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FINAL REPORT

ON THE

KULGERA SEISMIC SURVEY

OIL PERMIT 130

NORTHERN TERRITORY

SUBMITTED TO

EXOIL (N.S.W.) PTY. LTD.

BY

NAMCO GEOPHYSICAL COMPANY

DALLAS

C O N T E N T S

ABSTRACT

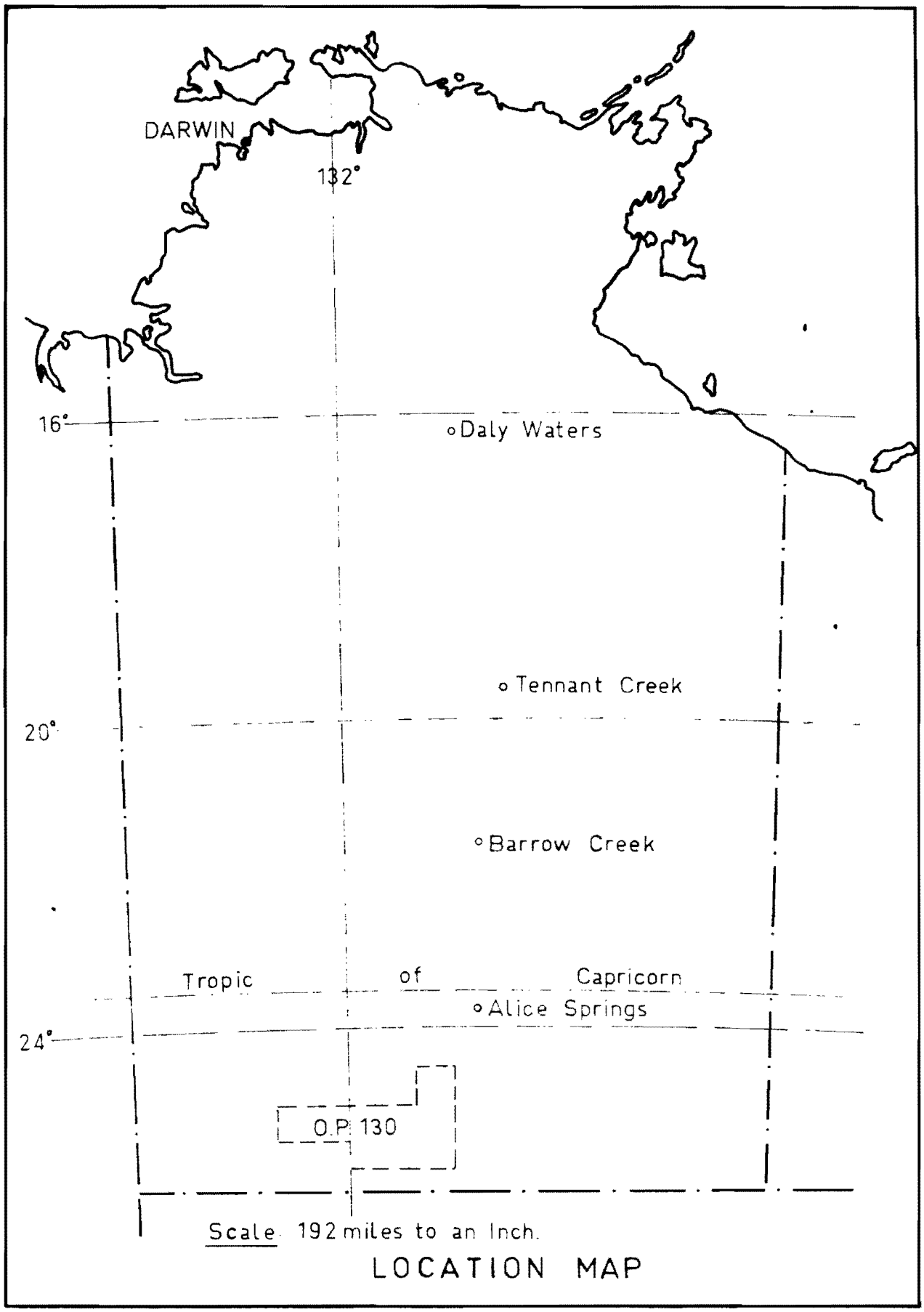
A reflection seismic survey was conducted during May, June and July for Exoil (N.S.W.) Pty. Ltd. by Party 85 of Namco Geophysical Company within Oil Permit 130 in the Northern Territory of Australia.

The objective of the survey was to obtain quantitative geophysical control over selected areas of the permit and to detail any significant structures encountered by the regional seismic lines.

The results of the survey reveal a number of shallow Proterozoic structural features of relatively high relief distributed rather evenly throughout the area covered by the regional traverses.

On the single line that approaches the southern margin of the Amadeus Basin towards Kulgera a significant loss of section was observed.

The thickest deposition has been described in the west-central area of the survey; however, continuity of reflected events appears interrupted by occurrences of intense faulting.



LOCATION MAP

1. INTRODUCTION

The Kulgera Seismic Survey was conducted in Oil Permit 130 in the Northern Territory of Australia during May, June, and July, 1965. The survey was conducted for Exoil (N.S.W.) Pty. Ltd., whose registered office in the Northern Territory of Australia is at Mitchell Chambers, Mitchell Street, Darwin. The geophysical contractor was Namco Geophysical Company of Dallas, Texas, with Australian headquarters at 15 Franklin Street, Adelaide, South Australia.

The location map (Frontispiece) shows the regional location of Oil Permit 130. The Alice Springs to Adelaide highway traverses the survey area which is centred approximately 130 miles southwest of Alice Springs.

Surface topography is characterised by a flat area, exhibiting low relief sand dunes, bounded on the south by the low-lying hills of the Musgrave Complex and on the north by the rugged outcrop features of the Kernot, Basedow and Erldunda Ranges. In the west prominent inselbergs project above the sand.

The climate of the area is normally fine, dry and clear. Small amounts of annual rainfall in recent years have resulted in desert conditions.

2. OBJECTIVES OF THE SURVEY

The objectives of the survey were three-fold:-

(a) To extend quantitative control previously provided by the Erldunda Seismic Survey over additional selected areas of Oil Permit No. 130 where (i) prospective Paleozoic and Upper Proterozoic sediments are masked by recent sands and flat-lying Mesozoic sediments and (ii) volcanics or other near-surface magnetic effects have not been indicated by the Charlotte Waters Aeromagnetic Survey.

(b) To investigate the cause of the Ayers Rock Gravity Depression disclosed by the Bureau of Mineral Resources' helicopter gravity survey conducted between 1959 and 1961.

(c) To detail any significant structures encountered by the regional seismic lines that may be prospective for oil and/or gas.

3. REGIONAL GEOLOGY

Since 1959, the south Amadeus Basin area has been mapped in considerable detail by several private companies and the Bureau of Mineral Resources, Gillespie (1959) and Leslie (1960) of Frome Broken Hill conducted detailed reconnaissance surveys along the northern margin of O.P. 130. In 1960, 1962 and 1963, Wells, Forman, Ranford, Stewart, Hancock and Skwarko mapped the southern margin of the Amadeus Basin for the Bureau of Mineral Resources. In 1963, Ranford, Cook, Wells and Stewart of the Bureau mapped the Henbury Sheet area, at the northeast edge of the permit. In 1963, Fitzpatrick Johnson and Associates of Adelaide carried out a photo interpretation of Oil Permit 130 (then O.P. 78) for Exoil (N.S.W.) Pty. Ltd., which was adjusted to comply with the Bureau of Mineral Resources' field mapping. It is mainly the findings of these several workers that are summarised hereunder.

Upper Proterozoic, Cambrian, Ordovician and Devonian-Carboniferous sediments of the Adameus Basin outcrop in several ranges at the northern edge of Oil Permit 130. South of these ranges the older rocks are covered by Quarternary sands and Mesozoic and Permian sediments of the Great Artesian Basin onlapping from the east. On the south side of the permit, in the general vicinity of the Northern Territory-South Australian border, outcrops of Upper Proterzoic gneisses, granites and tough unmetamorphosed quartzites form the Musgrave Complex and define the southern margin of the Amadeus Basin. West of the permit area, beyond the limits of Great Artesian Basin sedimentation, thick wedges of non-marine conglomerate and arkose believed of Cambrian age, outcrop from beneath a thin flat-lying layer of marine Ordovician sediments.

Two major orogenic episodes have been recognised by Bureau of Mineral Resources' geologists that would have

affected most of the O.P. 130 area. The first has been called the "Petermann Ranges Folding" and occurred in late Proterozoic times. The second has been called the "Lake Neale Folding" and probably took place immediately prior to Pertaoorrta sedimentation of Lower Cambrian times. The main compressional force came from the south during the "Petermann Ranges Folding" and from the southwest during the "Lake Neale Folding." The folds all trend west-northwest and the earlier folds in O.P. 130 are believed to have sharper troughs and to be smaller (shorter) than the later ones.

Most of the structures in the Kulgera area are believed to be a product of the latter orogenic episode. The many high relief subsurface features revealed in the area by seismic surveys seem to have been caused by compressional forces acting on the incompetent evaporitic Bitter Springs Formation. The structures all strike west-northwest and are assymetrical to the north, thus indicating their origin to be related to pressures generated during the "Lake Neale Folding" and/or the "Petermann Ranges Folding" to the southwest.

The oldest rocks outcropping in the ranges along the north side of the permit area belong to the Bitter Springs Formation. In the south, the oldest recognised unmetamorphosed sediments belong to the Dean Quartzite. The Dean Quartzite has been correlated to the Heavitree Quartzite which lies conformably beneath the Bitter Springs Limestone and forms the oldest recognisable stratigraphic unit outcropping in the MacDonnell Ranges.

Neither the Bitter Springs Formation nor younger Paleozoic rocks outcrop in the alluvial area immediately south of O.P. 130, although Ordovician rocks have been identified by fossil evidence at Mt. Johns and Mt. Chandler in the Musgrave Complex some distance farther south in South Australia.

Northwest along the northern edge of the Musgrave Complex, due west of the permit area, the Pinyinna Beds have been observed in outcrop lying conformably on the Dean Quartzite. These beds consist of marine shales, foetid dolomite and limestone and have been correlated to the Bitter Springs. In the same area the Inindia Beds lie conformably above the Pinyinna Beds and the Winnall Beds unconformably over the Inindia Beds. The latter two formations have been correlated to the Upper Proterozoic Areyonga Formation and Pertatataka Formation respectively. A total of 14,000 feet of Upper Proterozoic sediments have been measured in this area.

Subsequent to the 'Petermann Ranges Folding' which uplifted and overturned the Upper Proterozoic sediments on the southwest margin of the Amadeus Basin, large wedges of arkose and conglomerate were deposited in a northeastward direction. These sediments, the Ayers Rock Arkose and Mt. Currie Conglomerate, are probably of Lower Cambrian age. Further north the Cleland Sandstone (?) was deposited in a fluvatile environment marginal to the marine Cambrian facies of the Amadeus Basin. Some of these sediments likely to occur in the west part of O.P. 130 but have not been seen to outcrop further east.

In the northeast part of the permit area thick marine sequences of Upper Proterozoic and Cambrian sediments occur, while a thinner sequence of marine Ordovician sediments were deposited.

The drilling of the Erldunda well in the east central portion of O.P. 130 has done much to reveal the upper stratigraphic sequence in the area. A table of stratigraphy based on the present interpretation follows:

		Interval			Thickness
	Quarternary	0	-	30 feet	30
Silurian	Pertnjara	30	-	145	115
Ordovician	Mereenie	145	-	895	750
	Stairway	895	-	1243	348
Lower Cambrian	Cleland	1243	-	2065	822
	Pertatataka	2065	-	3743	1678
Upper	Areyonga	3743	-	4300	557
Proterozoic	Bitter Springs	4300	-	5439 t.d.	1139+

4. PREVIOUS GEOPHYSICAL EXPLORATION

The first geophysical work done in the area was a regional helicopter gravity survey conducted by the Bureau of Mineral Resources between 1959 and 1961.

In 1963, a semi-detailed aeromagnetic survey was conducted over the eastern part of O.P. 130 for Exoil (N.S.W.) Pty. Ltd. by Aero Service Limited.

In 1964, a six-week reconnaissance seismic survey was conducted over the central alluvial area on the east side of O.P. 130 by Geophysical Associates Pty. Ltd. for Exoil (N.S.W.) Pty. Ltd.

The regional gravity survey indicates an east-west positive ridge striking approximately along 25° latitude on the north side of Oil Permit 130. The Bouguer contours indicate a thickening of section south of this zone that obtains maximum development on the south side of O.P. 130 - even though this area is in close association with isolated outcrops of granite, gneiss and quartzite of the Musgrave Complex. This regional minima has been called the "Ayers Rock Gravity Depression." In magnitude, it is the third largest depression in Australia and, in view of its proximity to the Musgrave Complex, its existence has not yet been explained geologically.

The aeromagnetic survey is believed to have provided a more accurate assessment of sedimentary thicknesses where control was obtained. The regional attitude of magnetic basement in the southeast quarter of the permit does not agree with the gravity results which show an expression of the Ayers Rock Gravity Depression in this area. In the central and west part of the survey area the aeromagnetics show depth-to-magnetic-basement ranging from 10,000' to 12,000'.

The reflection seismic survey conducted in 1964 threw considerable light on the nature of the subsurface in the east central permit area. Besides revealing several immense subsurface salt structures, it presented additional regional information that helped explain gravity, aeromagnetic and geological paradoxes. The interpretation of a line along the Alice Springs-Adelaide highway reveals that the aeromagnetic depth-to-basement is essentially correct in this area. At the same time it reveals a thickening of upper - and probably less dense - sediments to the south as far as control has gone. This may explain, in part at least, the existence of the Ayers Rock Gravity Depression. This survey also delineated the Erldunda structure on which the site for Erldunda No. 1 stratigraphic test well was selected.

5. FIELD PROCEDURES

A reflection seismic survey was conducted using the continuous profile technique. Shotpoints were placed at 1800 foot intervals along the line of profile. Twenty-four channel recording was employed resulting in 150 foot station intervals. Details of a typical spread lay-out are shown diagramatically in Figure 1.

Details of equipment and personnel used are presented in Appendices 1 and 11, respectively. Commencement and completion dates, along with other statistical data, are presented in Appendix 111.

Recording was accomplished using SIE GA-22A seismic amplifiers and a PR11 oscillograph. An SIE PMR20 FM tape recorder and field playback unit was used to record magnetic tapes. A monitor seismogram was recorded simultaneously with the magnetic tape on each shot using a 2/20-2/78 filter setting and no mixing from adjacent traces. The magnetic tapes were later played back through the field playback unit with a 2/38-2/65 filter setting, selected as optimum for the area.

Twelve seismometers per trace distributed in the line of the profile were employed in the reflection programme. An extra cable and a set of seismometers were used to keep a spread laid ahead of the recorders.

Shot holes were obtained by two combination air-water drills.

The drilling conditions varied from good to poor with the major limitations to production being associated with layers of hard sandstone, caving sand, sticky clay and poor track conditions. Although it was possible to drill all of the shot holes using a water injection method to control near-surface sand, some of the sticky clay drilling could have been overcome more efficiently

if ample supplies of water for mud drilling procedures were available.

All instrument spreads were chained. Horizontal and vertical controls were obtained by alidade and plane table. Shotpoints of the Erldunda Seismic Survey and two National Mapping Association trig stations found within the area served as tie points for the survey.

6. QUALITY OF DATA

The quality of the reflection data varied from good to very poor. In general, the recordings displayed several prominent energy bands which vary greatly in depth throughout the area. Where the shallowest of these reflections persist it is possible to confidently map the attitude of the subsurface. When the section thins to the point where some of these energy bands disappear, interpretation becomes difficult. There can be some correlation made between poor reflection areas and zones of near-surface magnetic effects as shown by the Charlotte Waters Aeromagnetic Survey.

The poor reflection areas are believed to be related to the nearness to surface of the Upper Proterozoic/Bitter Springs Formation. Ground roll and other near-surface disturbances also appeared to affect reflecting events in those areas but attempts at improving the signal to noise ratio using multiple hole patterns and elaborate geophone arrangements were usually unsuccessful.

7. OPERATIONS

There were no unusual operating problems encountered while working the area. The use of a bulldozer reduced the effects of poor track conditions and was an asset to the operation.

The only major problem encountered concerned supplies of drilling water when sticky clay was encountered in shot holes. Copious amounts were used in neutralising clay collars in the hole and when clay drilling became common the time list in the long water hauls seriously reduced the progress of the crew.

8. INTERPRETATION PROCEDURES

Observed reflection times were corrected to a plane established at 1,000 feet above sea level using the standard uphole procedure with a correctional velocity of 10,000 foot per second within the zone from the shot reference position to the plane. Subsequent shots in the hole were corrected to the reference shot using a factor equal to the difference in uphole times. Standard time cross-sections were plotted as a preliminary interpretation. From the records, individual static trace corrections and moveout curves were computed for subsequent playback operations.

Corrected variable density-galvometer playback sections were prepared. The final interpretation was made from the playback sections.

Available velocity information was limited to a velocity survey of the Erldunda No. 1 Well and to delta "T" analysis of prominent reflections on recordings in the Erldunda and Kulgera seismic surveys. Horizon identification was made by a seismic tie to the Erldunda No. 1 Well.

9. DISCUSSION OF RESULTS

The results of the survey are presented as a structural control map of Horizon "B", Enclosure 1; generalized reflection profiles of lines 1 through 3, Enclosure 11, sheets 1 to 3 inclusive; a shot point location and elevation map, Enclosure 111; and a compilation of photogeology, gravity anomalies and aeromagnetics, Enclosure 1V.

Enclosure 1 has been prepared to provide a comprehensive view of the subsurface attitudes throughout the area. Although the control is essentially two dimensional, the map relates dips and relative depths between widely separated areas and is considered a useful collation of the data.

A more basic presentation of the results appears on the reflection profiles, Enclosure 11. The identifications and conversion from seismic times to depths are a function of a tie to the Erldunda well.

Line 1 extends the seismic control southwards from the south end of line 1, Erldunda seismic survey to the proximity of the granite outcrops near Kulgera. The two major reflection energy bands are conformable and rise from the syncline flanking the south side of the Erldunda structure until they disappear in the disturbed high feature centred about shot point 370. The high subsurface feature has expression on the surface as a group of low lying hills trending west northwest and locally known as the Sisters. The south flank of this feature is also well described by strong conformable dips below the major unconformity so that a major anticlinal fold with at least 2,000 feet of amplitude is portrayed. The dips are generally more severe to the south. Immediately south of the synclinal belt the quality of data deteriorates abruptly and gross faulting is suspected. The north end of the poor record area almost coincides with a fault postulated by aeromagnetics

which is less than ten miles from known granite outcrops of the Musgrave Complex.

The plan of Line 2 shows that the line is generally oblique to the grain of the tectonic features and as such may not measure the full vertical extent of the structures encountered. The profile commences on the north flank of the Erldunda structure, transgresses the northwest end of the anticline and then shows gradual plunge into a deep trough prior to entering a tectonically disturbed area where reflection quality deteriorates. West of the disturbed zone, a smooth sinusoidal downwarp describes an area of thick deposition terminated by a postulated fault. In the central section of the line, a fairly thin section characterized by low relief persists until another disturbed area is reached south of Angus Downs Homestead. Proceeding westward the disturbed zone is crossed and one final area of strong west dip with very thick section unveils. Beyond, record quality generally deteriorates and the profile has its terminus near Bitter Springs (?) outcrops.

Profile three is oriented where it can measure more of the components of dip. The profile describes an intensely folded and faulted section with gross faulting separating the profile into three main compartments. The deepest section measured on the line, and indeed the area, is found on the extreme south and centres about shot point 730. The low areas may provide an environment where great thicknesses of Ordovician and Cambrian sediments remain; several minor undulations within the troughs could represent excellent positions for a stratigraphic test of the complete sedimentary sequence in the area.

One additional enclosure has been added to show the position of the traverses with respect to photogeology, gravity anomalies (regional) and aeromagnetics, Enclosure IV.

Several observations can be made using this data:

1. Aeromagnetics display a major synclinal trough entering the area from the northwest, the major axis of which intersects line 3 near the deep zone about shot point 730.

2. Gravity data defines a minima south of the southernmost end of line 3, which trends east-west and intersects line 1 beyond the south end of the seismic control.

3. Faint basement trends are observed within the gravity minima trend by photogeology.

10. CONCLUSIONS AND RECOMMENDATIONS

The Kulgera Seismic Survey has provided valuable quantitative information on the attitudes of the subsurface in a heretofore unknown part of Oil Permit 130.

The correlation of two prominent and persistent reflection energy bands provide a basis for extrapolating some of the stratigraphic control gained by the Erldunda well into remote parts of the area, however, the effort must be qualified by the reliability of the data and the tectonics of the region.

It is useful to use the Erldunda anticline as a criterion for comparison of structural deformation. The results suggest that the Erldunda structure is one of many high relief subsurface structures found in O.P. 130. It exhibits a much gentler and smoother profile than some of the more intensely folded and faulted structures found elsewhere in the permit. The fact that the two deepest seismic events have been mapped continuously over the Erldunda anticline would suggest that the tectonics were not as severe and that in general Lower Cambrian-Upper Proterozoic beds were more deeply buried and thus insulated from erosion than in most of the features revealed by the Kulgera Survey.

It is not expected that post Upper Proterozoic beds would be encountered by a test at the culmination of the other sharp features, however, such a location would facilitate active exploration of Upper Proterozoic sediments due to their position near the surface.

A complete test of the stratigraphy could be made by drilling in one of the deeper areas, however, such a test would be of academic interest unless further subsurface control defined structural closure within the lows where accumulations of hydrocarbons might be expected.

The Ayers Rock gravity depression has not been fully

explained, however, seismic control does not transgress the anomaly. The information obtained in the western part of the area does suggest an area of thick sediments and one might speculate that thicker deposition could occur in the centre of the minima feature. It is considered that the line connecting Erldunda to Kulgera actually supports the gravity data on a regional basis; the gravity data is far too sparse to reveal much detail when the subsurface is so tectonically disturbed.

NAMCO GEOPHYSICAL COMPANY

R. L. MILLIKEN
Party Chief

H. E. BOWMAN
Supervisor

December, 1965

APPENDIX 1

A. GEOPHYSICAL EQUIPMENT

1 Complete set of 24-channel S.I.E. GA-22 seismic instruments.

1 Complete S.I.E. PMR-20 magnetic recording system.

450 EVS reflection geophones, 20 cycle, arranged six per string.

3 Reflection geophone cables for 1800-foot S.P. spacing.

1 Complete set of shooting equipment, including multi-hole blasters.

1 Complete set of surveying equipment.

1 International Model 160 4x4 recording truck with winch, power steering and sand tyres.

2 International Model 160 4x4 combination cable and shooting trucks with winches, power steering and sand tyres.

2 Heavy duty Mayhew 1000 combination air-water drills with 667-CFM air compressors, 5x6 Gardner-Denver mud pumps, 300 feet of drill pipe each, and mounted on International Model 192 4x6 trucks with winches, power steering and sand tyres.

2 Heavy duty water trucks with 1200-gallon flat tanks mounted on International Model 192 4x6 trucks with winches, power steering and sand tyres.

3 New Toyota 4x4 trucks with oversize tyres for surveying, administration and field management.

B. CAMP EQUIPMENT

1 Machine Shop Trailer manufactured by Elder Trailer Company and complete with drill press, benches, vices, air compressor, and all necessary tools and equipment for making repairs on any of the vehicles and equipment provided.

1 Welding trailer, complete with both arc and acetylene welding equipment and supplies.

B. CAMP EQUIPMENT (continued)

1 Elder Office Trailer, complete with printing machine, office machines, drafting equipment, McGukin dip plotter and supplies.

1 Shower and utility trailer with laundry machine.

1 Elder all-electric kitchen trailer completely equipped with all necessary appliances and utensils.

1 Elder dining trailer completely equipped with all necessary furniture, fixtures and tableware.

1 Elder power trailer, complete with two 25-KW diesel generators.

1 1200-gallon camp water trailer complete with pressure system and connections for kitchen and shower trailers.

1 Complete complement of tents, beds, linens etc. for accommodating all personnel and visitors.

1 Complete set of radio equipment for communication on the Flying Doctor system.

1 Supply truck capable of hauling fuel and explosives.

APPENDIX 11

PERSONNEL

Party Chief	R. L. Milliken
Seismologist	R. Chalker
Computer	W. M. Roberts
Party Manager	James A. Woodward
Surveyor	G. W. Cozby
Observer	Ed W. Dollar
Chief Driller	T. R. Daniel
Driller	J. Morris
Shooter	J. Band

The basic crew consisted of a total of twenty (20) men.

Technical and administration supervision was provided by Mr. W. J. Harkey.

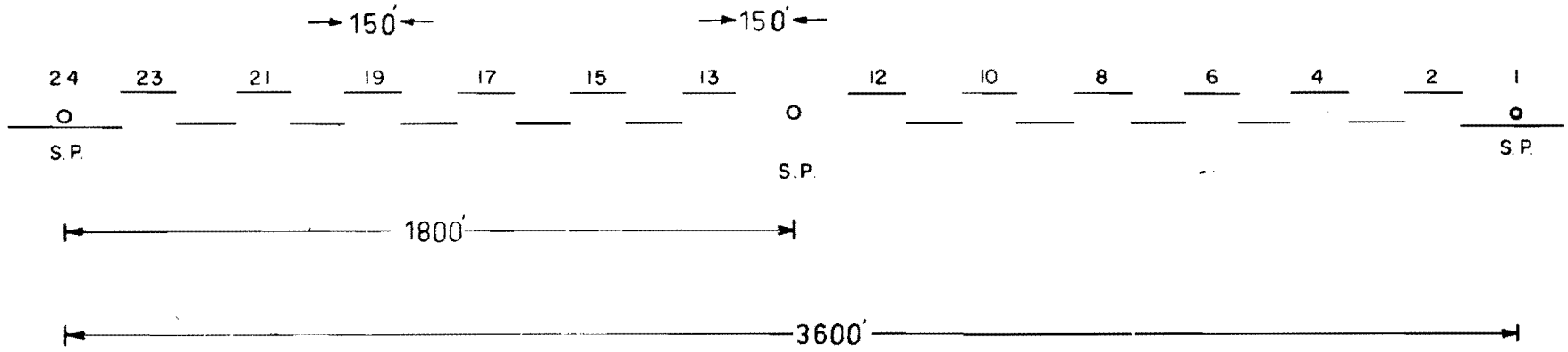
Mr. S. S. Chambers acted as the client's representative for Exoil (N.S.W.) Pty. Ltd.

APPENDIX III

STATISTICAL DATA

Starting date, first shot	10 May, 1965
Completion date, last shot	18 July 1965
Total number of shots	521
Total number of holes shot	410
Average holes per day	9.13
Total miles of subsurface coverage	134
Total number of moving days	35
Days lost due to weather	Nil
Days lost due to holiday	1
Days lost due to equipment repair	Nil
Total number of field days recording	44.89
Total number of field hours, recording	349.5
Total number of driving hours, recording	99.4
Total pounds of dynamite used	9026.5
Average pounds of dynamite per shot	17.3
Total number of detonators used	788
Total number of drill shifts in field	98.72
Total number of drill hours in field	734.8
Total number of drill hours driving	252.4
Total number of holes drilled	603
Total footage drilled	51049
Average number of holes drilled per shift	6.11
Average depth of holes in feet including patterns	84.66
Average depth of weathering in feet	38'
Rock bits used	6
Insert bits used	44
Mud used, bags	Nil
Bran used, bags	Nil

TYPICAL REFLECTION SPREAD LAYOUT



24 Traces

12 Seis per trace

1 hole pattern

1800' — 0 — 1800' Reversed split spread

150' foot Group Intervals

15' foot Seis. Intervals

FIG. 1

KULGERA SEISMIC SURVEY
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