

Blina oilfield

Introduction

The Blina oilfield was the first commercial oil discovery in the Canning Basin. Its discovery in 1981 led to a mini exploration boom in the basin. The Blina field is located in onshore Production Licence L6 in the Canning Basin, 105 kilometres east-southeast of Derby (Fig. 7). The field was discovered in May 1981, by Home Oil Australia with the drilling of Blina 1, which intersected two distinct reservoirs, namely the Upper Devonian (Famennian) Nullara Limestone and the Lower Carboniferous dolomitic Yellow Drum Formation. The development of vugs in these carbonate reservoirs has resulted in excellent permeability. A drill-stem test of the Nullara Limestone produced 35.7° API (American Petroleum Institute) oil at a rate of 144 kL/d (905 bbl/d) through a 12.7 mm (1/2") choke. A drill-

stem test of the Yellow Drum Formation produced 36.7° API oil at a rate of 5.7 kL/d (36 bbl/d). A total of eight wells have now been drilled in the field, four of which produced from the Nullara Limestone (1, 2, 3 and 5) and two from the Yellow Drum Formation (4 and 6). The other two wells did not intersect reservoirs. Blina 4 was subsequently re-completed and produced from the Nullara Limestone. The current operator of the field is Kimberley Oil NL.

Oil production from the Blina field commenced on 17 October 1983. At the time of writing, three wells, Blina 1, 4, and 5, were producing. Produced oil is gathered, separated and stored on site, until it can be transported by pipeline to the Erskine truck terminal on the Great Northern Highway. Details of the field are presented in Table 2.

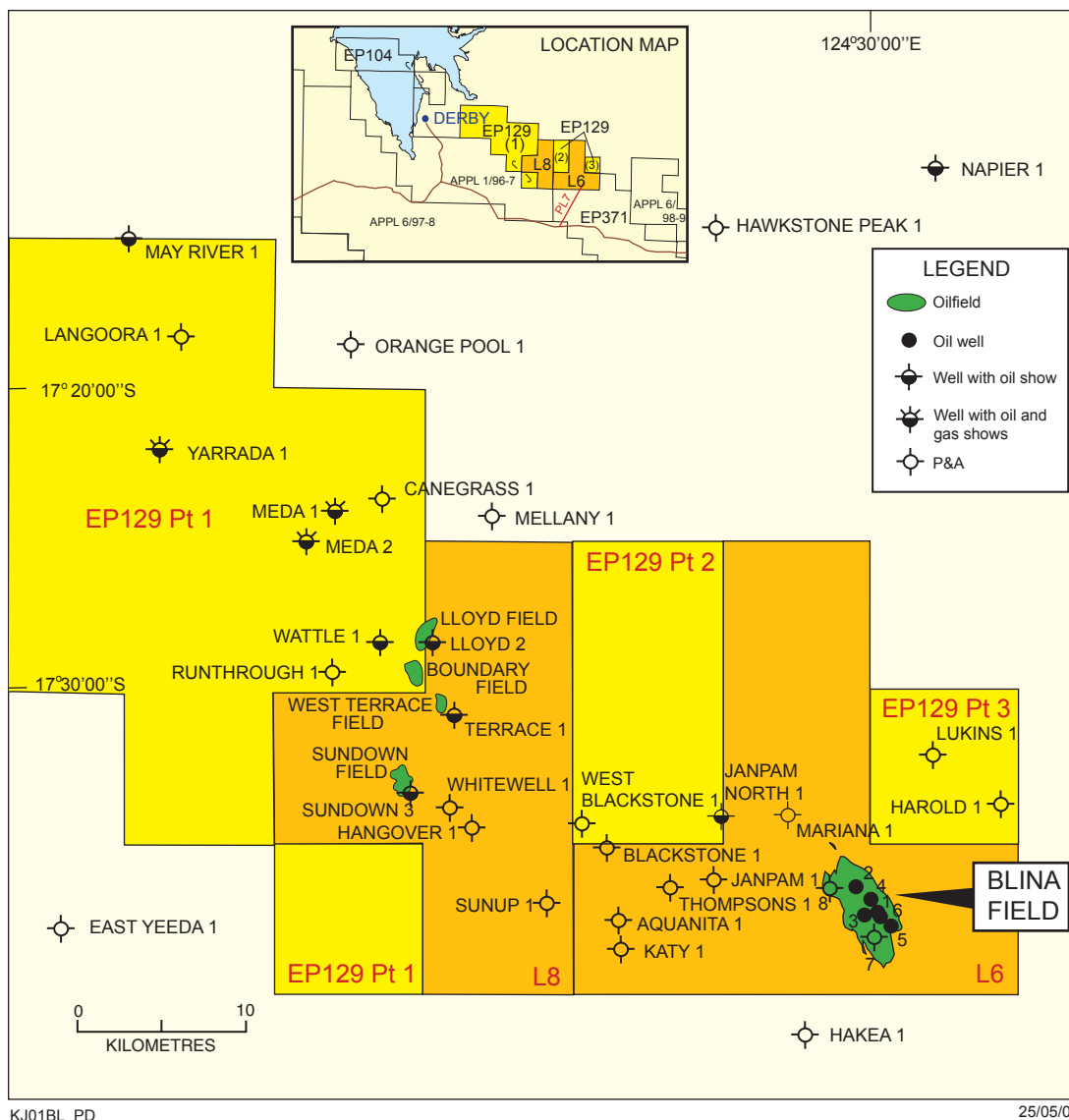


Figure 7. Location map, Blina oilfield

Table 2. Blina field summary

TITLE/LOCATION	
Permit/Licence	L6
Location	105 km southeast of Derby
Operator	Kimberley Oil NL (through its wholly owned subsidiary, Terratek Drilling Tools Pty Ltd) 86.6666%
Partner	Kanimbla Oil Pty Ltd 13.3334%
GEOLOGY	
Basin	Canning
Play type	structural, may be partly stratigraphic
Reservoir	Upper Devonian Nullara Limestone, Lower Carboniferous Yellow Drum Formation
Source	Givetian–Frasnian Gogo Formation
Seal	May River Shale Member (Gumhole Fm), intraformational shales of the Fairfield Group (Laurel Fm)
DISCOVERY WELL	
Blina 1	
Datum	GDA94
Latitude	17° 37' 21.44" S
Longitude	124° 30' 6.10" E
Permit	EP 129
Date	1981
KB elevation	62.2 m
Ground level	56.9 m
Total depth	2498.1 mKB (-2435.9 mSS)
Nullara Limestone	
Top reservoir	1438.0 mKB (-1375.8 mSS)
Gross pay	54 m
Net pay	unknown
Production test	
DST-3	
Choke size	12.7 mm
Interval	1402.1 to 1478.5 mKB (-1339.9 to -1416.3 mSS)
Flow rate (oil)	144 kL/d (905 bbl/d) 35.7° API
Yellow Drum Formation	
Top reservoir	1142.5 mKB (-1080.3 mSS)
Gross pay	7 m
Net pay	?7 m
DST-2	
Choke size	surface choke not reported
Interval	1160.0 to 1254.0 mKB (-1097.8 to -1191.8 mSS)
Flow rate (oil)	5.7 kL/d (36 bbl/d) 36.7° API
WELL STATUS	
No. of wells	8
Producers	3 (Blina 1, 4 and 5)
Suspended producers	3 (Blina 2, 3 and 6)
P&A	2 (Blina 7 and 8)
RESERVES (as at 30 June 2000)	
Oil	
Reserves produced	279 864 kL (1.76 MMbbl)
Reserves remaining	too small to measure, as currently developed
Daily production	
Maximum rate	132 kL/d (830 bbl/d)
Present rate	14.8 kL/d (93 bbl/d)

Stratigraphy

Reservoir

The primary reservoir of the Blina field is the Famennian (*G. lemurata*) Nullara Limestone, which consists of highly fractured cemented grainstones and packstones, deposited in a shallow-water carbonate platform environment. Initial depositional porosity was high; however, significant diagenetic alteration occurred and present day porosity is seen as fracture and leached vuggy porosity. A 58 m oil column is reseroired in an antiform structure within a prograding bank sequence. The Nullara reservoir consists of two main units: the upper partially dolomitised unit, which contains six producing zones, and the underlying pervasively dolomitised unit, which contains another four oil zones (Taylor, 1992).

A 9 m oil column is reseroired in dolomites of the Lower Carboniferous (*R. lepidophyta*) Yellow Drum Formation of the Fairfield Group. The dolomitised fine-grained sediments of the Yellow Drum Formation were deposited in a very shallow marine environment, with secondary porosity associated with the dolomitisation of the sediments. The carbonate units of this formation are generally thinner than in the Nullara Limestone and tend to be less fractured; hence secondary permeability, which is essential for sustained production, is less developed.

The Yellow Drum reservoir consists of a 10–12 m thick bed of highly porous and permeable dolomite, which lies in the middle of an approximately 110 m thick porous but tight dolomite unit. The entire unit was deposited in a shallow subtidal/intertidal/supratidal environment; however, the supratidal environment is not well represented in the Blina field (Moors et al., 1984). Permeability is related to significant vuggy porosity and is the result of leaching fossils, clasts and calcite pseudomorphs after gypsum (Blackburn, 1992a).

Seal

The Nullara accumulation is sealed by the May River Shale Member of the Gumhole Formation—a dolomitised tight marl. The Yellow Drum accumulation is sealed by intraformational permeability transitions above and below.

Source

Two regional source rock intervals exist in the Lennard Shelf, namely the Gogo and the

Laurel Formations. However, it is generally accepted that the source rocks for the hydrocarbons reseroired in both the Nullara Limestone and the Yellow Drum Formation are contained within the Givetian–Frasnian Gogo Formation, a basinal and intra-shelf marine facies of the Pillara reef complex (Cadman et al., 1993). The shales of the Gogo Formation contain marine algae deposited in a reducing anoxic environment. The hydrogen-rich kerogen formed in such an environment would produce large quantities of oil and gas, but no oil or source-rock characterisation is available for the formation (Crostellla, 1998). The source rocks probably reached maturity from the Mesozoic to the present over the shallow portions of the Lennard Shelf, where the Blina oilfield is found (Kennard et al., 1994a). The Gogo Formation is part of the Larapintine 3 Petroleum System, which covers the Lennard Shelf, the Barbwire–Jurgurra–Dampier Terraces and the Kidson Sub-basin.

Structure

The Blina field is situated on the Lennard Shelf, between the Devonian reefal outcrops fringing the Kimberley Block to the northeast, and the buried northern flank of the Fitzroy Trough to the southwest. The Blina 1 well was drilled to test a seismically defined reef structure, which later drilling and seismic data identified as a fault-controlled anticlinal ‘flower’ structure superimposed on the Devonian reef (Fig. 8). The ‘flower’ structure is interpreted to be related to major strike-slip movement along pre-existing deeper faults. Two trends of faults are interpreted: one oriented west-northwest and the other, north-northwest. These faults caused fracturing of the Nullara Limestone, which resulted in increased vertical permeability; hence, a relationship between proximity of the reservoir to the main strike-slip faults, and production, is evident. The structure was further enhanced during the Late Carboniferous when a period of major subsidence and compression occurred. Late reactivation during the Miocene enhanced the relief of the Blina anticline and resulted in the present-day feature. Figures 9 and 10 illustrate the structure of the Yellow Drum and Nullara reservoirs, respectively.

Reservoir description

Two reservoirs are present in the Blina oilfield; the shallower reservoir is located within the Yellow Drum Formation, and the deeper one is located at the top of

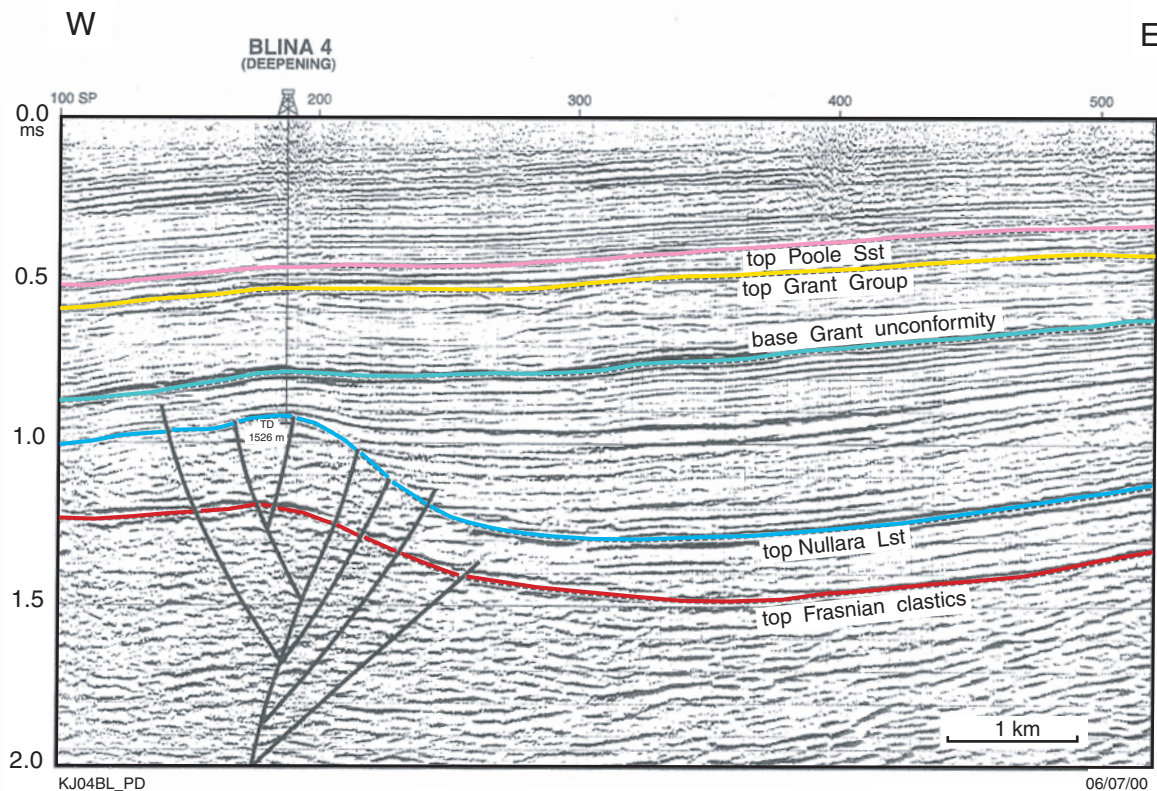


Figure 8. Seismic section BV93-17, showing positive flower structure across the Blina oilfield (after Crostella, 1998, modified from Robinson and Roche, 1994a)

the Nullara Limestone. The Yellow Drum Formation consists predominantly of very finely crystalline to microcrystalline, sucrosic dolomite and recrystallised, slightly to moderately dolomitic limestone, with minor interbeds of shale, especially towards the base. The Yellow Drum is a fractured reservoir and oil accumulated in fractures, vugs and intercrystalline porosity. The oil/water contact is not well defined.

The Nullara Limestone consists of recrystallised limestone and dolomite. The limestone is microcrystalline, occasionally cryptocrystalline, in parts slightly dolomitic and pyritic. The dolomite is micro- to very finely crystalline, partly sucrosic, calcareous, and slightly pyritic. The Nullara Limestone is a fractured reservoir with low porosity and permeability. The oil is contained in fractures, vugs and matrix porosity. The Nullara Limestone has been divided into three zones: a lower, essentially tight limestone unit; a middle, dominantly dolomitic unit; and an upper limestone unit with possibly correlatable dolomite zones.

Both reservoirs have active water drives.

Fluid migration, diagenesis and hydrocarbon entrapment

Blina is essentially a Famennian carbonate reefal structure; the Nullara Limestone back-reef facies providing the main reservoir discovered to date for oil accumulation. Hydrocarbon migration is believed to have occurred from deeply buried mature Gogo Formation source rocks in the Fitzroy Trough via northwest-trending transfer faults into the fractures in the Nullara Limestone. These faults were caused by the Mid-Late Carboniferous Meda Movement event, and migration into the available reservoirs has occurred over long distances since that time.

Dolomitic cycles represent periods of near subaerial exposure due to eustatic changes. Diagenetic alteration of a shallow subtidal to supratidal lime mudstone sequence resulted in the dolomitic Yellow Drum Formation. Early and rapid calcite cementation has reduced primary porosity. The remaining vuggy porosity is mainly due to leaching of large skeletal fragments by sulphide rich brines. The dolomite zones within the Upper Limestone Unit are related to pre-existing neptunian dykes and sills preferentially dolomitised and reactivated many times over (Carter et al., 1993).

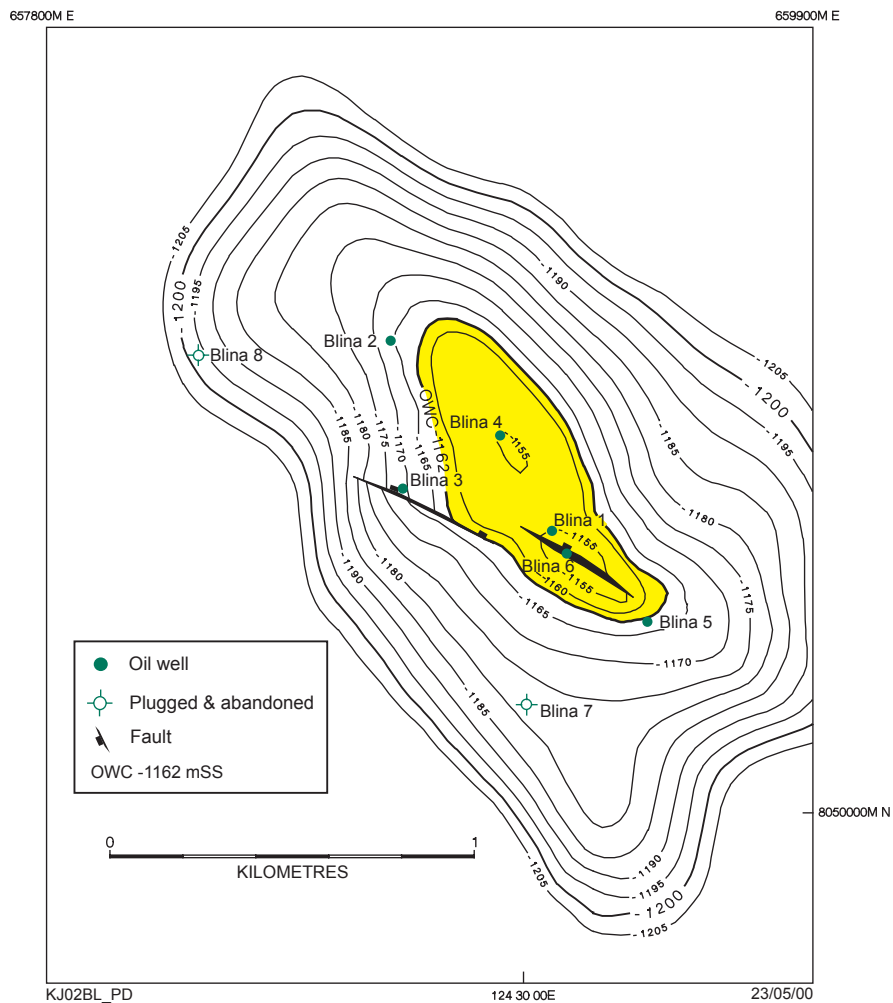


Figure 9. Depth structure map, top Yellow Drum reservoir (after Capital Energy NL, 1998)

Above the interpreted oil/water contact at -1430 mSS, the presence of oil is linked to secondary porosity development and, as such, oil migration is believed to have occurred either simultaneously with the development of secondary porosity, or shortly thereafter.

Permeability is secondary and is the result of fracturing related to the Meda Movement. Major subsidence in the Mid Carboniferous and strong compression along the Lennard Shelf edge would have resulted in refracturing of pre-existing dykes providing additional fluid conduits. This would allow access to both dolomitising fluids from the dewatering of basinal shelves, as well as oil and sulphide rich brines (Carter et al., 1993).

The Blina oil shows no signs of biodegradation, but may have been exposed to meteoric water at some stage of its post-pooling history. Hydrocarbon entrapment mechanisms within the Meda Embayment appear to have a strong stratigraphic component. The

major plays involve the Frasnian reef complex over which the Nullara Limestone is draped, with the Nullara seen as a secondary objective:

- the reef itself, to date not sharply imaged by the sparse seismic coverage, and penetrated by 10 wells over a reef trend length of over 200 km;
- the fore reef section, not yet tested by the drill;
- the subreef unconformity play: a section of Frasnian clastics, 250 m thick in Blina 1, was marked throughout (from the base of the reef to total depth) by strong gas activity on the mudlog. Blina 1 was the only Blina well to penetrate the reef and test the subreef section;
- the deep gas play, a series of huge four-way dip closures in probable Ordovician section marked by frequent DHIs (Direct Hydrocarbon Indicators) such as flat spots and phase changes.

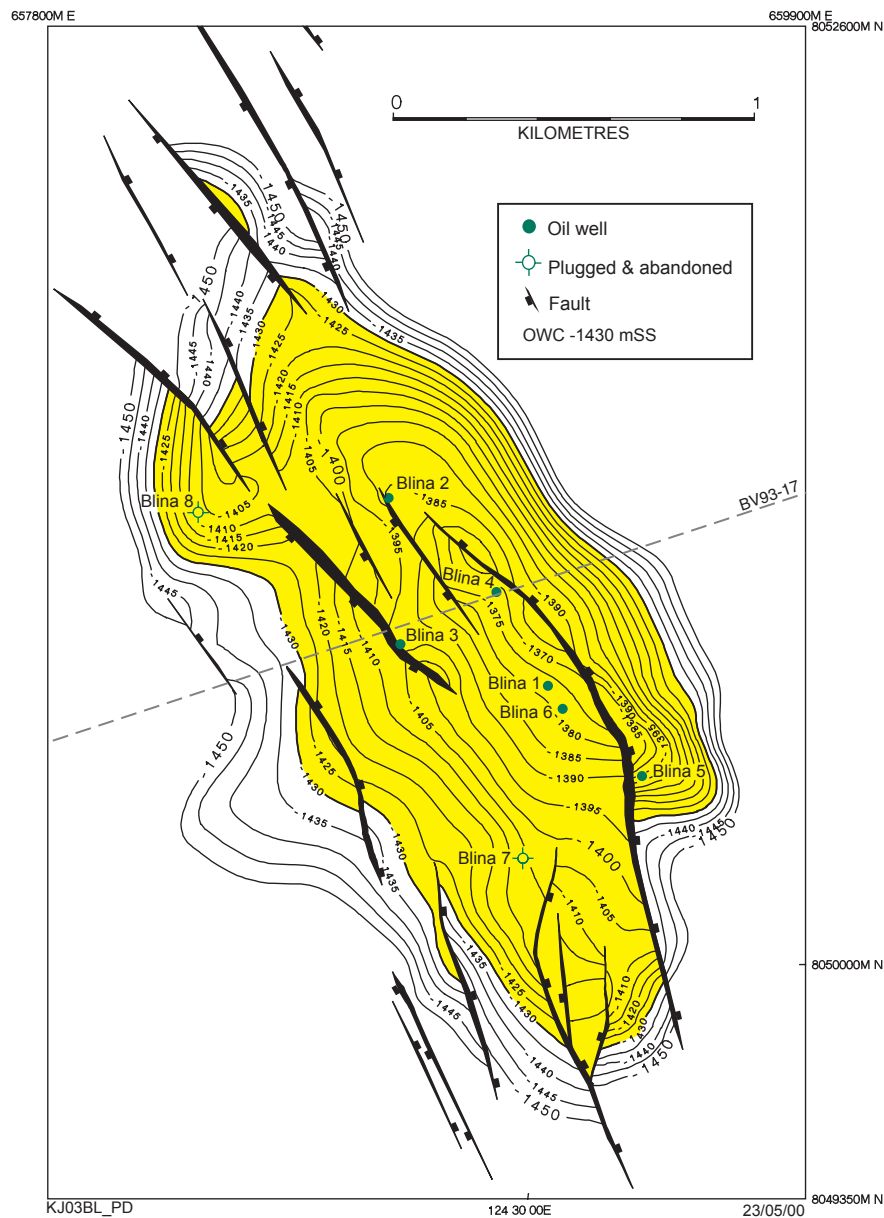


Figure 10. Depth structure map, top Upper Limestone unit, Nullara Formation (after Capital Energy NL, 1998)

Reservoir properties

Oil is produced from a 10 m thick dolomitic interval in the Yellow Drum Formation. Core analyses results indicate that the Yellow Drum Formation has relatively high porosity (average 22%). Log-derived porosities range up to 29%. The estimated average horizontal permeability is 211 millidarcies (md), however vertical permeability is restricted. Average water saturation derived from logs is 25–30%.

The Nullara Limestone has low porosity (10%) and the estimated water saturation derived from logs is 25–30%, while the average reservoir permeability is

23.3 md. Porosity and permeability are poor, but several fractures are evident. Reservoir water cut is over 98%.

The reservoir properties, consisting of log-interpreted porosity and water saturation, core porosity and permeability, and net and gross oil pay, for the Yellow Drum and Nullara reservoirs for the wells in the Blina field are listed in Table 3. The parameters used in the water saturation determinations are listed in Table 4. An interpretation of the wireline logs over the Yellow Drum reservoir and the Nullara Limestone reservoir in Blina 1 is illustrated in Figures 11a and 11b, respectively.

Table 3. Hydrocarbon reservoir thickness and quality, Blina field

Well name	Hydrocarbon column		Porosity (%)		Permeability (md)	Sw (%)
	Gross (m)	Net (m)	Log	Core		
Blina 1						
Yellow Drum Fm	7	?7	18.0	–	6.6	42.0
Nullara Limestone	54	unknown	4.2	–	14.7	52.0
Blina 2						
Nullara Limestone	47	unknown	6.0	6.0	21.9	29.8
Blina 3						
Nullara Limestone	37	unknown	8.9	5.3	1.2	45.7
Blina 4						
Yellow Drum Fm	7	?7	22.9	22±5	422.0	56.3
Nullara Limestone	58	unknown	–	–	–	–
Blina 5						
Nullara Limestone	32	unknown	9.1	–	–	–
Blina 6						
Yellow Drum Fm	9	?9	28.0	5.2	0.04	71.5

NOTE: Hydrocarbon column data from R.F. Reiser (pers. comm., 2000). Other data sourced from Jursa (1997) and Reservoir Engineering Analysis of the Blina 1 well completion report.

Table 4. Parameters used in saturation determination, Nullara Limestone dolomitic unit—zone 4, Blina field

Formation water resistivity (Rw)	0.75 ohm at 71°C (avg)
"m"	2.15
"n"	0.19
"a"	1.00

Hydrocarbons

Properties

The oils from the Yellow Drum Formation and Nullara Limestone are believed to have been generated from the same source rock, the shales of the Givetian–Frasnian Gogo Formation. The Yellow Drum oil is composed of 86.7% saturates, 11.3% aromatics, and 2.0% NSO (nitrogen/sulphur/oxygen) compounds. The Nullara oil is composed of 88.3% saturates, 10.2% aromatics, and 1.5% NSO compounds. Both

oils are paraffinic crudes, with an API gravity of around 36°, and essentially similar in composition, being low in sulphur (0.04%) and rich in saturate compounds, suggesting that they have probably been derived from a very hydrogen-rich kerogen. Such a kerogen would produce large quantities of oil and very little gas (Playford, 1982).

The pristane/phytane ratios (0.6) suggest that the oils have been derived from organic matter deposited in an extremely reducing environment. The input of high-wax compounds is very small; hence, these

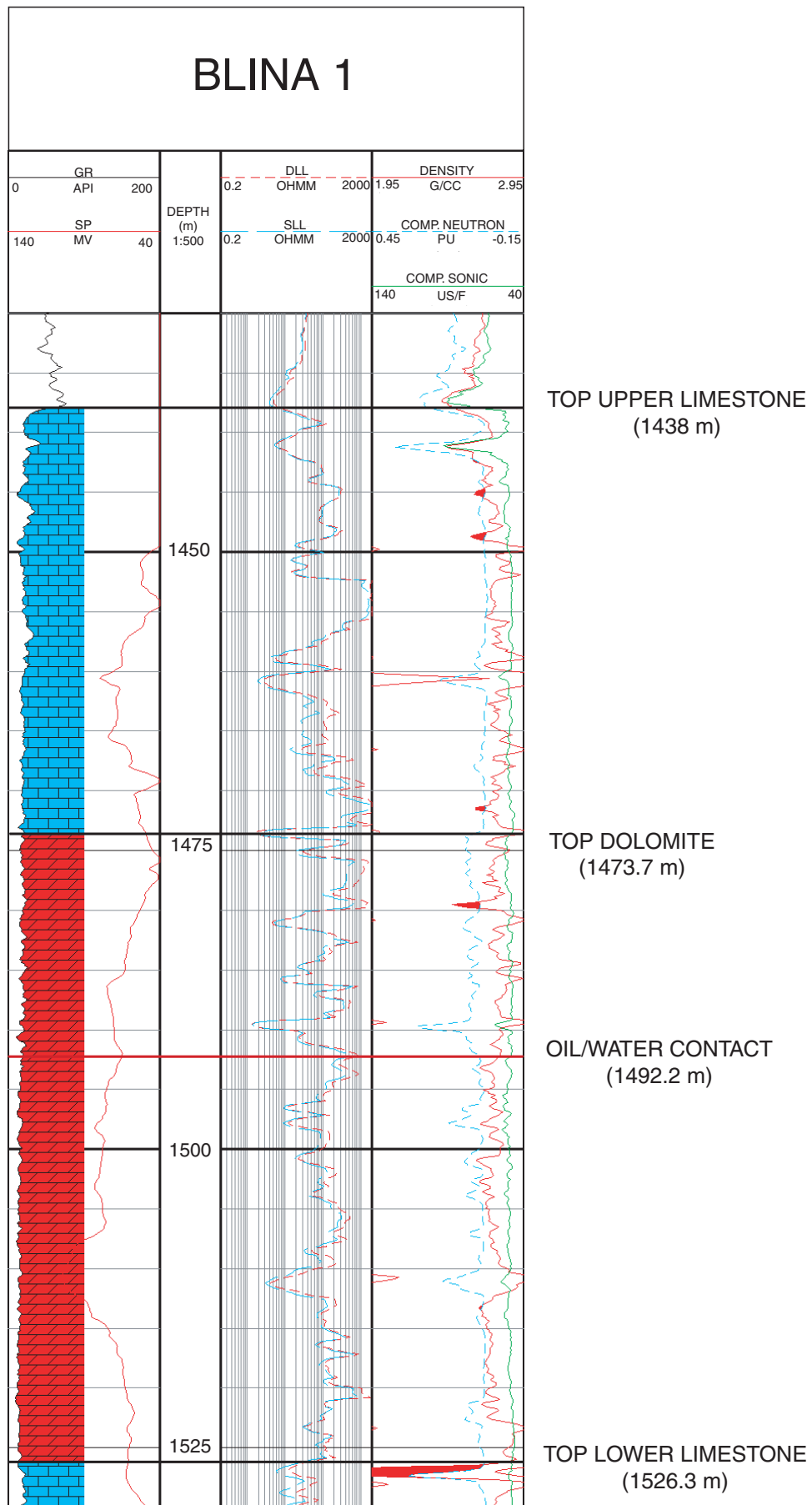


Figure 11b. Interpreted wireline logs over the Nullara Limestone reservoir, Blina 1

crudes are probably from a marine organic source (ie. algae or phytoplankton).

The fluid parameters of the hydrocarbons reservoid in the Yellow Drum Formation and Nullara Limestone are summarised in Table 5.

Reserves

The Yellow Drum reservoir has a maximum gross oil column of 9 m down to an oil/water contact at -1162 mSS (Fig. 8). The Nullara Limestone reservoir has a maximum gross hydrocarbon column of 58 m down to an oil/water contact at -1430 mSS (Fig. 9). The reservoir tops and the original interpreted fluid contacts for each well are listed in Table 6.

The 1998 original oil reserves (DME) were estimated at 278 000 kL (1.74 MMbbl). The produced reserves for the Blina oilfield, as of 30 June 2000, are 279 864 kL (1.76 MMbbl) of oil. The remaining reserves of the field as currently developed are too small to measure. Acid stimulation has been used to enhance production (Crostella, 1998).

Field history

Blina 1, the discovery well for the Blina field, was

drilled 105 km southeast of Derby in April–June 1981, by Home Oil Australia Ltd in onshore Exploration Permit EP 129, to test a seismically defined reef feature. The well intersected two reservoirs. Drill-stem testing of the Yellow Drum Formation flowed 5.7 kL/d (36 bbl/d) 36.7° API oil over the interval 1160–1254 mKB through a 12.7 mm (1/2") choke. Another drill-stem test of the Nullara Limestone flowed 144 kL/d (905 bbl/d) 35.7° API oil over the interval 1402.1–1478.5 mKB.

Following the Blina discovery, two appraisal/development wells, Blina 2 and 3, were drilled into the Nullara reservoir. They were spudded on 1 October and 21 November 1981, respectively, and completed as oil producers from the Yellow Drum and Nullara intervals in January 1982. Blina 2 is situated 680 m northwest of Blina 1. The Blina 3 well, located 442 m west-northwest of Blina 1, confirmed the oil/water contact in the Yellow Drum and established the oil/water contact in the Nullara Limestone at -1430 mSS. Blina 4 was spudded on 10 April 1982, to test the Yellow Drum interval only, and was completed as an oil producer. Blina 4 was shut-in in September 1987 and was deepened in November–December 1993 by Minora Energy (Australasia) Pty Ltd. Blina 4 initially produced from the Yellow Drum Formation at rates of 10.3–14.8 kL/d (65–93 bbl/d). The deepening

Table 5. Hydrocarbon fluid and reservoir parameters, Blina field

	<i>Yellow Drum reservoir</i>	<i>Nullara reservoir</i>
Structural crest	-1152 mSS	-1363 mSS
Lowest closing contour	-1205 mSS	-1515 mSS
Oil/water contact	-1162 mSS	-1430 mSS
Max gross pay	9 m	58 m
Net pay	?100%	unknown
Area at oil/water contact	0.3 km ²	1.8 km ²
Volume (gross rock)	1.5 million m ³	54 million m ³
Water saturation	25–30%	25–30%
Porosity	22%	10%
Permeability	0.1 md	23.3 md
Oil formation volume factor	1.06 RB/stb	1.09 RB/stb
Oil density	not reported as distinct for each reservoir	
Oil gravity	36.7° API	35.7° API
Oil bubble point	2000 kPa (290 psig)	2275 kPa (330 psig)
Temperature	65.5°C	97°C
Initial pressure	11 307 kPa (1640 psig)	14 202 kPa (2060 psig)
Drive mechanism	water drive	water drive

Table 6. Reservoir horizons and fluid contacts, Blina field

Well	Blina 1	Blina 2	Blina 3	Blina 4	Blina 5	Blina 6	Blina 7	Blina 8
<i>Nullara Limestone reservoir</i>								
Top Upper Limestone	1438.0 (mKB) -1375.8 (mSS)	1443.8 -1383.0	1454.3 -1393.5	1432.0 -1372.0	1460.1 -1398.5	-	1475.3 -1413.5	1467.0 -1405.0
Top Dolomite	1473.7 -1411.5 (mKB) (mSS)	1472.3 -1411.5	1478.2 -1417.4	1463.0 -1403.0	1504.1 -1442.5	-	1497.8 -1436.0	1500.1 -1438.1
Top Lower Limestone	1526.3 -1464.1 (mKB) (mSS)	1520.8 -1460.0	1528.3 -1467.5	1506.0 -1446.0	1567.6 -1506.5	-	-	1520.1 -1458.1
<i>Yellow Drum reservoir</i>								
Top Yellow Drum Fm	1142.7 -1080.5 (mKB) (mSS)	1149.8 -1089.0	1152.3 -1091.5	1140.4 -1080.4	1170.6 -1109.0	1160.6 -1100.0	1182.8 -1121.0	1181.0 -1119.0
Top Dolomite	1174.2 -1112.0 (mKB) (mSS)	1183.8 -1123.0	1186.8 -1126.0	1171.0 -1111.0	1180.6 -1119.0	1169.6 -1109.0	1194.8 -1133.0	1214.0 -1152.0
Top Dolomite porosity	1216.8 -1154.6 (mKB) (mSS)	1226.8 -1166.0	1229.3 -1168.5	1215.0 -1155.0	1224.6 -1163.0	1212.6 -1152.0	1224.8 -1163.0	? ?
Base Dolomite porosity	1227.0 -1164.8 (mKB) (mSS)	1236.8 -1176.0	1241.3 -1180.5	1225.4 -1165.4	1234.6 -1173.0	1222.1 -1161.5	1248.8 -1187.0	? ?
Status	Producer	Suspended producer	Suspended producer	Producer	Producer	Suspended producer	P&A	P&A

NOTE: Field oil/water contact for the Nullara reservoir is -1430.0 mSS; field oil/water contact for the Yellow Drum reservoir is -1162 mSS.

was designed to test the productivity of the Nullara Limestone and the primary target was the Nullara Dolomite zone, which is a proven producer in Blina 2 and 3.

Blina 5, located 365 metres southeast of Blina 1, was drilled in June 1985, with primary targets the Yellow Drum Formation and Nullara Limestone, to test seismically mapped extension to the field. Shows were encountered and producible oil was found in the Nullara, but the Yellow Drum Formation was tight. Blina 6 was drilled 75 metres southeast of Blina 1 in July 1985, to test and boost production from the Yellow Drum reservoir only, successfully supplementing production from Blina 4.

Blina 7, drilled in November 1987, lies approximately 425 metres southwest of Blina 1. Hydrocarbon shows were encountered in the Yellow Drum Formation, but drill-stem testing showed the formation to be tight. The principal objective, the Nullara Limestone, was considered to have no reservoir (porosity being very low), while in the Yellow Drum Formation, porosities were high, however permeability was negligible. The well was plugged and abandoned.

In July 1990, Petroleum Securities Energy Ltd drilled Blina 8, approximately 500 metres west of Blina 2. The well reached a total depth of 1550 m but did not encounter any hydrocarbons. Blina 8 was plugged and abandoned due to poor reservoir development in the Nullara Limestone.

Gathering, separating and storage facilities were completed in September 1983, 30 kilometres southwest of the Blina field. Oil is transported via pipeline to the Erskine receiving terminal on the Great Northern Highway and then trucked to Broome. It is then taken by sea-tanker to the Kwinana refinery, south of Perth. Production of the Blina field officially commenced on 17 October 1983, at an initial rate of 160 kL/d (1000 bbl/d).

Pump failure at the end of 1999 stopped production from Blina 4, which was averaging 6.8 kL/d (43 bbl/d) before it was shut-in. The well came back online in May 2000. The production history of the Blina oilfield is shown in Figure 12.

Future plans

The Blina field, as currently developed, is nearing the end of its commercial life. However, there appears to be an anomaly in the restricted and highly selective

zones of perforations in an oil column of 58 m. For example, Blina 1 has a gross oil column of 54 m and perforations over only 12 m in four widely separated zones; Blina 2, with 48 m of gross oil column has 7 m of perforations in three separate zones. Blina 2 and 3 have been extensively cored in the oil column, and the results of log analysis, core analysis, DSTs, and production tests prove that reservoir performance is impossible to predict. The unpredictable results provide further evidence to support the conclusion (see “Structure” above) that there is a system of vertical, or near vertical, fractures that is undetectable by logs or conventional cores.

The combination of highly variable reservoir development, vertical fracturing, and limited perforations through a 58 metre oil column leads to the conclusion that there is considerable by-passed oil in the reservoir — as much as 0.9 GL (6 million barrels) in place (Reiser, R. F., 2000, pers. comm.). This will be best produced via horizontal or near horizontal drilling, using the well bores of the inactive flank wells, Blina 7 and 8. The operator plans to drill these wells to the northeast, perpendicular to the major fault trend and presumably, to the trend of fracturing.

In addition, several of the seismic lines over the field have been reprocessed, one to the stage of pre-stack depth migration, in order to refine the depth mapping.

Blina field oil production

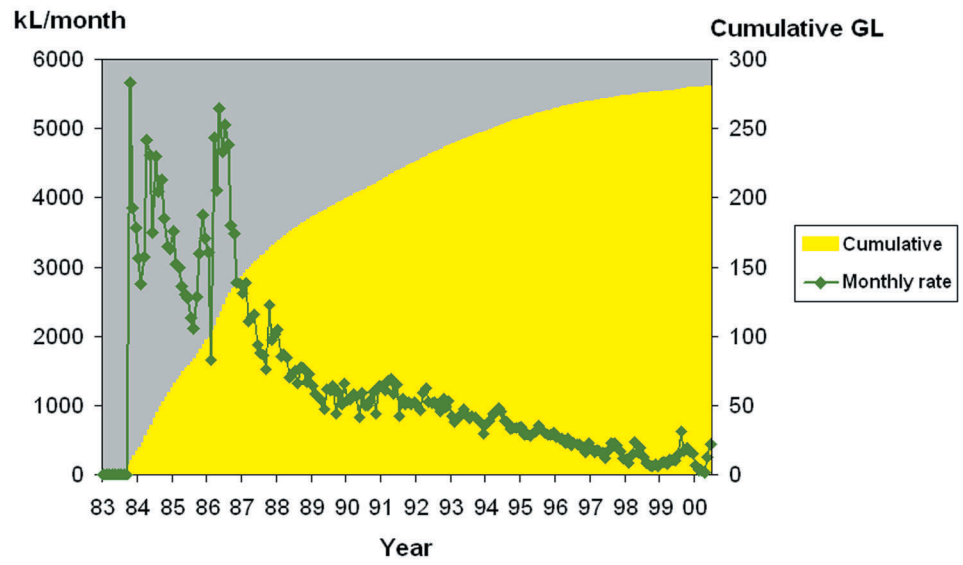


Figure 12. Production history, Blina oilfield