COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

*PETROLEUM SEARCH SUBSIDY ACTS*

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# THANGOO No. 1 and No. 1A WELLS, WESTERN AUSTRALIA

OF

## WEST AUSTRALIAN PETROLEUM PTY LIMITED

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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

*Minister :* SENATOR THE HON. W. H. SPOONER, M.M.

*Secretary :* H. G. RAGGATT, C.B.E.

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# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

*Director :* J. M. RAYNER

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*This Report was prepared for publication in the Geological Branch*

*Chief Geologist:* N. H. FISHER.

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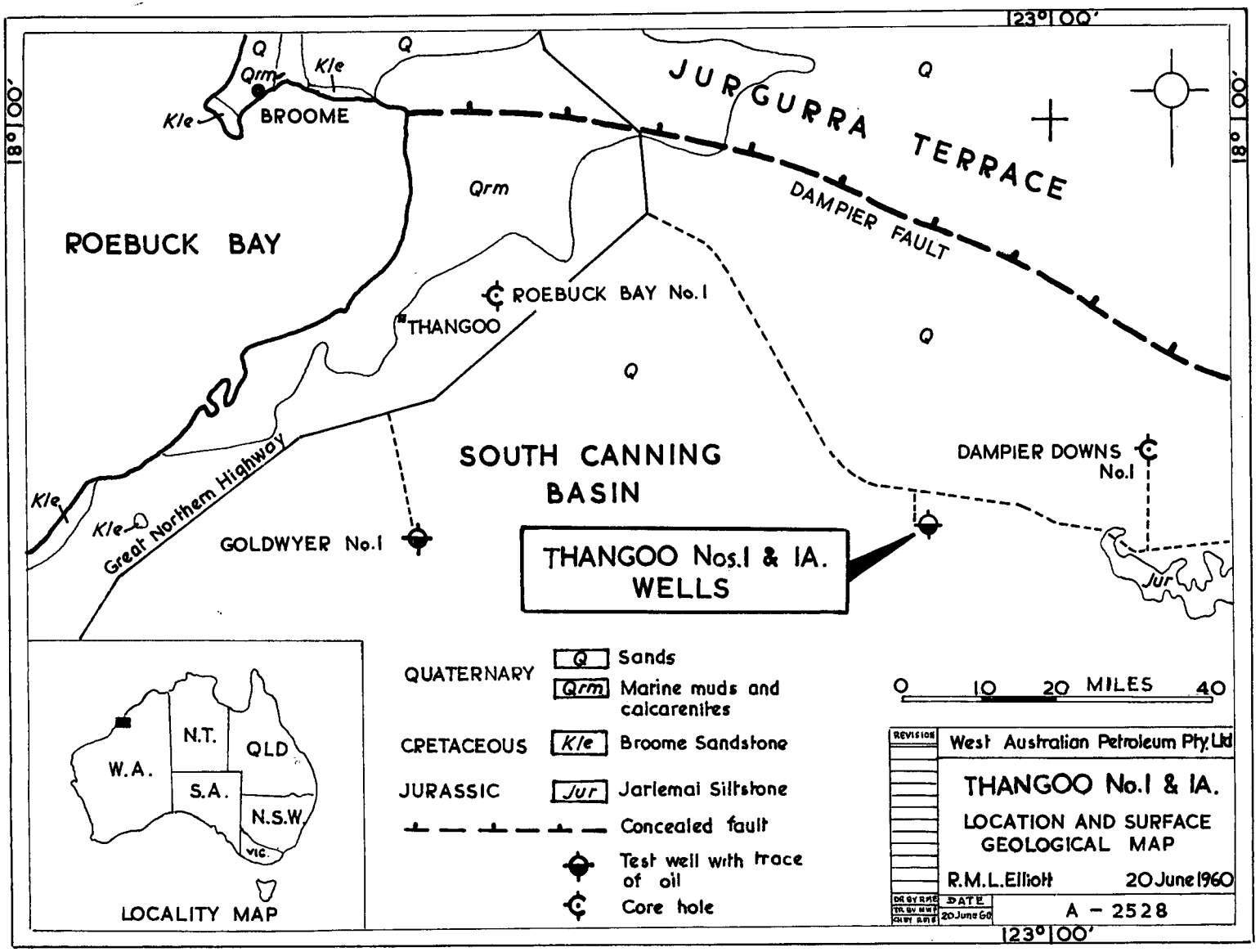
## WELL COMPLETION REPORTS

by

V. PUDOVSKIS & S.P. WILLMOTT

WEST AUSTRALIAN PETROLEUM PTY LIMITED




ENCLOSURE No.1

## SUMMARY

Thangoo No. 1A well was drilled as a result of mechanical difficulties encountered at the drilled depth of 3,475 feet in Thangoo No. 1 well which were insurmountable and prevented further operations on this well. Total loss of circulation at 3,475 feet in Thangoo No. 1 well resulted in unexpected total collapse of the hole below the 10 3/4" casing in a section of friable sandstone and conglomerate (Grant Formation). In Thangoo No. 1A well these formations were cased off. A lost circulation zone was tested for potential hydrocarbon production and found to contain water only. The well was drilled to 5,429 feet into basement rocks (programmed depth 4,500 feet).

Excellent hole control was maintained to total depth by drilling below the 16" conductor shoe with high pH, low shear and waterloss, freshwater mud.

The 1,366 feet of Mesozoic and 1,377 feet of Permian section in Thangoo No. 1A closely resemble that of Thangoo No. 1. The Ordovician section is 2,318 feet thick, consisting of 695 feet of Goldwyer Formation (new name) and 1,623 feet of Thangoo Limestone (amended name). Basement, consisting of Precambrian phyllite, was encountered at 5,100 feet in Thangoo No. 1A.

Traces of oil were observed throughout the Ordovician section. Oil shows are confined predominantly to vuggy veins of coarse crystalline dolomite. A minor show was also observed in the sandstone of the basal unit of the Thangoo Limestone. A porous zone within the Thangoo Limestone, causing some lost circulation, appeared at about 3,670 feet in Thangoo No. 1A. A formation test of this zone recovered only brackish water (11,999 ppm. total salts) with no signs of oil or gas. It is possible that the small shows of oil in the Thangoo Limestone are retained by the impervious Goldwyer Formation, as no shows were present in the Roebuck Bay and Dampier Downs wells, where porous Permian rocks directly overlie the Thangoo Limestone.

The correlation of the sections of the Thangoo Limestone in all the exploratory wells on the Broome Platform indicates that the Thangoo No. 1A well occupies a low structural position. Consequently the objectives of testing the structure in the Ordovician and Permian Grant Formation were not achieved.

The chances of finding commercial oil accumulations in the Ordovician section of the South Canning Basin in the vicinity of Thangoo Nos. 1 and 1A are very small at this time, because of the low source rock potential and flushing by meteoric waters of the Thangoo Limestone, the lack of porosity in the Goldwyer Formation, and the difficulties experienced in resolving the structure of the Ordovician with present seismic methods.

## INTRODUCTION

The Thangoo No. 1 well was abandoned because of mechanical difficulties resulting from a lost circulation zone in the Thangoo Limestone at a depth of 3,475 feet. Thangoo No. 1A was therefore drilled to achieve the objectives originally set out for Thangoo No. 1.

The drilling of Goldwyer No. 1 well showed that the Ordovician formations in the Canning Basin contain prospective oil source rocks and may also contain sufficient porosity to provide reservoirs suitable for hydrocarbon accumulation. Already, the drilling of Dampier Downs No. 1 well had demonstrated the presence of porosity in the Thangoo Limestone near the Thangoo area. The Thangoo No. 1 well was located between these two wells, on a seismic culmination. The objective of the test was to investigate the porosity and the fluid content of the Ordovician rocks, and to evaluate the oil possibilities in the Ordovician section down to the Precambrian basement.

The objectives of Thangoo No. 1A were to investigate the fluid content of the uppermost porous zone in the Ordovician Thangoo Limestone in the immediate vicinity of the Thangoo No. 1 test, and to evaluate the oil possibilities of the Ordovician sequence to basement. An evaluation of the oil-staining in the Grant Formation noted in Thangoo No. 1 was to be made in Thangoo No. 1A.

## WELL HISTORY

### General Data

| | Thangoo No. 1 | Thangoo No. 1A |
|---|---|---|
| Well name and number: | | |
| Location: | 618,400 yards E.<br>2,692,850 yards N.<br>National Mapping Grid<br>122° 53'22" E. Longitude<br>18° 22'06" S. Latitude | 618,000 yards E.<br>2,693,350 yards N.<br>National Mapping Grid<br>122° 53'09" E. Longitude<br>18° 21'52" S. Latitude |
| Tenement holder: | West Australian Petroleum Proprietary Limited, 251 Adelaide Terrace, Perth, Western Australia. | |
| Details of tenement: | Licence to Prospect No. 66H, in Permit to Explore 30H. | |
| District: | Kimberley Division of Western Australia | |
| Total depth: | 3,475 feet (driller) | 5,429 feet (driller)<br>5,431 feet (Schlumberger) |
| Date drilling commenced: | 7th November 1959 | 19th December 1959 |
| Date drilling completed: | 26th November 1959 | 15th February 1960 |
| Date well abandoned: | 11th December 1959 | 17th February 1960 |

| | Thangoo No. 1 | Thangoo No. 1A |
|---|---|---|
| Date rig released: | 11th December 1959 | 17th February 1960 |
| Drilling time in days to total depth: | 20 | 61 |
| Elevation (above M.S.L.): | Ground, 557 feet<br>Derrick floor, 566 feet | Ground, 559 feet<br>Derrick floor, 568 feet |
| Status: | Abandoned, plugged back to 1,432 feet, across 10 3/4" casing shoe; perforated at 1,150 feet to 1,170 feet with 4 jet shots per foot for completion as water well; sealed with plate welded across 10 3/4" casing stub at approx. 2 feet below ground level; steel well marker above ground level affixed to casing stub. | Abandoned, plugged back to 3,200 feet; plate welded on 10 3/4" casing stub; steel well marker affixed to casing stub above ground level. |

Drilling Data

| | | |
|---|---|---|
| Drilling Contractor: (drilling crews, supervision and camp operation only) | Oil Drilling & Exploration (W.A.) Pty Ltd, 237 Adelaide Terrace, Perth, Western Australia. | |
| Drilling plant: (owned by WAPET) | Make and type: | National T-32 |
| | Rated capacity with $4\frac{1}{2}$" drill-pipe: | 5,500 feet |
| | Motors: | 3 Cummins Model NHI-600. Full diesel industrial 1,800 RPM rated 180 BHP. Nominal rating 200 BHP at 2,100 RPM. |
| Mast: | Make and type: | L.C. Moore 94 foot Cantilever |
| | Rated capacity: | 300,000 lbs. API |
| Pumps: | Make and type: | 2 National C-250 |
| | Size: | 7 1/4" x 15" |
| | Motors: | 6 Cummins Model NHI-600. Full diesel industrial 1,800 RPM rated 180 BHP. Nominal rating 200 BHP at 2,100 RPM. |

Blowout preventor equipment:

| | | |
|---|---|---|
| Make: | Shaffer, Hydril | |
| Size: | 10" | 10" |
| Series (API): | 900 | 900 |

| | Thangoo No. 1 | Thangoo No. 1A |
|---|---|---|
| Hole sizes and depths: | 20" to 52 feet | 20" to 100 feet |
| | 13 3/4" to 1,483 feet | 13 3/4" to 3,280 feet |
| | 9 7/8" to 3,475 feet | 9 7/8" to 5,429 feet |

Casing and liner details:

| | | | | |
|---|---|---|---|---|
| Size | 16" | 10 3/4" | 16" | 10 3/4" |
| Weight (lbs/ft) | 65 | 40.5 | 65 | 40.5 |
| Grade | H40 | J55 | H40 | J55 |
| Range | 2 | 2 | 2 | 2 |
| Setting depth | 52 feet | 1,481 feet | 85 feet | 3,276 feet |

Casing and liner cementing details:

| | | | | |
|---|---|---|---|---|
| Size | 16" | 10 3/4" | 16" | 10 3/4" |
| Setting depth | 52 feet | 1,481 feet | 85 feet | 3,276 feet |
| Cement used (sacks) | 115 | 560 | 90 | 300 |
| Cemented to | Surface | 420 feet | Surface | 2,050 feet |
| Method used | Plug | Plug | Plug | Plug |

Drilling fluid:

To 16" conductor depths: Spud mud.

Out of 16" to total depth: high pH freshwater, low weight, shear and filtrate; bentonite-starch/CMC treated; caustic soda and myrtan were added where necessary. Water and plugging agents were used to combat lost circulation in Thangoo No. 1.

| | Thangoo No. 1 | | | | Thangoo No. 1A | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TPR (drilling days) | 1-7 | 8-14 | 15-20 | 21-35 | 3-9 | 10-16 | 17-23 | 24-30 | 31-37 | 38-44 | 45-51 | 52-59 |
| Weight (lbs/ft$^3$) | 73 | 79 | 78 | | 78 | 79 | 71 | 69 | 71 | 71 | 70 | 71 |
| Viscosity (Secs.Marsh) | 49 | 50 | 44 | | 46 | 51 | 52 | 45 | 52 | 46 | 47 | 51 |
| Filtrate (standard) | 5.5 | 5.0 | 5.5 | | 5.7 | 5.4 | 6.2 | 8.7 | 7.0 | 7.2 | 7.0 | 7.0 |
| Cake | 1 | 2 | 2 | | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| (inches) | 32 | 32 | 32 | | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| Sand (%) | 4.0 | 5.0 | 1.5 | | 7.2 | 2.3 | 1.0 | 0.6 | 1.0 | 1.0 | 1.0 | 1.0 |
| pH | 11 | 11 | 11 | | 11 | 11.5 | 12 | 12 | 12 | 12 | 12 | 11.5 |
| Shear (lbs/100 ft$^3$) | 0-0 | 0-0 | 0-0 | | 0-0 | 0-0 | 0-0 | 0-0 | 0-0 | 0-0 | 0-0 | 0-0 |

Water and plugging agents to time well abandoned

| | | |
|---|---|---|
| Water supply: | Two freshwater wells yielding a total of 440 bbl. per day were used during the operations. | |
| Perforation and shooting | For Thangoo No. 1: Perforated at 1,150-1,170' with 4 jet shots per foot for freshwater supply (sub-artesian). | |
| | For Thangoo No. 1A: | Nil. |
| | Thangoo No. 1 | Thangoo No. 1A |
| Plugging back and squeeze jobs: | Abandonment plug only: 268 sacks cement used across 10 3/4" casing shoe with top of plug at 1,432 feet. | Abandonment plug only: 100 sacks cement across 10 3/4" casing shoe with top of plug at 3,200 feet. |
| Fishing operations: | Nil | Depth 2,322 feet: Lost bit-sub and 13 3/4" bit; recovered fish with 8 1/4" DV overshot, 6 7/8" grapple. Depth 4,059 feet: Lost one drill collar, bit-sub and bit (total length 37.07 feet); also Eastco drift indicator. Recovered drill collar, bit-sub and bit on run 2 with 8 1/4" DV; recovered totally destroyed drift indicator with Globe Junk Basket. Depth 4,523 feet: Lost four drill collars, bit-sub and bit; recovered with 8 1/4" DV overshot using 6 5/8" slips. |
| Sidetracked hole: | Nil | Nil |

(Engineering data above prepared by P.H.J. Hammett)

Logging and Testing

| | | |
|---|---|---|
| Ditch samples: | Ditch samples were collected from the surface to total depth at 10-foot intervals while drilling and at 5-foot intervals during coring. Cuts of washed ditch samples were made for the Mines Department of Western Australia and West Australian Petroleum Pty Ltd. | No samples were collected above 400 feet. Ditch samples were collected at 10-foot intervals from 400 feet to total depth and 5-foot intervals during coring. The bulk ditch samples from 400 feet to 3,540 feet were forwarded to the Bureau of Mineral Resources, but from 3,540 feet to total depth the bulk samples were retained by WAPET.* |

* WAPET is used as an abbreviation of West Australian Petroleum Pty Ltd.

| | Thangoo No. 1 | Thangoo No. 1A |
|---|---|---|
| | In addition washed and bagged sample cuts were made for the Bureau of Mineral Resources under the terms of the Petroleum Search Subsidy Act (1957/58). Bulk ditch samples and WAPET's washed sample splits are stored in WAPET's Norma Road Corehouse. | From 3,400 feet to total depth washed sample cuts were made for B.M.R., Western Australian Mines Department and WAPET. WAPET's cuts of washed samples, and bulk ditch samples are stored in WAPET's Norma Road Corehouse. |
| Coring: | The original coring programmes for each well are set out below. | |
| | "Cores will be taken immediately following signs of hydrocarbons in any part of the section.<br>"Sidewall coring equipment will be available to examine portions of the softer Permian and Mesozoic sediments which are of interest.<br>"Cores for stratigraphic information and porosity will be taken as follows in the pre-Permian section.<br>The first routine core will be taken in the top of the pre-Permian at approximately 2,820 feet.<br>The top of the pre-Permian will be picked by the wellsite geologist from cuttings and the drilling time log. Subsequent cores will be taken at intervals not exceeding 200 feet in a predominantly carbonate sequence, and at intervals not exceeding 400 feet in a predominantly sandstone/siltstone sequence. Cores will be cut to evaluate formation changes, at signs of fossils, and in porous zones". | "Cores will be taken immediately following shows of oil or strong indications of gas in any part of the section.<br>"To evaluate the oil seen in the top of the first sandstone in the Grant Formation in Thangoo No. 1, a core should be cut in this sandstone.<br>"Coring in the Ordovician should be restricted to the new portion of the hole (below 3,475 feet). Cores in the Ordovician should be cut at signs of porosity in the cuttings, and, if possible, at zones of lost circulation, so long as these zones of porosity and lost circulation occur below a dense or tight section which might be considered a reservoir seal. The interval between cores in the Ordovician should not exceed 200 feet in a predominantly limestone lithology and 400 feet in a siltstone/sandstone sequence. Cores may be cut at signs of abundant fossils in the cuttings; to be taken, however, only when additional palaeontological information is considered essential.<br>"After sufficient Precambrian basement has been drilled to ensure that solid, unfractured rock is being penetrated a bottom hole core should be cut." |

| | Thangoo No. 1 | Thangoo No. 1A |
|---|---|---|
| | The coring programme was carried out as planned.<br>Four cores were cut using a Hughes Type "J" core barrel with 7 7/8" hard formation core heads. A total of 37 feet of Ordovician section was cored with 37 feet (100%) recovery.<br>Cores were cut at approximately 200 to 250 feet intervals from the top of the Ordovician section. No cores were cut in the Mesozoic or Permian sections. The cores are stored in the Norma Road Corehouse. Representative samples of all cores were reserved for the Mines Department of Western Australia. In addition core cuts were made for the Bureau of Mineral Resources as agreed under the terms of the Petroleum Search Subsidy Act (1957/58). Details of cores cut are listed in Appendix 4. | The coring programme was carried out as planned.<br>Ten cores were cut using a Hughes Type "J" core barrel. A soft formation core head was used to cut the core in the Permian section and hard formation core heads were used for coring in the Ordovician and Precambrian. A total of 110 feet of formation was cored with 89½ feet (81%) recovery. The cores are stored in WAPET's Norma Road Corehouse, Melville, W.A. Core cuts were made for the Bureau of Mineral Resources, and the Mines Department of Western Australia. |
| Sidewall cores: | One run was made with Schlumberger's Chronological Sample Taker. Thirty sidewall samples were attempted and 29 samples recovered. A split of these samples was forwarded to the Bureau of Mineral Resources; the remainder are stored in WAPET's Perth Office. A list of sidewall samples is attached in Appendix 4. | No sidewall cores were taken. |
| Schlumberger logging: | The following logs were run by Schlumberger: Electric, Gamma Ray-Neutron, Micro-caliper, Section Gauge and Temperature. The details of these logs are listed in Appendix 5.<br>The originals of all Schlumberger logs are filed at the office of West Australian Petroleum Pty Ltd, 251 Adelaide Terrace, Perth, W.A.; copies of all logs whether or not reproduced in this report may be consulted at the Bureau of Mineral Resources, Canberra. | |

Drilling rate, oil and gas logs: Drilling time for 5-foot intervals was recorded during drilling down to total depth in Thangoo No. 1 and down to 3,500 feet in Thangoo No. 1A. Drilling time for 1-foot intervals was recorded while coring in both wells and from 3,500 feet to total depth in Thangoo No. 1A.

Drilling rates in feet-per-hour over each five-foot interval have been plotted on the drilling time and gas logs (Plates 1 and 2). These logs also contain continuous graphic records of J.W. gas analyser readings and lithology.

Formation tests: A swabbing test of the zone of lost circulation at 3,670 feet was run in the open hole of Thangoo No. 1A, but no hydrocarbons were recovered.

The details of formation tests Nos. 1 and 1A together with the results of fluid analyses from test No. 1A are given in Appendix 3.

Deviation survey: Hole deviation was recorded with an Eastman Drift Indicator at 24 levels in Thangoo No. 1 and at 33 levels in Thangoo No. 1A. The maximum deviations recorded were $3^{o}$ at 3,240 feet in Thangoo No. 1 and $3^{o}$ at the bottom of Thangoo No. 1A. Details of these surveys are listed in Appendix 6.

Temperature surveys: Temperature logs were run from 150 feet to 1,430 feet in Thangoo No. 1, and from 120 feet to 3,233 feet in Thangoo No. 1A, to determine the position of the top of the cement behind the 10 3/4" casing.

## GEOLOGY

### Summary of Previous Work

The Bureau of Mineral Resources has conducted a regional geological survey and regional gravity and aerial magnetometer surveys in the area of Thangoo Nos. 1 and 1A. The gravity and magnetometer work suggested that a regional basement ridge ran in a north-west direction.

West Australian Petroleum Pty Ltd conducted semi-detailed gravity, aerial magnetometer, regional refraction seismograph, and detailed and regional reflection seismograph surveys in the area. These surveys also suggested the presence of a regional basement ridge in much the same position as that noted by the Bureau of Mineral Resources. Detailed reflection work finally led to the locating of Thangoo Nos. 1 and 1A wells on what appeared to be a structurally high position in the Ordovician on the suspected basement ridge.

The subsurface geology of the area was examined by two core holes, Roebuck Bay No. 1 and Dampier Downs No. 1, and one structural test, Goldwyer No. 1, prior to the drilling of Thangoo No. 1 (Fig. 1). These three wells were drilled by WAPET concurrently with the geophysical surveys, and provided a positive guide to the type of stratigraphical and structural problem confronting the company in its search for oil in this area. The traces of oil in the Ordovician, and the lack of any other pre-Permian section in Goldwyer No. 1, led WAPET to concentrate on structures in the Ordovician section on the basement ridge.

## Stratigraphy

Only one palaeontological report on the cores from the wells was available at the time this report was written, so that the ages of the formations are based mainly on data from adjacent wells.* The boundaries of the formations were established on lithology, and electrical and gamma ray-neutron log interpretation.

The stratigraphy of the Mesozoic and Permian was determined mainly from Thangoo No. 1, but the Ordovician was largely unexamined at the time of the collapse of the well. Thangoo No. 1A was drilled to complete the examination of the sequence to basement, and to check some of the details of the Permian sequence.

The details of the formations are shown on the composite logs of the two wells: Thangoo No. 1 on Plate 1, and Thangoo No. 1A on Plate 2. The depths to, and thicknesses of, the various formations in both wells are summarised in Table I.

### Quaternary

#### Surface Sands

The Quaternary is represented by loose red sand.

### Cretaceous

#### Broome Sandstone (Lower Cretaceous)

No samples were collected from this interval in Thangoo No. 1A. In Thangoo No.1 the formation is represented by poorly sorted fine to coarse porous quartz sandstone with colour varying from white to yellow and light brown. The rock is friable, and is slightly cemented by kaolinitic cement. In parts the sandstone contains a clay matrix with scattered white mica flakes. The basal part of the formation grades into fine conglomerate, with quartz pebbles up to 15mm., and a few pebbles of greenish granite with a red ferruginous coating.

In other wells in the South Canning Basin the Broome Sandstone unconformably overlies the Jarlemai Siltstone.

### Jurassic

#### Jarlemai Siltstone (Upper Jurassic)

Samples were collected only from the basal part of the formation (below 400 feet) in Thangoo No. 1A. In Thangoo No. 1 the top of the Jarlemai Siltstone is indicated by a sharp break in the gamma ray curve. This break is caused by the very clayey and silty nature of the formation, compared with the overlying Broome Sandstone. The formation consists of four lithological units; the two upper units form the weathered top of the Jarlemai Siltstone:

From 224 to 305 feet sandstone: ferruginous, dark red-brown, purple and yellow, poorly sorted, very fine to coarse-grained, in parts grading into conglomerate, with well rounded quartz pebbles. The sandstone contains abundant clay and silt matrix, in part grading into sandy claystone and siltstone.

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* Two palaeontological reports have been added since (Appendix 2).

From 305 to 360 feet sandstone as above is interbedded with red-brown and yellow, ferruginous siltstone, slightly sandy in parts. Some beds of siltstone grade into micaceous claystone.

Below 360 feet is the unweathered part of the Jarlemai Siltstone. In general, from 360 to 383 feet the lithology resembles that of the interval 305 - 360 feet, but the colour of the interbedded friable sandstone and siltstone is grey to brownish grey. This unit also contains nodules of pyrite and a few fine carbonaceous fragments.

The basal unit, from 389 to 549 feet, consists of brownish grey sandy and glauconitic siltstone with tubular pyritic nodules. In the upper part of the unit, the siltstone is very friable and does not appear as chips during drilling, but in the lower part it is firm to hard, sometimes containing abundant very fine sand grains.

No fossils were observed in the cuttings from the Jarlemai Siltstone. It conformably overlies the Alexander Formation.

### Alexander Formation (Upper Jurassic)

The upper part of the formation (from 549 to 683 feet in Thangoo No. 1 and 566 to 660 feet in Thangoo No. 1A) consists of interbedded sandstone and sandy siltstone. The sandstone is medium to very coarse-grained, sub to well-rounded, friable, and appears as loose sand in the ditch samples. Near the top it contains some ferruginous pebbles of brown, fossiliferous limestone and dark greenish-brown fossiliferous sandstone. The siltstone of this unit resembles the firm to hard siltstone in the lower part of the Jarlemai Siltstone.

The section from 683 to 814 feet in Thangoo No. 1 and 660 to 827 feet in Thangoo No. 1A consists of medium to very coarse-grained sandstone, well rounded, silty, with dark green glauconite, some pyrite, and fragments of belemnites and occasional pelecypods. It is interbedded with light brownish grey calcareous siltstone which, in part, contains abundant very fine sand, and some veins of brown calcite. Pyritized wood fragments are common in the lower part of this section.

The Alexander Formation conformably overlies the Wallal Sandstone.

### Wallal Sandstone (Middle to Upper Jurassic)

The formation consists predominantly of coarse sandstone, in part grading to very fine conglomerate. It is characterized by noticeable amounts of bluish, and some greenish, quartz. The middle section contains some beds of siltstone and, in Thangoo No. 1A, some beds of black coal. No carbonaceous material was seen in the cuttings from Thangoo No. 1. Pyrite nodules are common in the lower part of the formation. It overlies the Poole Sandstone unconformably.

## Permian

### Poole Sandstone (Artinskian)

Only the basal part of the Poole Sandstone is present in each well. It consists of light grey and light grey-brown siltstone and interbedded medium to coarse well sorted sandstone. The siltstone contains some finely disseminated pyrite in its upper part and some

TABLE I

FORMATIONS IN THANGOO NOS. 1 AND 1A WELLS

| AGE | | FORMATION | Thangoo No. 1 Formation Tops Depth D.F. | Depth Subsea | Thick-ness | Thangoo No. 1A Formation Tops Depth D.F. | Depth Subsea | Thick-ness |
|---|---|---|---|---|---|---|---|---|
| Quarternary | | Surface sand | 9' | +557' | 30' | 9' | +559' | 30' |
| | | UNCONFORMITY | | | | | | |
| Cretaceous | Lower | Broome Sandstone | 39' | +527' | 185' | 39' | +529' | 196' |
| | | UNCONFORMITY | | | | | | |
| Jurassic | Upper | Jarlemai Siltstone | 244' | +342' | 325' | 235' | +333' | 331' |
| | Upper | Alexander Formation | 549' | + 17' | 265' | 566' | + 2' | 261' |
| | Middle to Upper | Wallal Sandstone | 814' | -248' | 566' | 827' | -259' | 578' |
| | | UNCONFORMITY | | | | | | |
| Permian | Artinskian | Poole Sandstone | 1,380' | -814' | 70' | 1,405' | -837' | 77' |
| | Artinskian to Sakmarian | Nura Nura Member of Poole Sandstone | 1,450' | -884' | 44' | 1,482' | -914' | 54' |
| | | ?---?---DISCONFORMITY---?---?---?--- | | | | | | |
| | Sakmarian | Grant Formation | 1,494' | -928' | 1,303' | 1,536' | -968' | 1,246' |
| | | UNCONFORMITY | | | | | | |
| Ordovician | Lower to Middle | Goldwyer Formation | 2,797' | -2,231' | 578' | 2,782' | -2,214' | 695' |
| | | DISCONFORMITY | | | | | | |
| | Lower | Thangoo Limestone | 3,375' | -2,809' | 1,004' | 3,477' | -2,909' | 1,623' |
| | | UNCONFORMTIY | | | | | | |
| Precambrian | | Biotite phyllite | - | - | - | 5,100' | 4,532' | 329' |
| | | TOTAL DEPTH | 3,475' | -2,909' | | 5,429' | -4,861 | |

thin carbonaceous lenses. At the base in Thangoo No. 1A is a very fine conglomerate, with quartz pebbles up to 8mm. diameter.

Nura Nura Member of the Poole Sandstone (Artinskian)

The upper part of the section, from 1,482 to 1,487 feet in Thangoo No. 1A, consists of interbedded light grey, very fine to fine-grained silty, micaceous sandstone and light grey-brown siltstone with nodules of pyrite and white, siliceous worm tubes.

The interval from 1,487 to 1,513 feet consists of brown, cream and grey calcarenite, coarse, in part sandy, firm to hard, with abundant bryozoa, crinoids and pelecypods. From 1,513 to 1,525 feet is a similar but friable calcarenite, containing much calcilutite matrix and quartz sand. The lower part of the member, from 1,525 to 1,536 feet, is medium to dark grey siltstone, with light grey to white coarser lenses, grading into very fine sandstone. Some beds grade into claystone and micaceous shale, massive to thinly bedded. Carbonaceous fossil plant impressions are present in the fine-grained lenses.

In Thangoo No. 1 the Nura Nura Member is similar in lithology and extends from 1,450 to 1,494 feet. The Nura Nura Member is regarded from evidence in other wells as overlying the Grant Formation disconformably.

Grant Formation (Sakmarian)

Two major lithological units are recognised in the Grant Formation in Thangoo No. 1.

From 1,494 to 2,597 feet the formation consists predominantly of sandstone of fluvioglacial origin. The sandstones are mostly poorly sorted and vary from fine to very coarse-grained and to conglomerates. Feldspar grains are very common, and in places abundant. Pebbles of granite and quartzite are abundant; in some beds the granite pebbles exceed 50% of the rock. The sandstone is mostly porous, except the section from 2,050 to 2,250 feet, which contains numerous hard, very calcareous, non-porous, fontainebleau sandstone beds. Kaolinitic cement is common throughout the section, and is very abundant in the basal sandstone bed of the unit.

Interbedded with the sandstone are beds of the following lithologies:

Siltstone: medium grey, in part sandy, with beds grading into claystone;

Siltstone: light grey to white, fine to coarse, in part grading into very fine sandstone;

Siltstone (tillite): dark grey, consisting of sandy silt and clay groundmass, with scattered pebbles of granite and quartzite.

The upper sand bed of the unit in the well showed some oil staining. Oil was also observed deeper in the section in thin pyritic sandstone lenses.

The lower unit, from 2,597 to 2,797 feet, consists predominantly of dark grey

tillite with a great variety of pebbles and boulders, including granite, quartzite, jasper and oolitic limestone. The lower part of the member is very sandy, grading into sandstone and conglomerate. A hard, highly resistive fontainebleau sandstone bed from 2,718 to 2,726 feet can be correlated with a corresponding bed in the Goldwyer No. 1 and Roebuck Bay No. 1 wells.

In Thangoo No. 1A the lithology is similar to the upper unit and the lower part of the lower unit of Thangoo No. 1, but the dark grey tillite was not recognised. Because of the lower structural position the uppermost sandstone beds which contained oil traces in Thangoo No. 1 are barren in Thangoo No. 1A.

The Grant Formation unconformably overlies the Goldwyer Formation.

Ordovician

Goldwyer Formation (Lower to Middle Ordovician)

The Goldwyer Formation consists of a sequence of shale, limestone, dolomite, and siltstone. It is newly named and is defined and described in detail in Appendix 7.

Considerable interest was taken in this formation as traces of oil had been seen in it in Thangoo No. 1 and Goldwyer No. 1. The rocks are suitable for source beds and it was hoped sufficient porosity would be present for reservoirs. However no porosity was detected in the formation and no formation tests were carried out.

From evidence obtained in Thangoo No. 1 and 1A, it is considered that the Goldwyer Formation disconformably overlies the Thangoo Limestone. This is discussed in more detail in Appendix 7.

Thangoo Limestone (Lower Ordovician)

The Thangoo Limestone replaces the Thangoo Calcarenite and Roebuck Dolomite of McWhae et al. (1958); it is redefined and described in detail in Appendix 7. It consists of interbedded limestone and dolomite with some siltstone beds, and a sandstone unit at the base.

Only slight traces of oil were seen, in the upper part of the basal sandstone in dolomite veins. Formation tests Nos. 1 and 1A were carried out on a porous interval at 3,670 feet and recovered brackish water without signs of hydrocarbons (Appendix 3).

The Thangoo Limestone unconformably overlies the Precambrian.

Precambrian

Basement was reached only in Thango No. 1A. It consists of biotite phyllite. The rock is dark grey to black, thinly laminated, sericitic, graphitic, and with abundant porphyroblasts of red-brown biotite. It is traversed by quartz-carbonate veinlets containing pyrite, sphalerite, pyrrhotite, chalcopyrite, marcasite, galena, and arsenopyrite.

Structure

No dipmeter survey was run in either well. Visual estimates were possible from cores obtained from parts of the Ordovician section in each hole and from the Precambrian in Thangoo No. 1A. Dips up to $60^{o}$ were recorded near the top of the Goldwyer Formation in Thangoo No. 1 and of $15^{o}$ near the top of the Thangoo Limestone in Thangoo No. 1A. These were associated with abundant fractures and slickensides in the cores, probably indicating

proximity to small faults. Cores from the lower part of the Thangoo Limestone in Thangoo No. 1A also showed moderate dips. The rest of the Thangoo Limestone showed flat dips in Thangoo No. 1A, and the Goldwyer Formation in Thangoo No. 1 had dips between $5^{o}$ and $7^{o}$.

## Relevance to Occurrence of Petroleum

No signs of hydrocarbons were observed in the Mesozoic rocks.

Below 1,494 feet in Thangoo No. 1 the Grant Formation contains several hundred feet of medium to coarse, porous sandstone. The sandstone appeared in samples mostly as loose sand grains, but the highest samples contained some globules of red-brown clear oil, which showed yellow fluorescence and gave a fluorescent cut with carbon tetrachloride. Besides these free oil globules, the samples also contained some chips of sandstone with pyritic cement, with solid, waxy, and fluid red-brown hydrocarbons in the interstices between the grains. These pyritic sandstone chips were encountered in several samples throughout the Grant Formation.

To evaluate the distribution of hydrocarbons in the formation 29 sidewall cores were cut between 1,500 feet and 2,200 feet. Only the highest sidewall core (SWC No. 1) at 1,500 feet showed the presence of oil. The core consists of medium grained, porous sandstone; predominantly brown-stained, with patches of red-brown and yellow-brown waxy and fluid oil throughout the core.

The oil may have migrated into the Grant Formation from the underlying Ordovician rocks. It was trapped in the highest bed of porous sandstone by the impervious siltstone bed at 1,494 feet, the base of the Nura Nura Member. The presence of oil at 1,500 feet indicates that about 6 feet of oil sand (1,494-1,500 feet) may occur. It should be noted, however, that no oil saturation is indicated by the electrical log in this or any other interval in the Grant Formation.

The results of sidewall coring also indicate that all porous beds which may have been oil-bearing in the deeper part of the formation were flushed by fresh water and only the thin, slightly porous, pyritic lenses remained unflushed. No samples from these lenses were present in the sidewall cores.

No signs of hydrocarbons were seen in the Permian section in Thangoo No. 1A.

Cores and ditch samples indicate that all the dolomite beds of the Goldwyer Formation contain scattered small vugs with live green-brown and yellow-brown oil. In the lower part of the dolomite unit (2,914 to 3,005 feet) in Thangoo No. 1 and in the dolomite beds in the interval 2,782 to 3,125 feet in Thangoo No. 1A oil shows were also associated with slight intergranular porosity in saccharoidal dolomites. Slight oil staining was also observed in thin calcite veins. No signs of hydrocarbons were observed in the limestone units.

A strong petroliferous odour was noted in a core cut in the siltstone unit (3 090-3,375 feet) in Thangoo No. 1. This was accompanied by a slight reading (up to 5 units) on the J.W. gas detector while the section was being drilled. The formation was not tested because extensive caving caused the hole to be abandoned when circulation of the drilling fluids was lost at 3,475 feet.

Yellow and orange fluorescence was observed in the upper 15 feet of the Thangoo

Limestone in Thangoo No. 1. This section consists of white and grey-brown dolomite with sugary texture, low intergranular porosity and a few small vugs, mostly filled with dolomite crystals. Some brown oil staining was observed in the minute interstices. The amount of fluorescent chips in ditch samples varied from 30% in the upper part of the section to 10% at 3,385 feet. No hydrocarbons were noted below 3,390 feet. Minor traces of oil were also found in Thangoo No. 1A.

The main conclusions drawn from the two wells are:

(a) The Mesozoic section, and the Permian section to the base of the Poole Sandstone, have no suitable oil source rocks or structures for the entrapment of hydrocarbons.

(b) The upper sandstone of the Grant Formation has some oil staining in Thangoo No. 1, but is water saturated. Sediments of the Grant Formation should be considered as potential reservoirs if covered by the impervious Nura Nura Member.

(c) The Goldwyer Formation has the characteristics of a petroleum source rock with its lithologies of shale, siltstone, limestone, and dolomite. The lack of porosity in this formation prevents the accumulation of oil in these rocks.

(d) The underlying light-coloured Thangoo Limestone has locally-developed vuggy porosity and caves but low oil source potential.

(e) The large time break between the Ordovician and Permian and the extensive erosion of the Ordovician during the period has probably led to flushing of the porous zones in the Ordovician by meteoric waters. It is probable that additional flushing of the vuggy Thangoo Limestone occurred during a hiatus prior to the deposition of the Goldwyer Formation. The presence of meteoric waters is suggested by the low salinity (11,999 ppm total salts) recovered from formation test 1A.

(f) The Ordovician contains rocks with some source potential in the upper part but the main problem is to find associated porosity for the accumulation of oil.

## Porosity and Permeability

No laboratory porosity or permeability measurements were made on cores recovered from the wells. Porosity and permeability of the formations were estimated from the electric logs and microlog, and visual examination of the cores.

The sandstones in the Mesozoic and Permian formations generally show good porosity and permeability. In some beds in the Alexander Formation and Grant Formation the sandstones are silty, and permeability is lower. Siltstones and calcarenites in the Mesozoic and Permian show low porosity and very low permeability. Water was produced from the Wallal Sandstone, from 1,150 to 1,170 feet in Thangoo No. 1 through 80 perforations in the 10 3/4 inch casing. It was tested at 20 gallons per minute by swabbing.

In the Goldwyer Formation the only porosity seen was in vugs in carbonate veins,

and these have poor permeability. Microlog (ML-1) run over the interval 3,280 to 3,000 feet confirmed the low porosity of the Goldwyer Formation.

Abundant vugs in carbonate veins which cut the Thangoo Limestone give some porosity and permeability. Some poor intergranular porosity was present in some of the saccharoidal dolomite beds. The basal sandstone showed very low porosity and permeability as it was well cemented with dolomitic and siliceous cement (see report in Appendix 1 by Elliott).

The porous zone which was encountered in the Thangoo Limestone at 3,670 feet in Thangoo No. 1A and produced brackish water in formation test No. 1A is thought to be due to a fault zone or a cave much smaller than that encountered in Thangoo No. 1 at 3,475 feet. Excessive lost circulation with the breakdown of the mud-cake supporting the friable Grant Formation led to the abandoning of Thangoo No. 1 after the cave was encountered at 3,475 feet.

## Contributions to Geological Knowledge from the Drilling

(a) The presence of oil in the upper part of the Grant Formation in Thangoo No. 1 indicates the possibility of oil migration from the Ordovician into the Permian sediments. The top of the Grant Formation was met higher in this well than in any other drilled to date on the Broome Platform or on the Jurgurra Terrace. Seismic surveys have indicated other areas structurally higher in the Grant Formation than in the immediate vicinity of Thangoo No. 1. Thus it is possible that such structural highs may provide shallow drilling targets for oil accumulations in the excellent reservoir of the Grant Formation. Although this oil could have been derived from within the Permian section, it is believed that the source is more likely to be the underlying Ordovician rocks in which traces of oil were seen. The presence of oil globules in the secondary calcite veins cutting the upper part of the Goldwyer Formation indicates that oil has migrated from these Ordovician source beds.

(b) Early studies of the Ordovician section suggested that the source rock shales passed laterally in a northerly direction into more permeable limestones. The drilling of the Thangoo Wells showed little lateral lithological variation, especially in the Goldwyer Formation. The thickness of the Goldwyer Formation is variable, owing to erosion of the top prior to the Permian transgression and to deposition on an irregular eroded surface of the Thangoo Limestone. The evidence for this break in deposition is given mainly by the abrupt change in lithology, and also by the considerable thinning of the lowest member of the Goldwyer Formation from Goldwyer No. 1 to Thangoo No. 1 and to Thangoo No. 1A.

(c) In Thangoo No. 1 uncontrollable lost circulation conditions were encountered in what is believed to be a cave in the upper part of the Thangoo Limestone. No test of the formation fluid was possible. Similar lost circulation conditions, together with the actual dropping of the drilling bit into a substantial cavity, were experienced in the drilling of Dampier Downs No. 1. In Thangoo No. 1A a swabbing test of a porous zone high in the Thangoo Limestone yielded 740 barrels of brackish, connate water containing no traces of oil or gas. It is concluded that caves were formed by meteoric waters in the Thangoo Limestone probably during the hiatus prior to the deposition of the Goldwyer Formation.

(d) The chances of finding commerical oil accumulations in the Ordovician section of the South Canning Basin are considered very small for the following reasons :

The Thangoo Limestone cannot be regarded as a prolific source rock

and any oil accumulations in zones of primary porosity would be seriously affected by flushing by meteoric water.

The Goldwyer Formation appears to be a better source rock, but no significant porosity has been seen in it.

There is difficulty in resolving the Ordovician structural picture using currently practised seismic methods.

(e) The Permian section encountered consists of the Grant Formation, the Nura Nura Member, and only 70 feet of the basal, silty portion of the Poole Sandstone. It supports the evidence of Goldwyer No. 1, Roebuck Bay No. 1, and Dampier Downs No. 1, that the Liveringa and Noonkanbah formations are not preserved south-west of the Dampier Fault.

REFERENCE:

McWHAE, J.R.H., PLAYFORD, P.E., LINDNER, A.W., GLENISTER, B.F., and BALME, B.E., 1958 - The stratigraphy of Western Australia. J. geol. Soc. Aust. 4 (2) 161pp. (for 1956).

## APPENDIX 1

## PETROLOGICAL REPORTS

### Thangoo No. 1. Core No. 4 (3,391 to 3,401 feet)

By R.M.L. Elliott, West Australian Petroleum Pty Ltd

Hand Specimen. LIMESTONE, dolomitic, poorly banded, light grey and dark grey. The dark grey beds are more silty and sandy with slightly micaceous, non-porous fine quartz sand. They are pyritic, with crystal aggregates up to 1/4 inch across. The beds are poorly defined and much of the light grey limestone appears as small lenses or irregular shaped bodies; no reliable dip is apparent. By comparison with the wellsite description the sample is probably from the lower part of the core.

Thin Sections

(i) Perpendicular to the bedding. The dark grey silty portion of the rock consists of a mosaic of fine, anhedral calcite crystals and silt, with 10-20% of scattered, very fine-grained, angular quartz grains.

The light grey portion of the rock consists of a mosaic of fine, anhedral calcite crystals, with 5-10% of scattered, very fine, angular quartz grains. At the contact with the dark portion there is a thin bed of fine, euhedral dolomite crystals in a calcite groundmass. A few euhedral dolomite crystals can be seen in the main calcite groundmass.

(ii) Parallel to the bedding. The section consists of a mosaic of anhedral calcite crystals with about 10% of scattered fine angular quartz grains. There are some small, scattered crystal aggregates, and single crystals, of euhedral dolomite; these comprise 10-20% of the rock. One small calcite vein has euhedral dolomite crystals lining the contact between the calcite vein and the host rock.

### Thangoo No. 1A. Core No. 8 (5,038 to 5,048 feet)

By R.M.L. Elliott, West Australian Petroleum Pty Ltd

SAMPLE 1. DOLOMITE

Hand Specimen. Dolomite, in part dolomitized limestone, pale grey, slightly glauconitic, with a few thin contorted laminae of dark grey siltstone. It is hard, non-porous, mainly finely crystalline, with some patches medium to coarsely crystalline. Siliceous spicules up to 1/4 inch long are present.

Thin Section (perpendicular to the bedding). Dolomite, grey, consisting of a finely crystalline groundmass of dolomite, and in part calcite, in which are set many euhedral crystals of dolomite, some grains of green glauconite, many siliceous sponge spicules, and a few ostracods or small brachiopods. Sporadic carbonate fragments show organic structures like sponges or

stromatoporoids and a few of these fragments are partly replaced by glauconite. Some thin contorted beds of dark grey siltstone are also present.

SAMPLE 2. SANDSTONE

Hand Specimen. Sandstone, pale grey, silicified, hard, fine-grained, well sorted, non-porous, some thin veins of dolomite which show a little vuggy porosity. Laminae of very hard, grey-brown siltstone are common.

Thin Section (perpendicular to the bedding). Sandstone, pale grey, fine to very fine-grained, well sorted, angular. Dolomite cement, which forms about 20% of the rock, appears as unevenly distributed scattered clots. The rest of the cement is siliceous.

## Summary Report on Cores Nos. 7 and 9, Thangoo No. 1A

By R.T. Prider, University of Western Australia

Core 7 (4,898 to 4,908 feet)

This specimen is a fossiliferous silty limestone with undulating phyllitic bands. The dip is low ($15^{o}$ if the well is vertical at this point).

There are two distinct parts of this rock:-

(i) White calcareous bands consisting of fine-grained calcite with occasional larger detrital shell fragments and a minor amount of detrital quartz silt and fine sand. In the more silty bands the angular quartz grains constitute up to 25% of the rock. Some of these silty bands contain grains up to 0.2 mm. diameter of a bright grass-green mineral with "aggregate" polarization colours, which appears to be glauconite. In the calcilutite bands there are occasional carbonate rhombs which may be dolomite. On the whole there is very little recrystallisation of the carbonate.

(ii) Undulating dark coloured bands, consisting of abundant fine quartz grains averaging 0.1 mm. diameter, with rare glauconite grains as in the limestone bands. These are set in a brownish groundmass, which was originally clay, but shows slight recrystallization to a fine-grained, micaceous aggregate. There are no large recrystallized flakes of mica, but the incipient recrystallization of the clayey material is evident. The undulating nature of these clayey bands is probably due to differential compaction. This part of the specimen would be best described as silty shale in which there has been slight recrystallization probably due to superincumbent load only.

Core 9 (5,256 to 5,266 feet)

Two specimens were examined, both thinly laminated pyritized graphitic biotitic phyllites with carbonate veinlets.

The rock is dark grey with closely spaced very thin light-coloured beds. It has a slightly silky lustre, has cleavage parallel to the bedding, and is traversed by discordant pyritic quartz-carbonate veinlets. The bedding dips at $45^{o}$ to the axis of the core. On the silky-lustred cleavage surfaces there is a faint lineation which is parallel to the carbonate veinlets.

Under the microscope this rock has a fine schistose structure and consists mainly of fine-grained quartz and feldspar dusted with black fine-grained "amorphous" graphite. A most noticeable feature is the development of porphyroblastic red-brown biotite, abundantly and uniformly distributed throughout the rock; in the vicinity of the wider carbonate veinlets it has been completely altered to pale greenish, weakly birefringent chlorite. The biotite is undoubtedly of metamorphic origin and the development of the biotite - i.e. the development of the phyllite from an original carbonaceous shale - was prior to the formation of the carbonate veinlets.

The body of the rock contains some carbonate, which may have been in the original sediment or may have been introduced at the time of formation of the carbonate veinlets. The carbonate veinlets consist of a granular aggregate of carbonate, quartz with minor amounts of pyrite, and some large chlorite plates which could well be derived from the enclosing phyllite.

The most significant feature of this rock is the metamorphic development of the red-brown porphyroblastic biotite, which indicates that it has been subjected to much greater metamorphism than the silty limestone (Ordovician) of Core 7.

Conclusions

Core 7 is much less metamorpnosed than Core 9, taken from only 300 feet below it. It is a clastic sediment - a fossiliferous, silty calcilutite with shale bands. Core No. 9 is more highly metamorphosed to a phyllite, the higher grade of metamorphism being evidenced by the development of porphyroblastic red-brown mica. There can be no doubt that between the deposition of the sediments of Core 9 and Core 7 there was a period of biotite grade dynamothermal metamorphism. I believe, therefore, that if Core 7 is of Ordovician age, Core 9 represents the Precambrian basement.

Thangoo No. 1A. Core No. 9 (5,256 to 5,266 feet)

By W.B. Dallwitz, Bureau of Mineral Resources

The rock is dark grey, fine-grained, and well-cleaved. Thin layers of yellow sulphide occupy some of the cleavage planes, and veinlets and small pockets containing quartz and sulphides are plentiful; the veinlets run in at least four different directions. One vein of sulphide-bearing quartz is very much larger than the rest, and measures up to 2.5 cm. across.

In thin section (slide 5304) the rock is seen to be a phyllite. It consists essentially of sericite and subordinate quartz; the quartz grains are of silt size. Scattered through the rock are small prisms (up to 0.11 x 0.04 mm.) of brown tourmaline, and leucoxene pseudomorphs after prismatic crystals of rutile; the average size of the pseudomorphs is about 0.15 x 0.03 mm. Most of the prisms of leucoxene and tourmaline lie parallel or sub-parallel to the cleavage, but the long axes of some make a high angle with the cleavage.

The veinlets and pockets noted in hand-specimen contain quartz, pale yellow-grey chlorite, dolomite, sulphides (mainly pyrite), and very rare apatite, sericite, biotite, and tourmaline.

W.M.B. Roberts has reported as follows on the opaque minerals in the large vein of quartz referred to in the description of the hand-specimen:

"Pyrite is by far the most abundant sulphide. Next in order are sphalerite, pyrrhotite, chalcopyrite, marcasite, galena, and arsenopyrite. Pyrite forms small cubes ranging up to 0.02 mm. across, and large irregular masses up to 15 mm. in width. Sphalerite occurs as a small vein filling, 0.6 mm. long and 0.1 mm. wide, with which are associated irregular areas of chalcopyrite and pyrrhotite. Galena forms an almost perfect cube of 0.02 mm. edge enclosed in the sphalerite vein. Arsenopyrite occurs as small isolated clusters of euhedral and subhedral crystals, the largest of which is 0.04 mm. across. Only one crystal of marcasite, 0.1 mm. across, was observed in the section; it is associated with pyrite."

Comments

This rock belongs to the greenschist facies of regional metamorphism. It has been invaded by mineralizing fluids which have deposited, among other things, tourmaline, apatite, pyrrhotite, and arsenopyrite. The presence of these minerals implies the existence of an igneous source and, as a corollary, the absence of any incentive to pursue the search for oil to a greater depth unless there is a distinct possibility that the drill is sited on a block which has been raised by reverse or thrust faulting.

## APPENDIX 2

## PALAEONTOLOGICAL REPORTS

### Palynological Report No. 65

By B.E. Balme, University of Western Australia

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Sample: Pale grey claystone

Depth: 1,525 to 1,543 feet, Thangoo No. 1A Well

Quality of Separation: Good

Microfossil list:

| Spores: | Pollen grains: | Microplankton: |
|---|---|---|
| Granulatisporites n. sp. | Lunatisporites amplus | Leiosphaeridia spp. |
| G. micronodosus | L. limpidus | Micrhystrium sp. |
| Cirratriradites splendens | Vestigisporites cf. rudis | Botryococcus (braunii-type) |
| C. spp. | Entylissa cymbatus | |
| Punctatisporites gretensis | | |
| Apiculatisporites cornutus | | |
| Nuskoisporites spp. | | |

Age

From the quantitative composition of the assemblage and the presence of P. gretensis, A. cornutus, E. cymbatus, and V. cf. rudis the sample is considered to be of Lower Permian (upper Sakmarian - basal Artinskian) age. Microplankton are also abundant, although the forms present are indistinctive, suggesting marine influences during deposition of the sediment. Whether the sediment is most properly assigned to the Poole Sandstone or the Grant Formation is impossible to say from the microfloral evidence alone. The assemblage resembles others previously described from the upper part of the Grant Formation, but there is no clear evidence of a microfloral break at the Sakmarian - Artinskian boundary in other parts of the Canning Basin.

## Chitinozoa from Thangoo Nos. 1 and 1A

By P.R. Evans, Bureau of Mineral Resources

A systematic search of cores and cuttings from the Goldwyer Formation and the Thangoo Limestone of Thangoo Nos. 1 and 1A, with an interval between samples no greater than 100 feet, has provided a large number of Ordovician Chitinozoa, particularly from the Goldwyer Formation.

This is only the third location in Australia (following Samphire Marsh No. 1 and Goldwyer No. 1) at which Chitinozoa have been found and, therefore, any stratigraphic application of their occurrence is strictly limited. Little use can be made of them by a comparison with overseas material since so little is known of their distribution abroad, except in isolated locations. The genera to which the Thangoo species may be referred - Lageonchitina, Conochitina, Cyathochitina, Rhabdochitina and Desmochitina - are known to range from the Ordovician to the Devonian, covering almost the complete life-range of the fossil group itself. A descriptive paper of the new material is in preparation and, it is thought, by that means the needs of future stratigraphic work on these forms will be served to advantage.

However, it may be mentioned at this stage that a chitinozoan "swarm" seems to be restricted to a portion of the Goldwyer Formation in which a great abundance of both specimens and species is to be found. The swarm lies between 2,857 and 3,100 feet in Thangoo No. 1 (three samples) and between 2,900 and 3,200 feet in Thangoo 1A (four samples). Below this horizon, chitinozoans are very rare and their existence in situ may be doubted since they have been extracted only from cuttings. Cores within the Thangoo Limestone in particular have failed to yield this type of microfossil.

A similar swarm is known from the Goldwyer Formation of Goldwyer No. 1, between 2,867 and 3,227 feet (cores only). The Goldwyer assemblage differs from that of the Thangoo wells in relative species abundances, rather than in total specific listing. The significance of this variation remains to be tested.

# Ordovician Fossils from Thangoo No. 1 and Thangoo No. 1A Western Australia

By Joyce Gilbert-Tomlinson, Bureau of Mineral Resources

## Introduction

The Ordovician sequence penetrated in Thangoo No. 1 and Thangoo No. 1A is comparable in lithology to that of Goldwyer No. 1. The upper part of the sequence - the Goldwyer Formation of Middle Ordovician (Llanvirnian and possibly Llandeilian) age - also contains a shelly and graptolitic fauna closely comparable with that of Goldwyer No. 1. The lower part of the sequence - the Thangoo Limestone of Lower Ordovician (Arenigian) age - shows no faunal resemblance to other wells penetrating Lower Ordovician rocks (i.e. Samphire Marsh No. 1 and Goldwyer No. 1), but one of the trilobites is congeneric with a form in the Emanuel Limestone of the Prices Creek sequence.

Thicknesses of the formations are:

| | Thangoo No. 1 | Thangoo No. 1A |
|---|---|---|
| Goldwyer Formation | 578 feet | 695 feet |
| Thangoo Limestone | 100 feet + (base not reached) | 1,623 feet |

## Palaeontology

### Thangoo No. 1

Samples are available from four cores, distributed as follows:

| | | |
|---|---|---|
| Goldwyer Formation: | Core 1: | 2,852-59 feet |
| | Core 2: | 2,859-71 feet |
| | Core 3: | 3,147-55 feet |
| Thangoo Limestone: | Core 4: | 3,391-3,401 feet |

The distribution of fossils is shown in Table 1. In the Goldwyer Formation most of the fossils occur in the lowest sample (Core 3), which contains fragments of a plectambonoid brachiopod and the trilobites Triarthrus, an undetermined asaphid, and a new genus of Trinucleina. The sample also contains a varied assemblage of graptolites - Didymograptus, Amplexograptus, Glyptograptus?, and Glossograptus?. Cores 1 and 2 are sparingly fossiliferous: inarticulate brachiopods, a machaeridian, the trilobite Megistaspis, an ostracod, and Amplexograptus are present.

The graptolites of the Goldwyer Formation are Middle Ordovician, being closely comparable with forms identified by Thomas (1960) in Goldwyer No. 1, and the Triarthrus is probably the same species as that in Goldwyer No. 1 near the base of the Goldwyer Formation. The family-reference of the new genus of trilobite is at present uncertain; the trilobite shows characters intermediate between the Middle Ordovician forms Ampyxina and Endymionia. Core 4 can be dated by superposition only, as its fossils are undiagnostic.

Thangoo No.1A

The sequence is represented by seven cores, four of which (Cores 3, 5, 7 and 8) are unfossiliferous. The depths are as follows:

| | | |
|---|---|---|
| Thangoo Limestone : | Core 2: | 3,665-72 feet |
| | Core 3: | 3,906-17 feet |
| | Core 4: | 4,138-52 feet |
| | Core 5: | 4,393-4,403 feet |
| | Core 6: | 4,645-57 feet |
| | Core 7: | 4,898-4,908 feet |
| | Core 8: | 5,038-48 feet |

Table 2 shows the distribution of identifiable fossils. Except for Core 6, the sequence is remarkable for the poor preservation of the fossils. Orthoid brachiopods occur in Core 6 and plectambonoids in Cores 2 and 4. The fauna of Core 6 is surprisingly varied and contains, in addition to some undiagnostic forms, a gastropod, two genera of nautiloids, the agnostid trilobite Trinodus, two genera of asaphids, and two genera of graptolites.

Core 6, with a Tetragraptus of the quadribranchiatus group, is Arenigian. Core 4 is probably also Arenigian, but the age of Core 2 is uncertain. The plectambonoid in this sample is distinct from the forms in Goldwyer No. 1 near the top of the Thangoo Limestone, but bears some resemblance to the form in Core 3 of Thangoo No. 1, which is Middle Ordovician in age. The fossils are too fragmentary, however, to draw any firm conclusions. Lowermost Ordovician (Tremadocian) and Cambrian are not represented.

## Correlation

### Thangoo Limestone

No correlation on faunal grounds is possible between the type section in Thangoo No. 1A and Thangoo Limestone in Thangoo No. 1, which contained no diagnostic fossils.

Outside the Thangoo area, Lower Ordovician fossils have been identified in four other wells: Goldwyer No. 1, Roebuck Bay No. 1, Dampier Downs No. 1, and Samphire Marsh No. 1. In none of them do shelly fossils afford a basis for exact correlation.

On faunal evidence it is by no means certain that the Thangoo Limestone of Goldwyer No. 1 should properly be identified with the type section in Thangoo No. 1A. The general sequence, as far as can be seen, is not dissimilar: in both wells beds with numerous (though fragmentary) fossils are overlain by unfossiliferous rocks, and these in turn are succeeded by beds with a monotonous fauna of plectambonoid brachiopods. Also, the time-span is roughly the same, although Core 2 of Thangoo No. 1A may be younger than cores from the top of the formation in Goldwyer No. 1.

The only common genus is the long and wide-ranging gastropod Helicotoma. Without specific identity this offers no hope of correlation, and the plectambonoids in the upper levels are not conspecific and may not even be congeneric.

Some of the differences may merely reflect poor preservation and accidents of collecting, and it is quite possible that Goldwyer and the Thangoo wells have penetrated parts of the same rock body; but correlation between the various levels cannot be attempted.

Roebuck Bay No. 1 has yielded no larger fossils, and Dampier Downs No. 1 contains a brachiopod of a group (subfamily Tritoechiinae) not known in any other well. The upper part of the Ordovician sequence in Samphire Marsh No. 1 (Cores 4 to 6) occupies roughly the same time-span as the Thangoo Limestone, but no common genera can be identified. Resemblances in faunas may, of course, be obscured by differences in preservation: asaphid trilobites, for example, which are reasonably well-preserved in the Samphire Marsh sequence, are particularly fragmentary in the Thangoo Limestone.

Two of the fossils of the Thangoo Limestone have opened a prospect of future correlation with Ordovician sections known in outcrop. The first of these is the agnostid Trinodus (Thangoo No. 1A, Core 6), known also in the Prices Creek (Western Australia) sequence. Specific identity is not attainable on the present material. The second significant fossil is a brachiopod in Core 12 of Goldwyer No. 1, which resembles "Orthis" dichotomalis Tate, from central Australia. The Goldwyer material is rather fragmentary and probably immature, but future exploration may yield specimens suitable for specific identification.

Goldwyer Formation

The formation was not cored in Thangoo No. 1A, so no correlation based on shelly fossils is possible between the Thangoo wells.

A tentative correlation between Goldwyer No. 1 and Thangoo No. 1 is possible (Tomlinson, 1960, Table 4). Naturally, the correlation is surer in the lower levels where the fossils are most abundant. Even here some variation in the faunas is evident: Triarthrus is common in both wells, but the accessory fossils mostly belong to different genera. Correlation of the upper levels is rather speculative because of the scarcity of fossils. The highest levels of Goldwyer No. 1 are provisionally correlated with Cores 1 and 2 of Thangoo No. 1 The middle sequence of Goldwyer No. 1 cannot be matched in Thangoo No. 1: this is a sequence with orthid brachiopods and the asaphid trilobite Megistaspidella.

The fauna of the Goldwyer Formation is younger than the Ordovician faunas in all other Western Australian wells, and the trilobites, apart from the ubiquitous Ampyx and Carolinites, are generically distinct from those known in outcrop. Amplexograptus, too, has not previously been recorded in northern Australia.

Breaks

(1) From the palaeogeographic standpoint, the absence of Cambrian and early Tremadocian is important. Late Upper Cambrian is known on the surface in the Cambridge Gulf area and is suspected in Samphire Marsh No. 1 below the Ordovician.* The existence of Cambrian in the Prices Creek sequence is problematical.

(2) A faunal break occurs within the Thangoo Limestone between Cores 4 and 6 of Thangoo No. 1A. The break is dated as Arenigian.

(3) No fossil evidence for a break between the Thangoo Limestone and the Goldwyer Formation has been noted. The plectambonoid brachiopods are the only larger fossils present in both lithologies and, as far as can be seen, they suggest that the sequence is

* Tomlinson, Joyce Gilbert-,1961 - Lower Palaeozoic fossils from Samphire Marsh No. 1 bore, Western Australia. Appendix D in Samphire Marsh No. 1 Well of West Australian Petroleum Pty Ltd. Bur. Min. Resour. Aust. Petrol. Search Subs. Act Publ. 5.

conformable. The fossils are, of course, very fragmentary, and the resemblance between the brachiopods in Core 3 of Thangoo No. 1 (Goldwyer Formation) and those in Core 2 of Thangoo No. 1A (Thangoo Limestone) may be coincidental. Evidence from microfossils may shed light on this problem.

(4) The problem of breaks within the Goldwyer Formation is similar. As far as can be decided from the preliminary study of a completely undescribed fauna, the Goldwyer Formation and the top of the Thangoo Limestone together represent a sequence dominated by plectambonoid brachiopods and Megistaspis - like trilobites. Included in this sequence are two strange faunas - a lower fauna with Triarthrus and an upper with Megistaspidella and orthid brachiopods. Both these trilobites are, from the Australian point of view, exotic: Triarthrus is known from Europe and North and South America, and Megistaspidella is restricted to northern Europe. The tectonic event that initiated their arrival in northern Australia need not, however, have been local, and it would be premature to postulate breaks in the Middle Ordovician sequence without confirmatory data from other sections.

## References


THOMAS, D.E., 1960 The zonal distribution of Australian graptolites. J. Roy. Soc. N.S.W. 94 (Clarke Memorial Lecture, 1959).

TOMLINSON, JOYCE GILBERT- 1960 Ordovician fossils from Goldwyer No. 1, Thangoo No. 1 and Thangoo No. 1A bores, Western Australia. Bur. Min. Resour. Aust. Rec. 1960/94 (unpub.).

Table 1. Distribution of Ordovician fossils - THANGOO NO. 1

| Cores and uncored intervals \ Fossils | linguloid brach. plectambonoid br. | Plumulites | Triarthrus Megistaspis asaphid, gen. indet. Trinucleina n. gen. | "Primitia" | Amplexograptus Didymograptus Glossograptus ? Glyptograptus ? | Thickness ( feet ) | Formation |
|---|---|---|---|---|---|---|---|
| 1. 2,852-59 | | | | | ? | 19 | Goldwyer Formation |
| 2. 2,859-71 | | | | | | | |
| Interval 2,871-3,147 | | | | | | 276 | |
| 3. 3,147-55 | | | | | | 8 | |
| Interval 3,155-3,391 | | | | | | 236 | |
| 4. 3,391-3,401 | | | | | | 10 | Thangoo Limestone |

Table 2. Distribution of Ordovician fossils -THANGOO NO. 1A

| Fossils / Cores and uncored intervals | Sponge spicules | linguloid brach. orthoid brach. plectambonoid br. | cf. Helicotoma nautiloids | Trinodus Ptychopyge? asaphid gen. indet. tril. family indet. | echinoderm ossicles | Tetragraptus Didymograptus | Thickness ( feet ) | Formation |
|---|---|---|---|---|---|---|---|---|
| 2. 3,665-72 | | | | | | | 7 | THANGOO LIMESTONE |
| Interval 3,672-3,906 | | | | | | | 234 | |
| 3. 3,906-17 | | | | | | | 11 | |
| Interval 3,917-4,138 | | | | | | | 221 | |
| 4. 4,138-52 | | | | | | | 14 | |
| Interval 4,152-4,393 | | | | | | | 241 | |
| 5. 4,393-4,403 | | | | | | | 10 | |
| Interval 4,403-4,645 | | | | | | | 242 | |
| 6. 4,645-57 | | | | | | | 12 | |
| Interval 4,657-4,898 | | | | | | | 241 | |
| 7. 4,898-4,908 | | | | | | | 10 | |
| Interval 4,908-5,038 | | | | | | | 130 | |
| 8. 5,038-48 | | | | | | | 10 | |
| Interval 5,048-5,256 | | | | | | | 256 | |
| 9. 5,256-66 | Basement | | | | | | | Basement |

## APPENDIX 3

## FORMATION TESTS

by

S.P. Willmott

Geological background to test: A sharp drilling break occurred at 3,660 feet in Thangoo No. 1A in Thangoo Limestone, with an increase of drilling rate from 11 ft/hour to 60 ft/hour. A core was cut from 3,665 to 3,672 feet to check the lithology of the soft drilling; while coring at 3,670 feet partial loss of circulation occurred. The core, re-crystallized dolomite with a pyrite vein contained a zone of vuggy porosity which probably extends some feet above the top of the core. The geological and coring programme for the well required a formation test in the uppermost zone of lost circulation encountered in the Ordovician. No signs of hydrocarbons were noted prior to the test.

Electrical logging of the zone. No electric logs were run over the tested interval prior to the test, although an electric log had been run shortly before from 3,605 to 3,240 feet.

Results of the test. Formation Test No. 1 was attempted with a hook wall packer, but owing to faulty drag springs the packer would not set. The pressure recording device (PRD) in the tail pipe recorded 1,300 p.s.i., equivalent to a column of mud standing at 700 feet.

For Formation Test No. 1A the tools in the hole consisted of 5 feet of slotted tail pipe, with a PRD and drill pipe only. The PRD was at 3,217 feet. Swabbing commenced at 1850 hours on 11th January 1960, and was continued with several breaks till 0130 hours on 14th January 1960. The average swabbing rate was about 30 bbl/hour.

942 barrels of fluid were swabbed from the hole, comprising:

| | Density |
|---|---|
| 54 barrels mud | 69 - 71 lb/c.ft. |
| 67 barrels slightly salty, muddy water | 65 lb/c.ft. |
| 81 barrels brown, salty, slightly muddy water slightly cut with $H_2S$ | 63 lb/c.ft. |
| 740 barrels green (ferrous iron) salty water, slightly cut with $H_2S$ | 62 lb/c.ft. |
| Initial fluid level was found at | 828 feet |
| Fluid level after swabbing 156 barrels | 524 feet |
| Fluid level after swabbing 423 barrels | 416 feet and remained constant. |

Eight 1-gallon samples of formation fluid were collected during the test. These are:

| Sample Number | Fluid recovery (Cumulative total) |
|---|---|
| T 1A : GS1 | 140 bbl |
| T 1A : GS2 | 207 bbl |
| T 1A : GS3 | 274 bbl |
| T 1A : GS4 | 342 bbl |
| T 1A : GS5 | 402 bbl |
| T 1A : GS6 | 501 bbl |
| T 1A : GS7 | 651 bbl |
| T 1A : GS8 | 757 bbl |

The first 202 barrels were mud and contaminated formation fluid. Samples GS3 and GS8 were submitted to the Government Chemical Laboratories, Perth, for analysis. The results are as follows :-

| | | |
|---|---|---|
| GS3 | Reaction | Faintly alkaline |
| | pH | 7.8 |
| | Total soluble salts (by evaporation) | 11,950 ppm. |
| | Sodium chloride (calculated from chloride) | 11,100 ppm. |

| | | |
|---|---|---|
| GS8 | Specific resistance at 20°C | 65.9 ohm |
| | Reaction | Neutral |
| | pH | 7.0 |

| Mineral matter | Quantity (ppm.) |
|---|---|
| Calcium, Ca | 656 |
| Magnesium, Mg | 58 |
| Sodium, Na | 3,780 |
| Potassium, K | 80 |
| Bicarbonate, $HCO_3$ | 136 |
| Carbonate, $CO_3$ | Nil |
| Sulphate, $SO_4$ | 332 |
| Chloride, Cl | 6,910 |
| Silica $SiO_2$ | 23 |
| Iron oxide $Fe_2O_3$ ) Aluminium oxide $Al_2O_3$ ) | 24 |
| Total | 11,999 |

| Assumed combination on evaporation at N.T.P. | Quantity (ppm) |
|---|---|
| Calcium carbonate $CaC0_3$ | 112 |
| Magnesium carbonate $Mg\ C0_3$ | - |
| Sodium carbonate $Na_2C0_3$ | - |
| Calcium sulphate $CaS0_4$ | 470 |
| Magnesium sulphate $MgS0_4$ | - |
| Sodium sulphate $Na_2S0_4$ | - |
| Magnesium chloride $Mg\ C1_2$ | 227 |
| Potassium chloride KC1 | 153 |
| Sodium chloride NaC1 | 9,613 |
| Calcium chloride $CaC1_2$ | 1,309 |

| Hardness calculated as calcium carbonate | Quantity (ppm.) |
|---|---|
| Total hardness | 1,877 |
| Bicarbonate (temporary) hardness | 112 |
| Non-carbonate (permanent) hardness | 1,765 |
| Calcium hardness | 1,638 |
| Magnesium hardness | 239 |

Conclusion

The zone of lost circulation contains only brackish water, cut with $H_2S$ without traces of hydrocarbons.

## APPENDIX 4

## CORES

by

S.P. Willmott

Conventional cores

| Core No. | Depth (feet) | Recovery (feet) | Formation | Lithology | Specific Gravity | Remarks |
|---|---|---|---|---|---|---|
| **Thangoo No. 1** | | | | | | |
| 1 | 2,852-2,859 | 7 | Goldwyer Formation | Shale and dolomitic shale | - | |
| 2 | 2,859-2,871 | 12 | Goldwyer Formation | Shale and dolomitic shale | | |
| 3 | 3,147-3,155 | 8 | Goldwyer Formation | Siltstone, sandy, calcareous | 2.487 | |
| 4 | 3,391-3,401 | 10 | Thangoo Limestone | Dolomite | - | |
| **Thangoo No. 1A** | | | | | | |
| 1 | 1,525-1,536 | 11 | Nura Nura Member | Siltstone | 2.07<br>2.02 (wet)<br>2.40 | ) Badly<br>) sloughed |
| 1 | 1,536-1,543 | 5 | Grant Formation | Sandstone | 2.27 (wet) | |
| 2 | 3,665-3,672 | 1 1/2 | Thangoo Limestone | (Pyritic dolomite<br>(Shale | 3.01<br>2.31 | |
| 3 | 3,906-3,917 | 6 | Thangoo Limestone | Dolomite, limestone | 2.65 | |
| 4 | 4,138-4,152 | 14 | Thangoo Limestone | (Dolomite<br>(Shale, with limestone (nodules | 2.73<br>2.63 | |
| 5 | 4,393-4,403 | 7 | Thangoo Limestone | Dolomite | - | |
| 6 | 4,645-4,657 | 12 | Thangoo Limestone | (Shale<br>(Shaly limestone | 2.61<br>2.69 | |
| 7 | 4,898-4,908 | 10 | Thangoo Limestone | Limestone | 2.69 | |
| 8 | 5,038-5,048 | 10 | Thangoo Limestone | (Sandstone<br>(Limestone<br>(Dolomite | 2.56, 2.57<br>2.63<br>2.65, 2.67 | Two pieces<br><br>Two pieces |
| 9 | 5,256-5,266 | 8 | Precambrian | Slate | 2.67, 2.78<br>2.789 | Three pieces<br>Double checked |
| 10 | 5,370-5,378 | 5 | Precambrian | (Slate with pyrite<br>(Slate | 2.81<br>2.760 | <br>Double checked |

As a check on the results, a determination was made on a piece of crystal quartz. The specific gravity was measured as 2.63, compared with the figure of 2.65 quoted in references. Considering all factors it is thought that determinations are accurate within 0.02 for specific gravities quoted to two decimal places, and within 0.003 for figures quoted to three decimal places.

Sidewall cores

Sidewall cores were recovered from the following depths in Thangoo No. 1. All are from the Grant Formation.

1,500', 1,501', 1,502', 1,503', 1,504', 1,505', 1,506', 1,507', 1,508', 1,509',

1,510', 1,511', 1,512', 1,513', 1,514', 1,515', 1,516', 1,517', 1,518', 1,519',

1,520', 1,521', 1,686', 1,872', 2,140', 2,173', 2,180', 2,186', 2,200'.

## APPENDIX 5

### LIST OF SCHLUMBERGER LOGS RUN

Thangoo No. 1

Electrical Log

| | | |
|---|---|---|
| ESS-1 | 1,480' - 50' | 12th November 1959 |
| ESS-2 | 2,865' - 1,480' | 20th November 1959 |
| ESS-3 | 3,015' - 2,700' | 22nd November 1959 |

Gamma Ray-Neutron Log

| | | |
|---|---|---|
| GR-1 | 1,473' - 50' | 12th November 1959 |
| GRN-2 | 2,865' - 1,480' | 21st November 1959 |

Section Gauge

| | | |
|---|---|---|
| SG-1 | 1,480' - 50' | 12th November 1959 |
| SG-2 | 2,862' - 1,480' | 21st November 1959 |

Microlog

| | | |
|---|---|---|
| ML-1 | 3,012' - 2,450' | 22nd November 1959 |

Temperature Log

| | | |
|---|---|---|
| Run 1 | 150' - 1,430' | 13th November 1959 |

Thangoo No. 1A

Electrical Log

| | | |
|---|---|---|
| ES-1 | 3,280' - 87' | 3rd January 1960 |
| ES-2 | 3,603' - 3,240' | 9th January 1960 |
| ES-3 | 4,030' - 3,200' | 19th January 1960 |
| ES-4 | 5,430' - 3,930' | 16th February 1960 |

Gamma Ray-Neutron Log

| | | |
|---|---|---|
| GRN-1 | 3,280' - 55' | 3rd January 1960 |
| GRN-2 | 5,430' - 3,180' | 16th February 1960 |

Microlog

| | | |
|---|---|---|
| ML-1 | 3,280' - 3,000' | 3rd January 1960 |

Section Gauge

| | | |
|---|---|---|
| SG-1 | 3,280' - 87' | 3rd January 1960 |
| SG-2 | 3,345' - 3,115' | 8th January 1960 |
| SG-3 | 4,027' - 3,200' | 19th January 1960 |
| SG-4 | 5,430' - 3,200' | 16th February 1960 |

Temperature Log

| | | |
|---|---|---|
| Run 1 | 120' - 3,233' | 5th January 1960 |

## APPENDIX 6

## EASTMAN DEVIATION RECORDS

| Thangoo No. 1 | | Thangoo No. 1A | |
|---|---|---|---|
| Depth (feet) | Deviation (degrees) | Depth (feet) | Deviation (degrees) |
| 200 | 1 | 200 | 0 |
| 300 | 1 | 300 | 1/4 |
| 400 | 1/2 | 400 | 1/4 |
| 500 | 1/2 | 500 | 0 |
| 700 | 3/4 | 600 | 1/2 |
| 800 | 1/4 | 700 | 1/2 |
| 900 | 1/4 | 1,000 | 0 |
| 1,000 | 1/4 | 1,100 | 0 |
| 1,100 | 1/4 | 1,200 | 1/4 |
| 1,200 | 1/2 | 1,300 | 1/2 |
| 1,300 | 3/4 | 1,390 | 1/2 |
| 1,400 | 1 1/2 | 1,525 | 1/2 |
| 1,480 | 1 | 1,620 | 1/4 |
| 1,730 | 1/2 | 1,710 | 1/4 |
| 1,980 | 1/4 | 1,800 | 1/4 |
| 2,270 | 1 | 1,900 | 1/2 |
| 2,370 | 1 | 2,000 | 1/2 |
| 2,520 | 1 | 2,240 | 0 |
| 2,650 | 1 | 2,310 | 1/4 |
| 2,820 | 1 | 2,440 | 1/2 |
| 3,000 | 1 | 2,550 | 3/4 |
| 3,145 | 2 3/4 | 2,670 | 1/2 |
| 3,240 | 3 | 2,750 | 1/2 |
| 3,300 | 2 1/2 | 2,870 | 1/2 |
| | | 3,004 | 1/2 |
| | | 3,165 | 1/2 |
| | | 3,565 | 2 1/4 |
| | | 3,900 | 1 3/4 |
| | | 4,393 | 2 |
| | | 4,750 | 2 1/2 |
| | | 4,830 | 2 3/4 |
| | | 5,256 | 3 |
| | | 5,429 | 3 |

## APPENDIX 7

## NEW AND AMENDED FORMATION NAMES*

By R.M.L. Elliott, West Australian Petroleum Pty Ltd

### Goldwyer Formation (New name)

Definition:

The Goldwyer Formation is proposed as the name for the sequence of Ordovician shale, limestone, dolomite, and siltstone which underlies the Permian Grant Formation and overlies the Thangoo Limestone. It was seen in Goldwyer No. 1 and Thangoo Nos. 1 and 1A Wells in the Canning Basin, south-east of Broome. The formation was first described in Goldwyer No. 1 Well, from which it takes its name, but the type section is located in the Thangoo No. 1A Well, which is at 18° 21' 52" S., and 122° 53' 09" E. Goldwyer No. 1 Well was named from Goldwyer Water Well (18° 18' 00" S., 122° 11' 25" E.).

The following is a description of the type section from 2,782 to 3,477 feet in Thangoo No. 1A:

Grant Formation. Unconformably overlying -

| Goldwyer Formation (695') | | Thickness feet |
|---|---|---|
| 2,782-3,125' | Shale, greenish grey, with grey and brown-grey beds, micaceous, poorly laminated, with trilobites, graptolites, some brachiopods and ostracods; in the upper part fragments of crinoids are very common; interbedded with thin beds of dolomite, grey, brown-grey and brown, finely crystalline, with saccharoidal texture; a few calcite veins show slight yellow fluorescence and occasional brown oil staining. Some beds of siltstone, dark grey-brown, micaceous, near base of unit. | 343 |
| 3,125-3,175' | Limestone, white, light grey and cream, finely crystalline, fossiliferous. | 50 |
| 3,175-3,250' | Dolomite, medium to dark brown, finely crystalline, with saccharoidal texture; lower part contains abundant veins of white, coarsely crystalline dolomite with vugs filled with live brown oil and dark brown to black viscous oil residue. | 75 |
| 3,250-3,477' | Siltstone, dark grey-brown, micaceous, with veins of white dolomite as above, showing some brown oil staining; with some thin beds of limestone, dark brown, finely crystalline, silty. | 227 |
| | Disconformably overlies the Thangoo Limestone | |

* Names approved by the Western Australian Committee on Stratigraphic Nomenclature.

Lithology:

The Goldwyer Formation is a sequence of shale, limestone, dolomite and siltstone. The upper shale unit is constant in lithology; micaceous grey shale, poorly laminated, fossiliferous, with thin beds of grey and brown dolomite and grey siltstone. The carbonate lithologies were probably all originally white and light grey fossiliferous limestone, which has been partly altered to brown dolomite. The distribution of the limestone and dolomite is not constant, owing to the erratic nature of the dolomitization process. The lower siltstone unit consists of grey micaceous siltstone with some thin beds of brown limestone. In the Goldwyer No. 1 Well this lower siltstone unit is finer grained and is represented by shale with thin beds of limestone. Oil staining and oil in vugs and calcite veins are common throughout the various lithologies.

Stratigraphic relationships:

The Goldwyer Formation is overlain unconformably by the Permian Grant Formation. Evidence for this unconformity is the great difference in age between the formations, and seismic reflections which show an angular unconformity between the two formations. The Goldwyer Formation probably disconformably overlies the Thangoo Limestone on the evidence of the thinning by 58 feet of the basal siltstone unit of the Goldwyer Formation between Thangoo No. 1 and Thangoo No. 1A, and by 308 feet between Goldwyer No. 1 and Thangoo No. 1A.*

As this formation is known only from the subsurface the nature of its contacts must be taken from seismic and well data.

Distribution and thickness:

The Goldwyer Formation is known only from the subsurface in Goldwyer No. 1, and Thangoo Nos. 1 and 1A, and for an unknown distance about these wells. Measured thicknesses from these wells are:

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* The Bureau of Mineral Resources comments that the evidence of the thinning of the basal siltstone unit between Thangoo No. 1 and Thangoo No. 1A does not seem to be significant. The lithologies of the formation in the two wells are:

| Thangoo No. 1 | | Thangoo No. 1 A |
|---|---|---|
| 117 feet | Shale, with thin dolomite beds | 343 feet |
| 91 feet | Dolomite, some shale | Nil |
| 85 feet | Limestone | 50 feet |
| Nil | Dolomite | 75 feet |
| 285 feet | Siltstone, with thin beds and lenses of limestone | 227 feet |

Information on the thickness of units in Goldwyer No. 1 is not available.

Even if the dolomite is regarded as altered limestone, these variations are suggestive more of facies changes than thinning at a basal disconformity. The main stratigraphic purpose of these wells, and the reason why subsidy was granted for the drilling, was to test for such suspected facies changes in the Ordovician section, with a view to locating interfingering of reservoirs and source beds.

The existence of the disconformity is also doubted on palaeontological grounds by Joyce Gilbert-Tomlinson (Appendix 2).

| Well | Thickness |
|---|---|
| Goldwyer No. 1 | 752' |
| Thangoo No. 1 | 578' |
| Thangoo No. 1A | 695' |

The maximum thickness of the formation could be well in excess of 752 feet as the upper surface was extensively eroded before the Grant Formation was laid down.

Fossils and age:

The Goldwyer Formation is fossiliferous with graptolites, trilobites, ostracods, nautiloids, chitinozoans and brachiopods. The age of this formation based on determinations from Thangoo No. 1 is Middle Ordovician (Llanvirnian and possibly Llandeilian).

These determinations are discussed in Appendix 2 by P.R. Evans and J. Gilbert-Tomlinson. Determinations of fossils from this formation in Goldwyer No. 1 give an age of Middle to Lower Ordovician.

Environment of deposition:

The Goldwyer Formation is a sedimentary marine unit comprising fine-grained clastics with beds of limestone. In part the limestone has been altered to dolomite. These sediments were probably laid down under shallow-water marine conditions.

Repository of cores and electric logs:

The bulk of the cores and cuttings are stored in West Australian Petroleum Pty Limited's corehouse at Norma Road, Melville, W.A.; representative cuts of cores and samples are stored in Canberra by the Bureau of Mineral Resources. The originals of all electric logs are filed at the offices of West Australian Petroleum Pty Limited, 251 Adelaide Terrace, Perth, W.A.; copies are held by the Bureau of Mineral Resources in Canberra.

### Thangoo Limestone.* (McWhae et al., 1958: amended herein)

Definition:

The Thangoo Limestone was first referred to by McWhae et al. (1958) as the Roebuck Dolomite and the Thangoo Calcarenite. The section seen in Goldwyer No. 1 showed random distribution of the dolomite and suggested that these two formations should actually be one. It is therefore proposed to drop the names Roebuck Dolomite and Thangoo Calcarenite and use the name Thangoo Limestone for the sequence of limestone and dolomite encountered in Roebuck Bay No. 1, Goldwyer No. 1, Thangoo No. 1 and Thangoo No. 1A. The formation underlies the Goldwyer Formation and overlies Precambrian basement. The new type section of the Thangoo Limestone is in the Thangoo No. 1A well (18° 21' 52" S, 122° 53' 09" E) between 3,477 and 5,100 feet. The well is located 15 miles east from the most eastern boundary of Thangoo Station from which it takes its name. The original type locality of McWhae et al. was in Roebuck Bay No. 1 on Thangoo Station. This amended type section has been chosen because

* The general lithological term limestone has been used to cover various recrystallized sandy limestones in which no clear relict texture can be seen.

of greater thickness and greater detail available from this well. The following is a description of the section in Thangoo No. 1A:

Goldwyer Formation. Disconformably overlying —

| Thangoo Limestone (1,623') | | Thickness feet |
|---|---|---|
| 3,477-3,700' | Dolomite, light grey to cream, finely crystalline, saccharoidal texture, sandy and silty, stylolitic near base, with finely disseminated pyrite, some vugs and veins containing white, coarsely crystalline dolomite, minor brecciated shale from 3,665-75', in places showing fluorescence and oil staining. | 223 |
| 3,700-3,750' | Dolomite, as above, but saccharoidal texture absent; minor dark brown-grey siltstone. | 50 |
| 3,750-3,840' | Dolomite, grey, silty and sandy with saccharoidal texture; interbedded with limestone, recrystallized, white to light grey, dense, hard. | 90 |
| 3,840-3,915' | Dolomite, light grey, silty and sandy as above, with partings of green-grey dolomitic shale and brown-grey siltstone. | 75 |
| 3,915-4,255' | Limestone, recrystallized, light grey, dense, hard, partly dolomitic, stylolitic, silty and sandy, slightly fossiliferous (brachiopods?). In places some beds contain up to 50% very fine, angular quartz sand grains. Below 4,140' the limestone in places grades into dolomite, saccharoidal, finely pyritic, and occurs as irregular nodular lumps in a matrix of dark grey siltstone. | 340 |
| 4,255-4,605' | Dolomite, yellow-brown, finely crystalline, saccharoidal texture in parts, stylolitic, with lenses of black siltstone, a few scattered vugs, vertical fractures filled with coarse white dolomite, upper part interbedded with recrystallized limestone, brownish-cream, dolomitized with occasional fossil fragments. | 350 |
| 4,605-4,793' | Limestone, brownish white to greenish white, very finely recrystallized, often dolomitized, | 188 |

| Thangoo Limestone (Cont.) | | Thickness feet |
|---|---|---|
| | non-porous, some glauconite grains, stylolites containing greenish clay, fragments of trilobites and graptolites; occurs as lenses and nodules from 1/2" to 9" thick in a matrix of black, calcareous siltstone. Both lithologies cut by veins of white dolomite. Below 4,740' some limestone, white, fossiliferous. | |
| 4,793-4,840' | Dolomite, very finely saccharoidal, slightly porous; with lenses of siltstone, black, coarse; brachiopods and trilobites. | 47 |
| 4,840-4,920' | Dolomite, brown, saccharoidal, glauconitic, with cream limestone patches; and thin beds of siltstone, very fine, black; veins of white dolomite cutting both lithologies. | 80 |
| 4,920-5,100' | Sandstone, pale grey, fine to medium-grained, silicified, wih some dolomitic cement, very hard, porosity very low, slight oil staining and fluorescence in the upper part; at top and bottom interbedded with dolomite, sandy, as above in 4,840-4,920', and some limestone, recrystallized, dolomitized, pale brown-grey, with siliceous sponge spicules. Described partly from thin sections examined by Elliott (Appendix 1). | 180 |

Unconformably overlies Precambrian biotite phyllite.

Lithology:

The Thangoo Limestone consists of interbedded limestone and dolomite with some siltstone beds, and a sandstone unit at the base of the formation. The limestone is recrystallized, silty and sandy, various colours such as light grey, white, greenish white and pale brown are present, with light grey predominant; it is finely crystalline, non-porous, poorly fossiliferous. The dolomite is silty and sandy, predominantly light grey to grey in colour with some cream and brown present, and has saccharoidal texture. Limestone, white and light grey, finely crystalline, and dolomite, grey to brown, saccharoidal, very often appear as contorted lenses and nodules in a matrix of siltstone, dark grey to black. The Thangoo Limestone is traversed by veins of dolomite, white, coarsely crystalline, pyritic. Some oil staining and fluorescence were present in the dolomite veins and the top of the basal sandstone unit.

The general lithological term limestone has been used to describe this carbonate sequence, which is predominantly dolomites and limestones of various types.

Stratigraphic relationships:

The Thangoo Limestone probably disconformably underlies the Goldwyer Formation and unconformably overlies the Precambrian basement. The probable disconformity at the top of formation is discussed in the definition of the Goldwyer Formation. As this formation is only known from the subsurface the nature of its contacts must be taken from well data. Owing to the present lack of penetration of seismograph reflection into the Ordovician along the northern edge of the South Canning Basin, the seismic cross-sections give no idea of the relationships of the Thangoo Limestone to other formations. The difference in age between the Thangoo Limestone and the Precambrian basement and the much steeper dips in the Precambrian indicate that an unconformity exists between the Thangoo Limestone and the Precambrian.

Distribution and thickness:

The Thangoo Limestone is known only from the subsurface in Roebuck Bay No. 1, Goldwyer No. 1, Dampier Downs No. 1, and Thangoo Nos. 1 and 1A, and for an unknown distance about these wells. The following measured thicknesses are known from these wells:

| Well | Top eroded | Base reached | Thickness |
|---|---|---|---|
| Roebuck Bay No. 1 | Yes | No | 646' |
| Goldwyer No. 1 | Probably | Yes | 1,125' |
| Thangoo No. 1 | Probably | No | 100' |
| Thangoo No. 1A | Probably | Yes | 1,623' |
| Dampier Downs No. 1 | Yes | No | 403' |

A complete section of the Thangoo Limestone is probably not present in any of the five wells, so that the maximum thickness of the formation is not known.

Fossils and age:

The Thangoo Limestone has a poorly preserved fossil fauna which consists of graptolites, trilobites, brachiopods, gastropods, chitinozoans, nautiloids, siliceous sponge spicules and echinoderm ossicles. The age of this formation based on determinations from Thangoo No. 1A is Lower Ordovician (Arenigian). These determinations are discussed in Appendix 2 by P.R. Evans and J. Gilbert-Tomlinson. Fossil determinations from this formation in Goldwyer No. 1 give an age of Lower Ordovician.

Environment of Deposition:

The Thangoo Limestone is a marine sedimentary unit. The lithology is dominantly silty limestone and silty dolomite, with some beds of siltstone and sandstone. The dolomite has replaced the original limestone. These sediments were probably laid down in shallow water in a neritic environment.

Repository of cores and electric logs:

The bulk of the cores are stored in West Australian Petroleum Pty Limited's corehouse at Norma Road, Melville, W.A., and representative cuts of cores and samples are

stored in Canberra by the Bureau of Mineral Resources. Originals of all electric logs are filed at the office of West Australian Petroleum Pty Limited, 251 Adelaide Terrace, Perth, W.A. and copies are held by the Bureau of Mineral Resources in Canberra.

Reference

McWHAE, J.R.H., PLAYFORD, P.E., LINDNER, A.W., GLENISTER, B.F., BALME, B.E., 1958 - The stratigraphy of Western Australia. J. geol. Soc. Aust., 4 (2), 1956.

Plate 1

COMPANY: WEST AUSTRALIAN PETROLEUM PTY. LTD.
COMPOSITE WELL LOG
WELL NUMBER / REGION: THANGOO No.1 — CANNING BASIN
COUNTRY: WESTERN AUSTRALIA

LOCATION:
LATITUDE 18° 22' 06"S.
LONGITUDE 122° 53' 22"E.
COORDINATES:
YARDS EAST : 618,400
YARDS NORTH: 2,692,850
ELEVATION:
DERRICK FLOOR 566 FT.
GROUND 557 FT.
TOTAL DEPTH:
FROM DERRICK FLOOR 3475'
PLUG BACK DEPTH
FROM DERRICK FLOOR 1432'
DATE SPUDDED 7 NOV. 1959
DATE COMPLETED 11 DEC. 1959
LITHOLOGY BY V. PUDOVSKIS., M.H. JOHNSTONE., S.P. WILLMOTT.
COMPILED BY S.P. WILLMOTT

ELECTRIC LOG DATA

| RUN NUMBER | 1 | 2 | 3 |
|---|---|---|---|
| DATE | 12 NOV. 1959 | 20 NOV. 1959 | 22 NOV. 1959 |
| INTERVAL RECORDED | 1480'- 50' | 2865'-1480' | 3015'- 2700' |
| MUD NATURE | TREATED | TREATED | TREATED |
| MUD RESISTIVITY | 1·3 at 105°F | 1·3 at 85°F | 0·9 at 100°F |
| MUD RESISTIVITY B.H.T. | 1·25 at 110°F | 0·9 at 120°F | 0·75 at 120°F |
| MUD WEIGHT | 73 | 79 | 77 |
| MUD VISCOSITY | 49 | 50 | 48 |
| MUD WATER LOSS | 3·2 | 5·0 | 6·5 |
| MUD pH | 9·5 | 11·0 | 11·0 |

OTHER LOG COVERAGE: GR-1. 1473'-50', SG-1. 1480'-50', ML-1. 3015'-2480', GPN-2. 2865'-1480', SG-2. 2862'-1480'. TEMP. LOG 1510'-1430'.
SAMPLES TAKEN: 30 ATTEMPTED.
29 SAMPLES RECOVERED 1500'-2200'.

CONGLOMERATE; TILLITE; SANDSTONE; SILTSTONE; CLAYSTONE; SHALE; CALCARENITE
LIMESTONE; DOLOMITE; LATERITIC; CARBONACEOUS MATTER; GRANITE PEBBLES
U UNCONFORMABLE CONTACT; CONFORMABLE CONTACT; D DISCONFORMABLE CONTACT; OIL SHOW; ARKOSIC; CALCAREOUS; FOSSILS (INVERT, PLANT)
MICACEOUS; GLAUCONITIC; PYRITIC; COPE (Recovery black) SPECIFIC GRAVITY; SIDE WALL CORE; NUMBER OF PERFORATIONS; CASING SHOE

SPONTANEOUS POTENTIAL 100 Millivolts (− to +) mv
RESISTIVITY 20 ohms m²/m — 16" Short Normal; 64" Long Normal
RESISTIVITY 20 ohms m²/m — 18'8" Lateral
Cores & Spec. Gravity; LITHOLOGY; DEPTH; LITHOLOGIC DESCRIPTION

58' OF 16" CASING SET AT 52'
ES RUN 1.

9'- 39' SURFACE SAND (RECENT)

39'- 224'
**BROOME SANDSTONE**
(LOWER CRETACEOUS)
SANDSTONE: fine to coarse grained, poorly sorted, kaolinitic cement, some mica, colored white, yellow and brown. clay matrix in part.
Passes into fine conglomerate with sandstone matrix towards base.

224'- 549'
**JARLEMAI SILTSTONE**
(UPPER JURASSIC)
224'-305' SANDSTONE: fine grained, with some medium grained beds and very fine beds; dark red-brown, yellow, purple; poorly sorted, silty and clayey grading to sandy claystone in part.
305'-360' Interbedded SANDSTONE grey, yellow, purple; fine to very fine grained with some beds grading to fine conglomerate with clayey ferruginous matrix and SILTSTONE: dark red-brown, ferruginous, very fine, in parts slightly sandy, clayey, grading to CLAYSTONE; micaceous, poorly bedded.
360'-389' As for 305'-360' Unweathered, grey pyritic.
389'-549' SILTSTONE, very friable, sandy, with rounded coarse sand grains. glauconitic with lenses of silty, glauconitic, fine to medium grained SANDSTONE, fabular nodules of pyrite, common throughout. Glauconite decreases downwards, some carbonaceous fragments at 460'-470'. Below 480' little or no glauconite, abundant pyrite; SILTSTONE becomes firm, siliceous and contains abundant very fine sand grains in part.

549'- 814'
**ALEXANDER FORMATION**
(UPPER JURASSIC)
549'-683' Interbedded SANDSTONE: medium to coarse grained, with subrounded to rounded grains, some pebbles, brown fossiliferous limestone and brown ferruginous fossiliferous sandstone, grades to very coarse in part, with SILTSTONE; grey, firm, pyritic, glauconitic in part, with abundant very fine sand in parts. Sandstone becomes fairly clean from 657'-683'.
Carbonized plant remains at 640'-650'
683'-814' SANDSTONE: medium to coarse grained, well rounded, silty, with dark green glauconitic grains and fragments of belemnites, some pyrite, lenses of brown lignite.
Interbedded with SILTSTONE: medium to light grey, very sandy (fine) passing into SILTSTONE, light brown, grey, calcareous, sandy in parts, slightly pyritic, with some belemnites, pelecypods and pyritized wood fragments.

814'-1380'
**WALLAL SANDSTONE**
(MIDDLE TO UPPER JURASSIC)
SANDSTONE: medium to very coarse grained, with some conglomeratic beds (pebbles up to 6mm). Blue quartz common. Generally silty and clayey, with some clean sandstone beds. With beds and lenses of SILTSTONE; light brownish grey, very sandy with fine to very fine sand grains; grading to very silty fine SANDSTONE.
Several beds of SILTSTONE between 916' and 1007'

80 Perforations

1466' of 10¾" x 40·5 16/ft. casing set at 1481'

Plug Top at 1482'

ES RUN 2.

1380'- 1450'
**POOLE SANDSTONE**
(ARTINSKIAN)
SILTSTONE: light grey and grey-brown with very fine pyrite crystals.
Interbedded with SANDSTONE: medium to coarse grained, well sorted.

1450'- 1494'
**NURA NURA MEMBER**
(ARTINSKIAN)
CALCARENITE: cream and brown-grey, richly fossiliferous - bryozoa, echinoids, crinoids, and brachiopods.

1494'- 2797'
**GRANT FORMATION**
1494'-2597' (SAKMARIAN)
SANDSTONE: fine to very coarse to conglomeratic, feldspathic, with abundant pebbles of granite and quartzite, predominantly porous, with some non-porous fontainebleau sandstone beds; oil staining in the upper part interbedded with some SILTSTONE; medium grey, grading into claystone, SILTSTONE: light grey to white, fine to coarse, grading into very fine sandstone, and SILTSTONE (Tillite): dark grey, sandy, silt and clay ground mass with scattered pebbles of granite and quartzite. Member contains few thin pyritic sandstone lenses with traces of oil in interstices.

SWC 1-22; SWC 23; SWC 24; SWC 25; SWC 26-28; SWC 29

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THANGOO No.1

ES RUN 3

Lower part 40°-50° Slickensides

No visible dip

NO LOG RUN BELOW THIS DEPTH

T.D. 3475'
NO FORMATION TESTS CONDUCTED

2597'- 2797' (SAKMARIAN)
TILLITE: dark grey with pebbles, and boulders of granite, quartzite, jasper, oolitic limestone etc. upper part with silt and clay ground-mass, but in the lower part very sandy, grading into SANDSTONE.
Fontainebleau sandstone

2797'- 3375'
**GOLDWYER FORMATION**
(LOWER TO MIDDLE ORDOVICIAN)
2797'- 2914' SHALE: medium to dark grey, pyritic with trilobites and graptolites. Some beds dolomitized to argillaceous DOLOMITE.
2914'- 3005' DOLOMITE: light grey, fine grained, crystalline, firm to hard, low porosity and permeability; with beds of SHALE as above, in upper part, and thin beds and partings of SILTSTONE: brown grey, very finely micaceous.
3005'- 3090' LIMESTONE: white to light grey, very fine crystalline, hard, partly dolomitized in upper part; some pyrite, non-porous non-permeable, interbedded in lower part with SILTSTONE: dark brown-grey, micaceous, calcareous, thin bedded, grading to poorly laminated SHALE.
3090'- 3375' Passes gradually into SILTSTONE: as above, richly fossiliferous with graptolites, trilobites, nautiloids, and with minor lenses of dark brown, silty, LIMESTONE. Vertical calcite veins, Petroliferous odour. Very low gas reading on JW (3).

3375'- 3475'
**THANGOO LIMESTONE**
(LOWER ORDOVICIAN)
DOLOMITE: white to grey-brown, fine to very fine grained, crystalline, sugary texture, dolomite crystals in calcitic cement, up to 40% very fine quartz; few sponge spicules and pelecypods; H₂S odour on broken core. Veins and vugs of calcite and coarse dolomite.

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ENCLOSURE No. 5
FILE NUMBER B - 2559

WEST AUSTRALIAN PETROLEUM PTY. LTD.
**DRILLING TIME AND GAS LOG**
**THANGOO No. 1**
KIMBERLEY DISTRICT
WESTERN AUSTRALIA

NEW BIT
CORE BIT

BIT TYPE AND REMARKS; DRILLING RATE (Feet per hour) 90 60 30 0; LITHOLOGY AND DEPTH Shale, Siltstone, Sandstone, Limestone, % Cuttings; MUD GAS DETECTION (Arbitrary Units) 1 2 3 Live Oil 0 50 100

1. 20"
2. 13⅜" OSC
3. OSC.
4. 9⅝" OSC3
5. OSC3
6. OSC3
7. MH3C
8. MH3C
9. MH3C
10. HFCH
11. HFCH
12. OSC3
13. MH3C
14. HFCH
15. OSC3
16. SSSJ
17. HFCH
18. SSSJ

mostly cement; Shales

SCALE CHANGE 30 20 10

10¾" CASING SHOE AT 1481'

TOTAL (DRILLED) DEPTH: 3475'

COMPANY. WEST AUSTRALIAN PETROLEUM PTY. LTD.

COMPOSITE WELL LOG

WELL NUMBER. **THANGOO No.1A**

REGION CANNING BASIN

COUNTRY WESTERN AUSTRALIA

LOCATION:
LATITUDE : 18° 21′ 52″S.
LONGITUDE: 122° 53′ 09″E.
CO-ORDINATES:
YARDS EAST: 618,000
YARDS NORTH. 2,693,350
ELEVATION DERRICK FLOOR FT. 568
ELEVATION GROUND FT. 559
TOTAL DEPTH FROM DERRICK FLOOR FT. 5429
PLUG BACK FROM DERRICK FLOOR FT. 3200
DATE SPUDDED 19 DEC. 1959
DATE COMPLETED 17 FEB. 1960
LITHOLOGY BY V. PUDOVSKIS, M.H.JOHNSTONE, S.P.WILLMOTT, R.M.L.ELLIOTT.

ELECTRIC LOG DATA

| RUN NUMBER | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| DATE | 3 Jan. 1960 | 9 Jan. 1960 | 19 Jan 1960 | 16 Feb 1960 |
| INTERVAL RECORDED | 3280-87 | 3603-3240 | 4030-3200 | 5430-3930 |
| MUD NATURE | TREATED | TREATED | TREATED | TPEATED |
| MUD RESISTIVITY | 1·2 at 87°F | 1·2 at 97°F | 2·9 at 85°F | 3·4 at 90°F |
| MUD RESISTIVITY B.H.T. | 0·85 at 124° | 1·1 at 137°F | 1·6 at 138°F | 2·0 at 150°F |
| MUD-WEIGHT | 79 | 72 | 70 | 71 |
| MUD-VISCOSITY | 52 | 58 | 45 | 53 |
| MUD-WATER LOSS | 6 | 7·5 | 9 | 6·8 |
| MUD pH | 12 | 12 | 11·5 | 11·5 |

OTHER LOG COVERAGE: GRN-1: 3280′– 55′ · GRN-2:5430-3180′ ML-1: 3280′-3000′ SG-1:3280′– 87′ SG-2:3345′-3115′ SG-3:4027-3200′ SG-4: 5430-3200′. TEMP. LOG: 120′ - 3233′

CONGLOMERATE · BRECCIA · TILLITE · SANDSTONE · SILTSTONE · CLAYSTONE · SHALE · CALCARENITE
CALCILUTITE · LIMESTONE · DOLOMITE · COAL · CARBONACEOUS MATTER · METASEDIMENTS · GRANITIC · GRANITE BOULDERS
CALCITE VEIN · U UNCONFORMABLE CONTACT · CONFORMABLE CONTACT · D DISCONFORMABLE CONTACT · OIL SHOW · GAS SHOW · ARKOSIC · CALCAREOUS · FOSSILIFEROUS
VVV GLAUCONITIC · MICACEOUS · OOLITIC · PYRITIC · CORE (Recovery black) · SPECIFIC GRAVITY · SIDE WALL CORE · PERFORATED INTERVAL · CASING SHOE

SPONTANEOUS POTENTIAL 100 Millivolts (−k → +10 mv) · RESISTIVITY 20 ohms m²/m (16″ Short Normal 20; 64 Long Normal 20) · RESISTIVITY 20 ohms m²/m (18′8″ Lateral 20) · DEVIATION · CASING & PLUGS · DIPS via Schlumberger (s) (A) · DEPTH · Cores & Spec. Grav. · LITHOLOGY

16″ CASING SET AT 85′

LITHOLOGIC DESCRIPTION

9′ – 39′ SURFACE SAND (RECENT)

39′ – 235′
BROOME SANDSTONE
(LOWER CRETACEOUS)
Sandstone: white, yellow and brown, poorly sorted, clay matrix in part.

235′ – 566′
JARLEMAI SILTSTONE
(UPPER JURASSIC)
Sandstone: silty at top of formation; then Siltstone; sandy, with lenses of Sandstone, pyritic.

566′ – 827′
ALEXANDER FORMATION
(UPPER JURASSIC)
Sandstone; coarse to very coarse, friable, with pebbles of quartz up to 8 m.m., glauconitic, fragments of belemnites, pyritic; some beds of Siltstone, light brown and grey, sandy. Some pyritized wood in lower part of unit.

827′ – 1405′
WALLAL SANDSTONE
(MIDDLE TO UPPER JURASSIC)
Sandstone; coarse to very coarse, with beds grading into conglomerate, moderately to well sorted, subangular to well rounded, with beds of Siltstone; light brown, hard, sandy; with lenses of black coal in the middle part.

1405 – 1482′ POOLE SANDSTONE
(ARTINSKIAN)
Sandstone: coarse, interbedded with Siltstone, carbonaceous in part, conglomeratic at base.

1482 – 1536′ NUPA NUPA MEMBER
(ARTINSKIAN)
Calcarenite with some Sandstone and Siltstone

1536′ – 2782′
GRANT FORMATION
(SAKMARIAN)
Sandstone: coarse grained, conglomeratic, felspathic, with pebbles and boulders of granite, quartzite, mostly porous, with some non-porous fontainebleau sandstone beds; some fine grained beds; lower part interbedded with Siltstone: medium to dark grey, sandy (Hilitic) and light grey, siliceous, friable.

PLUG AT 3200′ · GAP IN CASING · E.S. RUN 3. · 10¾″ CASING C SHOE AT 3287′ · DST. No 1 · E.S. RUN 4. · SCALE CHANGE

2782′ – 3477′
GOLDWYER FORMATION
(LOWER TO MIDDLE ORDOVICIAN)
The formation consists of a sequence of Shale, Limestone, Dolomite and Siltstone.
2782′ – 3125′ Shale: grey, micaceous, fossiliferous, some thin beds of Dolomite, some oil staining.
3125′ – 3250′ Interbedded Limestone: light grey, fossiliferous; and Dolomite, dark brown, basal 10′ with veins of vuggy dolomite containing live brown oil, and viscous oil residue.
3250′ – 3477′ Siltstone: grey brown, micaceous, with some thin beds of Dolomite. Slight traces of oil in Dolomite veins.

3477′ – 5100′
THANGOO LIMESTONE
(LOWER ORDOVICIAN)
Interbedded Limestones, sandy and silty; Dolomites, sandy and silty. Some beds of Siltstone. A basal unit of interbedded Sandstone and Dolomite; sandy.

5100′ – 5429′
PRECAMBRIAN
Biotite Phyllite; dark grey to black, thinly laminated, pyritic, graphitic, with abundant porphyroblastic red-brown biotite, traversed by quartz-carbonate veinlets bearing slight sulphide mineralization.

FORMATION TESTS

FORMATION TEST No.1: 3672′ – 3287′ ATTEMPTED TO SET A HOOKWALL PACKER. SLIPS FAILED AND THE TEST WAS UNSUCCESSFUL.

FORMATION TEST No.1A: 3672′ – 3287′ TOOLS IN THE HOLE CONSISTED OF:- DRILL PIPE, 5″ SLOTTED TAIL PIPE AND PRD. THE ZONE WAS SWABBED FOR ABOUT 30 HOURS.

RECOVERY: 54 BBLS. MUD WEIGHT 69/71 LBS/CU. FT., 67 BBLS. SLIGHTLY SALTY MUDDY WATER WEIGHT 65 LBS./CU. FT., 81 BBLS. BROWN SALTY SULPHUROUS WATER. 740 BBLS. SALINE WATER. (11,999 P.P.M. TOTAL SALTS.)

**Plate 2**

WEST AUSTRALIAN PETROLEUM PTY. LTD.

# DRILLING TIME AND GAS LOG

## THANGOO No. 1A

KIMBERLEY DISTRICT
WESTERN AUSTRALIA

NEW BIT
CORE BIT

BIT TYPE AND REMARKS · DRILLING RATE (Feet per hour) 90 60 30 0 · LITHOLOGY AND DEPTH Shale, Siltstone, Sandstone, Limestone, % Cuttings · MUD GAS DETECTION (Arbitary Units) 1 2 3 Live Oil 0 50 100

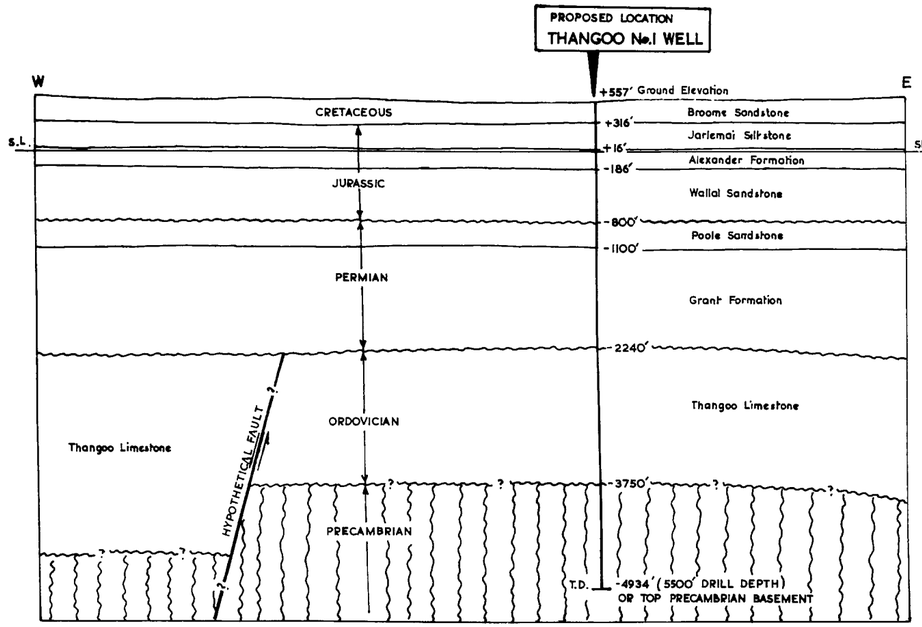
1. 16″ CASING AT 85′
2. 13¾″ OSC-3
NO SAMPLES TO 400′
NO DATA
3. OSC-3
4. 9⅝″ SSS-J
5. SP CH
6. 13¾″ OSC
7. OSC
8. OWS
9. OWS
10. OWS
11. 9⅞″ MD GRANGE
12. W7R
13. OSC.
14. 9⅞″ EDECO
16. SSS-J
17. OWS-J
18. OWS
19. HFCH
20. OWS
21. HFCH
22. OWS
23. W7R
24. HFCH
25. SSS-J
26. SSS-J
27. HFCH
28. OWS
29 OWS
30. HFCH
31. MD
32. MD
33. MD
34. HFCH
35 MD
36 W7R
37. MD
38. W7R
39. W7R
40. HFCH
41 W7R
42 MH3C
43 TT
44. HFCH
45 MD
46. MD
47 HFCH
48 TT

BIT TYPE AND REMARKS · DRILLING RATE (Feet per hour) 90 60 30 0 · LITHOLOGY AND DEPTH Shale, Siltstone, Sandstone, Limestone, % Cuttings · MUD GAS DETECTION (Arbitary Units) 1 2 3 Live Oil 0 50 100

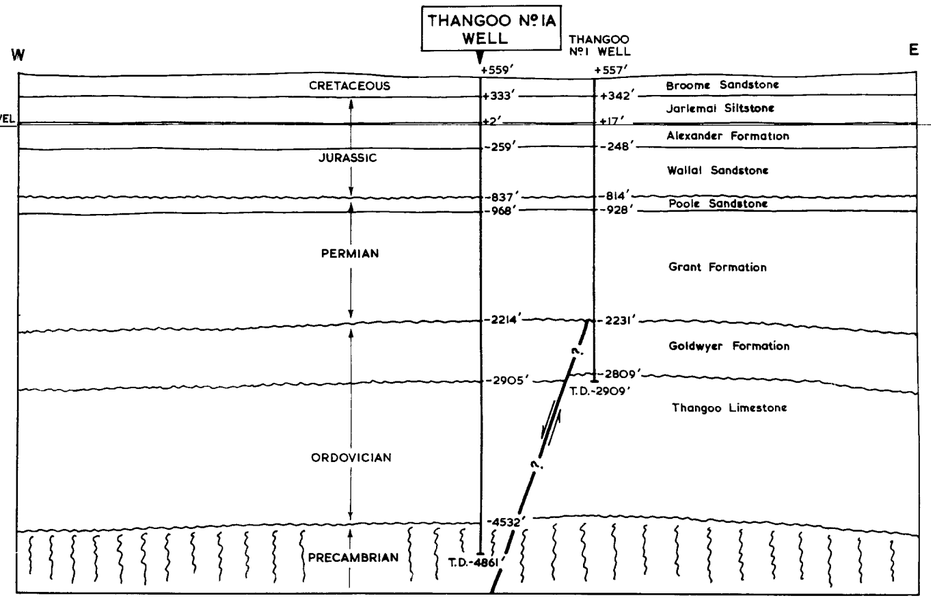
SCALE CHANGE 30 20 10 0
10¾″ CASING SHOE AT 3276′
N.S. (No Samples)
T T Cut in carbon tetrachloride.
SCALE CHANGE 15 10 5 0
N.S.
T. D. 5429′ DRILLER 5431′ SCHLUM.

PLATE 3

## BEFORE DRILLING




## AFTER DRILLING




THANGOO No.1A WELL IS LOCATED 1540' NORTH OF THE SECTION LINE.

ALL DEPTHS SHOWN ARE RELATIVE TO SEA LEVEL.

FAULT WITH DIRECTION OF MOVEMENT

UNCONFORMITY OR DISCONFORMITY

0 1000 2000 3000 FEET

VERTICAL & HORIZONTAL SCALE

| REVN. | WEST AUSTRALIAN PETROLEUM PTY. LIMITED | |
|---|---|---|
| | **THANGOO No.1A**<br>EAST - WEST<br>GEOLOGICAL CROSS-SECTIONS<br>THROUGH WELL<br>BEFORE AND AFTER DRILLING | |
| DR. R.M.E. | R.M.L. ELLIOTT — 11 JULY 1960 | |
| TR. A.J.S. CH. R.M.E. | 11 JULY 60 | B-2533 |

ENCLOSURE No 3