Drilling Observations:

Figure 2 shows rig time plotted against depth. A total of 746½ hours was required to drill the well from spudding in to rig release. The table below gives the time spent on various operations:-

| Operation | Hours | % of Total Hours |
|---|---|---|
| Drilling (a) on bottom | 399 | 53.5 |
| (b) trips | 58¾ | 7.9 |
| Coring (a) on bottom | 35¼ | 4.7 |
| (b) trips | 66 | 8.9 |
| Conditioning Hole | 36¾ | 4.9 |
| Deviation Surveys | 8½ | 1.1 |
| Rig Service | 7½ | 1.0 |
| Breakdown Time | 10¼ | 1.4 |
| Fishing | 9 | 1.2 |
| Logging | 28 | 3.8 |
| Casing, W.O.C., etc. | 57 | 7.7 |
| Ream for casing | 8½ | 1.1 |
| Abandonment | 11½ | 1.5 |
| Other | 10½ | 1.4 |
| Total | 746½ | 100.0 |

## G E O L O G Y

SUMMARY OF PREVIOUS WORK:

Geological -

Prior to 1956 only a few references had been made to the geology of the southern part of the Amadeus Basin, principally by Basedow, Chewings, Terry and Ellis. From 1956 onwards Prichard and Quinlan (1962) established the basic succession of the sediments of the Amadeus Basin and Quinlan (1962) followed this by compiling an extremely useful regional map of the whole basin.

Frome-Broken Hill Company investigated the entire Basin from a petroleum viewpoint (inter alia Leslie, 1960 Wulff, 1960) and they modified much of Quinlan's mapping in and around O.P. 130.

Continuing their mapping programme, the Bureau of Mineral Resources covered the Amadeus Basin on 1:250,000 scale and instituted local nomenclature for south-western and central facies variants in the Proterozoic and Cambrian sequences. (e.g. Wells, Ranford and Cook, 1963).

Geophysical -

The first geophysical work done in the area was a regional helicopter gravity survey conducted by the Bureau of Mineral Resources between 1959 and 1961. In 1963, a semi-detailed aeromagnetic survey was conducted over the eastern part of O.P. 130 for Exoil (N.S.W.) Pty. Ltd. by Aero Service Limited. In 1964, a six-week reconnasissance seismic survey was conducted over the central alluvial area on the east side of O.P. 130 by Geophysical Associates Pty. Ltd. for Exoil (N.S.W.) Pty. Ltd.

The large salt anticline on which the site of Erldunda No. 1 was selected was first revealed by a reconnaissance seismic traverse conducted along the Alice Springs to Adelaide highway. Detailed work was subsequently conducted over a 50 square mile area covering the crest of the structure. The regional gravity and aeromagnetic surveys conducted earlier had provided no evidence of the Erldunda feature. It may be significant to note that the Bouguer value from gravity station 72-9 located near the Erldunda No. 1 site fits well into regional Bouguer control and gives no indication of the existence of local underlying salt development.

The aeromagnetic survey indicates depth-to-basement at the well site of approximately 9,000 feet, which agrees well with depths shown from seismic results.

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Drilling -

No previous drilling for oil had been carried out in O.P. 130. Furthermore, prior to Erldunda No. 1 only one other well had been drilled in the southern Amadeus Basin,

this being Transoil Mt. Charlotte No. 1, located 55 miles to the north-east.

REGIONAL STRATIGRAPHY -

The Amadeus Basin comprises a northern trough with fair conformity between stratigraphy units and a southern, highly disturbed region which shows several major unconformities and hiati. The basin in its present form is an elongate, composite feature sub-latitudinally aligned between the Arunta (northern) and Musgrave (southern) Archaean complexes. The Amadeus section is in excess of 20,000 feet and embraces Upper Proterozoic to Devonian paralic shelf type strata considered to be south-western contributory deposits of a former extensive depositional basin.

In the northern part of the basin the Upper Proterozoic comprises a group of four conformable formations, each of which shows evidence of deposition for the most part, under marine shallow water conditions. The basal Amadeus unit is the Heavitree Quartzite, a transgressive sandstone/siltstone sequence up to 1,400 feet thick which shows bold outcrop along the truncated northern rim of the basin. The conformably overlying Bitter Springs Limestone consists mainly of algal bearing dolomitic limestone some 3,000 feet in thickness but varying minor amounts of shale and sandstone also occur and in places the carbonate rock has a high clastic content. The Areyonga Formation, which follows with transitional contact mainly, comprises a mixed unit of siltstones, sandstones and conglomerates of glacial aspect with limestone concentrated at the top and bottom of its sequence. Its thickness is 1400 feet in the north central part of the basin but it thins markedly to the east and west, suggesting a deltaic accumulation of outwash material. Conformably following this unit the unfossiliferous Pertatataka Formation comprises up to 2,000 feet of black to vari-coloured shales and siltstones with thin interbeds of glauconite sandstones and oolitic limestones.

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Along the south western margin of the basin the Dean Quartzite and the Pinyinna, the Inindia and the Winnall Beds have been respectively equated with the above four formations. A total thickness of some 14,000 feet has been estimated for these beds and each unit shows an appreciable thickening in comparison with its northern counterpart. In further contrast, local unconformity is suggested between the Inindia and the Winnall Beds in the former's type area and the latter is a distinctly sandy facies variant of the Pertatataka. The Winnall and Pertatataka may be Cambrian in their upper horizons.

The Cambrian deposits of the Amadeus Basin are included under the composite name Pertaoorrta Group, a 5-6,000 feet marine sequence which shows an interesting clastic to carbonate facies change. The better known central facies comprises the predominantly sandy Arumbera Formation, the abundantly fossiliferous Hugh River Shale and the sandy Goyder Formation. Eastward, the uppermost two units become more carbonate rich, through an increasing abundance of limestone tongues until, east of Alice Springs, this facies, the Jay Creek Limestone, occupies the entire lithological interval of the two formations.

To the west the Hugh River Shale becomes sandier, particularly in its second and uppermost quarters, whereby it is devisible into the Tempe Member, the Illara Sandstone, the Deception Member and the Petermann Sandstone. The Tempe overlies the Eninta Sandstone which is equivalent to the upper part, at least, of the Arumbera Formation. Further west the Deception Member also changes to sand and the sequence is mapped as the 3,000 feet thick, possibly continental Cleland Sandstone, which overlies the Winnall Beds with unconformity.

Conformably following the Pertaoorrta is the Larapinta Group of fossiliferous marine strata. The basal

unit is the Cambro-Ordovician Pacoota Sandstone, up to 2,500 feet thick, composed predominantly of clean quartz sandstone. The overlying Horn Valley Siltstone is 400 feet thick in the north-west but it thins and pinches out completely eastward and southward. The phosphatic Stairway Sandstone conformably overlies the Horn Valley but is more transgressive, overlapping the lower Larapintine units to the south and east where it unconformably rests upon Pertaoorrta. The formation is almost 900 feet thick in the north and central parts of the basin but it thins eastward and southward in harmony with its contiguous formations. The top Larapinta unit is the Stokes Formation comprising up to 2,000 feet of vari-coloured siltstones and limestones in the lower part and some transitional sands at the base. The formation pinches just out to the south of the Mt. Charlotte/Mt. Sunday/Basedow Ranges alignment.

The Mereenie Sandstone overlies the Stokes Formation conformably in the central part of the Amadeus Basin but elsewhere laps unconformably onto lower Larapintine units. Where conformity exists a basal 450 foot brown sand is always present which contains fossils of Ordovician aspect. The upper part of the Mereenie consists of some 2,000 feet of white to vari-coloured unfossiliferous, possibly continental sandstone, usually assigned to the Silurian on a residual basis. As with the underlying Larapinta units, the Mereenie Sandstone shows thinning to the east and south, the latter being the more marked.

The Pertnjara Formation, at least 10,000 feet of continental clastics, overlies the Mereenie with angular unconformity. It comprises a lower siltstone section and an upper unit of red-brown to white silty and pebbly sandstone. Plant and fish remains of Devonian aspect have been found in both sections. The Pertnjara Formation is the topmost Amadeus unit and it occurs as an obscuring fill type deposit over the northern and central regions of the trough.

## FORMATIONS PENETRATED

### Stratigraphic Table

| Age | Formation | Top Depth | Top Subsea | Thickness |
|---|---|---|---|---|
| Quaternary | Alluvium | Surface | 1343' | 30' |
| Devonian | Pertnjara | 30' | +1313' | 115'+ |
| ?Silurian | Upper Mereenie | 145' | +1198' | 750' |
| Ordovician | Stairway | 895' | +448' | 348' |
| Cambrian | Cleland | 1243' | +100' | 822' |
| Upper Proterozoic ? Cambrian | Pertatataka | 2065' | 722' | 1678' |
| Upper Proterozoic | Areyonga | 3743' | 2400' | 557'+ |
| Upper Proterozoic | Bitter Springs | 4300' | 2957' | 1163'+ |

Detailed Stratigraphy:

Alluvium

Surface - 30' (thickness 30')

Age: Quaternary

Fine to medium sand and brown clay.

Pertnjara Formation

30' - 145' (thickness 125'+)

Age: Devonian

Brown, fine grained, gypseous, quartzose sandstone and red brown siltstone, the latter much weathered to clay.

Upper Mereenie Sandstone

145' - 895' (thickness 750')

Age: ?Silurian

Predominantly sandstone, brown minor grey, micaceous, slightly calcareous, poorly sorted, fine to very fine quartz and lithic grains. Grades to minor siltstone and medium sandstone with occasional conglomerate pebbles in the latter. The formation stands out on the Gamma Log as a featureless line showing little more than statistical variation.

Stairway Sandstone

895' - 1243' (thickness 348')

Age: Ordovician

Mainly sandstone, white, grey, mauve, flesh, brown and

red-brown, fine to medium grained, argillaceous, slightly micaceous, quartzose. Trace of visual porosity throughout. Minor siltstone, grey to red-brown, slightly micaceous, siliceous. Gypsum flakes occur as a trace generally, but become abundant in the interval 1030' - 1040'. Black and green grains in 960' - 1000' interval may be phosphate.

Formation top is dubiously picked in samples at change to larger grain size sandstone. However, the pick is taken conclusively at the sharp decrease in drilling rate and at the marked increase in activity on the Gamma Log. Comparison of latter with Mereenie wells shows that whole Stairway section is represented but that the middle phosphatic member is extremely constricted here viz. 955' - 990'.

Cleland Sandstone

1243' - 2065' (thickness 822')

Age: Cambrian

Illara Sandstone Member 1243' - 1575' - White to pink, fine to medium grained, generally tight sandstone in slight excess of black, blue-grey and red-brown, micaceous, calcareous siltstone and shale. Pyrite trace below 1440 feet and some glauconite below 1390 feet. Top of unit picked at sharp increase in siltstone and shale in samples and at shift to shale on Gamma-Acoustic log.

Tempe Member 1575' - 2065' - Approximately equal amounts of sandstone, siltstone and shale. Sandstone as above to 1800 feet, but below this blue-grey, pink, white, arkosic to lithic, micaceous, abundantly glauconitic. Shale and siltstone black, grey and red-brown as above and also varying shades of mauve and purplish brown. Selenite common below 1800 feet and interval 2040' - 2065' is extremely calcareous with trace of white limestone. Top of member selected at sharp decrease in sand/shale ratio and at incoming of more vari-coloured shale and siltstone in cuttings.

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Pertatataka Formation

2065' - 3743' (thickness 1678')

Age: Upper Proterozoic - ? Cambrian

Unit A 2065' - 3015' - Black, blue-black, purplish-black, red, red-brown, brown, purplish brown, amber, grey, grey-green and green shale in considerable excess of siltstone. Both micaceous, slightly pyritic, variably calcareous often grading through marl to good traces of white limestone. Resinous lustre common, especially in shale. Unit's top is placed at disappearance of sand in samples, which corresponds to abrupt kick to uniform shale on the Gamma-Acoustic log and break to uniformly fast drilling rate.

Unit B 3015' - 3075' - White, fine grained, clean, slightly calcareous sandstone grading to conglomerate with minor dark grey, sandy, siliceous siltstone, especially towards the base of the unit. Unit stands out on all logs as distinct sand break in an almost unvarying shale line.

Unit C 3075' - 3743' - Predominantly dark grey to black, micaceous, silty, siliceous, dolomitic shale grading in places to siltstone and black dolomite. Interval 3210' - 3300' is entirely siltstone, as for shale above, but very platy and from 3300' to 3420' siltstone is prominent. Unit characterised on logs much the same as Unit A above, but curves show more variation and a slight offset to silt.

Areyonga Formation 3743' - 4300' (thickness 557')

Age: Upper Proterozoic

3743' - 4030'- Almost entirely white to grey, quartzose to cherty, poorly sorted, fine to conglomeratic sandstone, very hard, glassy, tight, grading to quartzite. Traces of dark grey to black silty shale and a band of grey siliceous, hard dolomite between 3970' and 3980'. Section shows as marked sand break on Gamma and Guard logs. Top of formation readily picked at sand kick on logs and at change to cherty arenite in samples.

4030' - 4300' - Predominantly dark grey to black shale, as above. Similar siltstone, red and blue silty shale and white, hard fine grained quartzitic sandstone also prominent, the latter below 4220 feet only. Section gives shale characteristics on logs except 4220' - 4260' interval where the sand break is evident.

Bitter Springs Limestone 4300' - 5463' (thickness 1163'+)

Age: Upper Proterozoic

4300' - 4785' - Approximately equal amounts of dolomite, sandstone and shale/siltstone to 4750 feet. Dolomite, dark brown to grey, mottled, hard, brittle, cherty, sometimes sugary, occasionally oolitic. Chert abundant; white, blue, brown, clear in part, oolitic. Sandstone, white, very fine to coarse grained, poorly sorted, siliceous, quartzose, often red stained, quartzitic. Black, silty, micro micaceous shale ranges throughout section. Siltstone occurs below 4610 feet only and is rust red, micaceous, sandy, siliceous. White, crystalline, sugary gypsum, dominant below 4750 feet, is apparently intrusive. Lithological heterogeneity of section reflected in logs by considerable oscillation. Top of formation is selected at the prominent cherty dolomite which coincides with kicks to high velocity and low gamma count on the logs.

4785' - 5463' - Buff, grey and mauve, slightly cherty, gypsiferous, dense, finely crystalline dolomite with traces of black shales to 5280' and gypsum ?interbeds dominant in interval 5170' - 5190'. Below 5280 feet, white, clear, crystalline gypsum gradually assumes dominance, and below 5442 feet, strata is indicated on drilling time and core as being mainly light reddish-orange, coarsely crystalline halite. Both gypsum and halite give evidence of being bedded. Washed out hole and increased salinity of circulating fluid suggest salt also occurs throughout the gypsum zone and possibly even higher in the sequence.

This lower half of the Bitter Springs stands out as an extremely high velocity zone showing relatively little variation on either Gamma, Acoustic or Guard log curves. The gypsum zone below 5280 feet is distinct in that it has a shale velocity and higher resistivity.

STRUCTURE

Four main episodes of folding are recognised in the Amadeus Basin sediments as follows:-

(1) The Petermann Ranges folding - post Bitter Springs - pre Areyonga.

(2) The Lake Neale folding - epi Pertatataka - pre Cleland.

(3) The Erldunda folding - post Cleland - pre Larapinta.

(4) The Amadeus Basin folding - epi Pertnjara.

Episodes 1, 2 and 4 were defined as above by Forman (1963) but some later Bureau of Mineral Resources' records refer to episode 2 as the Petermann Ranges folding. The name Erldunda folding is introduced herein to describe a period of structural and seismic importance within O.P. 130 and environs. The episode was first recognised by Wells, Ranford and Cook (loc.cit.) in the Angus Downs area and elaborated upon by Wells, Stewart and Skwarko (1964) in the Erldunda area.

The Amadeus Basin falls into three structural provinces in each of which the above folding episodes play varyingly important parts.

(a) The Missionary Plains downwarp which occurs between the McDonnel Ranges, Arunta block and the anticlinal hingeline which runs through the Gardner and James Ranges to the Hale River inlier of Arunta rocks.

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(b) The Mt. Burrell anticlinorium lies immediately south of the James Range hingeline. It displays severe compressional folding and

many positive features of diapiric aspect.

(c) The Kulgera platform - lies between the Musgrave-Mann block and the Mt. Burrell Anticlinorium and is separated from the latter by an anticlinal hingeline through the Basedow, Erldunda and Mt. Sunday Ranges. This anticlinal alignment is overturned in several places and can be traced eastward, from seismic and outcrop, to a point five miles north of the Mt. Charlotte No. 1 Well and thence to the overturned anticline ten miles south-east of Mt. Rodinga. To the north-west, it follows a line of overfolded diapiric structures through and beyond the Mt. Murray diapir.

The Petermann Ranges folding has been described in all three provinces, was recognised in the Mt. Charlotte No. 1 Well and may be represented in Erldunda No. 1. The Lake Neale episode is prominantly displayed in the Mt. Burrell anticlinorium, and occurs apparently to a lesser extent on the Kulgera platform but is conspicuously absent from the Missionary Plain downwarp. The universal orogeny over all three provinces is the Amadeus Basin folding whose structural products are posthumous, for the most part, over Lake Neale features. Evidence of the Erldunda folding episode is found only on the Kulgera platform where it was responsible for uplift and compression of the Cleland and older rocks and the exclusion of at least the lower Larapinta sea from the region. This movement appears to have been a posthumous expression of the Lake Neale episode. In the Mt. Charlotte area the whole Larapinta and even the Mereenie are variably missing over the platform indicating that the orogeny was most severe in the east. Conversely to the north-west in the vicinity of Lake Amadeus, the movement died out and the lower Larapinta units lap over

the Basedow Range hingeline in apparent conformity with the Cleland.

Erldunda No. 1 was drilled towards the northern edge of the Kulgera platform on an anticlinal feature showing at least 600 feet of closure on a prominent shallow seismic reflecting horizon. A marked lithological break was picked at the top of the Cambrian in the well, which point is placed at the above reflector by the well velocity survey and the Acoustic log. The seismic records indicate a pronounced regional unconformity below this horizon which is undoubtedly the sub-surface representation of the Erldunda folding episode as delineated in outcrop.

The two deeper seismic horizons which were mapped tie to Unit B Pertatataka and to the Bitter Springs evaporite in which the well terminated. These two horizons show reasonably good conformity suggesting that the Petermann Ranges folding was of small magnitude in this area.

On the contrary there is considerable relief in the isopach between the relatively flat Stairway/Cambrian reflector and the rather intensely folded Pertatataka horizon. As elsewhere this isopach shows appreciable thinning over the Erldunda structure and indicates an offstructure increase in section of 1,600 feet on the south-west flank and 2,600 feet on the north-east limb. While the seismic records demonstrate that most of this is due to addition of upper Cleland below the Stairway unconformity, the excessive increase on the north-eastern flank cannot be ascribed to this reason alone since the maximum known thickness of the Cleland is only 3,000 feet. It would appear therefore, that at least 400 feet of increased section on this flank can be appropriated elsewhere, most probably to the top of the Pertatataka where an unconformity due to Lake Neale folding would be expected.

## RELEVANCE TO OCCURRENCE OF PETROLEUM

Although no significant indications of hydrocarbons were encountered in Erldunda No. 1, interesting traces were observed, two of which tie to occurrences in other Amadeus wells.

Traces of pinpoint blue fluorescence and black residual hydrocarbon on sand grains at the base of the Illara (1560' - 1575') are reminiscent of such indications in this same stratigraphic position in Exoil's Ochre Hill No. 1 and Highway Anticline No. 1 wells, 135 miles to the north-west and 65 miles north respectively.

Within the Pertatataka, the extraction of small amounts of methane from cuttings and Core No. 6 over the interval 3420' - 3743' has no parallel in the Amadeus region. Conversely, good cuttings gas readings from the interval 4150' - 4180' in the Areyonga are in accord with the small gas flow and another trace within this formation in Exoil Ooroomina No. 1, over one hundred miles to the north-east.

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## POROSITY AND PERMEABILITY OF SEDIMENTS PENETRATED

The only significant porosity in the Erldunda No. 1 section is in the Stairway Sandstone. Estimates of up to 5% porosity were made in sandstones within the upper Stairway and the only measurable water flow encountered in the well was obtained from the lower member of the form-

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A small amount of salty water was struck at 90 feet in the Pertnjara but overall, both this unit and the underlying Mereenie were tight. The Cleland also was found to lack porosity. Even though many of the massive sandstone beds broke to small fragments, it was noted, upon closer inspection, that breakage through grains was prevalent indicating the absence of intergranular weakness.

The pelitic nature of most of the Pertatataka and much of the Areyonga and the dense, glassy siliceous matrix of the sub-quartzites of the two formations precludes any form of porosity other than the fracture type. Since no water was encountered in either of these formations, even though some fracturing was noted in cores, it is concluded that both were extremely tight.

Though fracturing and brecciating occur in the Bitter Springs Core No. 10 (4792' - 4802') the formation appears to be tight throughout with a complete absence of the lost circulation experienced in other Amadeus wells.

## CONTRIBUTION TO GEOLOGICAL CONCEPTS AS A RESULT OF DRILLING

From a petroleum viewpoint the most important result gained from drilling Erldunda No. 1 is that the Stairway Sandstone extends for a considerable distance into O.P. 130. The formation, together with the desirable Stokes caprock, outcrops dipping northward along the northern part of the tenement in such a fashion as to suggest that it does not occur any further south. The confirmation that the unit continues beneath the Erldunda alluvial plain andthe possibility that it may be overlain in part by the Stokes, considerably enhances the area for future petroleum search.

That the Cleland Sandstone can be demarcated in the Erldunda well clarifies the Cambrian stratigraphy of the southern Amadeus region. Most of the strata previously mapped in outcrop as "undifferentiated Pertaoorrta"

can now be confidently assigned to the Cleland, whose province encomposses the change from a south-west sand facies to the Hugh River Shale. The relationship of the Cleland to the Central Amadeus type Pertaoorrta has been established from Exoil's East Johnny's Creek No. 1 and James Range "A" No. 1 wells.

The penetration of Pertatataka facies in Erldunda No. 1 was completely unexpected considering the Bureau of Mineral Resources' mapping of theWinnall facies right into the north-eastern corner of O.P. 130. Pertatataka unit B in the well appears to be the equivalent of the 15-20 feet of conglomerate which separates the Basal Siltstone from the Middle Sandstone in the Winnall Beds outcrop, thus fairly convincingly establishing the facies relationship of the Winnall and Pertatataka. Undoubted Winnall Beds outcrop at Ippia Hill and Mt. Kingston, respectively 15 miles north north-west and 30 miles east of Erldunda No. 1, suggesting that the Pertatataka facies may extend westward as an embayment into the Erldunda sub basin. The occurrence of mapped Winnall facies to the north-east of Erldunda cannot be satisfactorily explained other than there may be an error in unit identification.

The three reflectors mapped in the Erldunda Seismic Survey were designated Upper Ordovician, Lower Ordovician and Lower Cambrian in the survey report. However, the results of drilling, together with the Acoustic Velocity log and the Well Velocity Survey, demonstrate that the horizons are Stairway/Cambrian (as anticipated) Unit B Pertatataka and the Bitter Springs evaporite. The well prognosis placed the horizons as Stairway/Cambrian salt, Cambrian Salt/Lower Cambrian and Upper Proterozoic salt. This was close to actuality except for the Cambrian salt pick which turned out to be the relatively low velocity Cleland Sandstone and Unit A Pertatataka.

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