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CANNING BASIN PROJECT, STAGE 1, LENNARD SHELF: EXPLANATORY NOTES for WELL FOLIO

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This Record accompanies and describes the A1-sized Well Folio containing 1:2,500 scale composite well logs of 18 wells studied in Stage 1 of the Project. It is not for sale separately. Digital copy of the wells in the folio is also available in Petroseis format. The wireline logs can be obtained from Wiltshire Geological Services, 13 St Andrews Avenue, Mt Osmond, SA (ph 0839324, fax 083932)

This information was gathered as part of the NATIONAL GEOSCIENCE MAPPING ACCORD, in a joint project with the Geological Survey of Western Australia.

CONTENTS

INTRODUCTION

PROJECT

The main aim of the Canning Basin project is to improve our understanding of the stratigraphic and structural evolution of the basin as a basis for more effective and efficient resource exploration. The first stage of the project involved studies on two contrasting scales; a basin-wide compilation of structural information (not reported here), and a detailed study of the stratigraphic architecture and evolution of the central part of the Lennard Shelf, some of which is presented here. The basic information generated during the Lennard Shelf study has been compiled into three folios - one containing interpreted seismic lines, one containing structure contour and isopach maps, and this folio containing sequence interpretations of the more important wells in the area. More detailed discussions of the interpretations of the Devonian-Carboniferous sequences in these wells are presented in Jackson & others., (1992); Kennard & others., (1992) and Southgate & others (1993).

FOLIO

The core of the accompanying folio is 18 composite well logs at 1:2,500 scale. These summarise, in graphic form, the main stratigraphic features and hydrocarbon occurrences of the key wells in the Stage 1 study area (locality map in folio). This Record contains basic well data, notes summarising the more important features of each well, and a summary of the sequence stratigraphy of the Stage 1 area.

The basic data for each well (ie lithology, lithostratigraphy, palaeontology and hydrocarbon occurrences) was abstracted from the unpublished Company Well Completion Reports. For some of the wells, especially the older and deeper wells, additional lithostratigraphic names have been used. These have been included on the composite well logs to facilitate comparison of lithostratigraphic and sequence stratigraphic nomenclatures. Generally, only three or four wireline log curves have been included on our composite logs although many other types were usually available. We used predominantly gamma ray and sonic log curves as these seemed to be the most useful for defining and identifying sequences and systems tracts. The wireline logs were obtained in digital form from Petroleum Securities in Sydney (the current Exploration Permit holder) or Wiltshire Geological Services in Adelaide. They were loaded into a well log data base and display system called PEP (produced by Petrosys Pty Ltd., Adelaide) and displayed at the most appropriate scales that enhanced sequence stratigraphic detail.

Subdivisions of the 'sequence', 'tract', and 'TWT' columns are based on our integrated sequence stratigraphic studies of the wells and seismic throughout the Stage 1 area. Consequently, it is not always possible to justify a boundary in an individual well with criteria in that well alone. Using time versus depth plots or synthetic seismograms, most sequence boundaries can be related to a specific reflection on a seismic line. The TWT value (in milliseconds) indicates the depth in time to that specific sequence boundary on the seismic line identified at the top of the column. Most of these seismic lines are included in the companion Stage 1 Seismic Folio.

The palaeontological data from several of the wells has been reviewed by AGSO palaeontologists and the resulting biostratigraphic revisions have been incorporated in the folio. These new biostratigraphic results have been used in conjunction with the Bureau of Mineral Resources Records on the Australian Phanerozoic Timescales (Archbold & Dickens, 1989; Balme, 1989; Jones, 1989; Webby & Nicoll, 1989; Young, 1989) to identify the various subdivisions in the 'Stage' and 'Period' columns, and to help assign a numeric age to a sequence boundary.

ACKNOWLEDGEMENTS

The Petroleum Securities Group and Wiltshire Geological Services are thanked for supplying, at no cost, extensive data that enables us to undertake this research. Their co-operation and support is greatly appreciated.

SEQUENCE NOMENCLATURE

Early on in the study it became evident that many of the lithostratigraphic units were diachronous. In many cases correlation of lithostratigraphic units between wells was not straightforward. This was especially evident in the Devonian - Carboniferous part of the section. The sequence stratigraphic approach we used dictated the adoption of a new scheme for identifying and naming our, largely seismically-defined, packages. Each sequence between the Ordovician and Tournaisian is identified by a number preceded by an appropriate Stage name, eg Frasnian 3, Tournaisian 6. The diachroneity of some of the established formations is indicated by our Famennian 2 sequence which in various drillholes has been called Windjana Limestone, Nullara Limestone, Gumhole Formation and Yellow Drum Limestone (Fig 1). However, in the younger part of the basin section, where the lithostratigraphic units appeared to be essentially chronostratigraphic we adopted pre-existing familiar terms, so as to keep new nomenclature to a minimum. For example, the Poole and Grant Sequences are similar to the Poole Sandstone and Grant Group; however, they are not synonymous. This initially simple scheme has been complicated by new biostratigraphic data which shows that some of our sequences are not in the Stage in which they were thought to be. For example, Famennian 3B and 4 are, infact, Tournaisian in age; and as Frasnian 5 Sequence was found to overlap a Stage boundary it was renamed the Frasnian-Famennian Sequence.

BACKGROUND AND REGIONAL SETTING

The vast Canning Basin in north-western Australia contains an unmetamorphosed Palaeozoic and Mesozoic section, possibly in excess of 12000 m (Brown & others., 1984; Purcell, 1984; Drummond & others., 1991). Covering an onshore area of 430000 square kilometres, it is one of Australia's largest basins with promising, but as yet largely unfullfilled, petroleum potential. In a review of the prospectivity of the basin, Goldstein (1989) recognised at least sixteen distinct episodes of regional transgression, where potential reservoir beds are sealed by shales, and noted that all of these are associated with oil and/or gas shows.

There have been several significant discoveries of hydrocarbons within the basin and oil is currently produced from a six small fields - Blina, Sundown, West Kora, West Terrace, Lloyd and Boundary. Blina produces from carbonate reservoirs in the Upper Devonian-Lower Carboniferous, the other fields produce from siliciclastics of either the Grant Group or Anderson Formation. Proven reserves from producing fields total about 3.3 million barrels of oil.

The oldest known rocks in the Canning Basin are of earliest Ordovician (Tremodocian) age. Seismic lines in the Stage 1 area show these Ordovician sediments preserved in a number of tilted horst blocks, but little is known of their composition, setting or evolution. They were intersected at the bottom of only two wells (Blackstone 1 & Aquanita 1). The Ordovician rocks are unconformably overlain by a Middle to Upper Devonian succession. During the Devonian, basin evolution was dominated by northeast-southwest extension which resulted in the development of the northwest-trending Fitzroy Trough, one of the major structural provinces of the basin. This trough developed as a series of interconnected asymmetrical half-grabens, bounded either on their southwestern margins by northeast-dipping listric faults or, in adjacent compartments, by southwest-dipping normal faults on their northeastern margins (Drummond & others., 1988, 1991).

The wells contained in the folio are situated along the hinged northeastern margin of one of these half-grabens (Plate 1). The basin sequence thickens gradually across the Lennard Shelf into the Fitzroy Trough, with the shelf margin delineated by the Pinnacle and Harvey Fault systems. These faults have been depicted traditionally as major basin-bounding normal faults (Brown & others., 1984; Yeates & others., 1984), but both recent deep seismic information (Drummond & others., 1991) and our interpretations of shallower seismic data indicate this is not the case. In the study area, these faults are antithetic to the major, northeast-dipping, listric Fenton Fault, which defines the southwestern margin of the half-graben. This fault crops out to the south-west of the study area, and probably forms a major basement detachment surface some 10-12 km deep below the Stage 1 area. The Harvey, Pinnacle and other antithetic faults along the margin of the Lennard Shelf form a system of en-echelon growth structures that were active during the Devonian and Carboniferous and were reactivated by transpression in the Middle-?Late Carboniferous and again in the Triassic-Jurassic. These two transpressive events have generated flower-type structures and large anticlines throughout the northern half of the basin. Many of these fault systems have had a direct influence on the producing hydrocarbon accumulations on the Lennard Shelf.

Plate 1 shows the geographic locations of the wells and their relationships to some of the main structural and palaeogeographical features that were present during the Devonian-Carboniferous. The wells in this folio are located along the front of a carbonate platform that is separated from the outcropping reef belt by the Fairfield valley - a trough containing basement highs and infilled by material sourced from both the basement to the north-east and the Fairfield valley highs.

SEQUENCE STRATIGRAPHY

GENERAL

Sequence stratigraphic concepts and models (Vail 1987; Posamentier and Vail 1988; Posamentier, Jervey, and Vail 1988; Sarg 1988; Van Wagoner & others, 1990; Wornardt 1991) have been utilised to interpret well and seismic sections. By applying the technique to the interpretation of these sub-surface data we have been able to subdivide an apparently complex sedimentary succession into packages that correspond to discrete depositional intervals. In the wells sequence boundaries were identified by abrupt facies shifts on lithologic and wireline logs or by breaks in the biostratigraphic record. Their component systems tracts were identified largely by position in the sequence, lithologic character, parasequence type and parasequence stacking patterns.

From a petroleum exploration perspective, the use of sequence stratigraphy has the distinct advantage of providing a more accurate spatial and temporal distribution of facies of petroleum significance (e.g. carbonaceous shales, porous sandstones, permeable carbonates).

ABBREVIATIONS

The following abbreviations of sequence stratigraphic terms have been used in the text:
BF - Basin Floor Fan, HST - Highstand Systems Tract, LST - Lowstand Systems Tract, MFS - Maximum Flooding Surface, PC - Prograding Complex, SF - Slope Fan, SMST - Shelf Margin Systems Tract, TST - Transgressive Sytems Tract.

TRIASSIC to EARLY PERMIAN

As noted earlier, the names applied to sequences in rocks younger than the Tournaisian follow the existing stratigraphic nomenclature, rather than Stage name. For example, the Noonkanbah Formation was sub-divided into three sequences named Noonkanbah 1, 2 and 3. This practice was adopted largely because age determinations are based on Australian palynological zones that are fairly broad and whose correlation with international stages are imprecise.

For units above the Grant Sequence, seismic reflections are essentially parallel so the sequence interpretation shown in the well folio relies mainly on wireline log signatures.

BLINA AND LIVERINGA SEQUENCES

Although the Blina and Liveringa sequences have been mapped in the companion seismic folio they have not been systematically subdivided using sequence concepts in the wells. This is partly because they have frequently not been logged by the electric logging tool, but also because they are too shallow to be considered prospective for hydrocarbons. In some of the wells, for example Sundown, Hangover and Terrace the base of the Liveringa sequence comprises a thin sandy succession overlain by a fining-upwards succession of parasequences that has tentatively been identified as a TST. This is overlain by a thicker succession of silty and sandy parasequences tentatively grouped together as a HST. However, parasequence trends from some of the other wells (eg Langoora 1) and reconnaissance outcrop information suggest that the Liveringa sequence may consist of three or more 3rd-order sequences.

The Greisbachian age of the Blina Shale is based on the identification of the Taeniasporites microfloral Assemblage of Balme (1990). The Liveringa Group sediments contain Unit VII and VIII microfloras of Kemp & others (1977) and thus are Kungurian to Dzhulfian in age.

NOONKANBAH SEQUENCE

Gamma ray and sonic log patterns show that in most wells the Noonkanbah Sequence comprises stacked cylindrical (terminology after Serra, 1985) parasequences or parasequence sets 3 - 30 m thick. Most of these coarsen-upwards, less commonly they fine-upwards. The coarsening-up successions probably represent prograding, shallow marine shelf to shoreface parasequences (Van Wagoner & others, 1990); whereas the fining-upward intervals probably represent sedimentation under progressively deepening water. An attempt was made to correlate broad fining-upward and coarsening-upward parasequence sets, and using parasequence set thickness trends. On the basis of this, the interval referred to as Noonkanbah Formation can be sub-divided into three sequences; TST and HST components have also been tentivatively suggested. Noonkanbah 1 is of similar thickness to the underlying Poole Sequence and probably represents a third order sequence. Noonkanbah 2 and 3 are relatively thick and may represent second order sequen-

_ulties in correlating on a finer ,nade further subdivision impractical.

ɪhe Noonkanbah sequences contain Unit IV, V and VI microfloras and thus are Artinskian in age (Kemp & others, 1977).

POOLE SEQUENCE

Based on Towner & Gibson (1980) the Poole Sandstone in this part of the Canning Basin would be expected to comprise an upper sandy interval and a lower calcareous unit called the Nura Nura Member. This type of two-fold subdivisions has been applied in the well completion reports to several of the wells (eg Hangover 1, Mimosa 1, Sundown 1), but because of lateral lithological variations it does not appear to have been applied systematically or strictly in accordance with the original definitions. Therefore, in some on the wells our Poole Sequence is much thinner, and generally only comprises the upper part (or member) of the succession that has been shown as Poole Sandstone. The lower shaler part (lower member in some wells) has been included in our Grant sequence. This modification is supported by palynological information where it is available.

In outcrop in the Deby-Mount Anderson 1:250, 000 Sheet areas the Poole Sandstone comprises one third-order sequence divisible into a TST and HST. In the Poole Range the base of the Poole Sequence is a low relief sequence boundary and flooding surface that truncates large-scale sedimentary structures in the underlying Grant Group. This surface is overlain by a sheet-like transgressive sandstone so that there is little lithological difference between the two sequences. In drillholes where this situation occurs the two sequences are likely to appear as a single sandstone unit on gamma logs. In such sections, the sequence boundary has been placed at the base of any slight shaling-upward trend on the log or at the base of the first coarsening upward parasequence. In some wells (e.g. Katy 1), the basal Poole transgressive sandstone consists of several coarsening-upward parasequences that are readily distinguishable from the underlying sandstone. Above the transgressive sandstone, the TST rapidly fines upwards to siltstones and mudstones to form a distinct peak on the wireline logs at the maximum flooding surface. The overlying HST consists of coarsening-upwards parasequences of shelf, shoreface and beach facies with some probable fluvial sandstone at the top that may be part of the Poole HST or the lowstand of the overlying Noonkanbah Sequence.

The Poole Sequence contains palynomorphs of Unit III of Kemp & others, (1977) and Powis's (1984) equivalent D. townrowii Assemblage - indicating a Sakmarian to Artinskian age. Our placement of the basal Poole sequence boundary is more consistent with palynological evidence for a time break between the Poole and the Grant Group (Powis, 1984) than the scheme used in some post-1984 Home Energy well completion reports.

EARLY PERMIAN TO EARLY CARBONIFEROUS

GRANT SEQUENCES

Major Subdivisions

We encountered problems applying some of the Vail concepts to the Grant Group ('Formation' in some wells). This is hardly surprising as the glacially-influenced Grant Group differs significantly in both facies architecture and sedimentary processes from the passive margin successions on which their models are based. On palynological grounds the Grant Group can be subdivided into two successions separated by a considerable time gap. The Lower Grant consists of sandstone with minor siltstone and shale and contains the *Speleotriletes ybertii* palynological assemblage of Kemp & others (1977). This assemblage indicates a Namurian to Westphalian age (mid Carboniferous). The Upper Grant consists of similar rock types containing Unit II microfloras (Kemp & others, 1977) or the equivalent *Granulatisporites confluens* Oppel-zone of Foster & Waterhouse (1988) and marine macrofossils of Asselian (Early Permian) age, Archbold (1982).

Despite this significant time break between the two parts of the Grant, the log character of the Lower and Upper Grant are very similar and there is no acoustic impedance difference between them. Therefore, in the wells, they can only be differentiated confidently on palynological grounds.

Upper Grant

The Upper Grant sequences are characterised by facies indicative of glaciation and numerous internal erosion surfaces of regional extent with up to 300 m of relief. Complex nesting of these erosion surfaces inhibited their regional mapping. In some instances (eg Mimosa 1 and Boronia 1) wells as close as 1500 m cannot be correlated with certainty. In the light of this complexity, log character and seismic evidence

..o define two types of sequen- .. upper Grant. Each represents a ..ent depositional style. Sequences of the same type are not necessarily correlatable from well to well.

Type A Sequences: Type A sequences are characterised by well-defined systems tracts. They typically start with a thick sandstone succession interpreted as lowstand valley fill (probably of fluvial origin) with a cylindrical gamma log signature. They are overlain by fining-upwards transgressive deposits (comprising internally coarsening upward parasequences) that pass from sandstone into shale and, in some wells, diamictite formed by ice rafting of debris into standing water. In some areas of good seismic data and close well spacing, it can be demonstrated that TST shales rest directly on sequence boundaries. In these instances, the LST is confined to a deep valley and the transgression onlaps what was a topographic high or interfluve (e.g. Terrace 1). Marine fossils occur in some TST shales on the Barbwire Terrace (Foster & Waterhouse, 1988) and in outcrop (Towner & Gibson, 1980).
HST deposits consist of coarsening-upward intervals. Individual sandstone bodies either coarsen-upwards, suggesting deltaic sedimentation, or display cylindrical log signatures. Transgressive shales provide seals for reservoirs in transgressive sandstones or for traps created by erosional topography.

Type B Sequences: Type B sequences consist of sandstone units with cylindrical gamma log signatures interbedded with minor shales. Transitions from sandstone to shale are abrupt or with a thin fining-up interval. Sandstone bases are sharp. Dipmeter readings within sandstone bodies in Type B sequences are unimodal. These characteristics suggest deposition of Type B sequences by bed load-dominated river systems. Systems tract terminology is inappropriate for such depositional systems. They represent periods of fluvial sedimentation and partial sediment bypass when sediment supply equalled or exceeded accommodation.

Lower Grant

Using the terminology applied in the Upper Grant, the Lower Grant sub-division appears to consist essentially of *type B sequences*. It represents sedimentation on a mid-Carboniferous alluvial plain. The Lower Grant pinches out onto the Lennard Shelf by onlap on its basal sequence boundary and erosion beneath the base Upper Grant sequence boundary.

ANDERSON SEQUENCES

In this part of the basin, especially the Fitzroy Trough, the Anderson Formation comprises thick marine to terrestrial clastics and minor carbonates. It contains the *Anapiculatisporites largus* and *Grandispora maculosa* microfloral assemblages of Playford (1985) and ranges in age from the Tournaisian to the the early part of Namurian. In the wells examined this part of the succession is the thin edge of a much thicker section in the Fitzroy Trough. Because of this, and the general absence of obvious sequence criteria on most seismic lines a comprehensive sequence stratigraphic analysis of the Anderson Formation was not carried out. However, in several wells the formation can be subdivided into three parts, which are here defined as sequences, and some of these can be correlated between the wells.

Y Sequence

On seismic lines the Y sequence forms a distinctive interval at the top of the Anderson Formation that has also been recognised in six wells - Yarrada 1, Meda 1, Terrace 1, Sundown 1, Hangover 1, and Katy 1. Over much of the Lennard Shelf the Y sequence is either very thin or missing due to truncation at the base of the overlying Grant Group. However, on seismic line H84-15.2 (Seismic Folio) it thickens markedly across a Carboniferous growth fault into the Fitzroy Trough. In the Terrace-Sundown area (on the Lennard shelf side of the growth fault) the Y sequence comprises 2-3 fining-upward cycles on the gamma log. Cuttings show that these cycles are composed of very coarse to fine grained sandstone and multi-coloured siltstone with glauconite and some carbonaceous material, suggesting sediment accumulation in shallow marine environments, possibly tidal channels. In Katy 1 (located on the downthrown side of the growth fault) glauconitic sandstones are also present indicating shallow marine depositional environments, but changes in the gamma log motif and the presence of limestone suggest facies changes in this area.

Anderson 1 & Anderson 2

Anderson sequences are recognised in seven wells - May River 1, Langoora 1, Yarrada 1, Meda 1, Terrace 1, Sundown 1 and Katy 1. In May River 1, Yarrada 1 and Katy 1 two sequences have been tentatively differentiated, but in the remaining four wells only the lower of the two Anderson sequences is recognised. The Anderson 1 sequence generally displays a funnel-shaped and serrated gamma log motif punctuated by several sharp positive shifts

..uch correspond with the occurrence of shale and siltstone. Fine to medium grained sandstone, vari-coloured siltsone, and shale are the principal lithologies. Glauconite and carbonaceous material, including fossil leaves and wood, are also present and bioclastic calcarenite occurs in Sundown 1. Collectively these data infer a marginal marine environment. The Anderson 2 sequence is characterised by several prominent bell-shaped fining upward trends on the gamma log. Fine to medium grained sandstone, vari-coloured siltstone and minor limestone are the main lithologies. Trace to abundant carbonaceous matter is also present. Systems tract identifications in the Anderson sequence are very tentative.

EARLY CARBONIFEROUS TO MIDDLE DEVONIAN

OVERVIEW

Integrated sequence analysis of seismic and well data of the Givetian to Tournaisian sedimentary succession has recognised eighteen third-order stratigraphic sequences in a major transgressive-regressive (T-R) facies cycle (Fig. 2). A Givetian phase of crustal extension initiated the T-R cycle, and the cycle terminated in the Tournaisian following a phase of slow thermal subsidence. The transgressive half cycle comprises at least four third order sequences; an initial Frasnian-Givetian sequence(s) followed by three backstepping Frasnian sequences. The regressive half-cycle comprises fourteen third-order sequences in which overall basinward advancement of the platform/shelf margin is interrupted by three second-order sealevel cycles which give rise to widespread transgressive marine shales within Famennian sequence 2A and Tournaisian sequences 1 and 6. Tectonic uplift and erosion in the latest Frasnian resulted in a major basinward shift in coastal onlap in the initial stages of the regressive half cycle.

Sequence and systems tract geometries (Fig. 3), their stacking patterns and component facies define two distinct styles of sedimentation:
1) a Givetian to early Famennian reef-rimmed platform complex comprising the Frasnian-Givetian sequence, Frasnian sequences 1-4 and Famennian sequences 1-2B; and,
2) a late Famennian to Tournaisian mixed carbonate and siliciclastic ramp complex comprising Famennian sequences 3A-4 and Tournaisian sequences 1-6.

The Frasnian-Givetian sequence and Frasnian sequences 1-4 correlate with the Pillara cycle, the Frasnian-Famennian sequence and Famennian sequences 1, 2A and 2B correlate with the Nullara cycle of Playford (1980).

The reef complex demonstrates marked reciprocal sedimentation; during lowstands terrigenous sediments by-passed the exposed platform to be deposited in the basin as basin floor fans, slope fans and prograding complexes. During transgressions and highstands carbonate sediments were deposited on the platform, allodapic carbonate particles were shed into proximal marginal-slope settings and clastics were trapped on the inner platform. Lowstand carbonate production occurred locally in areas starved of terrigenous clastic influx.

The recognition of relative sea level cycles in these strata has led to a new model of reef development (Fig. 4) which provides insights into the third order cyclicity within the larger Pillara and Nullara cycles recognised from previous outcrop studies. The previous outcrop model of backstepping and advancing reef complexes emphasises transgressive and highstand depositional systems, but fails to recognise phases of lowstand deposition.

The late Famennian-Tournaisian ramp complex comprises nine basinward advancing sequences (Famennian sequence 3A to Tournaisian sequence 6). Each of these sequences comprises a lowstand (?)clastic wedge (not intersected in any wells) and a thin and more laterally extensive, mixed carbonate and siliciclastic highstand deposit. Slope fans are restricted to Famennian sequences 3A, 3B and 4 and represent the gradual transition from a reef-rimmed platform to a distally-steepened ramp. Lowstand prograding complexes overlie the fans, and are the sole recognised lowstand component of Tournaisian sequences 1-6. Tournaisian sequences 1 and 6 record two major transgressive episodes that are characterised by widespread marine shale deposition.

Systems tracts and facies within the reef and ramp complexes are partitioned according to their position on the T-R cycle; in the transgressive half cycle lowstand deposits are subdued and transgressive and highstand deposits accentuated. In the regressive half cycle lowstand deposits are accentuated and provide a foundation for the overlying transgressive and highstand deposits. The extent of basinward highstand progradation was limited by the break point of their underlying lowstand

Sequence analysis provides a basis for predicting the distibution of source, seal and reservoir facies within the reef and ramp complex, and identifies new petroleum plays. Previous studies have been lithostratigraphic-based, focussing on carbonate depositional facies (Playford and Lowry 1966; Playford 1980, 1982, 1984; Playford and others 1989; Druce and Radke 1979; Hall 1984), and their diagenetic history (Kerans, and others 1986; Hurley and Lohmann 1989; Wallace and others 1991). These lithostratigraphic units are markedly diachronous and contrast with our new chronostratigraphic sequences. Subsurface exploration of the Lennard Shelf has been largely based on the outcrop-derived model for reef growth, and analogy to petroleum exploration in the Devonian Reef complexes of Alberta, Western Canada (Playford 1982). Comparatively little exploration activity has been focussed on basinal deposits outboard of the reef-rimmed platform.

Comprehensive analyses of the Devonian-Carboniferous reef and ramp complexes are given in Jackson and others (1992), Kennard and others (1992) and Southgate and others (in press).

REGIONAL SETTING

The Middle Devonian to Early Carboniferous reef and ramp successions occur on the outer margin of the Lennard Shelf (Laurel Downs Terrace) and in the adjacent Fitzroy Trough. Transfer faults subdivide the trough, terrace and shelf into a series of compartments (Drummond and others 1988, 1991) which are marked by offsets in the reef trend (Plate 1) and abrupt changes in structural and stratigraphic geometries and facies. Structural subdivisions in the area (eg. Meda Embayment, Blackstone High and Kimberley Downs Embayment) partly result from differential movement along transfer faults.

Most wells in the study area intersect dominantly platform successions; basinal clastic facies are intersected in Blina 1, Boronia 1, Janpam 1, Kennedia 1 (not included in this folio), Lukins 1, Mimosa 1 and Terrace 1. May River 1 is the most inboard well, and Mimosa 1 and Boronia 1 are the most outboard wells studied.

Age determinations are primarily based on conodont and microfloral data from cores and cuttings in the Blackstone 1, Langoora 1, May River 1, Meda 1 and Mimosa 1 wells (Jones and Young, in prep). Most of the wells drilled during the 1980's have microfloral determinations from side wall cores.

REEF-RIMMED CARBONATE PLATFORM

Sequences in the reef-rimmed carbonate platform complex are grouped into two sets (Figs 2, 3); the lower set displays successively backstepping platform margins (a transgressive half-cycle comprising Frasnian-Givetian sequence and Frasnian sequences 1-3), the upper set displays basinward advancing platform margins (a regressive half-cycle comprising Frasnian sequence 4, the Frasnian-Famennian sequence and Famennian sequences 1-2B). A marked basinward shift in coastal onlap occurs in the initial portion of the regressive half-cycle, at the base of the Frasnian-Famennian sequence. This shift reflects the onset of tectonic uplift and erosion in the Meda-Blackstone-Blina area. Within the regressive half-cycle, basinward advancement of the platform margins is temporally interrupted by a second-order relative sealevel rise within Famennian sequences 2A and 2B. This second-order cycle results in a widespread marine shale unit (the May River Shale, Famennian 2A) and the suppression of the succeeding third-order sealevel fall; Famennian sequence 2B is characterised by a shelf margin systems tract, lacks lowstand deposits and is interpreted as overlying a type 2 sequence boundary. Thick lowstand deposits occur in the upper set of sequences where they display advancing platform margins (Frasnian sequence 4, the Frasnian-Famennian sequence and Famennian sequences 1 and 2A). In the lower set of sequences lowstand deposits are subdued. Platform carbonates dominate transgressive and highstand deposits and basinal siliciclastic facies dominate lowstand deposits. This temporal and spatial separation of lithologies indicates reciprocal lowstand-highstand sedimentation.

Siliciclastic Lowstand Deposits

Lowstand deposits have been subdivided into three seismically-defined depositional systems; 1) basin floor fan, 2) slope fan and 3) prograding complex. A fourth depositional system, shingled turbidites, is present at the toes of some prograding complexes.

Basin floor fans have been intersected Boronia 1 and Mimosa 1 (in the Frasnian-Givetian and Frasnian-Famennian sequences). In cores and cuttings they are composed of poorly sorted scattered and clay-silt ogs the sandstone gnature. Seismic map- n of these fans were inter- al position, close to their basinal Kennedia 1 (not included in this intersected a similar succession of low- and fans to Boronia 1 and Mimosa 1.

Slope fan deposits intersected in Lukins 1 (Famennian sequence 2A) and Boronia 1 and Mimosa 1 (?Frasnian-Givetian, Frasnian-Famennian sequences and Famennian sequence 2A) are composed of siltstone, very fine-fine grained sandstone and occasionally medium-coarse grained sandstone and minor shale. The SP and gamma logs have a spiky motif arranged in crescentic patterns with a 20-50 m wavelength. These patterns are interpreted to represent deposition in channel-levee complexes.

Prograding complexes usually comprise the thickest depositional system within the reef-rimmed complex. Shingled turbidites locally occur at the toe of the prograding complex; in Lukins 1 (Famennian sequence 2A) they are composed of siltstone and display crescent-shaped log motifs similar to the underlying slope fans. Prograding complexes are intersected in Boronia 1 and Mimosa 1 (?Frasnian-Givetian sequence, Famennian sequence 2A) and Lukins 1 (Famennian sequence 2A), and comprise siltstone, shale and fine grained sandstone. In Boronia 1 and Mimosa 1 the gamma and SP logs show either upward-fining or upward-coarsening trends. However, in Lukins 1 the gamma, sonic and resistivity logs display several upward-fining trends; each upward-fining gamma motif is arrested by a short negative trend that coincides with a sharp increase in velocity on the sonic log. Well cuttings indicate that these intervals are composed of bioclastic wackestone, mudstone and calcareous shale; these calcareous intervals are interpreted as flooding surfaces that mark periods of relative terrigenous sediment starvation and increased carbonate production.

In Meda 1 and Yarrada 1 conglomerate composed of pebbles and boulders of quartzite, granite, chert, mica schist and rare carbonate lithoclasts overlies the Frasnian 4 sequence boundary. The conglomerate has a poorly sorted calcareous and dolomitic sandstone matrix and grades upward into pebbly and sandy limestone and dolostone. These deposits may represent proximal feeder channels for the basin floor and slope fans recognised in a basinward position from Meda 1. The sandy and pebbly limestone and dolostone overlying these conglomerate deposits represent proximal facies of the prograding complex. A 4 m thick conglomeratic lowstand deposit also overlies the Famennian 1 sequence boundary in Meda 1 (core 12).

<u>Calcareous Lowstand Deposits</u>

In the Kimberley Downs Embayment significant lowstand carbonate production occurred around topographic highs in areas of reduced clastic influx. These rocks are intersected in Blina 1 and Harold 1 (Famennian sequence 1) where they consist of pale red to brown limestone, sandy limestone, silty limestone and calcareous siltstone. In Lukins 1 silty and argillaceous bioclastic mudstone and wackestone containing crinoid ossicles, tubular spines and pelycypod fragments intersected at the base of the Famennian 2A sequence probably represent the distal toe of a lowstand carbonate unit. We postulate that encroaching lowstand siliciclastic deposits led to the demise of lowstand carbonate production. Lowstand carbonates are also interpreted in Famennian sequence 1 in Aquanita 1 and Janpam 1.

<u>Transgressive deposits</u>

Well log motifs permit the identification of two types of transgressive deposits: 1) Backstepping and 2) Keep-up. Backstepping transgressive deposits are best developed in Famennian sequence 2A (see Blina 1, Harold 1, Janpam 1, Lukins 1, Mariana 1, Yarrada 1). These deposits comprise a backstepping set of upward-thinning progradational parasequences, each progradational unit being truncated by an abrupt positive shift in the gamma log interpreted to mark a flooding surface and shaley limestone deposition. This backstepping set culminates in an interval of marine shale interpreted to represent a condensed section deposited during the period of maximum flooding.

In contrast to the distinctive log patterns described above, backstepping log motifs and condensed section deposits are subdued or lacking in keep-up transgressive deposits. In consequence criteria for delineating the boundary between transgressive and highstand deposits in keep-up depositional systems are equivocal. In Blina 1 keep-up transgressive deposits are interpreted to occur in the Famennian 1 sequence: a small but sharp negative shift in the gamma log marks the base of the transgressive deposits which have a uniformily low gamma log signature and are composed of recrystallised limestone with relict peloids and bioclast moulds. In Yarrada 1, transgressive deposits within Famennian sequence 2B have a subdued uniformily low gamma log motif, interrupted by small gamma peaks that define a set of uniformly thick parasequences beneath a subdued condensed section. These gamma peaks mark shaley mudstones intervals interpreted as minor flooding surfaces within a keep-up reef facies. Other sequences displaying well defined keep-up trangressive deposits include the Frasnian-Givetian, Frasnian 4, Frasnian-Famennian, Famennian 1 and Famennian 2B sequences in Meda 1, the Fammenian 1 sequence in Aquanita 1, Janpam 1 and Yarrada 1, and the Famennian 2B sequence in Blina 1.

Highstand Deposits

Highstand deposits comprise inner-platform, back-reef, reef and fore-reef carbonate facies. Where keep-up transgressive deposits underlie highstand deposits it is often difficult to separate highstand from transgressive deposits.

May River 1 provides an example of highstand facies development on the inner platform. The most distinctive feature of inner platform depositional systems is a cylindrical, spiky gamma log motif that defines a coarsening upward trend in each highstand deposit. Core and cuttings indicate that the principal lithologies are coarse to very fine sandstone, sandy dolostone and dolostone. Minor shale and siltstone occur at the base of each progradational trend.

Examples of highstand carbonates deposited in outer platform settings occur in the Frasnian-Famennian sequence in Meda 1, the Frasnian-Famennian and Famennian 1 sequences in Aquanita 1, the Famennian 1 sequence in Yarrada 1 and Blina 1, the Famennian 2A sequence in Meda 1 and the Famennian 2B sequence in Yarrada 1. These deposits have a uniformily low gamma signature and are interpreted as reef and back-reef facies.

The Famennian 2A sequence in Yarrada 1 provides an example of marginal-slope facies above shale and shaley limestone deposits of a condensed section. Six upward-cleaning parasequences define an overall progradational trend in which each progradational parasequence is terminated by a gamma peak which is interpreted as a minor flooding surface. In core 8 these sediments consist of nodular mudstone and wackestone with scattered crinoid, bryozoan and brachiopod debris (progradational parasequence) and shale (flooding surface). Dipmeter signatures are uniformly to the southwest at 10-30 degrees, consistent with the interpretation of marginal-slope facies.

Shelf Margin and Associated Transgressive Deposits

A shelf margin depositional system occurs at the base of Famennian sequence 2B. The type 2 sequence boundary is distinguished by a sharp change in the gamma log motif. In Blina 1, Lukins 1, Meda 1 and Mimosa 1 a sharp change in the baseline of the gamma log from low values to higher values coincides with a change in the logs character from uniform to spiky and irregular. This change in log character is interpreted to represent the rapid transition from reef and back-reef facies of the outer platform, to more proximal platform carbonate facies. In Yarrada 1 the same event is marked by an abrupt change from marginal-slope facies of the Famennian 2A highstand to reef facies of Famennian sequence 2B. The presence of a basinward shift in facies and absence of an associated lowstand wedge is interpreted to represent a minor lowering of relative sea level and a type 2 sequence boundary.

The overlying transgressive deposits initially display stacked aggradational patterns (eg. Yarrada 1 and Blina 1) characteristic of a keep-up transgressive depositional system followed by a subdued backstepping pattern beneath the maximum flooding surface. In Yarrada 1 the transgressive deposits are represented by reef facies, in Meda 1, Lukins 1 and Blina 1 they are middle platform facies.

Frasnian-Givetian Sequence and Frasnian Sequences 1-3

Carbonates of the Frasnian-Givetian sequence and Frasnian sequences 1-3 have only been intersected in Meda 1 and Yarrada 1. The Frasnian-Givetian sequence in Meda 1 and Yarrada 1 is interpreted as a keep-up transgressive depositional system. We are unsure where to place the sequence boundary at the base of this sequence and for this reason the underlying conglomerates lack a systems tract interpretation. Three backstepping sequences, Frasnian sequences 1-3, (pink, Fig 3) occur slightly basinward of the prominent Frasnian 4 highstand buildup (Figs 2, 3). These sequences are intersected in Meda 1 and Yarrada 1 in a position 3-4 kms outboard of the Frasnian 1 platform margin. In both wells Frasnian sequences 1-3 comprise a 60-80 m thick succession of predominantly dolostone and dolomitic limestone, with some sandy dolostone and dolomitic silty sandstone in Yarrada 1 (core 13). This succession overlies an interval of dolostone interpreted to comprise a keep-up transgressive depositional system capped by a prominent maximum flooding surface, and underlies conglomerate at the base of Frasnian sequence 4. In both wells this Frasnian succession contains three prominent peaks on the gamma log. Cuttings descriptions in Meda 1 emphasise that these peaks do not correspond with shale, but instead represent a radioactive mineral (Pudovskis, 1962). The gamma peaks may represent radioactivity associated with enhanced phosphate concentrations in these sediments. Based on the Meda 1 and Yarrada 1 log correlations and their location outboard from the platform margins of Frasnian sequences 1-3, this succession is interpreted as a condensed, slope to basinal section, equivalent to the three backstepping Frasnian sequences.

Frasnian-Givetian lowstand clastics are interpreted to occur in Blina 1, Boronia 1, Mimosa 1 and Yarrada 1.

RAMP COMPLEX

Wells intersecting the ramp complex are sited in middle to inner ramp positions. Consequently lowstand deposits have not been intersected and their lithologies and component facies remain unknown. Transgressive and highstand deposits are intersected in many wells; however, only rocks belonging to Famennian sequences 3B and 4 and Tournaisian sequences 1, 2 and 6 are identified. The remaining sequences are interpreted to have either already pinched out, or to be so thin that they cannot be resolved on well-logs.

In Famennian sequences 3B and 4 well logs show transgressive deposits to be thin and composed of two or three backstepping progradational parasequences. In cuttings and cores these rocks consist of sandy, silty and muddy dolostone deposited in peritidal settings. In middle ramp settings (eg. Yarrada 1 and Meda 1) highstand deposits are composed of bioclastic ooid grainstone and microbial boundstone, deposited in shallow water environments. A "spiky" gamma log motif that defines a forestepping progradational trend characterises highstand deposits in inner ramp positions. Parasequences are thin and composed of interbedded coarse to very fine sandstone, sandy dolostone and dolostone deposited in nearshore peritidal settings.

In Tournaisian sequences 1 and 6 marked landward shifts in coastal onlap are associated with relatively thick transgressive deposits. These major transgressions are represented by prominent backstepping gamma log patterns culminating in the deposition of 10-20m thick shale units which mark the condensed sections (see Meda 1, May River 1, Blina 1). Oils in the Sundown, West Terrace and Lloyd Fields are probably sourced from the shale at the base of Tournaisian sequence 1 (Goldstein, 1989). Highstand deposits in Tournaisian sequences 1 and 2 have a spiky gamma log motif and consist of bioclastic grainstone, calcareous sandstone, siltstone and shale. In inner ramp positions of the Meda Embayment continued progradation of Tournaisian sequences 3-5 results in either their absence, or their thinning below seismic and well resolution.

GIVETIAN and EIFELIAN

Givetian clastics are interpreted to occur in Aquanita 1, Janpam 1, May River 1, Meda 1, Mimosa 1 and Terrace 1, but only the section in Mimosa 1 has a definitive Givetian age. Mimosa 1 yielded an ostracod from cuttings at 3570 m that is typical of the torleyi ostracod Zone of late Givetian-earliest Frasnian age (Jones & Young, 1992). This fossil comes from a thick marine terrigenous clastic section. In addition, a section of probable Eifelian age - the Poulton Formation - was intersected in Blackstone 1. Its age is poorly defined by palynomorphs (Jones & Young, 1990) but its structural position suggests that it is older than the Givetian sediments in Mimosa 1. Blackstone 1 intersected the Poulton Formation in the crest of a tilt block formed by normal movement of the Oscar Fault to the northeast.

Givetian Sequence in Mimosa 1: Lensoid geometries on seismic lines, rock types and log patterns (particularly gamma and SP), suggest deposition in submarine fans. The sequence can be divided into three intervals. The lower interval exhibits well developed coarsening-upward sandstone units up to 75 m thick that resemble the succession produced by channel-levee complex migration on submarine fans (Walker, 1992). These units abruptly fine upwards suggesting channel abandonment. The next interval consists of thinner sandstone bodies with more abrupt tops and bases, suggesting decreasing size of submarine channel. The upper most part of the Givetian sequence consists of shale and siltstone with scattered thin silty sandstone beds probably formed as distal turbidites. The sequence probably represents deposition in a slope fan passing up into a prograding complex.

Eifelian Sequence in Blackstone 1: these sediments (Poulton Formation) are a succession of red-brown thinly interbedded siltstone, mudstone and sandstone with possible evaporites indicated by elevated drilling mud salinities. Deposition in an arid playa environment with ephemeral lake mudstone and sheet flood sandstones is suggested (cf Parkhash & others, 1983).

ORDOVICIAN

Ordovician sediments were penetrated in Aquanita 1 and Blackstone 1. Aquanita 1 bottomed in a sandstone containing early Ordovician (Llandelian) acritarchs. Blackstone-1 penetrated a thick section of early Ordovician age comprising shale to carbonate parasequences. These sediments have been tentatively subdivided into four sequences based on parasequence thickness and log trend characteristics. Possible sequence boundaries are suggested at the change from intervals of progressively cleaner and thinner parasequences to intervals of progressively shalier parasequences. Such changes can be quite abrupt. Ordovician 3 shows the best development of these log patterns. Ordovician 4 is dominated by thick dolostone and limestone beds. The sediments probably represent deposition in a broad epiric sea. The dolomitic facies of Ordovician 4 may represent a major downward shift of coastal facies.

REFERENCES

ARCHBOLD, N.W., 1982 - Correlation of the Early Permian faunas of Gondwana: implications for the Gondwanan Carboniferous-Permian boundary. Geological Society of Australia,, Journal, 29, 267-276.

ARCHBOLD N.W. & DICKENS J.M., 1989 - Australian Phanerozoic Timescales: 6. Permian. Biostratigraphic Chart and Explanatory Notes. Bureau Mineral Resources, Australia, Record 1989/36.

BALME B., 1989 - Australian Phanerozoic Timescales: 7. Triassic. Biostratigraphic Chart and Explanatory Notes. Bureau Mineral Resources, Australia, Record 1989/37.

BROWN, S.A., BOSERIO, I.M., JACKSON, K.S. & SPENCE K.W., 1984 - The Geological Evolution of the Canning Basin - Implications for Petroleum Exploration. in P.G. Purcell (Editor), The Canning Basin, W.A. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, W.A. 1984, 85-96.

DRUCE, E.C. & RADKE, B.M., 1979 - The Geology of the Fairfield Group, Canning Basin, Western Australia: Bureau Mineral Resources Geology and Geophysics, Australia, Bulletin 200.

DRUMMOND, B.J., ETHERIDGE, M.A., DAVIES, P.J., & MIDDLETON, M.F., 1988 - Half-graben model for the structural evolution of the Fitzroy Trough, Canning Basin, and implications for resource exploration: Australian Petroleum Exploration Association Journal, 28 (1) 76-86.

DRUMMOND, B.J., SEXTON, M.J., BARTON, T.J., & SHAW, R.D., 1991 - The nature of faulting along the margins of the Fitzroy Trough, and implications for the tectonic development of the trough: Exploration Geophysics, 22, 111-116.

FOSTER, C.B. & WATERHOUSE, J.B., 1988 - The Granulosporites confluens Oppel-zone and the early Permian marine faunas from the Grant Formation on the Barbwire Terrace, Canning Basin, Western Australia. Australian Journal of Earth Sciences, 35, 135-157.

GOLDSTEIN, B.A., 1989, Waxings and wanings in stratigraphy, play concepts and prospectivity in the Canning Basin: Australian Petroleum Exploration Association Journal 29 (1) 466-508.

HALL, W.D.M., 1984, The stratigraphic and structural development of the Givetian-Frasnian reef complex, Limestone Billy Hills, western Pillara Range, W.A.: in P.G. Purcell (Editor), The Canning Basin, W.A. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, W.A. 1984, 215-222.

HURLEY, N.F. & LOHMANN, K.C., 1989 - Diagenesis of Devonian reefal carbonates in the Oscar range, Canning basin, Western Australia: Journal of Sedimentary Petrology, 59, 127-146.

JACKSON, M.J., DIEKMAN, L.J., KENNARD, J.M., SOUTHGATE, P.N., O'BRIEN, P.E., AND SEXTON, M.J., 1992 - Sequence stratigraphy of the Devonian-Carboniferous of the Canning Basin and its use in the identification of basin floor fans and other petroleum plays. Australian Petroleum Exploration Association Journal, 32, 214-230.

JONES, P.J., 1989 - Australian Phanerozoic Timescales: 5. Carboniferous. Biostratigraphic Chart and Explanatory Notes. Bureau Mineral Resources, Record 1989/35.

JONES, P.J. & YOUNG, G.C., 1990 - Biostratigraphic summary of Blackstone No.1 well, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Professional Opinion, 1990/004.

JONES, P.J. & YOUNG, G.C., 1992 - Biostratigraphic summary of Mimosa No.1 well, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Professional Opinion, 1992/002.

JONES, P.J., & YOUNG, G.C., in prep. - Updated biostratigraphic summaries of selected wells on the Lennard Shelf, in Jones, P.J., and Young, G.C. (eds.,), Overview of Phanerozoic Biostratigraphy and Paleontology of the Canning Basin (Lennard Shelf), Appendix. Australian Geological Survey Organisation, Record.

KEMP, E.M., BALME, B.E., HELBY, R.J., KYLE, R.A., PLAYFORD, G., & PRICE, P.L., 1977 - Carboniferous and Permian palynostratigraphy in Australia and Antarctica: a review. BMR Journal of Australian Geology & Geophysics, 2, 177-208.

KENNARD, J.M., SOUTHGATE, P.N., JACKSON, M.J., O'BRIEN, P.E., CHRISTIE-BLICK, N., HOLMES, A.E., AND SARG, J.F., 1992 - A new sequence perspective on the Devonian reef complex and the Frasnian-Famennian boundary, Canning Basin, Australia. Geology, * (in press).

KERANS, C., HURLEY, N.F., & PLAYFORD, P.E., 1986 - Marine diagenesis in Devonian reef complexes of the Canning basin, Western Australia, in J.H. Schroeder and B.H. Purser, eds., Reef Diagenesis: Springer-Verlag, Berlin, 357-380.

PARKASH, B., AWASTHI, A.K. & GOHAIN, K. 1983 - Lithofacies of the Markanda terminal fan, Kurukshetra district, Haryana, India. In: Collinson, J.D. & Lewin, J. (editors) Modern and ancient fluvial systems. International Association of Sedimentologists Special Publication, 6, 337-344.

PLAYFORD, G., 1985 - Palynology of the Australian Lower Carboniferous. Compte Rendu, Dixieme Congres International de Stratigraphie et de Geologie du Carbonifere, Madrid 1983, 4, 247-265.

PLAYFORD, P.E., 1980 - Devonian "Great Barrier Reef" of the Canning Basin, Western Australia: American Association of Petroleum Geologists Bulletin, 64, 814-840.

PLAYFORD, P.E., 1981 - Devonian reef complexes of the Canning basin Western Australia: Field excursion guidebook, Fifth Australian Geological Convention, Geological Society of Australia. 64p.

PLAYFORD, P.E., 1982 - Devonian reef prospects in the Canning Basin: implications of the Blina oil discovery, Australia Petroleum Exploration Association Journal, 22, 258-271.

PLAYFORD, P.E., 1984 - Platform-margin and marginal-slope relationships in Devonian reef complexes of the Canning Basin, in Purcell, P.G., ed, The Canning Basin, Western Australia: Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, 190-214.

PLAYFORD, P.E. AND LOWRY, D.C., 1966 - Devonian reef complexes of the Canning Basin, Western Australia: Geological Survey of Western Australia Bulletin 118, 150 p.

PLAYFORD, P.E., HURLEY, N.F., KERANS, C. AND MIDDLETON, M.F., 1989 - Reefal platform development, Devonian of the Canning Basin, Western Australia, in Crevello P.D. and others, eds., Controls on Carbonate Platform and Basin Development: Society of Economic Paleontologists and Mineralogists Special Publication 44, 187-202.

POSAMENTIER, H.W., JERVEY, M.T., AND VAIL, P.R., 1988 - Eustatic controls on clastic deposition I - Conceptual framework, in Wilgus, C.K., and others, eds., Sea-level Changes: An Integrated Approach: Society of Economic Paleontologists and Mineralogists Special Publication 42, 109-124.

POSAMENTIER, H.W., AND VAIL, P.R., 1988 - Eustatic controls on clastic deposition II - Sequence and systems tract models, in Wilgus, C.K., and others, eds., Sea-level Changes: An Integrated Approach: Society of Economic Paleontologists and Mineralogists Special Publication 42, 125-154.

POWIS, G.D., 1984 - Palynostratigraphy of the Late Carboniferous sequence, Canning Basin, W.A. In: Purcell, P.G., (editor) The Canning Basin, W.A. Proceedings of the Geological Society of Australia, Petroleum Exploration Society of Australia Symposium, Perth, 1984, 429-438.

PURCELL, P.G., 1984 - The Canning Basin, W.A. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, W.A. 1984.

SARG, J.F., 1988, Carbonate sequence stratigraphy, in Wilgus, C.K., and others, eds., Sea-level Changes: An Integrated Approach: Society of Economic Paleontologists and Mineralogists Special Publication 42, 155-181.

SERRA, O., 1985 - Facies Classification from the sp curve on electric logs. A colour chart in Sedimentary Environments from Wireline Logs. Schlumberger.

SOUTHGATE P.N., KENNARD, J.N., JACKSON M.J., O'BRIEN, P.E. & SEXTON, M.J., 1993 - Reciprocal lowstand clastic and highstand carbonate sedimentation, subsurface Devonian Reef Complex, Canning Basin, Western Australia. in Loucks, R., & Sarg, J.F.,(Editors), Recent Advances and Applications of Carbonate Sequence Stratigraphy. AAPG Memoir (in press).

TOWNER R.R. & GIBSON, D.L., 1980 - Geology of the Late Carboniferous and younger rocks of the onshore Canning Basin, Western Australia. Bureau Mineral Resources, Australia, Record 1980/30.

VAIL, P.R., 1987 - Seismic stratigraphy interpretation using sequence stratigraphy, Part 1: Seismic stratigraphy interpretation procedure, in Bally, A.W., ed., Atlas of seismic stratigraphy: American Association of Petroleum Geologists, Studies in Geology, v. 27, pt. 1, 1-10.

VAIL P.R., MITCHUM, R.M., TODD R.G., WIDMIER, J.M., THOMSON III, S., SANGREE, J.B, BUDD, J.N. & HATFIELD, W.G., 1977 - Seismic Stratigraphy and global changes of sea level, in C.E. Payton, (editor) Seismic Stratigraphy - applications to hydrocarbon exploration: American Association of Petroleum Geologists, Memoir 26, Tulsa, Oklahoma, 49-212.

VAN WAGONER, J.C., MITCHUM, R.M., CAMPION, K.M., & RAHMANIAN, V.D., 1990 - Siliciclastic sequence stratigraphy in well logs, cores, and outcrops: concepts for high-resolution correlation in time and space. American Association of Petroleum Geologists Methods in Exploration Series, 7, 55p.

WALKER, R.G., 1992 - Turbidites and submarine fans. In: Walker, R.G. & James, N.P. (editors) Facies models: response to sea level change. Geological Association of Canada, 239-264.

WALLACE, M.W., KERANS, M.W., PLAYFORD, P.E., & MCMANUS, A., 1991 - Burial diagenesis in the Upper Devonian reef complexes of the Geikie Gorge region, Canning basin, Western Australia: American Association of Petroleum Geologists Bulletin, 75, 1018-1038.

WEBBY, B.D. & NICOLL, R.S., 1989 - Australian Phanerozoic Timescales: 2. Ordovician. Biostratigraphic Chart and Explanatory Notes. Bureau Mineral Resources, Australia, Record 1989/32.

WORNHARDT, W.W., (Compiler), 1991 - Sequence stratigraphy concepts and applications (Wall Chart), Version 1.0: Micro-Strat Inc., Houston.

YEATES, A.N., GIBSON, D.L., TOWNER,R.R. & CROWE, R.W.A., 1984 - Regional geology of the onshore Canning Basin, W.A., In Purcell, P.G. (Editor), The Canning Basin, W.A. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, 1984, 23-55.

YOUNG, G.C. 1989 - Australian Phanerozoic Timescales: 4. Devonian. Biostratigraphic Chart and Explanatory Notes. Bureau Mineral Resources, Australia, Record 1989/34.

FIGURES

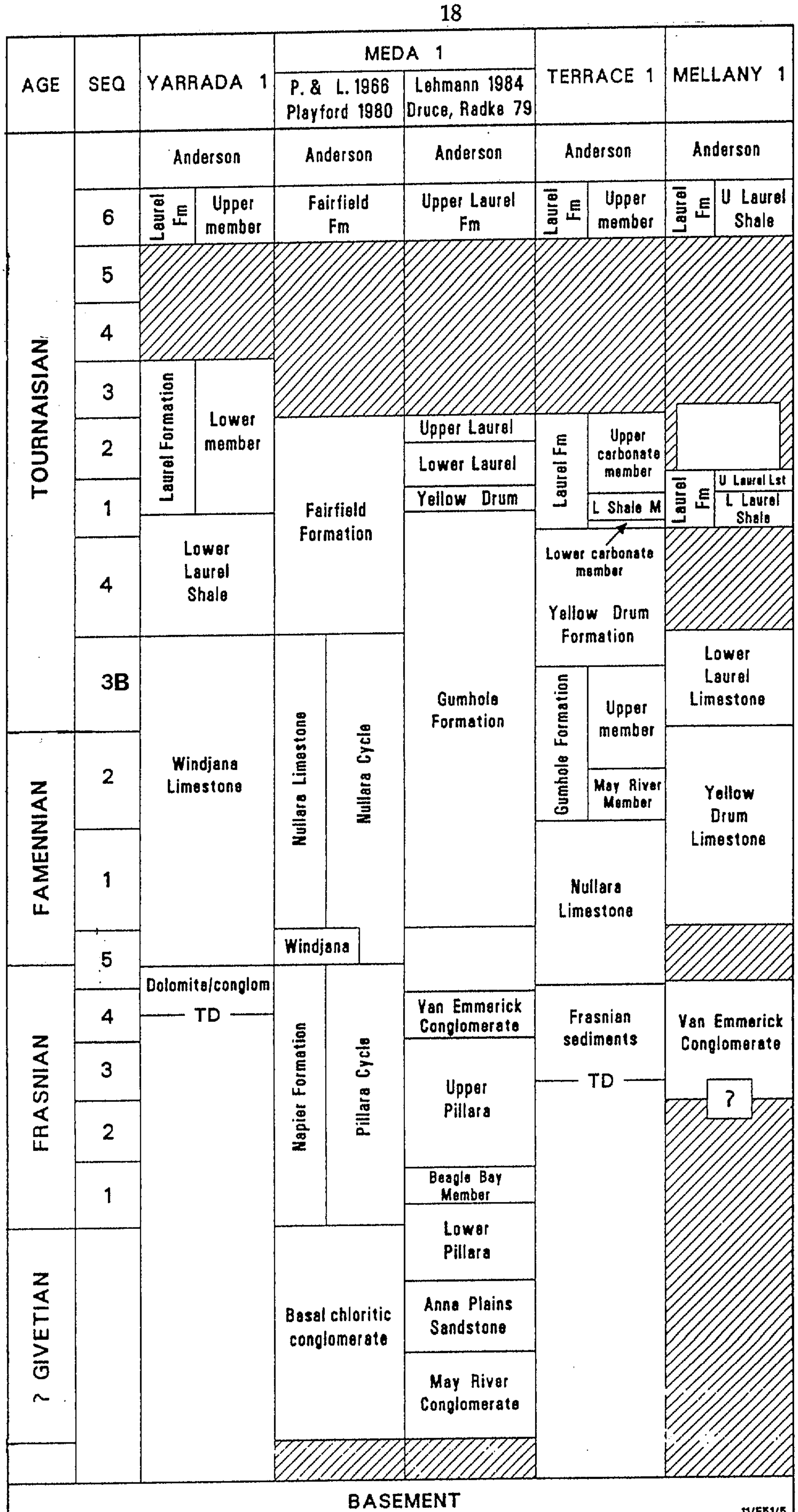

Figure 1. Lithostratigrahy of four wells from the Stage 1 study area compared to our sequence stratigraphic nomenclature. Frasnian 5 has now been renamed the Frasnian-Famennian sequence; also note the upper part of Famennian 3 and Famennian 4 sequences are now known to be Tournaisian in age. Note the variable use of many of the lithostratigraphic terms. [Fm = Formation; P&L = Playford & Lowry, (1966)]. The age of the base of the conglomerate in Mellany 1 is not known.

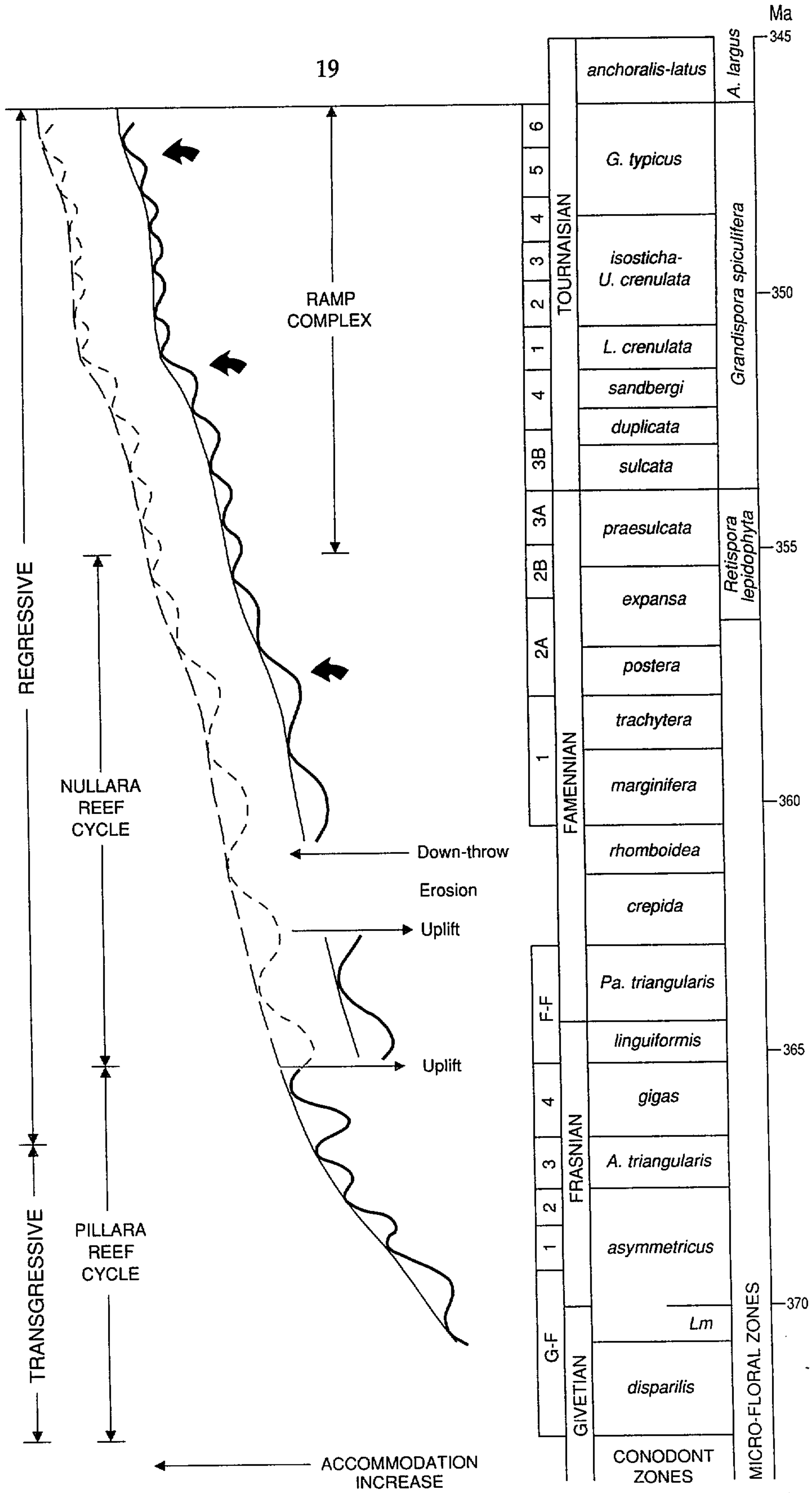

Figure 2. Relative tectonic-eustatic curve for the Givetian-Tournaisian succession on the Laurel Downs Terrace and adjacent Fitzroy Trough in the Meda area, showing the major transgressive-regressive (T-R) facies cycle (smooth curve) and the shorter wavelength third order relative sea level cycles. In the regressive half cycle the curves are offset by fault-movements and erosion in the latest Frasnian and the early Famennian. The dashed curves are corrected for these movements. Note the three second-order accommodation cycles in the regressive half cycle with maximum flooding surfaces in Famennian sequence 2A and Tournaisian sequences 1 & 6 (arrows). Recent biostratigraphic data indicates an early Tournaisian age for Famennian sequences 3B and 4.

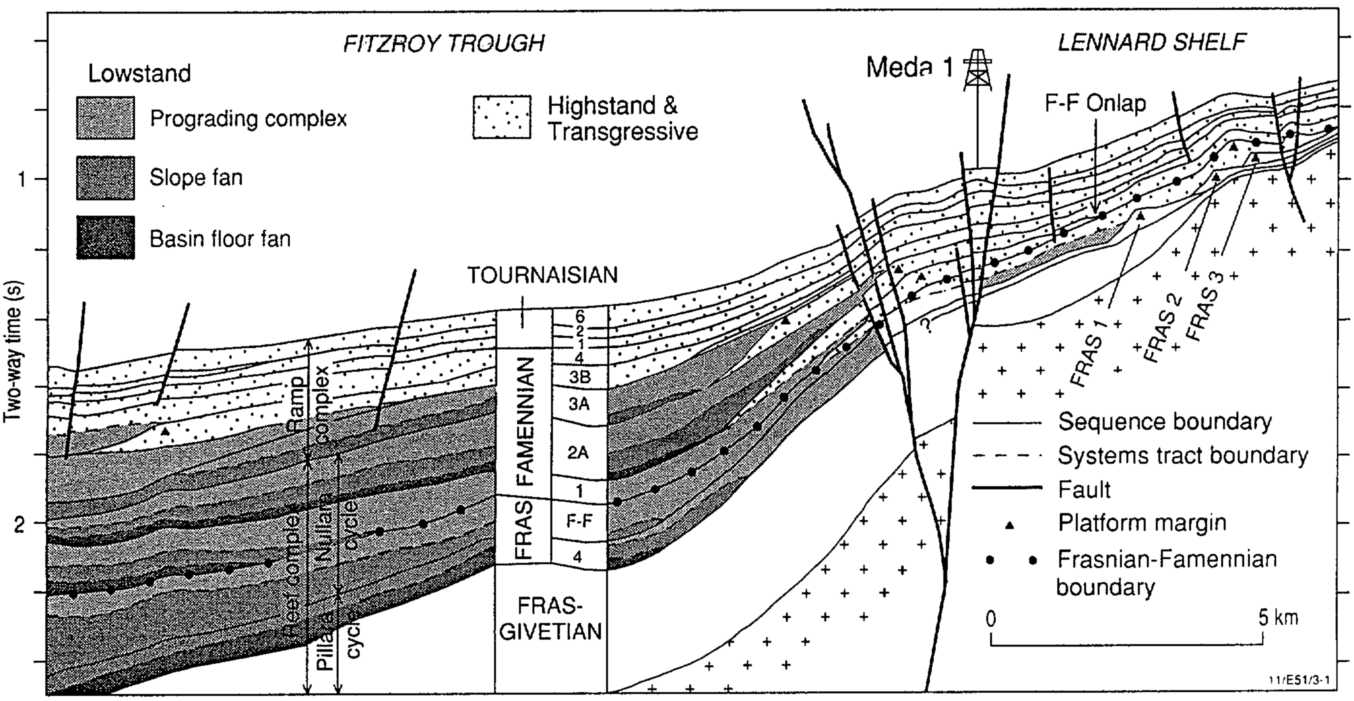

Figure 3. Line diagram depicting sequence and systems tract development in the Meda Embayment. Note coastal onlap of the Frasnian-Famennian sequence (arrow).

SUMMARIES OF INDIVIDUAL WELLS

WELL: **AQUANITA 1**

PEDIN No. W6820023

Operator:	Home Energy Co Ltd	**Year:**	1983
Lat:	17° 37′ 44.127"S	**Long:**	124° 21′ 26.569"E
KB:	88.15 m A.S.L	**Ground Level:**	81.27 m A.S.L.
TD:	3000 m		

Seismic Line: Meda Prospect Survey, intersection of lines H82-50.6 and H82-B.

OBJECTIVES

Aquanita-1 was drilled to test Famennian reef build ups on the faulted edge of a Palaeozoic high (Laurel Downs Terrace). Its primary objectives were Famennian reef carbonates and closure in the overlying Yellow Drum Formation (Famennian 2-4). Frasnian reef carbonates were seen as a secondary objective.

RESULTS

Aquanita-1 encountered a typical section down to the base of Famennian 3 with the Carboniferous represented by Tournaisian 1 and 6 overlain by the Grant Group. A thick Lower Grant Sequence is interpreted from well logs, but has not been confirmed by palynological studies.

The Devonian section features thick carbonates of the Frasnian 4, Frasnian-Famennian, Famennian 1 and Famennian 2 sequences. Lowstands in these sequences are relatively thin and composed of carbonates and, in the case of Frasnian-Famennian and Famennian 1 sequences, thin feldspathic sandstones. The sandstones are interpreted as channels cut in the platform margin that transported sand to slope fans. The well intersected a thin bed of ?Givetian sandstone and bottomed in Ordovician (Llandelian) sandstone.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

No significant hydrocarbon shows were reported, but minor gas was recorded from the Ordovician sandstones.

Source Rocks: TOC measurements on cuttings from the entire well section were too low to be source rocks.

Reservoirs: Good reservoir sandstones were encountered in the Grant Group but the target Famennian carbonates were tight. Lowstand sandstone at the base of Famennian 1 had log porosities up to 16%.

REFERENCES

MAH, A.W.H., 1983 - Aquanita #1 well completion report, Home Energy Company Ltd., Perth (unpublished).

WELL: **BLACKSTONE 1**

PEDIN No. **W6670005**

Operator:	West Australian Petroleum Pty. Ltd.	**Year:**	1967
Lat:	17° 35′ 14"S	**Long:**	124° 21′ 01"E
KB:	64.9 m A.S.L	**Ground Level:**	61.6 m A.S.L.
TD:	3049.5 m		
Seismic Lines:	The Sisters Survey, Line AB, SP 1046		

OBJECTIVES

The well was designed as a 2734 m (9000 ft) stratigraphic test of the Carboniferous and Devonian section on this part of the Lennard Shelf (Laurel Downs Terrace).

RESULTS

Blackstone 1 was programmed to reach 2743 m (9000 ft) but was deepened because of the unexpected Ordovician section and the failure to reach basement. As well as demonstrating a thick Ordovician section beneath parts of the Lennard Shelf, the well encountered probable Givetian redbeds that may contain evaporites. These red beds, (initially referred to as the Blackstone Formation) have since been defined as the type section of the Poulton Formation (Playford & others, 1975). Frasnian sequences are thin or absent because of pre-Famennian 1 erosion. The Famennian sequences are also thin, probably because of the wells position on a major structural high. A thin Namurian-Westphalian Lower Grant sequence is demonstrated by palynomorphs of the S. ybertii Assemblage.

The age of the Ordovician section is uncertain with McTavish & Legg (1976) identifying Darrawilian graptolites and conodonts and equating the rocks with the Nita and Goldwyer Formations, whereas Nicoll & others (in prep.) regard them as equivalent to the older Gap Creek and Emanuel Formations.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Rock Eval and hydrocarbon extract data, recorded on samples from the Carboniferous, Devonian and Ordovician show mostly poor source rocks in Blackstone-1. The best samples come from Tournaisian 6 and 1, having TOCs of 1.94 and 2.08 percent but are immature. However, the coring program was not designed to target source rocks.

Reservoirs: Core analyses from Blackstone 1 give poor reservoir characteristics. This is probably because none of the intervals that look promising on logs were cored. Intervals of possible good reservoirs are the Grant Group and the lower part of the Givetian sequence.

REFERENCES

DRUCE, E.C. & RADKE, B.M., 1979 - The geology of the Fairfield Group, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Bulletin, 200.
JOHNSON, N.E.A., 1968 - Blackstone No.1 well completion report, West Australian Petroleum Pty.Ltd. Bureau of Mineral Resources, Australia, File 67/4262 (unpublished)
JONES, P.J. & YOUNG, G.C., 1990 - Biostratigraphic summary of Blackstone No.1 well, Canning Basin, Western Australia. Bureau of Mineral Resources, Professional Opinion, 1990/004.
LEHMANN, P.R., 1984 - The stratigraphy, palaeogeography and petroleum potential of the Lower and lower Upper Devonian sequence in the Canning Basin. In: Purcell, P.G. (editor) The Canning Basin, W.A. Proceedings of the Geological Society of Australia Symposium, Perth, 1984, pages 253-275.
McTAVISH, R.A. & LEGG, D.P., 1976 - The Ordovician of the Canning Basin, Western Australia. In: Basset, M.G. (editor) The Ordovician System: proceedings of the Palaeontological Association symposium. University of Wales Press and National Museum of Wales, Cardiff, pages 447-478.
NICOLL, R.S., LAURIE, J.R. & ROCHE, M.T., in press. Stratigraphic subdivisions, correlation and palaeogeographic setting of Ordovician (Late Tremadoc-Arenig) Prices Creek Group, Emanuel Range, Canning Basin, Western Australia. BMR Journal of Australian Geology and Geophysics.
PLAYFORD, P.E., COPE, R.N., COCKBAIN, A.E., LOW, G.H. & LOWRY, D.C., 1975 - Geology of Western Australia. Geological Survey of Western Australia, Memoir, 2.

WELL: # BLINA 1

PEDIN NUMBER: **W6810023**

Operator:	Home Oil Australia Ltd.	**Year:**	1981
Lat:	17° 37′ 24.46"S	**Long:**	124° 34′1.60"E
KB:	62.2 m A.S.L	**Ground Level:**	56.9 m A.S.L.
TD:	2498 m		
Seismic:	Meda 1980 Seismic Survey Line H80-P, SP 286.5 Meda 1984 Seismic Survey Line H84-Q, VP 188.5		

OBJECTIVES

The well was programmed as a 2400 m test of the Carboniferous and Devonian sediments of the Lennard Shelf. A seismically defined Famennian reef comprised the primary target, sandstones in the Laurel Formation and possible reef development in the Yellow Drum Equivalent comprised secondary objectives. The well was deepened to 2498 m to enable as much of the Devonian section to be examined as possible.

RESULTS

Oil was discovered at two stratigraphic levels: in the uppermost parts of Famennian sequence 3A (1215-1228 m, Yellow Drum Formation) and in Famennian sequence 2A (1441-1495.5 m) in the upper "keep-up" parts of a backstepping transgressive systems tract (Nullara Limestone). In Famennian sequence 3A porosity is associated with vuggy dolostones. In these rocks evaporites, desiccation cracks and teepee structures provide evidence of emergence and peritidal depositional environments. The Famennian 1 sequence in Blina 1 provides evidence for lowstand and keep-up transgressive carbonate production (see seismic line H84-22). Parasequences in the transgressive deposits of Famennian sequence 2B display an aggradational keep-up pattern and minor backstepping at the maximum flooding surface. Erosion at the base of the Upper Grant Formation is interpreted as removing the Lower Grant, Y Unit, Anderson Formation, Tournaisian sequence 6 and the upper parts of Tournaisian sequence 1.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Of 27 samples analysed in the interval 1113.1-2210.0 m (comprising Tournaisian 1 to Famennian 1 succession) only the shale at 1113.1 m (TOC 0.63%) and calcareous samples in the intervals 1130-1140, 1410-1420, 1500-1510, 1650-1660 and 1800-1810 m (TOC 0.30-0.54%) are considered possible source rocks. In contrast, all of the nine samples in the interval 2250-2482 m (?Frasnian-Givetian Sequnce) are at least moderate source rocks with TOC values between 0.54 and 1.07% (Townsend, 1981). Soluble Organic Matter % and Saturated Organic Matter % suggests that all samples in the upper interval contain migrated hydrocarbons and these sediments should not be considered as source rocks, whereas samples in the lower interval have moderate to good source potential.

Maturity: Samples in the interval 1113-1400 m are immature, whereas those in the interval 2250-2484 m have been subject to a high degree of maturation. Sediments at and above 1780 m have a significant terrestrial organic component; sediments in the interval 2250-2484 m contain dominantly marine organic matter. Crude oil samples from DST 1, 2 & 3 have a similar gross composition and are derived from marine organic matter deposited in an extremely reducing environment.

Reservoirs: In Famennian sequence 3A the reservoir consists of secondary intergranular and discontinuous vuggy porosity. In Famennian sequence 2A the reservoir consists of fracture and leached vuggy porosity. Here primary porosity associated with high energy grainstones and packstones was occluded by early marine cements, compaction and later spar cementation associated with stylolite development.

REFERENCES

MOORS, H.T., GARDNER, W.E. & DAVIS, J., 1984 - Geology of the Blina Oilfield. in P.G. Purcell (Editor), The Canning Basin, W.A. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, W.A. 1984, p277-283.

TOWNSEND, B.A., 1981 - Blina 1 well completion report, Home Energy Company Ltd., Perth (unpublished).

WELL:	**BORONIA 1**		
PEDIN No.	**W6820076**		
Operator:	I. E. D. C. Aust. Pty. Ltd.	**Year:**	1982
Lat:	17° 45′ 29.7″S	**Long:**	124° 34′ 17.8″E
KB:	58.5 m A.S.L	**Ground Level:**	65 m A.S.L.
TD:	3391 m		
Seismic Line:	Amax Petroleum, Fitzroy Basin Survey, Line ED81-82, SP 161		

OBJECTIVES

Boronia 1 was drilled 1500 m southwest of Mimosa 1 and was originally scheduled to test two coincident seismic anomalies, both interpreted to be Devonian pinnacle reefs at the southern margin of the Lennard Shelf. The shallower objective was in the Famennian Nullara Cycle and was believed to be a low relief bioherm. The deeper primary objective was interpreted as a Frasnian bioherm equivalent to the Pillara reef outcrop. It was located on the back limb of a rotated fault block, bounded by the "Oscar Fault" to the northeast and the "Harvey Fault" to the southwest, basinward but updip from the Mimosa 1 well.

Although Upper Devonian carbonate reefs were not intersected in the nearby Mimosa 1 well, the Boronia target was interpreted to be structurally higher during the Frasnian and therefore in a more favourable position for reef development.

For "operational reasons" (quote from WCR), the well location was selected whilst interpretation of the 1981 seismic survey was incomplete. Prior to drilling, an alternate interpretation was developed which ascribed the Frasnian anomaly to a major intra-Frasnian unconformity above a tilted fault block, the stratigraphic section of which was interpreted to be 100 m higher than at the Mimosa 1 well. It was then decided that as a reef was not likely, Boronia 1 would be deepened to intersect the equivalent of a porous sandstone with hydrocarbon shows at 3356 m in Mimosa 1 (basin floor fan, ?Frasnian-Givetian Sequence).

RESULTS

The succession intersected in Boronia 1 correlates closely with that intersected in Mimosa 1, and consequently neither Pillara nor Nullara reef carbonates were intersected. The alternative interpretation of an intra-Frasnian unconformity was confirmed, but the porous Frasnian sandstones intersected in Mimosa 1 (prognosed to be 100 m higher in Boronia 1) were concluded to have silted out in Boronia 1.

HDT Dipmeter cluster analysis indicated that the Devonian-Carboniferous strata dips consistently to the southwest at about 5-10°, increasing to about 23° below 2900 m, whereas "low angle dips (<10°) probably to the northeast" are shown on seismic line ED81-82 (Boronia 1 Well Completion Report; a copy of this line has not been examined in the present study to confirm this dip direction). This discrepancy in structural dip between seismic and dipmeter data remained unresolved in the well completion report. Subsequent seismic data (Amax Petroleum Fitzroy Basin Survey, lines ED84-439, 442), however, clearly indicate that the Devonian to Carboniferous section in Boronia 1 dips to the southwest (in agreement with the HDT well log), and that equivalent strata occur approximately 100 m deeper (rather than 100 m higher) in Boronia 1 than in Mimosa 1. Thus the porous sandstone with hydrocarbon shows at 3356 m in Mimosa 1 (basin floor fan, ?Frasnian-Givetian Sequence 4) was not intersected. We expect it would occur approximately 60 m below TD of Boronia 1.

Boronia 1 also indicates (as did Mimosa 1) that the Boronia-Mimosa structure occurs within a structural terrace (Laurel Downs Terrace) on the southern flank of the Lennard Shelf (i.e., south of the Devonian carbonate platform).

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Mudlog shows throughout the Frasnian to early Famennian section suggest a thick hydrocarbon generative section. Four samples of Frasnian cuttings (2682, 2813, 2827 and 3013 m) have been analysed for TOC, and two (2682 & 2827 m) selected for Rock-Eval analysis (Woodhouse, 1982). The siltstones at 2813 & 3013 m and the shale at 2827 m are poor source rocks, but the shale at 2682 m (?Fras-Fam sequence: 1.87% TOC, $S_1 + S_2 = 3.41$, $S_2/S_3 = 2.8$) is a good oil source, is mature, and was derived mainly from eucaryotic marine organisms.

Reservoirs: The interpreted basin floor fan sandstone at the base of the Frasnian-Famennian sequence (2800-2820 m) is the best potential reservoir within the Devonian section. It comprises very fine to coarse, predominantly fine-medium, slightly calareous quartz sandstone with poor visual intergranular porosity and 8-12% crossplot porosity. This interval was tested by DST 1 which recovered 140 bbls of mud and formation fluid of which several litres were 35° API oil. Geochemical data (Woodhouse, 1982) indicates that the oil was sourced from a nearby mature marine clastic source. Although geochemical data suggests that the oil was not sourced from the sediment samples analysed in Boronia 1, it is likely that other parts of the Frasnian section may have been the source.

Hydrocarbon shows within sandstones at the top of the Clanmeyer Formation (Famennian 2A) were evaluated by DST 5, followed by an acid stimulation test (DST 5a). Although global interpreted porosities in this interval are good (14-16%), high clay content (39% at 1633.5 m) and test results indicate low permeabilities.

As noted above, the porous sandstone interval intersected at 3356 m in Mimosa 1 (basin floor fan, ?Frasnian-Givetian) was not intersected in Boronia 1 and is interpreted to occur approximately 60 m below TD.

REFERENCES

BORONIA #1 Well Completion Report, I.E.D.C. of Australia Pty Limited. Western Australia Department of Mines, Report S2055 (unpublished).

WOODHOUSE, G.W., 1982 - Geochemical evaluation of Boronia #1 SWC's and recovered oil, in BORONIA #1 Well Completion Report, I.E.D.C. of Australia Pty Limited, Appendix 10. Western Australia Department of Mines, Report S2055 (unpublished).

WELL: # HANGOVER 1

PEDIN NUMBER: **W6830056**

Operator:	Home Energy Company Ltd.	**Year:**	1983
Lat:	17° 34' 39.148"S	**Long:**	124° 16 31.843"E
KB:	53.97m A.S.L	**Ground Level:**	46.32m A.S.L.
TD:	1655m		
Seismic:	Meda Blackstone Survey, Line H79-2, VP 172 Sundown 1983 Survey, Line H83-20, SP 357		

OBJECTIVES

The primary objective of Hangover 1 was to explore for pockets of oil-bearing sandstone in the Grant Group on the southeast-trending anticlinal structure that Sundown 1 was drilled on. Hangover was sited 4.5 km southeast of Sundown 1 on a larger, elongated and closed high, and separated from it by a saddle. The prospect did not show closure below Grant level.

RESULTS

The stratigraphy encountered during drilling was largely as predicted, however Home Energy did revise picks for the top of both the Poole Sandstone and Grant Formation [sic] compared to their earlier picks in other wells. Even so their picks do not equate with our sequence boundaries. The top of our Poole Sequence (ie basal Noonkanbah sequence boundary) is taken at the base of a thin sandy interval - which we interpret as a Transgressive Systems Tract below the thick shaley Noonkanbah - in contrast to the sandstone/shale lithological break that Home Energy geologists use. Our Poole Sequence is thinner than Home's Poole Sandstone and is defined largely as the sequence that contains Unit III (D. Townrowii) microfloral association. The Poole sequence has a similar log motif to the lower Noonkanbah, ie a lower sandy TST overlain by prograding parasequences in the HST. Similar criteria and wireline log picks were used in Sundown 1 to define these sequence boundaries.

The upper and lower subdivisions of the Grant Sequence have been identified in this well largely through correlation with surrounding wells; palynological determinations from this well were poor. The upper part of the Grant has been further tentatively subdivided into 4 sequences. The upper Grant type A sequence between 990-1110m in Hangover 1 is largely a sandy channel fill deposit with a mudstone capping; it is not present in the Sundown 1 well. Otherwise, correlations between the two wells were good. The lowermost 115m is identified as our Y Unit sequence, based largely upon seismic ties with Sundown 1 along line H83-20 where some palynological control is available.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

No significant hydrocarbon shows were encountered in Hangover 1. Although slight fluorescence was observed at 1395-1405m and 1498-1500m, wireline log interpretations suggest that the entire section in Hangover 1 is water saturated. Based on cutting and side wall core analyses the Poole and Grant Sequences are organically lean with poor hydrocarbon generating capabilities. Shallower units contain some organic rich intervals but these appear to be largely of non oil prone organic matter.

Although no conventional cores were cut, log determinations suggest the Poole and Grant sequences have thick intervals (10-100m) with porosities commonly between 14-20%.

Following on from Hangover 1 a third well, Whitewell 1 situated approximately half-way between Sundown and Hangover, was drilled on the same structural trend in 1984 to further test for hydrocarbons in the Grant Group. It provided similar disappointing results as Hangover 1.

REFERENCES

Mah, A.W.H., 1983 - Hangover #1 Well Completion Report. Unpublished Report for Home Energy Company Ltd., Perth

Denn, S. 1984 - Whitewell #1 Well Completion Report. Unpublished Report for Home Energy Company Ltd., Perth.

WELL: **HAROLD 1**

PEDIN NUMBER: **W6870017**

Operator:	Home Energy Company Ltd.	**Year:**	1987
Lat:	17° 33' 40.496"S	**Long:**	124° 34' 18.049"E
KB:	68.05 m A.S.L	**Ground Level:**	63.79 m A.S.L.
TD:	1550 m		
Seismic:	Meda 1984 Seismic Survey Line H84-22, VP 570		

OBJECTIVES

Nullara carbonates comprised the primary objective, the secondary objective comprised dolostones in the Yellow Drum Formation. Both horizons are reservoirs in the Blina Field. Both objectives were interpreted as having four way dip closure.

RESULTS

Harold 1 was located on the easten side of the Kimberley Downs Embayment in a similar strutural setting to Blina 1. Primary and secondary porosity development were expected to be similar to Blina 1. Sourcing was expected from the Frasnian section. Results from the well showed that tight limestones in Famennian sequence 1 (Nullara Limestone) would have inhibited the vertical and lateral migration of hydrocarbons into the Famennian 2A play (top Nullara sealed by May River Member) where porous dolostones were expected and, in fact, encountered (829-890 m). The secondary predicted reservoir interval in the Yellow Drum Formation was was also identified (Famennian3A; 655-680 m). However, erosion at the base of the Grant has removed any seal. The Famennian succession intersected in Harold 1 was identical to that intersected in Blina 1. Erosion at the base of the Upper Grant Formation is interpreted as removing the Lower Grant, Y Unit, Anderson Formation, Tournaisian sequences 1 & 6 and Famennian sequence 4.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

No indications of commercial hydrocarbons were encountered.

REFERENCES

DENN, S., and JOHNSON, N.E.A., 1987 - Harold 1 well completion report, Home Energy Company Ltd., Perth (unpublished).

WELL:	**JANPAM 1**		
PEDIN No.	**W6820091**		
Operator:	Home Energy Co. Ltd.	**Year:**	1982
Lat:	17° 36′ 8.287″S	**Long:**	124° 24′ 51.845″E
KB:	96.85 m A.S.L	**Ground Level:**	89.95 m A.S.L.
TD:	2263 m		
Seismic line:	Meda Prospect, line H82-19.4, SP 332		

OBJECTIVES

Janpam 1 was drilled to test seismically defined structural closures in Fameniann reef carbonates and overlying Yellow Drum carbonates, with Frasnian clastics as a secondary objective.

RESULTS

Target horizons in the Tournaisian and Famennian were lower than predicted and the Frasnian clastics were 100m higher than predicted.

The Lower Grant sequence is probably absent from Janpam 1 with a Type A sequence of the Upper Grant Group resting unconformably on Tournaisian 6. Famennian 3 and 4 are both present as thin units and the Type 2 sequence boundary within Famennian 2 is also recognisable. The turbidites of probable Frasnian 4 age in which the hole bottomed are very sandy compared to other wells.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Cutting samples from below 1450 m show generally poor source characteristics with low TOCs and low S1 and S2 values. One sample from the Frasnian 4 sequence has 0.53% TOC, a fair proportion of organic matter but has low S1 and S2 values indicating poor source quality. Tmax values from the Tournaisian are immature and marginally mature to mature in Frasnian 4. Some hydrocarbon shows were recorded in Tournaisian 6, Famennian 2 and Frasnian 4 (oil stains, fluorescence and gas shows).

Reservoirs: Fair to good reservoir sandstones were encountered in the Poole, Grant and Tournaisian sequences. Dolostone in Famennian 2, 3 and 4 exhibit log porosities up to 11% whereas other carbonates were tight. Log analysis of Frasnian 4 sandstones suggests up to 11% porosity but the analysis was complicated by abundant micas in the rock.

REFERENCES

MAH, A.W.H. 1983 - Janpam #1 well completion report. Home Energy Company Ltd, Perth (unpublished).

WELL: **KATY 1**

PEDIN No. **W6830059**

Operator:	Home Energy Company Ltd.	**Year:**	1983
Lat:	17° 38′ 39.98″S	**Long:**	124° 21′ 29.34″E
KB:	90.35 m A.S.L	**Ground Level:**	82.82 m A.S.L.
TD:	1952 m		
Seismic line:	Meda Prospect, line H82-19Ext, SP 272		

OBJECTIVES

Katy 1 was drilled to test sandstone reservoirs in the Grant Group in a seismically defined anticline similar to and along strike from the Sundown discovery.

RESULTS

Katy 1 encountered much thicker sections of both Upper and Lower Grant sequences than most wells examined in this area. This is consistent with its more basinward position. This well shows that strong reflectors that appear continuous with Tournaisian events on the shelf are shales and limestones in the Y and Anderson sequences.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Shales with high TOCs are present in Noonkanbah, Poole and Grant sequences. All samples rated poorly on standard Rock Eval parameters (S1 and S2). Tmax values indicate immature to marginally mature source rocks.

Reservoirs: Log analysis (Locke, in Mah, 1983) indicates maximum porosities of 9 to 18% in the Poole, Upper Grant, Lower Grant and Anderson 2 sequences. These intervals were interpreted as fresh water-bearing. The absence of hydrocarbons in the Upper Grant could result from lack of migration pathways for oil generated in deeper source rocks, more discontinuous intra-Grant shales that form seals in the Sundown field or fresh water flushing of the reservoir facies.

REFERENCES

MAH, A.W.H., 1983 - Katy #1 well completion report, Home Energy Company Ltd., Perth (unpublished).

WELL: LANGOORA 1

PEDIN No. W6620008

Operator:	West Australian Petroleum Pty Ltd	**Year:**	1962
Lat:	17° 18′ 07″S	**Long:**	124° 06′ 48″E
KB:	23.7 m A.S.L	**Ground Level:**	21 m A.S.L.
TD:	1615 m		
Seismic:	Langoora 1959, Kimberley Downs line AG, SP 59.		

OBJECTIVES
Langoora 1 was drilled to test the Lower Carboniferous Laurel Formation and a suspected Upper Devonian reef in a structural position up-dip from, and at least 300 m higher than, the reef intersected in Meda 1. Seismic data indicated a "structural terrace" thought to be caused by differential compaction over a reef mass.

RESULTS
The suspected Devonian reef was not encountered, but age equivalent inner platform facies (Famennian sequences 1 & 2) were intersected above Proterozoic schist which was higher than expected. The "structural terrace" on which Langoora was sited is a mid-Carboniferous reverse fault block and lies 2-3 km inboard from the nearest (Frasnian) reefs identified on seismic line H85-6.6.

The Anderson sequence is truncated by a major unconformity at the base of the Lower Grant sequence which contains palymorphs of the S. ybertii* Assemblage.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY
No hydrocarbon shows were recorded in the well, and no potential source or reservoir rocks occur within the Devonian-Carboniferous succession. Sandstones within the Grant sequences have good porosity and permeability.

REFERENCES
DRUCE, E.C., & RADKE, B.M., 1979 - The geology of the Fairfield Group, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Bulletin 200, 62 p.

GARDNER, W.E., 1963 - Langoora No. 1 Well Completion Report, West Australian Petroleum Pty Limited. Bureau of Mineral Resources, Australia, File 62/1094 (unpublished).

JONES, P.J., FOSTER, C.B., & YOUNG, G.C., 1991 - Biostratigraphic summary of Langoora No. 1 Well, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Professional Opinion 1991/004 (Unpublished).

WELL: **LUKINS 1**

PEDIN NUMBER: **W6850073**

Operator:	Home Energy Company Ltd.	**Year:**	1985
Lat:	17° 32′ 14.645"S	**Long:**	124° 32′ 4.319"E
KB:	63.3 m A.S.L	**Ground Level:**	55.8 m A.S.L.
TD:	1675 m		
Seismic:	Meda 1985 Seismic Survey, Line H85-20.7, SP 312		

OBJECTIVES

Lukins 1 was drilled to test the hydrocarbon potential of the Yellow Drum Formation which at this location is mapped as having 4-way dip closure. The well was also designed to obtain stratigraphic information on basinal sediments in the Kimberley Downs Embayment.

RESULTS

No hydrocarbon indications were encountered in Lukins 1. Erosion at the base of the Upper Grant Formation is interpreted as removing the Lower Grant, Y Unit, Anderson Formation and the upper parts of the Tournaisian sequence 6. The shelf margin and transgressive systems tracts in Famennian Sequence 2B are well developed, as are lowstand deposits in Famennian sequence 2A. Shaley carbonate mudstones at the base of Famennian sequence 2A are interpreted as the distal toe of a lowstand carbonate unit (cf. Blina 1, Southgate & others in press). A systems tract interpretation of Famennian sequence 2A and 2B in the central parts of seismic line H85-20.7 is given in Southgate & others (in press).

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Reservoirs: The Poole and Grant Formations contain reservoir quality sands. Carbonates in Famennian sequences 2A, 2B and 4, and Tournaisian sequences 1 and 6 lack porosity. A 7.5 m interval of Famennian sequence 3B (Yellow Drum Formation) contains porosity associated with dolostones, and correlates with a production interval in Blina 1. Lowstand deposits in Famennian sequence 2A (slope fan, shingled turbidites and prograding complex) are fine-grained siltstones and lack reservoir development.

Source Rocks/Maturity: Vitrinite reflectance studies indicate marginally mature sediments between 754-1065 m (Tournaisianl - Famennian 2B) and marginally mature to mature rocks in the interval 1095-1400 m (Famennian 2A).

REFERENCES

Mah, A.W.H., 1985 - Lukins 1 well completion report, Home Energy Company Ltd., Perth (unpublished).

WELL: MARIANA 1

PEDIN NUMBER: W6840058

Operator:	Home Energy Company Ltd.	**Year:**	1984
Lat:	17° 33′ 56.662"S	**Long:**	124° 27′ 08.846"E
KB:	56.1 m A.S.L	**Ground Level:**	48.4 m A.S.L.
TD:	1700 m		
Seismic:	Meda 1982 Seismic Survey Line H82-A, VP 266 Meda 1984 Seismic Survey Line H84-19.6, VP 161		

OBJECTIVES

Primary objectives were dolostones in the Nullara Limestone and Yellow Drum Formation. Four way dip closure was interpreted to occur at both levels.

RESULTS

No hydrocarbon shows were encountered. A prominent shift in the gamma log at the base of Famennian sequence 2B coincides with the marked shift in facies at this type 2 sequence boundary. Erosion at the base of the Upper Grant Formation is interpreted as removing the Lower Grant, Y Sequence, Anderson Sequence and upper parts of the Tournaisian 6 sequence.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: The Poole Sandstone has fair to good TOC values (0.87% to 1.80%). The Laurel Formation has poor to fair organic richness (TOC values of 0.19% to 1.04%). The Grant Formation and Famennian sequences 2B to 4 have TOC values less than 0.5%.

Maturity: Tmax, Ro and TAI data indicate that the section to a depth of 1500 m is immature and beneath this depth the sediments are marginally mature.

Reservoir: Good pin-point and vuggy porosity occur in dolostones in the uppermost parts of Famennian sequence 3A (Yellow Drum Formation: 1372-1385 m) and correlate with the producing horizon in Blina 1. Log interpretation indicates the entire section to be water saturated.

REFERENCES

Mah, A.W.H., 1985 - Mariana 1 well completion report, Home Energy Company Ltd., Perth (unpublished).

WELL: MAY RIVER 1

PEDIN NUMBER: W6670003

Operator:	West Australian Petroleum Pty Ltd	**Year:**	1967
Lat:	17° 14′ 50"S	**Long:**	124° 05′ 01"E
KB:	20.4 m A.S.L	**Ground Level:**	17 m A.S.L.
TD:	1678 m		
Seismic:	Langoora 1959, Kimberley Downs Survey, line AF, SP 65		

OBJECTIVES

May River 1 was drilled to test a suspected Devonian reef complex where a buried Proterozoic ridge provides three-way closure and regional dip provides closure in the fourth direction. Interpretation of basement topography was based on previous drilling results (Meda 1, Langoora 1), coupled with seismic and gravity data.

RESULTS

The suspected Devonian reef was not intesected, but age equivalent inner platform facies (Famennian sequences 1 & 2) were intersected above Proterozoic schist which was higher than expected.

A thick section of Anderson sandstone and siltstone is unconformably overlain by sandstones of the Grant Group, and a thin Lower Grant sequence may be present based on wireline log correlations to Meda 1 and Langoora 1 (this correlation cannot been confirmed by palaeontological data).

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

No shows of oil or gas were recorded, but hydrocarbon staining was noted in fine dolomitic sandstones in the Laurel Formation (Tournaisian sequence 6). Sandstones within Famennian sequences 2 & 3 (Gumhole Formation) have moderate to good porosity and poor to moderate permeability. No potential source rock intervals were intersected.

REFERENCES

DRUCE, E.C., & RADKE, B.M., 1979 - The geology of the Fairfield Group, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Bulletin 200, 62 p.

GORTER, J.D., 1980 - Petroleum potential of the Permo-Carboniferous of the northern Canning Basin, Western Australia, Appendix 1: Detailed stratigraphy, palaeontology, porosity, permeability and source rocks, northern Canning Basin. ESSO Australia (unpublished).

JOHNSON, N.E.A., & BROWNHILL, M.H., 1967 - May River No. 1 Well Completion Report, West Australian Petroleum Pty Limited. Bureau of Mineral Resources, Australia, File 67/4252 (unpublished).

JONES, P.J., & YOUNG, G.C., 1991 - Biostratigraphic summary of May River No. 1 Well, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Professional Opinion 1991/001 (Unpublished).

WELL: **MEDA 1**

PEDIN NUMBER: **W6580002**

Operator:	West Australian Petroleum Pty Ltd	**Year:**	1958
Lat:	17° 24′ 00"S	**Long:**	124° 11′ 30"E
KB:	30.5 m A.S.L	**Ground Level:**	26.8 m A.S.L.
TD:	2685 m		
Seismic:	Meda 1957, Kimberley Downs Line G, ~400 m NE SP 5		

OBJECTIVES

Meda 1, the first exploration well drilled by WAPET on the Lennard Shelf, was sited near a positive gravity anomaly with the objective to test possible Devonian reefs associated with a basement high. The well was located over a small seismically-defined closure with erratic dips (possible reef) in the vicinity of a gravity maximum.

RESULTS

An Upper Devonian reef complex was intersected above a basal (?Givetian) conglomerate which overlies Proterozoic schist. Three prominent radioactive dolostone beds in the Lower Frasnian section (2313-2317, 2328-2330, 2341-2344 m) may represent condensed basinal deposits of backstepping Frasnian reefs identified 3-5 km NE of Meda 1 on seismic line H84-10.5. The thick boulder conglomerate and sandstone interval within the reef complex (2271-2317 m, Frasnian sequence 4) represents lowstand deposits equivalent to the Van Emmerick conglomerate in the Napier Range. Similar pebbly lowstand deposits also occur at the base of Famennian sequence 1 (2013-2018 m). Thick transgressive-highstand forereef and reef facies occur in three sequences (Frasnian 4, Frasnian-Famennian, Famennian 1). The prominent shale unit within Famennian sequence 2 (1875-1881 m) indicates a major marine flooding event that correlates with the May River Shale identified in neighbouring Home Oil wells.

Siltstones and shales of the Y sequence are truncated by a major unconformity at the base of the Lower Grant sequence (1144-1280 m) which contains palymorphs of the S. ybertii Assemblage.

The seismic closure on which Meda 1 was sited is thought to be mid-Carboniferous transpressional reactivation ("flower" structure) of a Givetian normal growth fault.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Rock Eval, hydrocarbon extract and vitrinite data of Permian, Carboniferous and Devonian sections indicate poor source rocks and that the Devonian-Tournaisian section is mature to immature (R_o 0.69-0.77)

Reservoirs: Several gallons of paraffin-base crude oil were recovered from calcareous and dolomitic sandstones in the Tournaisian section above the reef complex, and weak gas flows and numerous gas shows were recorded in carbonates of the Upper Devonian reef complex. Analysis of the crude oil recovered from Meda 1 indicate it is a very mature, saturate-rich, 37.8° API crude oil originating from algal organic matter (Tybor, 1983).

Hydrocarbon shows in Meda 1 provided much of the stimulus for further exploration of Devonian reefs on the Lennard Shelf.

REFERENCES

DRUCE, E.C., & RADKE, B.M., 1979 - The geology of the Fairfield Group, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Bulletin 200, 62 p.

GORTER, J.D., 1980 - Petroleum potential of the Permo-Carboniferous of the northern Canning Basin, Western Australia, Appendix 1: Detailed stratigraphy, palaeontology, porosity, permeability and source rocks, northern Canning Basin. ESSO

Australia (unpublished).

JONES, P.J., & YOUNG, G.C., in prep - Updated biostratigraphic summaries of selected wells on the Lennard Shelf. In Jones P.J., & Young, G.C., Overview of Phanerozoic biostratigraphy and palaeontology of the Canning Basin (Lennard Shelf), Appendix. Australian Geological Survey Organisation, Record **.

LEHMANN, P.R., 1984 - The stratigraphy, palaeogeography and petroleum potential of the Lower to lower Upper Devonian sequence in the Canning Basin. In Purcell, P.G. (ed.), The Canning Basin, W.A. Proceedings of the Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, Perth, 1984, 253-275

PLAYFORD, P.E., & LOWRY, D.C., 1966 - Devonian reef complexes of the Canning Basin, Western Australia. Geological Survey of Western Australia, Bulletin 118, 150 p.

PUDOVSKIS, V., 1959 - Meda No. 1 Geological Completion Report, West Australian Petroleum Pty Limited. Bureau of Mineral Resources, Australia, File 62/1022 (unpublished).

PUDOVSKIS, V., 1962 - Meda No. 1 Well, Westwern Australia of West Australian Petroleum Pty Limited. Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Publication 7, 51 p.

TYBOR, P., 1983 - Crude oil characterization of the oils from the Sundown and Meda No. 1 wells, in Mah, A.W.H., Sundown #1 Well Completion Report, Home Energy Company Ltd., Appendix 5.4 (unpublished).

WELL: **MELLANY 1**

PEDIN NUMBER: **W6870015**

Operator:	Home Energy Company Ltd.	**Year:**	1987
Lat:	17° 24' 06.577"S	**Long:**	124° 17' 17.790"E
KB:	37.3 m A.S.L	**Ground Level:**	32.9 m A.S.L.
TD:	1476 m		
Seismic:	Meda 1986 Seismic Survey, line H 86-13.4, VP 167		

OBJECTIVES

Mellany 1 was sited to test the high point of a mapped four-way dip-closed structure of the base Famennian event, interpreted to be a Frasnian pinnacle reef.

RESULTS

Drilling showed that the original interpretation of a Frasnian pinnacle reef was invalid. The depositional high was found to be a sequence of clastic conglomerate in a limestone matrix and was correlated with outcropping conglomerate at Van Emmerick in the northern Napier Range. In the well the conglomerates occur at three distinct horizons and each are separated by finely crystalline limestones lacking abundant terrigenous compnents. In Frasnian sequence 4 and Famennian sequences 1 & 2A the conglomerates and sandy limestones are interpreted as lowstand and proximal transgressive deposits. Because Mellany 1 was drilled on the inner platform most facies in the reef and ramp complexes are sandy and silty. Basement was intersected higher than predicted.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Small hydrocarbon shows were encountered in very fine grained sandstone in the transgressive deposits of Tournaisian sequences 1 (1100-1102 m) & 6 (1047-1057 m). Wireline logs showed the upper interval to be tight.

Reservoirs: Good porosities (20-25%) exist in the Poole and Grant Sequences. Sands in Tournaisian sequences 1 & 6 had porosities ranging from 2-13.5%. Dolostones in Famennian sequence 3B had porosities ranging from 6-22%.

REFERENCES

DENN, S., and JOHNSON, N.E.A., 1987 - Mellany 1 well completion report, Home Energy Company Ltd., Perth (unpublished).

WELL: **MIMOSA 1**

PEDIN NUMBER: W6730013

Operator:	West Australian Petroleum Pty Ltd	**Year:**	1973
Lat:	17° 44′ 57.58"S	**Long:**	124° 35′ 0.32"E
KB:	58 m A.S.L	**Ground Level:**	54 m A.S.L.
TD:	4117 m		
Seismic Line:	Sisters-Mt North C-CF, SP 36		

OBJECTIVES

Mimosa 1 was drilled to test a Middle-Late Devonian structure on a large, seismically defined, southeast plunging "nose" at the southern edge of the Lennard Shelf. Seismic data indicated four-way closure of the prospect and closure was estimated at 65 km^2 with a vertical relief of about 244 m. NE closure results from downward throw and rotation of the Mimosa tilt block against a major low angle, southwest-dipping, normal fault ("Oscar Fault") to the northeast. The structure is bounded to the southwest by the Pinnacle Fault system, interpreted to mark the margin of the Lennard Shelf. The primary objective was platform-margin reefs in the Middle-Late Pillara Limestone capped and sealed by shales of the Napier Formation, and sourced by Carboniferous and Devonian basinal facies in the Fitzroy Trough and by mixed Devonian facies on the Blina Terrace. A secondary objective was the Middle Devonian Poulton Formation.

RESULTS

The well intersected a predicted Permian-Carboniferous section (to base Laurel Formation), but instead of the predicted Famennian (Nullara) and Givetian-Frasnian (Pillara) reef carbonates, a thick section of equivalent clastic basinal facies (Luluigui and Clanmeyer Formations, and "Frasnian Unit A", respectively) was intersected. These clastics are here interpreted as lowstand deposits. Palaeontological and seismic data indicate that the prominent limestone (2376-2395 m) within this clastic succession is a condensed, unconformity-bounded, mid Famennian sequence (Famennian sequence 1). The underlying late Frasnian to ?Givetian succession can be divided into three depositional sequences (Givetian, ?Frasnian-Givetian & Frasnian-Famennian sequences), each comprised of basin floor fan, slope fan and prograding complex (the base of the Givetian sequence is beyond total depth, and basin floor facies were not intersected within that sequence). Clastics above the condensed carbonates of Famennian sequence 1 are similarly interpreted as slope fan and prograding complex (Clanmeyer Formation; Famennian sequence 2A), capped by a thin carbonate unit (basal Luluigui Formation) interpreted as highstand slope deposits. The remainder of the Luluigui Formation is interpreted as shelf margin, transgressive and highstand slope carbonates (Famennian sequences 2B & 3).

The Anderson, Y unit and Lower Grant sequences are not present, and Tournaisian sequence 1 (Laurel Formation) is unconformably overlain by the Upper Grant Group.

The pre-drill concept that the "Pinnacle" Fault marks the southern margin of the Devonian carbonate platform is clearly incorrect in the Mimosa area; the Devonian succession in Mimosa 1 represents basinal facies outboard and to the south of the Devonian carbonate platform (this new palaeogeographic information and its affect on petroleum prospectivity is not addressed in the Well Completion Report). The rotated tilt block on which Mimosa 1 was sited is now regarded as a structural terrace (Laurel Downs Terrace) bounded to the north by the Sixty-seven Mile - Oscar Fault system and to south by the Harvey-Pinnacle Fault system.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Mudlog shows throughout the Givetian-Frasnian section suggest a thick hydrocarbon generative section. Rock-Eval and Extract data of Cores 1, 2 & 3 indicate poor source rocks, but hydrocarbon extract data from Core 1 suggest it is a very good potential source. Vitrinite data suggest that the late Famennian-Carboniferous section and Core 1 are marginally mature (R_o 0.70-0.75), and that Cores 2 & 3 are over mature (R_o 1.61 & 2.08, respectively). In view of the fact that only a few Devonian samples have been analyses, systematic source rock analysis of the Frasnian-Famennian section is recommended.

Reservoirs: The interpreted basin floor fan sandstones at the base of the ?Frasnian-Givetian and Frasnian-Famennian sequences are the best potential reservoirs within the Devonian section. They comprise poorly sorted very fine to medium sandstone with scattered coarse grains and a calcareous and clay-silt matrix. Core analysis indicates 5-13% porosity but negligible permeability, and Drill Stem Test 1 demonstrated that the ?Frasnian-Givetian basin floor sandstones are tight. Seismic interpretation indicates that these sandstones occur at the basinward pinchout of the basin floor fans, and thus better quality reservoirs may occur within thicker proximal portions of the fans.

Numerous thin sandstones in the Clanmeyer Formation (Famennian sequence 2A) have 14-16% sonic porosity, but sandstone cuttings have low visual porosity.

REFERENCES

JONES, P.J., & YOUNG, G.C., 1992 - Biostratigraphic summary of Mimosa 1 well, Canning Basin, Western Australia. Bureau of Mineral Resources, Australia, Professional Opinion 1992/002.

OSBORNE, D.G., & O'SHAUGHNESSY, P.R., 1973 - Well Completion Report, Mimosa No. 1 (E.P. 44 Canning Basin), West Australian Petroleum Pty Limited. Bureau of Mineral resources, Australia, File 73/233 (unpublished).

WELL: **SUNDOWN 1**

PEDIN NUMBER: **W6820104**

Operator:	Home Energy Co Ltd	**Year:**	1982
Lat:	17° 33' 10.030"S	**Long:**	124° 14' 30.849"E
KB:	46.22m A.S.L	**Ground Level:**	39.25m A.S.L.
TD:	2736m		
Seismic:	Meda Prospect i983 Survey, line H83-20, SP 177		

OBJECTIVES
Sundown 1 was drilled on the same geological trend as occurs at the Blina Oil Field - ie the fringing reef at the southwestern edge of the Lennard Shelf. In this area the trend has been structurally enhanced by northwest-trending late ?Triassic wrenching. At the drillsite locality dip closure was interpreted to be present at all stratigraphic levels. The primary objective of the well was to test structural closure of the late Devonian-early Carboniferous section (Nullara and Yellow Drum Formations); these are the oil producing units at the Blina Field (28km to the southeast). Secondary objectives were to test structural closure above this, especially sands in the Anderson-Grant-Poole interval.

RESULTS
The stratigraphy of the section penetrated in Sundown 1 down to the Tournaisian was largely as predicted in the WCR (Mah, 1983). However, Mah comments that the Grant was thinner, and the Anderson three times thicker, than anticipated. Except for the Laurel Formation the section below Anderson was not as predicted; and it was descibed as undifferentiated carbonates. Based on palynological determinations and comparisons with nearby wells the upper half of the section identified as Anderson in the WCR is here interpreted as our Y Unit sequence. Based largely on wireline log patterns and sequence information from seismic lines Home H83-20 and H83-15.2, together with information from Terrace 1 and Aquanita 1, we have subdivided the thick Devonian carbonate sequences in the well below 2000m into its component sequences. In most wells the May River Member (top of TST in Famennian 2A sequence) is clearly identifiable as a series of prominent postive deflections on the gamma ray logs. However, it is not evident in Sundown; the reason for this in unknown.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY
Hydrocarbon shows were encountered at many levels in the well between 540 m (Noonkanbah Sequence) and 2500 m (Frasnian-Famennian Sequence). Two (possibly three) oil pools were identified in the Grant Sequence at approximately 900 m, 1100 m and 1180 m; in all cases they are situated in fine-medium grained sandstone units (20-40 m thick) which are overlain and sealed by grey silty shale units (20-30 m thick). Extensive fluorescence and shows are also present in the Carboniferous clastics between 1500-1800 m and in carbonates in the Famennian 1 and Frasnian-Famennian sequences. Gas shows in the carbonates are thought to originate from fractures as the carbonates have no visible porosity. DST of fractured intervals failed to produce fluid indicating that the fractures have effectively healed. According to Goldstein (1989) oil has been recovered from 6 separate levels in the Grant through Anderson sequence in the Sundown field. Hydrocarbons were not found in the late Famennian to early Tournaisian carbonate section between 1840 - 2200 m; initially considered the primary objective of the well.

The main result of this well, therefore, was to greatly enhance the petroleum prospectivity of the Anderson to Grant sequence in the Canning Basin.

Source rocks and Oil analyses: Organic geochemical analyses of 55 samples between 818-2705 m, reported in the WCR (Mah, 1983), indicate that the shales in the Poole Sequence have good potential for generating hydrocarbons, whilst shales in Tournaisian 6 have generated hydrocarbons from moderately rich source beds; the rest of the section consists of poor quality source beds. GC-MS analyses of oil samples from the upper two oil pools in the Grant Sequence show the oils to be very mature, saturated crudes and probably from an algal source. These samples, and interestingly a sample from Meda 1, are geochemically indistinguishable. This may imply that they are all genetically related (Mah, 1983; Hoffmann, unpubl); Goldstein (1989) suggests they are sourced by the Laurel Shale (Tournaisian 6).

Reservoirs: Porosity determinations in the WCR are based on electric log values. Sandstones in the Grant to Anderson section have porosities ranging from 10-20%. The carbonate section below this is essentially tight.

REFERENCES

GOLDSTEIN, B.A., 1989 - Waxings and Wanings in Stratigraphy, Play Concepts and Prospectivity in the Canning Basin. APEA Journal 1989, p466-504.

HOFFMAN, C., (in prep) Canning Basin Geochemistry (AGSO unpublished report)

MAH, A.W.H., 1983 - Sundown 1 Well Completion Report for Home Energy Co Ltd., Perth. (unpubl.)

WELL: # TERRACE 1

PEDIN NUMBER: **W6840086**

Operator:	Home Energy Company Ltd.	**Year:**	1984
Lat:	17° 30′ 23.338"S	**Long:**	124° 15′ 15.592"E
KB:	39.4 m A.S.L	**Ground Level:**	31.75 m A.S.L.
TD:	2389 m		
Seismic:	Meda 1980 Seismic Survey Line H80-15, SP 174 Meda 1984 Seismic Survey Line H84-A, VP 470.72 Meda 1984 Seismic Survey Line H84-51.6, VP 296		

OBJECTIVES

Terrace 1 was designed to test the hydrocarbon potential of Carboniferous sandstones and Devonian carbonates. Prior to drilling sediments at the pre-Nura Nura and pre-Grant unconformities were interpreted as having four way dip closure elongated in a NW-SE direction. At the Yellow Drum and Nullara levels the structure was interpreted as having low relief four-way dip closure at the end of a northwest extension of the Blackstone High. A shallow syncline, controlled by deep-seated faulting separated the Blackstone High from the drill site. After drilling, two seismic lines were shot to intersect the well (H84-A & H84-51.6) and the 1980 line was reprocessed. This new data showed that the well was drilled on the flank of the structure and was therefore out of closure.

RESULTS

The section encountered was essentially as predicted. Famennian sequences 1 & 2 (Nullara and Gumhole Formations and May River Member)and their maximum flooding surfaces are readily recognisable from the gamma logs. Sequence subdivision of the Frasnian sediments (WCR stratigraphic nomenclature) is equivocal. Microfloral determinations suggest a late Givetian to early Frasnian age for these sediments. Seismic interpretation suggests that the interval beneath the Famennian 1 sequence boundary belongs to Frasnian sequence 4 (late Frasnian age). However, biostratigraphic data infers an early Frasnian age. Between 2218 and 2243 m the gamma log shows a similar log motif to the condensed section deposits in Frasnian sequences 1-3 (Yarrada 1 and Meda 1). This interpretation would be consistent with the biostratigraphic data, but has not been confirmed by seismic.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Geochemical and vitrinite reflectance techniques show that samples from the Grant Group to TD are organically lean (usually < 0.5% TOC). Samples from the Noonkanbah and Poole Formations have TOC values between 1.2-2.8% indicating good to very good organic richness. Coal maceral determinations suggest that the organic matter is slightly more oil-prone than gas prone.

Maturity: Tmax values of sediments from the Noonkanbah to the Laurel Formation are less than 433° indicating immature organic matter. The Frasnian sediments are considered to be just within the oil window (Tmax 436°). Vitrinite reflectance data support the Tmax determinations (between 823-2351 m Ro values are between 0.59% to 0.67%)

Reservoirs: Pyrolosis data from samples at 930 m (Grant) and 1857 m (Tournaisian 1) indicates the presence of accumulated hydrocarbons. A DST over the interval 930-934 m recovered 6 kl of formation water and the oil is considered as being residual. A DST over the interval 1837-1868 (Tournaisian sequence 1) recovered 300 litres of 38° API oil and 900 litres of formation water. The oil bearing zone in the Laurel Formation has average water saturation of 43% and an average porosity of 14%.

REFERENCES

Mah, A.W.H., 1984 - Terrace 1 Well Completion Report, Home Energy Company Ltd., Perth (unpublished).

WELL: **YARRADA 1**

PEDIN NUMBER: **W6810051**

Operator:	Home Oil Australia Limited	**Year:**	1981
Lat:	17° 21′ 59.53"S	**Long:**	124° 06′ 09.03"E
KB:	26.7 m A.S.L	**Ground Level:**	21.2 m A.S.L.
TD:	3295.5 m		
Seismic:	Blackstone 1979 Survey Line H79-15, SP 168.5 Meda 1985 Survey Line H85-7.5, VP 207		

OBJECTIVES

Yarrada 1 was proposed as a 3300 m test of Carboniferous and Upper Devonian facies. A seismically defined Famennian reef comprised the primary objective and the well was located on the apex (platform margin) of the Famennian platform. Sandstones of the Laurel Formation were regarded as a secondary objective.

RESULTS

Both of the targets were intersected. An interval of conglomerate and dolomite underlies a thick Famennian reef sequence. Close similarities in the gamma and deep-resistivity well logs between Meda 1 and Yarrada 1, particularly in the Frasnian part of the succession, enable the interval of conglomerate and dolomite to be differentiated. Yarrada was sited at the platform margin of the Famennian 2B highstand within a structurally complex zone associated with the Pinnacle Fault. Difficulties associated with structural interpretations of the Pinnacle Fault and seismic data quality inhibit an accurate seismic-well tie for Yarrada 1. In consequence emphasis is placed on the well-well correlation.

The caliper log displays a prominent wash-out between 2275-2290 m. This equates with the May River Member, ie the condensed section for Famennian sequence 2A. The R. lepidophyta microfossil assemblage (which is characteristic of the May River Member) reported in the side wall core 300m lower down in the hole (at 2586.1 m), is here interpreted as contamination.
Reef facies in Famennian sequence 2B represent the youngest reef intersected in the study area. In other Home Energy wells the top of the Windjana Limestone (reef facies) coincides with the top of Famennian sequence 1. A marked change in the dipmeter log from a random "bag of nails" motif (2030-2235 m) to uniform southwest dips of 2-6 degrees (1980-2030 m) suggests that the carbonates in this upper interval are probably platform carbonates rather than reef facies. The shift in the wireline logs at 1972.7 m is thought to be due to a casing shoe, and not a lithological change. The basinward shift in facies from marginal-slope deposits to reef deposits at the Famennian 2B sequence boundary results in an abrupt shift in the gamma log and a change in the dipmeter log from uniform dips to the southwest at 20-30° to a random "bag of nails" motif.

IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Source Rocks: Geochemical analyses suggest poor to moderate source potential in the Tournaisian and poor source potential in the condensed section of Famennian sequence 2A (May River member).
Maturity: Samples from the Grant Group and Anderson Formation are marginally mature (1156 m & 1570 m), those from Tournaisian sequences 1, 2 & 6 are moderately mature, the sample from the condensed section of Famennian sequence 2A has a moderately high level of maturity. The organic matter is derived from mixed terrestrial and marine sources.
Reservoirs: Sands in the Liveringa, Poole and Grant Formations display good reservoir quality and are all water saturated. Silty sands in Tournaisian sequence 6 and carbonates in the Famennian and Frasnian succession are tight and have poor porosity.

REFERENCES

TOWNSEND, B.A., 1981 - Yarrada 1 well completion report, Home Energy Company Ltd., Perth (unpublished).