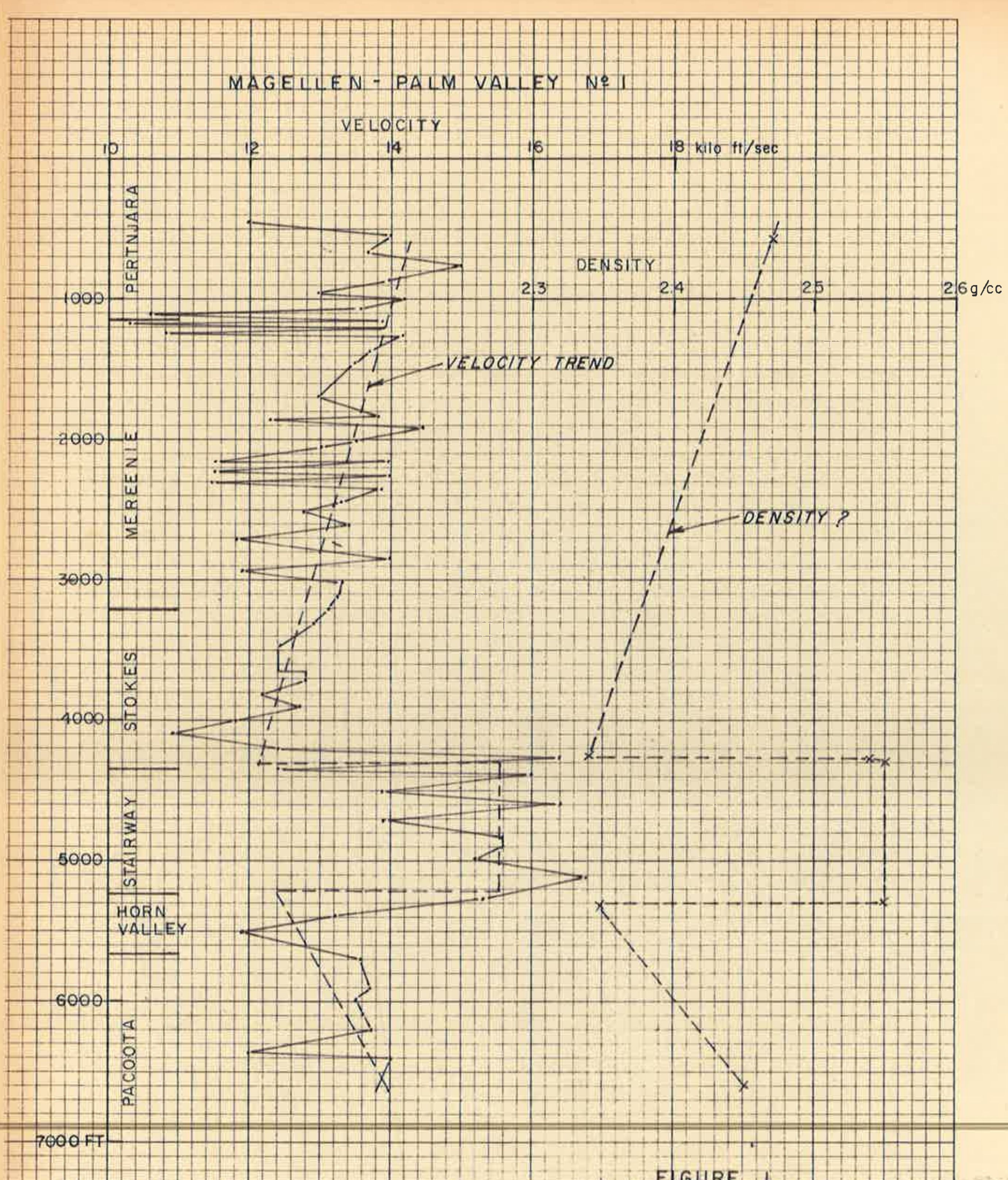

FIGURE 1

MAGELLAN – PALM VALLEY Nº 1

VELOCITY DATA

FROM

WELEX CONTINOUS VELOCITY LOG, 380 – 6650 FT

AND

POSSIBLE AVERAGE DENSITIES

GAPL HOUSTON, TEXAS 25 JAN 1966

From the gravity results in the vicinity of the Palm Valley well, where there is nearly 1000 ft of topographic relief, it is quite clear that the original elevation factor of .068 (density 2.04) is too high. A new map with factor .063 (density 2.42) is considerably smoother. Since the topography is mostly from the Pertnjara outcrop this indicates a density which is in fair agreement with that from the Century profile on the Pertnjara.

The accompanying charts, Figures 1 and 2, show velocity measurements from the Palm Valley and East Mereenie No. 2 wells. These are based on continuous velocity logs by Welex and Schlumberger, respectively. The times (microseconds/ft) have been converted to velocities for plotting on the charts. We have estimated an average velocity in each of the principal components of the sedimentary section as indicated by the dashed lines. The Palm Valley chart shows a general decrease in density from the surface to the Stairway, a strong increase at the Stairway, low velocity at the top of the Horn Valley, and an increase to the bottom of the hole in Pacoota.

There has been some work published in the geophysical literature which attempts to establish relations between seismic velocity and density for clastic sediments.* The over-all velocity changes, indicated by the dashed lines, have been converted to densities by the Nafe and Drake curve (see footnote) to give the density changes indicated on the right-hand side of the charts. For the Palm Valley well the Stairway is shown as having a density about 0.2 g/cc higher than adjacent formations above and below.

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* A curve by Nafe and Drake is reproduced by Talwani, Journal Geophysical Research, Vol. 64, No. 10 (Oct., 1959), p. 1548. Another curve, by Woollard, is given in Journal Geophysical Research, Vol. 64, No. 10 (Oct., 1959), p.1530. A few isolated points are given by Wylie, GEOPHYSICS, Vol. 21, No. 1 (Jan, 1956), Fig. 18 which are quite close to the Nafe and Drake curve.

Further indications of density contrasts are given by the gravity traverses which were carried into or across the MacDonnell Range outcrops:

1. North of Gosse's Bluff the Century data on the Haast Bluff road show a very sharp minimum at the -130 gravity contour. This minimum is mostly in the Pacoota outcrop. To the north there is an extremely sharp change of 5 mg which appears to be about at the outcrop between the Hugh River and the Arumbera with the Arumbera on the high gravity side and therefore presumably of higher density. There is another steep change at the base of the Arumbera which would indicate that the Pertatataka formation is still heavier. These inferences as to density contrasts are not very accurate as the station spacing is greater than the width of some of the outcrops. A line of very closely spaced stations in this area, with spacing considerably less than the outcrop widths, would give very sharp changes that should give definite indications of the density contrasts.

2. On the north end of seismic line 2-2.7 near the Glen Helen Tourist Camp there are very sharp changes with the minimum shown by the -135 contour corresponding approximately with the Mereenie and Stokes outcrops. The sharp gravity rise to the south apparently is caused by the thickening of the Pertnjara formation away from its truncation at the foot of the MacDonnell Range.

3. The Century Geophysical Company's data south of Alice Springs show a very sharp gravity negative feature which corresponds closely with the MacDonnell Range outcrops, but we have insufficient geological detail here to determine the relation of gravity features to individual outcropping formations.

The general conclusions with regard to densities and density contrasts of the rocks under the area of the Missionary Plain survey are as follows:

1. There is an indication that density decreases with depth below the Pertnjara, with the Pertnjara section being definitely heavier than the underlying Mereenie.

2. In that part the geologically disturbed Pertnjara area the density is significantly lower.

3. The Stairway in the Palm Valley well is distinctly heavier than the overlying Stokes and underlying Horn Valley and Pacoota, but does not stand out distinctly in the East Mereenie No. 2 well.

4. The Bitter Springs is much lighter and strong gravity effects should be encountered where Bitter Springs is in steeply dipping contact with younger formations.

5. The gravity traverses across the outcrops on the MacDonnell Range show very sharp changes; the detail is insufficient to clearly define the density contrasts within the section, but there are indications that the Pacoota is relatively light, that the Pertnjara is relatively heavy and that there are some very strong density contrasts in the Lower Cambrian and Upper Proterozoic parts of the section.

THE BOUGUER GRAVITY MAP

The gravity map is contoured at 0.5 interval (except in the part west of longitude 131°30'). The values were reduced with an elevation factor of 0.063 mgs/ft, (density 2.44) computed from sea level. The original map was reduced with an elevation factor of 0.068 mgs/ft (density 2.05). This makes a difference of approximately 10 mgs (exactly 10 mgs for elevation 2000 ft) with the new survey being algebraically higher. The change in elevation factor and the recontouring have given the revised map a somewhat different appearance in detail than the original field map.

On the whole, we believe that the lower elevation factor (higher density) gives a distinctly better map and recommend that this factor be continued for any other gravity work done in the area unless and until a definite correlation of gravity anomalies with topography is developed which would indicate a revision of the elevation factor.

The Century Geophysical Company's Bouguer gravity map has been used to extend the map where significant additions could be made. Locations of Century stations used are shown by small x's. The use of a different elevation factor causes a minor complication when gravity values from this survey are compared with those of the earlier Century survey which was reduced with an elevation factor of .068. We believe that it is more important to use the more nearly correct elevation factor and reduce correlations with topography than it is to maintain an exact compatibility of the two surveys. Therefore, the datum of the Century survey was changed locally and segments of contours added with values re-numbered to fit the local datum of the new survey. The principal such extensions are southeast of the Palm Valley well, north of the West Waterhouse area, along the road northwesterly from the Tyler area and north of Gosse's Bluff, and at the south edge of the survey south of Gosse's Bluff.

For the most part, the local features as now shown have substantially the same form as when discussed in the preliminary report. The local features in the West Waterhouse, Tyler-Glen Helen, Carmichael, and Western areas are little changed and the present comments are similar to those made earlier.

Regional Aspects

From the east limit of the survey to the Carmichael area, the over-all regional pattern is of a gravity basin plunging to the west. Note that at the east end of the survey the lowest gravity values near the minimal axis are about -118 and that in the Carmichael area they are about -150. This corresponds with the westward decrease in gravity shown by the B.M.R. reconnaissance survey mentioned above. While not very apparent from the Bouguer gravity map because of the strong local irregularities, this regional westward decrease of gravity is nearly uniform across the map. The regional apparently rises again to the west but is not well defined because of the wide gaps in the control. In a general way, the regional gravity trough corresponds with the Missionary Plain Basin between the MacDonnell and Gardiner Ranges.

THE RESIDUAL GRAVITY MAP

The Residual Gravity Map has been constructed to bring out more clearly the local features which are distorted by the regional pattern. The regional removed is shown by the smooth background contours at 5 mg interval from -120 in the eastern part of the map to -145 in the Carmichael area. These contours show the simple westerly plunging gravity basin corresponding approximately with the Missionary Plain as a whole.

The residual contours, at 0.5 mg interval, are the gravity pattern remaining after subtraction of the smooth regional contours from the contours of the Bouguer gravity map.

LOCAL FEATURES

Introduction

The comments which follow consider each of the local features of particular interest. Usually the local features are better expressed on the residual map although, for the particularly sharp ones, the same features are apparent on either the observed or residual map. The features are discussed generally in order from east to west across the survey.

West Waterhouse Area, Lat. 24°00'; Long. 133°10'

The principal feature is a very sharp, elongated gravity minimum. Observed gravity profiles (Fig. 3) are on seismic line 3-4 (Fig. 3A) and on seismic lines 3-3.75 and 3-3.7 (Fig. 3B). The horizontal scale matches that of the reduced seismic sections. The

The profile shows a very sharp gravity decrease going northward as the line leaves the wide-spread Pertnjara outcrop. It is our opinion that this decrease of about 6 mg from S.P. 6 to gravity station 2569, a distance of one mile, is caused almost entirely by the termination of the Pertnjara and its positive density contrast with respect to the underlying lower density Mereenie and Stokes formations. For an assumed density contrast of 0.4 the required thickness of the Pertnjara to account for 6 mg is about 1200 ft. The gravity rise of about 2 mg from stations 2569 to 2571 is attributable to higher density Stairway formation. These density relations, in a general way, confirm those derived from the continuous velocity log in the Palm Valley well (Fig. 1) as given in the section on densities.

Tyler Area, Lat. 23°45'; Long. 132°25'

The seismograph shows a prominent structure with some closure centring east of S.P. 50 on line 2-5. There is no confirmation in the gravity as the seismograph feature extends across the quite regular residual contours on the northeasterly flank of Gosse's Bluff minimum.

A rather prominent gravity anomaly centres to the southeast at about S.P. 40 on line 2-4 which appears to be near the centre of the syncline shown by the seismograph results. The gravity anomaly may be caused by local thickening of the Pertnjara in the syncline.

Gosse's Bluff, Lat. 23°50'; Long. 132°20'

Removal of the regional has developed the Gosse's Bluff anomaly into a very regular circular minimum with a relatively flat internal area which is highly disturbed locally (the contouring immediately around the Gosse's Bluff No. 1 test was controlled by stations from the Frome-Broken Hill survey but not shown on the map). The centre of the relatively steep band of contours on the flank of the minimum (approximately the -2.0 residual gravity contour) has an average diameter of about 13 miles. The feature as a whole, as shown by this minimum, is very much larger than the circular Gosse's Bluff topographic extension of the gravity decrease into the MacDonnell Range as shown farther west by line 2-2.7. From its gravity expression the anomaly is rather an attractive suggestion of a broad structure. However, it may be primarily an expression of changes in thickness of relatively heavy Pertnjara formation where it is truncated on the north at the foot of the MacDonnell Range and increases in thickness toward the synclinal axis of the basin.

<u>Palm Valley Area, Lat. 24°00'; Long. 132°40'</u>

Gravity control over the Palm Valley structure is poor because of the very severe topography and only scattered stations in the Pertnjara outcrops. The stations to the south edge of the control were observed by helicopter with barometric elevations and are less precise than those of the remainder of the survey. There is topographic relief of nearly 1000 ft in the area south of the Palm Valley axis. The residual map shows an east-west trending maximum that coincides approximately with the probable axis of the Palm Valley structure. The area, as a whole, is rather strongly negative. This may be due to the structural uplift in combination with the decrease of density with depth as inferred from the velocities in the Palm Valley well (see velocity data chart in section on densities). The uplift of these lower density formations together with the Pertnjara formation could cause a broad negative anomaly with the central positive part being caused by more local uplift of the relatively heavy Stairway formation.

<u>Glen Helen Area, Lat. 23°42'; Long. 132°40'</u>

As pointed out in the section on densities, the very sharp gravity changes at the north end of line 2-2.7 are almost certainly associated with density contrasts in the steeply dipping outcrops of the MacDonnell Range and the truncation of the relatively heavy Pertnjara formation. The situation is illustrated by Figure 4 where the gravity along seismic line 2-2.7 and its north and south gravity extensions which are shown together with a schematic geologic section. This section is inferred from the map of B.M.R. Report No. 61, showing the outcrops in the MacDonnell Range; the variation of dip of the different beds is not shown.

profile on the easterly seismograph line (Fig. 3B) shows a sharp gravity minimum with flanks which correspond closely to the fault indications from the seismograph. From the sharpness of the gravity indication its source must be quite shallow, probably not over 2000 to 3000 ft deep. This would correspond to times of less than 0.5 second on the seismic record sections in a zone where reflections are not readily identifiable. On line 3-4 (Fig. 3A) there is a broad maximum in the gravity profile centring at about S.P. 28 which is near the centre of the uplift shown by the seismic section; this corresponds to the broad positive band with a southwesterly trend centring at about S.P. 30 on the Residual Gravity Map. There are indications of relatively shallow faulting on the flanks of this anomaly; a fault with a relief of about 0.8 mg, positive side to the north is near S.P. 23 and one with relief of about 0.2 mg, positive side to the south is between 33 and 34. These correspond with the flanks of the positive anomaly of the residual map. In both indications the gravity feature is too sharp to have a depth of over 3000 to 4000 ft which would be above 0.5 sec in the seismic section where reflections are not readily recognizable.

A seismograph fault farther south, crossing the intersection of lines 3-4 and 3-B, is not sharply expressed by the gravity results. There is a possible expression of the fault to the west where it crosses line 3-5 in the fairly regular band of northwesterly trending gravity contours with values from zero to -2.0 on the Residual Gravity Map, but the postulated eastward extension, east of line 3-4, is in an area where the residual gravity is very flat.

The local positive anomaly to the south (south end of line 3-4) apparently does not have a corresponding expression in the deeper reflections as these show a regular north dip. The southern flank is quite sharp and must have its origin in much shallower density contrasts.

<u>Northwest Waterhouse Area, Lat. 23°50'; Long. 132°50'</u>

This large elongated northwesterly trending positive anomaly is defined by the northern parts of lines 2-1 and 2-2. The steep northern flank, as shown on the residual map, is only inferred but is a reasonable feature. It seems probable that the central maximum at the drilling test is due to a steep, plug-like body of Stairway formation with its relatively high density suggested by the velocities in the Palm Valley well. The rim of the anomaly must have a shallow source because the seismic traverses which cross the area are not locally disturbed in the deeper reflections.

Gardiner Range Fault, Lat. 23°55'; Long. 132°05'

The large fault at the northeast boundary of the Gardiner Range outcrop is shown conspicuously by the sharp southerly gravity increase at the south limit of the survey. The steep band of contours, as shown both by the observed and residual maps, corresponds closely with the fault and must have its origin in the high density of the Lower Cambrian and Proterozoic formations on the upthrown side in contrast with the younger Palaeozoic Missionary Plain section on the downthrown side.

Carmichael Area, Lat. 23°42'; Long. 131°50'

This area is largely west of the Residual Gravity Map, and only the east end of the anomaly is included on the residual map. As shown by the Observed Gravity Map, there is a long east-west trending negative area which is poorly defined because it is largely dependent on the single gravity traverse along the road. The gravity profile, Fig. 5A, on seismic line 1-1 shows a gravity rise extending from S.P. 29 to 45 with an amplitude of about 3.5 mg. This could be caused by a thrust fault with its high density side to the north. If it comes up to shallow depths, the surface trace should be about at S.P. 29 or 30. This is in a zone where the seismic record section begins to be quite highly disturbed.

On seismic line 1-2 (Fig. 5B) the gravity is very highly disturbed in the area from S.P. 21 to about S.P. 39. As indicated on the gravity profile, there could be two very large faults, probably thrust from the north. One is near S.P. 24 or 25 with a gravity relief of about 5 mg with its positive side to the north, and another is about at S.P. 33 or 34 with a very large relief, possibly as much as 9 mg. The sources of these anomalies are very shallow probably less than 2000 ft. These seem to be within a broad negative zone with relief of the order of 15 mg as indicated by the dashed line on the profile sheet. This negative zone corresponds with the area where the reflections seem to be completely lost. Probably the general feature is a diapir, overthrust from the north, with blocks of heavy material (Pertnjara ? or Stairway ?) overriding low density, possibly Bitter Springs material.

Western Area, Lat. 23°30' to 23°55'; Long. 131°00' to 131°30'

In this area the gravity is controlled by only a few widely spaced profiles which did not permit a reliable determination of the regional. Therefore it is shown only on the Bouguer gravity map. The area is so highly disturbed that any continuity of local features between individual lines is not very reliable. Line 1-3 is probably the most reliable as it is approximately perpendicular to the trends in the area. A gravity profile on this line at the scale of the reduced seismic record sections and with schematic sections from the scattered outcrops is shown as Figure 6. In a number of places the disturbances can be interpreted as faults. The series from S.P. 19 to S.P. 42 could be caused by thrust blocks, probably thrust from the north. They are quite sharp and could be immediately under the alluvial cover.

The highly disturbed area from about S.P. 46 to 64 is generally in the area of Ordovician and Cambrian outcrops shown as on the north flank of an anticline having its crest approximately at S.P. 55. The gravity over the north flank of the structure with north dipping Cambrian and Ordovician sediments apparently is caused by density contrasts between these sediments. Because of the relatively small scale (1 : 250,000) of the geologic map used, the location of the outcrops may not be precise. The gravity maximum at S.P. 58 may be caused by outcropping Pacoota. The very strong maximum from S.P.50 to 56 probably is caused by heavy Precambrian rocks on the crest of the anticline and at very shallow depth.

GAPL has no geological information to aid in the interpretation of the very irregular gravity north of S.P. 70. These features must be caused by relatively shallow contacts which could be beveled edges of outcrops of different densities or a series of faults.

Any of these sharp features might be caused, at least in part, by topography under the alluvium. With a density of, say, 1.9 for alluvium and 2.4 for bedrock, it would require about 150 ft of local buried topographic relief per milligal of gravity to explain the gravity anomalies.

GRAVITY FIELD OPERATIONS

A higher precision of vertical control than that normally needed for seismic operations to provide accurate gravity values at each seismic shot was required. Elevations to the order of 0.1 ft are needed to make the gravity reductions with sufficient precision to preserve the accuracy of the meter observations.

The field procedure was generally standard for gravity operations with the horizontal and vertical control at the seismic shot points being determined by the gravity surveyor. An exception to common procedure was that traverse locations were carried by turning plate angles with the transit rather than using compass bearings. This slowed the field procedures somewhat and also considerably increased the computer work in the field office.

Personnel

Party Chief and Computer	Jiggs Aston
Surveyors	W. Dodds and T. Bear
Meter Operator	S. Harris

Survey Control

Horizontal and vertical control was from B.M.R. bench marks and triangulation stations.

Gravity Datum

This was established from B.M.R. Station No. 35 near Alice Springs with gravity value 978.6536. We understand that this is the same location as the international gravity network station WA 3003 at the Alice Springs airport (Woollard and Rose, p. 73), latitude 23°48.4'S, longitude 133°53.5'E, elevation 1792 ft, gravity = 978.6541.

Meters

Two LaCoste and Romberg gravity meters were available. Most of the work was done with L-76, and the standby meter, D-1, was used only to a limited extent. Both meters were calibrated at B.M.R. calibration ranges at Brisbane and Alice Springs at the beginning and end of the survey. The original calibration figure furnished by the manufacturer checked within less than 0.2%. The Alice Springs calibration was used for calculating gravity values.

Field operations began on 3 June, 1965 and ended on 26 November, 1965. Nominal operations were 10 hours per day and seven days per week. Actually, stations were made in the field on an average of about six days per week with interruptions from moving camp, using the meter operator to help survey, weather (rain or high winds), using meter operator in the office, etc. Only one day was lost because of instrument difficulty (broken heater cable), and two days due to vehicle failure.

MAPPING

Initially, the field mapping was done at a scale of 1 : 60,000 and later at a scale of 1 : 120,000 so that all the area is included on one sheet. The entire survey was re-mapped at 1 : 120,000 after the completion of the field work and on a composite base map prepared by GAPL.

DATA REDUCTION

The original field observations were reduced by standard procedures. Latitude corrections were made from the international formula. Elevation corrections were made originally with an elevation factor of .068 mgs/ft corresponding with a density of 2.05. This factor was used for the Century Geophysical Company survey and was adopted to give results consistent with that survey. Later it was found that there were correlations with topography, especially in the Palm Valley area; and the entire survey was recalculated in Houston with a factor of .063 (corresponding to a density of 2.42) which gives considerably less correlation with topography. This gives values which are inconsistent with those of the Century Geophysical Company's survey. Where that survey was used to extend the control, the datum was established locally and the Century's contours renumbered to correspond with values from the revised Bouguer map.

Footnote 1: See Page 38.

The density profiles 2 and 3 through shot points 55 and 59 are on the Pertnjara conglomerate in the molasse hills where it is not particularly disturbed. The conglomerate is a synorgenic detrital or talus deposit derived from the rapidly rising MacDonnell front. Considerable variation of density probably exists through the formation due to its progressive detrital content of the entire basin series. I.e. The top of the conglomerate is gently south-dipping and contains detritus of principally Arunta complex and Bitter Springs; lower "layers" dip progressively steeper to the south and are composed of detritus of successively younger formations until the base is reached where its principal content is restricted to detritus of the Mereenie formation. It is therefore proposed that the Pertnjara conglomerate would indicate considerable density differences, probably in the inverse order to that of the normal succession of the stratigraphic section.

It is not known which detrital zones are to be found at the two density profiles through shot points 55 and 59 on line 2-5. It is therefore considered hazardous to arrive at conclusions of densities for projection into other areas.

In this particular area, also, topography encourages quick run off and drainage of the subsurface by the deep ravines which probably results in virtually "dry" surface formations. Lonsdale and Flavelle, (Record No. 1963/152, p.18), indicate densities of rock samples including a Precambrian sandstone, porosity 31%; density 2.02 (dry) but 2.33 when water saturated. Hence, the results of GAPL profiles 2 and 3, probably dry, may be misleading when applied to normal computations in other areas.

Further, the Pertnjara conglomerate with its great differences in composition locally along the MacDonnell front rapidly grades into a normal coarse-grained feldspathic sandstone away from the front. At Palm Valley, Mereenie and Gardiner Range there are only a few inclusions of pebbles. It is thought that its density away from the conglomeratic facies is probably very similar to that of the Mereenie formation.

E.A.K.

APPENDIX VI

PROSPECTS

1. West Waterhouse Prospect

a. General (See Plates XIX - XXIX)

The West Waterhouse seismic prospect is a west-plunging anticlinal nose about 30 square miles in area with about 2,500 feet of fault closure. The nose is apparently separated from the surface expression of Waterhouse anticline by a major thrust fault or fault zone. The prospect is located about 60 miles southwest of Alice Springs, from which it is accessible by the Herrmannsburg Mission road and along recently cleared seismic lines (Fig. 2). Topography is flat to gently rolling with an average elevation between 2,100 and 2,200 feet.

b. Geology

Waterhouse Range is a doubly-plunging, west-trending, box-shaped anticline with steep flanks and a gentle western plunge. The major axis parallels the MacDonnell homocline to the north and the axes of the James Ranges to the south (See Plate XIX); however, the trace of the axes at the east and west plunge arc slightly north-ward parallel to the change in strike of the MacDonnell Ranges. Several northwest-trending minor faults and fractures cut the Pertnjara and Mereenie sandstones near the west end of the fold and parallel the northwesterly swing of the anticlinal axis (see Plate XIX). Bedding trends in the low Pertnjara conglomerate hills west of the surface anticline reflect a strike change in the syncline north of the Waterhouse Range. This surface syncline contains well-bedded Pertnjara, whereas the syncline to the south is covered by alluvium and dune sands. The surface expression of the West Waterhouse prospect is also concealed by surface sands, terrace gravels and alluvium.

The stratigraphic succession which crops out in the eroded core of Waterhouse anticline extends from Cambrian Jay Creek limestone to Devonian (?)

Pertnjara conglomerate. Centralia Waterhouse No. 1 spudded in Jay Creek, drilled 2,255 feet of Jay Creek-Hugh River, and reached a total depth of 3,081 feet after penetrating 826 feet of Arumbera sandstone. No significant shows of oil or gas were reported and the well encountered strong flows of fresh water. A major unconformity between Mereenie sandstone and eroded Pacoota is present on the north flank of the anticline, and between Mereenie and eroded Horn Valley on the south flank. The Ordovician Stokes and Stairway formations (about 1,000 to 2,000 feet of section) are absent because of pre-Mereenie erosion of Waterhouse or partly by non-deposition on a positive structure. The angular unconformity, which apparently trends northwesterly, is also present in the MacDonnell Ranges, where Mereenie onlaps progressively older formations to the east. This unconformity is truncated by the sub-Pertnjara unconformity, where the conglomerate onlaps all older beds and ultimately overlies Cambrian Jay Creek-Hugh River formations.

West Waterhouse nose is apparently in the area where pre-Mereenie erosion would have removed most or all of the Stokes shale, and Mereenie would unconformably overlie lower Stokes shale or upper Stairway sandstone. Potential reservoir characteristics of the Stairway, Pacoota, Jay Creek-Hugh River and Arumbera formations at West Waterhouse were assessed by Williams (1966). He reports that the reservoir potentiality of the Stairway is fair to poor, because the sandstones are generally fine-grained and organically reworked. Potential reservoir characteristics of the Pacoota are largely unknown, but prospects for porous clean sandstones in the upper and lower members are good on the crest of the anticline. Most of the Jay Creek-Hugh River sequence will be tight; however, should the salt zone be present in the lower part of the section, it could be associated with porous fractured dolomite as was the case in the Alice No. 1 well. Reservoir characteristics of the Arumbera are fair to good, since the Arumbera section penetrated in Waterhouse No. 1 had fair porosity. Fractures present in any of the potential reservoirs would greatly enhance their original porosity.

c. Gravity

The gravity pattern at West Waterhouse (Plate XXIX) indicates a sharply defined local gravity minimum. The source of this gravity anomaly must be quite shallow, probably not over 2000 to 3000 ft deep (Nettleton, 1966). Relatively shallow faults are indicated coincident with the flanks of the West Waterhouse uplift.

d. Seismic

Seismic reflection data from good quality records indicate a west-plunging anticlinal nose separated from the Waterhouse surface anticline by a major zone of deep-seated faults thrust from the north (Plates XX to XXIV). Direct evidence of complex faulting is present on several of the lines, but evidence for effective fault separation between structures is mainly indirect and based on the projection of poor quality data on lines 3-C, 3-3.75, and 3-3.7. Horizons on the south end of line 3-3.7 are 100 to 200 milliseconds higher than equivalent horizons at the east end of line 3-C or the north end of 3-3.75, indicating that the highest structural position in deep horizons has been offset to the north from the surface trace of Waterhouse anticline. A deep reversal at shot points 38 and 48 on line 3-4 probably reflects the northwest projection of the axis of Waterhouse anticline. This corresponds with the northward migration of the adjacent synclinal axes with depth, indicating that axial planes of both anticlines and synclines dip to the north. The syncline north of Waterhouse uplift is appreciably deeper than that to the south. Diffractions at the north end of line 3-4 suggest proximity to faults along the MacDonnell Range front, which are probably related to the major southerly-directed thrust faults at West Waterhouse. An earlier thrust fault which dips south is confined to deeper horizons and is cut and displaced by the more apparent major faults which are post-Mereenie in age probably related to the Alice Springs orogeny.

Isochron maps in the area show a complex depositional and erosional pattern in the prospective area (Plates XXV to XXVIII). Eastward thinning of the post-Ordovician succession is possibly the result of erosion, since consistent shallow reflections present to the west are absent east of line 3-4. Isochron data indicate that Ordovician units thicken from north to south over the crest of West Waterhouse, supporting the structural data that West Waterhouse and Waterhouse anticlines are separate structures with different growth histories. Isochrons from the D-E interval show anomalous thickening in the core of West Waterhouse, part of which may be due to repetition by faulting and the remainder probably due to diapiric injection of Cambrian or Proterozoic mobile material (see Plate XV).

e. Conclusions and Recommendations

On the basis of semi-detailed seismic reflection profiles, a large Ordovician and Cambrian prospect is defined at West Waterhouse. Dip to the west, south and north is certain, and closure to the east is against major thrust faults which are postulated to separate the plunging subsurface anticlinal nose from the deeply breached surface anticline. Multiple reservoir objectives are the Ordovician Stairway and Pacoota sandstones, the Cambrian Jay Creek carbonate and Arumbera sandstone. Seismic and gravity data suggest that faults cut the structure at all horizons, and if fractures are present in the objectives then primary reservoir characteristics could be greatly improved. A location to test the crest of the structure is recommended.

2. Tyler Prospect

a. General (See Plates XVI and XXX - XL)

The Tyler seismic prospect is a symmetrical anticline about 18 square miles in area with more than 700 feet of closure. It is located in the foothills of the MacDonnell Ranges 90 miles west of Alice Springs and 50 miles north-northeast of Mereenie gas field. Access is by improved road through Hermannsburg and by cleared seismic lines (Fig. 2). Topography is gently rolling to severely dissected with flat-topped hills and steep ravines. Elevation ranges from 2,300 to over 2,600 feet above sea level.

b. Geology

The Tyler anticline is part of an ancestral arcuate uplift which extends beneath the Missionary Plain from the Gardiner fault northeasterly for 25 miles through Gosse's Bluff to Tyler, where its trend has been influenced by tectonic movements of the Alice Springs orogeny. Except for Gosse's Bluff, a spire with faulted and contorted Ordovician rocks in the core, the uplift is concealed by surface deposits or by Pertnjara conglomerate, which completely masks the deeper structure.

Goyder Pass, a faulted diapiric structure which is tilted 90 degrees to reveal its internal morphology, is exposed in the MacDonnell Ranges four miles north of Tyler (Plate XXX). Although geographically close to Tyler, palinspastic studies and tectonic trends (McNaughton et al 1964) suggest that Goyder Pass is more closely related to the Carmichael - Deering Creek uplift than to Tyler. Complex faulting in the Proterozoic and Cambrian cores of the structures suggest that Goyder and Tyler could be related in their early development, and abrupt thinning in parts of the Ordovician section at Tyler and Goyder Pass suggests that they had similar subsequent growth histories.

According to Williams (1966), the Mereenie sandstone could contain a gross porous section in excess of 1,000 feet in this area. The Stairway formation would probably contain three principal sandstone members with several potential reservoir sandstones. The upper Pacoota probably contains up to 50 feet of clean sandstones in the zone equivalent to the main producing gas zone at Mereenie, and the remainder of the formation might contain an additional 150 feet of clean sandstones. If fractures are present in any of the sandstone, reservoir potential would be greatly enhanced.

c. Gravity

According to Nettleton (1966), there is no clear gravity confirmation of the closed seismic structure at Tyler. Although there is no local irregularity conforming with the area of maximum seismic closure, local gravity anomalies may be masked by the steep gravity gradient on the northeast flank of the Gosse's Bluff negative anomaly (Plate XL). A strong northeasterly-trending negative anomaly increases in magnitude toward the Finke River, parallel to the general structural orientation of Tyler.

d. Seismic

Seismic reflection data from good quality records have defined an east-west trending faulted anticline. Although shallow horizons appear to be symmetrical and unfaulted, local imbricate thrusting is present along the eastern plunge, particularly at deeper horizons. Fault displacement appears to die out in the upper Ordovician sequence, and isochron maps of that interval indicate abrupt thickening on the south flank where shallow horizons are unfaulted and deep horizons are thrusted and repeated. There appears to be considerable diapiric movement in several horizons as high as the Stokes - Stairway (Horizon "B"). (See Fig. 3 and Plate XVI). Structural closure is about 100 milliseconds (750 feet) at the near Pacoota "C" - horizon (Plate XXXIII). Critical closure lies on the southwest plunge, where a saddle separates Tyler from Gosse's Bluff. In other directions Tyler exhibits more than 200 milliseconds (1,500 feet) of plunge, so that the effective amplitude of closure may exceed the minimum as mapped. The syncline separating Tyler from the MacDonnell Range outcrops is deeper than that to the south.

Closure at the A and B horizons is slightly less, 80 milliseconds (about 600 feet), indicating that structural relief may increase with depth (Plates XXXI and XXXII). Isochron maps of all intervals indicate thinning over the crest, which may be due to faulting or to structural growth during deposition.

e. Conclusions and Recommendations

On the basis of semi-detailed seismic profiles, a major drillable anticlinal prospect is defined at Tyler. Minimum dip closure of 700 feet in all directions at Pacoota level is indicated. Pacoota and Stairway sandstones are faulted on the east flank and are likely to be fractured in the structure. This could greatly enhance their primary reservoir characteristics. Inflammable gas was encountered in two seismic shot holes drilled into Pertnjara conglomerate on the south flank of Tyler. This may suggest an origin from buried Ordovician source rocks or leakage from a deeper reservoir. If the source of gas is Pacoota or Stairway (the Stairway had a gas show at 3090 feet in the nearest well at Gosse's Bluff) and fractures are the avenue of egress, rising gases would have to pass through the regionally porous Mereenie sandstone acquifer. The lower Mereenie contains about 1,000 feet of porous sandstone, and there is at least 600 feet (80 milliseconds) of structural closure at this horizon. A drilling location on the crest of the anticline is recommended.

3. Gosses's Bluff Prospect (See Plates XLI - LI)

a. General

The Gosse's Bluff Prospect as defined by a combination of surface geologic and seismic profiles is a circular uplift with a complex core. This striking landmark is located in the west central Missionary Plain 105 miles west of Alice Springs. Access to the Bluff is by way of the Hermannsburg road, the Haast's Bluff track, and recently cleared seismic tracks (Fig. 2). Topographic relief is gentle in the surrounding plain, with rolling foothills around the towering ramparts which ring an undulating interior valley. Elevation ranges from 2,250 feet on the plains to about 3,000 feet on the cliffs.

b. Geology

The low central core of Gosse's Bluff has been eroded from steeply tilted shales, thin limestones and calcareous siltstones of the Stokes formation and thin-bedded sandstones of the Stairway formation. The core is surrounded by steeply dipping to overturned Mereenie sandstone which is offset by numerous radial faults especially along the south side of the structure. The cliffs at Gosse's Bluff are surrounded by a saucer shaped depression as defined by the annular drainage pattern which is cut in vertical and overturned Pertnjara (?) siltstone and breccia or slide debris. Pertnjara sandstones and conglomerates overlying the recessive unit crop out in vertical and overturned beds in low hills fully four miles from the centre of Gosse's Bluff, before being overlapped by dune sands and alluvium of the Missionary Plain.

Exoil Gosse's Bluff No. 1 well in the core of the structure drilled a fractured sequence of vertical and overturned (?) Stokes and upper Stairway formations to total depth of 4,535'. A non-commercial flow of gas was encountered in Stairway sandstones at 3,090 feet. Distinctive "pressure cone" or "shatter cone" structures are present in cores of the well, and are abundant on outcrops of all formations in and around the Bluff. Some of the best - developed cones are present on Pertnjara ledges four miles from the centre of the Bluff. The origin of the cone structures is not known, but they suggest great pressures or strong impact. The Pertnjara (?) contains a peculiar lithologic unit preserved in small outcrops in the low valley west of the Bluff. It consists of coarse angular breccia composed mainly of sandstone and shale fragments in an altered, porous matrix of unknown origin. The matrix has been examined under the petrographic microscope and described as altered ryholite, as devitrified glass, or as a leached and silicified (billified) matrix of indeterminate origin. The significance of this deposit, its age and origin are unknown; it could be related to shallow explosive volcanicism or meteoric explosion or it could be the result of in situ combustion of a pre-existing shallow hydrocarbon deposit (Leslie, 1959 P. 3).

Although the exposed stratigraphic succession in the Bluff is faulted, the Mereenie and Stokes formations appear to be abnormally thin and the Mereenie contains local intraformational breccias. (Hopkins, 1962). The potential reservoir characteristics of the Mereenie, Stairway, and Pacoota on the flanks of the structure are likely to be fair to good. If the structure were positive during deposition of Ordovician sandstones, or if fractures and faults are present at depth, the reservoir potential of the sandstones would be greatly improved.

c. Gravity

The residual gravity shows a nearly circular minimum with a diameter of 13 miles having a sharp symmetrical peripheral gravity rise and a central maximum (Nettleton 1966). The sharpness of the flanks points strongly toward a shallow source for this minimum. Regional and local gravity are discussed in the APPENDIX on Gravity.

d. Seismic

Seismic reflection data from profiles radial to Gosse's Bluff are of good quality to the outer edge of the outcrop belt of Pertnjara sandstone. Between the outer edge and the inner ramparts of the Bluff proper, shallow data are no good whereas some deep reflections continue with reliability (Plates XLI to XLVI). In general, shallow reflections appear to rise steeply toward the Bluff in all directions, whereas deeper horizons rise gently or continue flat toward the core. B.M.R. shooting within the ramparts of the Bluff resulted in poor quality data which indicate that Gosse's Bluff is a diapiric structure of salt dome type with the core material deeper than 6,000 feet, (Moss, 1964, P. 8). Contour and isochron data on all horizons indicate that the Bluff is situated on a broad structural ridge which was growing since the Proterozoic. Gosse's Bluff proper appears to be a diapiric spire situated on this north-northeast trending cross-basin uplift which reached from Gardiner to Tyler. Isochrons of deepest reliable data indicate that Bitter Springs formation is the probable source of the injected core material. The critical areas for closure are across the saddles between Gardiner and Tyler, and these sites appear to be faulted. Relief on the east and west sides where the uplift is flanked by synclines is much greater, being on the order of 300 to 400 milliseconds (2,000 to 3,000 feet). Diffractions and displacements on good quality records indicate that faults are common; however, it is not certain whether or not they are radial to the Bluff.

e. Conclusions and Recommendations

Seismic profiles radial to Gosse's Bluff have indicated a broad domal uplift with closure distinct from the Tyler and Gardiner structures. Gosse's Bluff proper appears to be a prominent spire near the centre of a regional uplift, and was probably caused by diapiric injection of mobile Bitter Springs (and other) evaporitic material. The magnitude of structural closure is unknown because of the peripheral no-record area; however, it exceeds 750 feet at the Pacoota level and is probably far greater. The Mereenie, Stairway and Pacoota formations probably have fair to good primary reservoir characteristics due to their position near the crest of a growth structure. Radial and peripheral faults are abundant, and fractures would serve to improve their reservoir characteristics.

Nine shot holes surrounding the Bluff blew gas upon detonation. Although many locations are possible, an initial site for a stratigraphic test is recommended at the northeast margin along the crest of the regional uplift.

4. Northeast Gardiner Prospect (See Plates XVII and LII-LXII)

a. General

The Northeast Gardiner seismic prospect is a broad flat-topped terrace with at least one low-relief structural closure. The prospect is situated in the southwestern Missionary Plain 105 miles west-southwest of Alice Springs (Fig. 2). Access is by improved road through Hermannsburg to the Gosse's Bluff - Areyonga track and along cleared seismic lines. Topography is generally flat with an average elevation of 2,500 to 2,600 feet.

b. Geology

The central part of the Gardiner Range is bounded on the northeast by a zone of major faulting, the Gardiner fault. It is overthrust from the south with Proterozoic Bitter Springs in contact with Devonian (?) Pertnjara sandstone where displacement is maximum (Plate LII). The surface attitude of the fault indicates it to be a high angle reverse fault with a length of more than 50 miles. The B.M.R. seismic survey (Moss, 1964, P.8) however, suggests that the fault may dip gently south at depth and have appreciable horizontal displacement. On the upthrown side, south of Areyonga, a prominent zone of north-trending transverse faults cuts all formations older than Mereenie. A shallow north-plunging syncline occurs in Pertnjara sandstone on the downthrown (north) block opposite this zone and may reflect the extension of transverse faulting in buried pre-Mereenie beds. Outcrops of Stairway and Stokes adjacent to the fault west of this syncline possibly indicate local transverse uplifts or imbricate fault slices where the Pacoota may be locally at shallow depth on the downthrown block.

A complete stratigraphic succession from Bitter Springs to Pertnjara crops out in the central Gardiner Range in a south-dipping homocline.

Bitter Springs is in fault contact with an abnormally thin, possibly faulted, succession of vertical Stairway, Stokes, Mereenie and Pertnjara on the downthrown (north) side. This sequence thickens markedly to the east, from about 1,500 feet six miles northwest of Areyonga to over 5,000 feet six miles east of Areyonga (Plate LII).

The lower Mereenie sandstone could contain a gross porous section in excess of 1,000 feet in this area. The Stairway sandstone is usually tight, fine-grained, and organically reworked with some clean, well-sorted, coarse-grained, potential reservoir sandstone near the base. The Pacoota would probably contain well-sorted, medium-grained, sandstones some of which are good potential reservoirs. As the subsurface structure was positive during deposition of Ordovician sands the best potential reservoir sandstones should be localized on the crest. If fractures are present at depth, the reservoir potential of the sandstones would be greatly improved.

c. Gravity

The gravity pattern at Northeast Gardiner is relatively smooth except for the steep gradient due to the Gardiner fault and the outcrops of older rocks at the northeasterly edge of the Gardiner Range (Nettleton 1966). Across the prospect area contours spread anomalously, suggesting a broad north-trending deep-seated positive structure.

d. Seismic

Seismic reflection data from good quality records north of the Gardiner fault indicate a gentle terrace about 50 square miles in area with at least one localized low-relief closure (Plates LIII to LVII). The terrace is abruptly truncated by the fault, which results in a no-record area wherever crossed. The terrace edge falls off more than 100 milliseconds (750 feet) to the north, west and northeast, but rises slightly to the south-east. Indicated closure on the low relief structure is at least 16 milliseconds (112'+) at the 'A' horizon, 23 milliseconds (160'+) at the 'C' Mid-Pacoota horizon, and

70 milliseconds (300'+) at the 'E' horizon. Isochron data in the Ordovician and Cambrian indicate no thickness changes in a band parallel to and in front of the Gardiner fault (Plates LVIII to LXI). Both sections thicken to the north and east, however, indicating the possibility of stratigraphic traps caused by permeability pinchouts along these edges. Local minor faults cut the terrace at several localities, setting up the possibility for local closures against the Gardiner fault. Evidence of transverse faulting is lacking at the critical southeast border of the terrace. The sharp syncline evident on the east side of the structure, shown by line 2-6 (Plate XVII) flattens to the south along lines 2-D and 2-6XAX. As the terrace is part of an ancestral structural uplift which extends from Gardiner fault to Tyler, lack of southeast closure may be due to local post-Devonian tilting as a result of uplift of Palm Valley anticline.

e. Conclusions and Recommendations

Northeast Gardiner is a relatively attractive prospect as defined on the basis of seismic profiles. There is a low-relief closure on a broad terrace. Its position on the crest of an ancestral regional uplift enhances the possibility for a hydrocarbon column greatly exceeding the indicated 150 feet of closure at the near-Pacoota horizon.

The gentle surface syncline in the Pertnjara and the low dips along lines 2-6XAX and 2D could reflect the concealed position of a transverse fault zone similar to that south of Areyonga. Even minor cross faults could serve as effective seals preventing up-dip hydrocarbon migration. Facies changes and porosity pinchouts of reservoir beds from the crest of a growth structure to the flanks could produce stratigraphic separation to the southeast without structural reversal. If any of the above barriers to migration are present to the southeast, the entire terrace could be sealed or closed against the Gardiner fault.

The Mereenie, Stairway and Pacoota have fair to good primary reservoir potential. Combustible gas was encountered in two shot holes on the east flank of the terrace. A stratigraphic test is recommended on the crest of the low-relief closure.

5. Carmichael Prospect (See Plates XVIII and LXIII-LXXIII)

a. General

The Carmichael prospect is defined seismically as an elongate half dome about 20 square miles in area with about 2,000 feet of closure against a high angle reverse fault. It is located 115 miles west of Alice Springs, south of Mereenie Bluff near the west end of the MacDonnell Ranges and 30 miles north-northeast of Mereenie gas field (see Fig. 2). The area is accessible from Alice Springs via the Hermannsburg-Gosse's Bluff-Deering Creek track and along recently cleared seismic lines. Topography is flat to gentle with an average elevation of 2,500 to 2,600 feet above sea level.

b. Geology

Carmichael structure is part of a major east-west uplift more than 50 miles long which extends across the northwestern Missionary Plain from the Deering Creek anticline toward the Goyder Pass structure (see Plate LXIII). Most of the uplift is concealed by surface deposits or by Devonian (?) Pertnjara formation. The Carmichael outcrops are located 17 miles east of the Deering Creek surface anticline from which it is separated by dune sands and alluvial gravels. The axis of the Deering Creek anticline is extensively covered. The south limb is overturned and the north limb dips at a moderate angle into the Idirriki Range syncline. Complete stratigraphic sections from Pacoota to Pertnjara have been measured at several locations along the south flank by Hopkins (1962) and the B.M.R. (1963). These indicate rapid stratigraphic thinning from west to east. The Deering Creek and Carmichael sections are much thinner than the Stokes Pass section six miles to the north and the West Gardiner section five miles to the south, which suggests a strongly positive linear growth structure during Larapinta and Mereenie deposition (see Plate LXIII).

An east-plunging anticlinal nose is defined at north Carmichael by outcrops along line 1-1 between shot points 36 and 42. The oldest beds exposed along the surface axial plunge were tentatively correlated by Gwinn (1965) with the Cambrian Cleland sandstone on the basis of lithologic similarity; however, their precise age is uncertain. North of these outcrops a thin, nearly continuous section from Pacoota to Pertnjara was identified by Williams (1965) as forming the north flank of the structure. East of shot point 37, line 1-1, Pertnjara sandstone unconformably onlaps the Cleland (?) sandstone. Further northeast the Pertnjara thins against the Carmichael structure and some zones wedge out while others show marked facies changes (see Plate LXIII).

Faint arcuate lineations present on aerial photographs coincide with and support the interpreted east and west plunges of the Carmichael structure (see Plate LXIII). There is an east-west lineation south of shot point 36, line 1-1 which may mark the surface expression of the fault separating the Carmichael outcrops from the Missionary Plain syncline. The fault apparently cuts across a complex diapiric anticline, and has produced several possible closures along the axis with shallow Cambrian and Proterozoic prospects on the upthrown north side. Deep Ordovician prospects exist on the downthrown south flank.

Outcrops of Stairway and Pacoota sandstones at Carmichael were examined by Williams (1965). He reports that the reservoir potentiality of the Stairway is generally poor because the sandstones are fine-grained, thin-bedded and organically reworked. The potential reservoir characteristics of the Pacoota are good, with several porous medium-to coarse-grained clean sandstones in both Upper and Lower members. If fractures are present in either the Stairway or Pacoota sandstones at depth, the reservoir potentiality would be greatly enhanced.

c. Gravity

The local gravity pattern is extremely complex at Carmichael (Plate LXIII). It reflects faulting, uplift and injection of low density material along the axis. Gravity data support the interpretation that the Deering Creek-Carmichael-Goyder trend is interrelated and highly disturbed. Diapirism appears to be extreme along the axis of the Deering Creek anticline where closed gravity minima indicate that sources of the anomalies are possibly as shallow as 2,000 feet. The gross structure is interpreted by Nettleton to be a highly faulted diapiric structure with faults overthrust from the north(1966).

d. Seismic

Seismic reflection data from good quality records south of the Carmichael outcrops indicate a sharp east-west linear uplift which is abruptly cut off by a major high angle reverse fault up-thrown to the north (Plate XVIII). Faulting, probably during Alice Springs orogeny, thrust the northern half of the anticline southwards over the south limb. The former has been removed by erosion and the latter preserved by burial. Migration of the steep dips, a good tie with surface outcrops, and reliable correlations across the no-record faulted area indicate a minimum throw of 1,300 milliseconds (9,000 feet). This places the major Ordovician Pacoota sandstone objective in fault contact with either impermeable Proterozoic Pertatataka shales or the mobile diapiric core of probable Bitter Springs formation. Continuous correlation along the south side of the fault indicates that eastern plunge is certain and that western plunge is likely, with the highest point of the structure, at the Pacoota horizon, on line 1-1.5. Closures at the A, B, and C horizons average 350 milliseconds (2,500 feet) and isochron maps of the Ordovician indicate gradual thinning into the core of the structure from near maximum thicknesses to the north, south and east (Plates LXIX, LXX). Isochron data of the C-D and D-E intervals, on the other hand, indicate extreme thickening into the core, in part due to repetition by faulting and in part to diapirism (Plates LXII, LXXIII).

e. Conclusions and Recommendations

On the basis of surface geology and semi-detailed seismic profiles, a large Ordovician prospect is defined at Carmichael. Plunge to the east and south is certain, to the west is very probable and closure to the north is against a major fault. The Pacoota and Stairway objectives are likely to be fractured near the fault and this could greatly enhance their primary reservoir potentialities. The structure is localized along an ancestral tectonically positive area with strong indications of growth during deposition of the Ordovician and younger rocks, a situation probably conducive to enhancing original reservoir characteristics of sandstones. A location to test the structure is recommended on the downthrown side of the fault.

APPENDIX VII

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