820'	¼°	3,785'	5°	5,828'	5½°
1,120'	½°	3,880'	5½°	6,062'	5½°
1,430'	1°	3,960'	5¼°	6,166'	5½°
1,485'	1°	4,000'	5¼°	6,280'	5°
1,760'	1°	4,125'	5°	6,360'	5½°
2,100'	misrun	4,155'	5°	6,644'	6¾°
2,150'	1¾°	4,180'	4¾°	6,750'	6½°
2,235'	2°	4,415'	4¾°	6,870'	6¾°
				7,300'	6½°

Temperature Surveys:

No temperature surveys were run.

Drilling Observations:

Fig. 2 shows average drilling time plotted against drilling depth. 2,260¼ hours were required to drill the Alice No. 1 Well, from spudding to rig release.

Seventeen coreheads were used to core 215 feet for an average of 12.6 feet per corehead. 210 hours, or 10.8% of total time, were used in coring operations. Coring costs are estimated at £9,390, or nearly £5 an inch for cores.

Fifty-seven drill bits were used to drill 7,518 feet of hole (including reaming core hole for intermediate casing) for an average of 132 feet per bit. The overall average penetration rate for the hole was 6.2 feet per hour. A total of 102½ hours was used to ream the hole for surface and intermediate casing.

G E O L O G Y

PREVIOUS WORK

Geological:

Surface geological mapping on a regional scale has been carried out in the Amadeus Basin by the Bureau of Mineral Resources, Frome-Broken Hill Co. Pty. Ltd. and Magellan Petroleum Corporation. The structure on which the Alice No. 1 Well was drilled is not a surface feature.

Geophysical:

A semi-regional gravity survey was conducted over the area by Century Geophysical Corporation for Magellan Petroleum Corporation in 1961. Regional seismic lines by the Bureau of Mineral Resources pass east and west of the prospect. The gravity survey showed a gravity minimum, suggesting a salt anticline and further seismic surveys in 1962 and 1963 by Exoil delineated an area of about

three square miles with structural closure of about 130 feet. An anomalous zone thought to be due to reefing was defined from the seismic survey.

Drilling:

The nearest well is Ooraminna No. 1, twelve miles to the south-east. This spudded in the Arumbera formation in which Alice No. 1 bottomed.

STRATIGRAPHY

Regional Stratigraphy:

The nearest complete section measured by a number of workers is the Ellery Creek section in the Macdonell mountain front. The sediments of this section fill the Amadeus Basin and constitute the typical Proterozoic-Palaeozoic rocks for the area.

The Upper Proterozoic Sequence:

(i) The Heavitree Quartzite:

Overlying the peneplained Arunta metamorphic complex is some 1,400 feet of shales, quartzitic sandstones and siltstones termed the Heavitree Quartzite. Worm trails in the sandstone and carbonaceous argillaceous siltstones at the top of the Heavitree formation anticipate the abundance of life in the succeeding Bitter Springs formation.

(ii) The Bitter Springs Limestone:

The Bitter Springs limestone has a thickness of 2,700 feet at Ellery Creek and lies conformably on the Heavitree Quartzite. The extensive algal development (Collenia), beds of gypsum, pelletoids and glauconitic beds indicate shallow water conditions throughout. The limestone has been found to have a foetid odour in many localities and has attractive source characteristics. Several hundred feet of the formation drilled at Ooraminna No. 1 was found to be highly fractured but the fractures were mostly filled with gypsum.

(iii) The Areyonga Formation:

The Areyonga formation lies transitionally on the Bitter Springs limestone although local unconformities exist in places, particularly in the south and west parts of the Amadeus Basin. Interbedded limestones and siltstones at the base grade into

coarse sandstones and conglomerates in the middle and into a brecciated limestone at the top. It appears to be a product of eustatic lowering of the sea. A flow of methane gas was recovered from a fracture zone in the Areyonga at Ooraminna No. 1.

(iv) The Pertatataka Formation:

The Pertatataka lies conformably on the Areyonga but like the Areyonga is preceded by strong local unconformities in the south and west parts of the Amadeus Basin. Where the thickness varies, the lithology varies but it is generally considered to transgress from a shale facies in the north to a limestone facies in the south. At Ellery Creek the formation is 1,860 feet thick and consists predominantly of shale with a middle limestone member containing some pisolitic, pelletoid and oolitic bands. At Ooraminna No. 1 it consisted of, from the top downwards, 194 feet of massive carbonate followed by 216 feet of interbedded carbonates and sands with shale breaks, underlain by 1,637 feet of monotonous dark grey, green and black shales of possible marine origin, resting on 157 feet of red continental shales.

The Palaeozoic Sequence:

(i) The Arumbera Sandstone:

Lying conformably on the Pertatataka formation is the fine, porous Arumbera sandstone. It is 1,100 feet thick at Ellery Creek and carries interbeds of siltstone. At Ooraminna it is 1,890 feet thick and consists predominantly of porous ferruginous sandstones interbedded with shales and siltstones. At Alice No. 1 it was found to be porous at depth but tested salt water. The negative results of the test were not discouraging since the well was not on structure at this point.

(ii) The Pertaoorrta Group:

The Pertaoorrta Group includes all the Cambrian section from the Arumbera to Pacoota inclusively. The type section includes a lower shale member (Hugh River) a middle limestone member (Jay Creek) and an upper sandstone member (Goyder). The divisions are transitional. The Goyder and Hugh River thicken and become sandier in a westward direction.

The Jay Creek thickens in an eastward direction and practically envelops the Hugh River and Goyder at Alice No. 1.

Crude oil (gravity 43) was extracted from the Jay Creek in Alice No. 1 and an asphaltic residue was encountered in the Goyder. The Goyder lacked adequate capping in this well and the Jay Creek failed to have porosity. The net result of the well was that the Cambrian was shown to be a good source rock.

(iii) The Larapinta Group:

The Larapinta Group, as defined by Prichard and Quinlan (1962), conformably overlies the Pertaoorrta Group and is followed after regional unconformity by the Mereenie Sandstone. It is divided into four formations.

An Ordovician age has been assigned to the Group, although Upper Cambrian trilobites have been found in the lowest formation, the Pacoota Sandstone.

(a) Pacoota Formation:

The Pacoota Sandstone lies transitional on the Goyder Formation and is a sequence of silicified quartz sandstone. It has a maximum thickness of 2,500 feet at Ellery Creek and thins southward to about 1,000 feet at Mt. Peachy. Crossbedding is common and 400 feet above the base there occurs a bed packed with worm tubes lying normal to the bedding. Upper Cambrian and Lower Ordovician trilobites have been found.

(b) Horn Valley Formation:

The Horn Valley is a 440 foot thick siltstone formation overlying the Pacoota conformably at Ellery Creek. It contains glauconite and thin interbedded fossiliferous limestones. It is absent at Alice No. 1.

(c) Stairway Formation:

The Stairway Formation is about 480 feet thick at East James Range and thickens to the west. It pinches out eastward and is absent at Alice No. 1. The lithology is a reddish weathering marine sand-

stone formation that carries worm borings and clam borings and occasional pelecypod and gastropod casts and impressions. It provides a good reservoir between the Horn Valley and Stokes siltstone formation.

(d) The Stokes Formation:

The Stokes is a siltstone formation carrying a few limestone stringers in its lower portion and some evaporites. It is conformably overlain by the Mereenie Sandstone.

(iv) The Mereenie Formation:

The Mereenie sandstone is a thick fairly clean cross-bedded sandstone that usually weathers a very deep red colour. It is 1,200 feet thick at Ellery Creek. It is believed to be of Ordovician or Silurian age.

(v) The Pertnjara Formation:

This is a very thick sequence of non-marine sandstones, greywackes and conglomerates that fill in the Amadeus trough fronting the Macdonnell Range. It is of Silurian and Devonian age and has no petroleum prospects.

Formations Penetrated:

Stratigraphic Table: (Refer also, Fig. 3.)

Age	Formation	Formation Top K.B.	Subsea	Thickness
?Silurian	Pertnjara	surface	+1,742'	1,154' +
Ordovician	Mereenie	1,165'	+ 588'	950'
Ordovician	Pacoota	2,115'	- 362'	889'
Cambrian	Goyder	3,004'	-1,251'	846'
Cambrian	Jay Creek	3,850'	-2,097'	3,390'
Cambrian	Arumbera	7,240'	-5,487'	278' +

Detailed Stratigraphy:

Surface - 1,165 feet (penetrated thickness 1,154 feet)

Pertnjara Formation

Age: Palaeozoic (?Silurian)

Sandstone, red, generally poorly consolidated, with very poor sorting; very fine to granular and pebbly, grading rarely to siltstone, sub-rounded to sub-angular,

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occasionally frosted grains. Many zones conglomeratic, pebbles of sandstone, quartzite, quartz, chert, and igneous and metamorphic rock. Cementing material varies from red ferruginous, silty and argillaceous to white calcareous and kaolinitic. Sand is often arkosic, some feldspars having been altered to clay; other accessories are muscovite and biotite, chert and dark mineral grains. Thin red shale and silty partings are occasionally present. The interval 740 feet to 775 feet is red, soft, gummy clay. Base of the Pertnjara is picked on a rough Gamma-ray correlation with B.M.R. water bores in the area. No clearly defined lithological break was recognised between Pertnjara and Mereenie Sandstone in Alice No. 1.

1,165 feet - 2,115 feet (Thickness 950 feet)

Mereenie Sandstone

Age: Palaeozoic (Ordovician)

Sandstone generally clean, tan, white and light rusty brown, mostly current-bedded, poorly to fairly consolidated, generally well sorted, very fine to medium grained, with rare coarse, pebbly streaks (pebbly zones in samples may be due to contamination from the Pertnjara); rounded to angular, with generally poor to fair intergranular porosity. Cementing material is silty, quartzose, occasionally calcareous; thin red shale and siltstone beds and partings are present throughout. Sand is rarely arkosic, feldspars are generally altered to kaolin.

2,115 feet - 3,004 feet (thickness 889 feet)

Pacoota Sandstone

Age: Palaeozoic (Ordovician)

The Pacoota in Alice No. 1 consists predominantly of sandstone with approximately 30% shales, claystones and siltstones. Sandstones are of varying colours and lithologies. They are red, brown, white, purple, orange and yellow and vary from well sorted to very poorly sorted and from very fine to very coarse grained. Angularity is also variable. Cementing material may be argillaceous, siliceous, silty, calcareous or kaolinitic. Some zones in the upper Pacoota are brecciated, consisting of fragments of sandstone in sandstone matrix. Fossil

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remains are indicated by zones of Scolithus worm tubes, infilled with sand and by white calcite patches which may have replaced fossil debris. All cores show strong current bedding. The top half of the Pacoota is characterized by an abundance of white calcareous claystone which varies from soft to siliceous and very abrasive and appears in beds up to forty feet thick. Also present throughout, and making up approximately 30% of the section, are beds of varicoloured shales and siltstones ranging in thickness from partings to twenty feet. These are red, green, brown, orange and yellow, variably calcareous, micaceous and sandy. The base of the Pacoota is placed at the top of the first carbonate of theGoyder Formation..

3,004 feet - 3,850 feet (thickness 846 feet)

Goyder Formation

Age: Palaeozoic (Middle Cambrian)

3,004 feet - 3,179 feet - Interbedded dolomite and sandstone, beds 5 feet to 15 feet thick, gradational. The dolomite is white to light grey and brown, fine to medium crystalline with coarse crystalline patches, very sandy, grading to dolomitic sandstone, white to light grey and brown, crystalline dolomite matrix, fine to medium grained. Glauconite is common, ranging from traces to locally making up 25% of the rock as dark green pelletoid grains. Pyrite and mica are minor accessories. Oolitic zones are present in the dolomite, and well preserved but badly broken shell fragments occur in rare zones. Vuggy porosity is present rarely in coarsely crystalline beds. Shale partings occur throughout. Shale is brown and green, occasionally as stylolites, often micaceous, and contains worm trails.

3,179 feet - 3,399 feet - Dolomite and limestone with minor sandstone and shale beds. Dolomite continues as above, white to light grey and brown, partly calcareous grading at times to limestone, generally sandy, rarely glauconitic, crypto-crystalline to coarsely crystalline, often oolitic, rarely partly chalky. Sands and shales are as above.

3,399 feet - 3,850 feet - Sandstone with thin dolomite and shale beds. Sandstones are similar to those above:

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white to light grey and brown, very fine to medium grained, with generally fair sorting, but some poorly sorted intervals. Matrix is silty, dolomitic and calcareous, with the sand grading in places to sandy dolomite and limestone. Cross-bedding is present throughout. Mica and glauconite are accessory minerals. Shale occurs throughout in thin laminations and beds, locally intimately mixed with sand as lenses and fine laminations. Shales are red, brown, green and black and rarely grade to siltstones. Sandstones and dolomites over the interval 3,450 feet to 3,640 feet contain variable amounts of heavy black asphaltic oil. Base of the Goyder is placed at the change to dominantly limestone lithology.

3,850 feet - 7,240 feet (thickness 3,390 feet)

Jay Creek Limestone

Age: Palaeozoic (Middle Cambrian)

The Jay Creek in Alice No. 1 can be divided into five units. They are, from the top down: (i) 370 feet of limestone with interbedded sandstone in the upper part; (ii) 640 feet of limestone with 20% interbedded shale; (iii) 950 feet of interbedded shale 60% and limestone and dolomite 40%; (iv) 840 feet of interbedded dolomite and shale, dolomite predominating; (v) 590 feet of shale, salt and siltstone. No reef facies has been recognised.

(i) 3,850 feet - 4,220 feet: Limestone, very light to medium grey and brown, rarely becoming dark brown; mostly crypto-crystalline to fine crystalline, often very oolitic, rarely chalky and granular, with rare coarse crystalline patches, with traces of micro-vugular porosity. Some zones are coarse, and appear bio-clastic with poorly preserved recrystallized fossil debris; generally sandy, grading rarely to sandstone. Thin dolomite beds are scattered throughout the section. They are generally green, silty, sandy, dense, and grade to siltstone. Three sandstone beds in the upper 120 feet are gradational with limestone, light grey and brown very fine to medium grained, sub-angular, with calcite matrix. Varicoloured shales are present throughout as thin partings, often stylolitic, and as irregular patches. Glauconite, pyrite and

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traces of galena are rarely present in the limestone.

(ii) 4,220 feet - 4,860 feet: Limestone, thin to medium bedded, interbedded with 20% variegated shales, and with numerous dolomitic, silty and sandy streaks. Limestones are similar to those above, often oolitic, with clastic zones, rarely becoming dark brown, argillaceous. Limestones are variably sandy and dolomitic, and grade to grey and green dolomite, and, rarely, sandstone. Shale beds are green, black, brown, red and orange, sometimes sandy and silty, quite often micaceous. Current bedding is evident in cores.

(iii) 4,860 feet - 5,810 feet: Shale interbedded with 40% dolomite and limestone. Beds vary from five to forty feet in thickness. Shales are varicoloured - red, brown, green, grey, variably calcareous, silty, sandy and micaceous. Below 5,165 feet, shales become mostly rusty red brown, silty, with scattered gypsum throughout in fine to large irregular patches and fracture fillings. These shales grade locally to siltstone. Limestones are the predominant carbonate in the upper part of this interval, and resemble generally those above, but tend to be more generally argillaceous, and in places a lamellar concentric pattern of algal growth is developed. Dolomites predominate in the lower half of the interval. They are white, brown, grey and greenish, silty, rarely micaceous, generally very fine and dense: locally becoming coarser and granular, with a calcarenitic appearance. Varicoloured chert is found occasionally in the dolomite, also white and bluish gypsum patches. The carbonate beds are never very homogenous and contain numerous sandy, silty and argillaceous streaks.

(iv) 5,810 feet - 6,650 feet: Interbedded dolomite, minor limestone and shale, carbonates predominating. Dolomites are very light to dark grey and brown, and green, often silty and argillaceous, often grading with shale and siltstone in thin beds and laminations; generally crypto-crystalline to fine crystalline, locally granular, rare fragmented zones; generally dense and tight, with rare intercrystalline and micro-vugular porosity. Gypsum is generally present in small amounts as irregular patches and fracture fillings, and appears to destroy porosity. Scattered algal

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growth is indicated by fine irregular laminated structures; rare beds are oolitic. Shaly streaks, laminations and stylolites are developed throughout, and several thin cherty and siliceous streaks are present. Dolomites over the interval 6,080 feet to 6,130 feet contain zones saturated with dark brown, high gravity oil (see descriptions Cores 22 and 23). Interbedded shales in this interval occur in beds up to 20 feet in thickness. Shales are rusty red, brown, green and purple, generally calcareous or dolomitic, silty, occasionally micaceous. They grade to both dolomite and siltstone. White, brown, blue and pink crystalline gypsum is often present as eyes, patches, and as fracture fillings.

(v) 6,650 feet - 7,240 feet: Red beds (shale and silt) and salt.

124 feet shale, rusty red brown, silty, micromicaceous, brittle - small gypsum patches scattered throughout.

78 feet - Halite, transparent partly stained brownish, massive - extremely coarse crystalline.

20 feet - a ten foot bed of red shale interbedded between two beds of light grey very fine crystalline, stylolitic dolomite. This interval contained a small amount of heavy hydrocarbon gas.

113 feet - Halite.

65 feet - shale, rusty red brown.

108 feet - Halite.

82 feet - Mudstone, shale and siltstone, rusty red brown, soft to firm, calcareous, gypsiferous.

<u>7,240 feet - 7,518 feet (penetrated thickness 278 feet)</u>

Arumbera Formation

Age: Palaeozoic (Lower Cambrian)

The top of the Arumbera is gradational into the base of the Jay Creek, and is taken at the first appearance of sand in the red beds underlying the salt. The Arumbera is a shale siltstone sandstone sequence, and generally rusty brown, with rock types often intimately bedded and gradational. Sandstones are usually rusty brown, but are also light brown, grey and white and are poorly

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sorted, often siliceous, partly silty and calcareous. The Microlaterolog shows many permeable streaks through this interval; this was substantiated by production of salt water in a D.S.T.

Three thin dolomite beds occur in the upper part of the interval. They are grey and brown to pinkish, silty, very fine, and tight.

STRUCTURE

The well was located on the highest point of a small seismic structure with 130 feet of closure on Cambrian and Ordovician horizons. In addition, it was located in such a position as to test two seismically anomalous zones occurring within the lower half of the Jay Creek Formation. Fig. 14 is a map showing seismic contours on the middle Jay Creek reflector occuring at the top of the uppermost anomalous zone.

The uppermost zone was characterised by diverging cycles which were extremely strong and apparent in the west but difficult to identify in the east where record quality became poorer. The heavy dotted lines in Fig. 14 represent the interpreted edges of maximum and minimum buildups. The well was located closer to the north-east edge than to the west edge although definition of the anomalous dips were best in the west.

The lower anomalous zone had the appearance of a lens-shaped inclusion whose maximum thickness was at the well location.

Both the zones were interpreted to represent biohermal developments within the lower Jay Creek Formation. The lower zone was found from drilling and subsequent analysis of the continuous velocity log to be caused by salt. The upper zone yielded six feet of oil bleeding core but no positive indication of reef was found.

It appears that salt movement in the Jay Creek Formation created the structure and that the underlying Arumbera sandstone has essentially no closure.

In the well, dips measured on cores were reported as flat throughout the section penetrated.

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RELEVANCE TO OCCURRENCE OF PETROLEUM

Although Alice No. 1 failed to make a commercial discovery it was an important well inasmuch as it demonstrated the existence in the Amadeus Basin of sediments with the potential to produce. It discovered 43 gravity oil in non-commercial quantities in the Middle Cambrian Jay Creek Limestone, and a small amount of asphaltic oil in the Upper Cambrian Goyder Formation. It established the existence of porous zones in the Ordovician-?Silurian sandstones of the Larapinta Group and showed the Arumbera to have porosity at depth.

Judging by Alice No. 1 the Cambrian sediments of the Amadeus Basin have potential both as source and reservoir beds and the overlying Ordovician-?Silurian sediments contain reservoir beds.

POROSITY AND PERMEABILITY OF SEDIMENTS PENETRATED

Measured porosities and permeabilities are shown in Appendix A(ii). The Pertnjara and the Mereenie exhibit good porosities and permeabilities as does the Pacoota.

In the Jay Creek Limestone, cores 22 and 23 were found to have very high oil saturations but porosities and permeabilities were very low.

The Arumbera Sandstone, found to be porous near surface at Ooraminna, was porous at depth in Alice No. 1.

In the lower parts of the section the permeability was seriously reduced by the presence of secondary anhydrite. The latter mineral commonly fills fractures and joints in the Jay Creek Limestone which is oil-bearing in parts but exhibits low permeability.

CONTRIBUTION TO GEOLOGICAL CONCEPTS

The Alice No. 1 Well proved that the Cambrian of the Amadeus Basin was petroliferous. This fact had been suspected by some workers for some years on evidence of petroleum in outcrop and in shallow bores. The discovery of high gravity oil in beds of this age in Alice No. 1 lends incentive to further exploration aimed at Cambrian and Ordovician sediments.

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The well did not determine whether reefing was present in the Jay Creek Limestone and the question is still open. It confirmed that the gravity minimum over the structure is due to intrusion of salt, a common feature of this Basin.

Potential reservoir beds were found in the Arumbera, Pacoota, Mereenie and Pertnjara formations; the Pacoota and Mereenie are well situated to receive hydrocarbons from Cambrian source beds.

The well established that the Horn Valley Shale and the Stairway Sandstone are missing from the section in this locality. The Jay Creek has thickened eastward from the type section at Ellery Creek and is 3,390 feet thick at Alice No. 1. The Pacoota Sandstone has thinned to 889 feet from its Ellery Creek thickness of 2,500 feet and the Mereenie has thinned from 1,200 feet at Ellery Creek to 950 feet in the well.