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Australian Petroleum Accumulations Report 10

Perth Basin, Western Australia

S. J. Cadman, L. Pain and V. Vuckovic
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Cover : View of Mount Horner, Western Australia, and the Mount Horner-5 well. Photograph : Arthur Mory.

Other reports in the Australian Petroleum Accumulations series are :

1. Amadeus Basin, Northern Territory, 1986
2. Bass Basin, Victoria and Tasmania, 1987
3. Gippsland Basin, Victoria, 1987
4. Adavale Basin, Queensland, 1988
5. Bonaparte Basin, Northern Territory and Western Australia, 1989
6. Otway Basin, Victoria and South Australia, 1990
7. Browse Basin, Western Australia, 1991
8. Carnarvon Basin, Western Australia, 1993
9. Canning Basin, Western Australia, 1993
11. Bowen and Surat Basins, New South Wales and Queensland and other Australian Basins (in preparation)
12. Cooper and Eromanga Basins, South Australia and Queensland (in preparation)

FOREWORD

This report on the Perth Basin, Western Australia, is the tenth in the Australian Petroleum Accumulation Series. The series presents data on Australia's identified petroleum resources, together with an appraisal of their geological setting, hydrocarbon habitat and characteristics. In the case of commercial accumulations, details of their size, development and production history are included.

The APA database, on which this series is based, was developed in cooperation with petroleum companies and State and Northern Territory Mines Departments. It is linked to PEDIN, the publicly available petroleum exploration information database maintained jointly by the Bureau of Resource Sciences and the Australian Geological Survey Organisation.

To date, twenty hydrocarbon discoveries have been made in the Perth Basin, the most significant of which are located near the Dongara Saddle, on the western margin of the Dandaragan Trough. Future onshore exploration in the basin will no doubt continue to focus on the northern Dandaragan Trough. Offshore, the Vlaming and Abrolhos Sub-basins remain sparsely explored. Here, a number of significant discoveries and shows indicate these areas hold considerable potential for further hydrocarbon discoveries. The information compiled in this report makes valuable reading for petroleum explorers interested in evaluating this important petroleum producing basin.

Paul E. Williamson
Director
Petroleum Resources Branch
Bureau of Resource Sciences

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ABSTRACT

As at March 1994, twenty petroleum accumulations (including the recent Arranoo discovery), have been discovered in the Perth Basin. Nine of these discoveries have proved to be commercial. All commercial discoveries lie onshore in the Dandaragan Trough/Dongara Saddle area. Oil and gas is produced from Jurassic coal sequences within the Cockleshell Gully Formation, from Triassic sandstones within and underlying the Kockatea Shale and from the Late Permian Wagina Sandstone. Commercial quantities of gas have also been produced from the Permian Carynginia Formation and the Irwin River Coal Measures.

The largest accumulation discovered to date is at Dongara. Here, the original gas in place has been estimated at 430 billion cubic feet and the original oil in place at 1.107 million barrels (WADME, 1992). Oil from the producing fields is trucked to the BP refinery at Kwinana, south of Perth, while gas is produced via spur lines into the Dongara-Perth pipeline.

Offshore, hydrocarbons have been recovered from a number of wells in the Vlaming and Abrolhos Sub-basins. These areas remain underexplored and many of the petroleum plays have yet to be adequately tested. In the southern Perth Basin, gas has been recovered from Permian coal sequences within the Bunbury Trough. Wells drilled in this sub-basin have so far failed to intersect good quality reservoirs, source rocks or competent regional seals.

1. INTRODUCTION

This report contains technical data on the twenty petroleum accumulations discovered in the Perth Basin to March 1994. It summarises the evolution of the basin, stratigraphy, exploration history, hydrocarbon habitat and development of the commercial accumulations.

A discrete, measured recovery of hydrocarbon during a well test qualifies an accumulation for inclusion in the Australian Petroleum Accumulations (APA) database. Where available on open file, test results from the discovery well are listed in the database. A copy of the database accompanies this report (6. Hydrocarbon accumulation summaries). Petroleum accumulations inferred from wireline log data but not tested are excluded. Fluorescence and high gas chromatograph readings recorded while drilling wells are included in a tabulation of hydrocarbon shows.

Hydrocarbon accumulations are classed as commercial if production has occurred or development plans have been announced by the operator(s). The category 'other discovery' covers any other accumulation.

2. BASIN SUMMARY

2.1 Basin Setting

The Perth Basin is an elongate, north-south trending trough underlying approximately 100 000 square kilometres of the Western Australian margin between Geraldton and Augusta. Slightly more than half the basin lies offshore in water depths of up to 1000 m (Figure 1).

To the north, the basin is bounded by the Northampton block. This Precambrian basement high separates the Perth Basin from the Carnarvon Basin. The eastern margin of the Perth Basin is defined by the Darling Fault - a north-south trending fault with up to 15 kilometres of displacement on the western downthrown side (Jones, 1976). Here, sediments shed from the Western Australian Shield into the downthrown half-grabens and grabens are juxtaposed against the granites and gneisses of the Precambrian Yilgarn Block.

In the northern Perth Basin, the most important depocentre adjacent to the Darling Fault is the Dandaragan Trough. Up to 15 000 m of Silurian to Cretaceous sediments were deposited in this half-graben in response to rifting, which began in the Early Permian and culminated in the final separation of India and Australia in the Neocomian. To the west, the Dandaragan Trough is flanked by series of north-south trending detachment faults and a ridge of relatively shallow basement (Beagle Ridge).

To the south, the Harvey Ridge, another shallow basement feature, extends obliquely northwest from the Darling Fault and separates the Dandaragan Trough from the Bunbury Trough. The latter is a deep graben in the southern Perth Basin which shallows to the south and probably contains in excess of 10 000 m of Permian to Cretaceous sediments (Playford and others, 1976). These sediments were shed from the adjacent Yilgarn Block to the east and possibly, to a lesser extent, from a narrow belt of Proterozoic granulite and gneiss between Capes Leeuwin and Naturaliste termed the Leeuwin Block.

Offshore and en echelon to the structural lows of the onshore Dandaragan and Bunbury Troughs lie the Vlaming Sub-basin (to the south) and the Abrolhos Sub-basin (to the north). The limits of the Vlaming Sub-basin are ill-defined. Tectonism in the Late Jurassic and Early Cretaceous caused large scale axial basin arching (Jones, 1976). East of this mid-basin arch, sediments thicken into the Dandaragan Trough. Westward, sediments thicken into the Vlaming Sub-basin. It is possible that a northwest extension of the Precambrian Leeuwin Block and a fault system extending southwest from the Edward's Island Block, merge to form the western boundary of the Vlaming Sub-basin (Jones, 1976). The sedimentary sequence in the Vlaming Sub-basin is notable for its thick (up to 11 000 m) Lower Cretaceous section.

The major structural feature of the northern offshore Perth Basin is the Abrolhos Sub-basin. This sub-basin plunges and opens to the north-northwest and probably developed contemporaneously with the Dandaragan Trough. It is bounded to the east by the Precambrian Northampton Block and to the southeast by the Beagle Ridge. Between these two basement highs lies the Dongara Saddle. To the southwest, the

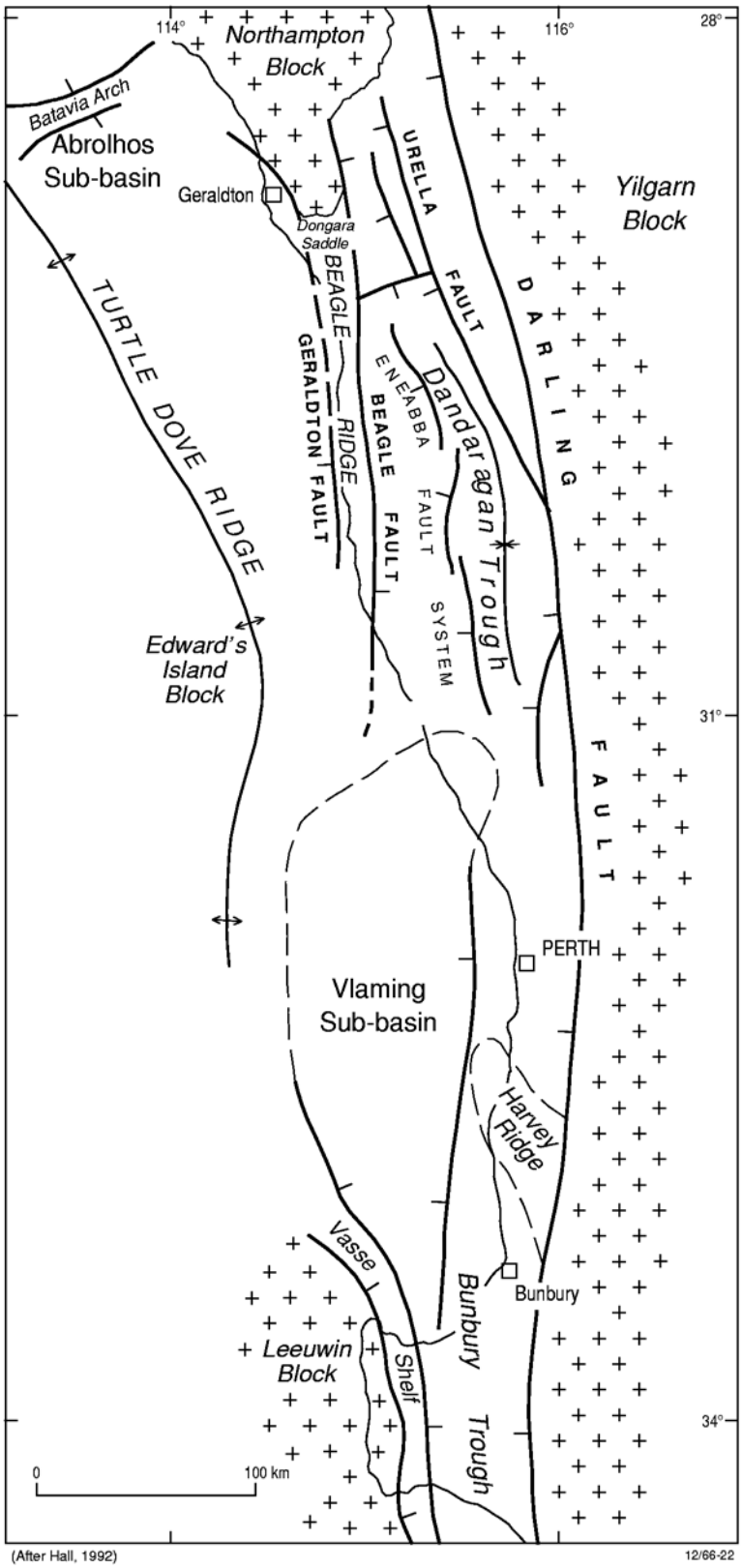


Figure 1 TECTONIC ELEMENTS, PERTH BASIN, WA.

Abrolhos Sub-basin is bounded by the Turtle Dove Ridge - a shallow basement feature, which lies along the edge of the continental shelf. The northern boundary of the sub-basin with the Carnarvon Basin is usually taken as being the Batavia Arch.

2.2 Basin Evolution and Stratigraphy

Sedimentation in the Perth Basin began in the Late Ordovician to Silurian when, in the far north of the basin, in a structural low adjacent to uplifted Precambrian basement, the fluviatile Tumblagooda Sandstone was laid down (Figure 2). No sediments of Devonian or Carboniferous age have yet been found in the Perth Basin.

By Early Permian times, the initial phases of rifting had established a north-south trending trough down the axis of the basin. In the north, this trough was initially filled by a coarse, tillitic boulder conglomerate (Nangetty Formation) which was then followed by a marine shale (Holmwood Shale). A regression in the Artinskian saw the deposition of shallow marine sands followed by a fluviatile and paludal coal measure sequence (Irwin River Coal Measures) over much of the northern Perth Basin (Playford & others, 1976). When shallow marine conditions returned in the Late Artinskian, shales, siltstones and carbonates with thin, interbedded sandstones (Carynginia Formation) were deposited in this area.

In Late Permian times, after uplift and some erosion of the Artinskian and older sequences, an alluvial fan delta system spread westward from the Darling Fault into the northern Perth Basin (Wagina Sandstone). Sediment was supplied from uplifted areas to the east and northeast of the Darling Fault with minor contributions from the Northampton Block and possibly the eastern flank of the Beagle Ridge (Bergmark & Evans, 1987). Although the Wagina Sandstone has a limited areal distribution, it is an important hydrocarbon producing reservoir in the Dongara Saddle area. In the southern Perth Basin, a fluviatile to coal-swamp depositional environment prevailed throughout most of the Permian and into the Early Triassic (Sue Coal Measures).

By the Early Triassic the rifting that had commenced in the Late Palaeozoic had established a series of en echelon rifts and shallow basement highs in the northern Perth Basin (Marshall & others, 1989). A relative rise in sea level at this time gave rise to a widespread marine transgression into the basin from the north. Basal Triassic transgressive sandstones are widely distributed throughout the northern Perth Basin. They were deposited in a number of environments ranging from fluvial to shallow marine and form commercial hydrocarbon reservoirs in the Dongara Saddle area.

Continued subsidence associated with major movements on the Darling and Urella Faults in the Early Triassic saw the deposition of the Kockatea Shale (a transgressive marine sequence of black shale, siltstone and fine sandstone) over much of the northern Perth Basin. In the south, continental sedimentation continued in the Bunbury Trough (Sabina Sandstone) and gradually spread northwards, until by Middle Triassic times, fluviatile sedimentation prevailed throughout most of the basin (Lesueur Sandstone).

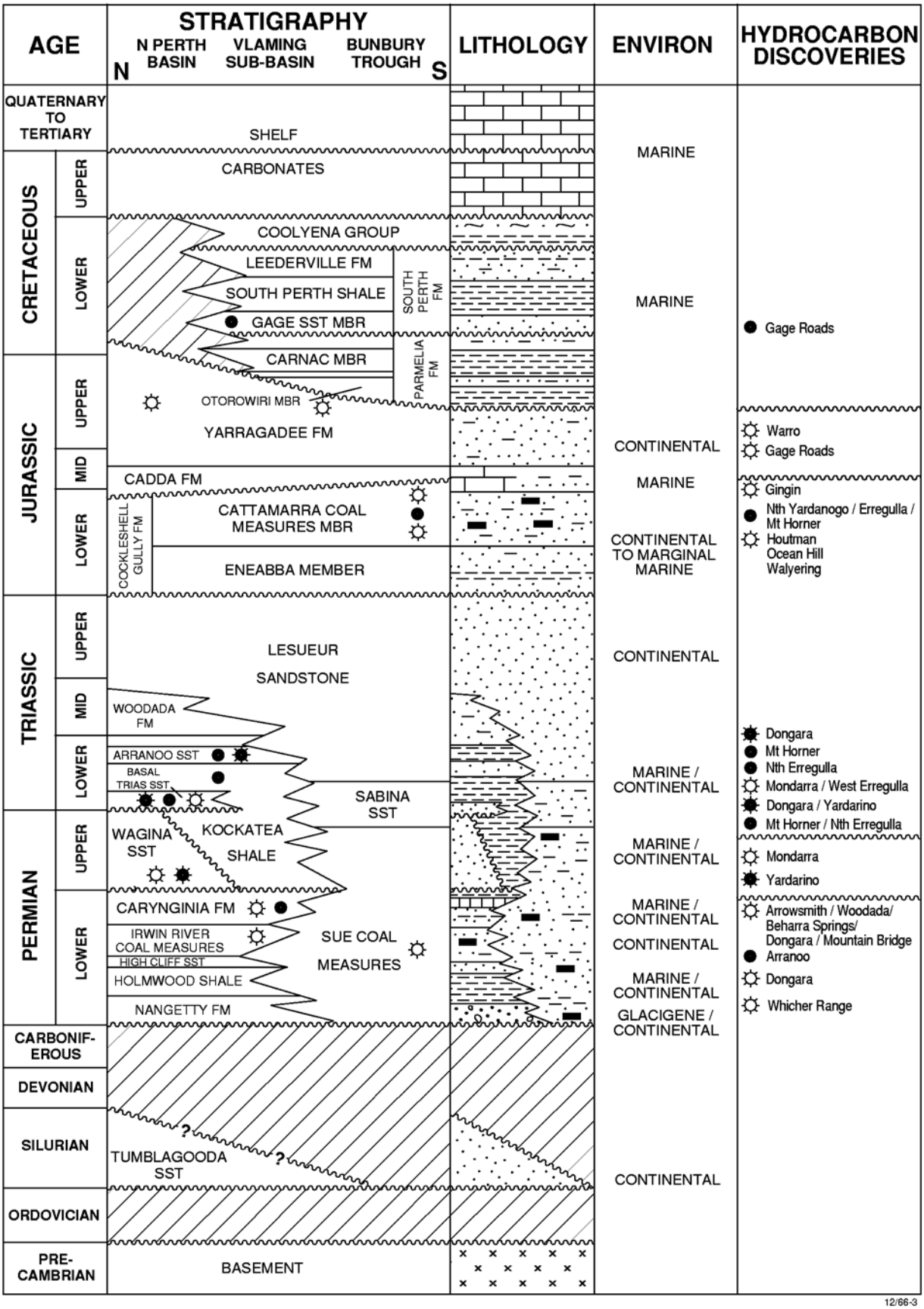


Figure 2 GENERALISED STRATIGRAPHY AND PETROLEUM ACCUMULATIONS, PERTH BASIN, WA.

Movement on the Darling and Urella Faults continued without significant interruption from Middle Triassic to middle Neocomian times (Playford & others, 1976). Large volumes of fluviatile sediments were shed into the half grabens and troughs adjacent to these fault scarps. In the Early Jurassic, a thick sequence of alluvial coal-bearing sandstones, claystones, siltstones and shales (Cockleshell Gully Formation) was deposited in the subsiding Dandaragan Trough, Bunbury Trough and Abrolhos Sub-basin. This was followed by a brief marine transgression in the northern Perth Basin which drowned the Cockleshell Gully coal swamps and deposited the marine shales of the Cadda Formation over much of this area. In the central and southern Perth Basin, the Cadda Formation becomes arenaceous and non-marine.

Major rifting with associated faulting occurred on the Urella and Darling faults in the Middle Jurassic. This tectonic episode corresponds to the main Gondwanaland breakup event in the Carnarvon Basin during the Oxfordian (Hall & Kneale, 1992). Large quantities of coarse, poorly sorted sand derived from the elevated Yilgarn Block to the East were subsequently shed into the subsiding grabens and troughs of the Perth Basin (Yarragadee Formation). Over 4000 m of Yarragadee Formation sandstones were deposited in the Dandaragan Trough, in excess of 1200 m in the Abrolhos Sub-basin and more than 3000 m in the Vlaming Sub-basin.

Further rifting in the Neocomian, followed by a period of uplift and erosion, produced the intra-Neocomian breakup unconformity (Falvey and Mutter, 1981). These tectonic events mark the end of the rifting and the commencement of the drift phase as the continents of India and Australia finally separated and moved apart. Although the Perth basin developed under an extensional regime, there appears to have been some degree of right lateral movement during the Neocomian. This may have formed rollovers and anticlines on the downthrown side of some pre-existing faults (Hall and Kneale, 1992). Basaltic lavas were extruded onto the Neocomian unconformity surface in parts of the Bunbury Trough before a series of Late Cretaceous marine transgressions from the west deposited shales and sandstones of the Warnbro and Coolyena Groups in the Vlaming Sub-basin.

Tertiary sedimentation in the Vlaming and Abrolhos Sub-basins occurred under stable, passive margin conditions. As unrestricted oceanic circulation became established, up to 1200 m of sandstones, calcareous shales and shelf carbonates were deposited in these areas.

2.3 Exploration History

Exploration in the Perth Basin began in 1935 with an initial gravity survey. In 1951-52, a further basin-wide reconnaissance gravity survey was conducted by the Bureau of Mineral Resources (BMR). This established the existence of an elongate trough, filled with Phanerozoic sediments.

In 1952, WAPET was awarded Perth Basin exploration Permit 27H. The company undertook additional gravity work and, in 1956, an initial seismic survey in the Gingin area. This survey identified the large anticlinal Gingin structure (which was not

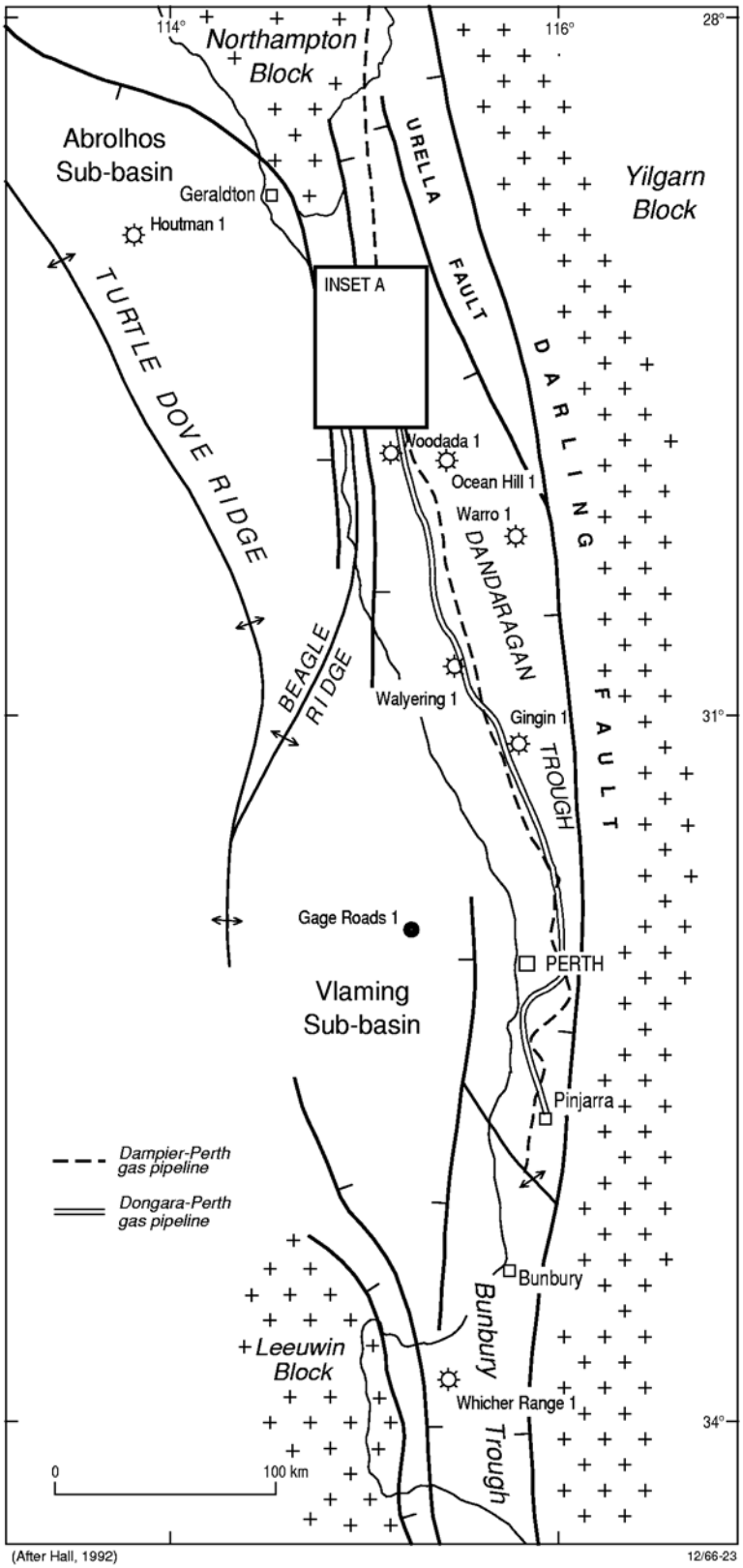


Figure 3 DISCOVERY WELLS AND PETROLEUM ACCUMULATIONS, PERTH BASIN, WA.

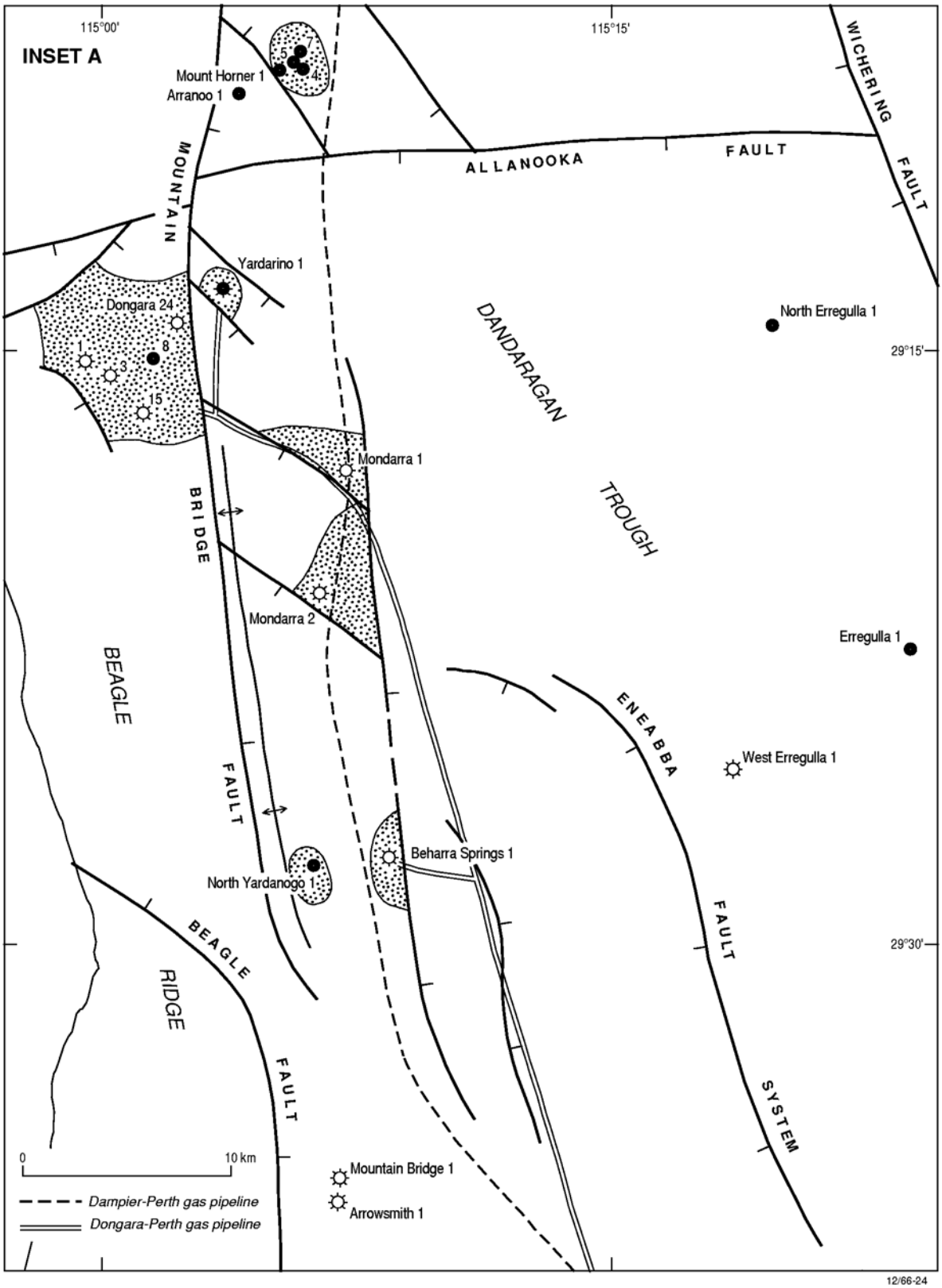


Figure 4 DISCOVERY WELLS AND PETROLEUM ACCUMULATIONS, NORTHERN DANDARAGAN TROUGH, PERTH BASIN, WA.

tested until further detailed seismic was shot in 1964-65). WAPET began the evaluation of structural leads in 1961, with the drilling of Eneabba-1.

The first discovery in the Perth Basin was made in 1964 when Yardarino-1, drilled to test a faulted anticline in the Dandaragan Trough (Figure 4), flowed oil and gas from the Permian Wagina Sandstone and gas from basal Triassic sands. Further discoveries were made in the late 1960's and early 1970's. They include Gingin, Arrowsmith, Mt Horner, Dongara, Mondarra, Whicher Range and Walyering (figures 3 and 4).

The rapidly escalating price of oil in the early 1980's provided impetus for further exploration in the basin. Increased exploration activity resulted in the discovery and development of the Woodada gas field. Further incentive to exploration was given by the Western Australian Government in 1988 with the deregulation of the Western Australian gas market. Ensuing discoveries include Beharra Springs, West Erregulla, Ocean Hill and North Yardanogo.

In the past, exploration in the onshore Perth Basin has been hampered by poor quality seismic data. Data acquired prior to the early 1970's is single-fold analogue data, while more recent seismic data has been degraded by the presence of surficial limestones and the energy absorbing, Jurassic Cattamarra Coal Measures. Consequently, many of the early exploration wells in the onshore Perth Basin were drilled off structure. This has led to an historical success rate of one in eight (Hall, 1989). Recent advances in seismic acquisition and processing techniques have allowed more accurate delineation of structures.

The first offshore seismic surveys were undertaken in 1965, with the first offshore exploration well (Quinn's Rock-1) spudded in 1969. In that same year, Gage Roads-1 (drilled in the Vlaming Sub-basin), recovered oil from the Gage Sandstone Member of the South Perth Formation. Further encouragement for offshore exploration was provided by the recovery of gas from the Cockleshell Gully Formation in Houtman-1, in the Abrolhos Sub-basin.

The most recent discovery in the Perth Basin was made by the Arranoo-1 well in January 1994.

To January 1994, 103 exploration wells have been drilled in the Perth Basin - 20 offshore and 83 onshore. Of these, twenty have made significant hydrocarbon discoveries, nine of which are commercial. The most recent discovery, made by the Arranoo-1 well in January 1994, is, at the time of writing being evaluated. All the commercial discoveries made in the basin to date occur in the Dandaragan Trough.

3. HYDROCARBON HABITAT

3.1 Reservoirs and Seals

3.1.1 *Tumblagooda Sandstone*

In excess of 1800 m of red sandstones, conglomerates and siltstones of this unit outcrop around the margins of the Northampton Block. Porosities and permeabilities within the Tumblagooda are likely to be excellent. However, the areal distribution of this formation is restricted and it has not been encountered in the subsurface south of Geraldton. The absence of good quality source rocks and competent seals for Tumblagooda reservoirs remains problematical. If this formation is intersected to the west of Geraldton in the Abrolhos Sub-basin, it should retain good reservoir properties.

3.1.2 *Nangetty Formation*

The distribution of the Nangetty Formation is restricted to the northern Perth Basin. This sequence of tillite, shale, sandstone and conglomerate achieves a maximum thickness of over 1500 m adjacent to the Urella Fault and pinches out to the west against the Northampton Block and Beagle Ridge. Over most of the Dandaragan Trough the Nangetty Formation is too deeply buried to constitute a viable exploration target. Sandstones in this unit are white and poorly sorted, with a clayey and silty matrix. The presence of this clay matrix together with silicification has generally occluded primary porosity and permeability in these sandstones. However, in Wicherina-1, the Nangetty Formation develops porosities of 7-20%, and permeabilities of up to 3740 md (Hall, 1989). Possible seals and source rocks for Nangetty Formation reservoirs may be provided by intraformational shales or the overlying Holmwood Shale. (The latter achieves a maximum thickness of around 450 m between the Urella and Darling Faults and thins to the west.)

3.1.3 *Holmwood Shale*

This unit provides a regional seal for the underlying Nangetty Formation. Typically, this formation comprises grey-green shale with thin interbeds of lenticular limestone and occasional interbedded sandstones. Sandstone interbeds were intersected in Abbarwardoo-1 and Wicherina-1 where porosities of 14-27% and permeabilities of up to 3740 md were measured. In the Dandaragan Trough, where silicification and clays have not reduced primary porosity, these sands may form valid reservoirs. Both source and seal for these sandstones would be provided by enveloping shales.

3.1.4 *Sue Coal Measures*

The Sue Coal Measures are a Permian sequence of interbedded sandstone, siltstone and coal deposited in the Bunbury Trough. This unit has only been encountered in the subsurface and attains a maximum thickness of 1128 m in Sue-1. Although Late Permian sandstones in the Dandaragan Trough to the north have proven reservoir potential, greater depth of burial, silicification and the presence of porosity occluding

clays have greatly reduced the reservoir capacity of this formaton. Both porosity (averaging between 3% and 12%) and permeabilities are low. In spite of this, a number of wells have recorded hydrocarbon shows within this sequence. The most significant of these occurred in Whicher Range-1. Here, a DST at 4164 m in the Sue Coal Measures flowed gas to surface at a rate of 53 800 m^3/day. Porosities of up to 18% were measured around this depth but low permeabilities (11 md) prevented sustained production from this sand. Seal is provided by thin, intraformational siltstones, clays and shales.

3.1.5 *Irwin River Coal Measures (Includes High Cliff Sandstone)*

The Irwin River Coal Measures are an alternating sequence of sandstone, siltstone and claystone with lenticular beds of sub-bituminous coal. This formation occurs in the subsurface through much of the northern Perth Basin and is difficult to distinguish from the underlying High Cliff Sandstone in well sections. Together with the Holmwood Shale, it is the northern Perth Basin time equivalent of the Sue Coal Measures. As might be expected in a fluvial/paludal/lacustrine sequence, porosity is variable (2-29%). Sandstones tend to be lenticular and argillaceous with low permeabilities (5-10 md). In spite of the above, gas is produced from the Irwin River Coal Measures in the Dongara field. In the Dongara-3 well, porosities of around 18% and permeabilities of 10 md were measured in the producing reservoir. Seals for reservoirs within this formation are likely to be intraformational claystones and siltstones.

3.1.6 *Carynginia Formation*

The Carynginia Formation is a marine unit deposited over a wide area of the northern Perth Basin. Much of the section has been deposited under conditions of restricted circulation (Playford and others, 1976). It consists of a basal, deeper water shale member, (which contains thin interbeds of siltstone, sandstone and limestone), and a shallow water, shelfal, skeletal limestone unit, deposited on the eastern flank of the Beagle Ridge. It is possible that this limestone facies extends offshore into the Abrolhos Sub-basin (Lane and Watson, 1985). Thin, discontinuous sandstones, sealed by intraformational shales and limestones, form valid reservoirs within the Carynginia Formation. These sandstone stringers are known to produce gas in the Dongara field (Jones, 1976), where porosities range from 11% to 20% and permeabilities around 5 md are typical. Offshore, in the Abrolhos Sub-basin, Carynginia Formation sandstones are well cemented with carbonates and clays and have log derived porosities of less than 10% (Smith and Cowley, 1987).

In the Carynginia Limestone facies, primary porosity was occluded by clays and sparry calcite early during diagenesis. Porosity in this unit is now exclusively secondary. It consists of fracture porosity, porosity resulting from dissolution of intergranular calcite within thin sandstone interbeds, dolostone porosity and fine void or vugular porosity. Gas is produced from the Carynginia Limestone at Woodada where porosities of up to 15% and permeabilities of 134 md have been measured. At this location, the Carynginia Limestone is sealed by the overlying Kockatea Shale and the shaling out of the limestone facies updip.

3.1.7 *Wagina Sandstone*

The distribution of the Late Permian, Wagina Sandstone is probably limited to the northern, onshore Perth Basin (although Marshall and Lee (1988) have suggested that the unit may be present as a syn-rift deposit in some offshore half-grabens)(figure 5). The Wagina Sandstone rests unconformably on the underlying Carynginia Formation. This white, fine to medium grained, poorly sorted, clayey quartz sandstone was deposited as a humid, alluvial fan delta centred on the Darling Fault, to the east of Depot Hill (Bergmark and Evans, 1987). Sediment was supplied predominantly from uplifted areas to the east and northeast of the Darling Fault in a braided stream environment. The western distal facies of the Wagina Sandstone fan (south of Dongara), was deposited in a shallow marine environment and typically contains interbedded calcareous sands, shales and thin limestones. Thin interbedded siltstones are developed in floodplain environments.

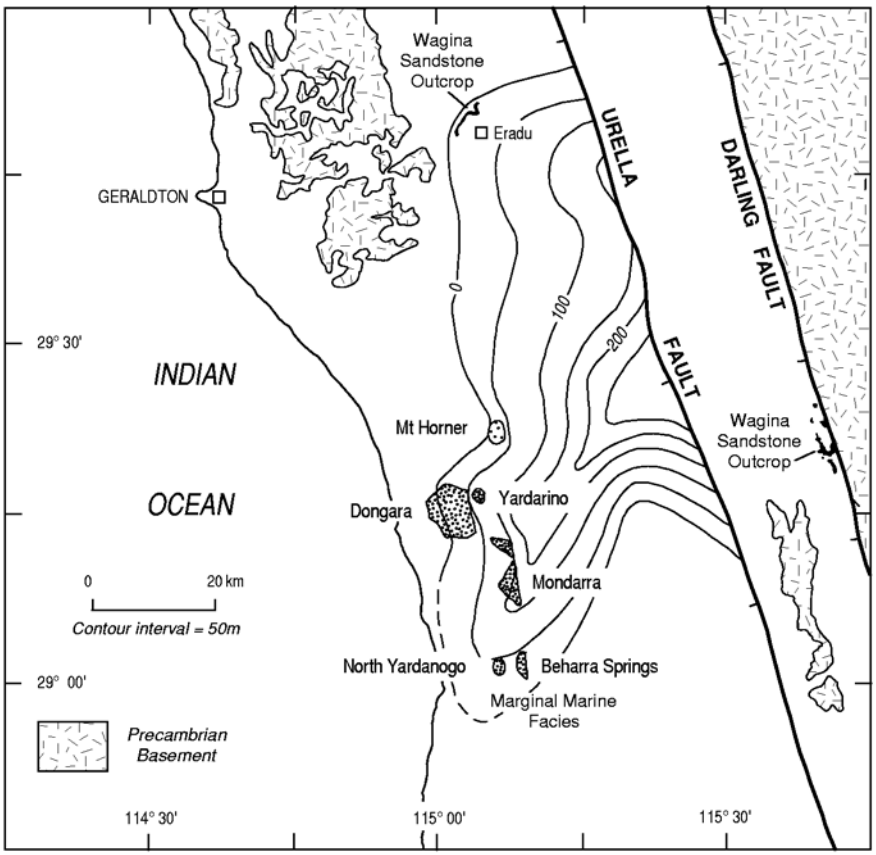
Porosity in the Wagina Sandstone ranges between 5% and 15% and permeabilities tend to be low. However, gas is produced from this formation at Mondarra and both oil and gas at Yardarino. Here, porosities average around 15% and permeabilties in excess of 300 md have been measured. Seals for Wagina Sandstone reservoirs are provided by either intraformational siltstones and shales or by the overlying Kockatea Shale.

3.1.8 *Basal Triassic Sandstones (Kockatea Shale)*

In response to a rise in sea level and subsequent marine transgression in the Early Triassic, basal Triassic sandstones were deposited over a wide area of the northern Perth Basin. To the south, the Kockatea Shale rests conformably on shales of the Carynginia Formation. Early authors considered basal Triassic sands to be beach bar and strand line accumulations. However, the absence of sedimentary structures expected in a nearshore environment and the presence of authigenic dicktite in a number of localities indicates that many of these sands were probably deposited in a predominantly fluvial environment (Bergmark and Evans, 1987).

These sands are discontinuous and variable in character. Their development offshore is patchy - basal Triassic sandstones have been encountered in Batavia-1 and Geelvinck-1A but are absent in Wittecarra-1, Leander Reef-1 and South Turtle Dove-1B. Their restricted distribution offshore is probably a function of both depositional environment and subsequent erosion (Marshall and others, 1989). In places, quartz overgrowths and minor carbonate cementation have occluded primary porosity and authigenic kaolin group clays are common.

Basal Triassic sandstones are a primary exploration target in the northern Perth Basin. Hydrocarbons have been recovered from these sandstones at Mondarra, Yardarino, Dongara, Mount Horner, West Erregulla and North Erregulla. Reservoir quality is highly variable. Porosities range from 2% to 32% and permeabilities average around 300 md (although permeabilities as high as 5537 md have been measured at Yardarino) (Hall, 1989). The Kockatea Shale provides a regional seal for the Basal Triassic sandstones.



(After Bergmark and Evans, 1987)

12/66-25

Figure 5

ISOPACH MAP OF WAGINA SANDSTONE,
NORTHERN DANDARAGAN TROUGH

3.1.9 *Kockatea Shale (Arranoo Sandstone Member)*

Although the Kockatea Shale is primarily noted for its source rock potential and its importance as a regional seal for the basal Triassic sandstones, the upper section of this unit contains interbeds of sandstone and siltstone. These thin, discontinuous, lenticular, fine grained sandstones and siltstones within the upper Kockatea Shale (Arranoo Sandstone Member) probably represent a regressive, shallow marine facies of this unit. Commercial quantities of oil have been produced from these units at Dongara and Mount Horner. A small quantity of 38 degree API oil was also recovered from a thin, interbedded sandstone/siltstone sequence in the Upper Kockatea Shale at North Erregulla and an oil flow was recorded from these sands in Mount Horner-1. Both seal and source for these reservoirs is provided by enveloping Kockatea Shales.

3.1.10 *Woodada Formation*

This unit consists predominantly of fine grained interbedded sandstones and siltstones. It conformably overlies the Kockatea Shale and is distributed over much of the northern Perth Basin. Although the Woodada Formation exhibits fair porosity and permeability, to date, the only indication of hydrocarbons within this unit has been a minor gas show and fluorescence recorded in Donkey Creek-1. Lack of widespread intraformational and top seals (the formation is overlain by the Lesueur Sandstone) limits the reservoir potential of the Woodada Formation.

3.1.11 *Sabina Sandstone*

The Sabina Sandstone is a medium to coarse grained, fluviatile quartz sandstone, with occasional thin shale interbeds. Its distribution is restricted to the Bunbury Trough and it appears to be the southern time equivalent to the Upper Kockatea Shale. Although the Sabina Sandstone has good reservoir potential, lack of adequate seals and the absence of good quality source rocks remain a problem in this formation. To date, no significant hydrocarbon shows have been recorded in the Sabina Sandstone.

3.1.12 *Lesueur Sandstone*

The Lesueur Sandstone is a fine to very coarse grained fluviatile quartz sandstone deposited over most of the Perth Basin. In the north, it conformably overlies the Woodada Formation while in the south, it rests directly on the Sabina Sandstone. Porosities in this formation are variable (3% to 30%), averaging around 17% and permeabilties are high (Hall, 1989). However, as with the underlying Sabina Sandstone, lack of adequate seal and source for Lesueur Sandstone reservoirs remains problematical. To date, no petroleum discoveries have been made in this unit. A minor gas show with associated fluorescence was noted in Donkey Creek-1 in the Lesueur Sandstone.

3.1.13 *Cockleshell Gully Formation*

Over most of the Perth Basin, the Lesueur Sandstone is conformably overlain by a fluviatile sequence of sandstones, claystones, shales and coals termed the Cockleshell Gully Formation. The basal unit (Eneabba Member) is composed of fine to coarse grained sandstone with interbedded multicoloured claystone and siltstone. The upper Cattamarra Coal Measures Member consists of very fine to very coarse grained sandstone with interbedded shales, siltstones and coals.

Some of the best quality reservoirs in the Perth Basin occur in the Cockleshell Gully Formation. The Eneabba Member has porosities of between 10% and 34% (averaging 24%) and high permeabilities (Hall, 1989). Porosities in sandstones of the Cattamarra Coal Measures are more variable (between 4% and 32%) with permeabilities of to 700 md recorded in Eneabba-1. Four commercial discoveries in the Dandaragan Trough (Gingin, Mount Horner, North Yardanogo and Walyering) have produced both oil and gas from multiple sands within the Cattamarra Coal Measures. Other discoveries made in the Cockleshell Gully Formation include Erregulla, West Erregulla and Ocean Hill (in the Dandaragan Trough) and Houtman (in the Abrolhos Sub-basin). Hydrocarbon reservoirs within this formation are sealed by either intraformational shales or, in the northern Perth Basin, by the overlying transgressive marine shales of the Cadda Formation. In the southern Perth Basin the Cadda Formation is absent. Here, the Cockleshell Gully Formation is directly overlain by the Yarragadee Formation.

3.1.14 *Yarragadee Formation*

This sequence of interbedded silty sandstones, claystones, shales and siltstones was deposited throughout most of the Perth Basin. It achieves thicknesses in excess of 3000 m in the Dandaragan Trough and Vlaming Sub-basin. Although most of the Yarragadee Formation is thought to be fluviatile, with sediments sourced from uplifted areas to the east of the Darling Fault, the upper part of the unit was probably laid down in a shallow marine environment (Playford and others, 1976).

Porosities and permeabilities in the Yarragadee Formation are variable. Porosities between 5% and 40% have been measured with permeabilties of up to 7870 md recorded in Gingin-1 (Hall, 1989). Warro-2, drilled in the Dandaragan Trough, recorded gas flows from two sands in the Yarragadee Formation around 4000 m and 4100 m. However porosities were low (less than 10%) and permeabilities poor (3 md). Offshore, in the Vlaming Sub-basin, Gage Roads-1 found gas saturation in tight Yarragadee Formation sands beneath the Otorowiri Member of the overlying Parmelia Formation (Jones, 1976).

Thomas, (1984) undertook a study of clean, relatively well sorted Yarragadee Formation Sandstones in the Dandaragan Trough in an attempt to establish porosity trends within this unit. He found that porosity retention with depth is greatest in the deepest parts of the trough adjacent to the Darling Fault and porosity progressively deteriorates westwards towards the Beagle Ridge. It is believed that this reduction in porosity towards the west is probably the result of pre-Neocomian deep burial

diagenesis. The depth to a 10% porosity cut-off varies from around 3500 m adjacent to the Darling Fault, to less than 2000 m on the eastern flank of the Beagle Ridge.

Yarragadee Formation reservoirs are sealed by either intraformational shales or, in the offshore northern Perth Basin, shaly units at the base of the overlying Parmelia Formation (Otorowiri Member).

3.1.15 *Parmelia Formation*

In the offshore Perth Basin (Vlaming Sub-basin), the Late Jurassic to Early Cretaceous interbedded sandstone, siltstone shale sequence (formerly the Upper Yarragadee Formation) has been renamed the Parmelia Formation. Parmelia Formation sandstones are known to have good reservoir potential in the Vlaming Sub-basin.

3.1.16 *South Perth Formation*

Offshore in the Vlaming Sub-basin, immediately above the intra-Neocomian unconformity, the basal transgressive sands of the Gage Sandstone Member were deposited. In Gage Roads-1, oil was recovered from this unit. The reservoir is probably sealed by an interbedded shale/siltstone section within the Gage Sandstone Member. Porosities of around 22% and permeabilities of 300 md were measured in the reservoir. Immediately overlying the Gage Sandstone Member is the South Perth Shale. This unit provides a competent top seal for the basal transgressive sands.

3.2 Hydrocarbon Source Rocks and Maturation

3.2.1 *Holmwood Shale*

Geochemical analyses from four wells in the northern Perth Basin indicate that this formation may have some source potential. The limited number of TOC measurements available range between 0.03% and 3.30% (1.2% average), although the organic matter present is predominantly humic and gas prone. Maturation modelling by Thomas and Brown, (1983) indicates that this unit is probably overmature over much of the Dandaragan Trough and oil generative only on the Dongara Saddle and the eastern flank of the Beagle Ridge.

3.2.2 *Irwin River Coal Measures*

The interbedded coals and carbonaceous shales of the Irwin River Coal Measures are organic rich (TOC values in excess of 14% have been measured) and gas prone. Coals range in rank from anthracite to hard-brown with the dominant macerals being inertinite and vitrinite (Kantsler and Cook, 1979). It is possible that in the Abrolhos Sub-basin, where restricted marine facies of Permian age constitute the major component of the syn-rift succession, a more oil prone facies is developed. As with the underlying Holmwood Shale, the Irwin River Coal Measures are overmature over most of the northern Perth Basin and are likely to lie within the oil window only on the Dongara Saddle and the flanks of the Beagle Ridge.

3.2.3 *Carynginia Formation*

The basal marine shales and claystones of the Carynginia Formation have moderately good source potential. TOC values of up to 11.4% have been recorded, although the organic matter present is hydrogen poor and inertinite rich having been derived from land plants (Kantsler and Cook, 1979). Moderate amounts of sapropelic material were analysed in samples from one well, indicating that Carynginia Formation shales may have some potential as an oil source. However, this unit is predominantly gas prone.

The Carynginia Formation is overmature and in the dry gas generative phase over much of the northern Perth Basin. On the Dongara Saddle and the flanks of the Beagle Ridge, where source rocks in this unit are less mature, the shale facies is, in part, replaced by the shallow water, Carynginia Limestone reservoir facies.

3.2.4 *Sue Coal Measures*

The Sue Coal Measures contain gas prone source rocks that currently lie within the oil window over much of the Bunbury Trough (Kantsler and Cook, 1979). A mature, oil prone source facies has yet to be identified in the southern Perth Basin.

3.2.5 *Kockatea Shale*

The Kockatea Shale is one of the most important source rocks in the Perth Basin. Typically, the formation contains a thin (15 m to 38 m thick), organically rich (TOC

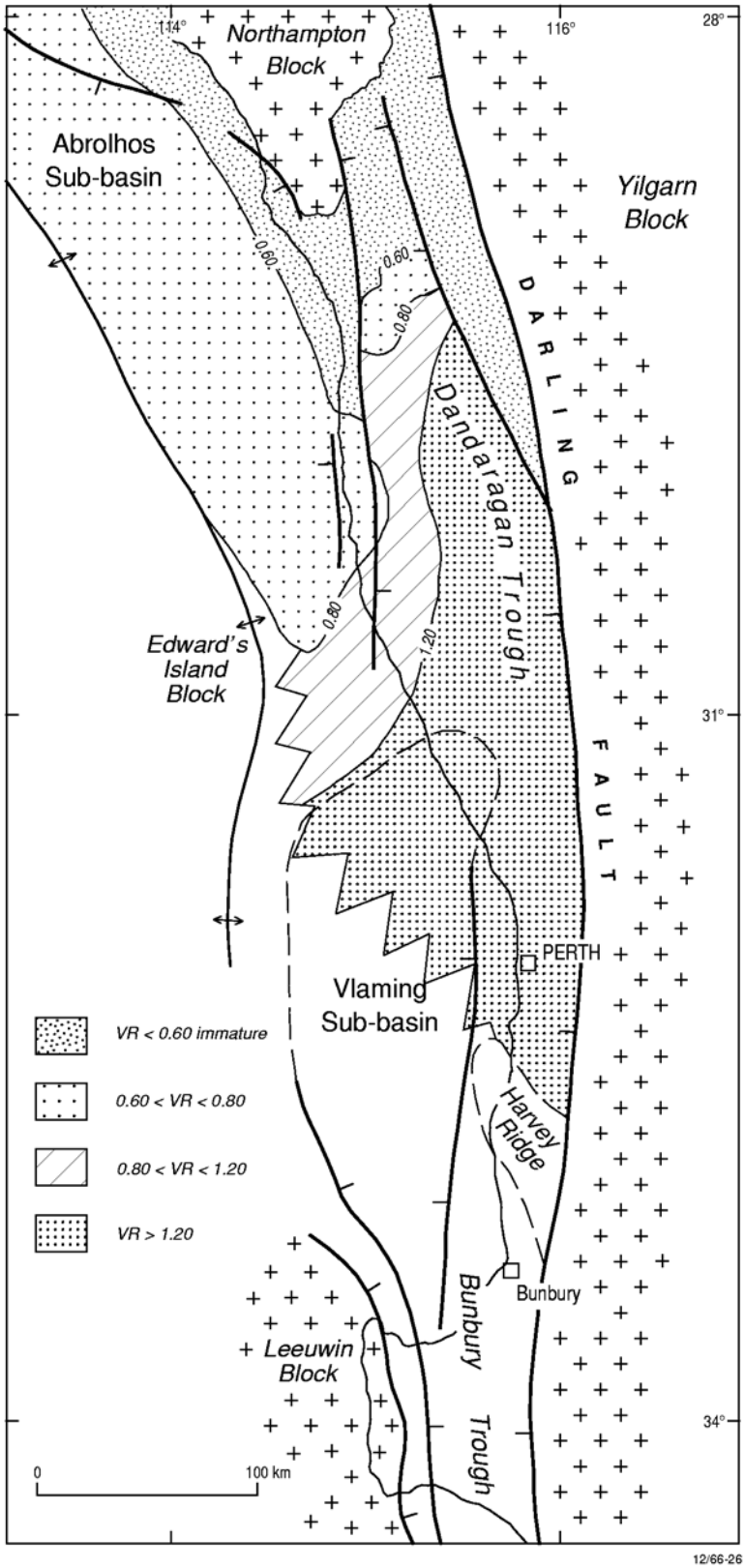


Figure 6 THERMAL MATURITY, TOP KOCKATEA SHALE, PERTH BASIN

values in excess of 2%) basal section, rich in phytoplankton and finely divided exinite. The Type II kerogen dominant in this interval is likely to have sourced significant quantities of liquid hydrocarbons. The shales overlying this basal unit are less rich (TOC values decline upwards to less than 0.5%), and contain a higher proportion of gas prone, land plant derived organic matter. In the deeper areas of the Dandaragan Trough, the Kockatea Shale is likely to be overmature (Figure 6). However, in the Dongara Saddle area, parts of Beagle Ridge and much of the Abrolhos Sub-basin this formation probably lies within the oil window at the present time.

3.2.6 *Woodada Formation*

Although the Woodada Formation is not generally regarded as having significant source potential, in Wittecarra-1, drilled in the Abrolhos Sub-basin, TOC values of between 0.5% and 2.5% were recorded in this unit. The organic matter analysed in this interval is oil prone (predominantly exinite and alginite with minor inertinite and vitrinite). Maturation levels within the Woodada Formation are probably similar to the underlying Kockatea Shale and in parts of the northern Perth Basin, this formation may constitute a potential oil source.

3.2.7 *Cockleshell Gully Formation*

The Cattamarra Coal Measures (upper member of the Cockleshell Gully Formation), are a thick, coal-rich sequence where TOC values of up to 27% have been recorded. Although the organic matter present is predominantly gas prone, (H/C ratios range between 0.73 and 0.84) exinite contents of up to 30% have been reported (Kantsler and Cook, 1979). Consequently, this unit is viewed as a mixed source, capable of generating both oil and gas.

In the southern Perth Basin, the Cockleshell Gully Formation becomes sand prone and is unlikely to have significant source potential. Similarly, in the Abrolhos Sub-basin, the formation becomes sandstone dominated, with only minor carbonaceous mudstones and thin coaly units intersected in Batavia-1 (Smith and Cowley, 1987).

Maturation modelling by Thomas, (1984) suggests that the Cattamarra Coal Measures are presently within the zone of peak oil generation over most of the Dandaragan Trough. Cockleshell Gully Formation source rocks may have passed into the post-mature, dry gas generative phase in the deepest parts of the trough and may be early oil generative on the eastern flank of the Beagle Ridge and Dongara Saddle.

3.2.8 *Cadda Formation*

The marine shales of the Cadda Formation are distributed over most of the Dandaragan Trough and extend offshore into the Abrolhos Sub-basin. Warris, (1988) considers them to be good quality, oil-prone source rocks with TOC values typically ranging between 0.7% and 3.4%. However Thomas and Brown, (1983) analysed a number of samples from this unit and found them to be organically lean (average TOC of around 0.6%) and gas prone, suggesting source quality within this formation is variable. Cadda Formation shales are probably immature to marginally mature in

the Abrolhos Sub-basin (Marshall and others, 1989) but may be oil generative in the central Dandaragan Trough.

3.2.9 *Yarragadee Formation*

Although this formation is predominantly sandy over most of the Perth Basin, Thomas and Brown, (1983) have indicated that a thick, fine-grained fluvial-lacustrine shale developed in the central Dandaragan Trough has some source potential. Here, shales and siltstones average 1.8% TOC and are predominantly gas prone. However, local concentrations of exinite (Kantsler and Cook, 1979) suggest that the Yarragadee Formation may have some potential as an oil source.

Vitrinite reflectance data from Gun Island-1, Walyering-1 and Gage Roads-1 indicate that this unit is probably immature to marginally mature in the Dandaragan Trough and Abrolhos Sub-basin and marginally mature to mature in the Vlaming Sub-basin.

3.2.10 *Parmelia Formation (Otorowiri Member)*

The basal Otorowiri Member of the Parmelia Formation (formerly the Quinns Shale Member of the Yarragadee Formation) is a lacustrine shale unit recognised in the Vlaming Sub-basin. This unit has moderately good to good source potential (TOC values range between 0.4% to 2.5%) and is believed to be oil prone (Hall, 1989). Although thermally mature Parmelia Formation sediments have yet to be intersected by the few wells drilled in the Vlaming Sub-basin, it is believed that Otorowiri Member shales are probably oil generative in the deeper central areas of the Vlaming Sub-basin.

3.2.11 *South Perth Formation (South Perth Shale)*

The South Perth Shale is a grey and black shale and claystone sequence developed offshore from Perth in the Vlaming Sub-basin. It thickens rapidly to the west, where, on the edge of the continental shelf, it may be several thousand meters thick (Jones, 1976). This formation has good source potential (average TOC of 2.3%) and is oil prone (Hall, 1989). Although the South Perth Shale section has been immature in all wells drilled to date in the Vlaming Sub-basin, this unit is believed to be oil generative in the central Vlaming Sub-basin.

3.3 Play Types

Petroleum traps in the Perth Basin can be broadly grouped into four categories - tilted fault blocks, anticlines, compressional rollovers and structural/stratigraphic traps. Hydrocarbon accumulations are reservoired in all four trapping mechanisms. A summary of the petroleum plays in the basin validated by hydrocarbon discoveries is shown in Table 1.

To date, tilted fault blocks in the Dandaragan Trough (including the Dongara Saddle area) have been the most successful exploration target in the Perth Basin. These traps formed as the extensional regime that commenced in the Late Palaeozoic caused extensive north-south oriented, detachment faulting over much of the Perth Basin. Movement on these faults in response to rifting is likely to have occurred at any time between the Triassic and Neocomian, with reservoirs relying on impermeable lithologies juxtaposed across faults for seal. These traps have been charged by hydrocarbons generated from source rocks ranging from Late Permian to Early Jurassic in age which approached peak oil generation in the Dandaragan Trough anywhere between Late Triassic and the present day (see Table 1).

At the end of rifting in the Neocomian, as India finally separated and moved northward from the Australian continental plate, there appears to have been some right lateral movement in the basin (Hall, 1989). This has given rise to compressional structures such as anticlines and compressive rollovers into faults. These late-formed traps have been successfully tested at a number of locations in the Dandaragan and Bunbury Troughs (see Table 1). Adequate hydrocarbon charge is provided by Triassic/Jurassic source rocks which have been generating hydrocarbons since Late Triassic times

At Woodada, gas is reservoired in the Carynginia Limestone, which is sealed updip by a shaly, non-reservoir facies of the Carynginia Formation. The only other recorded instance of the stratigraphic trapping of hydrocarbons in the Perth Basin is offshore, in the Vlaming Sub-basin, at Gage Roads. Here, oil is reservoired above the intra-Neocomian unconformity in the Gage Sandstone Member, which pinches out beneath the South Perth Shale.

The plays listed in Table 1 will continue to constitute the primary exploration targets in the Perth Basin for some time to come. Tilted fault blocks with associated compressional rollovers and flower-like structures have been identified from seismic data in the Abrolhos Sub-basin (Marshall and others, 1989). Rapid lateral facies changes and the discontinuous distribution of many of the reservoir sands in the fluvial sequences in the Perth Basin may mean that some traps will have at least some stratigraphic component.

Table 1. Proven play types, Perth Basin

D AN D A R A G A N T R O U G H

Trap Type	Age of Trap	Reservoir	Seal	Source	Timing of Peak Oil Generation	Discoveries	HC Type
TILTED FAULT BLOCKS	Jurassic - Neocomian	Cockleshell Gully Fm	Cockleshell Gully Fm	Cattamarra Coal Measures	Tertiary - Present	Erregulla	Oil
	Late Triassic - Neocomian	Kockatea Shale	Kockatea Shale	Kockatea Shale	Late Triassic - Mid Jurassic	Dongara North Erregulla	Oil and Gas Oil
		Kockatea Shale	Cockleshell Gully Fm	Kockatea Shale	Late Triassic - Mid Jurassic	Mount Horner	Oil
	Late Triassic - Neocomian	Basal Triassic Sandstones	Kockatea Shale	Kockatea Shale	Late Triassic - Mid Jurassic	Dongara Yardarino Mondarra North Erregulla	Oil and Gas Oil and Gas Gas Oil
	Late Triassic - Neocomian	Wagina Sandstone	Kockatea Shale	Kockatea Shale / Carynginia Fm	Late Triassic - Mid Jurassic	Yardarino Mondarra	Gas Gas
	Late Triassic - Neocomian	Carynginia Fm	Kockatea Shale	Kockatea Shale / Carynginia Fm	Late Triassic - Mid Jurassic	Dongara Beharra Springs	Gas Gas
	Late Triassic - Neocomian	Carynginia Fm	Kockatea Shale / Basement	Kockatea Shale / Carynginia Fm	Late Triassic - Mid Jurassic	Arrowsmith	Gas
	Late Triassic - Neocomian	Irwin River Coal Measures	Kockatea Shale	Irwin River Coal Measure / Kockatea Shale	Late Triassic - Mid Jurassic	Dongara	Gas

Table 1...contd

D A N D A R A G A N T R O U G H contd

Trap Type	Age of Trap	Reservoir	Seal	Source	Timing of Peak Oil Generation	Discoveries	HC Type
ANTICLINES	Neocomian	Yarragadee Fm	Yarragadee Fm	Yarragadee Fm ?	Presently marginally mature	Warro	Gas
	Neocomian	Cockleshell Gully Fm	Cockleshell Gully Fm	Cattamarra Coal Measures	Tertiary - Present	Walyering Gingin Nth Yardanogo Ocean Hill	Gas Gas Oil Gas
	Neocomian	Basal Triassic Sandstone	Kockatea Shale?	Kockatea Shale	Late Triassic - Cretaceous	West Erregulla	Gas
COMPRESSIONAL ROLLOVERS	Neocomian	Cockleshell Gully Fm	Cockleshell Gully Fm	Kockatea Shale	Late Triassic - Cretaceous	Mount Horner	Oil
	Neocomian	Basal Triassic Sandstones	Kockatea Shale	Kockatea Shale	Late Triassic - Cretaceous	Mount Horner	Oil
STRUCTURAL / STRATIGRAPHIC	Permian	Carynginia Fm	Carynginia Fm	Carynginia Fm	Late Triassic - Mid Jurassic	Woodada	Gas

B U N B U R Y T R O U G H

ANTICLINES	Neocomian	Sue Coal Measures	Sue Coal Measures	Sue Coal Measures	Early Jurassic - Cretaceous	Whicher Range	Gas

V L A M I N G S U B-B A S I N

STRUCTURAL / STRATIGRAPHIC	Neocomian	Parmelia Fm	South Perth Shale	Otorowiri Member	Late Tertiary - Present	Gage Roads	Oil

Table 1....contd

A B R O L H O S S U B - B A S I N

Trap Type	Age of Trap	Reservoir	Seal	Source	Timing of Peak Oil Generation	Discoveries	HC Type
ANTICLINES	Neocomian	Cattamarra Coal Measures	Cattamarra Coal Measures	Cattamarra Coal Measures	Tertiary - Present ?	Houtman	Gas

4. PETROLEUM ACCUMULATIONS AND SHOWS

4.1 Dandaragan Trough

4.1.1 *Commercial Accumulations* (Plate 1)

1. Beharra Springs

In April 1990, Beharra Springs-1, drilled as a test of a tilted fault block in the Dandaragan Trough, recovered gas from a sandstone bed within the Carynginia Formation. The reservoir is sealed by a downthrown section of the Kockatea Shale juxtaposed across the Beharra Springs Fault. An initial production test flowed gas at the rate of 708 000 m^3/day through a 16 mm choke over the interval 3298-3307 m.

Using a temporary processing facility, gas production to Alcoa of Australia via a 1.6 kilometre spur line connected to the Dongara-Perth pipeline commenced in January 1991. Production was temporarily halted in February due to the high hydrogen sulphide content of the gas but was resumed in July of the same year after the installation of a hydrogen sulphide removal system.

Beharra Springs-2, located 1.6 kilometres south of the discovery well, was drilled in March 1991 and flowed gas at the rate of 736 000 m^3/day through a 16 mm choke over the interval 3355-3363.7 m. The well was connected to the temporary gas processing plant via a separate 1.8 kilometre flowline in February 1992.

In December 1992, a second development well, Beharra Springs-3, was drilled 1.5 kilometres north of Beharra Springs-1. This well flowed gas at the rate of 566 000 m^3/day and was linked to the production system early in 1993.

2. Mondarra

Mondarra-1 was drilled in 1968, 320 kilometres north of Perth in the Dandaragan Trough, to test a tilted fault block (Figures 10 and 11). The well flowed gas from Basal Triassic Sandstones at a rate of 140 000 m^3/day. A second well (Mondarra-2) located half a kilometre to the south on an adjacent fault block, intersected a gas zone in the underlying Wagina Sandstone. After stimulation, this horizon flowed gas at a rate of up to 80 000 m^3/day. Mondarra-3 and Mondarra-4, which were drilled as downdip tests of the two discovery wells, failed to encounter commercial quantities of hydrocarbons and were plugged and abandoned. A small quantity of oil was recovered from the Basal Triassic Sandstone in Mondarra-3, indicating a thin oil leg is probably present in this reservoir.

Porosities and permeabilities in the Basal Triassic Sandstone reservoir are moderately good (17% and 300 md respectively) while the Wagina Sandstone reservoir is of variable quality, depending on the degree of silicification. Seal is provided by the Kockatea Shale, or, in the case of Mondarra-2, partly by shales and claystones of the Woodada Formation juxtaposed across the bounding fault.

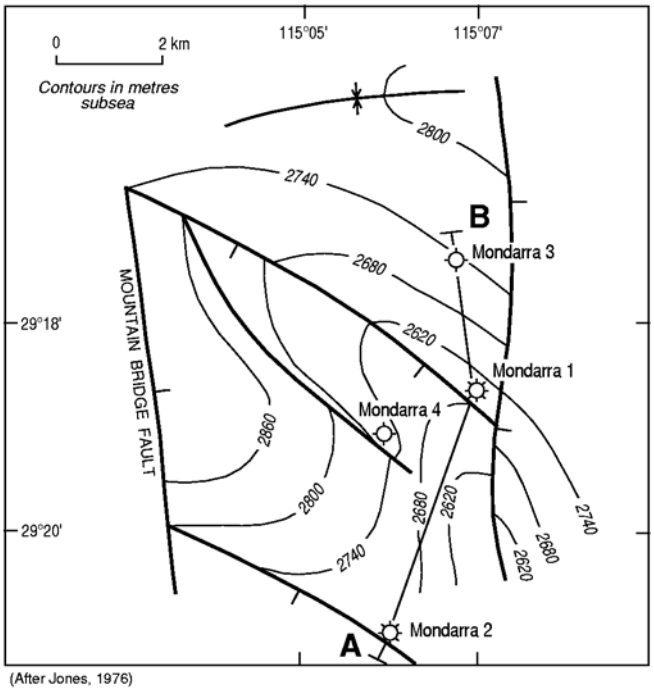


Figure 7 STRUCTURE TOP BASAL TRIASSIC SANDSTONE, MONDARRA ACCUMULATION

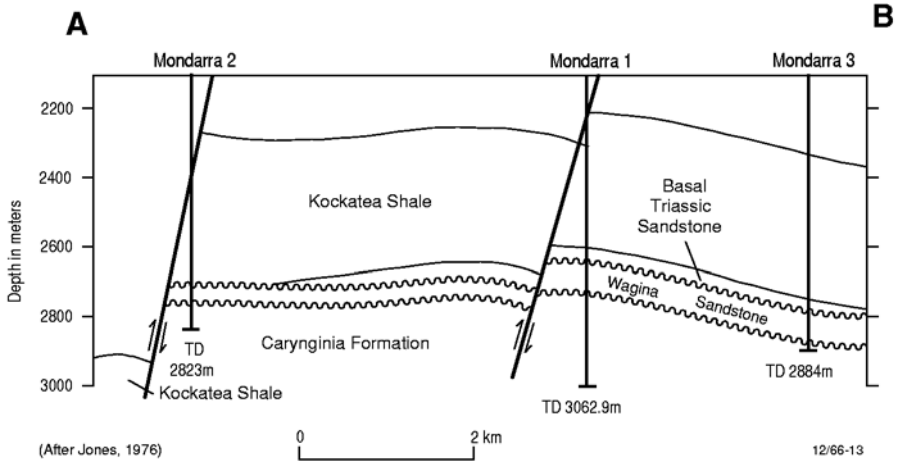


Figure 8 CROSS SECTION THROUGH THE MONDARRA ACCUMULATION

At June 1993, remaining reserves (50% probability level) have been calculated at 0.003×10^9 m^3 (WADME, 1993).

3. Yardarino

In 1964, Yardarino-1 was drilled as a test of a small, tilted fault block 322 kilometres north of Perth (Figures 18 and 19). This well flowed gas with associated condensate from the Basal Triassic Sandstone and gas together with a small quantity of oil from the Wagina Sandstone. A follow up well, Yardarino-2, tested an adjacent fault block but recovered water from the zones of interest. Yardarino-3, sited in a crestal position less than a kilometre south of the discovery well, flowed oil at a rate of 1000 bbl/day from the Basal Triassic Sandstone. A further well, Yardarino-4, was drilled as a downdip test of Yardarino-1 and 3. This well produced only salt water from the Basal Triassic and Wagina Sandstones.

Reservoir quality at Yardarino is moderately good. Approximately 30 m of Basal Triassic Sandstone were encountered with porosities ranging between 11% and 14% and permeabilities of between 39 md and 340 md. The Wagina Sandstone is up to 60 m thick at Yardarino. In this unit porosities average 15% and permeabilities 340 md.

Production from the Yardarino field commenced in 1978. Approximately 0.133×10^9 m^3 of gas and 0.002×10^6 kL of oil were subsequently produced (WADME, 1993). The Yardarino field has been depleted and is currently shut in.

4. Woodada

Woodada-1, drilled in May 1980 in the northern Perth Basin to test objectives in the Irwin River Coal Measures, Carynginia and Cockleshell gully Formations, intersected a previously unknown limestone facies within the Carynginia Formation. This unit flowed gas at a rate of 190 000 m^3/day on production test, which improved to 889 000 m^3/day after acid stimulation.

The reservoir facies is typically 100 m to 130 m thick and consists of a skeletal limestone with occasional quartz sand interbeds deposited in an inner shelf environment. Primary porosity in the skeletal carbonates was occluded early during diagenesis by terrigenous clays and sparry calcite. Similarly, the quartzose sands have undergone silicification and cementation with calcite. Porosity in the Carynginia Limestone is now exclusively secondary and occurs either as fractures, quartz sand porosity (formed by the removal of intergranular calcite prior to dolomitisation), dolostone porosity or fine voids porosity (Lane and Watson, 1985). Consequently, reservoir quality is highly variable (porosities of 2% to 19% and permeabilities of around 134 md are typical).

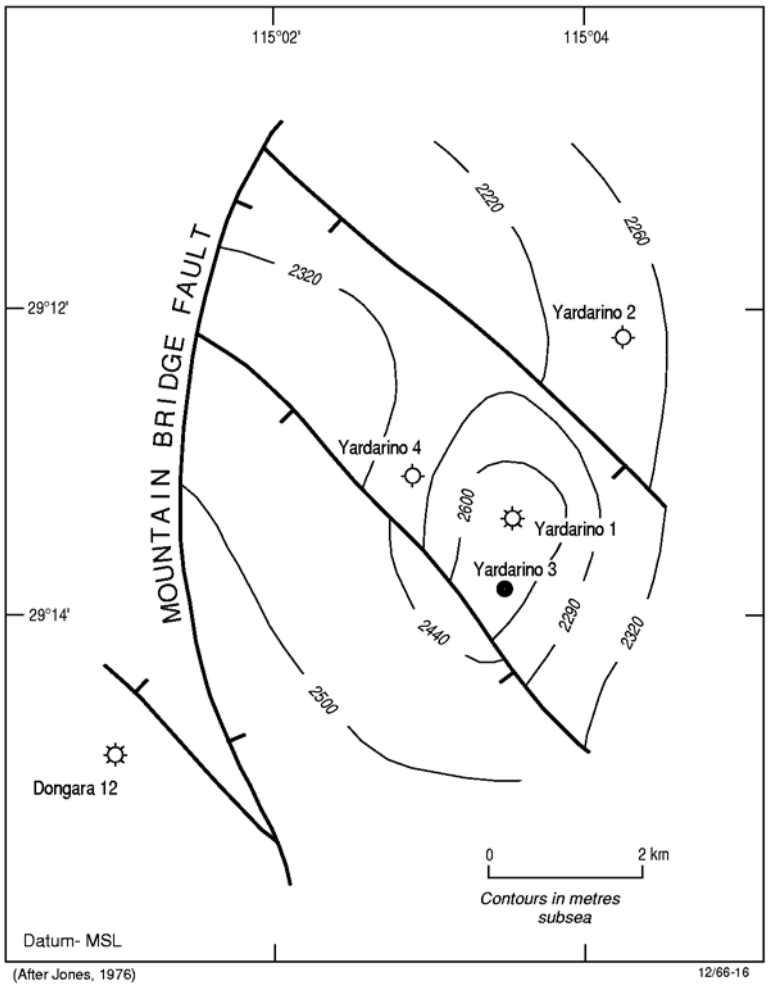


Figure 9 STRUCTURE TOP BASAL TRIASSIC SANDSTONE
YARDARINO ACCUMULATION

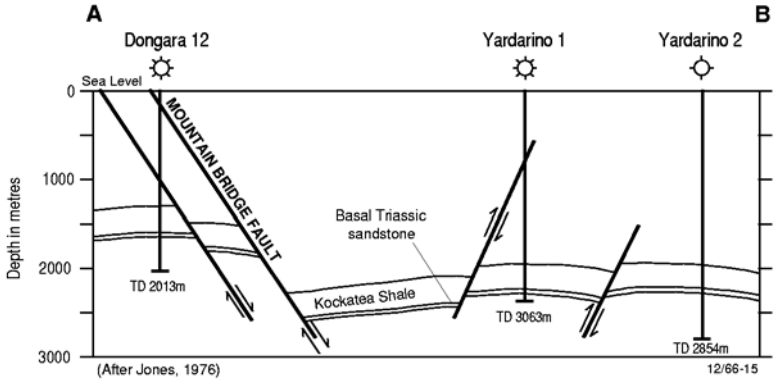
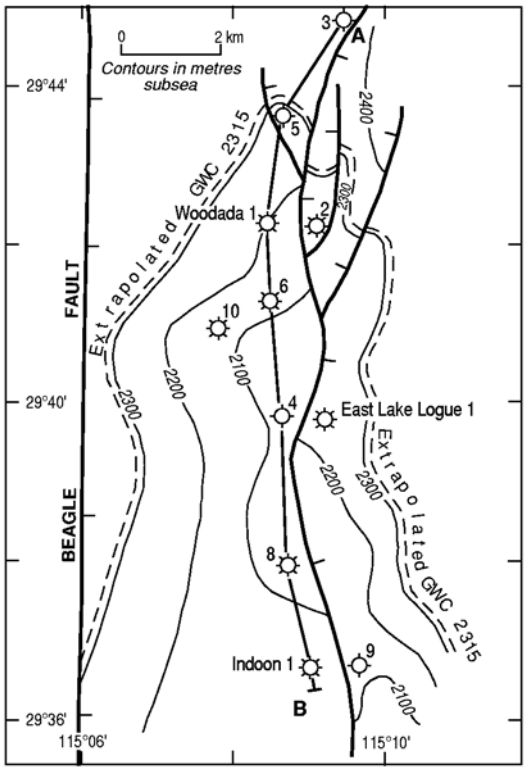


Figure 10 SCHEMATIC SECTION THROUGH YARDARINO ACCUMULATION



(After Lane & Watson, 1985)

Figure 11 STRUCTURE TOP CARYNGINIA LIMESTONE, WOODADA ACCUMULATION

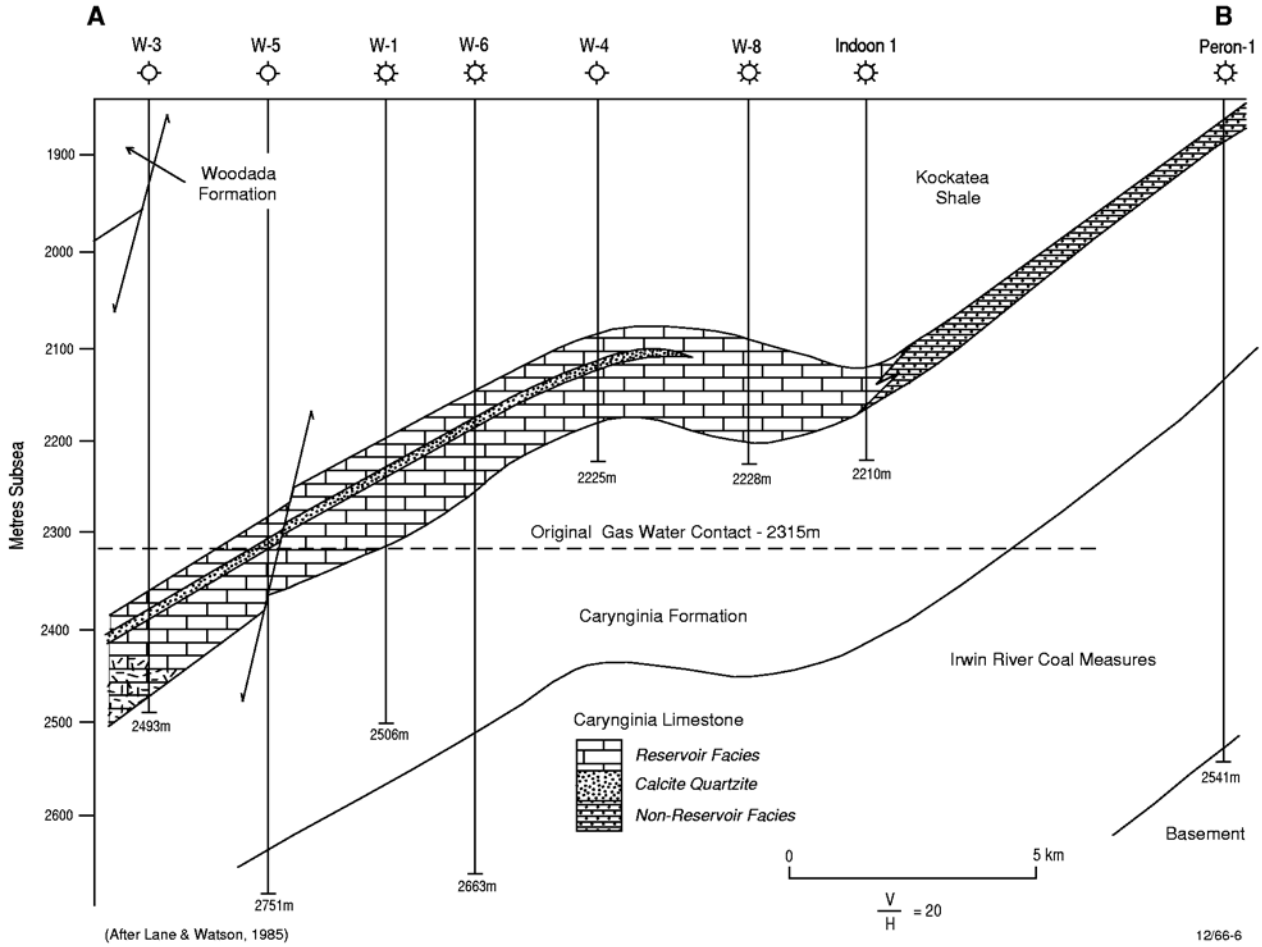


Figure 12 CROSS SECTION THROUGH THE WOODADA ACCUMULATION

The Woodada field is located on the nose of a north plunging anticline (Figure 16). To the southwest, the anticlinal nose is cut by the north-south trending Beagle Fault. Here, the Carynginia Limestone (if it does occur) is faulted against crystalline basement, which may provide a partial seal for this unit. However, as most of the producing wells at Woodada lie outside structural closure, the shaling out of the carbonate facies updip and to the south probably provides a stratigraphic seal for the reservoir (Figure 17).

A total of eleven development and appraisal wells (not including Indoon-1, East Lake Logue-1 and Peron-1, which were drilled between Woodada-6 and Woodada-8), have been drilled at Woodada since its discovery in 1980. Gas production from the field commenced in May 1982.

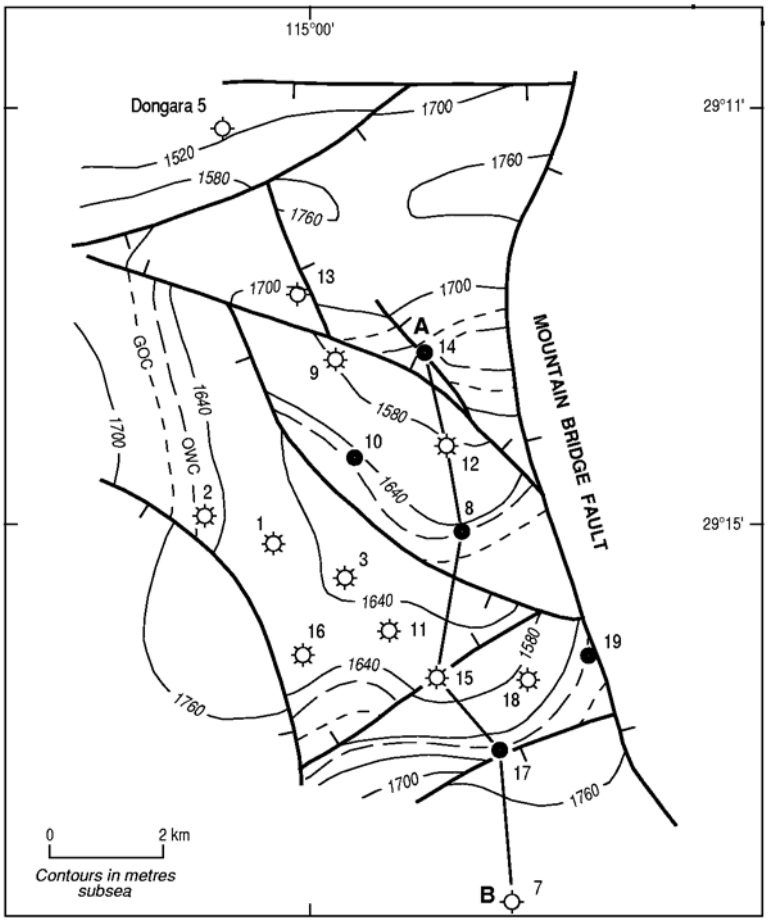
5. Dongara

The Dongara structure is a complex, faulted anticlinal feature within a northwest plunging fault block, located in the saddle area between the Beagle Ridge and the Northampton Block (Figure 7). The structure resulted from Late Triassic block faulting but was subsequently modified by Late Jurassic tectonism which has influenced the present distribution of hydrocarbons within the compartmentalised Permo-Triassic reservoirs (Jones, 1976).

The initial discovery well (Dongara-1), drilled in 1966, flowed gas from the Basal Triassic Sandstone at around 1622 m. Further pools were discovered by Dongara-3 (flowed gas from the Irwin River Coal Measures), Dongara-8 (which intersected an oil leg beneath the gas in the Basal Triassic Sandstone), Dongara-15 (flowed gas from the Carynginia Formation) and Dongara-24 (which flowed gas and recovered oil from the Arranoo Sandstone Member of the Kockatea Shale). To January 1994, a total of twenty seven exploration, appraisal and development wells have been drilled on the Dongara feature.

Reservoir quality is highest in the transgressive marine sands of the Basal Triassic Sandstone. Here, porosities of around 23% and permeabilities of 200 md are typical. The fluviatile and lacustrine sands of the Irwin River Coal Measures tend to be finer grained and more argillaceous, with porosities of around 18% and permeabilities of up to 10 md. The limestone/sandstone, Carynginia Formation gas reservoir has good porosity (around 20%) but poor permeability (up to 5 md).

After the completion of a 415 kilometre pipeline to Perth and Kwinana, gas production from the Dongara field commenced in October 1971. By early 1973, the field was producing 2 300 000 m^3/day of gas from ten wells. Oil production from Dongara commenced in the late 1970s at a rate of around 300 bbl/day (limited by the availability of transport). The oil is high pour point crude that must be heated while in storage to prevent solidification. At June 1993, 11.796×10^9 m^3 of gas had been produced from the Dongara accumulation (WADME) (Table 2).



(After Jones, 1976)

Figure 13 STRUCTURE TOP BASAL TRIASSIC, DONGARA ACCUMULATION

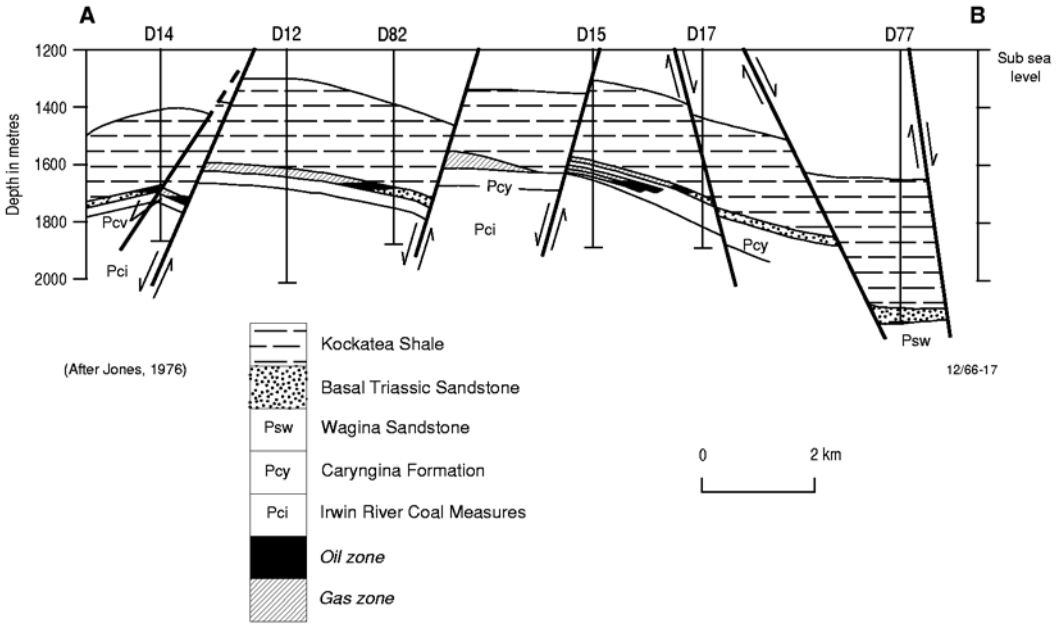


Figure 14 CROSS SECTION THROUGH DONGARA ACCUMULATION

6. Gingin

Gingin-1, located 89 km north of Perth in the Dandaragan Trough, was one of the first structures defined by seismic to be tested in the Perth Basin. Drilled in 1965, on a large, faulted anticlinal structure (Figure 9), it flowed gas (with associated condensate) at up to 109 000 m^3/day from four sands within the Cockleshell Gully Formation. A second well was drilled, but this recorded a poor gas flow from two of the zones (5600 m^3/day).

Porosities and permeabilities in the reservoirs are poor - up to 14% and 5 md respectively. However, early in 1971, after fracturing and cleanup, Gingin-1 flowed gas at a rate of 370 000 m^3/day on a short test. This well subsequently began producing into the Dongara-Perth gas pipeline that same year and by late 1972 was producing gas at the rate of 140 000 m^3/day. Gingin-1 was shut in at the end of 1972 after producing 0.049×10^9 m^3 of gas and nearly 17 000 bbls of condensate.

7. Mount Horner

Mount Horner-1, located 380 kilometres north-northwest of Perth in the Dandaragan Trough was drilled in 1965 as a test of a tilted fault block (Figure 13). The well found oil reservoired in fine, regressive sands near the top of the Kockatea Shale (Arranoo Sandstone Member) in the upthrown fault block (Figure 12). The reservoir is sealed across the bounding fault by the Eneabba Member of the Cockleshell Gully Formation. Due to poor fault seal, the upthrown fault block has only limited oil reserves trapped in the Arranoo Sandstone Member. A downdip test (Mount Horner-2) proved to be dry and in 1973, the permit was relinquished by the operator (WAPET). Further seismic work was undertaken by the new permittees which established that a small compressional anticline on the downthrown side of the fault had developed in response to Neocomian wrenching.

Between 1980 and 1981 Mount Horner-3, 4 and 5 were drilled. Mount Horner-4, drilled on the downthrown side of the fault, intersected a Basal Triassic Sandstone oil pool. Closure and seal for this pool is independent of the main fault and is controlled by the anticlinal structure. Mount Horner-5 subsequently discovered a new oil pool reservoired in the 'B' sand of the Cockleshell Gully Formation. As with the Basal Triassic Sandstone pool, closure on the 'B' sand reservoir is independent of the main fault. This pool is of limited areal extent (the reservoir sand pinches out to the east).

The main reserves in the Mount Horner field were discovered in 1987 by Mount Horner-7. This well intersected an oil pool in the 'F' sand of the Cockleshell Gully Formation. The pool is trapped in the anticlinal closure on the downthrown side of the fault and is sealed independently of the main fault.

The best quality reservoirs in the Mount Horner accumulation are found in the Basal Triassic Sandstone. This unit typically comprises massive, cross-bedded coarse sandstones with porosities varying between 6.3% and 27.7%. Horizontal permeabilities are generally excellent (up to 5050 md) with exceptionally high vertical permeability measured in Mount Horner-7 (3078 md). Consequently, this reservoir is susceptible to

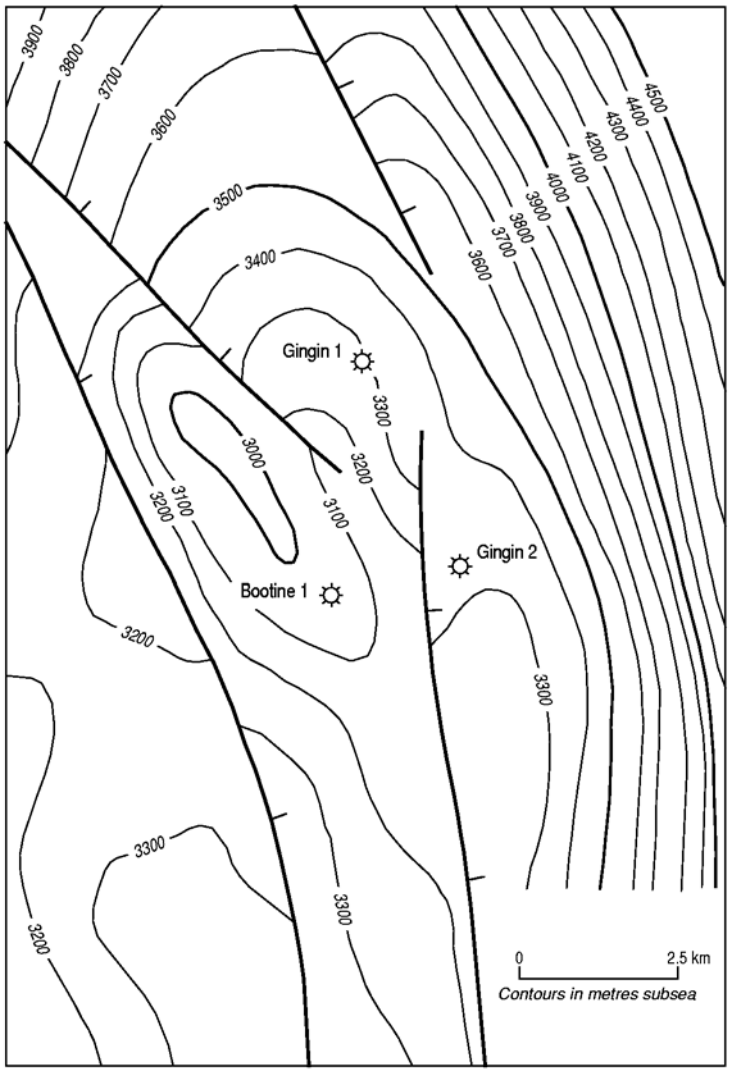
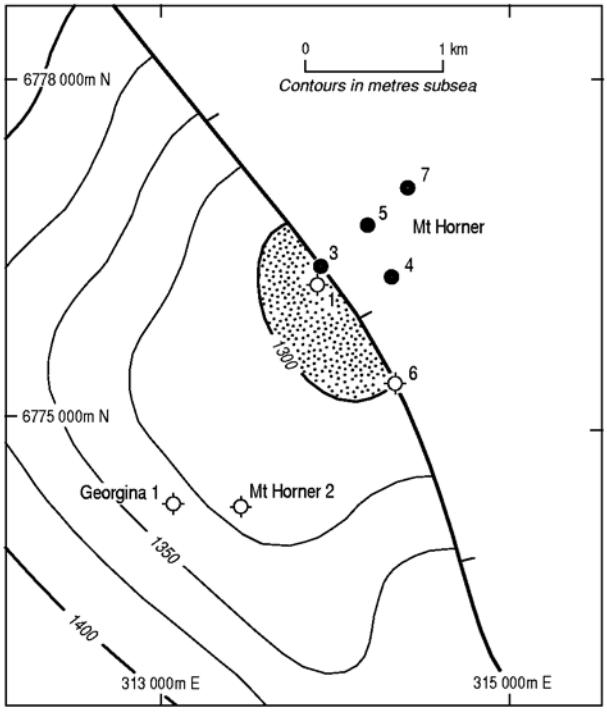
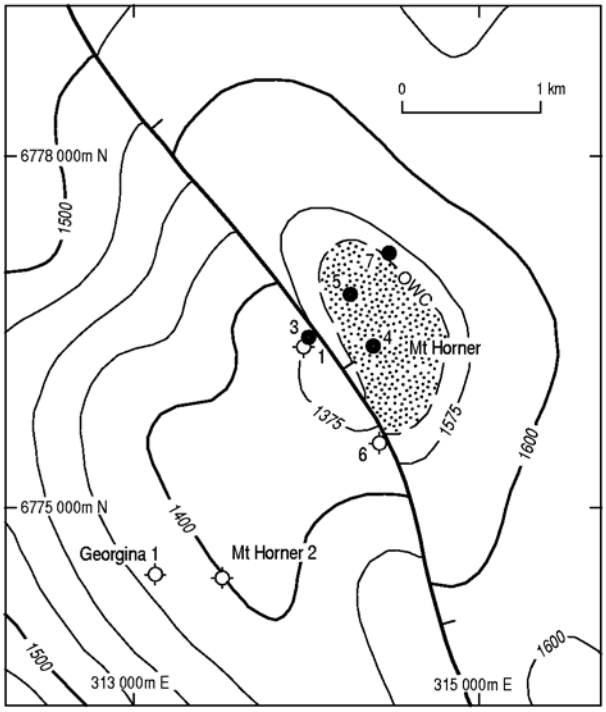


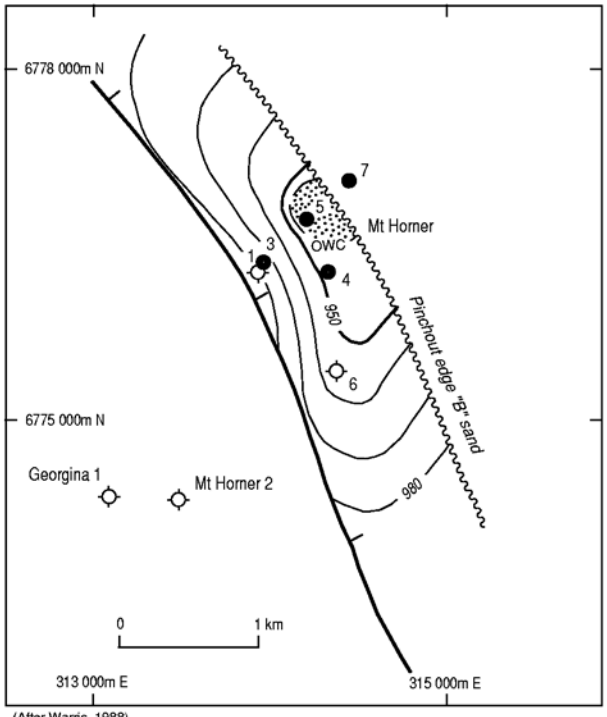
Figure 15 STRUCTURE EARLY JURASSIC, GINGIN ACCUMULATION



Arranoo Sandstone Member

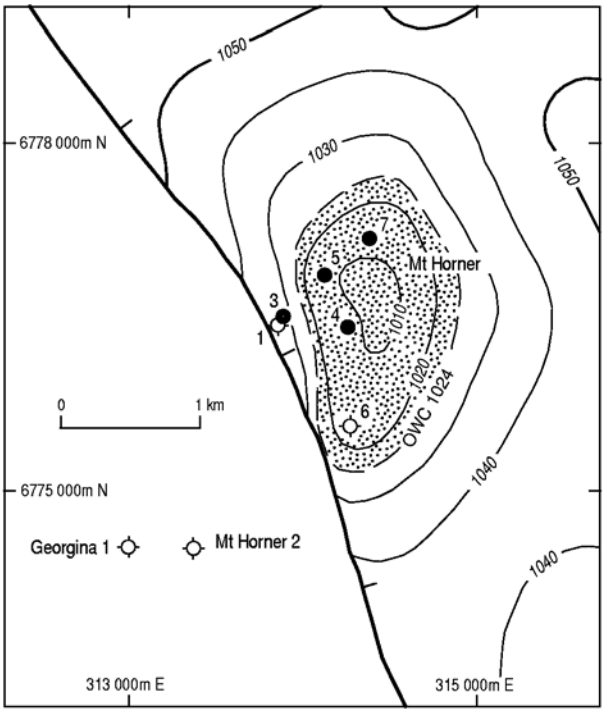


Basal Triassic Sandstone



(After Warris, 1988)

'B' Sand, Cockleshell Gully Formation



12/66-4

'F' Sand, Cockleshell Gully Formation

Figure 16 STRUCTURE MAPS, PRODUCING RESERVOIRS, MOUNT HORNER ACCUMULATION

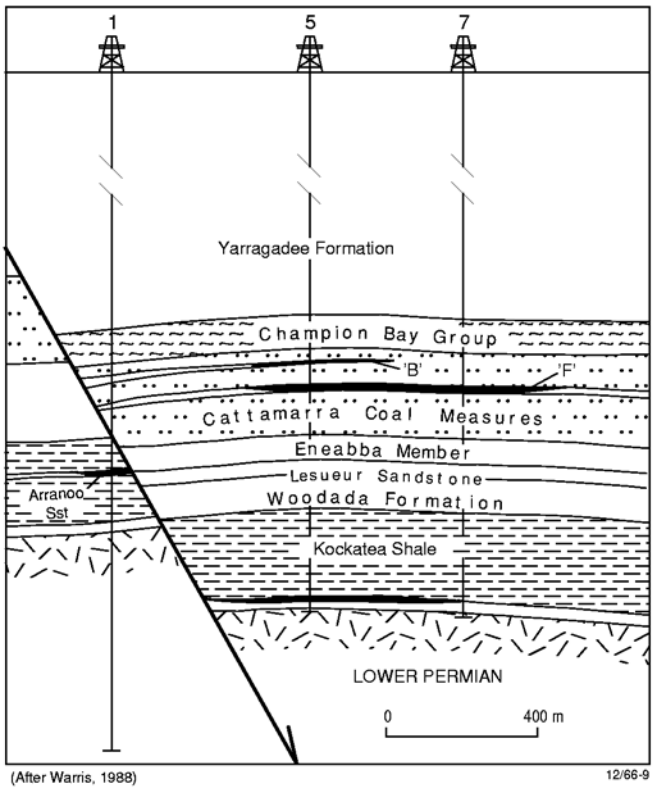


Figure 17 STRUCTURAL CROSS SECTION, MOUNT HORNER ACCUMULATION

water coning (Warris, 1988). The fine grained argillaceous sandstones of the Arranoo Sandstone Member are poor quality reservoirs at Mount Horner (14.7% average porosity and 10 md average permeability). Oil reservoired in this unit is probably residual - much of the original oil in place having escaped across the main fault which is non-sealing. The 'F' sand reservoir is fine grained, cemented in part with calcite with porosities and permeabilities of around 21.8% and 70 md respectively. The 'B' sand,

although a good quality reservoir, (calculated log porosity of 25%), is of limited extent and the oil is biodegraded (Warris, 1988).

Production from the Mount Horner field commenced in May 1984. Mount Horner-4 initially produced oil from the Basal Triassic Sandstone, but water cut rapidly increased and the well was shut in July 1984. Mount Horner-5 was also completed in the Basal Triassic Sandstone, but water coning forced the abandonment of the Basal Triassic Sandstone pool in 1986. In that same year, however, Mount Horner -5 commenced production from the 'B' sand. In 1987, Mount Horner-7 identified the 'F' sand reservoir and in 1992 a deeper 'L' sand pool was discovered by Mount Horner-12.

Oil from the Mount Horner field is trucked by road to the BP refinery at Kwinana, south of Perth. At June 1993, 0.128×10^6 kL of oil had been produced (WADME,1993).

8. North Yardanogo

In 1990, North Yardanogo-1 was drilled five kilometres west of Beharra Springs to test a small anticline. Oil flowed at a rate of 1200 bbl/day from a DST taken in the Cattamarra Coal Measures around 1640 m. Approximately 0.001×10^6 kL of oil were subsequently produced from this field before North Yardanogo-1 was shut in (WADME, 1992).

9. Walyering

In 1971, Walyering-1 was drilled 130 km north of Perth to test an anticlinal feature delineated by seismic surveys in the late 1960s (figures 14 and 15). Gas flows were recorded from two sands within the Cattamarra Coal Measures. Walyering-2, designed to test the northern extension of the anticline, encountered the same gas bearing sands intersected in the discovery well. A further well (Walyering-3), investigated the potential of uplifted fault blocks to the southeast. However the two zones of interest proved to be water wet at this location. A deeper sand tested by this well flowed gas at the rate of 17 000 m^3/day.

The gas reservoirs at Walyering are poor quality. Porosities average around 9% and permeabilities are low (93 md). A production licence was awarded and Walyering-1 was connected to the Dongara-Perth gas pipeline in March 1972. After rapid production and pressure declines, the well was shut in. (Jones, 1976).

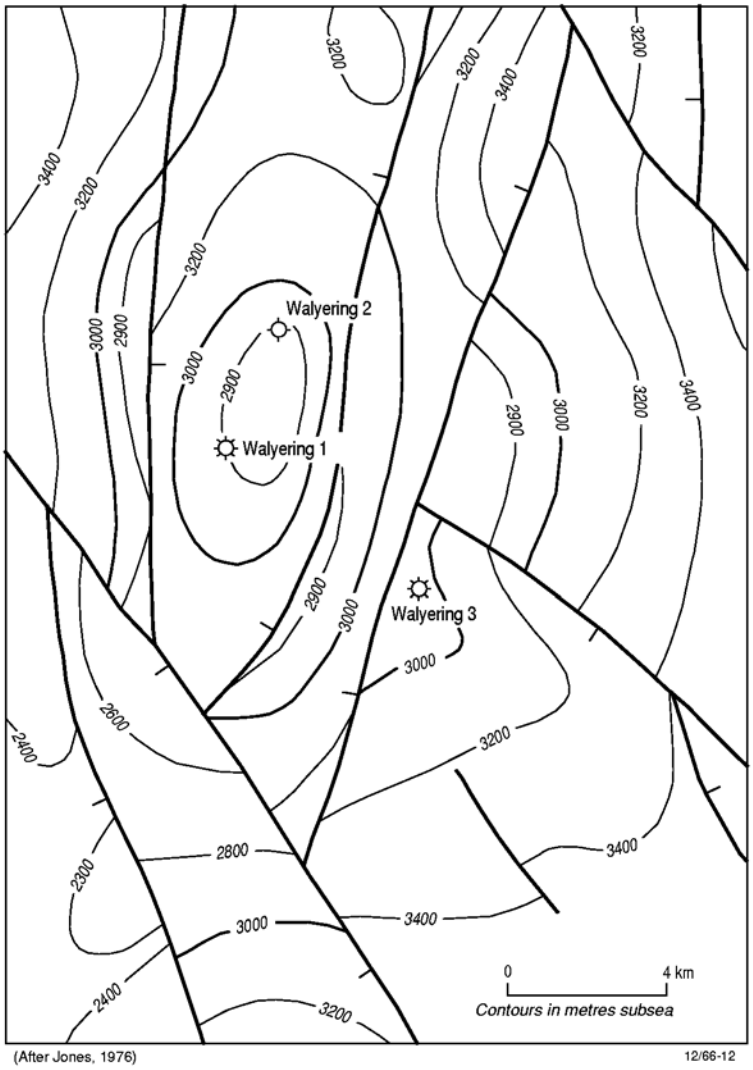


Figure 18 STRUCTURE EARLY JURASSIC
WALYERING ACCUMULATION

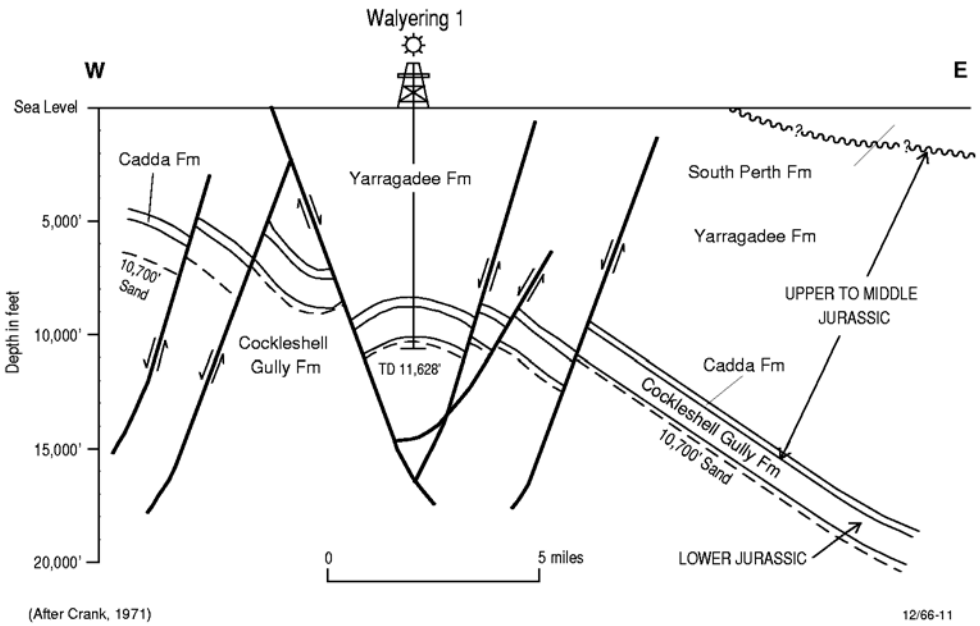


Figure 19 SCHEMATIC CROSS SECTION THROUGH THE WALYERING ACCUMULATION

Table 2. Reserves and Cumulative Production, commercial accumulations, Perth Basin

ACCUMULATION	REMAINING RECOVERABLE RESERVES (50% Prob) (at 30/6/93)			CUMULATIVE PRODUCTION (at 30/6/93)		
	OIL (10^6kL)	GAS (10^9m^3)	COND (10^6kL)	OIL (10^6kL)	GAS (10^9m^3)	COND (10^6kL)
Beharra Springs	0	0.465	0	0	0.233	0.002
Dongara	0.013	0.882	0	0.166	11.796	0.045
Mondarra	0	0.003	0	0	0.663	0.009
Mount Horner	0.090	0	0	0.128	0	0
Woodada	0	2.390	0.016	0	0.933	0.007
North Yardanogo	0	0	0	0.001	0	0
Yardarino	0	0	0	0.002	0.133	0.001
Walyering	0	0	0	0	0.007	0
Gingin	0	0	0	0	0.049	0.003

Source : Western Australian Department of Minerals and Energy (WADME), 1993.

4.1.2 *Other Accumulations* (Plates 1 and 2)

10. Arrowsmith

In 1965, Arrowsmith-1, drilled by French Petroleum, tested Permian objectives in an elongate structural closure sealed by the Beagle Fault (Figure 20). A DST taken between 2816 m and 2821 m in a sandstone near the top of the Carynginia Formation flowed gas at a rate of 113 000 m^3/day through a 1/2" choke. However, on production test, the flow rate and pressure rapidly declined, indicating the reservoir was of limited areal extent. Additional gas shows were encountered in tight reservoirs in the underlying Irwin River Coal Measures, but the well was eventually plugged and abandoned.

11. Erregulla

Erregulla-1 was drilled in 1966 to test Mesozoic and Permian objectives in a tilted fault block 50 kilometres southeast of the Dongara accumulation (Figure 21). A swab test over a perforated interval between 3174 m and 3181 m in the Cockleshell Gully Formation recovered 22.5 bbls of 47 degree API crude. After attempts to stimulate the well yielded a further 36 bbls of light green oil, Erregulla-1 was completed as a suspended oil well.

12. North Erregulla

North Erregulla-1 was drilled in 1967 as a follow up to Erregulla-1 which discovered oil in the Cockleshell Gully Formation. North Erregulla-1 failed to intersect hydrocarbon bearing sands in the Lower Jurassic section, but recovered 90 litres of 38 degree API oil from tight sands near the top of the Kockatea and 36 litres of oil from the Basal Triassic Sandstone.

13. West Erregulla

West Erregulla-1 was drilled on an anticlinal feature, 11 kilometres west of the Erregulla accumulation in 1990. A small gas flow (510 m^3/day) was measured in a DST taken between 3944 m and 3975.5 m in the Basal Triassic Sandstone. West Erregulla-1 has been plugged and abandoned.

14. Mountain Bridge

In May 1993, Mountain Bridge-1 was drilled 1 kilometre north of the Arrowsmith accumulation. DST 2A, taken over the interval 3185-3235 m in the Carynginia Formation, flowed gas at a rate of 7079 m^3/day. The accumulation was considered uneconomic and the well plugged and abandoned.

15. Arranoo-1

In January 1994, Arranoo-1, drilled in the Dandaragan Trough, encountered significant hydrocarbon shows between 1549 m and 1566 m in the Wagina Sandstone and over several intervals in the Carynginia Formation and Irwin River Coal Measures. Wireline logs and sidewall cores indicated 6 m and 3 m net oil columns in the Arranoo Sandstone and the Carynginia Formation, respectively. A subsequent production test in the Carynginia Formation recovered 6.5 bbls of 35 degree API oil at an estimated flow rate of between 13 and 25 bbls/day. A production test conducted in the Wagina Sandstone recovered formation water. At the time of writing, (March 1994), this discovery was still being evaluated by the operator (Discovery Petroleum NL).

16. Ocean Hill

Ocean Hill-1, was drilled in 1991 to test an anticlinal structure in the Dandaragan Trough. Gas flowed at a rate of 822 m^3/day from sands in the Cattamarra Coal Measures between 3063 m and 3130 m. The discovery was considered to be uneconomic and the well was plugged and abandoned.

17. Warro

In 1977, Warro-1 tested an anticlinal feature 200 kilometres north of Perth in the Dandaragan Trough. Gas sands were encountered while drilling the Upper Jurassic section, but testing proved inconclusive and the well was subsequently abandoned. A follow up well, Warro-2, penetrated two gas bearing sands in the Upper Yarragadee Formation. In the upper sand, a DST taken between 3977 m and 4016 m flowed gas at a rate of 2700 m^3/day. A second DST, between 4086 m and 4120 m, tested the lower sand. Here, the Yarragadee Formation flowed gas at a rate of 2940 m^3/day. The flow rates were not considered economic and the well was abandoned.

4.2 Abrolhos Sub-basin (Plate 2)

4.2.1 *Other Accumulations*

18. Houtman

In 1978, Houtman-1 was drilled 98 km north-northwest of Geraldton in the Abrolhos Sub-basin. The well tested a complex, north-northwest trending faulted anticline at Triassic level.

A number of RFTs were conducted in the Cattamarra Coal Measures Member of the Cockleshell Gully Formation - three of which recovered small quantities of gas. A black oil scum was also noted in one RFT taken at 3378.5 m. A production test over the hydrocarbon bearing intervals recovered only small quantities of solution gas. Analysis of the gas showed it was wet (approximately 20% by volume of C2+ hydrocarbons) and suggested significant quantities of light liquids may be present in the reservoir. The failure to achieve significant flow rates on production test may, in part, have been due to formation damage caused by high mud weights used while drilling the Lower Jurassic section.

Estimated log porosities for the gas sands range between 7% and 10.5% and permeabilities are low (estimated FIT/RFT permeabilities range from 0.3 md to 24 md). Houtman-1 was plugged and abandoned.

4.3 Vlaming Sub-basin (Plate 2)

4.3.1 *Other Accumulations*

19. Gage Roads

In 1968/69, Gage Roads-1 was drilled in the Vlaming Sub-basin to test Cretaceous and Jurassic objectives below the intra-Neocomian unconformity. Sited on a north-south trending fault dependent closure on the western flank of the Rottnest Trench (Figure 22), the well encountered two hydrocarbon bearing intervals. The first occurred in the Gage Sandstone Member of the South Perth Formation and the second in sandstones of the Yarragadee Formation, immediately below the Otorowiri Member.

Two DSTs in the Gage Sandstone Member recovered quantities of oil. DST 1A, taken over the intervals 1760-62 m and 1765-69 m recovered 40 bbls of 37 degree API oil in a swab and flow test. DST 2A recovered 58.5 bbls of 41.2 degree API oil in a swab and flow test from a deeper interval in the same unit (1779-82 m). Although the zones tested display good reservoir characteristics (porosity of around 22% and permeabilities averaging 300 md), water saturation was too high for clean oil production. The trap for the Gage Sandstone reservoir is stratigraphic. The reservoir sands pinchout on the eastern flank of the Roe anticline and are sealed either by intraformational shales and siltstones or by the overlying South Perth Shale.

Wireline log interpretation indicated that four sands between 2618 m and 2646 m in the Yarragadee Formation (immediately below the Otorowiri Member) were probably gas bearing. A core cut over this interval showed that permeabilities were too low to allow significant production of hydrocarbons (1.0-5.5 md). No hydrocarbons were recovered from these sands.

A follow-up well, Gage Roads-2, was drilled 1.6 kilometres west-northwest (updip within the Gage Sandstone Member) of the discovery well. Wireline log evaluation indicated that a 1.5 m oil saturated zone was present in the Gage Sandstone Member between 1351 m and 1352.5 m. However cores cut over this interval showed the reservoir was tight (porosities between 1.1% and 16.4% and permeabilities between 0.1 md and 10.0 md) and the oil bearing sand was not tested.

4.4 Bunbury Trough (Plate 2)

4.4.1 *Other Accumulations*

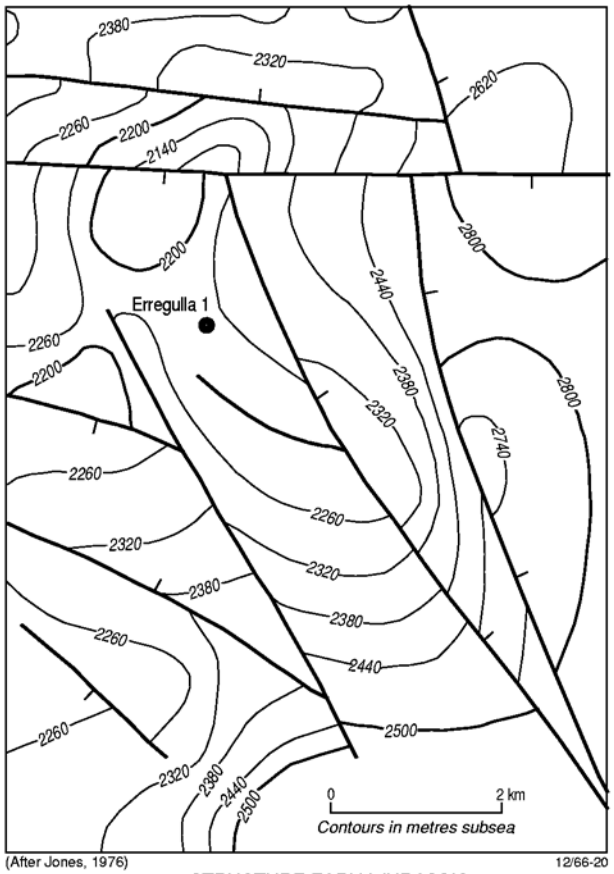
20. Whicher Range

In 1969, Whicher Range-1 was drilled on the culmination of the Whicher Range fold - a well defined domal structure at Triassic level in the Bunbury Trough (Figure 23). The well encountered a total of nine gas bearing sands in the Permian Sue Coal Measures.

The reservoirs comprise medium to coarse grained sandstones with scattered quartz pebbles in an argillaceous matrix with minor calcareous cement. The sands are sealed by intraformational siltstones, shales and coals. Reservoir quality is highly variable, with porosities ranging between 5% and 18% and permeabilities between 0 md and 23 md.

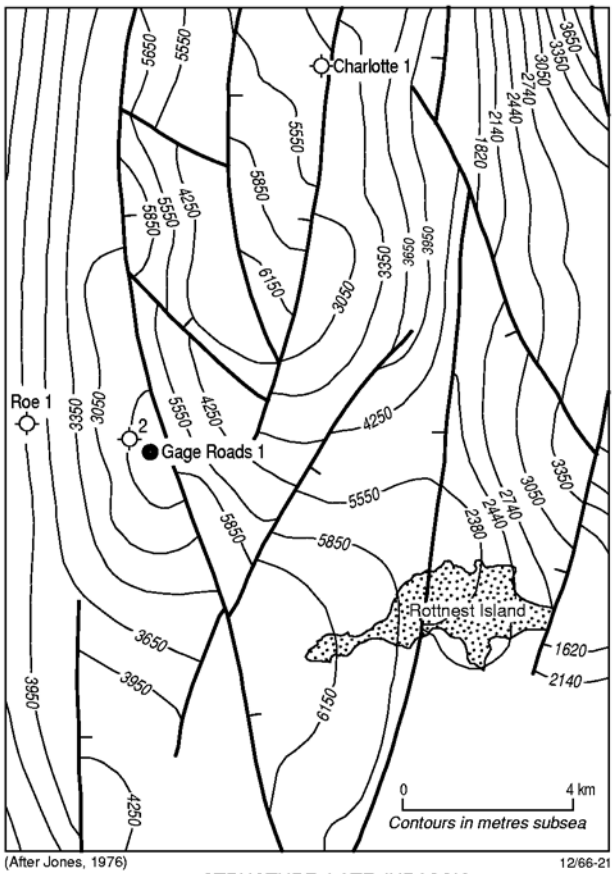
A DST taken at 4164 m flowed gas at a rate of 53 800 m^3/day. A deeper interval (4200 m) flowed gas at 35 700 m^3/day. Both gas flows were accompanied by small quantities of condensate. Attempts to improve the flow rates by fracturing the formation were unsuccessful and the well was eventually abandoned.

A stratigraphic summary of Perth Basin petroleum accumulations is shown in Table 4.



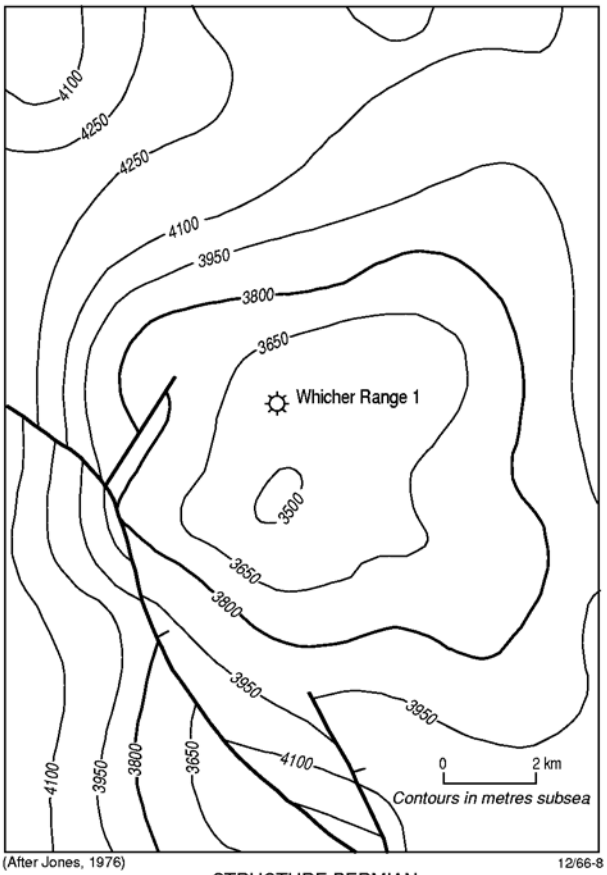
(After Jones, 1976) 12/66-20

Figure 21 STRUCTURE EARLY JURASSIC, ERREGULLA ACCUMULATION



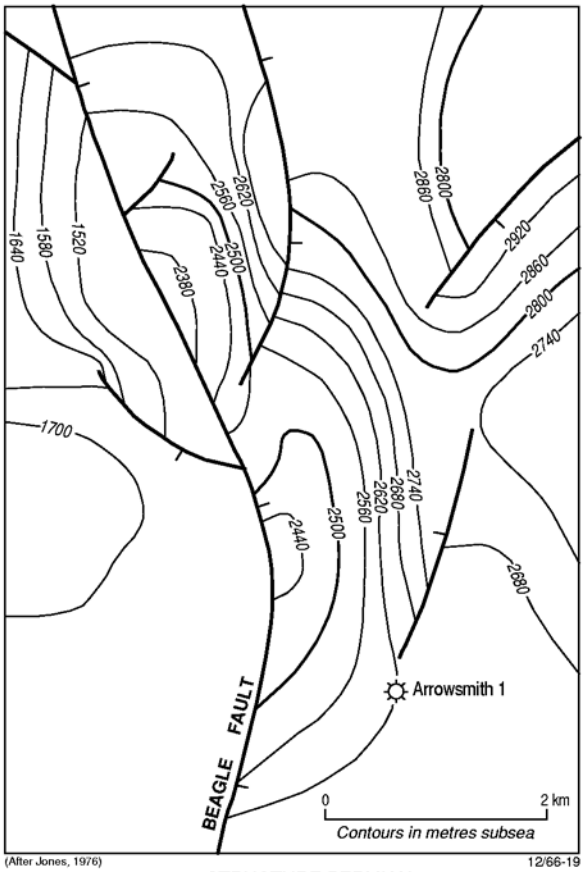
(After Jones, 1976) 12/66-21

Figure 22 STRUCTURE LATE JURASSIC, GAGE ROADS ACCUMULATION



(After Jones, 1976) 12/66-8

Figure 23 STRUCTURE PERMIAN, WHICHER RANGE ACCUMULATION



(After Jones, 1976) 12/66-19

Figure 20 STRUCTURE PERMIAN, ARROWSMITH ACCUMULATION

4.5 Hydrocarbon Shows

In addition to the commercial and non-commercial discoveries discussed above, several wells in the Perth Basin have encountered minor hydrocarbon shows. The most significant of these are shown in Table 3.

Table 3. Hydrocarbon shows, Perth Basin.

Wellname	Sub-basin	Hydrocarbon Show	Formation
Batavia-1	Abrolhos	mnr fluor 1785-1815m	Lesueur Sandstone
Lake Preston-1	Bunbury Trough	mnr gas shows	Sue Coal Measures
Sue-1	Bunbury Trough	mnr gas shows, fluor	Sue Coal Measures
Wonnerup-1	Bunbury Trough	mnr gas shows	Sue Coal Measures
Blackwood-1	Bunbury Trough	mnr gas shows	Sue Coal Measures
Connolly-1	Dandaragan Trough	oil show	Cadda
Bonnifield-1	Dandaragan Trough	fluorescence	Basal Triassic Ss
Conder-1	Dandaragan Trough	oil show	Basal Triassic Ss
Jay-1	Dandaragan Trough	tr oil in DST, 1010-26m	Cockleshell Gully
Coomallo-1	Dandaragan Trough	mnr gas shows	Cattamarra Coal M.
Donkey Creek-1	Dandaragan Trough	mnr gas and fluor	Lesueur Sandstone
		mnr gas and fluor	Woodada
Cadda-1	Dandaragan Trough	mnr oil and gas shows	Kockatea Shale
Eneabba-1	Dandaragan Trough	oil and gas shows	Kockatea Shale
Jurien-1	Dandaragan Trough	tr oil, oil staining, fluor	Kockatea Shale
Woolmulla-1	Dandaragan Trough	mnr oil and gas shows	Kockatea Shale
		gas cut mud, DST, 2752m	Irwin River Coal M.
Woodada-3	Dandaragan Trough	Oil show	Carynginia
Warnbro-1	Vlaming	mnr gas show, fluor	Yarragadee
Peel-1	Vlaming	mnr fluor, slow milky cut	Yarragadee
Tuart-1	Vlaming	mnr oil show	South Perth Shale

Table 4. Continued.

AGE	FORMATION /MEMBER	West Erregulla	North Erregulla	Yardarino	Mondarra	Arranoo	Beharra Springs	Arrowsmith	Woodada	Mountain Bridge	Whicher Range
CRETACEOUS	Gage Sandstone Mbr										
	Parmelia Fm										
JURASSIC	Yarragadee Fm										
	Cadda Fm										
	Cockleshell Gully Fm										
TRIASSIC	Lesueur Sandstone										
	Woodada Fm										
	Kockatea Shale										
	Arranoo Sandstone Mbr										
	Kockatea Shale		**Oil**								
	Basal Triassic Sandstone	**Gas**	**Oil**	**Oil+Gas**	**Gas**						
PERMIAN	Wagina Sandstone			**Oil+Gas**	**Gas**						
	Carynginia Fm					**Oil**	**Gas**	**Gas**	**Gas**	**Gas**	
	Irwin River Coal Measures										
	Sue Coal Measures										**Gas**
	Holmwood Shale										
	Nangetty Fm										
SILURIAN	Tumblagooda Sandstone										

Table 4. Hydrocarbon accumulations, Perth Basin.

AGE	FORMATION /MEMBER	Gage Roads	Warro	Gingin	Houtman	Ocean Hill	Walyering	North Yardanogo	Erregulla	Mount Horner	Dongara
CRETACEOUS	Gage Sandstone Mbr	**Oil**									
	Parmelia Fm										
JURASSIC	Yarragadee Fm		**Gas**								
	Cadda Fm										
	Cockleshell Gully Fm			**Gas**	**Gas**	**Gas**	**Gas**	**Oil**	**Oil**	**Oil**	
TRIASSIC	Lesueur Sandstone										
	Woodada Fm										
	Kockatea Shale										
	Arranoo Sandstone Mbr									**Oil**	**Oil+Gas**
	Kockatea Shale										
	Basal Triassic Sandstone									**Oil**	**Oil+Gas**
PERMIAN	Wagina Sandstone										
	Carynginia Fm										**Gas**
	Irwin River Coal Measures										**Gas**
	Sue Coal Measures										
	Holmwood Shale										
	Nangetty Fm										
SILURIAN	Tumblagooda Sandstone										

Oil Oil accumulation **Gas** Gas accumulation

4.6 Hydrocarbon Characterisation

4.6.1 *Oil*

Powell and McKirdy (1973), undertook a study of a number of crude oil samples from the Perth Basin. These include the Dongara, Yardarino and Mondarra oils (reservoired in the Basal Triassic Sandstone), the Mount Horner and North Erregulla oils (recovered from the Arranoo Sandstone Member of the Kockatea Shale) and the Erregulla crude (recovered from the Cockleshell Gully Formation). Analyses of these crudes showed that they are all highly paraffinic and similar in composition.

Distillation data from the Dongara, Mondarra and Yardarino oils shows that these crudes have been stripped of their light ends. The absence of the low molecular weight compounds from the oils indicates that they are not in equilibrium with the overlying gas and implies that the oil and gas were emplaced in the Basal Triassic Sandstone reservoirs at different times.

Loss of the low molecular weight fraction in an oil is usually attributed to water washing of the crude by meteoric waters in the reservoir. However, Powell and McKirdy, (1973) have suggested that the oil reservoired in the Basal Triassic Sandstone at Dongara, Mondarra and Yardarino was sourced from the Kockatea Shale, whereas the gas originated downdip, from Permian coals in the Irwin River Coal Measures. It is possible that the late emplacement of dry gas may have mobilised and stripped the light ends from these oils.

All the oils analysed from the Perth Basin are extremely waxy and are solid at room temperature. There is a predominance of high molecular weight compounds and an absence of naphthenic components in the crudes. The above indicate that the Perth Basin oils were sourced from terrestrial organic matter which has undergone little thermal alteration. Pristane to phytane ratios are anomalously low in these oils (usually indicative of a marine source). However, low rank coals which have not undergone extensive thermal alteration have low pristane to phytane ratios (Brooks and others, 1969).

Basic properties of some Perth Basin oils are shown in Table 6.

4.6.2 *Gas*

Gas analyses from a number of gas accumulations in the Perth Basin are shown in Table 5. Gas reservoired within the Cockleshell Gully Formation (Gingin, Houtman, Walyering) tends to be wet. The hydrocarbons are believed to have been generated within the Cattamarra Coal Measures and the presence of condensate is attributed to the relatively high proportion of exinite in the source sequence (Thomas and Brown, 1983).

Powell and McKirdy (1973), analysed condensate samples from two different levels within the Gingin and Walyering accumulations. They showed the condensates are

paraffinic to naphthenic, with those from deeper levels having a high wax content. All condensates exhibit intermediate pristane to phytane ratios, indicating a mixed source.

Gases recovered from the deeper Permo-Triassic reservoirs (Dongara, Mondarra, Yardarino, Woodada and Whicher Range) tend to be dry. This reflects the greater thermal maturity and the higher proportion of gas prone organic matter present in the Permian source rocks.

Table 5. Compositional data, selected gas accumulations, Perth Basin

WELL	Arrowsmith-1	Dongara-1	Dongara-1	Dongara-3	Gingin-1	Gingin-2	Mondarra-1	Walyering-1
FORMATION	Carynginia	Basal Triassic Sandstone	Irwin River Coal Measures	Basal Triassic Sandstone	Cockleshell Gully	Cockleshell Gully	Basal Triassic Sandstone	Cockleshell Gully
GAS (% Volume)								
Methane	81.7	96.5	96.3	97.9	88.8	86.6	92.44	93.0
Ethane	9.2	2.4	2.6	1.7	6.3	7.3	2.77	3.65
Propane	4.3	0.7	0.8	0.4	2.2	3.2	0.59	1.09
Isobutane	0.7	0.2	0.1	tr	0.6	1.0	0.07	0.175
n-Butane	1.4	0.2	0.2	-	0.6	1.1	0.11	0.275
Isopentane	0.4	-	-	-	0.2	0.5	0.03	0.085
n-Pentane	0.5	-	-	-	0.1	0.3	0.03	0.080
Hexanes +	-	-	-	-	-	-	0.9	-
Nitrogen	-	-	-	-	-	-	0.29	0.32
Oxygen	-	-	-	-	-	-	tr	0.07
Carbon Dioxide	-	-	-	-	0.8	-	3.52	0.98
Hydrogen Sulphide	-	-	-	-	-	-	-	-
Specific Gravity	-	0.574	0.579	-	0.65	-	0.615	0.611

WELL	Yardarino-1	Yardarino-3	Woodada-1	Whicher Range-1	Houtman-1
FORMATION	Basal Triassic Sandstone	Basal Triassic Sandstone	Carynginia	Sue Coal Measures	Cockleshell Gully
GAS (% Volume)					
Methane	96.8	62.5	89.72	92.0	78.8
Ethane	2.3	3.6	0.91	4.4	7.9
Propane	0.7	1.0	0.49	3.2	3.1
Isobutane	0.1	0.1	0.48	-	0.6
n-Butane	0.1	0.2	0.99	-	0.6
Isopentane	-	0.1	-	-	0.5
n-Pentane	-	tr	-	-	0.5
Hexanes +	-	-	0.95	-	0.8
Nitrogen	-	24.0	2.35	0.4	-
Oxygen	-	-	-	-	-
Carbon Dioxide	-	-	4.11	-	7.0
Hydrogen Sulphide	-	-	-	-	-
Specific Gravity	0.576	-	0.65	-	-

Table 6. Selected crude oil and condensate analyses, Perth Basin.

WELL	Dongara-1	Dongara-4	Dongara-14	Yardarino-1	Mondarra-1	Mount Horner	Whicher Range-1	Gage Roads-1	Yardarino-1
FORMATION	Basal Triassic Sandstone	Basal Triassic Sandstone	Basal Triassic Sandstone	Basal Triassic Sandstone	Basal Triassic Sandstone	Basal Triassic Sandstone	Sue Coal Measures	Gage Sandstone Member	Wagina Sandstone
PROPERTY									
Gravity	35 deg API	54.1 deg API	35.5 deg API	35 deg API	47.9 deg API	32 deg API	41.5 deg API	37 deg API	37.6 deg API
Sulphur	Low	nd	nd	0.06% (wt)	nd	0.13 (ppm)	0.6% (wt)	0.6%(wt)	0.4%(wt)
Initial GOR	326 SCF/bbl	nd	nd	500 SCF/bbl	nd	nd	nd	nd	nd
Pour Point	32.2 deg C	nd	nd	32.2 deg C	nd	nd	nd	nd	nd
Viscosity	19.3-19.9 cs (100 deg F)	nd	nd	13.03 cs (100 deg F)	nd	nd	nd	nd	nd
Bubble Point	2470 psi	nd	nd	nd	nd	nd	nd	nd	nd
% Aromatics	nd	0.4	10.2	nd	4.3	nd	12.6	12.1	8.5
% Saturates	nd	96.5	81.7	nd	93.5	nd	83.2	81.2	85.1
% ONS comp.	nd	3.0	8.0	nd	1.5	nd	4.1	6.6	6.2
% Asphalt	nd	<0.05	<0.05	nd	<0.05	nd	0.19	0.05	0.05
Prist/Phytane	nd	1.1	1.2	nd	1.3	nd	5.3	5.0	1.0

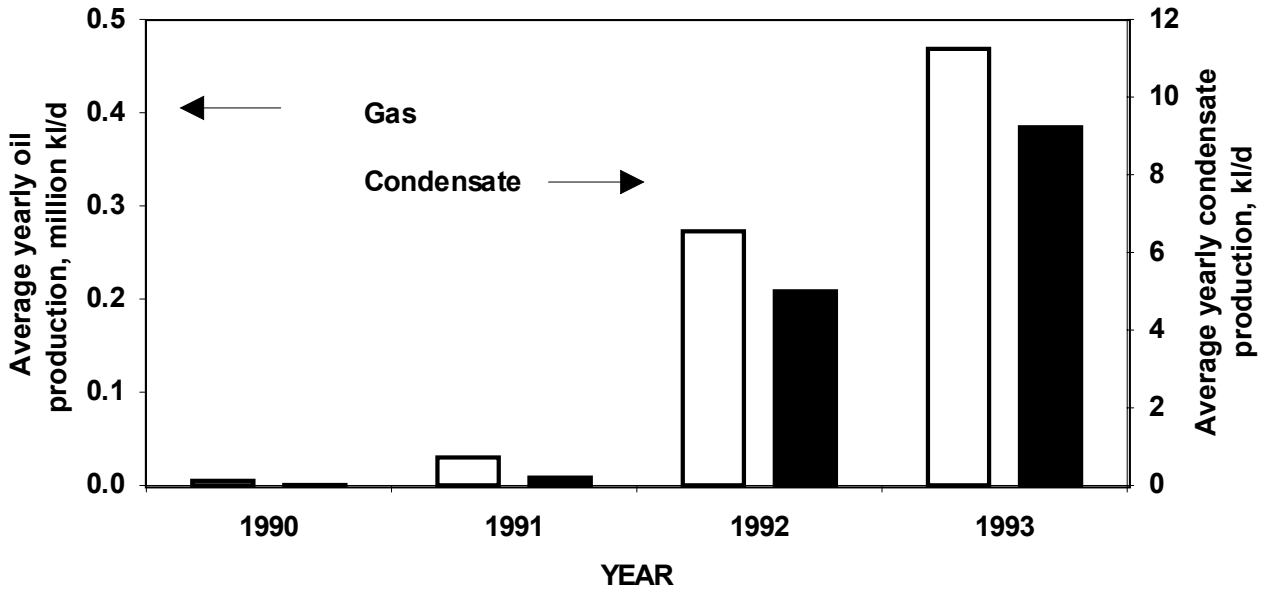
WELL	Mondarra-3	Nth Erregulla-1	Mount Horner-1	Gingin-1	Gingin-2	Mount Horner	Mount Horner	Erregulla-1	Walyering-1	Walyering-2
FORMATION	Wagina Sandstone	Arranoo Sandstone Member	Arranoo Sandstone Member	Cockleshell Gully	Cockleshell Gully	"B" Sand Cockleshell Gully	"F" Sand Cockleshell Gully	Cockleshell Gully	Cockleshell Gully	Cockleshell Gully
PROPERTY										
Gravity	35.7 deg API	34.6 deg API	36.7 deg API	41.8 deg API	38.5 deg API	25.2 deg API	35.5 deg API	34.8 deg API	45.2 deg API	45.6 deg API
Sulphur	nd	nd	nd	nd	<0.1% (wt)	0.03 (ppm)	0.01 (ppm)	0.03% (wt)	0.1%(wt)	nd
Initial GOR	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pour Point	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Viscosity	nd	nd	nd	nd	nd	nd	nd	35.1 (s.u.s.) (100 deg F)	nd	nd
Bubble Point	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
% Aromatics	6.7	24.4	18.0	13.7	19.7	nd	nd	7.6	9.8	15.5
% Saturates	91.6	73.9	70.9	83.3	72.6	nd	nd	90.5	86.3	79.3
% ONS comp.	1.6	1.6	11.0	2.9	7.6	nd	nd	1.8	3.7	5.0
% Asphalt	0.05	0.05	0.31	0.05	0.08	nd	nd	0.05	0.05	0.30
Prist/Phytane	1.1	1.1	1.2	5.5	3.1	nd	nd	1.1	2.8	3.4

5. DEVELOPMENTS IN THE PERTH BASIN

5.1 Beharra Springs

Operator:	SAGASCO Resources Ltd	
Location:	350 km north of Perth	
Discovered:	May-90, Beharra Springs 1	
Production started:	June-90 extended production test May-92 permanent production facilities commissioned November-93 permanent production facility expanded	
Product:	Gas	
No. of wells:	Producers	3
	Shut in	0
	Plugged and abandoned	0
	Injection and water source	0
	Suspended 0	
	Total	3

Production history:



Production Facilities:

Located onshore, 1.6 km from the Western Australian Natural Gas pipeline in the Perth Basin, the Beharra Springs gas field was discovered in April 1990. Beharra Springs-1 flowed gas at a stabilised rate of 241 000 m^3/d. Production commenced on 9 January 1991 using a temporary production facility.

On 10 May 1992, SAGASCO commissioned a $9.4 million permanent gas processing plant at Beharra Springs, replacing the temporary facility. Gas from the permanent plant flowed at an initial rate of 5 TJ/d, rising quickly to 15 TJ/d. Projected sales to Alcoa of Australia over 10 years (from 1 January 1992), are 39.5 PJ. The installation of replacement membranes in the

treatment plant in October 1992, has increased production to an average rate of 18 TJ/d. Sustainable gas production was increased to 25% above maximum plant design in 1993.

The permanent gas process configuration includes inlet gas cooling and separation, low temperature separation of water and condensate (utilising "Joule Thompson" expansion), refrigeration for hydrocarbon dew point control, semi-permeable membrane removal of carbon dioxide, hydrogen sulphide and water and fixed bed hydrogen sulphide removal.

Under an agreement announced in March 1992, deliveries to Alcoa can double to 30 TJ/d. Under the terms of that contract, (to become effective should the proven recoverable reserves exceed 60 PJ), from 1996, Alcoa would be supplied with up to 40.5 PJ of additional gas.

To prove additional reserves, SAGASCO drilled the Beharra Springs number 3 appraisal well in December 1992. This well proved the existence of gas in the Northern portion of the field. The new well flowed gas at a rate of 538 000 m^3/d and entered production on 4 April 1993.

A review of recoverable reserves at Beharra Springs revealed that the gas field could contain 66 PJ of recoverable sales gas. SAGASCO have since negotiated with Alcoa for increased gas deliveries which have now commenced.

With the successful commissioning of the expanded plant facilities, gas sales from the Beharra Springs plant increased to 25 terajoules per day in November 1993. This was the culmination of 12 months of studies, design and fabrication installation activities headed up by the Perth Resources team to cost effectively increase the production capabilities.

In the first three months of 1993, initial design and optimisation studies were carried out in the Melbourne offices of design contractor Davy John Brown (Davy) by a SAGASCO and Davy team. A joint proposal was approved in April to spend some $2.2 million on the Beharra Springs plant to increase the design capacity from 15 to 25 TJ/D. The facilities design included three large high pressure vessels - two to remove the hydrogen sulphide from the gas using a zinc/copper oxide absorbent and the other to protect the specialised semi-permeable membranes from contamination at high gas rates utilising an activated carbon absorbent.

In July 1993, the contract to fabricate the vessels was won by a Victorian manufacturer working for Process Group International. They were delivered to Western Australia on schedule in October. Site activities commenced in October and culminated in a four and a half day tie-in shutdown of the Beharra Springs plant. Approximately 35 contractors working 12 hours per day, seven days per week, completed the activities within the time allocated. Some highlights of the project include:

- 680 high pressure welds completed without one re-weld being required.

- SAGASCO operations processed 140 permits to work within the gas plant in a two week period.

- The project was completed earlier than scheduled.

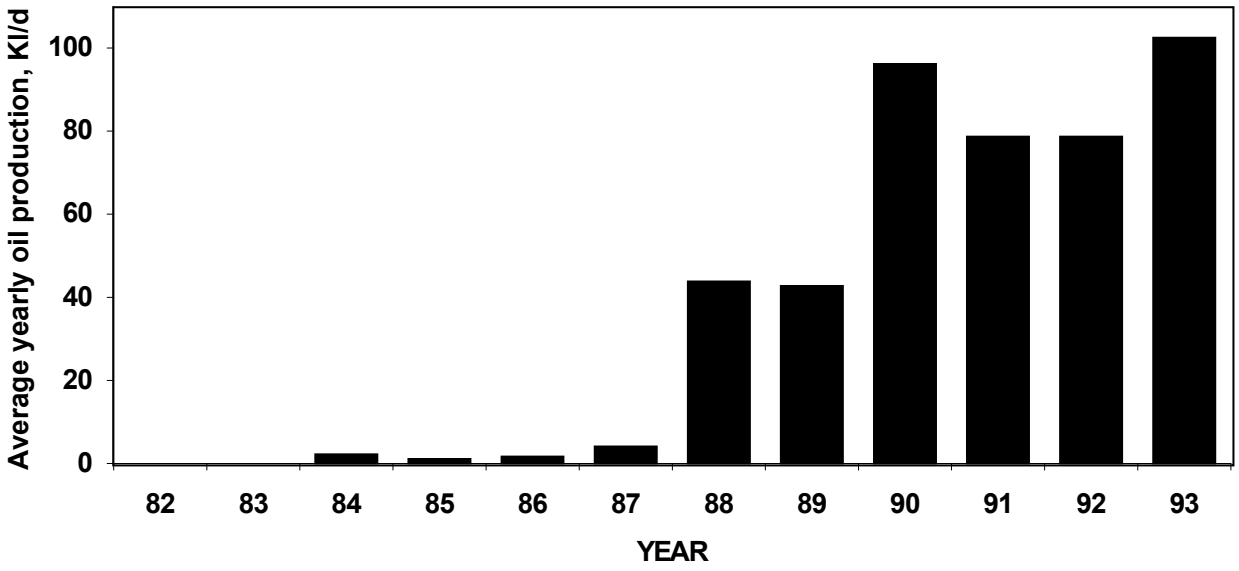
- The project was completed at an expected cost of 10% below the project budget.

The Beharra Springs gas plant is operated by SAGASCO Resources for the EP320 joint venture, (67% SAGASCO Developments and 33% Discovery Petroleum).

5.2 Mount Horner

Operator:	Discovery Petroleum NL	
Location:	380 km north of Perth and 30 km east of town of	
Discovered:	April-65, Mount Horner 1	
Production started:	May-84	
Product:	Oil	
No. of wells:	Producers	7
	Shut in	5
	Plugged and abandoned	
	Injection and water source	
	Suspended	
	Total	12

Production history:



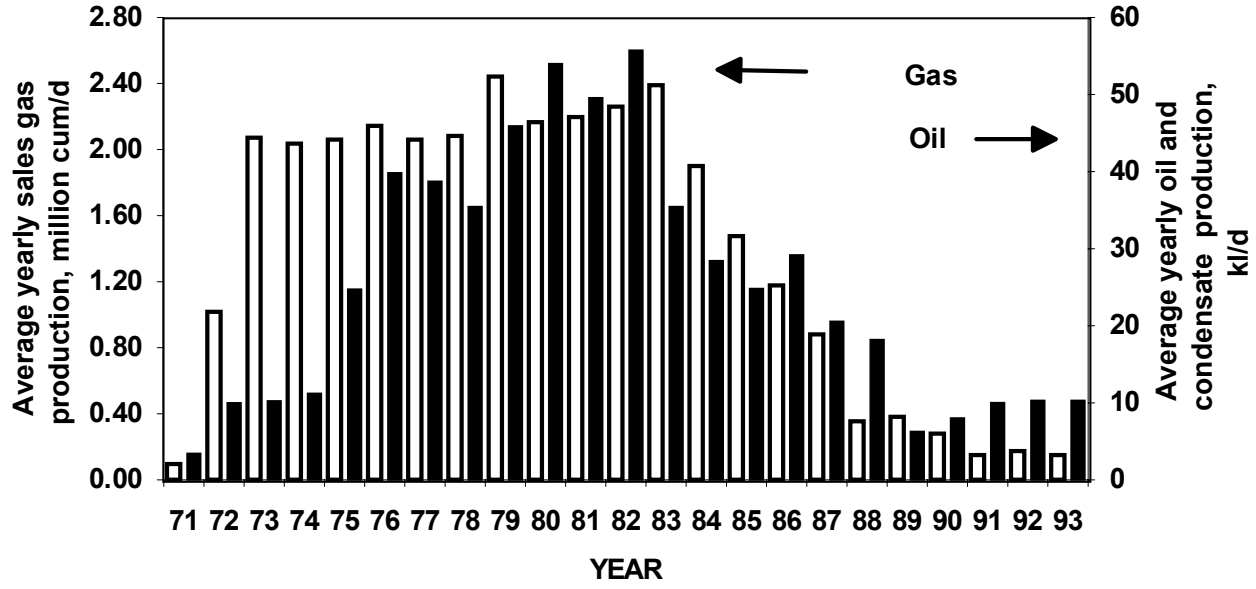
Production Facilities:

Oil is gathered from the producing wells and placed in oil dehydration and storage facilities. As Mount Horner oil contains no gas, there are no gas separation facilities installed at the field. The water produced is separated in water settling tanks and drained to evaporation ponds. Dehydrated oil is stored in four 600 bbls storage tanks before transport. The oil is transported by road tankers to the BP refinery at Kwinana, south of Perth.

5.3 Dongara

Operator:	West Australian Petroleum Pty Ltd	
Location:	Onshore, 386 km north of Perth and about 65 km south of Geraldton	
Discovered:	Jun-66, Dongara 1	
Production started:	25-October-71	
Product:	Oil and Gas	
Well status: (December 92)	Producers	10
	Shut in	9
	Plugged and abandoned	7
	Injection and water source	0
	Suspended	1
	Total	27

Production history:



Production Facilities:

Gas is gathered from producing wells to centrally located field processing facilities. These consist of three phase separators, a dehydration plant and compressors. Dry gas is compressed and transported to Perth and Pinjara via the WANG pipeline.

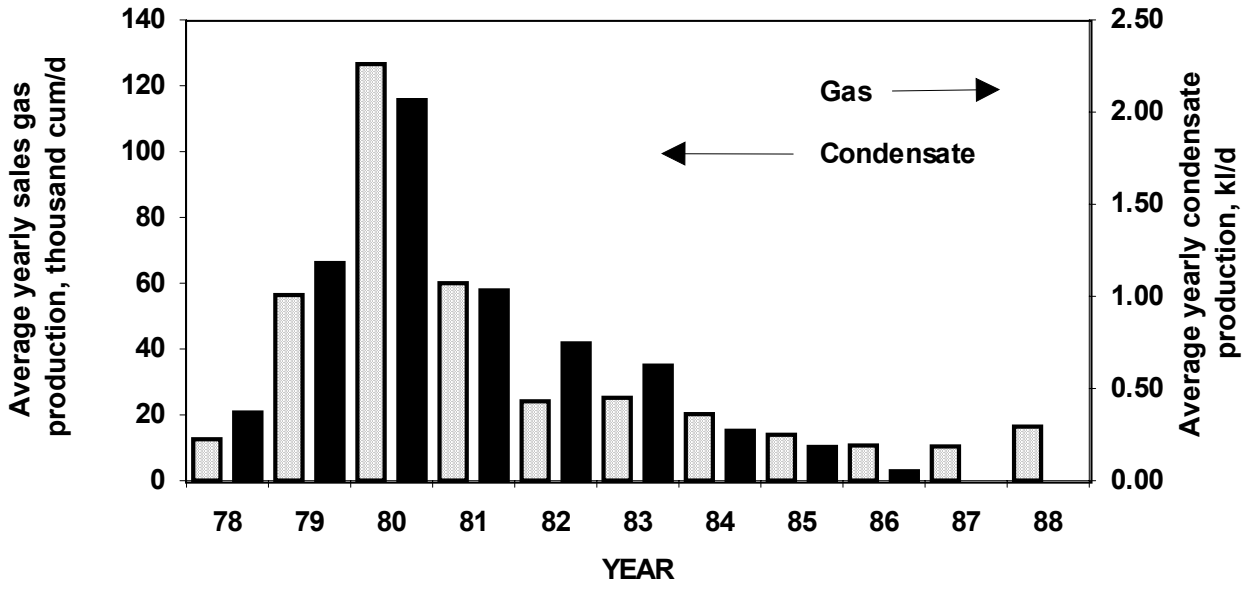
5.4 Yardarino

Operator:	West Australian Petroleum Pty Ltd	
Location:	Onshore, 320 km north of Perth	
Discovered:	April-64, Yardarino 1	
Production started:	January-78	
Product:	Gas	
No. of wells:	Producers	0
	Shut in	1
	Plugged and abandoned	3
	Injection and water source	0
	Suspended 0	
	Total	4

Field processing facilities consist of a gas gathering pipeline, a three phase separation unit, dehydration plant and compressors for transport to Perth and Pinjara via a spur pipeline connected to the main WANG pipeline .

It appears that the field is now virtually depleted. Due to an inability to handle the water production on the lease, the only producing well has been shut in since May 1988. An attempt to return the well to production in 1991 failed because of high water cut. Swabbing may be carried out in the future to determine the well's deliverability.

Production history:



5.5 Gingin

Operator:	West Australian Petroleum Pty Ltd	
Location:	Onshore, 80 km north of Perth	
Discovered:	March-65, Gingin 1	
Production started:	January-72	
Product:	Gas	
No. of wells:	Producers	0
	Shut in	0
	Plugged and abandoned	2
	Injection and water source	0
	Suspended 0	
	Total	2

Gingin 1 produced gas and condensate during two periods in 1972 and 1975. Production facilities consisted of a gathering line and separator for gas production into the WANG pipeline. Cumulative production over the life of the field was 49 million cubic metres of gas.

5.6 Walyering

Operator:	West Australian Petroleum Pty Ltd	
Location:	Onshore, 130 km north of Perth	
Discovered:	May-1971, Walyering 1	
Production started:	March-1972	
Product:	Gas	
No. of wells:	Producers 0	
	Shut in	0
	Plugged and abandoned	3
	Injection and water source	0
	Suspended 0	
	Total	3

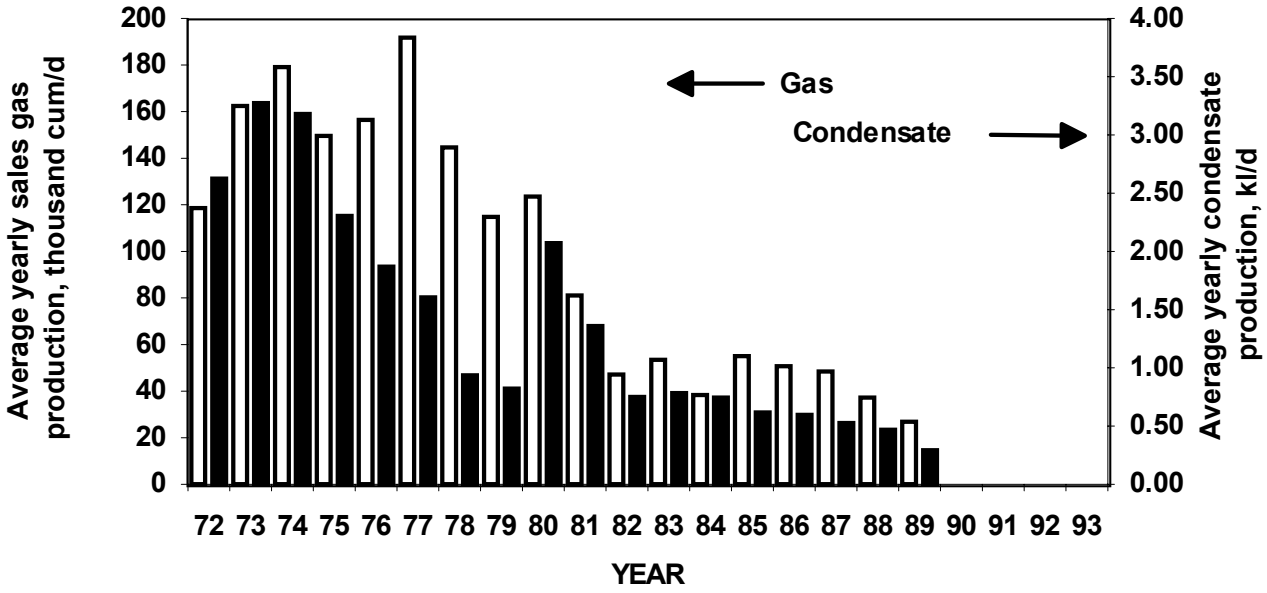
For a short period in 1972, Walyering 1 produced gas into the Dongara-Perth gas pipeline. The field is now considered depleted. Cumulative production was 7 million cubic metres of gas. Production facilities consisted of a gathering pipeline, gas separation and dehydration facilities.

5.7 Mondarra

Operator:	West Australian Petroleum Pty Ltd	
Location:	Onshore, 320 km north of Perth	
Discovered:	October-67, Mondarra 1	
Production started:	April-72	
Product:	Gas	
No. of wells:	Producers	2
	Shut in	0
	Plugged and abandoned	2
	Injection and water source	0
	Suspended 0	
	Total	4

Production facilities consist of gathering pipelines and separators. After separation, gas and condensate flow to the Dongara plant for further processing. The gas is then transported to Perth and Pinjara via the WANG pipeline.

Production history:

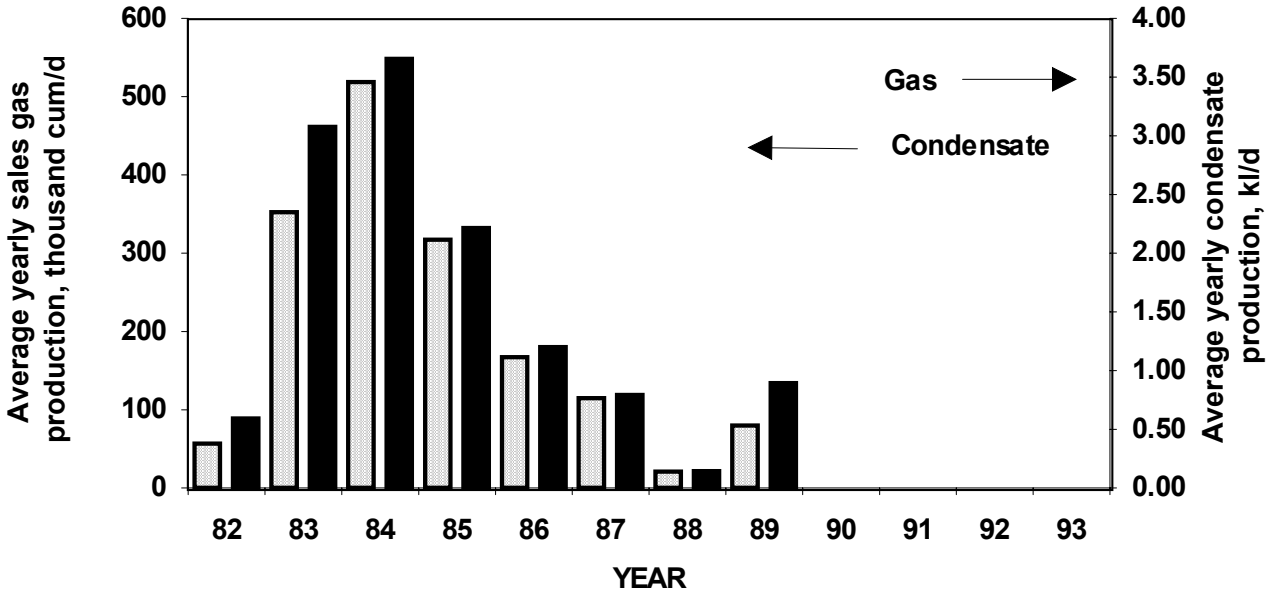


5.8 Woodada

Operator:	Consolidated Gas Pty Ltd	
Location:	Onshore, 320 km north of Perth	
Discovered:	June-80, Woodada 1	
Production started:	May-82	
Product:	Gas	
No. of wells:	Producers	6
	Shut in	0
	Plugged and abandoned	0
	Injection and water source	0
	Suspended 6	
	Total	12

Production facilities consist of a gas gathering system, a gas separation and dehydration plant, and gas compressors for gas transport through the WANG pipeline. In 1987 the field was virtually shut in due to lack of local markets. Production was increased in 1989 after a 4 year contract was finalised to supply gas to SECWA.

Production history:



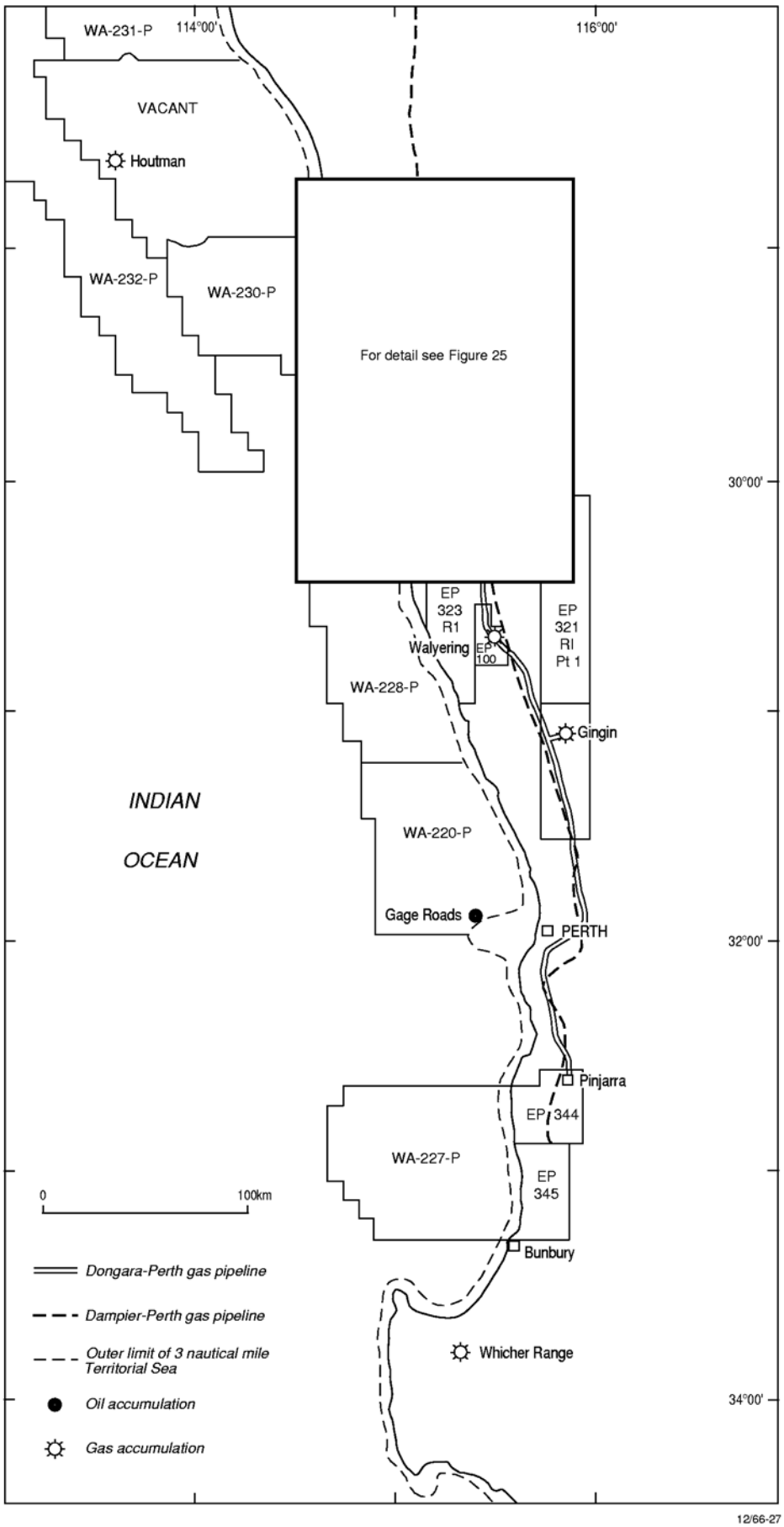


Figure 24 PIPELINES, PERMITS AND DISCOVERIES, PERTH BASIN

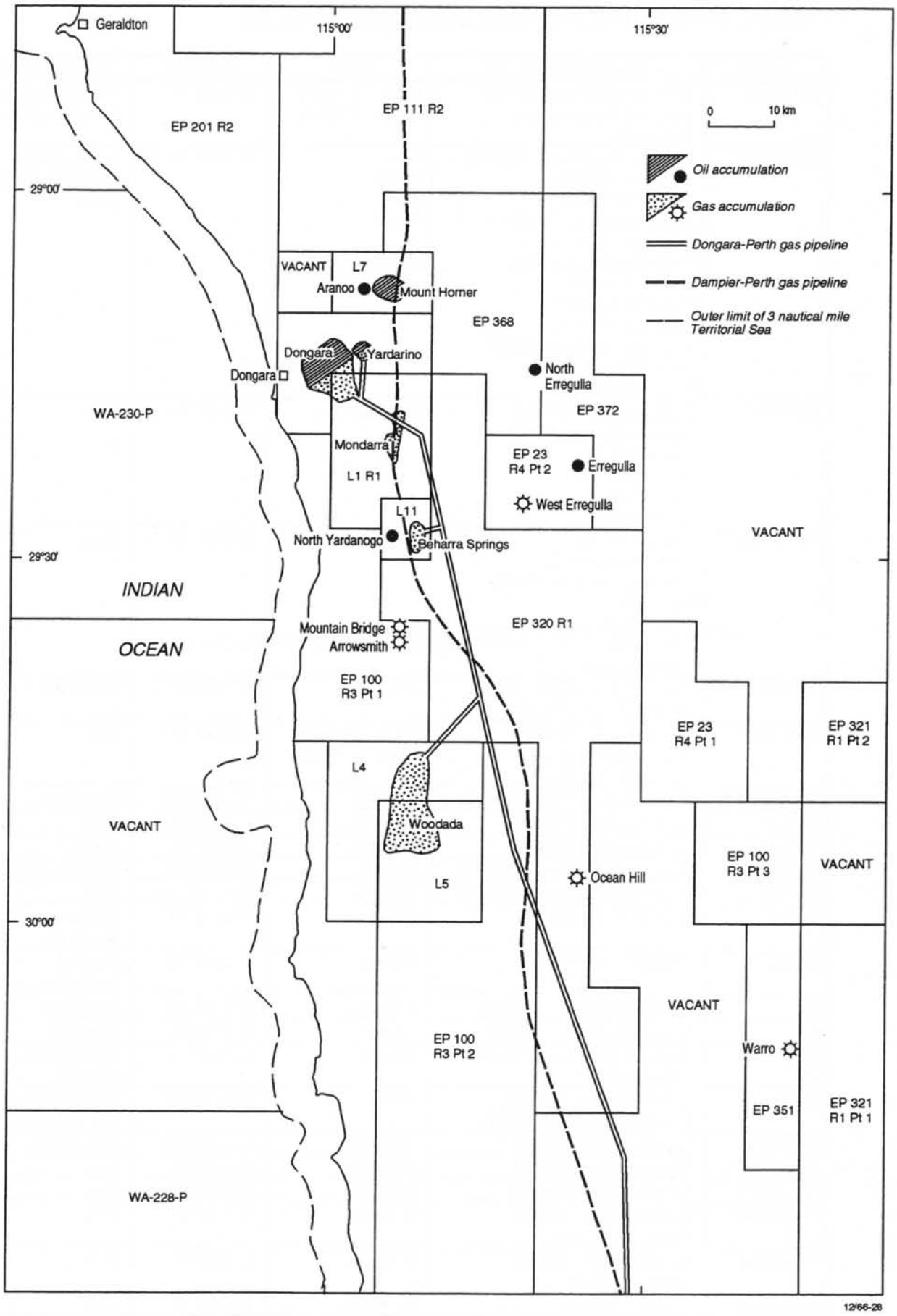

Geraldton
115°00'
115°30'
EP 111 R2
EP 201 R2
0 10 km
Oil accumulation
Gas accumulation
Dongara-Perth gas pipeline
Dampier-Perth gas pipeline
Outer limit of 3 nautical mile Territorial Sea
29°00'
VACANT
L7
Aranoo
Mount Horner
EP 368
Dongara
Yardarino
Dongara
North Erregulla
EP 372
WA-230-P
Mondarra
L1 R1
EP 23 R4 Pt 2
Erregulla
West Erregulla
L11
VACANT
North Yardanogo
Beharra Springs
29°30'
INDIAN
OCEAN
Mountain Bridge
Arrowsmith
EP 320 R1
EP 100 R3 Pt 1
EP 23 R4 Pt 1
EP 321 R1 Pt 2
L4
VACANT
Woodada
L5
Ocean Hill
EP 100 R3 Pt 3
VACANT
30°00'
VACANT
EP 100 R3 Pt 2
Warro
EP 351
EP 321 R1 Pt 1
WA-228-P
12/66-28

Table 7. Permit holders, Perth Basin. (See Figures 24 and 25).

TITLE	TITLE HOLDER (%)	AREA	EXPIRY	DISCOVERIES
EP 23 R4	**Carnarvon Energy * (15.98)** Discovery Petroleum (na) Turkey (na)	Part 1 5 Blocks Part 2 4 Blocks	20 MAR 96	**West Erregulla, Erregulla** (Part 2)
EP 100 R3	**Discovery Petroleum *(42.608)** Burns A R (0.467) Burns V W (0.467) Carnarvon Energy (20.986) Cladium (1.623) Consolidated Gas (1.623) Geary J K (0.284) Hughes D A (6.253) Hughes D J (6.253) Kiwi Inter. Resources (2.556) SAGASCO Dev. (na) Turkey (16.882)	Part 1 Part 2 Part 3 Part 4 41 Blocks (total)	03 MAR 98	**Arrowsmith, Mountain Bridge** (Part 1)
EP 111 R2	**Victoria Inter. * (35.80)** Carnarvon Energy (36.50) Chimelle (8.70) Geometals (5.00) SRL (13.29) Turkey (10.00)	23 Blocks	11 SEPT 94	None
EP 201 R2	**Lassoc * (53.30)** Carnarvon Energy (na) Kiwi Inter. Resources (7.00) Pace (2.80) Royal (11.00) Stirling (na) Treenbrook (na)	15 Blocks	25 SEPT 96	None
EP 320 R1	**Discovery Petroleum * (33.00)** SAGASCO Dev. (67.00)	27 Blocks	18 JAN 97	**Ocean Hill**
EP 321 R1	**Ampolex Ltd * (60.00)** Carnarvon Energy (na) SAGASCO Res. (25.00)	Part 1 35 Blocks Part 2 4 Blocks	15 MAR 97	None
EP 323 R1	**Discovery Petroleum * (100.00)**	18 Blocks	12 APRIL 97	**Walyering**
EP 344	**Hardman Oil * (100.00)**	18 Blocks	15 OCT 94	None
EP 345	**Hardman Oil * (100.00)**	17 Blocks	15 OCT 94	None
EP 368	**Discovery Petroleum * (100.00)**	8 Blocks	10 JUNE 97	**North Erregulla**
EP 372	**Discovery Petroleum * (100.00)**	7 Blocks	05 APRIL 98	None
L1 R1	**WAPET * (100.00)**	5 Blocks	17 MAY 14	**Dongara, Mondarra**
L2 R1	**WAPET * (100.00)**	4 Blocks	17 MAY 14	**Dongara, Yardarino**
L4	**Consolidated Gas * (100.00)**	5 Blocks	24 MAR 04	**Woodada**
L5	**Consolidated Gas * (100.00)**	4 Blocks	28 DEC 04	**Woodada**
L7	**Discovery Petroleum * (86.70)** Sortec (13.30)	2 Blocks	13 MAY 05	**Mount Horner, Arranoo**
L11	**SAGASCO Res. * (67.00)** Discovery Petroleum (33.00)	1 Block	14 MAY 13	**Beharra Springs, Nth Yardanogo**
WA-220-P	**Ampolex Ltd * (100.00)**	78 Blocks	15 AUG 96	**Gage Roads**
WA-227-P	**Woodside Oil * (100.00)**	110 Blocks	14 NOV 97	None
WA-228-P	**Woodside Oil * (100.00)**	77 Blocks	14 NOV 97	None
WA-230-P	**Enterprise Oil * (50.00)** Nippon Oil (50.00)	80 Blocks	31 DEC 97	None
WA-231-P	**Enterprise Oil * (50.00)** Nippon Oil (50.00)	82 Blocks	31 DEC 97	None
WA-232-P	**Conoco * (100.00)**	165 Blocks	14 AUG 97	None

6. HYDROCARBON ACCUMULATION SUMMARIES

ACCUMULATION:	ARRANOO
PRESENT OPERATOR:	Discovery Petroleum NL.
TYPE:	Oil
COMMERCIAL STATUS	Other Discovery
LOCATION:	2 km southwest of Mount Horner.
STATE:	WA
PETROLEUM TITLES:	L7
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Arranoo-1
Longitude (E):	115.0766
Latitude (S):	-29.1399
Date total depth reached:	10 FEB 94
Ground level:	157.6 m
Kelly bushing:	3.4 m
Operator:	Discovery Petroleum NL
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
RESERVOIR UNITS:	1 petroleum bearing unit.

PETROLEUM BEARING UNIT No. 1:	Carynginia Formation
CONTENTS:	Oil
AGE:	Permian

TEST DATA FROM THE DISCOVERY WELL (Arranoo 1):

Production Test, Recovered 6.5 bbl of 35 degree API oil at rates between 13 bbl/day and 25 bbl/day	Carynginia Formation
Production Test, Recovered formation water.	Wagina Sandstone

ACCUMULATION:	ARROWSMITH
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Gas
COMMERCIAL STATUS:	Non-commercial
LOCATION:	48 km south of the Yardarino accumulation and 20 km north of the Woodada accumulation.
STATE:	WA
PETROLEUM TITLES:	EP 100
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Arrowsmith 1
Longitude (E):	115.1153
Latitude (S):	-29.6117
Date total depth reached:	10 JUN 65
Ground level:	51 m
Kelly Bushing:	5 m
Operator:	French Petroleum Company.
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
STRUCTURE:	Fault trap, north-south trending, limited by 2 major faults.
RESERVOIR UNITS:	1 petroleum-bearing unit.
PETROLEUM-BEARING UNIT No 1:	Carynginia Formation
CONTENTS:	Gas
FORMATION:	Carynginia Formation
AGE:	Early Permian
LITHOLOGY:	Siltstone, interbedded with sandstone and minor shale.
FORMATION TOP (mss):	2760 m
POROSITY:	24 %
REMARKS:	Shut in.

TEST DATA FROM THE DISCOVERY WELL (Arrowsmith 1):

DST, 2817 m.	Carynginia Formation.
Flowed gas at an initial rate of 113 000 m^3/day, rapidly declining.	

ACCUMULATION:	BEHARRA SPRINGS
PRESENT OPERATOR:	SAGASCO Resources
TYPE:	Gas
COMMERCIAL STATUS:	Commercial
LOCATION:	250 km north of Perth.
STATE:	WA
PETROLEUM TITLES:	L11
SUB-BASIN	Dandaragan Trough
DISCOVERY WELL:	Beharra Springs 1
Longitude (E):	115.1397
Latitude (S):	-29.4654
Date total depth reached:	05 MAY 90
Ground level:	42 m
Kelly Bushing:	7 m
Operator:	Barrack Energy
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1 Development: 2
STRUCTURE:	Tilted faulted block.
RESERVOIR UNITS:	1 petroleum-bearing unit.
PRODUCTION:	Gas: commenced in JAN 91
INFRASTRUCTURE:	Supplying gas to Alcoa's Pinjarra and Kwinana alumina refineries.

PETROLEUM-BEARING UNIT No 1:	Sandstone unit within Carynginia Limestone.
CONTENTS:	Gas
FORMATION:	Carynginia Formation.
AGE:	Late Permian
LITHOLOGY:	Limestone, massive, fossiliferous, with sandstone and minor shale.
FORMATION TOP (mss):	3248 m
PRODUCTION STATUS:	Producing
REMARKS:	Production delayed by five months shutdown caused by high hydrogen sulphide levels.

TEST DATA FROM THE DISCOVERY WELL (Beharra Springs 1):

DST 1, 3298-3303m, Flowed 240 700 m^3/day of gas through a 1/2" choke.	Carynginia Limestone
Production Test, 3298-3307 m, Flowed 708 000 m^3/day of gas through a 40/64" choke.	Carynginia Limestone

ACCUMULATION:	DONGARA
PRESENT OPERATOR:	WAPET
TYPE:	Gas and Oil
COMMERCIAL STATUS:	Commmercial
LOCATION:	386 km north of Perth.
STATE:	WA
PETROLEUM TITLES:	L1; L2
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Dongara 1
Longitude (E):	114.9892
Latitude (S):	-29.2533
Date total depth reached:	28 JUN 66
Ground level:	45 m
Kelly bushing:	4 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 27 Development: 14
STRUCTURE:	Tilted fault block.
AREAL CLOSURE:	21.0 sq km
VERTICAL CLOSURE:	100.0 m
RESERVOIR UNITS:	7 petroleum-bearing units.
PRODUCTION:	Gas: commenced in OCT 71
INFRASTRUCTURE:	Transmitted via a 415 km long 36 cm diameter gas pipeline to consumers in Perth and Kwinana.During 1972, three compressors were installed along the Dongara-Perth pipeline.
PETROLEUM-BEARING UNIT No 1:	Arranoo Sandstone Member
CONTENTS:	Gas
FORMATION:	Kockatea Shale
AGE:	Early Triassic
LITHOLOGY:	Sandstone, thin, lenticular; fine grained, silty.
FORMATION TOP (mss):	1439 m
POROSITY:	24 %
PERMEABILITY:	94 md

PETROLEUM-BEARING UNIT No 2:	Arranoo Sandstone Member
CONTENTS:	Gas
FORMATION:	Kockatea Shale
AGE:	Early Triassic
LITHOLOGY:	Sandstone, thin, lenticular; fine grained; silty.
POROSITY:	24 %
PERMEABILITY:	94 md

PETROLEUM-BEARING UNIT No 3:	Arranoo Sandstone Member
CONTENTS:	Oil
FORMATION:	Kockatea Shale
AGE:	Early Triassic
LITHOLOGY:	Sandstone, thin; lenticular, fine grained; silty.
FORMATION TOP (mss):	1425 m
POROSITY:	24 %
PERMEABILITY:	94 md

PETROLEUM-BEARING UNIT No 4:	Basal Triassic Sandstone
CONTENTS:	Gas
FORMATION:	Kockatea Shale
AGE:	Early Triassic
LITHOLOGY:	Sandstone, shale; minor limestone.
FORMATION TOP (mss):	1621 m
POROSITY:	23 %
PERMEABILITY:	200 md

PETROLEUM-BEARING UNIT No 5:	Basal Triassic Sandstone
CONTENTS:	Oil
FORMATION:	Kockatea Shale.
AGE:	Early Triassic
LITHOLOGY:	Sandstone; shale; minor limestone.
FORMATION TOP (mss):	1654 m
POROSITY:	23 %
PERMEABILITY:	200 md

PETROLEUM-BEARING UNIT No 6:	Carynginia Formation
CONTENTS:	Gas
FORMATION:	Carynginia Formation
AGE:	Early Permian
LITHOLOGY:	Limestone, massive; fossiliferous; with sandstone stringers and shale.
FORMATION TOP (mss):	1567 m
POROSITY:	20 %

PERMEABILITY:	5 md
PETROLEUM-BEARING UNIT No 7:	Irwin River Coal Measures
CONTENTS:	Gas
FORMATION:	Irwin River Coal Measures
AGE:	Early Permian
LITHOLOGY:	Sandstone, argillaceous.
FORMATION TOP (mss):	1641 m
POROSITY:	18%
PERMEABILITY:	10 md

TEST DATA FROM THE DISCOVERY WELL (Dongara 1):

Production Test, 1670.9-1674.6 m. Flowed 291 000 m^3/day of gas through a 1/4" choke.	Basal Triassic Sandstone.

TEST DATA FROM THE DISCOVERY WELL (Dongara 3):

Production Test. Flowed 55 000 m^3/day of gas through a 1/4" choke.	Irwin River Coal Measures.

TEST DATA FROM THE DISCOVERY WELL (Dongara 8):

Production Test, 1708.4-1711.4 m. Flowed 600-800 bbl/day of 34 degree API oil through a 3/8" choke.	Basal Triassic Sandstone.

TEST DATA FROM THE DISCOVERY WELL (Dongara 15):

Production Test. Flowed gas.	Carynginia Formation.

TEST DATA FROM THE DISCOVERY WELL (Dongara 24):

DST, 1320 m, Flowed gas at 25 000 m^3/day through a 1/2" choke.	Arranoo Sandstone Member
DST, 1469-1493 m, Flowed gas at 153 000 m^3/day through a 1/2" choke.	Arranoo Sandstone Member
DST 4, 1500-1533 m, Flowed gas at a rate too small to measure and recovered 3 bbl of oil.	Arranoo Sandstone Member

ACCUMULATION:	ERREGULLA
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Oil
COMMERCIAL STATUS:	Other Discovery
LOCATION:	50 km southeast of the Dongara accumulation.
STATE:	WA
PETROLEUM TITLES:	EP-23
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Erregulla 1
Longitude (E):	115.3975
Latitude (S):	-29.3772
Date total depth reached:	16 NOV 66
Ground level:	233 m
Kelly bushing:	4 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
STRUCTURE:	Tilted fault block.
RESERVOIR UNITS:	1 petroleum-bearing unit.

PETROLEUM-BEARING UNIT No.1:	Cockleshell Gully Formation
CONTENTS:	Oil
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Sandstone, with interbedded; siltstone; claystone, shale; and coal.
FORMATION TOP (mss):	2551 m

TEST DATA FROM THE DISCOVERY WELL (Erregulla 1):

DST 1, 3147-3155 m, Misrun.	Cockleshell Gully Formation
Swab Test, 3174-3181 m. Recovered 22.5 bbl of 47 degree API oil. After stimulation, a further 36 bbl of light green crude was recovered.	Cockleshell Gully Formation.
DST 4, 3227-3236 m, Misrun.	Cockleshell Gully Formation.
DST 4A, 3227-3236 m, Test terminated early. Decision to acidise.	Cockleshell Gully Formation.

DST 4B, 3227-3236 m, Tight. Weak blow after acidising. Recovered water cushion and gas cut mud.	Cockleshell Gully Formation.
DST 3, 3248-3251 m, Tight.	Cockleshell Gully Formation.
DST 3A, 3248-3251 m, Tight.	Cockleshell Gully Formation.
DST 2, 3905-3913 m, Gas flow at a rate too small to measure.	Cockleshell Gully Formation.
DST 1A, 3984-4054 m, Misrun.	Cockleshell Gully Formation.
DST 1B, 3984-4054 m, Misrun.	Cockleshell Gully Formation.

ACCUMULATION:	GAGE ROADS
PRESENT OPERATOR:	Ampolex Ltd
TYPE:	Oil
COMMERCIAL STATUS:	Non commercial
LOCATION:	Offshore, 37 km west north-west of Fremantle.
STATE:	WA
PETROLEUM TITLES:	WA-220-P
SUB-BASIN:	Vlaming
DISCOVERY WELL:	Gage Roads 1
Longitude (E):	115.3786
Latitude (S):	-31.9558
Date total depth reached:	24 JAN 69
Water depth:	58 m
Kelly bushing:	21 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 2
STRUCTURE:	Structural/stratigraphic trap at Lower Cretaceous level on the west flank of the Rottnest Trench.
AREAL CLOSURE:	103.0 sq km
VERTICAL CLOSURE:	30.0 m
RESERVOIR UNITS:	1 petroleum-bearing unit.

PETROLEUM-BEARING UNIT No 1:	Gage Sandstone Member
CONTENTS:	Oil
FORMATION:	South Perth Formation
AGE:	Early Cretaceous
LITHOLOGY:	Sandstone, siltstone and shale.
FORMATION TOP (mss):	1739 m
POROSITY:	22 %
PERMEABILITY:	300 md

TEST DATA FROM THE DISCOVERY WELL (Gage Roads 1):

DST 1, 1760 m, Tool failed.	Gage Sandstone Member
DST 1A, 1760-62 m, 1765-69 m, Recovered 40 bbl of 37 degree API oil and 82 bbl of water in a swab and flow test.	Gage Sandstone Member
DST 2, 1779 m,	Gage Sandstone Member

Test failed. DST 2A, 1779-82 m, Recovered 58.5 bbl of 41.2 degree API oil and 25 bbl of water (38 200 ppm NaCl).	Gage Sandstone Member	

ACCUMULATION:	GINGIN
PRESENT OPERATOR:	Vacant
TYPE:	Gas
COMMERCIAL STATUS:	Commercial
LOCATION:	89 km north of Perth.
STATE:	WA
PETROLEUM TITLES:	Vacant
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Gingin 1
Longitude (E):	115.8272
Latitude (S):	-31.1431
Date total depth reached:	31 MAR 65
Ground level:	198 m
Kelly bushing:	4 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal:3
STRUCTURE:	Faulted anticline.
AREAL CLOSURE:	30.0 sq km
RESERVOIR UNITS:	2 petroleum-bearing units.
PRODUCTION:	Gas: commenced in MARCH 72. Field depleted in JAN 76. No production between DEC 72 and JUN 75.
INFRASTRUCTURE:	Gathered; separated; and piped to the Dongara-Perth pipeline.
PETROLEUM-BEARING UNIT No 1:	Cattamarra Coal Measures
CONTENTS:	Oil and gas
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Sandstone, interbedded with shale and siltstone.
FORMATION TOP (mss):	3661 m
POROSITY:	14 %
PERMEABILITY:	5 md
TEMPERATURE (C):	118 degrees at 3807 mss
RESERVOIR PRESSURE:	5945 psia at 3880 mss
PETROLEUM-BEARING UNIT No 2:	Cattamarra Coal Measures
CONTENTS:	Oil and gas
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Sandstone, interbedded with shale and siltstone.
FORMATION TOP (mss):	3745 m

POROSITY:	14 %
PERMEABILITY:	5 md
TEMPERATURE (C):	118 degrees at 3807 mss
RESERVOIR PRESSURE:	5945 psia at 3880 mss

TEST DATA FROM THE DISCOVERY WELL (Gingin 1):

DST 18, 3790 m. Cockleshell Gully Fm
Tool plugged.

DST 18A, 3790 m. Cockleshell Gully Fm
Tight.

DST 16, 3814 m. Cockleshell Gully Fm
Recovered 15 bbl of formation water.

DST 17, 3814 m. Cockleshell Gully Fm
Flowed gas at 850 m^3/day and recovered
49 bbl of gas cut formation water.

DST 15, 3814 m. Cockleshell Gully Fm
Tight formation.

DST 14, 3824 m. Cockleshell Gully Fm
Tight formation.

DST 19, 3865 m. Cockleshell Gully Fm
Flowed gas at 67 394 m^3/day,
condensate at 32 bbl/day (46 degree API)
and water at 15 bbl/day.

DST 19A, 3865 m. Cockleshell Gully Fm
Flowed gas at 71 642 m^3/day and
condensate at 32 bbl/day (46 degree API).

DST 6, 3870 m. Cockleshell Gully Fm
Misrun.

DST 13, 3871 m. Cockleshell Gully Fm
Flowed gas at 109 000 m^3/day, condensate
at 39 bbl/day (45 deg. API) and water at
3 bbl/day.

DST 13A, 3871 m. Cockleshell Gully Fm
Flowed gas at 91 000 m^3/day.

DST 13B, 3871 m. Cockleshell Gully Fm
Flowed gas at 105 000 m^3/day, condensate at 35 bbl/day (44.7 degree API) and water at 9 bbl/day.

DST 12, 3888 m. Cockleshell Gully Fm
Tight.

DST 11, 3929 m. Cockleshell Gully Fm
Tight.

Production Test 1, 3949 m. Cockleshell Gully Fm
Flowed gas at 51 000 m^3/day, condensate at 36 bbl/day and water at 3.7 bbl/day.

DST 10, 3951 m. Cockleshell Gully Fm
Flowed gas at 64 000 m^3/day, condensate at 23 bbl/day (45.5 degree API) and water at 13 bbl/day.

DST 9, 3956 m. Cockleshell Gully Fm
Flowed gas at 85 000 m^3/day and water at 420 bbl/day.

DST 8, 4047 m. Cockleshell Gully Fm
Flowed gas at 108 000 m^3/day, condensate at 47 bbl/day (46 degree API) and water at 10 bbl/day.

DST 7, 4057 m. Cockleshell Gully Fm
Tight.

DST 4, 4151 m. Cockleshell Gully Fm
Flowed gas at 96 000 m^3/day, condensate at 73 bbl/day (46 degree API) and water at 37 bbl/day.

DST 5, 4228 m. Cockleshell Gully Fm
Tight.

DST 3, 4332 m. Cockleshell Gully Fm
Tight.

DST 2, 4436 m. Tight.	Cockleshell Gully Fm
DST 1, 4449 m. Flowed gas at 1400 m^3/day.	Cockleshell Gully Fm

ACCUMULATION:	HOUTMAN
PRESENT OPERATOR:	Enterprise Oil
TYPE:	Gas
COMMERCIAL STATUS:	Other Discovery
LOCATION:	Offshore, 98 km west northwest of Geraldton.
STATE:	WA
PETROLEUM TITLES:	Vacant
SUB-BASIN:	Abrolhos
DISCOVERY WELL:	Houtman 1
Longitude (E):	113.5764
Latitude (S):	-28.6653
Date total depth reached:	05 APR 78
Water depth:	152 m
Kelly bushing:	25 m
Operator:	Esso Explor and Prod Australia
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
STRUCTURE:	Faulted, complex anticline.
RESERVOIR UNITS:	2 petroleum-bearing units.
PETROLEUM-BEARING UNIT No 1:	Upper Cattamarra Member
CONTENTS:	Gas
FORMATION:	Cockleshell Gully Formation
AGE:	Early-Middle Jurassic
LITHOLOGY:	Sandstone: siltstone; and minor coal.
FORMATION TOP (mss):	3353 m
POROSITY:	18%
PERMEABILITY:	0.5 md
TEMPERATURE (C):	115 degrees at 3395 mss
RESERVOIR PRESSURE:	5021 psig at 3353 mss
PRODUCTION STATUS:	Nil
PETROLEUM-BEARING UNIT No 2:	Lower Cattamarra Member
CONTENTS:	Gas
FORMATION:	Cockleshell Gully Formation
AGE:	Early-Middle Jurassic
LITHOLOGY:	Sandstone: siltstone; and minor coal.
FORMATION TOP (mss):	3405 m
POROSITY:	7%
PERMEABILITY:	9.5 md
TEMPERATURE (C):	91degrees at 3428 mss
RESERVOIR PRESSURE:	5174 psig at 3405 mss
PRODUCTION STATUS:	Nil

TEST DATA FROM THE DISCOVERY WELL (Houtman 1):

WFT 1, 3048.5 m. Recovered 2300 cc of water/filtrate mixture.	Unknown formation.
Production Test 1, 3367 m. Recovered 412 bbl of water (28 000-30 000 ppm NaCl).	Cockleshell Gully Formation.
WFT, 3370 m. Recovered 1900 cc of mud.	Cockleshell Gully Formation.
WFT 2, 3378 m. No recovery.	Cockleshell Gully Formation.
WFT 4, 3378 m. Recovered .03 m^3 of gas and 4400 cc of filtrate.	Cockleshell Gully Formation.
WFT 3, 3378.5 m. Recovered .01 m^3 of gas and 7600 cc of filtrate with a scum of oil.	Cockleshell Gully Formation.
WFT 13, 3430.5 m. Recovered .036 m^3 of gas and 2000 cc of filtrate.	Cockleshell Gully Formation.
WFT 12, 3460 m. Misrun. Recovered 8350 cc of mud.	Cockleshell Gully Formation.
WFT 11, 3460.5 m. Recovered .03 m^3 of gas, 540 cc of brown water and 7710 cc of mud and filtrate.	Cockleshell Gully Formation.
WFT 5, 3461 m. Tight test.	Cockleshell Gully Formation.
Repeat WT, 3484.5 m. Tool failure.	Cockleshell Gully Formation.
WFT 10, 3508 m. Misrun, recovered 2500 cc of mud.	Cockleshell Gully Formation.

WFT 6, 3645 m. Misrun, no seal, recovered mud.	Cockleshell Gully Formation.
WFT 8, 3645 m. Misrun, recovered 14 600 cc of mud.	Cockleshell Gully Formation.
WFT 7, 3645.5 m. Misrun, recovered 19 000 cc of mud.	Cockleshell Gully Formation.
WFT 9, 3765 m. Misrun, recovered 15 900 cc of mud.	Cockleshell Gully Formation.

ACCUMULATION:	MONDARRA
PRESENT OPERATOR:	WAPET
TYPE:	Gas
COMMERCIAL STATUS:	Commercial
LOCATION:	322 km north of Perth.
STATE:	WA
PETROLEUM TITLES:	L1
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Mondarra 1
Longitude (E):	115.1167
Latitude (S):	-29.3016
Date total depth reached:	25 NOV 68
Ground level:	77 m
Kelly bushing:	6 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1 Development: 2
STRUCTURE:	Tilted fault block.
AREAL CLOSURE:	14.0 sq km
VERTICAL CLOSURE:	160.0 m
RESERVOIR UNITS:	2 petroleum-bearing units.
PRODUCTION:	Gas: commenced in APR 72
INFRASTRUCTURE:	Mondarra was placed on production in 1972,and delivers gas to the Dongara-Perth pipeline.

PETROLEUM-BEARING UNIT No 1:	Basal Triassic Sandstone
CONTENTS:	Gas
FORMATION:	Basal Triassic Sandstone
AGE:	Early Triassic
LITHOLOGY:	Sandstone, coarse, conglomeratic.
FORMATION TOP (mss):	2605 m
POROSITY:	17%
PERMEABILITY:	300 md

PETROLEUM-BEARING UNIT No 2:	Wagina Sandstone
CONTENTS:	Gas
FORMATION:	Wagina Sandstone
AGE:	Late Permian
LITHOLOGY:	Sandstone, interbedded; quartz conglomerate, shale; and siltstone.
FORMATION TOP (mss):	2704 m
POROSITY:	15%
PERMEABILITY:	300 md

TEST DATA FROM THE DISCOVERY WELL (Mondarra 1):

DST, 2606 m. Basal Triassic Sandstone
Flowed 140 000 m^3/day of gas through a 1/4" choke.

TEST DATA FROM THE DISCOVERY WELL (Mondarra 2):

Production Test, 2604 m. Wagina Sandstone.
Tight. Flowed 50 000 - 80 000 m^3/day of gas after stimulation.

ACCUMULATION:	MOUNTAIN BRIDGE
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Gas
COMMERCIAL STATUS:	Other Discovery
LOCATION:	1 km north of the Arrowsmith accumulation and 15 km south of the Beharra Springs accumulation.
STATE:	WA
PETROLEUM TITLES:	EP 100
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Mountain Bridge 1
Longitude (E):	115.1145
Latitude (S):	-29.6014
Date total depth reached:	05 MAY 93
Ground Level:	39 m
Kelly bushing:	7 m
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
RESERVOIR UNITS:	1 petroleum-bearing unit.
PETROLEUM-BEARING UNIT No 1:	Carynginia Formation
CONTENTS:	Gas
FORMATION:	Carynginia Formation
AGE:	Early Permian
LITHOLOGY:	Limestone

TEST DATA FROM THE DISCOVERY WELL (Mountain Bridge 1):

DST 4, 2625-2660 m, Misrun.	Carynginia Formation
DST 3A, 2755-2790 m, No recovery.	Carynginia Formation
DST 3, 2755-2790 m, Misrun.	Carynginia Formation
DST 2A, 3185-3235 m, Flowed 7079 m^3/day of gas with 2000 bbl/day of gas cut water.	Carynginia Formation
DST 2, 3185-3235 m, Misrun.	Carynginia Formation

ACCUMULATION:	MOUNT HORNER
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Oil
COMMERCIAL STATUS:	Commercial
LOCATION:	380 km north-north west of Perth and 30 km east of the town of Dongara.
STATE:	WA
PETROLEUM TITLES:	L7
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Mount Horner 1
Longitude (E):	115.0850
Latitude (S):	-29.1283
Date total depth reached:	22 MAR 65
Ground level:	195 m
Kelly bushing:	5 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1 Development: 6
STRUCTURE:	Rollover anticline on downthrown side of fault.
RESERVOIR UNITS:	5 petroleum-bearing units.
PRODUCTION:	Oil: commenced in MAY 84
INFRASTRUCTURE:	Oil is trucked to the BP Refinery at Kwinana, south of Perth.

PETROLEUM-BEARING UNIT No 1:	B sand
CONTENTS:	Oil
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Siltstone, claystone; with interbeds of sandstone.
FORMATION TOP (mss):	943 m
POROSITY:	25%

PETROLEUM-BEARING UNIT No 2:	F sand
CONTENTS:	Oil
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Siltstone, claystone with interbeds of sandstone.
FORMATION TOP (mss):	1005 m
POROSITY:	26%
PERMEABILITY:	623 md
PRODUCTION STATUS:	Producing
REMARKS:	Currently producing from seven wells

PETROLEUM-BEARING UNIT No 3:	Arranoo Sandstone Member
CONTENTS:	Oil
FORMATION:	Kockatea Shale.
AGE:	Early Triassic
LITHOLOGY:	Siltstone, claystone, micaceous, with minor interbeds of sandstone.
FORMATION TOP (mss):	1273 m
POROSITY:	24%
PERMEABILITY:	10 md

PETROLEUM-BEARING UNIT No 4:	Basal Triassic Sandstone
CONTENTS:	Oil
FORMATION:	Basal Triassic Sandstone
AGE:	Early Triassic
LITHOLOGY:	Sandstone, fluvial; massive; conglomeratic; quartzose.
FORMATION TOP (mss):	1517 m
POROSITY:	27%
PERMEABILITY:	604 md

PETROLEUM-BEARING UNIT No 5:	L sand
CONTENTS:	Oil
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Siltstone, claystone with interbeds of sandstone.
REMARKS:	L sand was discovered by Mount Horner 12.

PETROLEUM-BEARING UNIT No 6:	K Sand
CONTENTS:	Oil
FORMATION:	Cockleshell Gully Formation.
AGE:	Early Jurassic
LITHOLOGY:	Siltstone, claystone with interbeds of sandstone.
FORMATION TOP (mss):	1350 m
REMARKS:	K sand was discovered by Mount Horner 13.

TEST DATA FROM THE DISCOVERY WELL (Mount Horner 5):

Production Test, 1159-1162 m,	Cockleshell Gully Formation ('B' Sand)

Flowed 36 bbls/day of 25.2 deg. API oil.

TEST DATA FROM THE DISCOVERY WELL (Mount Horner 7):

DST 1, 1222.5-1240.5 m,	Cockleshell Gully Formation ('F' Sand)
Recovered 39 bbl of 35.5 degree API oil and 2 bbl of mud filtrate.	

TEST DATA FROM THE DISCOVERY WELL (Mount Horner 1):

Production Test, 1473-1492 m,	Kockatea Shale. (Arranoo Sandstone Member).
Flowed 50 bbl/day of 38 degree API oil with 50% water cut.	

TEST DATA FROM THE DISCOVERY WELL (Mount Horner 4):

Production Test, 1776.7-1883.6 m,	Basal Triassic Sandstone
Swabbing operations recovered 140 bbl of fluid with 40% average oil cut.	

ACCUMULATION:	NORTH ERREGULLA
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Oil
COMMERCIAL STATUS:	Other Discovery
LOCATION:	300 km north of Perth.
STATE:	WA
PETROLEUM TITLES:	EP 368
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	North Erregulla 1
Longitude (E):	115.3269
Latitude (S):	-29.2386
Date total depth reached:	25 NOV 67
Ground level:	162 m
Kelly bushing:	5 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
STRUCTURE:	Tilted fault block.
RESERVOIR UNITS:	2 petroleum-bearing units.

PETROLEUM-BEARING UNIT No 1:	Kockatea Shale
CONTENTS:	Oil
FORMATION:	Kockatea Shale.
AGE:	Early Triassic
LITHOLOGY:	Siltstone, claystone; micaceous; with interbeds of sandstone.
FORMATION TOP (mss):	2757 m

PETROLEUM-BEARING UNIT No 2:	Basal Triassic Sandstone
CONTENTS:	Oil
FORMATION:	Basal Triassic Sandstone
AGE:	Early Triassic
LITHOLOGY:	Sandstone, shale; minor limestone.
FORMATION TOP (mss):	3049 m

TEST DATA FROM THE DISCOVERY WELL (North Erregulla 1):

DST 1, 2757-2768 m, Recovered 90 L of 38 degree API oil.	Kockatea Shale
DST 2, 3049-3060 m, Recovered 36 L of oil.	Basal Triassic Sandstone
DST 3, 3052-3073 m, Recovered 22 bbl of formation water.	Basal Triassic Sandstone

DST 4, 3082-3085 m, Misrun.	Irwin River Coal Measures
DST 5, 3081-3085 m, Misrun.	Irwin River Coal Measures

ACCUMULATION:	NORTH YARDANOGO
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Oil
COMMERCIAL STATUS:	Commercial
LOCATION:	5 km west of Beharra Springs.
STATE:	WA
PETROLEUM TITLES:	L11
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	North Yardanogo 1
Longitude (E):	115.1017
Latitude (S):	-29.4676
Date total depth reached:	02 MAR 90
Ground level:	35 m
Kelly bushing:	7 m
Operator:	Barrack Energy
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1 Development: 1
STRUCTURE:	Anticline
RESERVOIR UNITS:	1 petroleum-bearing unit.
PRODUCING UNITS:	1 petroleum producing unit.

PETROLEUM-BEARING UNIT No 1:	Cattamarra Coal Measures
CONTENTS:	Oil
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Sandstone, interbedded with shale and coal.
FORMATION TOP (mss):	1597 m
POROSITY:	32%
PERMEABILITY:	700 md

TEST DATA FROM THE DISCOVERY WELL (North Yardanogo 1):

DST 1, 1639.5 m, Flowed 191 m^3/day of 34 degree API oil through a 1/2" choke from the Cattamarra Coal Measures.	Cockleshell Gully Fm

ACCUMULATION:	OCEAN HILL
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Gas
COMMERCIAL STATUS:	Other Discovery
LOCATION:	32 km southeast of Beekeeper 1.
STATE:	WA
PETROLEUM TITLES:	EP 320
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Ocean Hill 1
Longitude (E):	115.3964
Latitude (S):	-29.9369
Date total depth reached:	29 APR 91
Ground level:	213 m
Kelly bushing:	17 m
Operator:	Arrow Petroleum
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
AREAL CLOSURE:	59.0 sq km
RESERVOIR UNITS:	1 petroleum-bearing unit.

PETROLEUM-BEARING UNIT No 1:	Cattamarra Coal Measures Member
CONTENTS:	Gas
FORMATION:	Cockleshell Gully Formation
FORMATION TOP (mss):	2843 m

TEST DATA FROM THE DISCOVERY WELL (Ocean Hill 1):

DST 2, 3063-3130 m, Flowed gas at 822 m^3/day through a 1/2" choke.	Cattamarra Coal Measures
DST 3, 3672-3712.5 m, No flow to surface.	Cattamarra Coal Measures

ACCUMULATION:	WALYERING
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Gas
COMMERCIAL STATUS:	Commercial
LOCATION:	129 km north of Perth
STATE:	WA
PETROLEUM TITLES:	EP 323
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Walyering 1
Longitude (E):	115.4653
Latitude (S):	-30.7158
Date total depth reached:	10 APR 71
Ground level:	94 m
Kelly bushing:	5 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 3 Development: 1
STRUCTURE:	Faulted anticline.
AREAL CLOSURE:	2.0 sq km
VERTICAL CLOSURE:	300.0 m
RESERVOIR UNITS:	2 petroleum-bearing units.
PRODUCTION:	Gas: commenced in MAR 72
INFRASTRUCTURE:	Produced gas into the Dongara-Perth pipeline in March 1972. Pressure decline led to shutting in of the well.

PETROLEUM-BEARING UNIT No 1:	Upper Cattamarra Coal Measures
CONTENTS:	Gas
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Sandstone, with interbedded siltstone and coal.
FORMATION TOP (mss):	3171 m
POROSITY:	9%
PERMEABILITY:	93 md

PETROLEUM-BEARING UNIT No 2:	Lower Cattamarra Coal Measures
CONTENTS:	Gas
FORMATION:	Cockleshell Gully Formation
AGE:	Early Jurassic
LITHOLOGY:	Sandstone, interbedded with siltstone and coal.
FORMATION TOP (mss):	3268 m
POROSITY:	9%

PERMEABILITY:	93 md

TEST DATA FROM THE DISCOVERY WELL (Walyering 1):

Production Test 2, 3270-3280.9 m, Flowed gas to surface at an average rate of 83 000 m^3/day.	Cockleshell Gully Formation
DST 1, 3367 m, Flowed gas to surface at 380 000 m^3/day.	Cockleshell Gully Formation
Production Test 3, 3368 m, Flowed gas at an average rate of 198 000 m^3/day, condensate at 50 bbl/day and water at 13 bbl/day.	Cockleshell Gully Formation
Production Test 1, 3368 m, Flowed gas to surface at an average rate of 283 000 m^3/day with minor 44.9 degree API condensate.	Cockleshell Gully Formation
DST, 3371 m, Flowed 370 000 m^3/day of gas through a 1/2" choke.	Cockleshell Gully Formation

ACCUMULATION:	WARRO
PRESENT OPERATOR:	Ampolex Ltd
TYPE:	Gas
COMMERCIAL STATUS:	Other Discovery
LOCATION:	200 km north of Perth.
STATE:	WA
PETROLEUM TITLES:	EP 351
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Warro 2
Longitude (E):	115.7364
Latitude (S):	-30.1683
Date total depth reached:	11 SEP 77
Ground level:	291 m
Kelly bushing:	8 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 2
STRUCTURE:	Anticline.
AREAL CLOSURE:	160.0 sq km
VERTICAL CLOSURE:	350.0 m
RESERVOIR UNITS:	2 petroleum-bearing units.

PETROLEUM-BEARING UNIT No 1:	Yarragadee Formation
CONTENTS:	Gas
FORMATION:	Yarragadee Formation
AGE:	Late Jurassic
LITHOLOGY:	Sandstone, interbedded with siltstone and thin coals.
FORMATION TOP (mss):	3928 m
POROSITY:	6.2 8.2%
PERMEABILITY:	3.0 md

PETROLEUM-BEARING UNIT No 2:	Yarragadee Formation
CONTENTS:	Gas
FORMATION:	Yarragadee Formation
AGE:	Late Jurassic
LITHOLOGY:	Sandstone, interbedded with siltstone and thin coals.
FORMATION TOP (mss):	4037 m

TEST DATA FROM THE DISCOVERY WELL (Warro 2):

DST, 3977-4016 m,	Yarragadee Formation
Flowed gas at 2700 m^3/day.	

DST, 4086-4120 m,	Yarragadee Formation

Flowed gas at 2940 m^3/day.

ACCUMULATION:	WEST ERREGULLA
PRESENT OPERATOR:	Discovery Petroleum NL
TYPE:	Gas
COMMERCIAL STATUS:	Other Discovery
LOCATION:	11 km west of the Erregulla accumulation
STATE:	WA
PETROLEUM TITLES:	EP-23
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	West Erregulla 1
Longitude (E):	115.3089
Latitude (S):	-29.4270
Date total depth reached:	23 JUL 90
Ground level:	220 m
Kelly bushing :	7 m
Operator:	Barrack Energy
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 1
STRUCTURE:	Anticline
RESERVOIR UNITS:	1 petroleum-bearing unit.

PETROLEUM-BEARING UNIT No 1:	Basal Triassic Sandstone
CONTENTS:	Gas
FORMATION:	Basal Triassic Sandstone
AGE:	Early Triassic
LITHOLOGY:	Massive sandstone.
FORMATION TOP (mss):	3735 m

TEST DATA FROM THE DISCOVERY WELL (West Erregulla 1):

DST 2, 3815 m,	Basal Triassic Sandstone/Wagina Sandstone

No gas to surface.

DST 1, 3944-3975.5 m,	Basal Triassic Sandstone

Flowed 510 m^3/day of gas.

ACCUMULATION:	WHICHER RANGE
PRESENT OPERATOR:	Vacant
TYPE:	Gas
COMMERCIAL STATUS:	Other Discovery
LOCATION:	200 km south of Perth.
STATE:	WA
PETROLEUM TITLES:	Vacant
SUB-BASIN:	Bunbury Trough
DISCOVERY WELL:	Whicher Range 1
Longitude (E):	115.3717
Latitude (S):	-33.8386
Date total depth reached:	23 JUL 68
Ground level:	148 m
Kelly bushing:	5 m
Operator:	Union Oil Dev Corporation.
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 3
STRUCTURE:	Anticline.
AREAL CLOSURE:	22.0 sq km
VERTICAL CLOSURE:	37.5 m
RESERVOIR UNITS:	2 petroleum-bearing units.
PETROLEUM-BEARING UNIT No 1:	Sue Coal Measures
CONTENTS:	Gas
FORMATION:	Sue Coal Measures
AGE:	Early Permian
LITHOLOGY:	Sandstone with scattered pebbles of quartz, argillaceous cement; and minor calcareous cement.
FORMATION TOP (mss):	3999 m
POROSITY:	18%
PERMEABILITY:	11 md
RESERVOIR PRESSURE:	5942 psig at 3996 mss
PETROLEUM-BEARING UNIT No 2:	Sue Coal Measures
CONTENTS:	Gas
FORMATION:	Sue Coal Measures
AGE:	Early Permian
LITHOLOGY:	Sandstone, with scattered pebbles of quartz; argillaceous matrix; with minor calcareous cement.
FORMATION TOP (mss):	4047 m
POROSITY:	18%
PERMEABILITY:	11 md
RESERVOIR PRESSURE:	5942 psig at 3996 mss
PRODUCTION STATUS:	Nil

TEST DATA FROM THE DISCOVERY WELL (Whicher Range 1):

DST 1, 3950 m. Misrun	Sue Coal Measures.
DST 1A, 3950 m. Flowed gas to surface at 17 000 m^3/day	Sue Coal Measures.
DST 2, 3973 m. Misrun.	Sue Coal Measures.
DST 2A, 3950 m. Flowed gas at 20 000 m^3/day.	Sue Coal Measures.
DST 3, 3996 m. Misrun.	Sue Coal Measures.
DST 3A, 3996 m. Misrun.	Sue Coal Measures.
DST 3B, 4004 m. Flowed gas to surface at 8200 m^3/day and recovered 762 m of water cushion.	Sue Coal Measures.
DST 4, 4056 m. Flowed gas at 23 200 m^3/day water cushion to surface (610m fresh water).	Sue Coal Measures.
DST 8, 4150 m. Recovered 30 m of condensate and 91 m of watery mud. Flowed gas at 36 500 m^3/day.	Sue Coal Measures.
DST 5, 4162 m. Misrun.	Sue Coal Measures.
DST 6, 4164 m. Flowed gas to surface at a rate of 53 800 m^3/day with some condensate.	Sue Coal Measures.
DST 9, 4164 m. Recovered 305m of water cushion, 549 m of spent acid water, 55 m of sand and flowed gas to surface at a rate too small to measure.	Sue Coal Measures.

DST 10, 4164 m. Recovered 305 m of fresh water, 1276 m of spent acid water and 3 m of sand.	Sue Coal Measures.
DST 7, 4200 m. Recovered 137 m of condensate (reversed out). Gas to surface at a rate of 35 700 m^3/day.	Sue Coal Measures.

ACCUMULATION:	WOODADA / EAST LAKE LOGUE / INDOON
PRESENT OPERATOR:	Consolidated Gas
TYPE:	Gas
COMMERCIAL STATUS:	Commercial
LOCATION:	13 km northwest of the township of Eneabba.
STATE:	WA
PETROLEUM TITLES:	L4 ; L5.
SUB-BASIN:	Beagle Ridge/Dandaragan Trough
DISCOVERY WELL:	Woodada 1
Longitude (E):	115.1392
Latitude (S):	-29.7958
Date total depth reached:	12 JUN 80
Ground level:	34 m
Kelly bushing:	6 m
Operator:	Hughes Oil.
NUMBER OF WELLS DRILLED:	Exploration: 1 Development and appraisal: 10
STRUCTURE:	Structural/stratigraphic
RESERVOIR UNITS:	1 petroleum-bearing unit.
PRODUCING UNITS:	1 petroleum producing unit.
PRODUCTION:	Gas: commenced in MAY 82
INFRASTRUCTURE:	Gas is collected by a 12 km gas gathering system and after separation and dehydration is connected to the Dongara-Perth pipeline, 11 km to the northeast of the accumulation.
PETROLEUM-BEARING UNIT No 1:	Carynginia Formation
CONTENTS:	Gas
FORMATION:	Carynginia Formation
AGE:	Early Permian
LITHOLOGY:	Limestone, massive; fossilifereous; with thin sandstone stringers.
FORMATION TOP (mss):	2257 m
POROSITY:	15%
PERMEABILITY:	134 md
PRODUCTION STATUS:	Producing

TEST DATA FROM THE DISCOVERY WELL (Woodada 1):

Production Test, 2297-2345 m. Carynginia Formation
Flowed gas at 190 000 m^3/day through a 3/4" choke.
Flowed gas at 889 000 m^3/day after stimulation with 15% hydrochloric acid.

ACCUMULATION:	YARDARINO
PRESENT OPERATOR:	WAPET
TYPE:	Gas and oil
COMMERCIAL STATUS:	Commercial
LOCATION:	322 km north of Perth.
STATE:	WA
PETROLEUM TITLES:	L2
SUB-BASIN:	Dandaragan Trough
DISCOVERY WELL:	Yardarino 1
Longitude (E):	115.0550
Latitude (S):	-29.2219
Date total depth reached:	04 JUN 64
Ground level:	43 m
Kelly bushing:	4 m
Operator:	WAPET
NUMBER OF WELLS DRILLED:	Exploration and appraisal: 4 Development: 2
STRUCTURE:	Tilted fault block
AREAL CLOSURE:	26.0 sq km
VERTICAL CLOSURE:	122.0 m
RESERVOIR UNITS:	3 petroleum-bearing units.
PRODUCING UNITS:	3 petroleum producing units.
INFRASTRUCTURE:	Producing gas and oil.

PETROLEUM-BEARING UNIT No 1:	Basal Triassic Sandstone
CONTENTS:	Gas
FORMATION:	Kockatea Shale
AGE:	Early Triassic
LITHOLOGY:	Sandstone, shale with minor limestone.
FORMATION TOP (mss):	2237 m
POROSITY:	14%
PERMEABILITY:	340 md
TEMPERATURE (C):	90 degrees at 2310 mss
RESERVOIR PRESSURE:	3395 psig at 2310 mss

PETROLEUM-BEARING UNIT No 2:	Basal Triassic Sandstone
CONTENTS:	Oil
FORMATION:	Kockatea Shale
AGE:	Early Triassic
LITHOLOGY:	Sandstone, shale, with minor limestone.
FORMATION TOP (mss):	2250 m
POROSITY:	11%
PERMEABILITY:	39 md

PETROLEUM-BEARING UNIT No 3:	Wagina Sandstone
CONTENTS:	Gas and oil
FORMATION:	Wagina Sandstone
AGE:	Late Permian
POROSITY:	15%
PERMEABILITY:	340 md

TEST DATA FROM THE DISCOVERY WELL (Yardarino 1):

DST, 2238 m, Flowed 433 000 m^3/day of gas with associated 44 degree API condensate.	Basal Triassic Sandstone
DST 2, 2280.8 m, Flowed gas to surface at 380 000 m^3/day and recovered approximately 6 m of condensate.	Wagina Sandstone
DST 1A, 2284.1 m, Recovered 5 m of condensate.	Wagina Sandstone
DST 1, 2285.1 m Misrun.	Wagina Sandstone
DST 3, 2298.9 m, Recovered mud and water.	Wagina Sandstone
DST 3, 2298.9 m, Flowed gas to surface at 283 000 m^3/day and recovered 5 m of clean oil and 265 m of oil and filtrate.	Wagina Sandstone
Production Test 1, 2304.1 m, Flowed 35 bbl/day of oil, 3 bbl/day of water and 68 000 m^3/day of gas.	Wagina Sandstone

TEST DATA FROM THE DISCOVERY WELL (Yardarino 3):

DST, 2240 m, Flowed 1000 bbl/day of 35 degree API oil through a 5/8" choke.	Basal Triassic Sandstone.

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CARTOGRAPHY BY : Cartographic Services Unit, Australian Geological Survey Organisation

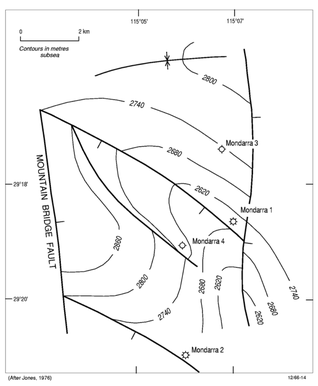
Perth Basin, Western Australia
Bureau of Resource Sciences, Australia,
Australian Petroleum Accumulations Report 10.

AUSTRALIAN PETROLEUM ACCUMULATIONS

PERTH BASIN

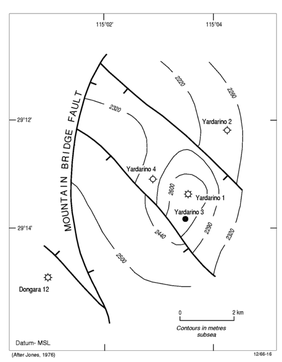
STATUS	COMMERCIAL	OTHER DISCOVERIES
SUB-BASIN	DANDARAGAN TROUGH	

ACCUMULATION	BEHARRA SPRINGS	MONDARRA	YARDARINO	WOODADA	DONGARA	GINGIN	MT HORNER	NTH YARDANOGO	WALYERING	ARROWSMITH
AGE / FORMATION										
CRETACEOUS	SOUTH PERTH FM; PARMELIA FM									
JURASSIC	YARRAGADEE FM; CADDA FM; COCKLESHELL GULLY FM									
TRIASSIC	LESUEUR SST; WOODADA FM; KOCKATEA SHALE; BASAL TRIASSIC SST; WAGINA SST; CARYNGINIA FM									
PERMIAN	IRWIN RIVER COAL MEASURES; HOLMWOOD SHALE; NANGETTY FM									
TRAP TYPE	*TILTED FAULT BLOCK*	*TILTED FAULT BLOCK*	*TILTED FAULT BLOCK*	*STRUCTURAL/STRATIGRAPHIC*	*TILTED FAULT BLOCK*	*FAULTED ANTICLINE*	*ROLLOVER ANTICLINE ON DOWNTHROWN SIDE OF FAULT*	*ANTICLINE*	*FAULTED ANTICLINE*	*TILTED FAULT BLOCK*



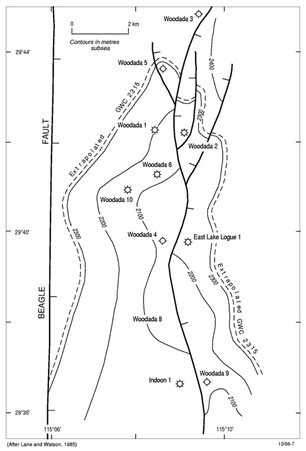
(After Jones, 1976) 12/66-14

STRUCTURE TOP BASAL TRIASSIC SANDSTONE
MONDARRA ACCUMULATION



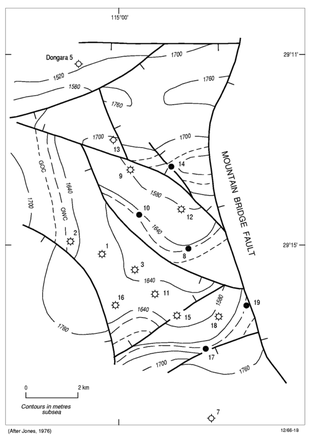
(After Jones, 1976) 12/66-16

STRUCTURE TOP BASAL TRIASSIC SANDSTONE
YARDARINO ACCUMULATION



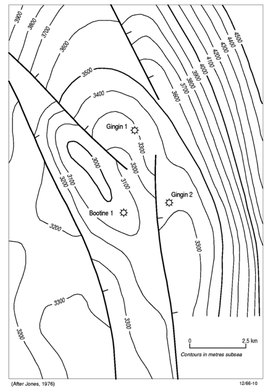
(After Lane and Watson, 1985) 12/66-7

STRUCTURE TOP CARYNGINIA LIMESTONE
WOODADA ACCUMULATION



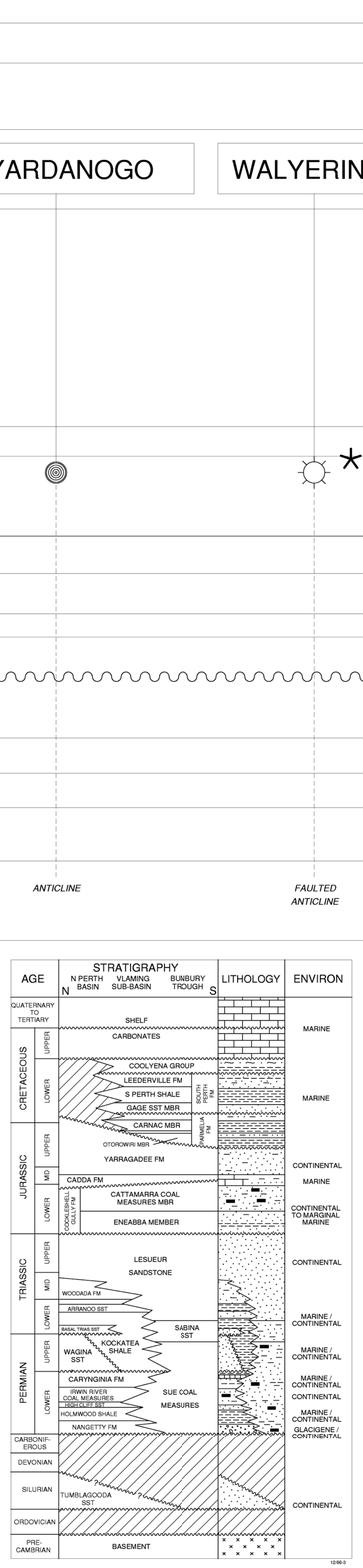
(After Jones, 1976) 12/66-18

STRUCTURE TOP BASAL TRIASSIC SANDSTONE
DONGARA ACCUMULATION



(After Jones, 1976) 12/66-10

STRUCTURE EARLY JURASSIC
GINGIN ACCUMULATION



GENERALISED STRATIGRAPHY, PERTH BASIN, WA.

PETROLEUM RESERVES AND PRODUCTION

REMAINING RESERVES	as at	3	6	93
Sales Gas and LPG		3.790 x 10 m^3	9	3
Condensate		0.016 x 10 kL^6		
Oil		0.103 x 10 kL^6		
CUMULATIVE PRODUCTION	as at	3	6	93
Sales Gas and LPG		13.814 x 10 m^3	9	3
Condensate		0.067 x 10 kL^6		
Oil		0.296 x 10 kL^6		

Comments

Estimates listed above are the totals for the nine commercial accumulations shown on Plate 1. Reserve estimates for individual accumulations are shown in Table 2.

Figures supplied by WADME (6-92) and APEA (1993).

Reserve estimates at 50% probability level.

Oil *Oil & gas* *Gas* *Multiple reservoirs*

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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AUSTRALIAN PETROLEUM ACCUMULATIONS

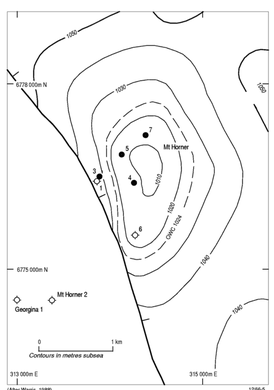
PERTH BASIN

BRS Bureau of Resource Sciences

STATUS: OTHER DISCOVERIES

SUB-BASIN	DANDARAGAN TROUGH							ABROLHOS SUB-BASIN	VLAMING SUB-BASIN	BUNBURY TROUGH
ACCUMULATION	ERREGULLA	N ERREGULLA	W ERREGULLA	MOUNTAIN BRIDGE	ARRANOO	OCEAN HILL	WARRO	HOUTMAN	GAGE ROADS	WHICHER RANGE
TRAP TYPE	TILTED FAULT BLOCK	TILTED FAULT BLOCK	FAULTED ANTICLINE	FAULTED ANTICLINE	?	FAULTED ANTICLINE	ANTICLINE	FAULTED ANTICLINE	STRUCTURAL/STRATIGRAPHIC	FAULTED ANTICLINE

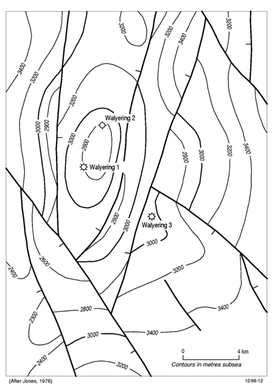
AGE	FORMATION	FORMATION
CRETACEOUS	SOUTH PERTH FM	YARRAGADEE FM
	PARMELIA FM	
JURASSIC	YARRAGADEE FM	COCKLESHELL GULLY FM
	CADDA FM	
	COCKLESHELL GULLY FM	
TRIASSIC	LESUEUR SST	LESUEUR SST
	WOODADA FM	SABINA SST
	KOCKATEA SHALE	
	BASAL TRIASSIC SST	
PERMIAN	CARYNGINIA FM	SUE COAL MEASURES
	IRWIN RIVER COAL MEASURES	
	HOLMWOOD SHALE	
	NANGETTY FM	



(After Warris, 1988) 12/66-5

STRUCTURE, 'F' SAND, COCKLESHELL GULLY FORMATION

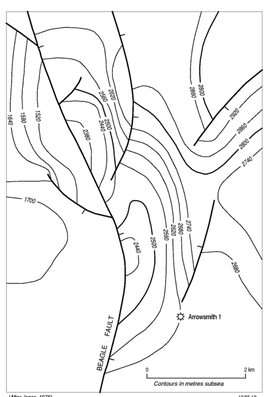
MOUNT HORNER ACCUMULATION



(After Jones, 1976) 12/66-12

STRUCTURE EARLY JURASSIC

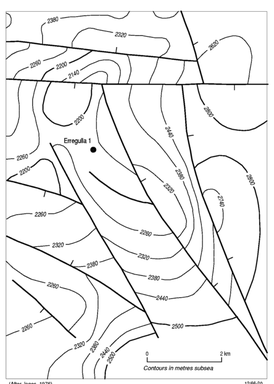
WALYERING ACCUMULATION



(After Jones, 1976) 12/66-19

STRUCTURE PERMIAN

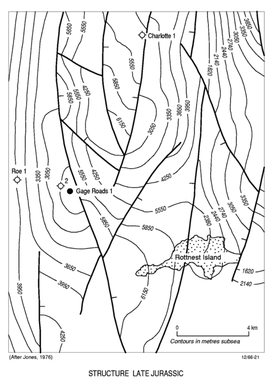
ARROWSMITH ACCUMULATION



(After Jones, 1976) 12/66-20

STRUCTURE EARLY JURASSIC

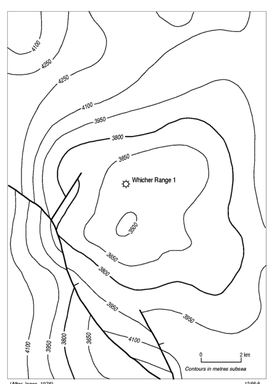
ERREGULLA ACCUMULATION



(After Jones, 1976) 12/66-21

STRUCTURE LATE JURASSIC

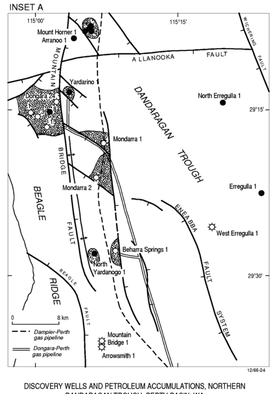
GAGE ROADS ACCUMULATION



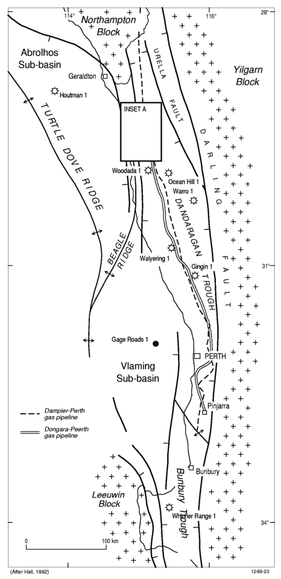
(After Jones, 1976) 12/66-8

STRUCTURE PERMIAN

WHICHER RANGE ACCUMULATION



DISCOVERY WELLS AND PETROLEUM ACCUMULATIONS, NORTHERN DANDARAGAN TROUGH, PERTH BASIN, WA.



(After Hall, 1992) 12/66-23

DISCOVERY WELLS, PERTH BASIN, WA.

PETROLEUM RESERVES AND PRODUCTION

REMAINING RESERVES	as at	3	6	93
Sales Gas and LPG		3.790 x 10 m^3		3
Condensate		0.016 x 10 kL^6		
Oil		0.103 x 10 kL^6		
CUMULATIVE PRODUCTION	**as at**	**3**	**6**	**93**
Sales Gas and LPG		13.814 x 10 m^3		3
Condensate		0.067 x 10 kL^6		
Oil		0.296 x 10 kL^6		

Comments

Estimates listed above are the totals for the nine commercial accumulations shown on Plate 1. Reserve estimates for individual accumulations are shown in Table 2.

Figures supplied by WADME (6/92) and APEA (1993).

Reserve estimates at 50% probability level.

Oil · Oil & gas · Gas · Multiple reservoirs

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