AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

APIRA

AUSTRALIAN PETROLEUM SYSTEMS

Roebuck and Offshore Canning Basins - Beagle Sub-basin Module

Volume 1

by

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EXECUTIVE SUMMARY

Three of the six petroleum supersystems that are recognised in the Australian Phanerozoic occur in the module area -- the Westralian, Gondwanan and Larapintine Petroleum Supersystems. All the significant hydrocarbon discoveries are within the Mesozoic Westralian Supersystem. The oil at Nebo 1 and gas in the Phoenix wells shows that at least one viable petroleum system is present. Good shows up into the Cainozoic occur in Picard 1 whilst the best shows are found in the Westralian 1 section in all wells. Some hydrocarbon shows occur within the Gondwanan Supersystem (on the Pender Terrace) and some petroleum potential can be speculated about in the Larapintine interval as it is a proven source in the adjacent onshore Canning Basin.

In contrast to other areas, to the north and south in the Barrow Dampier Sub-basins and the Timor Sea, in the Beagle Sub-basin the Late Jurassic source rock section is thin, with the exception of the west Cossigny Trough. It is also probably immature over most of the area but, again in the west Cossigny Trough, may just enter the oil window. In the Beagle Sub-basin the source is in the pre-Argoland breakup sequence of the Late Triassic and or Early Jurassic fluvio-deltaics (**Westralian 1**). It has been established from previous work that the delta front slope sequences are the best source facies in the fluvio-deltaic sequences and perhaps some of the coaly sequences are sources as well. These are the source rocks for the gas condensate of the Rankin Trend. There is no obvious major palaeoenvironmental differences between the Westralian 1 of the southern module area and that of the Rankin Trend, so it is concluded that this is the dominant source of the area.

Tectonism in the Late Triassic (Fitzroy Movement), produced an interpreted palaeogeography of restricted coastal-marine troughs bordered by emergent highland areas, ideal for the deposition of source rocks. These troughs may provide an additional source kitchen not previously recognised.

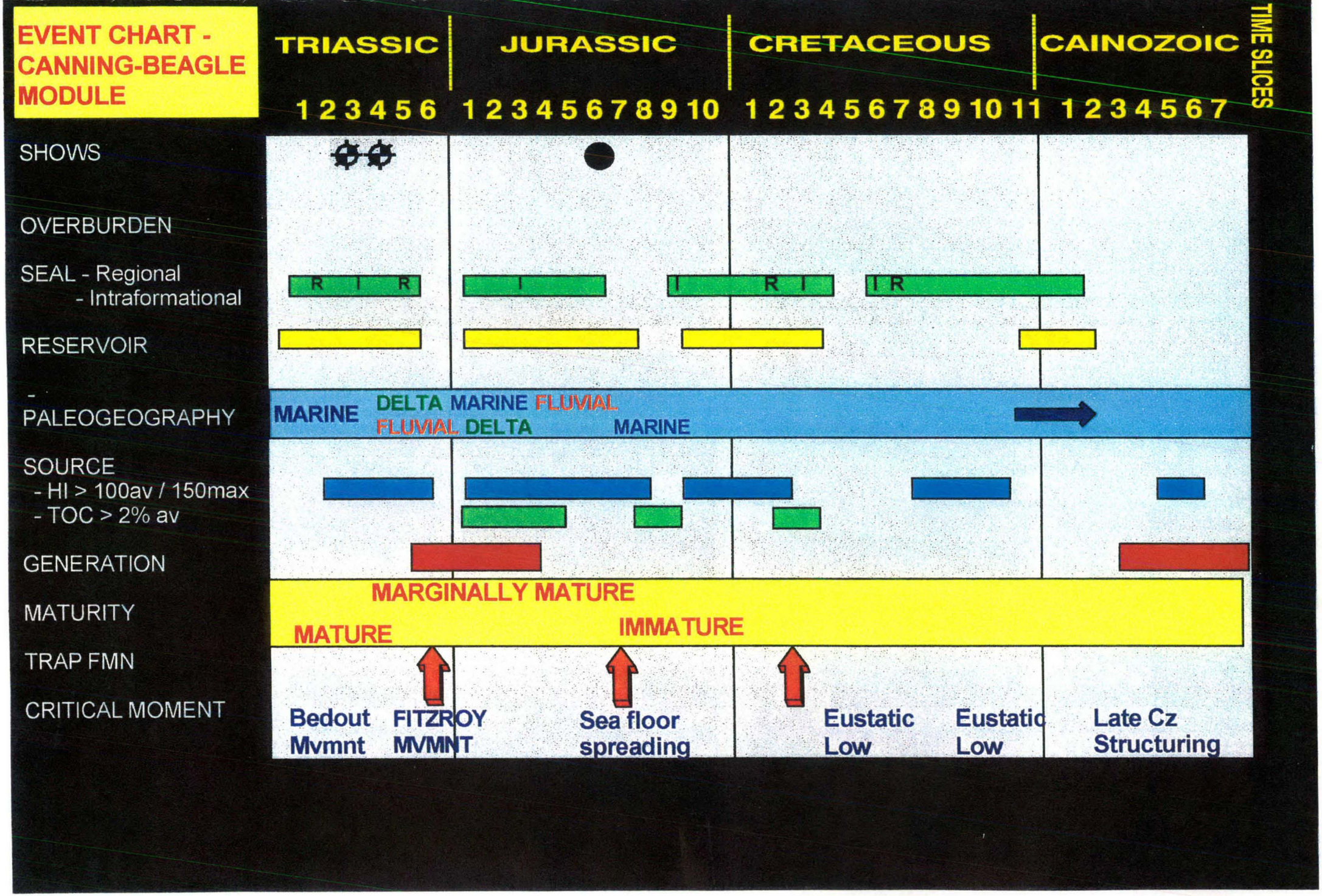
In addition to the top Triassic and top Jurassic conventional plays, other more stratigraphically controlled plays have been recognised. Regionally, time slices K1 and K2, and in part time slice K3, are highly prospective especially in the west Bedout Sub-basin and east Beagle Trough. These time slices have good reservoir quality sands enclosed in the first post Westralian 1 regional seal facies, and are overlain by the regional seal facies of time slice K3. However, drilling appears to have been focussed on the structural culmination of tilted Jurassic horst blocks. Structural traps at the lower Cretaceous may not have been tested adequately as structural closure is not vertically coincident. Palaeodepositional environments interpreted for time slices K1 and K2 sands include: incised valley fills, channels in a coastal estuarine system and upper shoreface sands. These reservoirs would need to be sourced from the **Westralian 1** source rocks of either the Beagle Trough, and/or from the southwest part of the Inner Rowley Sub-basin.

Vertical migration paths are needed for mature source to charge younger reservoirs in all areas. There is a distinct reduction of faulting intensity from the west to the east within the Beagle and Rowley Sub-basins. The higher intensity fault areas (Argoland and Greater India breakup age) in the western and middle Beagle Sub-basin could provide conduits for hydrocarbons to migrate past the Upper Jurassic and Lower Cretaceous reservoir horizons. As an example Picard 1, a valid closure, recorded shows all the way up to the Cainozoic but did not reservoir any hydrocarbons. This is interpreted to imply seal breaching by the faults that also acted as migration pathways. The lower intensity fault areas (in places no faulting at all) in the Bedout Sub-basin do not provide migration pathways into the Upper Jurassic-Lower Cretaceous reservoirs. Because of this fault distribution, the east Beagle and west Bedout Sub-basins and outer northwest Bedout High are believed to be the best location for this time slice K1-K3 play. Here the faults extend approximately up to the top of the lower Cretaceous providing a migration path into time slice K1, K2 or K3 reservoirs.

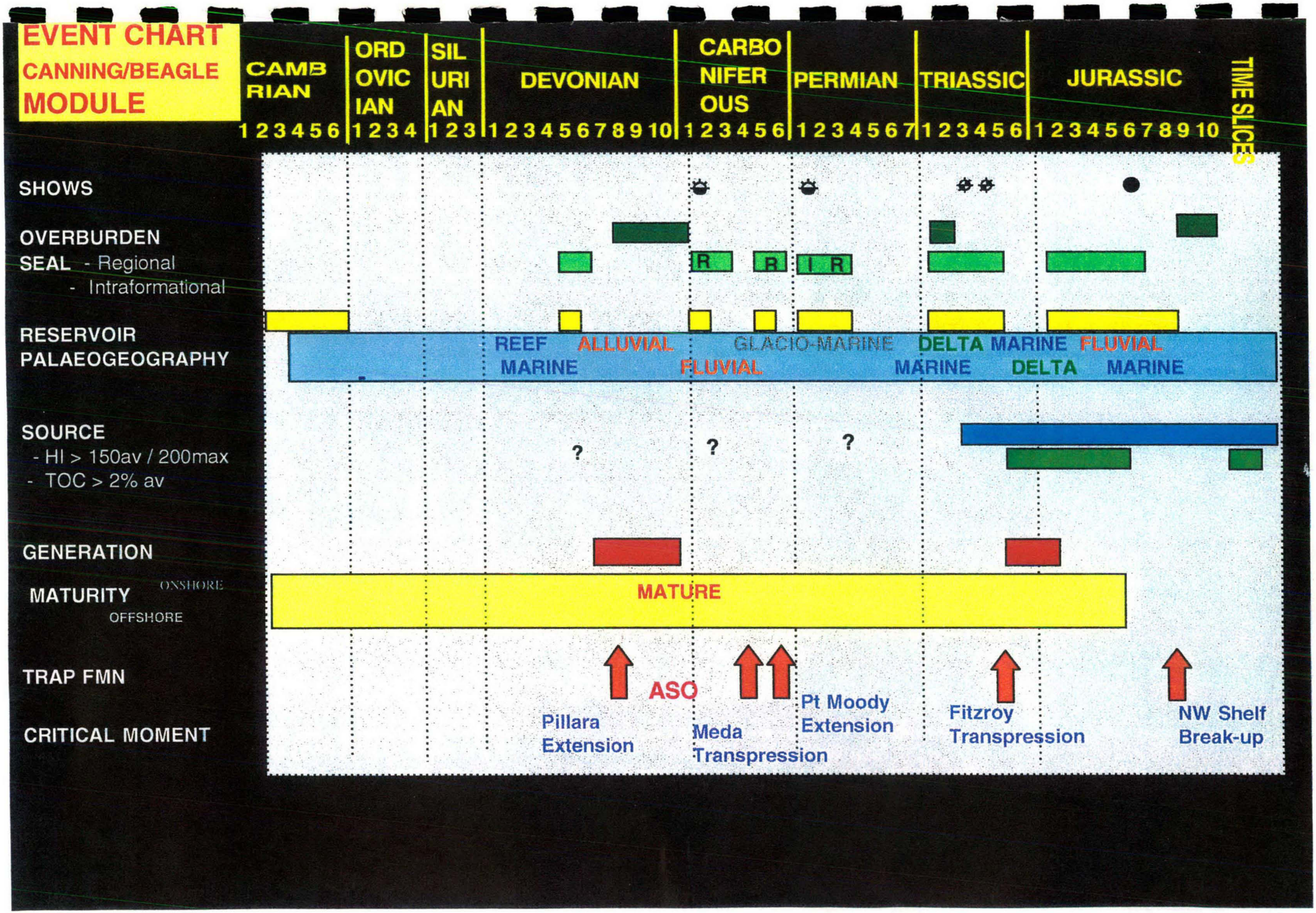
The lower Cainozoic reservoirs have a higher chance of accumulating hydrocarbons in the west Beagle Sub-basin where the faults extend up into the lower Cainozoic. In this area the Cretaceous is a poorer reservoir facies and as a result the first potential reservoirs are in the lower Cainozoic.

Migration needs to have occurred post time slice K3, and tectonic movements at time slices K8 to K9, and in the Oligocene and Miocene provide an opportunity for this to occur. Any intertidal to supratidal fringes found around offshore landmasses during time slices J9 - K3 are likely to be reworked coarse clastics and provide a untested stratigraphic target. Geochemical analyses carried out by AGSO have demonstrated the potential for better quality gas or light oil prone source rocks within the Mid Jurassic in the Rowley Sub-basin. The older Petroleum Systems, although mature, are perceived as higher risk than Westralian 1 simply because it is difficult to clarify migration and trap forming event relationships at this time.

EVENT CHART - CANNING-BEAGLE MODULE



EVENT CHART
CANNING/BEAGLE MODULE



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INTRODUCTION

PURPOSE

The project aim is to apply the time slice palaeogeographic concept to the module area. The time slice concept was developed in, and is based on the work of the BMR-APIRA Palaeogeographic Maps and Phanerozoic History Projects. For each time slice defined palaeogeographic interpretation, the project has examined the controls on source, seal, reservoir distribution, structural and potential maturation history. The analysis is based on information from 21 wells and examination of approximately 6200km of seismic line data. Results are presented as time slice data maps, palaeogeographic interpretation maps, regional well log cross sections, seismic structure and isochron contour maps and summary tabulations in addition to this report.

ACKNOWLEDGMENTS

In the preparation of this report and the accompanying Enclosures, significant time and effort was contributed by members of the Australian Petroleum Systems Group and others within AGSO. Without their help, the project would have been less extensive.

Jacques Sayers and Lynton Spencer are the senior authors of this report and were mainly responsible for the geophysical and geological interpretation respectively. In conjunction with other members of the Group, the senior authors have been involved in most of the other aspects of the study.

John Bradshaw is the manager and coordinator of the Australian Petroleum Systems Group. He was responsible for the organisation of geological and geophysical information for the project study and producing various output from the STRATDAT, RESFACS and ORGCHEM databases for analysis. Based on his experience in the previous Projects, John has provided valuable technical information and assistance to the Stage III Project.

Marita Bradshaw, based on her experience in the previous Palaeogeographic Map Projects, synthesised the results of the Beagle & offshore Canning Sub-basin analysis into a petroleum system framework. She also provided valuable technical information and editing assistance.

Clinton Foster was involved with the organisation of the STRATDAT database and contributed towards the analysis of the biostratigraphic data that was synthesised by consultant Alan Partridge.

Jane Blevin provided assistance with the interpretation of the Beagle Sub-basin.

Technical support was provided by Irena Borissova, Cameron Buchanan, Scott Edgecombe, John Vizy, Terry Brown and Giuliana Zuccaro. This included data collation and the writing of software programs to generating the various products.

Others who provided technical and scientific assistance include: Chris Johnston who granted permission for the use of AGSO seismic lines; Howard Stagg and Jim Colwell who gave an overview of the deep regional structural framework of the Beagle and offshore Canning Sub-basin based on AGSO deep seismic lines. Andrew Murray, Dianne Edwards and Ian Atkinson provided assistance with geochemical interpretation of the data.

MODULE AREA AND BASIN DEFINITION

Geographically the module is defined as the area between 15°45'S:116°30'E and 20°00'S:123°00'E. This area allows for an overlap with the previously completed modules of the Dampier Sub-basin, to the south and the Browse Basin, to the north. The study area for new wells is limited to 16°00'S:116°30'E and 19°24'S:123°00'E.

Geologically the module area covers the northern extremity of the Carnarvon, all of the Roebuck, the offshore extension of the Canning and the southern end of the Browse Basins on Australia's North West Shelf. Within these basins are the Beagle, Rowley and Bedout Sub-basins and the offshore Fitzroy Trough (Hocking et al 1994 p36).

The location of the module area, the cross-section locations and the location of the adjacent earlier Dampier Sub-basin and Browse Basin modules is shown on Figure 1.

DAMPIER SUB-BASIN & BROWSE BASIN MODULES OVERLAP

The well Cossigny 1 is a common control point between the current module and the earlier Dampier Sub-basin whilst Lynher 1 is a common control point with the Browse Basin module. These two wells are additional to the twenty one wells interpreted in this study and for the most part are not referred to in the text. For a discussion of these wells see the appropriate module report. The overlap aided in combining the

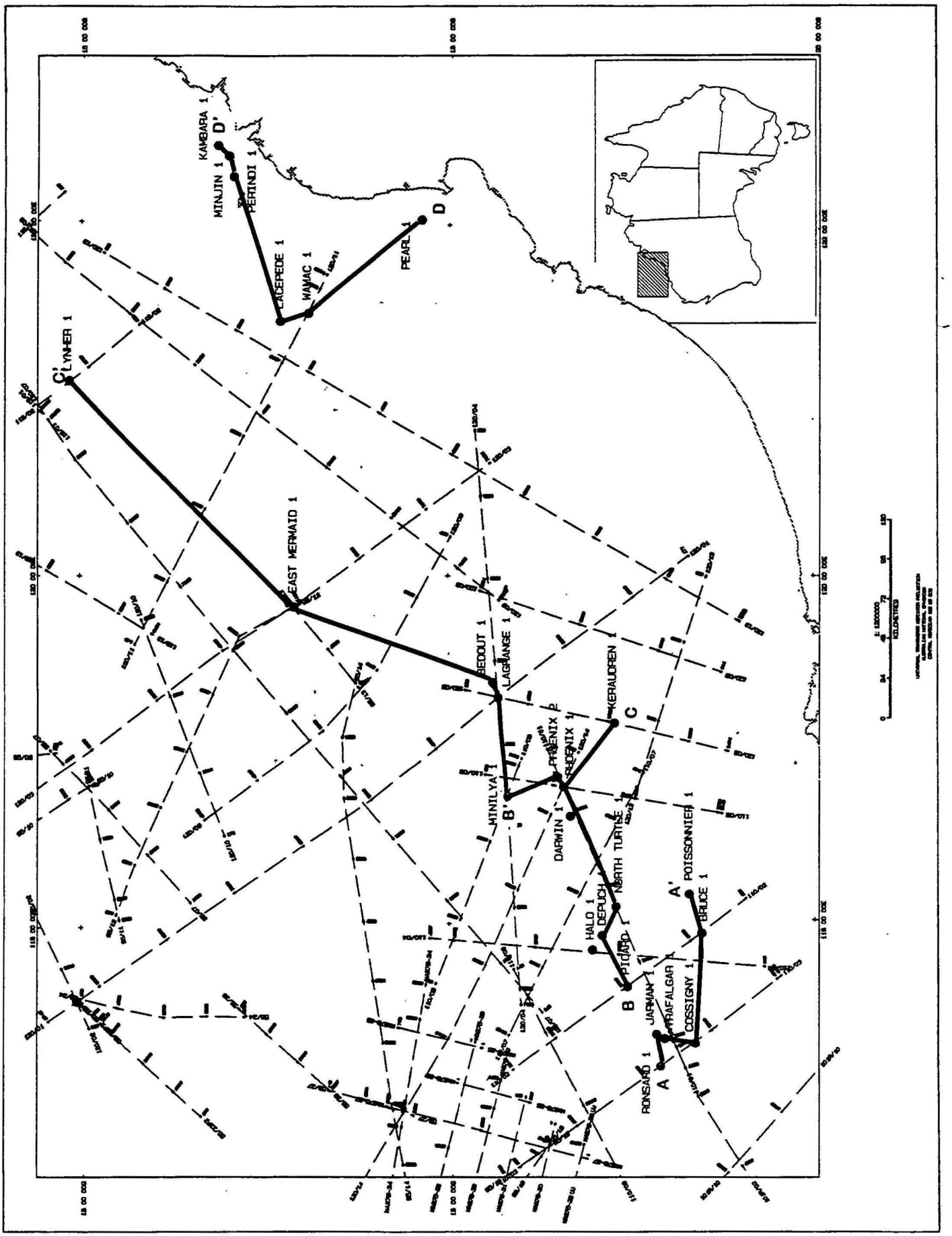


FIGURE 1: MODULE AND CROSS-SECTIONS LOCATION DIAGRAM.

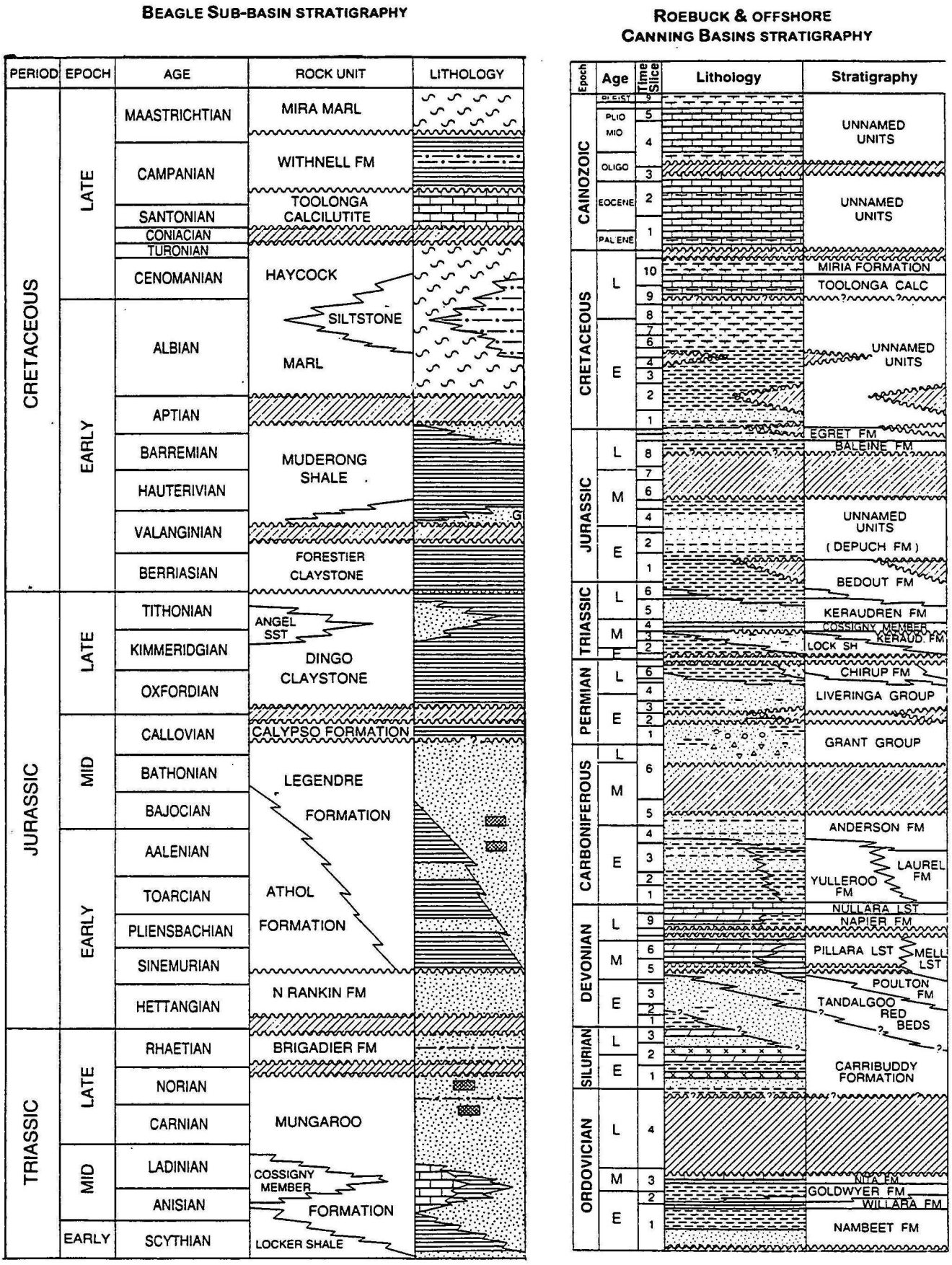


FIGURE 2: SUMMARY STRATIGRAPHIC DIAGRAM FOR THE BEAGLE SUB-BASIN, ROEBUCK AND OFFSHORE CANNING BASINS. BEAGLE SUB-BASIN STRATIGRAPHY IS AFTER BLEVIN ET AL (1994) WHILST ROEBUCK AND OFFSHORE CANNING BASINS STRATIGRAPHY IS AFTER COLWELL & STAGG (1994).

palaeoenvironmental interpretations of the Dampier Sub-basin and Browse Basin modules with the interpretations for the current Roebuck and Offshore Canning Basins - Beagle Sub-basin module. To facilitate a comparison between the Dampier Sub-basin and the current moduie a brief summary of the Dampier Sub-basin module results is occasionally included within the time slice sections of this report.

WELL LOG CROSS-SECTIONS AT 1:7500 SCALE

The cross-section set is generated at a scale of 1:7500 (see Enclosures 4 to 7). Practical limitations on plotter paper width and plot scale meant that it was difficult to provide full well depth cross-sections at the same vertical scale as those created for the Dampier Sub-basin module.

NOTES ON TIME SLICE DEFINITION AND BOUNDARIES

The biostratigraphic schemes used in this study are the:

- Integrated dinoflagellate and spore-pollen zonation of the Australian Mesozoic developed by Helby et al (1987).
- Foraminiferal zonations for the North West Shelf (Wright, 1977; Heath & Apthorpe,1981,1984; Apthorpe, 1988).
- Foraminiferal zonations for the Tertiary (Blow, 1969, 1979; Berggren, 1969; Kennett & Srinivasan, 1983).
- Australian Phanerozoic Timescales Volume 1 - 10 (Shergold, 1989; Webby & Nicoll, 1989; Strusz, 1989; Young, 1989; Jones, 1989; Archibold & Dickens, 1989; Balme, 1989; Burger, 1989a; Burger, 1989b; Truswell et al, 1989).

These schemes are referenced to the Harland 1982 Time Scale (Harland et al, 1982).

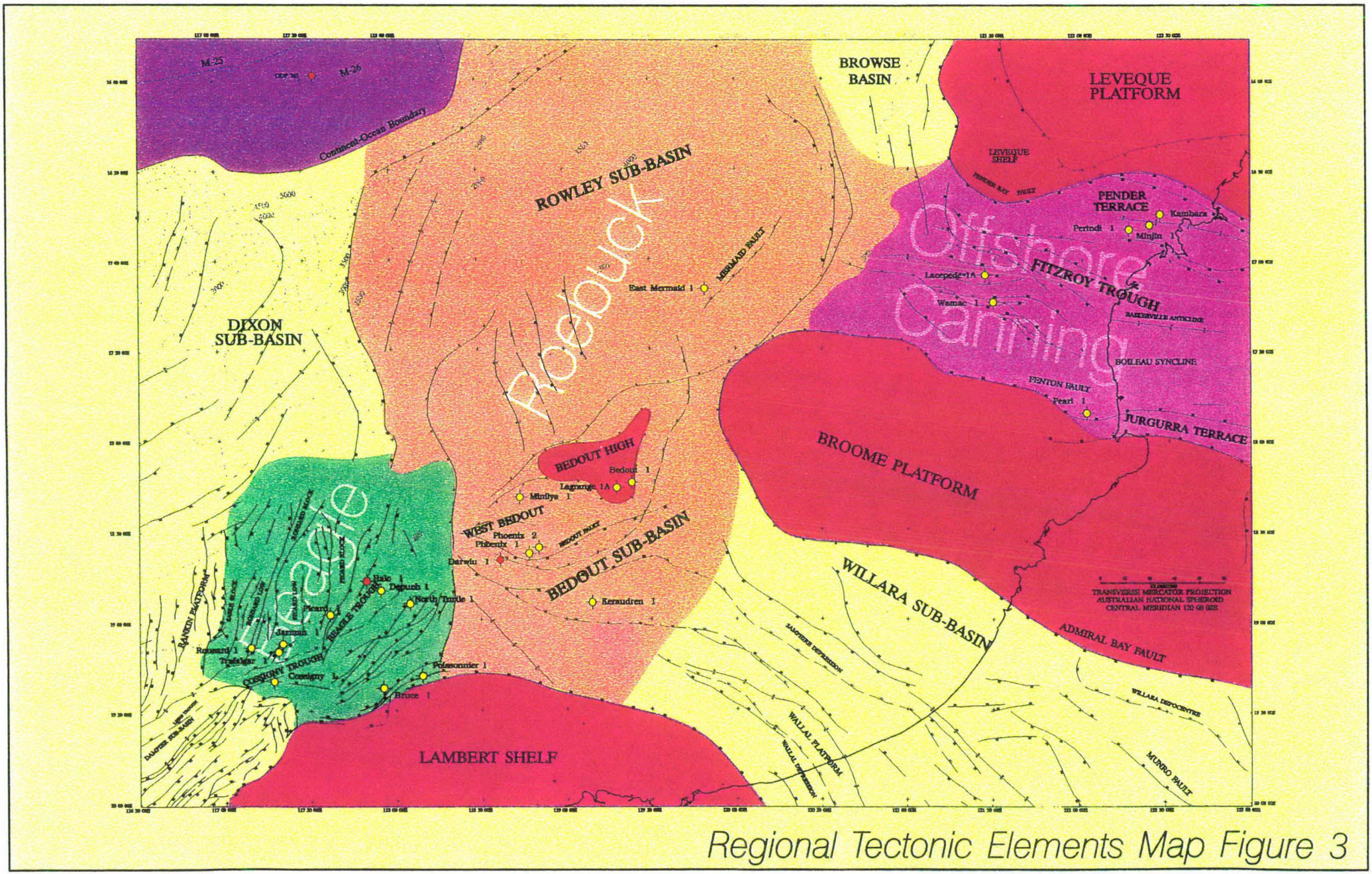
The time slice boundaries occur at natural breaks in sedimentation or changes in facies that are common to several basins. Some time slices are representative of geological events that have continent wide effects. However, there are difficulties in selecting time slices that are applicable across Australia, due to contrasting depositional and tectonic regimes, as well as differences in biostratigraphy such as the spore-pollen zonation in Eastern Australia and the dinoflagellate zonation in western Australia. The precise correlation, duration and absolute ages of the time slices were derived from lengthy consultation with many biostratigraphers, industry sponsors and the State Geological Surveys. The time slices are the basis of the products in both the Palaeogeographic Maps Project and the Phanerozoic History of Australia project. Thus the details presented in this study can immediately be related to more regional concepts and to maps already produced.

Time slices interpreted in the Roebuck and Offshore Canning Basins - Beagle Sub-basin module range from the Devonian to the Tertiary. Of the time slices defined within these periods, palaeogeographic data and interpretation maps were made for grouped time slice intervals D5-D10, P1-P3, TR1-TR4, J3-J6, J9-J10, K5-K7. Time slice intervals TR1-TR4, J3-J6, J9-J10 and K5-K7 are consistent with the data sets from the previous Dampier Sub-basin module. No data and interpretation maps were made for time slices D1-D4, CRB1, CRB3-6, P4-P7 and time slices younger than CZ2 due to lack of data or poor data control. Individual palaeogeography interpretation maps were made for time slicesTR1-TR6, J1-J5, J8, K1-K4, K8-K11, CZ1 and CZ2.

The selection criteria for these time slices are discussed in the following sections. They are derived from Bradshaw & Yeung (1988) and Bradshaw et al (1994). Enclosure 3 summarises the spore-pollen, dinoflagellate and foraminiferal zones and related time slice boundaries. In this report the time slice definitions have been included with the appropriate time slice section. In addition to time slices, a summary stratigraphic diagram is represented in Figure 2.

NOTES ON HARLAND AGES APPLIED TO THE CAINOZOIC IN THIS MODULE

In Stage I of this project the Cretaceous used the Harland (1982) time scale with the K/T boundary at 65.0 MA while the Tertiary used Berggren (1969) with a K/T boundary at 66.4 MA. This inconsistency was explained in the notes. In Stage II the project opted for a mixed time scale, Harland (1982) for the pre-Tertiary and Berggren (1969) for the Tertiary. The change was at the K/T boundary taken at 66.4 MA so that the Harland defined Maastrichtian was shortened. The development of STRATDAT, where Time Scales can be selected from a list, necessitated the development of a strict Harland (1982) based time scale that was applicable to the North West Shelf. The specific palaeontology used to define the Tertiary time slices is outlined in the Barrow Exmouth Module Report (Spencer et al 1994).



Regional Tectonic Elements Map Figure 3

NOTES ON PALAEONTOLOGY CODES

Reference will be made to the confidence rating of palynological data in the form of short hand terminology that includes a lettered first character and a numeral second character where: A (core), B (sidewall core),C (coal cuttings), D (ditch cuttings), E (junk basket), F (miscellaneous or unknown), G (outcrop), H (horizon) and the second character descriptions are :

1 Excellent, high diversity assemblage with key zone species,

2 Good, moderate diversity assemblage with key zone species,

3 Fair, low diversity assemblage with key zone species,

4 Poor, mod.-high diversity assemblage without key zone species,

5 Very low, low diversity assemblage without key zone species,

6-9 lower, unreliable.

NOTES ON LITHOLOGY

The lithology descriptions for each time slice include both reference to the type of rock encountered, as described in the mudlogs or composite logs, as well as the gamma ray log signature. Gamma Ray log patterns are described as bell shaped (equivalent in most cases to a fining upward sequence), cylinder shaped (equivalent to blocky or representative in most cases to a channel) or funnel shaped (equivalent in most cases to a coarsening upward sequence). Each of these (bell, cylinder, funnel) signature patterns may be smooth in appearance implying a more uniform sequence or they may have varying degrees of serration implying interbedded or intercalated stratigraphy. This terminology has been used in contrast to more sedimentological terms such as fining or coarsening upwards. The reasons are many and include the following:

- to save time in describing the lithology,
- to apply the same descriptive terminology to both clastic and non clastic geology. Some of the Pre-Triassic rocks, time slice TR3 and most of the post Lower Cretaceous rocks are none clastic,
- a higher emphasis was placed on gamma ray log patterns to interpret palaeo-environments as opposed to mudlogger descriptions of coarsening and fining upward trends in the drill cuttings that are not always accurate,
- to remove the assumption that a bell shaped curve immediately implies a fining upward sedimentological pattern and that a funnel shaped curve implies a coarsening upward sedimentological pattern, and
- to allow the reader to get a visual representation of the geology and to appreciate the range of lithology's possible using the Gamma Ray log signature patterns that removes the bias of a purely sedimentological and potentially inaccurate description.

NOTES ON PALAEOGEOGRAPHY

Seismic amplitude strength and continuity of reflectors has been used throughout the palaeogeographic maps of the Triassic and the Jurassic to define likely coal and shale prone areas based on higher acoustic impedance variations. The coal areas may be more representative of a backswamp environment whilst the shale areas may reflect a lacustrine landform. As a result a number of lacustrine or backswamp environments are shown, and these may indicate more source prone areas. Realistically, higher amplitude strength if used for establishing environments is best thought of as reflecting a lower sand to shale plus coal ratio, rather than as positively identifying good source prone areas. Nevertheless this technique was used in the palaeogeographic interpretations for time slices TR1 to TR6 and J1 to J6; taking particular care with time slices TR3 to TR4 due to the known presence of carbonates and the possible mis-interpretation of large acoustic impedance variations from this lithology.

NOTES ON TECTONIC HISTORY

In this report the relevant regional and local tectonic events have been described within the section for the appropriate Time slice. Seismic interpretation of the Roebuck and Offshore Canning Basins - Beagle Sub-basin establishes that the area contains a number of basement provinces (Enclosure 1, Figure 3). These include from east to west the:

- **stable Kimberley Block** that includes the Leveque Shelf and the Pender Terrace. The extent of the Kimberley Block offshore is uncertain,

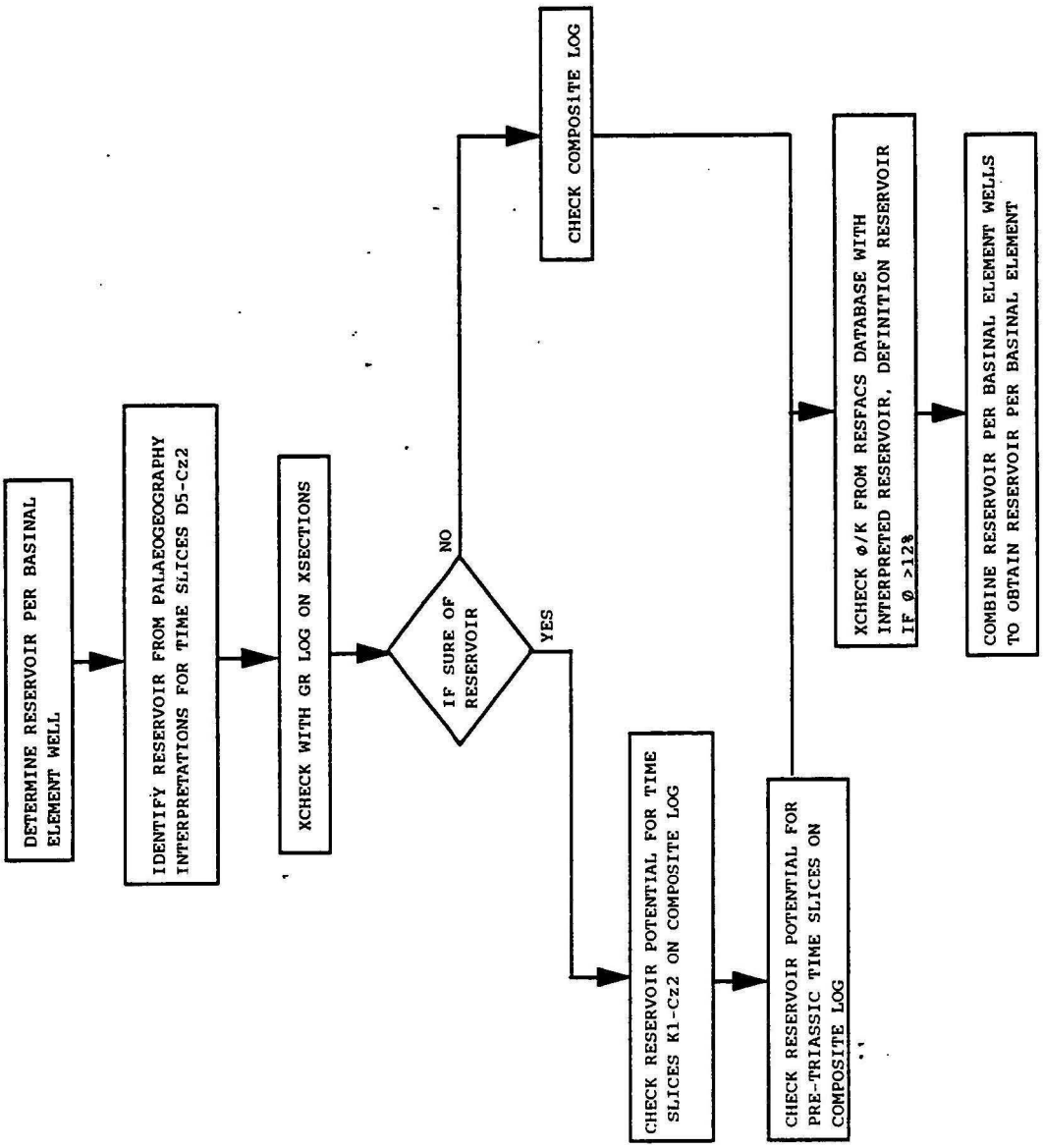


Figure 4: Flowchart for reservoir determination, used in Enclosure 3.

NOTE: The GR log does not necessarily reflect lithology so reservoir potential has to be checked on the composite log.

- **Offshore Fitzroy Trough** with Carboniferous to Ordovician rocks (inversion structures, horsts and grabens, tight synclines and anticlines, substantial uplift and erosion present),
- stable **Broome pre-Cambrian and Palaeozoic Platform** that includes also the Jurgurra Terrace,
- **Inner Rowley Sub-basin** that is characterised by reduced a Argoland breakup (Late Jurassic) faulting intensity as well as syn-depositional sediments of Carboniferous-Permian age creating large wedges below the basal Triassic. This is a transitional area between the Fitzroy Trough basement and the Outer Rowley Sub-basin basement provinces. The basement province is bounded to the northeast by a potential transfer fault separating it from the Browse Basin and bounded arbitrarily to the southwest by the Swan Canyon,
- **Outer Rowley Sub-basin area**. The Mesozoic sequence in this area appears to be less affected by the Argoland breakup faulting than areas to the west. This is interpreted to be due to a different basement rheology and consequent different tectonic response to the pull apart regime,
- **Bedout High** that is interpreted as a Palaeozoic age feature later intruded by igneous bodies of late Permian-earliest Triassic age,
- **Bedout Sub-basin** that is characterised by low density faulting (Argoland to Greater India breakup age) and a dish shape style of Mesozoic sediment fill. It is bounded to the north by the Bedout High, to the west by basement hinge zones. The Broome Platform bounds the Bedout Sub-basin basement to the east although the boundary appears more progradational on the southern side of the Broome Platform. The area is probably delineated to the east by a Palaeozoic ridge, that also includes inversion structures and that may act as the main ridge axis dividing the Roebuck and Offshore Canning Basins,
- stable **Pilbara pre-Cambrian craton** that includes the Lambert Shelf, its extent offshore being problematic,
- **Beagle Sub-basin** with extensive and intense Argoland and Greater India breakup faulting induced on it. The basement province includes the western part of the Rowley Sub-basin (west of the Argo transfer zone), Dixon Sub-basin and Beagle Sub-basin (Beagle and Cossigny Troughs, Picard, Ronsard, Sable blocks, Outer Beagle Platform, North Turtle Wrench Zone). Structural styles include aged normal and wrench style faulting, rotated fault blocks, horsts and grabens, tight synclines and anticlines, and
- **oceanic crust** north of the COB that is interpreted to be offset by the Argo transform fault,

Within these larger basement provinces are defined basinal element areas. Basinal element areas include wells that lie geographically within a similar setting, and or have similar basinal and hydrocarbon evolutionary schemes. The basinal elements are useful for summarising the interpretations and will be referred to often in this report. The basinal elements are:

- the Cossigny Trough (Ronsard 1, Trafalgar 1, Jarman 1),
- the Beagle Trough (Picard 1, Depuch 1, North Turtle 1, Bruce 1, Poissonnier 1),
- the west Bedout Sub-basin (Minilya 1, Phoenix 1 and 2),
- the Bedout Sub-basin (Keraudren 1),
- the Bedout High (Bedout 1, Lagrange 1),
- the Rowley Sub-basin (East Mermaid 1),
- the Jurgurra Terrace (Pearl 1),
- the Offshore Fitzroy Trough (Lacepede 1A, Wamac1), and
- the Pender Terrace (Kambara 1, Minjin 1, Perindi 1).

The basinal elements are used in Enclosure 3 where the prospectivity elements (source, reservoir and seal) are summarised for each. The selection criteria for source rock is that Rock-Eval gives HI > 150, TOC > 1.0% or 100 < HI < 150, TOC > 0.5% with S2 > 5. These are the best source rocks and are summarised in Appendix 5, part 2. The selection criteria used to define reservoir and seal is shown in Figures 4 and 5 respectively.

EXPLORATION HISTORY OF STUDY WELLS

The Roebuck and Offshore Canning Basins - Beagle Sub-basin have a drilling history that dates back to 1971 and includes recent wells such as Nebo 1 and Cimba 1 (Beagle Trough, 1993), Halo 1 (Beagle Trough, 1995) and Darwin 1 (west Bedout Sub-basin, 1995). These recent wells have not been included in this module due to the two year confidentiality status of newly drilled wells. Table 1 summarises the basic data for the wells used in this study. Papers reviewed that address the exploration and geology of the module area include: AGSO (1994), Baillie et al (1994), BMR Palaeogeography Group (1990a), BMR (1981), Blevin et al (1993), Bradshaw et al (1988, 1993), Buffler (1994), BMR (1990), Burger (1994),

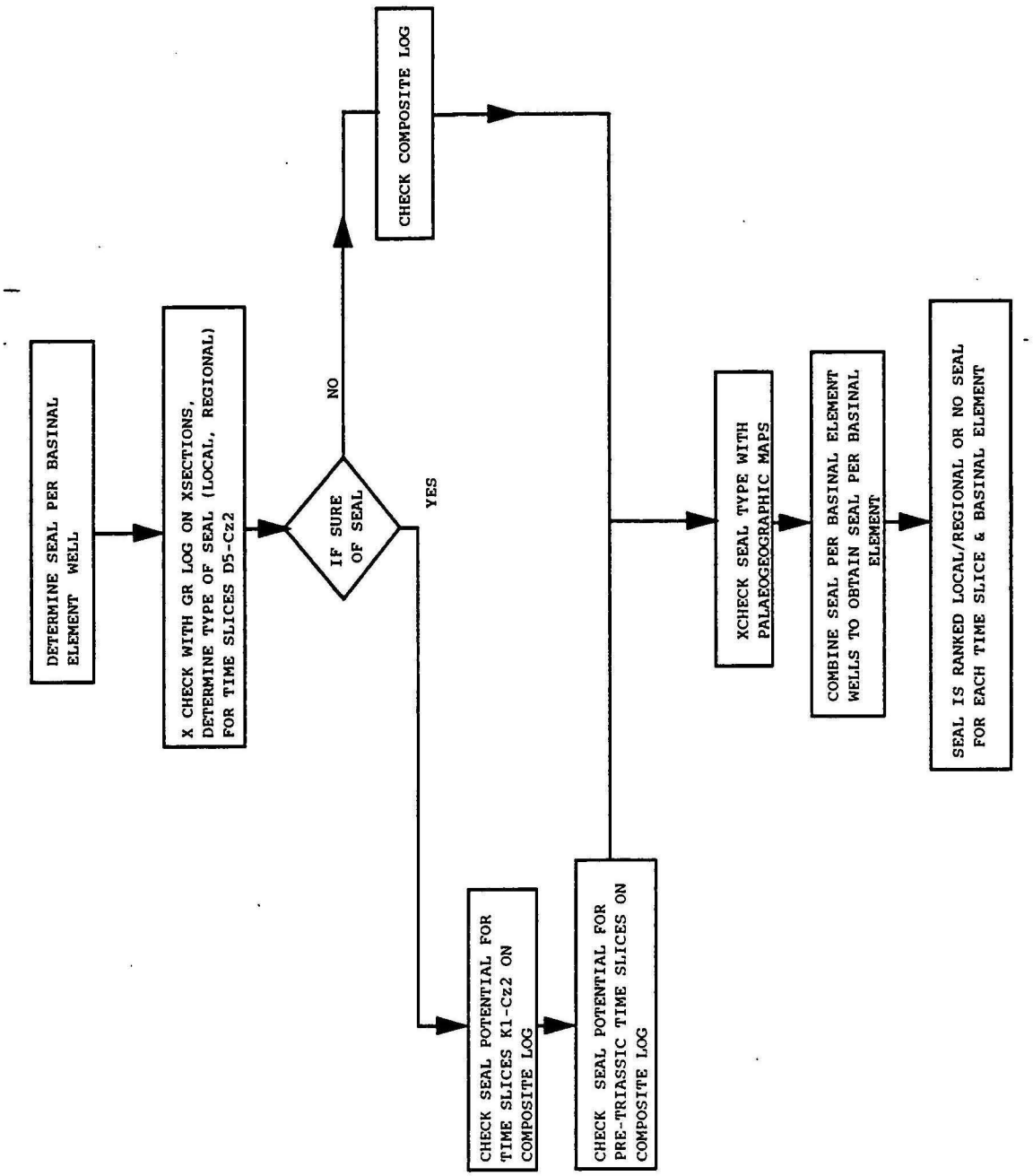


Figure 5: Flowchart for seal determination, used in Enclosure 3.

NOTE: The GR log does not necessarily reflect lithology so seal potential has to be checked on the composite log.

Campbell (1994), Chapri (1993), Colwell et al (1994), Colwell & Stagg (1994), Exon (1994a & b), Grant-Mackie (1994), Kaminski et al (1992), Kennard et al (1994), Lehmann (1984), Lipski (1993), Ramsay & Exon (1994), Reckmann & Mebberson (1984), Sager et al (1992), Shafik (1994), Stagg & Colwell (1994), Stanley (1994), Towner & Gibson (1983), Von Rad & Thurow (1992) and Wales & Forman (1981).

TABLE 1: WELLS USED IN STUDY

WELLNAME	OPERATOR	STATUS AT TD DATE	TD (mKB)	TD DATE
BEDOUT 1	BOCAL	NO SHOWS, P & A	3073	1971
BRUCE 1	STIRLING PET.	SHOWS, P & A	2169	1979
DEPUCH 1	WOODSIDE/BOCAL	SHOWS, P & A	4300	1974
EAST MERMAID 1	SHELL	NO SHOWS, P & A	4068.6	1973
JARMAN 1	WOODSIDE	SHOW, P & A	2906	1978
KAMBARA 1	ESSO	SHOW, P & A	3150	1982
KERAUDREN 1	HEMATITE PET.	NO SHOWS, P & A	3844	1973
LACEPEDE 1A	BOCAL	SHOW, P & A	2286	1970
LAGRANGE 1	BP	NO SHOWS, P & A	3260	1982
MINILYA 1	WOODSIDE/BOCAL	NO SHOWS, P & A	2400	1974
MINJIN 1	ESSO	NO SHOWS, P & A	1850	1984
NORTH TURTLE 1	BP	SHOWS, P & A	4420	1982
PEARL 1	HOME ENERGY	NO SHOWS, P & A	2203	1983
PERINDI 1	ESSO	NO SHOWS, P & A	1867	1983
PHOENIX 1	BP	SHOWS, P & A	4880	1980
PHOENIX 2	BP	SHOWS, P & A	4970	1982
PICARD 1	BOCAL	SHOWS, P & A	4216	1972
POISSONNIER 1	WOODSIDE/BOCAL	SHOWS, P & A	1962	1974
RONSARD 1	BOCAL	NO SHOWS, P & A	2848	1973
TRAFALGAR 1	AMPOL	NO SHOWS, P & A	2747	1988
WAMAC 1	AMAX PETROLEUM	NO SHOWS, P & A	2764	1973

List of Operators

BOCAL	Burmah Oil Co of Australia Ltd
BP	British Petroleum Development Australia Pty Ltd
ESSO	Esso Exploration and Production Australia Ltd
HEMATITE PET	Ex BHP subsidiary

PALAEOGEOGRAPHIC INTERPRETATION

METHODOLOGY

Biostratigraphic data from Well Completion Reports and published information were reviewed by consultant biostratigrapher Alan Partridge. His report is enclosed in Appendix 2. Interpretations of the ages of palynological and palaeontological assemblages were conducted for the module wells and loaded into the STRATDAT database. Age-depth plots were constructed to provide quick-look interpretations of apparent changes in the rate of sedimentation, presence of condensed sections, unconformities, and fault intersections at well locations. This was done by plotting the occurrences of species zones against ages, with associated codes representing highest or lowest known occurrences and youngest or maximum age determinations. An example of an interpreted age-depth plot is shown in Figure 6, and an example illustrating age-depth plot interpretation schemes is shown in Figure 7. Depths of time slice boundaries are derived from age-depth plots and correlated with wireline logs.

The interpreted pick of the time slice boundaries, from the age-depth plots, usually coincides with key sequence boundaries and marine flooding surfaces with reasonable consistency. This result provides confirmation of the picks of the chronostratigraphic surfaces from the log correlations and palaeogeographic maps.

Palaeoenvironmental interpretations were made mainly from gamma ray, dipmeter and sonic log signatures. Lithological descriptions from ditch cuttings, sidewall cores and conventional cores were used with log correlations to determine the facies type and depositional environments for each time slice. In this module considerable seismic stratigraphic interpretation was also applied to aid the palaeogeographic reconstructions. Biostratigraphic data were also used to provide additional information on the environment of deposition from fossil content such as the ratio of spore-pollen to marine microfossils. Palaeoenvironments and palaeogeography were reconstructed for selected time slices. The codes representing the various depositional environments and are shown in Figure 8 and Table 2.

Time slice data maps and palaeogeographic interpretation maps have been constructed over 48 time slices ranging from Eifelian to Early Tertiary (see also page ii). Each time slice data map shows the location of the twenty one wells used in the study as well as two additional wells, one from the Dampier Sub-basin and one from the Browse Basin modules. At each well location is a symbol that indicates whether the time slice is present, absent or not penetrated by the well. Hydrocarbon indications within the time slice are shown by the well symbol. For those wells that did intersect the time slice a shaded gamma ray log section, at a vertical scale of 1:10,000 has been posted near and if possible immediately below, the well symbol. Palaeogeographic interpretation maps have been compiled for those time slices with sufficient information to allow an interpretation. These maps are based on the time slice data map series and are self explanatory. Detailed descriptions for each time slice data and palaeogeographic interpretation map are provided in the following sections, together with a brief discussion of prospectivity.

A summary of the organic chemistry data was synthesised from AGSO's ORGCHEM database. It is shown as time slice maps of Total Organic Carbon (TOC), Hydrogen Index (HI), Potential Generation(S2) and Vitrinite Reflectance (VR) in Appendix 5. When referring to the stages for generation of hydrocarbons, we have followed the scheme and cut-off points used by Peters(1986).

Four well log cross sections showing detailed time slice correlations have been constructed. Figure 1 shows the locations of these cross sections. These cross sections are constructed at 1:7500 scale and should be referred to in conjunction with the palaeogeographic interpretation maps (see Enclosures 4 to 7).

Because of the time slice approach the palaeogeographic reconstructions are of necessity a composite interpretation rather than an instantaneous interpretation of a point in time and this should be borne in mind when viewing them. **In particular we have attempted to illustrate the range of environments and scale of the features interpreted within the time slice, even though, in some cases, these environments may not have been contemporaneous.**

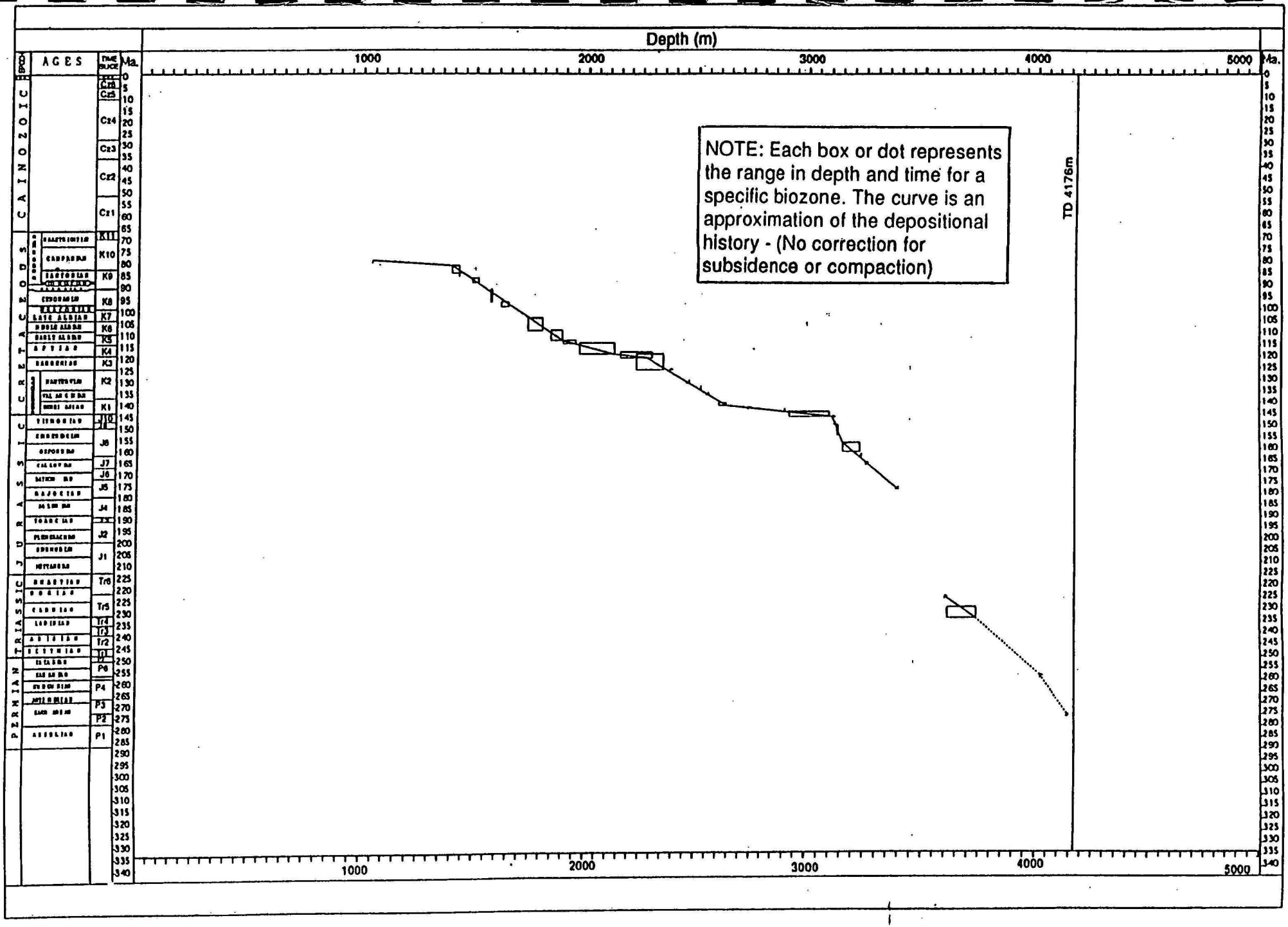


Figure 6

Age/Depth Plot Interpreted Example.

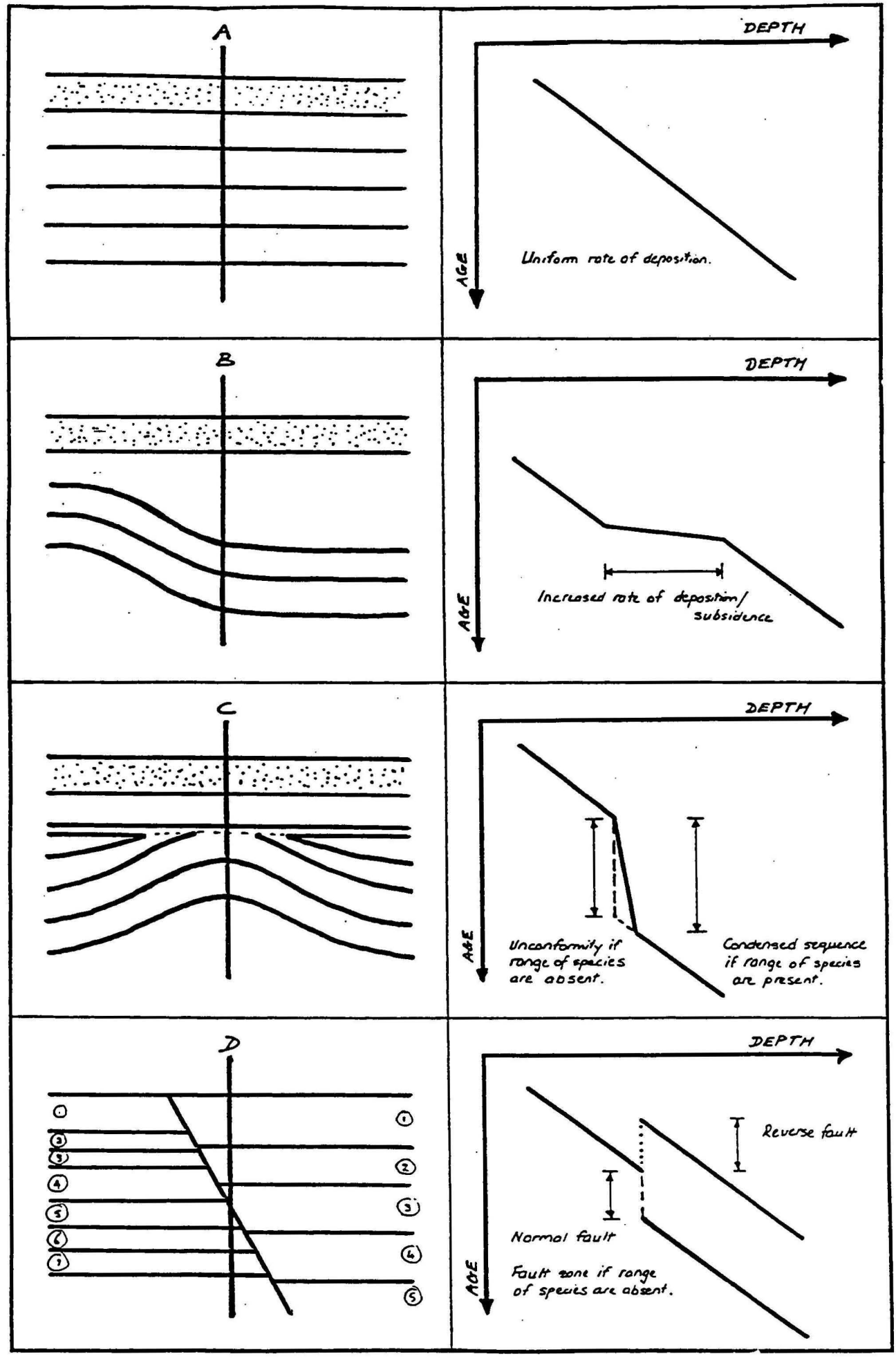
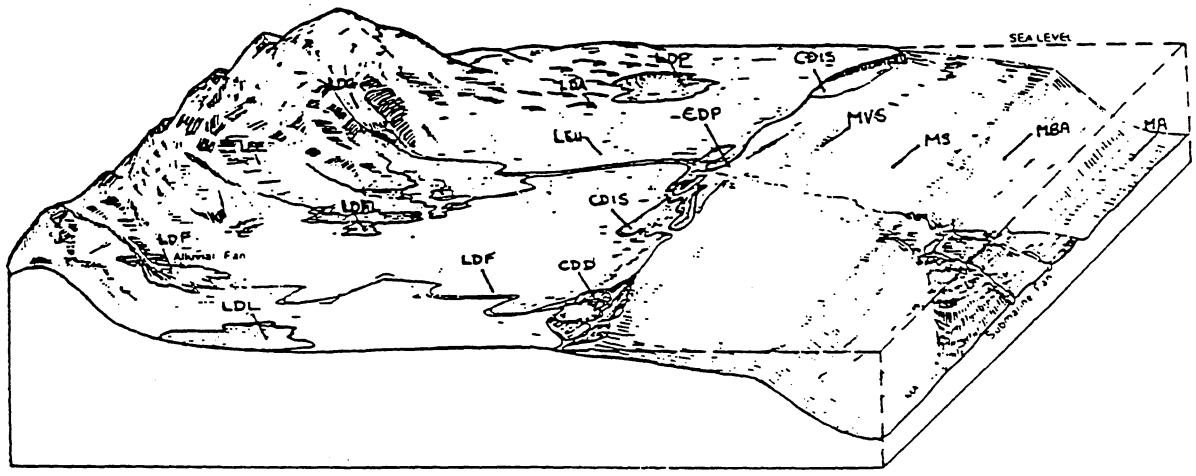


Figure 7 Age/Depth Plot Interpretation Schematic.

CODE	ENVIRONMENT	WORKING DEFINITION
Land & land depositional environments		
LEU	Unclassified	Areas with no preserved sediments of time-slice age, interpreted as land, for example the Ashmore Platform. Also areas that are largely unknown that may have Jurassic sediments, such as the Queensland Plateau.
LEE	Erosional	Highland areas of sediment erosion, indicated by palaeocurrents, provenance studies, tectonic setting and the presence of igneous intrusions, for example the Arburn Arch.
LDF	Depositional, Fluvial	River deposits such as alluvial fans, braided and meandering channel deposits and coarser overbank sediments, and sand-dominated continental sequences with no evidence of aeolian or lacustrine deposition.
LDFL	Depositional, Fluvio-Lacustrine	Sediments deposited in low-energy river environments such as channels, overbanks, backswamps and shallow lakes on low-gradient floodplains; typically sequences dominated by fine-grained sediments and coal, with sheet geometry.
LDL	Depositional, Lacustrine	Deposits of deep, persistent lakes, usually in tectonically controlled basins. Distinguished from LDFL by thicker shales and more restricted distribution.
Coastal depositional environments		
CDP	Paralic	Deposits of coastal or marginal marine environments. Includes the range of environments situated at the land/sea boundary such as lagoonal, beach, intertidal, deltaic, etc., and is recognised by a variety of depositional facies ranging from coarse cross-bedded beach sand, to sand deposited in tidal deltas, to finely laminated organic sediment deposited in lagoons and estuaries (includes deltaic and intertidal-supratidal environments).
CDIS	Intertidal-Supratidal	Sediments deposited in the tidal zone, indicated by the presence of finely interlaminated fine and coarse detritus, herringbone cross-bedding, flaser bedding, evidence of periodic exposure, etc.
CDD	Deltaic	Deltaic deposits indicated by isopach patterns, upward-coarsening sequences and the map pattern of adjacent environments. Cuspate or lobate form of deltas on maps in some cases follows isopach pattern
Marine environments		
MVS	Very Shallow (0-20 m water depth)	Marine sediments with evidence of deposition above wave base and/or occasional emergence, e.g. oolites, cross-bedding.
MS	Shallow (0-200 m water depth)	Marine sediments deposited on the continental shelf or on flanks of volcanic islands, e.g. sand, mud and limestone containing fossils that typically lived in shallow water; also includes areas along young, active spreading ridges (includes MVS).
MBA	Bathyal to Abyssal (> 200 m water depth)	Marine sediments with indicators of deep-water deposition, e.g. condensed sequences, turbidites, monotonous shale, and the presence of deeper-water organisms (includes abyssal environments).



Schematic Diagram Showing
Classifications of Depositional Environments

Figure 8 Depositional Environments Classification Diagram.

TABLE 2
Environment & Landform Elements Codes

ENVIRONMENT CODES					LANDFORM ELEMENT CODES			
	LEU	Unclassified						
	LEE	Erosional						
	LUD	Unclassified Depositional			V	Volcano		
					LF	Lava Field		
					VM	Volcano Mixed		
	LDF	Fluvial	LDFB	Braided	C	Channel		
					AF	Alluvial Fan	AFT	Fan Toe
							AFD	Debris Flow
							AFS	Sheet Flow
			LDFM	Meandering	PB	Point Bar		
					AC	Abandoned Channel		
					LE	Levee		
LAND					CS	Crevasse Splay		
					BS	Backswamp		
	LDL	Lacustrine			LD	Lacustrine Delta		
	LDFL	Fluvial-Lacustrine			OD	Overbank Deposits		
		Upper Shoreface						
	LDP	Playa			SF	Salt Flat		
					MF	Mud Flat		
					P	Pond		
	LDA	Aeolian			D	Dune		
					S	Swale		
	LDG	Glacial			GD	Glacial Deposit		
	CDP	Paralic						
	CDIS	Intertidal / Supratidal			B	Beach		
					BR	Beach Ridge		
	CDD	Deltaic	CDDU	Upper Delta Plain	SMB	Stream Mouth Bar		
			CDDL	Lower Delta Plain	IDB	Interdistributary Bay		
			CDDF	Delta Front	SML	Submarine Levee		
COASTAL			CDDP	Pro Delta	CE	Chenier		
	CDE	Estuarine			M	Marsh		
					LA	Lagoon		
	CSF	Shoreface	CSFU	Upper Shoreface				
			CSFM	Middle Shoreface				
			CSFL	Lower Shoreface				
	MU	Unclassified						
	MSS	Starved Shelf						
	MS	Shallow (0-200m)			OB	Offshore Bar		
					BB	Barrier Bar		
					BI	Barrier Island		
					F	Fan	FP	Fan Proximal
							FM	Fan Mid
							FD	Fan Distal
			MVS	Marine Very Shallow (0-20m)	R	Reef	RT	Reef Toe
							RF	Reef Front
MARINE							RB	Reef Back
	MBA	Bathyal to Abyssal (>200m)			CSH	Continental Shelf	CSHI	Continental Shelf Inner
							CSHM	Continental Shelf Middle
							CSHO	Continental Shelf Outer
					CSL	Continental Slope		
					TF	Turbidite Fan	TFP	Turbidite Fan Proximal
							TFM	Turbidite Fan Mid
							TFC	Turbidite Fan Complex
							TFD	Turbidite Fan Distal
			MA	Marine Abyssal	AP	Abyssal Plain	MFD	Mixed Fan Distal

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AUSTRALIAN PETROLEUM SYSTEMS PROJECT: ROEBUCK & OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN

PALAEOZOIC TIME SLICES

DEVONIAN TIME SLICES D1-D10.

PETROLEUM SYSTEM: LARAPINTINE 3.

EIFELIAN TO FAMENNIAN (387.0 TO 360.0 MA), DEVONIAN TIME SLICES D1-D4 WERE NOT INTERSECTED.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Devonian stratigraphy in the Beagle Sub-basin is unknown as, due to the great depth to these sediments, no wells have intersected Devonian age rocks.
- The Carribuddy and Poulton Formations and Tandalgoo Red Beds are present in the offshore Canning and Roebuck Basins. The top of time slice D5 is bounded by a regional unconformity. Time slices D1-D5 are overlain by the Pillara and Mell Limestone's, both facies equivalents (time slices D5-D7). The top of these limestone's is a regional unconformity. These limestone's are overlain by the Napier Limestone that spans time slices D9 and D10 (see Colwell and Stagg 1994).

DEFINITION OF TIME SLICES: (SEE ENCLOSURE 3).

The Harland (1982) timescale does not have the equivalent Pragian and Lockovian series ages that were used in the Palaeogeographic Map series (Olissoff, S. 1990). These ages were not used as they are not critical to the time slice definitions. Gavin Young (pers comm.) has interpreted the conodont boundaries or events used to define the tops of the original ten time slices of which the youngest five are :

TIME SLICE D5: DEVONIAN: Lower Givetian & Eifelian (378.5 to 387.0 MA).
Top is the boundary between lower and middle *varcus*

TIME SLICE D6: DEVONIAN: Upper & Middle Givetian (374.0 to 378.5 MA).
Top is the boundary between *norrisi* and *asymmetricus.* Top Givetian.

TIME SLICE D7: DEVONIAN: Lower Frasnian (370.5 to 374.0 MA).
Top is the boundary between *A.triangularis* and *gigas.*

TIME SLICE D8: DEVONIAN: Upper Frasnian (367.5 to 370.5 MA).
Top is the boundary between *linguiformis* and *P. triangularis.*

TIME SLICE D9: DEVONIAN: Middle & Lower Famennian & Uppermost Frasnian(360.5 to 367.5 MA).
Top is the boundary between middle and upper *praesulcata.*

TIME SLICE D10: DEVONIAN: Upper Famennian (360.0 to 360.5 MA).
Top is the boundary between *praesulcata* and *sulcata.*

PALAEONTOLOGY: (SEE ENCLOSURE 2).

The Devonian is recognised only in the three Pender Terrace wells. Poor age control and resolution, due to long ranging species, meant that log character was mainly used in correlating the Devonian time slices.

ROEBUCK & OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN HISTORY:

Australia was part of Gondwana. The Fitzroy Trough acted as an important depocenter for Devonian sedimentation. Reef Platforms with adjacent paralic environments are interpreted on each side of the Fitzroy Trough, with deeper water sedimentation down the axis of the Trough. Lithology's are dominantly limestones with secondary sandstones and siltstones. The Pender Terrace has both source and seal potential but reservoir quality is uncertain.

TECTONICS (SEE ENCLOSURES 1 & 3)

Regional:

The Canning Basin is a NW-SE orientated basin, initiated in the early Ordovician as an intracratonic sag basin. The basin is bounded to the north by the pre-Cambrian Kimberley Block and to the south by the Archaean Pilbara Block. Although fairly well known onshore, the offshore extension of the Canning Basin is relatively deep and poorly known. Interpretation and inferences about the offshore section are based on analogy to the onshore section.

During the Late Devonian to early Carboniferous times, West Australia was part of Gondwana before its collision with Laurasia to form Pangea (Baillie et al, 1994). After this, from the Namurian (Carboniferous) to the Carnian (Triassic), West Australia was part of Pangea. From the Late Carboniferous to the mid Permian a number of continental blocks from Sibumasu, which include China, West Thailand and East Burma, drifted during the initial breakup phases of Pangea (Von Rad, 1992).

Local:

Line 120/11 extends NW from the Offshore Fitzroy Trough across the Inner and Outer Rowley Sub-basins. The portion of line 120/11 in Figure 9 shows a Palaeozoic aged basement structurally deformed during the Alice Springs Orogeny, with typical large scale folding and faulting. The lows were later filled with Permian and Carboniferous sediments that were later eroded and reworked.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Time slice D5 lithology for Kambara 1 consists of interbedded siltstone, sandstone and limestone towards the base and middle. It is equivalent to the Sadler Limestone and Gogo Formation. Uniform fossiliferous limestones (the Pillara Formation) are present above these Formations . The Pillara Formation is also represented in Perindi 1 and Minjin 1. Corals have been recorded in Minjin 1. The Pillara Formation of time slice D6 age is present in Kambara 1 and Minjin 1. In Kambara 1, time slice D8 consists of sandstones and siltstones.

THICKNESS VARIATIONS: (SEE ENCLOSURE 8).

A total of 1345m was intersected in Kambara 1, 301m in Minjin 1 and 89m in Perindi 1. All these wells reached total depth within Devonian section, so no drillholes have fully penetrated the Devonian. Regional onshore studies suggest approximately 3km of preserved Devonian sediment (Kennard et al, 1994; Lehmann, 1984; Begg, 1987). A similar thickness is estimated from seismic in the Offshore Fitzroy Trough.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 9).

The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a transgression from the top of time slice D5 to the top of time slice D7; a uniform eustatic regime during time slice D8 and a regression during time slice D9 and D10. Australia underwent warm to cool conditions as inferred from the moderate latitudes derived from polar wander curves. Carbonate reef, both fore reef and platform and a deep water marine basin are the major environments interpreted. Mixed clastic and carbonate submarine fans or slumps are inferred to be present in local areas at the base of the fore reef talus slope.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 9).

The primary sources of data include all wells with interpreted time slice palaeogeography and the palaeogeography developed by Lehmann (1984) and Kennard et al (1994). Palaeogeographic interpretation is restricted to the Fitzroy Trough area where data control points exist. Due to the lack of control points time slices D5 to D10 were combined to produce a composite time slice map.

The emergent landmasses during time slices D5-D10 are taken directly from Kennard et al (1994). It is evident from seismic that time slices D6-D10 onlap the Jurgurra Terrace but do not extend onto the Broome Platform. During time slice D5 at least part of the Broome Platform was probably immersed (Kennard, 1995 - personal communication). Carbonate platform areas are interpreted bordering the Kimberley Block on the northern side of the Fitzroy Trough and the Broome Platform on the southern side of the Fitzroy Trough. Major syn-depositional faults were active on either side of the Fitzroy Trough.

GEOCHEMISTRY: (TOC, HI, S2 AND Vr, SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. Only one sample in Minjin 1 meets these criteria. It has a TOC of 1.5%, an HI of 356 and good generative potential, but is immature.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Strong oil and gas indications have been recorded in Perindi 1 in time slice D5. The following list summarises the porosity data for the time slice:

Kambara 1	D5	0.6% < porosity < 6.7%(logs),
Kambara 1	D5	porosity av = 12%(logs),
Perindi 1	D5	porosity av = 9.7%,
Minjin 1	D5/D6	porosity av = 13.8%, and
Kambara 1	D6	0.6%< porosity< 6.0% (logs).

Perindi 1 also lost circulation at top of Devonian section.

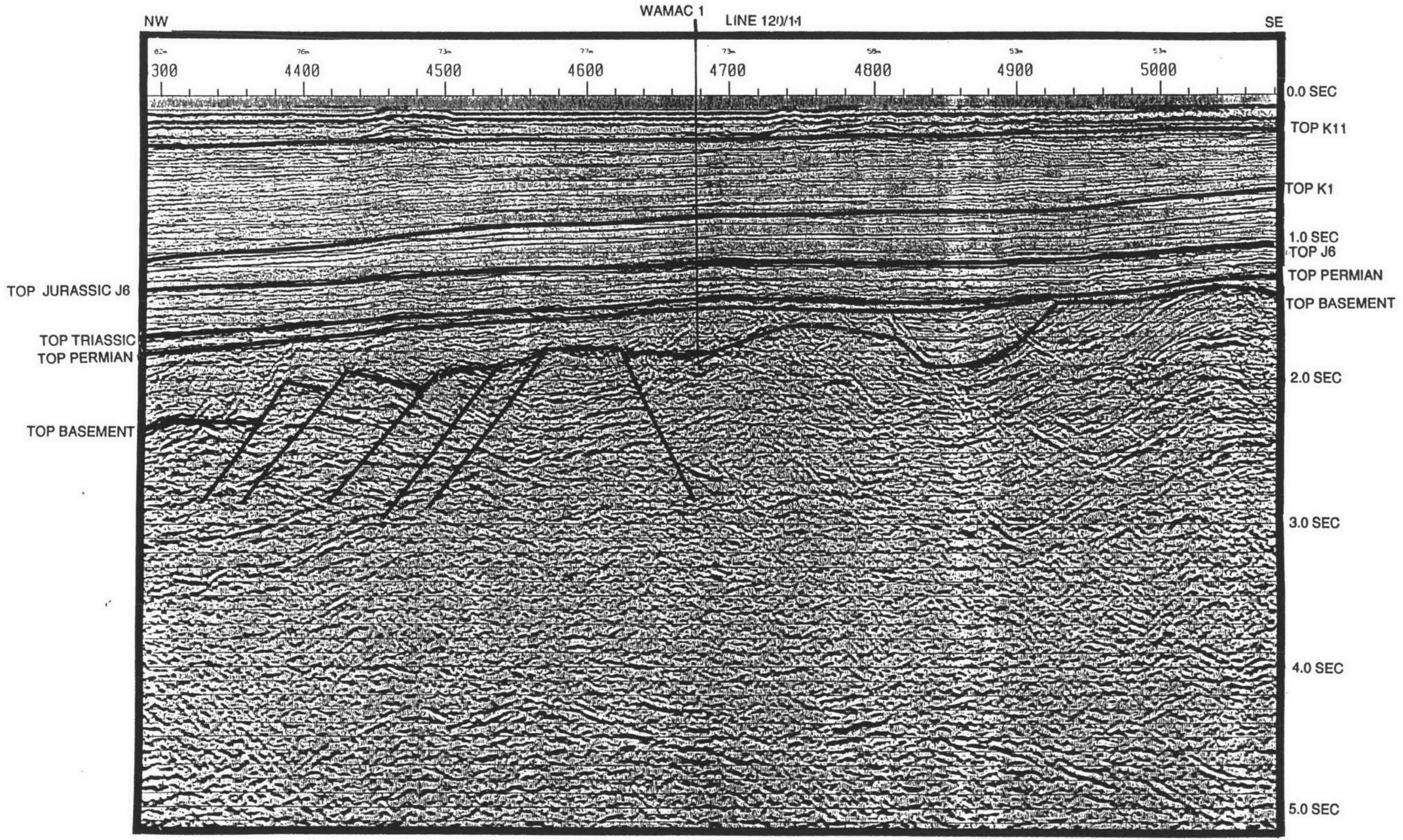


FIGURE 9: SEISMIC REPRESENTATION OF THE PALAEOZOIC & WAMAC 1, OFFSHORE FITZROY TROUGH, LINE 120/11.

PROSPECTIVITY: (SEE ENCLOSURE 3).

Depositional lows are interpreted in the axis of the onshore Fitzroy Trough. Due to the half graben nature of the Fitzroy Trough this axis is located on the southern side of the trough. The Fitzroy Trough is the main depocenter of:

- the marine shales of the Gogo Formation of Givetian to Frasnian age (time slices D5-D8),
- the lagoon or sabkha facies of the Mellinjerie Formation also of Givetian to Frasnian age (time slices D5 to D8),
- the Mirbelia dolomite of Late Devonian age, and
- the Boab Sandstone of Late Devonian age.

These form potential source rocks in the onshore Fitzroy Trough that may have lateral equivalents in the offshore Fitzroy Trough (Kennard et al 1994). Hydrocarbons from these potential source rocks could migrate and be trapped in overlying reservoirs, provided the timing of migration post dated the formation of seals. The shows in the Perindi 1, Wamac 1 and Kambara 1 wells confirm this potential. Potential time slice D5 to D6 oil and gas source rocks, carbonate reservoirs and seals have been recognised on the Pender Terrace.

TRAPS & PLAYS: (SEE ENCLOSURE 3).

A potential play on the Pender Terrace occurs in carbonate reservoirs (Devonian time slice D5) sourced by Ordovician time slices O1-O3 *G.prisca* type I, and or II oil source rocks speculated to be present offshore. The seals are interpreted as local and therefore present a weakness in the areal scope of the play. Both structural and stratigraphic traps are possible with fracture, vuggy or karst reservoirs possible.

CARBONIFEROUS TIME SLICES CRB1 TO CRB6

CARBONIFEROUS: TOP STEPHANIAN TO TOP FAMENNIAN (286.0 TO 360.0 MA).

PETROLEUM SYSTEM: LARAPINTINE 3 AND TRANSITIONAL FOR TIME SLICES Crb1-Crb5, GONDWANAN 1 FOR TIME SLICE CRB6.

This poorly known interval appears to have source rock potential

FORMATION SYNONYMS: (SEE FIGURE 2).

- Due to the depth of burial no offshore wells have intersected Carboniferous rocks in the Beagle Sub-basin.
- The Yulleroo and Laurel Formations, time slices CRB1-CRB4, are both facies equivalents (offshore Canning and Roebuck Basins). They are overlain by the Anderson Formation of time slices CRB4-CRB5 age (see Colwell and Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

C. Foster (pers comm.) has interpreted the boundaries or events used to define the original six time slices:

TIME SLICE CRB6: CARBONIFEROUS: Middle Westphalian to top Stephanian (286.0 to 308.5 MA)
Defined as equivalent to the *D.birkheadensis* spore pollen zone.

TIME SLICE CRB5: CARBONIFEROUS: Lower Westphalian & Upper Namurian (308.5 to 322.0 MA).
Defined as equivalent to the *S.ybertii* spore pollen zone.

TIME SLICE CRB4: CARBONIFEROUS: Lower Namurian & Upper Visean (322.0 to 340.0 MA).
Defined as equivalent to the *G.maculosa* spore pollen zone.

TIME SLICE CRB3: CARBONIFEROUS: Lower Visean (340.0 to 350.0 MA).
Defined as equivalent to the *A.largus* spore pollen zone.

TIME SLICE CRB2: CARBONIFEROUS: Lowermost Visean (350.0 to 352.0 MA).
Defined as equivalent to the *G.praecipua* spore pollen zone.

TIME SLICE CRB1: CARBONIFEROUS: Tournaisian (352.0 to 360.0 MA).
Defined as equivalent to the *G.spiculifera* spore pollen zone.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slices. The following summarises the palaeontological species zonation control and confidence rating for it (refer to introduction for description of confidence rating, page iii):

- Wamac 1:	CRB1	*G.spiculifera* (E3),
- Kambara 1:	CRB1, CRB2	*G.spiculifera* (D3, B2),
- Wamac 1:	CRB2	no palaeontological control,
- Perindi 1:	CRB2	*A.largus*(B3), *S.ybertii* (D5), *G.spiculifera* (B3),
- Pearl 1:	CRB2	*G.spiculifera* (D5),
- Pearl 1:	CRB3	*A.largus* (B2, D5),
- Wamac 1:	CRB3	*A.largus* (B3),
- Pearl 1:	CRB5	*S.ybertii* (B2, B4, D5),
- Wamac 1:	CRB6	*Falcisporites Sz*(B5),
- Lacepede 1A:	CRB6	*D.birkheadensis* (B5), and
- Perindi 1:	CRB6	*Stage 1* (D5).

ROEBUCK & OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN HISTORY

Australia formed part of Greater Pangea. Rifting and drifting of South China blocks was occurring on the outer margin of the supercontinent. On a local scale, syn-depositional wedges of Carboniferous and Permian sediment were being deposited on an older folded and eroded Palaeozoic surface. The Middle Carboniferous is the end of the Alice Springs Orogeny and the start of the Gondwanan petroleum system. The Upper Carboniferous is a time of cold climate. Permanent glaciers and a large ice cap are present in time slice CRB6. There are insufficient data control points to be able to distinguish the variety of palaeoenvironments thought to be present within each time slice. Lithology's range from sandstones to claystones with secondary limestones and coal. Potential good quality oil and gas prone source rocks exist but are likely to be only sub-mature in the Offshore Fitzroy Trough. Time slices CRB1 to 3 act both as source and regional or local seal. Time slice CRB5 is a reservoir and seal unit and time slice CRB6 is a source and regional seal.

TECTONICS:(SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

West Australia formed part of Gondwana before its collision with Laurasia to form Pangea during early Carboniferous times (Baillie et al, 1994). From the Namurian in the Carboniferous to the Carnian in the Triassic, West Australia was part of Greater Pangea. From the Late Carboniferous to the mid Permian, a number of continental blocks from Sibumasu, including China, West Thailand and East Burma were rifted from Gondwana. The drifting of these blocks marks the initiation of the breakup of Pangea (Von Rad, 1992 and Metcalfe, 1993) .

Local:

Colwell & Stagg (1994) defined a tectonic phase in the Middle Carboniferous equivalent to the start of the Gondwanan and Westralian extension phase (late stages of the Alice Springs Orogeny).

A highly deformed Ordovician to early Carboniferous basement, with a very irregular erosional surface, is overlain in most places by sediments of probable Permian to Carboniferous age. Examples can be seen on lines 120/11 (sp 3800-5190) and 120/01 (sp 4400-3700).

Contact between the overlying Triassic, Carboniferous and Permian sediment wedges and an older Lower Palaeozoic basement can be seen in line 120/03 (Figure 10). The same contact has been interpreted on lines 120/03 (sp 3800-4900), 120/11 (sp 500-2500), 120/07 (sp 6600-9100) and 120/09 (sp 4789-2800). Line 120/03 extends NNW from the Broome Platform across the Inner and Outer Rowley Sub-basin and terminates over the Argo Abyssal Plain.

The portion of line 120/03 in Figure 10 shows:

- that Permian and probable Carboniferous onlaps a much older Palaeozoic basement. This section is unconformably overlain by time slice TR1 which has an onlap edge on the southeast end of the line, and
- the structure at the location of the East Mermaid 1 well that terminated in time slice J1.

Pre-Triassic structuring is seen in most of the project area, in the form of basement highs and lows with fault throws mappable principally around the Lambert and Leveque Shelves, Wallal Embayment, Rowley Sub-basin and Fitzroy Trough. A number of basement hinge zones are seen throughout the project area and help define the basement elements. Individual structural styles can be identified principally in the Fitzroy Trough and to a lesser degree in the Wallal Embayment. A line diagram of line 120/12 shows examples of tight synclines, horst blocks and the marked unconformity seen within the Fitzroy Trough (Enclosure 70). The more stable Palaeozoic Broome Platform with its mild horst and graben structural style is in marked contrast to the highly structured Fitzroy Trough and Wallal Embayment The Wallal Embayment has thick Permian and Carboniferous deposits that show inversion (eg line 120/13).

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Time slice CRB1: Limestones with secondary siltstones (the Laurel Formation) are present in Kambara 1. In Wamac 1 lithology's range from sandstones to claystones to limestones, with dolerite intrusions.

Time slice CRB2: In Kambara 1 a sandstone with secondary siltstone grades to a calcareous mudstone and siltstone lithology at the base. Wamac 1 contains sandstone to quartzite and olive black claystones with secondary siltstone and limestone. The time slice is intruded by dolerite sills. Pearl 1 lithology's include sandstone to shales with substantial chert beds.

Time slice CRB3: Lithology's in Wamac 1 range from claystone to sandstone with secondary coal and limestone. Claystone to sandstone lithology is found in Pearl 1 with only a trace of calcareous material present .

Time slice CRB5: A uniform lithology of sandstone and siltstone beds with minor shale is found in Pearl 1 belonging to the Grant Formation, here interpreted as time slice CRB5.

Time slice CRB6: Shale to sandstone with minor coal towards the top is recorded in Lacepede 1A with minor calcareous cements present. Sandstone to claystone with trace of limestone is present in Wamac 1 whilst a very sandy Grant Formation occurs in Perindi 1.

THICKNESS VARIATIONS: (SEE ENCLOSURE 10).

A total of 235m was intersected in Kambara 1, 288m in Lacepede 1A, 1050m in Pearl 1, 108m in Perindi 1 and 800m in Wamac 1. These thicknesses may not be representative of the module area due to the poor well control, or wells not fully penetrating the Carboniferous.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 10)

The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) show a regression during time slices CRB1 and CRB2, a

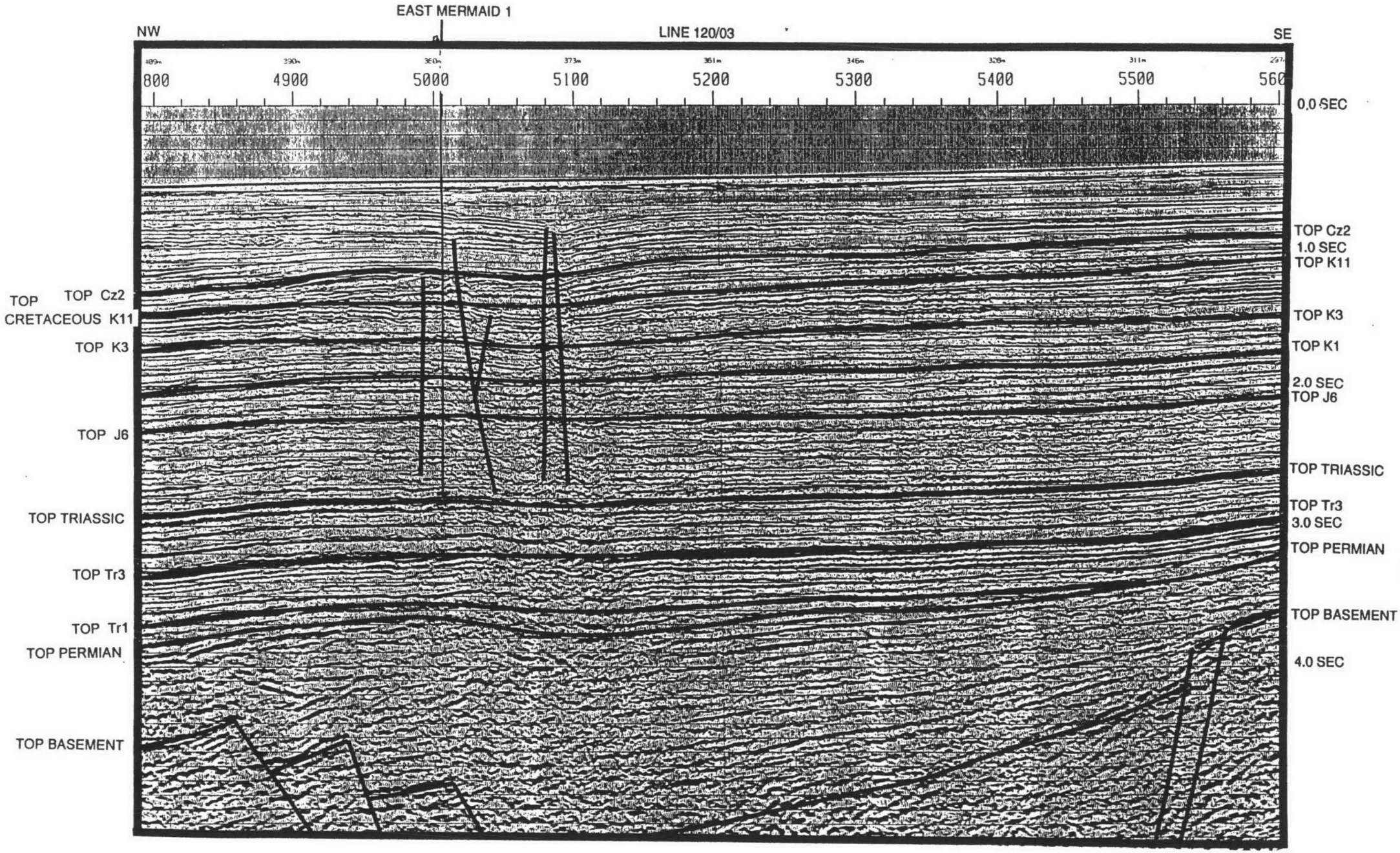


FIGURE 10 : SEISMIC REPRESENTATION OF CARBONIFEROUS-PERMIAN SEDIMENT WEDGES & EAST MERMAID 1, ROWLEY SUB-BASIN, LINE 120/03.

static regime during time slices CRB3-CRB5 and the lower part of time slice CRB6 followed by a transgression during the upper part of CRB6 (Struckmeyer & Brown 1990).

Australia underwent cold conditions as evidenced from the high latitudes derived from polar wander curves but the early-middle Carboniferous is still devoid of ice in the module area.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 11)

The primary sources of data include all wells with interpreted time slice palaeogeography, palaeogeographic interpretations from onshore Canning Basin wells and outcrop. Secondary sources are from AGSO(BMR), industry and university published work.

The outline of the emergent landmass during time slice CRB2 is taken from Kennard at al (1994) and shows deposition mainly within the Fitzroy Trough. Major active faults are interpreted on either side of the onshore Fitzroy Trough. These trends have been extrapolated offshore. The palaeogeography interpretation of the Carboniferous has been restricted to time slice CRB2 due to lack of data control points.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. The six samples meeting the selection criteria revealed a potential gas and oil source rock quality with very good TOC's and good generative potential but immature. One sample was from the Pender Terrace and the other five from the offshore Fitzroy Trough. The Carboniferous is mature in the Rowley Sub-basin but it is not likely to be mature within the offshore Fitzroy Trough.

The one sample analysed by AGSO in conjunction with this module in Wamac 1 (Appendix 5, part 3) gave low TOC, poor generative potential and low HI.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4)

Gas indications have been recorded in Pearl 1 in time slices CRB2, CRB3 and CRB6 with a strong oil indication in Perindi 1 in time slice CRB6.

The following list summarises the porosity data for the time slice:

Kambara 1	CRB1	porosity av = 14%,16% (logs),
Kambara 1	CRB2	porosity av = 18% (logs),
Pearl 1	CRB5	9% < porosity < 25% (logs), and
Pearl 1	CRB6	porosity av = 21.4% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

Recognised source rocks in the onshore Fitzroy Trough (Kennard et al, 1994) include:

- the organic rich shales of the Laurel Formation of Tournaisian to Visean (time slices CRB1-CRB3), and
- the Anderson Formation also of Tournaisian to Visean age (time slices CRB1-CRB3).

It is unknown whether these extend offshore or if they are potential source rocks offshore. Offshore oil and gas sources are recognised in time slice CRB2 on the Pender Terrace and in time slices CRB3 to CRB6 in the offshore Fitzroy Trough whilst inferred sources are interpreted in time slices CRB2 and CRB3 on the Jurgurra Terrace and offshore Fitzroy Trough. Both regional and local seals exist.

The Carboniferous is potentially prospective particularly on the Pender Terrace. Time slice CRB2 onlaps the offshore extension of the Tappers Inlet High. This unit has regional, fair to poor, top seal potential, and could have some source potential though it is immature in the wells on the Pender Terrace.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

Pender Terrace: Carboniferous CRB1 carbonate reservoirs may be sourced by either the Ordovician time slices O1 to O3 *G.prisca* type I or II source rocks that are potentially present offshore, or time slice D6 oil and gas source rocks. Regional seals are present. Both structural and stratigraphic traps are likely with fracture, vuggy or karst reservoirs possible.

Jurgurra Terrace: Carboniferous time slice CRB5 clastic reservoirs may be sourced by either Ordovician time slices O1 to O3 *G.prisca* type I or II oil source that is potentially present offshore, or by time slice D6 oil and gas source or a Lower Carboniferous source. Regional seals are present in time slices CRB5 and CRB6. Both structural and stratigraphic traps are possible.

PERMIAN TIME SLICES P1 - P7.

PERMIAN: TOP STEPHANIAN TO LOWER SCYTHIAN ON THE HARLAND SYSTEM (1982) (286.0 TO 247.0 MA).

PETROLEUM SYSTEM: GONDWANAN 1 AND 2.

The lower Permian is the glacial retreat period following the major glaciation of the late Carboniferous. Good fluviolacustrine and coal based light oil to condensate rich source rocks occur in the Cooper Basin at this time. The Gondwanan 1 system must be seen as a potential source rock interval provided facies similar to those in the Cooper Basin area could be identified or inferred.

FORMATION SYNONYMS:

- Only Poissonnier 1 has intersected Permian sedimentary rocks in the Beagle Sub-basin
- The Grant Group is restricted to time slices CRB6 to P2, the Liveringa Group to time slices P3 to P6 and the Chirup Formation to time slices P5 to P7. The Grant Group is bounded by unconformities at the base and the top, the basal unconformity equates with the late stages of the Alice Springs Orogeny. The base of the Liveringa Group is also an unconformable surface whilst the top is diachronous with the Chirup Formation. The top of the Chirup Formation represents the unconformable surface resulting from the Late Permian Bedout Movement (see Colwell and Stagg, 1994).
- The Poole Sandstone, Nurra Member and Noonkanbah Formation.

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

C. Foster (pers comm.) has interpreted the boundaries or events used to define the tops of the original seven time slices as follows

TIME SLICE P1: PERMIAN: Asselain (286.0 to 277.0 MA).

Biostratigraphically equivalent to palynological zone *APP1.* Carnarvon Basin areas are in high latitudes, approximately 55 degrees south. Thick glacial ice cap are retreating from Pilbara Craton area.

TIME SLICE P2: PERMIAN: early - middle Sakmarian (277.0 to 274.0 MA).

Biostratigraphically equivalent to palynological zone *APP2.1.* Ice retreat and final deglaciation and sea level rise. Isostatic uplift due to unloading of craton probable.

TIME SLICE P3: PERMIAN: late Sakmarian - Middle Artinskian (274.0 to 268.0 MA).

Biostratigraphically equivalent to palynological zone *APP2.2.*

TIME SLICE P4: PERMIAN: Middle Artinskian - Kungurian (268.0 to 261.0 MA).

Biostratigraphically equivalent to palynological zones *APP3.1 to APP3.3.*

TIME SLICE P5: PERMIAN: Early Kazanian (261.0 to 255.0 MA).

Biostratigraphically defined by the range of palynological zone *APP4.* Major transgression in much of eastern Australia.

TIME SLICE P6: PERMIAN: Middle Kazanian to Middle Tatarian (255.0 to 249.5.0 MA).

Biostratigraphically defined by palynological zone *APP5.* The top occurs near the top of *PP5.2* and the base occurs near the top of *PP4.3*

TIME SLICE P7: PERMIAN: Late Tatarian (249.5 to 247.0 MA).

Biostratigraphically defined by palynological zone *APP6.*

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and confidence rating for the species zone (refer to introduction for description of confidence rating, page iii):

- Pearl 1:	P1	*Stage 2, M.tentula* (B5, D3),
- Perindi 1, Minjin 1:	P1	no palaeontological control,
- Kambara 1:	P1	*Stage 2* (B2, B4),
- Perindi 1:	P2	*Stage 3a*(A1, B2, B3),
- Kambara 1:	P2	*M.tentula* (B2), *Stage 3a*,
- Minjin 1:	P2	*Stage 3a* (B1, B3),
- Pearl 1:	P2	no palaeontological control,
- Pearl 1:	P3	*Stage 3b*(D3),
- Perindi 1:	P3	*Stage 3b* (B4),
- Minjin 1:	P3	*Stage 3b* (B1),
- Kambara 1:	P3	*Stage 3b, lower Stage 4* (B4), *D.townrowii* (B2), and

- Poissonnier 1: P7 *L.pellucidus* (B5).

ROEBUCK & OFFSHORE CANNING BASIN & BEAGLE SUB-BASIN HISTORY

Australia formed part of Greater Pangea. Rifting of South China blocks was occurring on the outer margin of the supercontinent. On a local scale syn-sedimentary wedges of Carboniferous to Permian sediments overlie an older folded and eroded Palaeozoic surface. The Lower Permian is dominated by glacial sediments related to waning phases of the Late Carboniferous glaciation. A more temperate climate dominates the Middle to Upper Permian. Overall time slice P1 is a lowstand with transgressive systems tracts present in time slice P2 and younger. Offshore interpretations are poor due to the lack of data control. Dominant lithology's are sandstone, siltstone and carbonates with glacial sediments in time slice P1. Oil indications were encountered in time slices P1 to P3. Both local and regional seals exist on the Pender Terrace whilst source, reservoir and local and regional seals exist on the Jurgurra Terrace.

TECTONICS:(SEE ENCLOSURE 1& 3 & FIGURE 2).

Regional

From the Namurian in the Carboniferous to the Carnian in the Triassic, West Australia was part of Greater Pangea (Baillie et al, 1994). From the Late Carboniferous to the mid Permian, a number of continental blocks from Sibumasu, that included China, West Thailand and East Burma, were drifted from Gondwana, marking the initiation of the breakup of Pangea (Von Rad, 1992 and Metclalfe 1993).

Local:

Contact between the overlying Triassic and syn-depositional Carboniferous and Permian sedimentary wedges with the older Lower Palaeozoic basement can be seen in Figure 10 and on lines 120/03 (sp 3400-5800), 120/09 (sp 4789-2800), 120/11 (sp 500-2500), 120/07 (sp 6600-9100). The structure at the location of the East Mermaid 1 well that terminated into J1 aged rocks can also be seen.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Time slice P1: Kambara 1 lithology's includes sandstones of glacial origin (the Grant Formation), at the base and middle with interbedded mudstone and siltstone near the middle and a sandstone at the top. Secondary siltstone and one minor limestone bed is also present. Minjin 1 has a sandstone base with secondary sandstone, siltstone with minor limestone beds in the middle and top of the intersected time slice. The Grant Formation in Pearl 1 is dominantly a sandstone with a secondary siltstone and a significant bed of claystone towards the top. Perindi 1 has similar lithology's of sandstone with secondary siltstone and claystone.

Time slice P2: Lithology's in Kambara 1 include sandstone and claystone. Interbedded sandstone, siltstone and claystone with secondary beds of limestone comprise the Minjin 1 and Perindi 1 lithology's. Sandstone to claystone lithology's are represented in Pearl 1.

Time slice P3: Kambara 1 lithology's include interbedded sandstone, siltstone and claystone with secondary beds of limestone. Significant limestone beds bound the base of this time slice. Minjin 1 comprises all siltstone and limestone belonging to the Poole Sandstone, Nurra Member and Noonkanbah Formation. Claystone and siltstone lithology's comprise the base and middle of the intersected Grant Formation that is overlain by the top most Grant Formation sandstone in Pearl 1. The Poole Formation of Perindi 1 comprises dominant sandstone with secondary limestone and siltstone.

Time slice P7: Lithology's of Bedout 1 and Lagrange 1 are igneous rocks (may be as young as lower Time Slice TR2) whilst calcilutite, claystone and sandstone represent intersected sediments of this age in Poissonnier 1.

THICKNESS VARIATIONS: (SEE ENCLOSURE 12).

A total of 52m and 391m of igneous rocks were intersected in Bedout 1 and Lagrange 1 respectively, 804m of sediment and igneous rocks in Perindi 1, 915m of sediments in Kambara 1, 441m of igneous rocks and sediments in Pearl 1 and 842m in Perindi 1. These thicknesses may not be representative of the Permian in the module area.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 13).

The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply a static sea level during time slice P1, followed by a gradual regression during time slices P2 to P7. Australia underwent cold conditions as evidenced from the high latitudes derived from polar wander curves and glacial retreat deposits. Diamictites and tillites are found in the lower and middle Permian.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 13).

The primary sources of data include all wells with interpreted time slice palaeogeography, and palaeogeographic interpretations from onshore Canning Basin wells and outcrop. Secondary sources are from AGSO(BMR), industry and university published work.

The northerly Kimberley Block did not have any Permian deposited on it, whilst the Pilbara Block to the south probably had an ice cap present during time slice P1. This ice cap retreated during time slices P2 and P3 time. Intermittent regressions and transgressions are probable, particularly during time slices P1 and P2, that are related to wanning glacial conditions. The Broome Platform was not emergent and had probable glacial to fluvial sedimentation during time slice P1, followed by a rapid transgression during time slices P2 and P3. Active faulting on the northern side of the Broome Platform is probable.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. No samples with values of HI >150, TOC > 1.0% or 100<HI<150, TOC > 0.5% with S2>5 occur, but the available samples, from a very limited area, may not be representative of Permian source rock potential.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

In the Perindi 1 well, oil indications have been recorded in time slice P3 with oil and gas indications present in top time slice P2 and base time slice P1.

The following list summarises the porosity data for the time slice:

Kambara 1	P1	18% < porosity av < 25% (logs),
Minjin 1	P1	13.5% < porosity < 27.1% (logs),
Pearl 1	P1	22.5% < porosity < 30% (logs),
Perindi 1	P1/ P2	porosity av = 21.4% (logs),
Kambara 1	P2	porosity av = 25% (logs),
Minjin 1	P2	21.6% <porosity av < 28.6% (logs),
Pearl 1	P2	22.5% < porosity < 30% (logs),
Kambara 1	P3	porosity < 9% (logs),
Minjin 1	P3	porosity = 28.7% (logs),
Perindi 1	P3	porosity av = 5.7%, 15.3% (logs), and
Poissonnier 1	P7	10% < porosity < 14% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

Reservoir potential exists in time slices P1 to P3 on the Jurgurra Terrace. Both local and regional seals exist on the Pender, Jurgurra and Bruce (Beagle Trough area) Terraces. The Permian is thought to have source potential but is only sub-mature where encountered.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

One potential play is on the Jurgurra Terrace. Here, Permian time slices P1 to P3 clastic reservoirs could be sourced by either the Ordovician time slices O1-O3 *G.prisca* type I and II source rocks that are potentially present offshore, or by an identified oil and gas source of time slice D6 age or by Carboniferous sources of time slices CRB1 to CRB3 and CRB6 age. Regional and local seals are present within the time slices. Both structural and stratigraphic traps are possible.

TRIASSIC TIME SLICES

TIME SLICE TR1:

EARLY TRIASSIC: SCYTHIAN (247.0 TO 244.5 MA).

PETROLEUM SYSTEM: GONDWANAN 2.

The Perth Basin is the only place in the Gondwanan Petroleum System where a proven oil source exists in the earliest Triassic in a marine sedimentary facies; the Locker Shale equivalent. However the Locker Shale does not appear to be a potential source rock in the module area. Although TOC levels are often high, the kerogen is dominantly inertinite and has a low HI. There remains a remote possibility that more distal, as yet unencountered facies, could have source potential. In general Gondwanan 2 provides a thick regional seal to the underlying Petroleum Systems.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Locker Shale and Mungaroo Formation in the Beagle Sub-basin are interpreted as diachronous (Blevin et al, 1994).
- The Locker Shale and Keraudren Formation (Offshore Canning and Roebuck Basins) are interpreted as diachronous (Colwell & Stagg, 1994).
- The Blina Shale, Millyit, Erskine and Culvida Sandstones are present in the onshore Canning Basin (BMR, 1981).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice TR1 is defined as being equivalent to the *P.samoilovichii* spore pollen zone.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

The spore pollen zone *P.samoilovichii* was identified in Poissonnier 1, the only well to have intersected time slice TR1. The low diversity fauna and lack of key zone species in the sidewall core gives a very low confidence level for this time slice pick.

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of Greater Pangea. The module area is thought to have been connected to the greater Tethys ocean to the north. Time slice TR1 corresponds to the time of the Bedout Movement that imposed a NE-SW structural and depositional grain on the area. Depositional hinge zones are present north of the Bedout High and west of the Bedout Sub-basin. Time slice TR1 is conformable with TR2 but was deposited on an unconformable surface of variable age. Time slice TR1 has poor palynological control and as a consequence the time slice top and base are determined on log character. The time slice is a marine transgressive unit. A range of minor upper delta to lower shoreface environments is also represented in the time slice with typical clastic lithology's including sandstone to claystone. No shows have been detected. Time slice TR1 acts as a regional seal unit to the older Palaeozoic but no definite source or significant reservoirs have as yet been identified.

TECTONICS (SEE ENCLOSURE 1, 3 & FIGURE 2).

Regional:

Australia was part of Greater Pangea (Baillie et al, 1994) and the northwest Australian margin was part of a failed continental rift zone. During time slice TR1 a marine shaly facies, with similar microflora and fauna was deposited along the 3000km extent of the Westralian Superbasin (Yeates et al, 1987) that had a connection to the greater Tethys sea to the north.

The interpreted seismic has demonstrated the effect of the Late Permian to Early Triassic Bedout Movement. Following this event the Triassic gradually filled the lows and onlapped the highs. The lower Triassic sequence boundary being defined by the strong truncational erosion of the Carboniferous and Permian particularly in the Roebuck Basin (Figure 10). This boundary is less apparent in the Beagle Sub-basin due to a lack of seismic resolution of the basal Triassic. The boundary is characterised by a change from, in places, stronger top Permian reflectors (most probably indicating coal sequences) to semi opaque reflectors in the basal Triassic.

Local:

During the Late Permian to lower time slice TR1 a strong NE-SW structural grain was imposed across the area by the Bedout Movement; the older Lower Palaeozoic has a NW-SE structural grain. A number of basement highs in the Rowley Sub-basin were onlapped during time slice TR1 (Enclosure 15). The tectonic trend of basement highs and depocenters has been biased to a NE-SW direction to fit in with the accepted

structural grain of this time on the North West Shelf and partially loop tied where seismic lines were close enough. It is expected that a variation of azimuth from a pure NE-SW trend of the sediment depocenters will exist around the more stable cratons and landmasses.

Two probable depositional hinge zones are present NNW of the Bedout High and on the western side of the Bedout Sub-basin (Enclosure 15). These may be associated with fracture systems of the Bedout Movement, and or reflect a distinct variation in the rheological properties of two basement provinces in the underlying crust.

The presence of these hinge zones is based on the following observations:

- a distinct depositional thinning of the Triassic from west to east on a regional scale, and
- a distinct west to east reduction in faulting intensity within the top time slice J7 (Callovian) to top time slice K1 (Valanginian) sequence across these hinge zones, and extensions to them along an approximately similar longitude. The implication of this is that Late Jurassic to Early Cretaceous faulting intensity variations are linked to different basement types. These different basement types may also be reflected by changes in depositional fill and content.

Line 120/04 extends west from the Broome Platform across the NE Bedout Sub-basin, Bedout High to Minilya 1 well and terminates on the Outer Beagle Platform. The portion of line 120/04 in Figure 11 shows:

- a significant basement offset that is part of a Triassic aged structural and depositional hinge zone, located just to the west of the Minilya 1 well around shotpoint 4700. Figure 11 also shows the decrease of faulting intensity east of the basement offset as discussed above, and
- the structure at the location of the Minilya 1 well that terminated in the Middle Jurassic.

Line 120/03 extends NNW from the Broome Platform across the Rowley Sub-basin and terminates in the Argo Abyssal Plain. The portion of line 120/03 in Figure 12 with respect to time slice TR1 shows:

- the Triassic unconformably deposited onto the Permian with probable erosion of the Permian off the Broome Platform. The Permian here forms part of a syn-depositional sediment wedge that thickens basinward, and
- the progressive onlap of the Triassic TR1-TR5 onto the northern end of the Broome Platform.

Line 120/05 extends NNE from the Lambert Shelf across the Bedout Sub-basin and terminates just beyond the Bedout High. The portion of line 120/05 in Figure 13 shows:

- the structure at the location of the Lagrange 1 well that terminated into probable Late Permian to Early Triassic aged igneous rocks, and
- that the Triassic onlapped against the Bedout High in the Bedout Sub-basin.

The geological evolution of the Bedout High is thought to be as follows:

Stage 1: The Bedout High is an Alice Springs Orogeny aged fold, with probable thrust and other style faults present, that was uplifted during this phase and then underwent erosion during the Late Carboniferous. Late Carboniferous glaciation may have also shaped this feature.

Stage 2: The High was then onlapped by the Permian. Towards the end of the Permian, coincident with the Bedout Movement, it was intruded by Late Permian to Early Triassic volcanic igneous rocks. Both Lagrange 1 and Bedout 1 reached total depth in these volcanics. It is possible that Permian rocks may have been deposited across the feature and eroded prior to the volcanic episode, however the current interpretation agrees with other contacts seen regionally. It is probable that little erosion took place on the high point of the structure following the volcanic event, as volcanic ash layers have been preserved.

Stage 3: Time slice TR1 onlapped the Bedout High that was still a mild topographic high, followed by deposition of time slices TR2-TR3 with some erosion occurring during the Mid-Triassic Movement.

Stage 4: Time slices TR4 and TR5 were probably deposited and later removed during the Fitzroy Movement. Remnants are expected to be present on the edge of the Bedout High. Time slice TR6 is not thought to have been deposited as structural uplift occurred on the Bedout High, during the early time slice TR6 Fitzroy Movement, and

Stage 5: Finally the Jurassic, Cretaceous and Tertiary were deposited over the High which was still influencing deposition in the Cretaceous as evidenced from the Cretaceous isochron maps.

The portion of line 120/04 in Figure 14 shows:

- the structure at the location of the Lagrange 1 well that terminated into Late Permian to Early Triassic aged extrusives,
- that there is a very thin Triassic cover over the high overlain by a more uniform Mesozoic cover, and

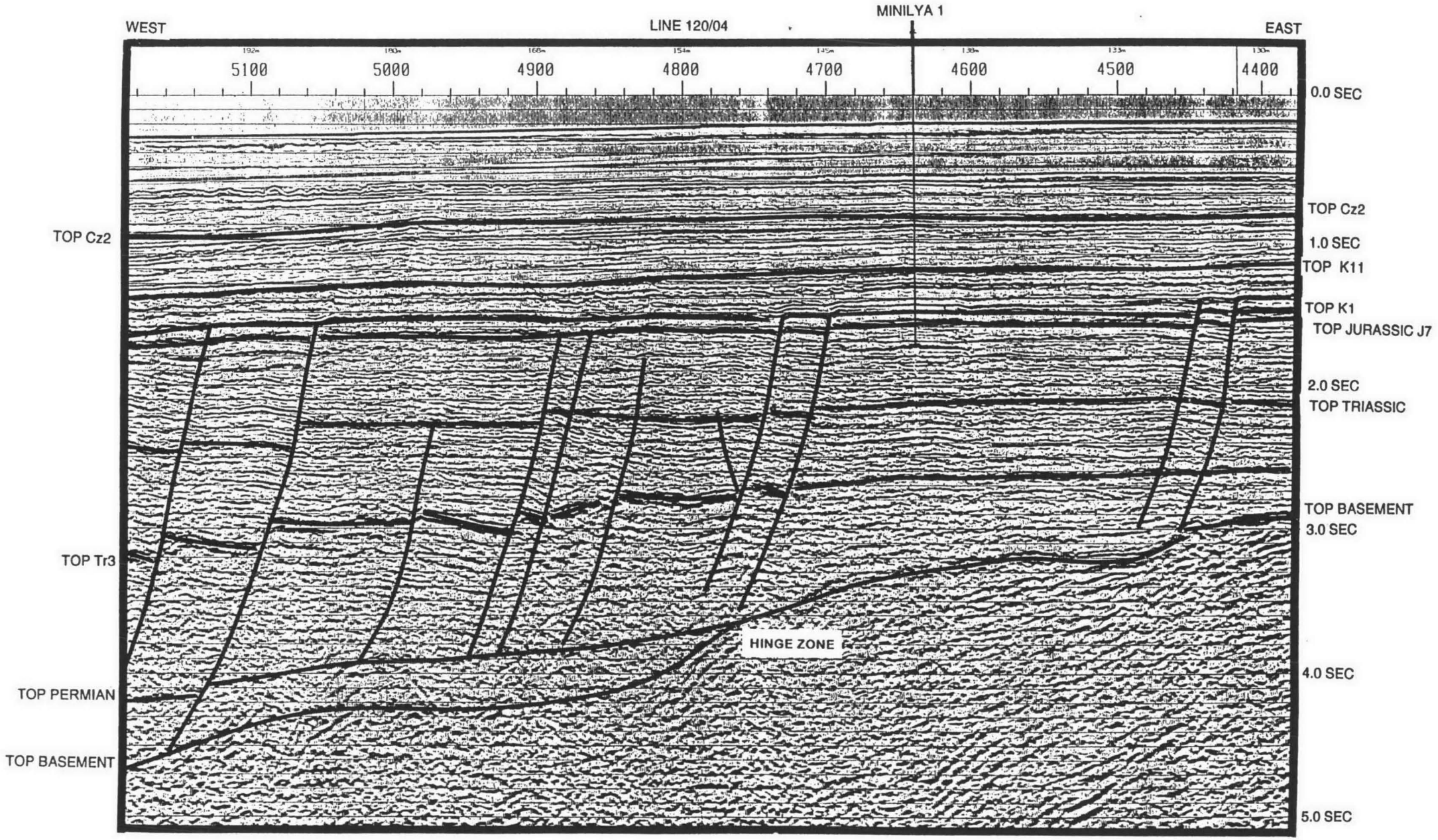


FIGURE 11: SEISMIC REPRESENTATION OF A HINGEZONE, FAULTING INTENSITY VARIATION & MINILYA 1, WEST BEDOUT SUB-BASIN, LINE 120/04.

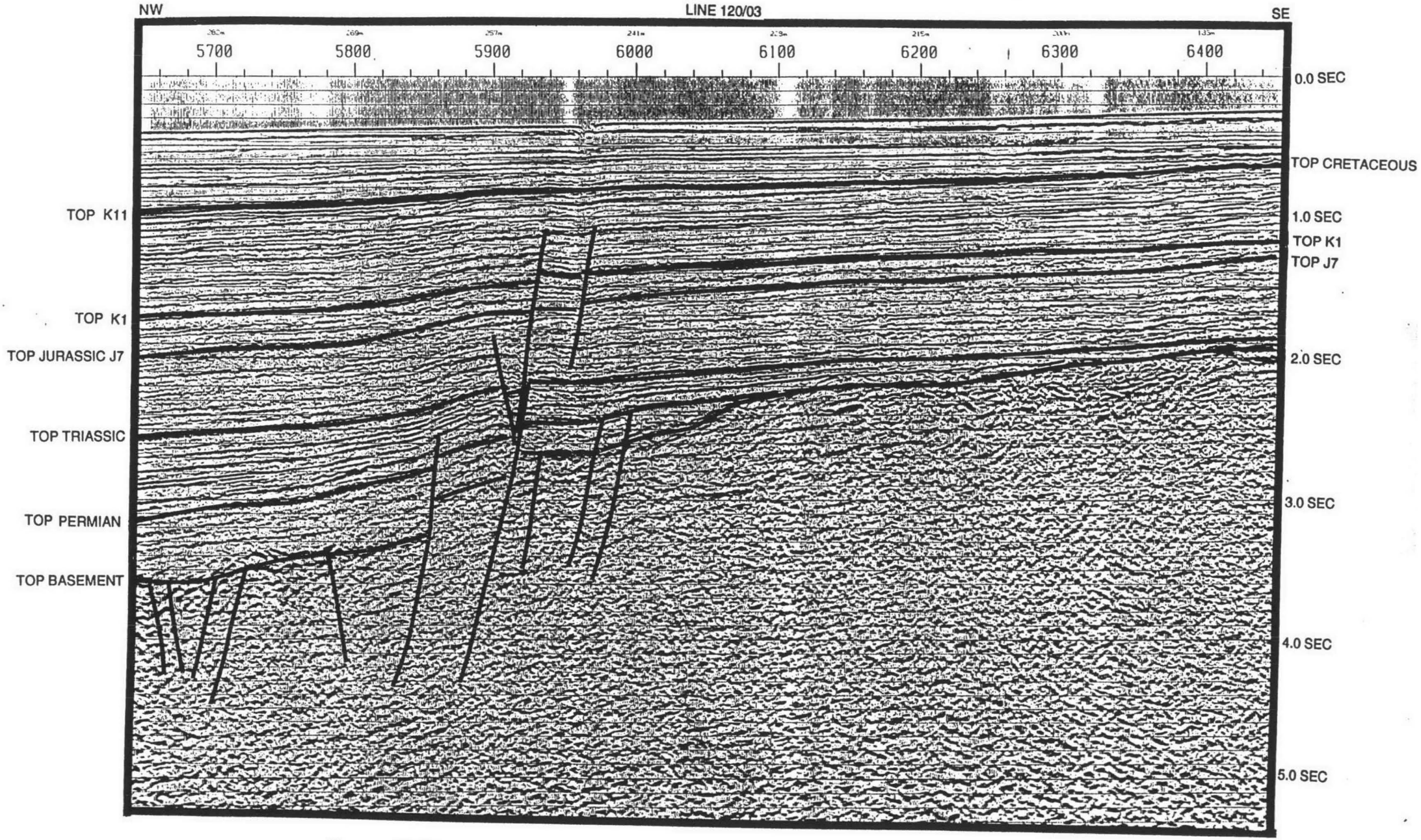


FIGURE 12: SEISMIC REPRESENTATION OF THE NORTHERN CONTACTS OF THE BROOME PLATFORM, ROWLEY SUB-BASIN, LINE 120/03.

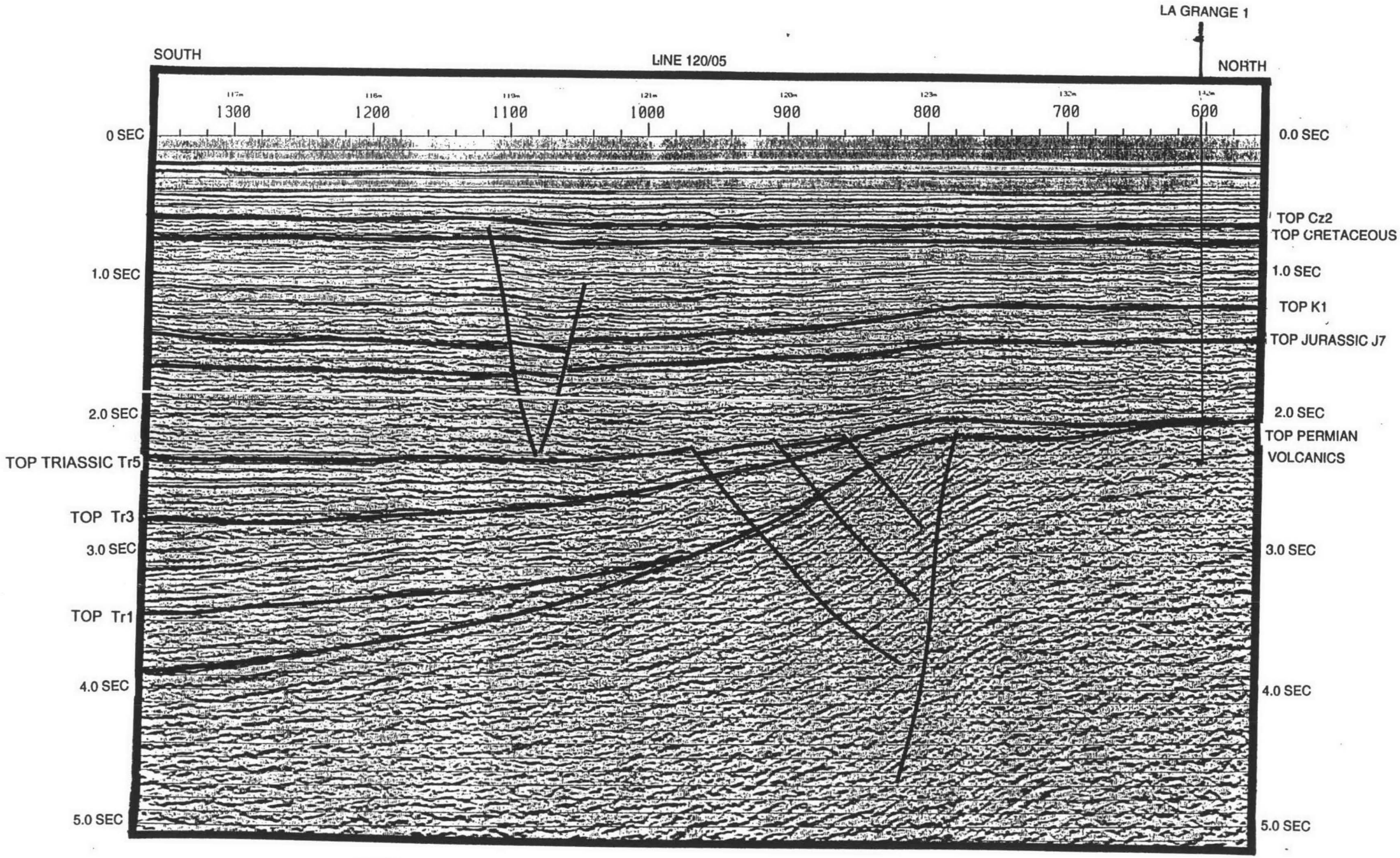


FIGURE 13: SEISMIC REPRESENTATION OF THE SOUTHERN CONTACTS OF THE BEDOUT HIGH, LINE 120/05.

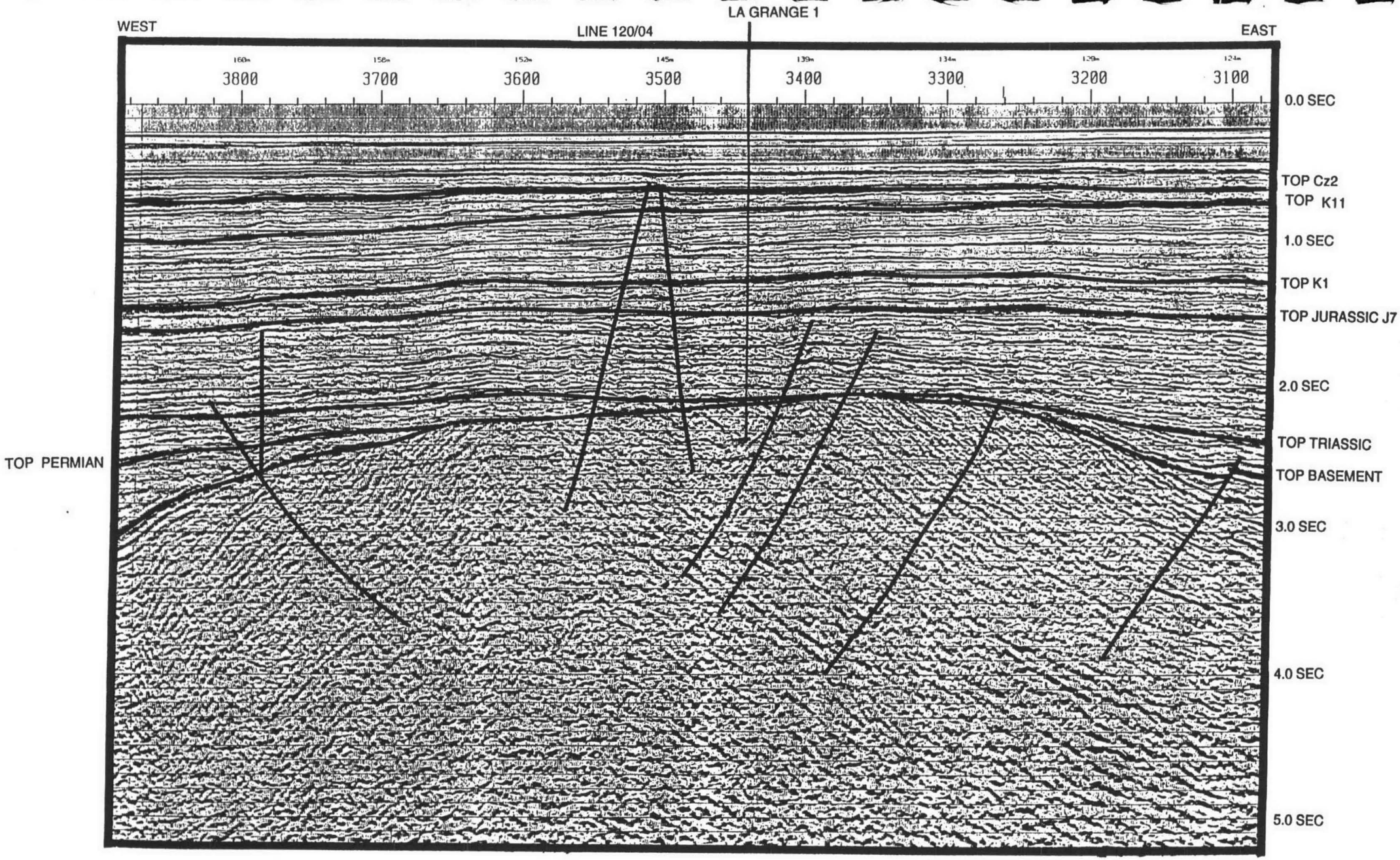


FIGURE 14: SEISMIC REPRESENTATION OF THE BEDOUT HIGH & LAGRANGE 1, LINE 120/04.

- isolated strong dipping reflectors below the total depth of the well of probable Palaeozoic origin that were uplifted during the Alice Springs Orogeny. The surface was then further peneplained by possible Permo-Carboniferous glaciation and later tectonic and erosional events.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Time slice TR1 in Poissonnier 1 is dominantly an olive to medium grey claystone (the Locker Shale) with an isolated sandstone bed towards the top of the time slice.

THICKNESS VARIATIONS: (SEE ENCLOSURE 14).

Poissonnier 1 intersected 16m. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from Phoenix 1 on line 120/14 in the Beagle Trough), is 1150M. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 700m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 15 & 19).

Globally time slice TR1 is characterised by a relative sea level low but in this area the coastline is interpreted to have transgressed during time slice TR1. Within the time slice there is one globally recognised 3rd order eustatic sea level drop (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a transgression.

In the Dampier Sub-basin, a marine transgression commenced in early time slice TR1. An outer shelf environment covered most of the study area with coastal and very shallow marine environments occurring on the eastern margin.

PALAEOGEOGRAPHY: (SEE ENCLOSURES 15 & 19).

The primary sources used for the palaeogeographic interpretations include the Poissonnier 1 well with interpreted time slice palaeogeography, 6200km of mapped seismic sections, palaeogeographic interpretations from onshore Canning Basin wells and outcrop and palaeogeographic interpretations from the adjacent Browse Basin and Dampier Sub-basin modules (Spencer et al, 1993; Wilmot et al , 1993). Secondary sources are from AGSO(BMR), industry and university published work.

It is interpreted that the Late Permian to Early Triassic time slice TR1 Bedout Movement was one of a number of tectonic movements involved in the initial breakup of Gondwana, with local and regional readjustment phases following. The topography in the module area is expected to have been more pronounced relative to later time slices, with depositional lows filling with marine sedimentation and onlap occurring on the emergent land surfaces.

A number of these landmasses can be interpreted in the Rowley Sub-basin and Offshore Fitzroy Trough. The largest of these in the Rowley Sub-basin could have an alternative interpretation if the base of the Triassic was interpreted to be deeper.

Any landmass to the north of the Cossigny and Beagle Troughs is as yet unsubstantiated. This area is only known to have been a topographic high from time slice TR5 (Blevin et al, 1993). Time slice TR1 is absent in Bedout 1 and Lagrange 1, but on seismic onlaps the Bedout High, which is interpreted to have been a topographic high attached to the Broome Platform and the Pilbara Block forming one landmass.

Marine to land environments are interpreted in the very northwest part of the palaeogeographic map (future Argoland), directly over what is present day oceanic crust. Argoland is the name given to the landmass that separated from the Australian plate during the late Callovian, and consists of what is today West Burma and northwest Sumatra, with probably other undetected but still preserved landmasses (Metcalfe, 1993).

The onlap edges of time slice TR1 are more apparent relative to other time slices due to larger variations of topographic relief following the Bedout Movement. Time slice TR1 was intersected in one well (Poissonnier 1) but could not be tied around the basin due to its weak signature in this area and lack of available seismic sections through this particular well. Areas of mapped onlap and depositional hinge-zones are shown on the map.

The deeper parts of Triassic and Jurassic marine seaways, when present in the module area, have been taken to originate from the Kangaroo Syncline, occasionally linked to the Dampier Sub-basin and northern Dixon Sub-basin, both west of the module area, and from the Browse Basin to the northeast. The location of these seaways have been highgraded where possible at the location of present structural lows, sometimes where onlap is visible, and biased to a recognised NE-SW azimuth for tectonic grain and depositional axes. The thick marine shales in Poissonnier 1 and the more open marine environment interpreted in the Dampier Sub-basin (Spencer et al, 1993) give credence to seaways in the southwest corner of the map.

The Blina Shale of the onshore Wallal-Samphire Embayment is Smithian age (BMR 1981, fig 28). It straddles both the TR1 and TR2 time slice zonations but most likely represents time slice TR1 and the earlier part of time slice TR2. The Wallal Embayment is therefore interpreted as a shallow marine embayment that accumulated a relatively thin section during time slice TR1 and early time slice TR2 .

The Blina Shale, Millyit, Erskine and Culvida Sandstones of the onshore Fitzroy Trough are interpreted as being from Scythian to Anisian age and are thought to correspond to time slices TR1 and TR2 (BMR, 1981). The Millyit sandstone is thought to be a facies equivalent of the Blina Shale during time slice TR1 and is interpreted as a delta complex. An estuarine environment is also interpreted for the onshore Fitzroy Trough. There appears to be a NW-SE depositional grain from the distribution of Triassic sediments on the onshore Fitzroy Trough. The Offshore Fitzroy Trough was a site of thin shallow marine deposition during time slice TR1. Sediments of this age though thought to be present in lows, were not intersected in any of the Fitzroy Trough or Pender Embayment wells. At these locations time slice TR1 sediments were probably eroded during the Fitzroy Movement.

Mafic intrusions of tholeiitic affinity classed as dolerites, microgabbros and basalts have been identified in a number of wells and mapped on seismic (Reeckmann et al, 1984). These have been intersected in Minjin 1, Pearl 1, Wamac 1, Bedout 1 and Lagrange 1. Ages determined from K/Ar and fission track dating range from Late Permian to Early Jurassic clearly suggesting difficulty in allocating an accurate age. In Lagrange 1 early time slice TR2 sediment immediately overlies material described as volcanic ash. The implication is that little erosion has taken place since the aerial ash deposits were covered. If this interpretation is correct it implies a late time slice TR1 to early time slice TR2 age for the volcanics, that is coincident with the Bedout Movement. This assumes that the extrusives and intrusives define a single volcanic event.

The adjacent Dampier Sub-basin to the south saw some volcanism in the form of rhyolites of a similar age. It was also a time of a major marine transgression as evidenced from thick marine shales with minor limestone interbeds. The sand content increases in the northern part of the Dampier Sub-basin, suggesting probable landmasses extending eastwards into the current module area (Spencer et al, 1993). The Locker Shale and Mungaroo Formation interface was diachronous and at any particular time, the facies boundary between the marine shales and the fluvio-deltaic environments was irregular in plan view.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

There is no detected source within this time slice.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

No shows have been recorded and no porosity and permeability data exist.

PROSPECTIVITY: (SEE ENCLOSURE 3).

At present no source rocks have been recognised in time slice TR1 but with only one control point, Poissonnier 1, it is possible to speculate on potential source rock locations. It is reasonable to expect that deeper more established troughs may be conducive to the preservation of source rocks. Such areas have not been detected in this study, due perhaps to the studies regional extent and the limited number of seismic lines used. However the pre-Triassic surface is interpreted to be folded and eroded, and to have considerable topographic relief. Such features enhance the probability that local areas of restricted marine circulation with potential source facies exist. Poissonnier 1 shows that minor reservoir potential exists.

Time slice TR1 is a regional seal facies on the underlying Palaeozoic section. It may possess some currently mature source potential in localised areas. Reservoir potential is low and the overall prospectivity is therefore poor.

Speculative shallow marine horst blocks are interpreted in the Outer Beagle Platform. Onlapping sand fringes which could form potential stratigraphic traps may be associated with those horst blocks that were emergent.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

Time slice TR1 short lived low stand fans and incised valley fills may exist within an accepted high stand regime on the North West Shelf, but such plays have not been recognised by current work within this area although they have been recognised in the Barrow Sub-basin.

Stratigraphic traps may exist in the Rowley and Dixon Sub-basins where lower delta plain environments have been interpreted. In particular sediments onlapping a high feature in the Outer Rowley Sub-basin may have stratigraphic potential (see enclosure 15).

TIME SLICE TR2:

EARLY TRIASSIC: LATE SCYTHIAN TO EARLY ANISIAN (244.5 TO 240.5 MA).

PETROLEUM SYSTEM: GONDWANAN 2.

The Perth Basin is the only place in the Gondwanan Petroleum System where a proven oil source exists in the earliest Triassic, present there in marine sedimentary facies. The Locker Shale does not appear to be a potential source rock in the module area. Although TOC levels are often high, the kerogen is dominantly inertinite and has a low HI. There remains a remote possibility that more distal, as yet unencountered facies, could have source potential.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Locker Shale and Mungaroo Formation (Beagle Sub-basin) are interpreted as diachronous (Blevin et al, 1994).
- The Locker Shale and Keraudren Formation (Offshore Canning and Roebuck Basins) are interpreted as diachronous (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICES: (SEE ENCLOSURE 3).

Defined as equivalent to the *T.playfordii* spore pollen zone.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bruce 1/Poissonnier 1: *T.playfordii* (B5),
- Bedout 1: *T.playfordii* (B2),
- Phoenix 1: *T.playfordii* (D4/D5),
- Phoenix 2: *T.playfordii* (B2/B4), and
- Keraudren 1: *T.playfordii* (B4).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of Greater Pangea. Time slice TR2 is thought to be a tectonically quiescent interval. Depositional hinge zones are present north of the Bedout High and west of the Bedout Sub-basin. Time slice TR2 is conformable with both time slices TR1 and TR3. Time slice TR2 has poor palynological control and consequently the top and base are based on log character correlations. The younger part of the time slice TR2 is substantially less marine than time slice TR1. The seaways have reduced in size and a range of fluvial to lower shoreface environments are now present. Typical clastic lithology's included sandstone to claystone and minor coal with secondary calcareous claystones and fossil beds. Oil and gas indications have been recorded in Phoenix 1 and Poissonnier 1. Time slice TR2 is both a reservoir and intraformational or regional seal unit. Mature identified source exists in west Bedout Sub-basin.

TECTONICS (SEE ENCLOSURE 1, 3 & FIGURE 2).

Regional:

Australia was part of a Greater Pangea (Baillie et al 1994).

Local

Two probable depositional hinge zones are present NNW of the Bedout High and on the western side of the Bedout Sub-basin (Enclosure 16). These may be associated with fracture systems of the Bedout Movement, and or reflect a distinct variation in the rheological properties of two basement provinces in the underlying crust (see time slice TR1 section for details).

Line 120/04 extends WNW from the Phoenix wells across the Outer Beagle Platform and terminates in the Dixon Sub-basin. The portion of line 120/04 in Figure 15 shows:

- the structure at the location of the Phoenix 1 well that terminated into time slice TR2 Triassic rocks, and
- the complex structural fault systems present here.

Line 120/05 extends NNE from the Lambert Terrace across the Bedout Sub-basin to terminate on the Bedout High. The portion of line 120/05 in Figure 16 shows:

- the onlapping relationship of time slices TR1 and TR2 in the Bedout Sub-basin, and
- the structure at the location of the Keraudren 1 well that terminated in time slice TR2 aged rocks. There is a lack of significant rollover at the basal Triassic level and only mild closure, if any, at top Triassic level casting doubt on whether Keraudren 1 was a valid test, and

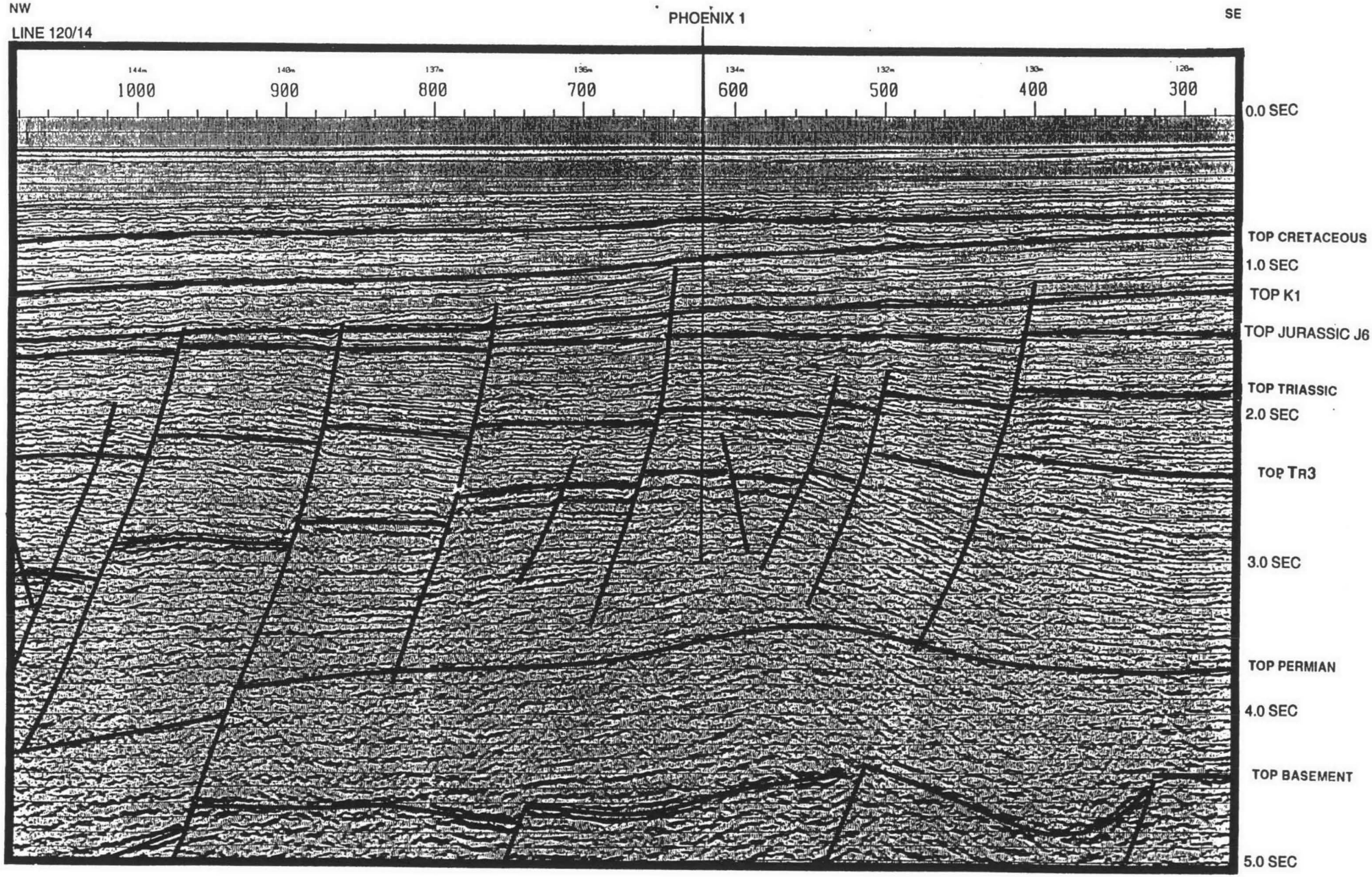


FIGURE 15: SEISMIC REPRESENTATION OF FAULTING/HINGEZONE CONTACTS & PHOENIX 1, WEST BEDOUT SUB-BASIN, LINE 120/14.

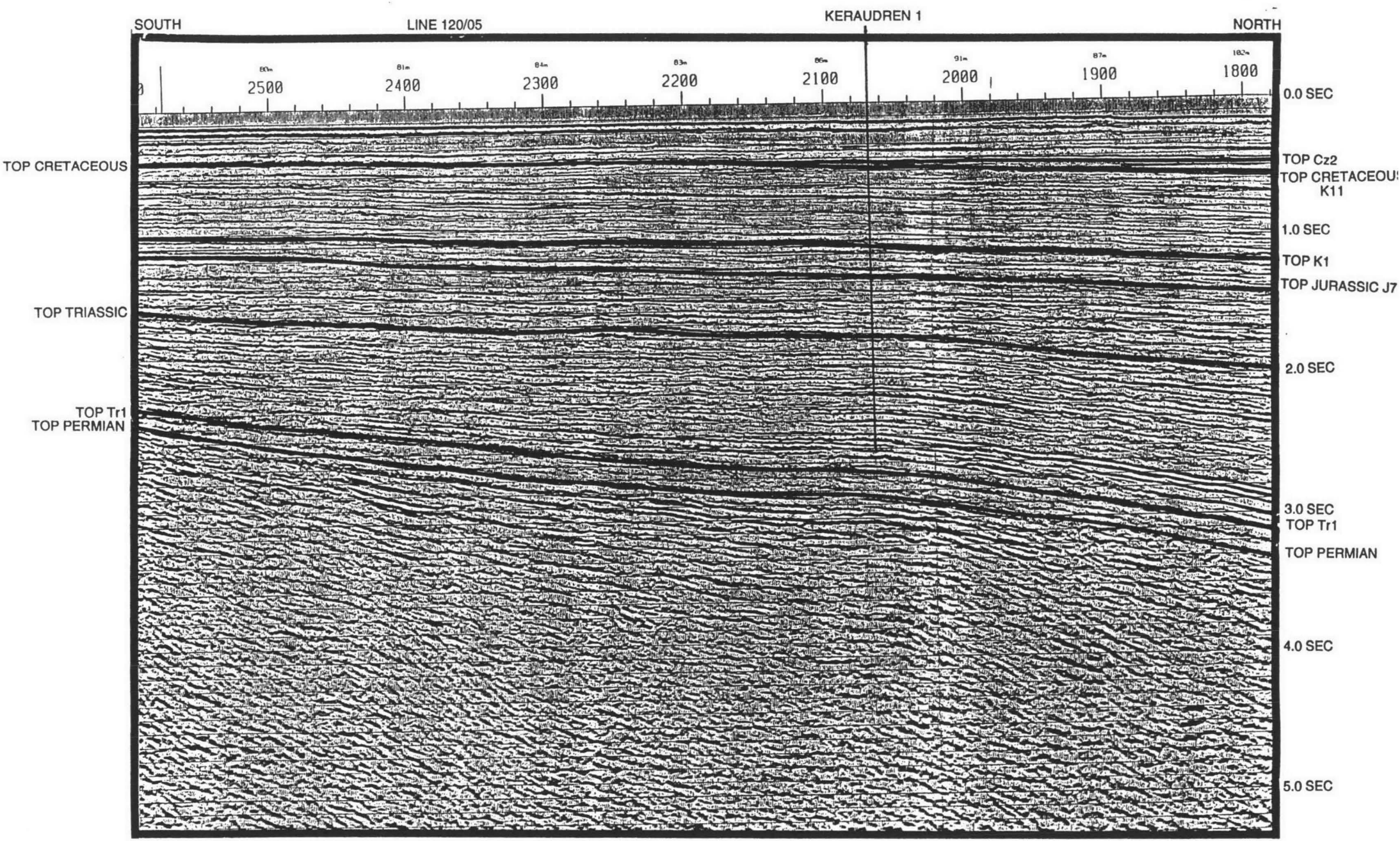


FIGURE 16: SEISMIC REPRESENTATION AT KERAUDREN 1, BEDOUT SUB-BASIN, LINE 120/05.

- isolated strong reflectors, possibly coals, within the Triassic and Jurassic sequences. These are examples of seismic signatures used to indicate potential lakes, swamps or lagoons, both here and in other time slices of the module area.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Beagle Trough and Bruce Terrace: In Bruce 1 and Poissonnier 1, the section is a massive claystone with minor interbedded sandstones that grades to siltstone towards the top of the time slice. The claystone is brownish or olive or medium grey. The sands are light olive to medium grey, dominantly very fine to medium, well sorted, subangular to subrounded with a trace to good porosity. A trace of calcilutite has also been noted.

West Bedout Sub-basin: In Phoenix 1 and 2 the section is dominantly a massive claystone with minor to substantial beds of sandstone and coal. Phosphatic, ferruginous and manganiferous nodules, dolomitic and calcareous streaks, macro fossils and glauconite, together with beds of muddy limestone are present towards the base of the unit indicating marine conditions.

Bedout High - Bedout Sub-basin: Bedout 1 and Keraudren 1 are very sandy intervals. Bedout 1 sands are white to dark greenish grey, a reworked product of the Bedout High igneous bodies intermixed with siltstone and arenaceous claystone. Keraudren 1 is dominantly sandy with medium to substantial beds of siltstone and claystone. Both wells show less marine influence within the sediments than in time slice TR1.

THICKNESS VARIATIONS: (SEE ENCLOSURE 14).

Two wells intersected time slice TR2. Poissonnier 1 intersected 224m whilst Bedout 1 drilled through 41m. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from Phoenix 1 on line 120/14 in the Beagle Trough), is 1650m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 950m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 16).

Globally time slice TR2 is characterised by a relative sea level low. There are within time slice TR2 two globally recognised 3rd order eustatic sea level drops (Haq et al, 1987). The coastline is interpreted to have regressed in the module area. This agrees with Struckmeyer & Brown (1990) who suggest a transgressive phase during time slice TR1 that peaked in time slice TR1, coincident with the maximum development of the Locker Shale (a middle to outer shelf siltstone and claystone) which then regressed during the later part of time slice TR2. This is also the case in the Dampier Sub-basin.

During Time slice TR2 and early Time slice TR3 a fluvial system built into the area. The sea within the greater Westralian Superbasin (Yeates et al, 1987) has regressed since time slice TR1 and is thought to be no longer directly linked to the Tethys. Instead the overall situation is thought to be more like an epicontinental sea. Regional open marine conditions did not return until the end of time slice J7. Until then only intermittent transgressions or short lived open marine incursions in an infra basin setting occurred.

PALAEOGEOGRAPHY: (SEE ENCLOSURES 16, 19).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, palaeogeographic interpretations from onshore Canning Basin wells and outcrop and palaeogeographic interpretations from the adjacent Dampier Basin module (Spencer et al, 1993). Secondary sources are from AGSO(BMR), industry and university published work.

It is interpreted that the Late Permian to Early Triassic Bedout Movement was one of a number of tectonic movements involved in the initial breakup of Gondwana, with local and regional readjustment phases following. As in time slice TR1, the topographic relief is more pronounced than in later time slices; the lows are still filling with marine sediment that onlapped onto relatively young emergent land surfaces.

A number of these landmasses can be seen in the Rowley Sub-basin and outer Offshore Fitzroy Trough, some of which are conceptional and others based on seismic. They are shown to have reduced in area since time slice TR1 due to erosion and sediment infill.

Marine to land environments are interpreted in the very northwest part of the palaeogeographic map (future Argoland), directly over what is present day oceanic crust. Argoland is the name given to the landmass that separated from the Australian plate during the late Callovian, and consists of what is today West Burma and northwest Sumatra, with probably other undetected but still preserved landmasses (Metcalfe, 1993).

The deeper parts of the Triassic and Jurassic marine seaways, when present in the module area, have been taken to originate from the Kangaroo Syncline, Dampier Sub-basin and Dixon Sub-basin (all lying west of the module area) and from the Browse Basin to the northeast. These seaways have been interpreted to be

located in present structural lows, sometimes where onlap is visible and biased to a recognised NE-SW azimuth for tectonic grain and depositional axes.

The Blina Shale of the onshore Wallal-Samphire Embayment is Smithian age (BMR 1981, fig 28). It straddles both the TR1 and TR2 time slice zonations but most likely represent time slice TR1 and the earlier part of time slice TR2. The Wallal-Samphire Embayment is therefore interpreted as a shallow marine embayment that accumulated a relatively thin time slice TR1 and early time slice TR2 section beyond the depositional hinge zones.

The Blina Shale, Millyit, Erskine and Culvida Sandstones of the onshore Fitzroy Trough are interpreted as being from Scythian to Anisian age and are thought to correspond to time slices TR1 and TR2 (BMR, 1981). A marine fairway, responsible for deposition of marine sediments in the Offshore Canning Basin is regressing, via the Offshore Fitzroy Trough, to the west. The shallow marine deposition of time slice TR1 is being replaced by a lower delta plain to restricted marine environment. Time slice TR2 deposition was restricted and was later reworked as evidenced from all the Fitzroy Trough wells having no time slice TR2 preserved. The Erkine and Culvida Sandstones are thought to be facies equivalent of the Blina Shale during time slice TR2. They are interpreted as fluviatile sediments prograding over the original time slice TR1 aged estuarine to deltaic environments. There appears to be a NW-SE grain from the distribution of Triassic sediments in the onshore Fitzroy Trough.

In the Dampier Sub-basin the Locker Shale and Mungaroo Formation interface is diachronous with the facies boundary between the marine shales and the fluvial-deltaic sands being irregular in plan view. The time slice TR2 regression continued into TR3. Significant fluvial-deltaic sediments were sourced from the ancient equivalents of the Pilbara River Systems.

Intrusives have been identified in wells, and on seismic, on the Pender Terrace and Fitzroy Trough. These intrusives are though to be mainly time slice TR1 or upper Permian age but may extend into basal time slice TR2.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%.

The samples meeting these criteria cover the following ranges 0.54<TOC<7.56, 4.23<S2<18.2, 169<HI<303 and 431<Tmax<436 indicating a dominantly gas to light oil source rock.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Oil indications were recorded in Poissonnier 1. Oil and gas indications were recorded in Phoenix 1 and 2. The following lists the wells and summarises the porosity data for them:

Phoenix 1	2.9% < porosity av < 10.1% (core), and
Phoenix 2	3.0% < porosity av < 10.33% (logs), 0.8% < porosity av < 15% (core).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- It is speculated that the deeper troughs would be the most favourable location for the preservation of source rocks. Such areas have not been detected in this study, due perhaps to the studies regional extent and the limited number of seismic lines used. However the pre-Triassic surface is interpreted to be folded and eroded, and to have considerable topographic relief. Such features enhance the probability that local areas of restricted marine circulation with potential source facies exist.
- Oil and gas source potential exists in the west Bedout Sub-basin and is presently mature.
- Reservoirs are found in the Beagle Trough, west Bedout and Bedout Sub-basins and Bedout High. It is probable that these reservoirs may be sealed adequately by intraformational time slice TR2 seals.
- A regional seal on time slice TR2 is present in the west Bedout Sub-basin, whilst intraformational seals are found in the Beagle Trough and Bedout Sub-basin. These features suggest that the prospectivity of time slice TR2 is fair.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Beagle Trough:** The southern extent of the Beagle Trough, the North Turtle Hinge Zone and Bruce Terrace have potential traps if identified reservoirs are adequately sealed by what has been interpreted from the Bruce 1 and Poissonnier 1 wells to be local seals. The presence of a Triassic source in this area is speculative but this section and deeper sections are currently mature.
- **West Bedout Sub-basin:** Triassic time slice TR2 clastic reservoirs sourced by a Lower Triassic source and sealed by regional seals may be a viable play.

TIME SLICE TR3:

EARLY TRIASSIC: LATE ANISIAN TO EARLY LADINIAN (240.5 TO 236.0 MA).

PETROLEUM SYSTEM: UPPER GONDWANAN 2, LOWER WESTRALIAN 1.

The Perth Basin is the only place in the Gondwanan Petroleum System where a proven source exists in the earliest Triassic, present there in marine sedimentary facies (Locker Shale equivalent). The Locker Shale does not appear to be a potential source rock in the module area. Although TOC levels are often high, the kerogen is dominantly inertinite and has a low HI. Although the Locker Shale may extend into lower time slice TR3 it is not a dominant lithofacies within this time slice. The Locker Shale is a major regional seal on older section.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Cossigny Member and Mungaroo Formation in the Beagle Sub-basin are interpreted to be diachronous (Blevin et al, 1994).
- The Locker Shale and Keraudren Formation in the Roebuck and Offshore Canning Basins are interpreted to be diachronous. The Cossigny Member that was initiated in time slice TR3 also extends into time slice TR4 (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICES: (SEE ENCLOSURE 3).

The base of time slice TR3 is the boundary of spore pollen zones *S.quadrifidus* and *T.playfordii* and the top is the top of dinoflagellate zone *S.ottii*.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bruce 1: *S.quadrifidus* (B5),
- Poissonnier 1: no palaeontological control,
- Bedout 1: *S.quadrifidus* (D5),
- Lagrange 1: *S.speciosus* (D5) thought to be down hole cavings,
- Phoenix 1: *S.quadrifidus* (D4/D5),
- Phoenix 2: *S.quadrifidus* (B1), and
- Keraudren 1: *S.quadrifidus* (B4).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Pangea at the start of time slice TR3. Time slice TR3 is interpreted to encompass a pre-breakup structural phase of the Pangean continent. Final breakup of Pangea commenced in the Norian. Depositional hinge zones were present north of the Bedout High and west of the Bedout Sub-basin. Time slice TR3 is conformable on time slice TR2 but is unconformably overlain by time slice TR4, as determined from seismic. Time slice TR3 has poor palynological control and as a consequence the time slice top and base are determined on log character correlations. Time slice TR3 is substantially more marine than time slice TR2 with a major seaway present across the whole module area and the Dixon Sub-basin. This is interpreted from the presence of strong reflectors (probably carbonates) and the development of the carbonate Cossigny Member in several wells. A range of fluvial to lower shoreface environments is also represented in time slice TR3. Clastic lithology's include sandstone to claystone, minor coal and some calcareous claystones. Oil and gas indications have been recorded in Phoenix 1. Time slice TR3 is both a reservoir and intraformational seal unit. Mature source exists in the west Bedout Sub-basin.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of greater Pangea (Baillie et al, 1994). Structural phases occur in the Middle Triassic time slice TR3; precursor events to the breakup of the Pangean continent.

Local

Colwell & Stagg (1994) interpret a localised event at the time slice TR3-TR4 boundary of Ladinian age within the Roebuck Basin referred to as the Mid Triassic Movement (Enclosure 3). Dredging on the present continental slope, in the canyons and shelf break areas has established that Middle Triassic rocks crop out (Colwell et al, 1994). Rocks of this age are prevalent on the outer continental slope on lines 120/01 and 120/03 (Enclosure 68, Figure 17) where distinctive separate seismic packages can be seen and correlated.

The portion of line 120/01 in Figure 17 shows:

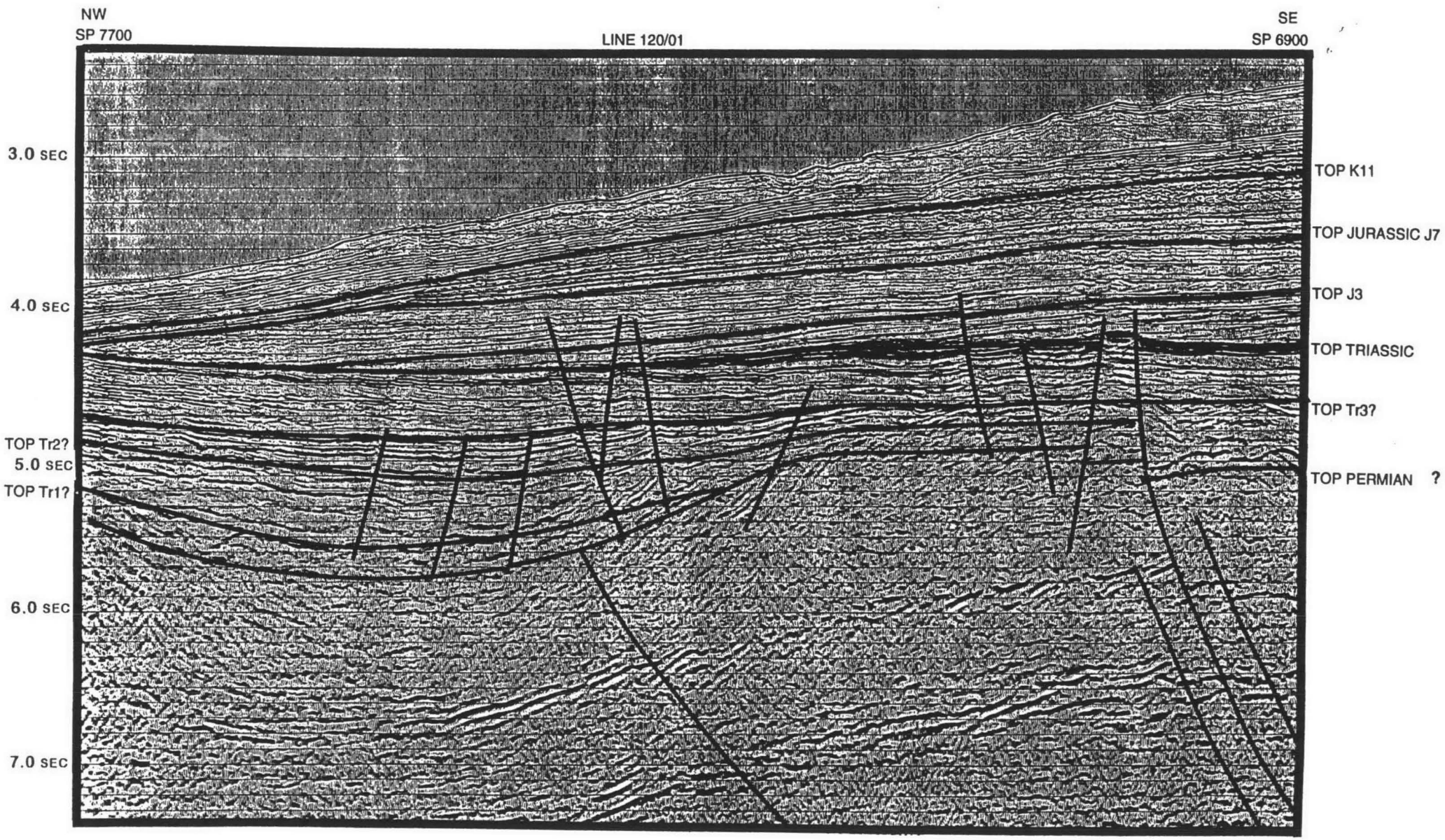


FIGURE 17: SEISMIC REPRESENTATION OF JURASSIC DOWNLAP ONTO A SUBMERGED TRIASSIC PLATFORM & TRIASSIC FEATURES, OUTER ROWLEY SUB-BASIN, LINE 120/01.

- the unconformity at the top of time slice TR3 on the outer Rowley Sub-basin (note the truncational erosion on this surface, also see figure 13 on the Bedout High). Similar truncational erosion can be deduced in the Offshore Fitzroy Trough (Enclosures 15-18, 21-22). Deltaic deposits prograded from the onshore Canning Basin during early time slice TR3 (BMR, 1981). However this section is absent in Wamac 1 and Lacepede 1A. It is interpreted that time slice TR3 was eroded from the Lacepede 1A and Wamac 1 areas, before the deposition of time slice TR5 which is present in Wamac 1. This implies a structural episode between time slice TR3 and late time slice TR5. This is the Mid Triassic Movement that would have eroded time slice TR3 as well as time slices TR1 and TR2 which are not present in Wamac 1 and Lacepede 1A,
- the high character strength and continuity of reflectors characteristic of this time slice, and
- that the Outer Rowley Sub-basin may have been influenced by rejuvenated Triassic aged wrench faults making depositional/palaeogeography interpretations difficult.

Line 110/05 extends WNW from the Minilya 1 well across the Outer Beagle Platform and Thouin Graben. The portion of line 110/05 in Figure 18 shows the good Cossigny Member carbonate reflector. This has been used to regionally divide up the Triassic and help interpret the palaeogeography of the middle Triassic. Strong top time slice TR3 carbonate reflectors are also seen in Figure 19.

Time slice TR3 structuring is obvious in the outer Rowley Sub-basin, Offshore Fitzroy Trough, Bedout High and Outer Beagle Platform but less evident in the west Bedout, Bedout, inner Rowley and Beagle Sub-basins. Its influence within the Beagle Sub-basin is uncertain. A time slice TR3 structuring event implies enhanced topographic relief that has ramifications for palaeogeographic reconstructions in the Roebuck Basin and Beagle Sub-basin, in particular a higher variability of environments (enclosure 17). Two probable depositional hinge zones are present NNW of the Bedout High (Figure 20) and on the western side of the Bedout Sub-basin (Enclosure 17). These may be associated with fracture systems of the Bedout Movement, and or reflect a distinct variation in the rheological properties of two basement provinces in the underlying crust (see time slice TR1 section for details). Rejuvenation of these hinge zones may have occurred at the top of time slice TR3, during the Mid Triassic structural phase.

The top of time slice TR3 to the base Triassic TWT isochron map (Enclosure 59) shows:

- the absence of Triassic deposition on the Leveque and Lambert Shelves, Pender Terrace and Broome Platform. The basal Triassic was deposited in the Wallal Sub-basin and Offshore Fitzroy Trough (the Blina Shale). Thinning occurs towards the Lambert Shelf and the Wallal Embayment that is thought to be both erosional and depositional. The thinning onto the Broome Platform is thought to be primarily depositional although a certain degree of localised erosion may have taken place,
- a thinning of the Triassic in the Rowley Sub-basin reflecting depositional thinning as opposed to the uplift and erosional thinning seen in the Bedout Sub-basin. The thin over the Bedout High reflects both erosional and depositional thinning. A depositional hinge zone is here defined to comprise escarpments, embayments and faulted contacts and such depositional hinge zones are mapped, striking N-S, both west and north of the Bedout High,
- that numerous Triassic horst blocks can be expected to be found within the Beagle Sub-basin. Their presence is inferred from the higher intensity structural regime present west of the Rowley Sub-basin and higher variability of contour gradients of the time slice TR3 to base Triassic isochron map, and
- much more gentle thinning throughout the Rowley Sub-basin relative to the Beagle Sub-basin implying reduced structuring in the Rowley Sub-basin.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Bedout High: Bedout 1 has dominantly bell and funnel shaped gamma ray log patterns (sandstone and siltstone) whilst Lagrange 1 contains mainly sandstone. The claystone and sandstone in Bedout 1 is multicoloured, including light greyish red colour, indicating possible subaerial oxidation, although these may be an igneous by-product. Some coal steaks are present.

West Bedout and Bedout Sub-basin: Phoenix 1 and 2 have a massive and uniform claystone base with a serrated gamma ray log pattern in the upper part reflecting sandstone and minor siltstone lithology's. Claystone is 20% whilst the sandstone and siltstone is 80% of this section. Calcilutite and dolomitic limestone (the Cossigny Member) are present in Phoenix 1 at the very top of the time slice. Calcarenites are identified towards the base. Sand (funnel shaped) and black grey shales grade to limestone in Phoenix 2. Keraudren 1 has about 30% sand content, and common funnel shaped gamma ray log patterns.

Beagle Trough/Bruce Terrace: Poissonnier 1 is dominantly sandstone whilst Bruce 1 has equal amounts of sandstone and siltstone (dominantly bell shaped gamma ray log patterns). The sandstones in Bruce 1 are clear to white with some clay matrix and dolomitic cement.

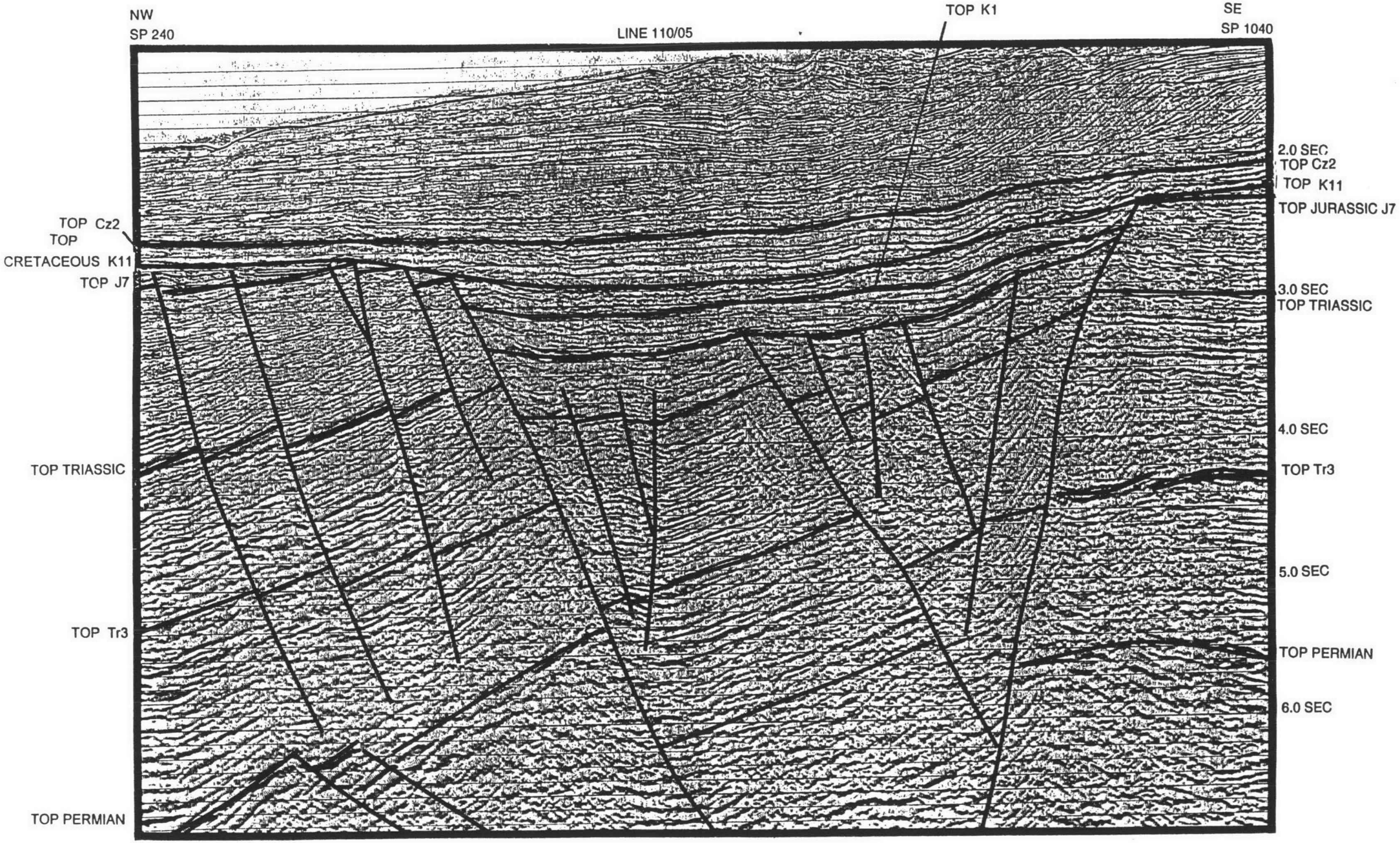


FIGURE 18: SEISMIC REPRESENTATION OF THE THOUIN GRABEN PULLAPART FEATURE, DIXON SUB-BASIN, LINE 110/05.

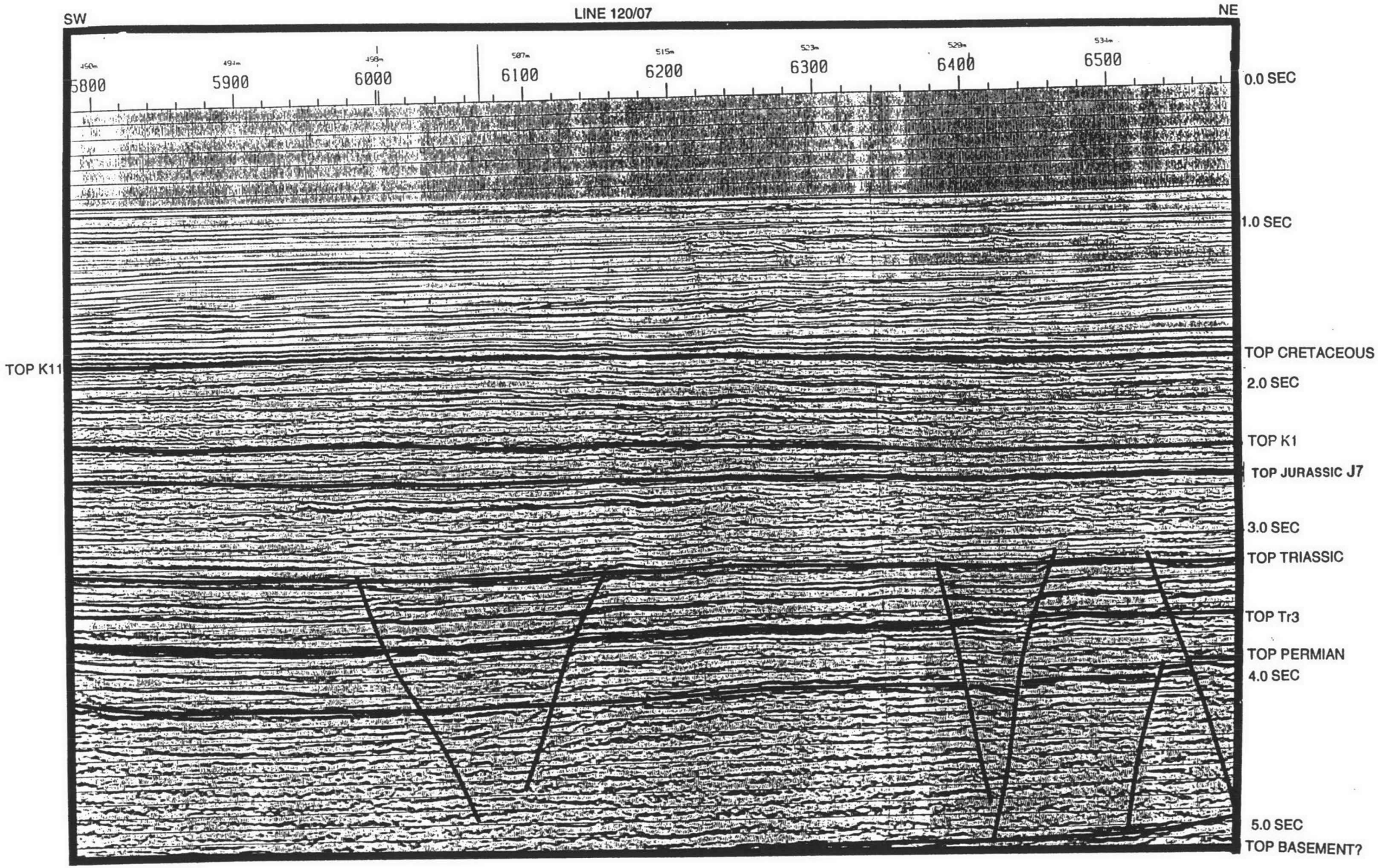


FIGURE 19: SEISMIC REPRESENTATION OF THE ROWLEY SUB-BASIN, LINE 120/07.

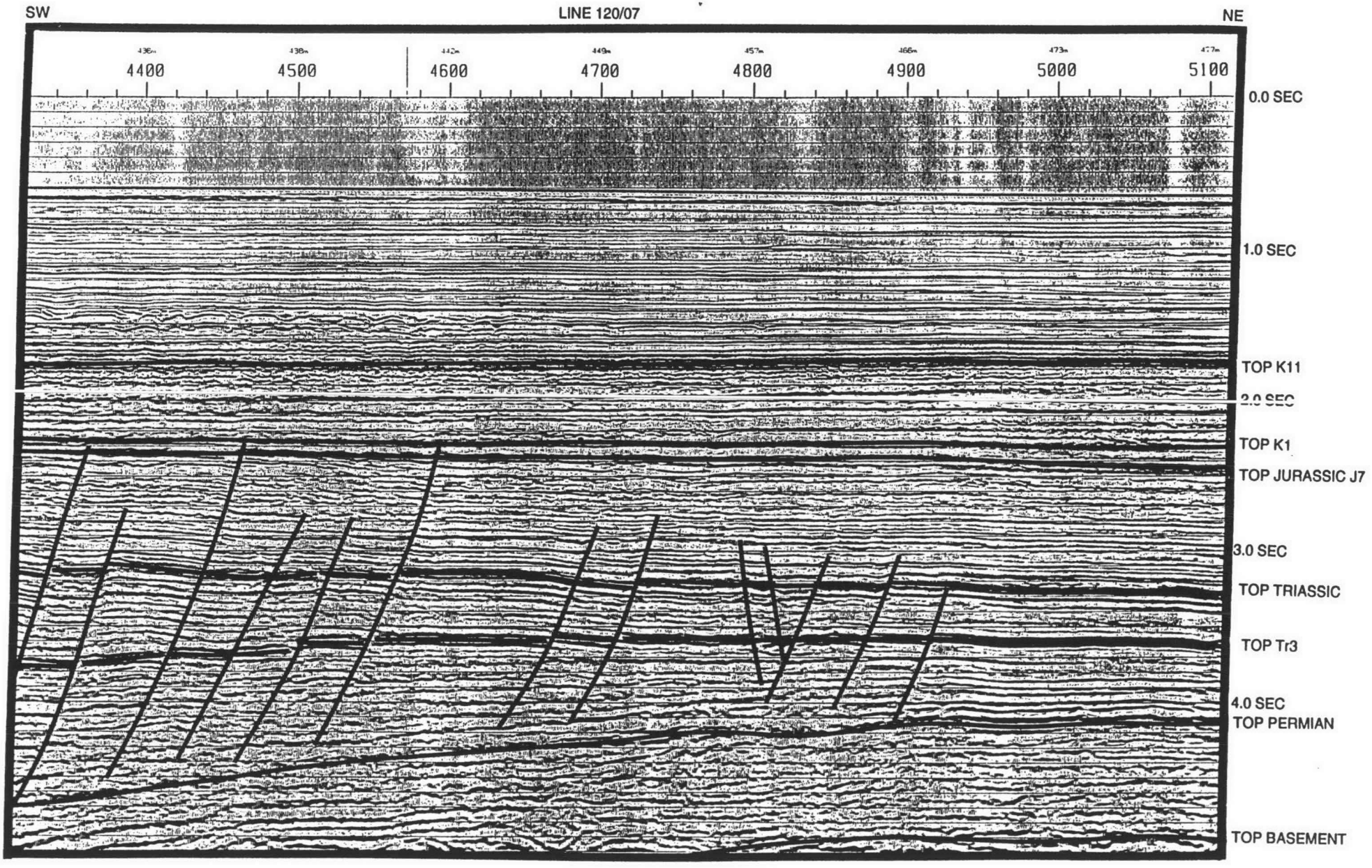


FIGURE 20: SEISMIC REPRESENTATION OF A DEPOSITIONAL HINGE ZONE & FAULTING INTENSITY VARIATION, ROWLEY SUB-BASIN, LINE 120/07.

THICKNESS VARIATIONS: (SEE ENCLOSURE 14).

Thickness ranges from 34m in Lagrange 1 to 279m in Bruce 1 with the bulk of the wells not penetrating the Triassic. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from Phoenix 1 on line 120/14 in the Beagle Trough), is 400m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 500m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 17, 19).

Globally this time slice TR3 is characterised by a relative sea level low but the coastline in the module area is interpreted to have transgressed during time slice TR3. Within time slice TR3 there are two globally recognised 3rd order eustatic sea level drops (Haq et al 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a transgression. The adjacent Dampier Sub-basin saw a rapid regression during the middle of time slice TR3 where paralic, deltaic and fluvial sediments were deposited. The carbonates of the Cossigny Member are diachronous from time slice TR2 in the Dampier Sub-basin to time slice TR3 in the module area.

PALAEOGEOGRAPHY: (SEE ENCLOSURES 17, 19).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, palaeogeographic interpretations from onshore Canning Basin wells and outcrop and palaeogeographic interpretations from the adjacent Dampier Basin module (Spencer et al, 1993). Secondary sources are from AGSO(BMR), industry and university published work.

Marine to land environments are interpreted in the very northwest part of the palaeogeographic map (future Argoland), directly over what is present day oceanic crust. Argoland is the name given to the landmass that separated from the Australian plate during the late Callovian, and consists of what is today West Burma and northwest Sumatra, with probably other undetected but still preserved landmasses (Metcalfe, 1993).

Landmasses that existed in the Outer Rowley Sub-basin during previous time slices have now submerged beneath shallow seas or are low relief paralic landforms.

Triassic and Jurassic marine seaways, when present in the module area, are interpreted to connect to open marine conditions via the Kangaroo Syncline, Dampier Sub-basin and northern Dixon Sub-basin to the west and the Browse Basin to the northeast. The axes of these seaways have been interpreted where possible, to coincide with concurrent structural lows, determined where onlap is visible and biased to a recognised NE-SW azimuth for the inferred tectonic grain. The restricted marine seaways in time slice TR3 are better thought of as epicontinental seas (Yeates, 1987).

Evidence for such shallow seas is in the form of the carbonate rich Cossigny Member present in Cossigny 1, Phoenix 1 and Phoenix 2 and presence of carbonate cement in other wells. The Phoenix 1 well completion report points out the areal extent of a high amplitude reflector which may reflect the extent of the carbonate. Interpretation of the Cossigny Member shows it to be an oolitic to mixed ooid peloid grainstone shoal deposited in very shallow shelf conditions (7 to 10m water depth or less), associated with a back reef facies from a slightly deeper environment (Chapri 1993).

The epicontinental sea is connected from the Dampier Sub-basin area to the Kangaroo Syncline area. Sea level rises and associated transgressions within time slice TR3 are thought to be partly a result of concurrent tectonic events These events are also thought to have established topographic relief by reactivating older features.

Since the time slice shows more marine conditions in the Beagle Trough at this time, it is likely that thin deposits of time slice TR3 existed in part or all of the Wallal Embayment but were later reworked, and or removed. Alternatively some uplift could have occurred in the eastern Bedout Sub-basin essentially isolating the Wallal Embayment so that no deposition occurred. Time slice TR3 deposition is restricted to depositional hinge lines with thin reworked deposition existing beyond these hinge lines.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

No significant source has as yet been identified in this time slice.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Strong oil and gas indications were recorded in Phoenix 1.

The following list summarises the porosity data for the time slice:

Phoenix 1 15%<porosity av<30% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas source potential has been interpreted in the west Bedout Sub-basin and is presently mature.
- Reservoirs are present in the Beagle Trough, Bedout Sub-basin and Bedout High. Any trapped hydrocarbons may leak up into younger Triassic units due to the thinness of the time slice and the sandy nature of overlying time slices TR4 and TR5.
- Intraformational seals are present in the west Bedout and Bedout Sub-basins and the Bedout High.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- Higher risk traps may exist in the **Bedout and Beagle Sub-basins** where intraformational seals would be sealing the sands.
- Higher risk traps may exist in the **outer Offshore Fitzroy Trough** where sands deposited in lower and upper delta plain environments may be intraformationally sealed or regionally sealed by time slice TR4 shales (see enclosures 17 and 18).

TIME SLICE TR4:

MIDDLE TRIASSIC: MID AND UPPER LADINIAN (236.0 TO 231.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 1.

The Westralian Petroleum System is defined and described as..."Middle Triassic to Tertiary in age....The tectonic regime (included)... extension and eventual break-up and seafloor spreading in the Late Jurassic to Early Cretaceous. Reservoirs for giant gas fields...and significant oil fields...include Late Triassic to Middle Jurassic fluvial to deltaic sandstones...(D)eposition of the (Jurassic) source rock (was) in marine anoxic conditions with the contribution of a significant amount of terrestrial organic matter... The Westralian system has thick regional shales so that there is the potential for faults to seal: thus trap types include horst blocks, tilted fault blocks, faulted anticlines as well as simple anticlines." (see M. Bradshaw 1993, pp48).

In the module area, a Ladinian age unconformity occurs at the time slice TR3-TR4 boundary. This provides a structural based datum between the Gondwanan Petroleum System and the Westralian Petroleum System. Time slice TR4 has good oil and condensate shows and is an inferred good source rock on this basis.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Cossigny Member and the Mungaroo Formation (Beagle Sub-basin) are interpreted to be diachronous (Blevin et al, 1994).
- The Keraudren Formation and Cossigny Member are interpreted in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994). An unconformity is interpreted at the base of the Cossigny Member. The member is emplaced within the Keraudren Formation that spans time slices TR1-TR5.

REGIONAL DEFINITION OF TIME SLICES: (SEE ENCLOSURE 3).

Time slice TR4 is biostratigraphically defined by spore pollen zones, upper *S. quadrifidus* and Lower *S. speciosus*. No dinoflagellate zone is recognised within this interval.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slice as *S.quadrifidus* straddles both TR3 and TR4 whilst *S.speciosus* straddles both time slices TR4 and TR5 The age depth plots were used to estimate the best location for the boundary. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bruce 1: *S.quadrifidus* (B5), *S.speciosus* (B5),
- Poissonnier 1/Keraudren 1/Phoenix 2: no palaeontological control, and
- Phoenix 1: *S.speciosus* (D5, B3).

There is an hiatus recognised in both the Browse Basin and Dampier Sub-basin modules at the top of time slice TR4 that is widely recognised as a regional unconformity (Spencer et al, 1993; Wilmot et al, 1993). This Middle-Triassic unconformity is diachronous and appears to be older in the present module area. It defines the boundary between the Gondwanan and Westralian Petroleum Systems. In the Dampier Basin, a sea-level rise commenced.

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Pangea. Depositional hinge zones were present north of the Bedout High and west of the Bedout Sub-basin. The time slice is conformable with time slice TR5 but appears, on seismic evidence, unconformable on time slice TR3. Time slice TR4 has poor palynological control and as a consequence the time slice top and base are based on log character correlation. Time slice TR4 is substantially less marine than time slice TR3, the main seaways having withdrawn to the Kangaroo Syncline and Beagle Trough. A range of fluvial to lower shoreface environments are present in the time slice. Typical clastic lithology's include sandstone to claystone, minor coal and some calcareous claystones. Oil and gas indications have been recorded in Bruce 1 and Phoenix 1 and 2. Time slice TR4 is both a reservoir and intraformational seal unit. Mature source has been identified on the Bruce Terrace and sub-mature source identified in the west Bedout Sub-basin.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of greater Pangea (Baillie et al,1994). Pre Norian structural events occur in the Middle Triassic, precursors to the breakup of the Pangean continent. Uplift and tilting of strata in the Canning Basin to the north, provided the sediment to initiate the widespread Rankin delta, (the fluvio-deltaic

sediments of the Mungaroo Formation), in the Dampier Sub-basin (BMR Palaeogeographic Group, 1990, pp58).

Local

Two probable depositional hinge zones are present NNW of the Bedout High and on the western side of the Bedout Sub-basin (Enclosure 18). These may be associated with fracture systems of the Bedout Movement, and or reflect a distinct variation in the rheological properties of two basement provinces in the underlying crust (see time slice TR1 section for details).

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

West Bedout Sub-basin: Phoenix 1 and 2 have both bell and funnel shaped gamma ray log patterns. The percentage of sandstone and siltstone is about 80%, with 20% claystone.

Bedout Sub-basin: Keraudren 1 has dominantly bell and funnel shaped gamma ray log patterns. The base has a greater percentage of siltstone, some coal intercalations and rare coal beds are present.

Beagle Trough/Bruce Terrace: Both Poissonnier 1 and Bruce 1 have bell and funnel shaped gamma ray log patterns where claystone represents 20% of the lithology. The sandstone in Poissonnier 1 is dominantly very fine to coarse, well sorted, angular to rounded. The claystones are light greys and browns. Some of the claystones in Bruce 1 are calcareous.

THICKNESS VARIATIONS: (SEE ENCLOSURE 14).

Thickness ranges from 252m in Poissonnier 1 to 345m in Phoenix 1. The bulk of the wells do not penetrate the Triassic. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from Phoenix 1 on line 120/14 in the Beagle Trough), is 700m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 950m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 18, 19).

Globally this time slice is characterised by a low to intermediate relative sea level. Within time slice TR4 there is one globally recognised 3rd order eustatic sea level drop (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. The coastline is interpreted to have transgressed in the module area during time slice TR4 .

Within the Dampier Sub-basin, a major fluvial-deltaic system (the Mungaroo Formation) sourced in the northeast started to dominate deposition. Coastal deltaic, especially tidal, and paralic environments, and fluvial meanderbelt environments dominate this area throughout time slice TR4 and into time slices TR5 and TR6 (also see Thompson et al, 1990).

PALAEOGEOGRAPHY: (SEE ENCLOSURES 18, 19).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, the absence of time slice TR4 aged rocks in the onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Dampier Sub-basin module (Spencer et al, 1993). Secondary sources are from AGSO(BMR), industry and university published work.

Marine to land environments are interpreted in the very northwest part of the palaeogeographic map (future Argoland), directly over what is present day oceanic crust. Argoland is the name given to the landmass that separated from the Australian plate during the late Callovian, and consists of what is today West Burma and northwest Sumatra, with probably other undetected but still preserved landmasses (Metcalfe, 1993).

The elongate ENE-WSW trending landmasses in the NW corner of the map represent the segregation or isolation of portions of a greater basinal area caused by probable stretching of the crust with isostatic rebound of blocks in some areas. Some of these landmasses were initiated during time slice TR2 (Enclosure 16). The submerged apex of these elevated blocks are probable sites of reef growth during time slice TR6 (Rhaetian). The subaerial parts of these blocks are interpreted to be reduced in area, compared to time slice TR3, due to erosion, and or relative sea level rise. Time slice TR4 is thought not to have been deposited onshore. Time slices TR4-TR5 aged sediments are believed to have been deposited over the Bedout High and later eroded off during the Late Triassic Fitzroy Movement.

Triassic and Jurassic marine seaways, when present in the module area, are interpreted to connect to open marine conditions via the Kangaroo Syncline, Dampier and northern Dixon Sub-basins to the west and the Browse Basin to the northeast. The axes of these seaways have been interpreted where possible, to coincide with concurrent structural lows, determined where onlap is visible and biased to a recognised NE-

SW azimuth for the inferred tectonic grain. The restricted marine seaways in time slice TR4 are better thought of as epicontinental seas (Yeates, 1987).

Within the Dampier Sub-basin, a sea-level rise commenced. The Dampier Sub-basin palaeogeographic maps illustrate a snapshot in early time slice TR4, where in response to this sea level rise, the shoreline transgressed.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. One sample meets these criteria with values of TOC = 1.5%, S2=2.36, HI = 157 and Tmax = 432. As a result no significant source interval is identified in time slice TR4. Nevertheless the good oil and condensate shows imply this interval is a potential source rock.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Oil indications were recorded in Poissonnier 1 on the Bruce Terrace whilst strong oil indications were present in Bruce 1. Strong oil and gas indications were recorded in Phoenix 1 and 2.

The following list summarises the porosity and permeability data for the time slice:

Bruce 1	14.8%<porosity av<31.2% (core), 167<permeability<1555 mD(core),
	20%<porosity av<30% (logs), and
Phoenix 1	8%<porosity av<19% (logs), 13%<porosity av<20.7% (core), and
	0.7<permeability<1682 mD (core).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas prone source is interpreted in the west Bedout Sub-basin. It is sub-mature to generate oil. An oil source is present in the Beagle Trough and is mature for oil generation.
- Reservoirs are present on the Bruce Terrace, in the Beagle Trough area, and in the west Bedout and Bedout Sub-basins. Any hydrocarbons generated in these areas may leak up into time slice TR5 due to the lack of a regional seal. Intraformational seals are interpreted on the Bruce Terrace, west Bedout and the Bedout Sub-basins. Time slice TR4 is considered to have good prospectivity.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **West Bedout Sub-basin:** Triassic time slice TR4 clastic reservoirs sourced by a Lower Triassic source and sealed by TR5 regional seals may be a viable play.
- **Bedout Sub-basin:** Triassic time slice TR4 clastic reservoirs sourced by a Lower-Middle Triassic source and sealed by TR5 regional seals may be a viable play. A Lower-Middle Triassic source is still at this stage speculative, making this play higher risk.

TIME SLICE TR5:

MIDDLE TO LATE TRIASSIC: CARNIAN TO EARLY NORIAN (231.0 TO 222.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 1.

This is one of the most significant time slices of the Westralian System. It is almost certainly one of the major source intervals as well as a significant reservoir interval for the giant gas condensate accumulations of the Rankin Trend. Many of the gas accumulations in the Barrow-Exmouth and Dampier region, if not reservoired in the Triassic can be shown to have a reasonable probability of being sourced from this or the immediately associated time slices. Timing of maturation of this interval appears to be post Aptian in most places. There is no obvious significant difference in the palaeoenvironments found in this area and those to the south in the Barrow-Exmouth and Dampier Sub-basin. On this basis the time slice TR5 is considered to be a viable source within the module area and could be the source for the Nebo oil.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Mungaroo Formation is present in the Beagle Sub-basin (Blevin et al, 1994).
- The Keraudren Formation is present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice TR5 is defined by spore pollen zones Upper *S.speciosus and* Lower *M.crenulatus.* Enclosure 3 summarises the spore-pollen, dinoflagellate and foraminiferal zones and related time slice boundaries. Recent work by Nicoll and Foster (1994) revises the position of the *S.speciosus* to *M.crenulatus* spore-pollen boundary upwards from the base of the Norian to well within this stage.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bruce 1: *S.speciosus* (B5),
- Poissonnier 1: *M.crenulatus* (B5),
- Wamac 1/Phoenix 1: no palaeontological control,
- Phoenix 2: *A.reducta* (B5), and
- Keraudren 1: *Falcisporites* (B5).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

In early time slice TR5 Australia was part of greater Pangea that then split to form greater Gondwana in late time slice TR5, coincident with the Fitzroy Movement. The severity of the movement was greatest in the Beagle and Dixon Sub-basins where both depositional and erosional thinning are more pronounced than in the adjacent Roebuck Basin. Depositional hinge zones were present north of the Bedout High and west of the Bedout Sub-basin. Time slice TR5 is bounded at the top by the Upper Triassic rift related unconformity but is conformable on time slice TR4. The time slice is substantially more marine than time slice TR4 with dominant seaways interpreted in the Kangaroo Syncline, Beagle and Outer Rowley Sub-basins. A range of fluvial to lower shoreface environments are present in the time slice. Typical clastic lithology's include sandstone to claystone with minor coal. Oil and gas indications have been recorded in Bruce 1 and Phoenix 2. Time slice TR5 is both a reservoir and intraformational and or regional seal unit. Mature source rocks exist on the Bruce Terrace and sub-mature source rocks are present in the west Bedout Sub-basin.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of Pangea prior to its breakup in the Norian, following which it was a part of greater Gondwana (Baillie et al 1994). Uplift in the onshore and Offshore Canning Basin continued, with erosion of these and other uplands believed to be the major provenance for the Late Triassic sediments of the North West Shelf (BMR Palaeogeographic Group, 1990).

Local

Two probable depositional hinge zones are present NNW of the Bedout High and on the western side of the Bedout Sub-basin (Enclosure 21). These may be reactivated fracture systems of the Bedout Movement, and or reflect a distinct variation in the rheological properties of two basement provinces in the underlying crust (see time slice TR1 section for details).

Syn-rift hinge lines have been speculatively interpreted in the area of the Outer Rowley Sub-basin during late time slice TR5 and time slice TR6 structuring (Fitzroy Movement). Substantial Jurassic thicks lie on trend in

the adjacent Dixon Sub-basin suggesting deposition in structural lows interpreted as being syn-rift here (and Willcox 1980). This would conform to an extensional regime with subtle syn-rift grabens developing within the thinned crust. The hinge lines are interpreted to be the distal equivalents of an extensional regime, active on the northern side of Argoland where potential rifting of Asian Terrains and opening of the Tethys ocean occurred during the Fitzroy Movement. As a precaution, the hinge lines are termed as such rather than specific faults or flexures so as to better reflect their distal location relative to the movements that occurred in the terrain (future Argoland) that was present on the present day location of the Argo Abyssal Plain.

The portion of line 120/11 in Figure 9 shows time slice TR5 onlapping the Permian surface. This is overlain by a regional cover of Jurassic rocks.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Beagle Trough/Bruce Terrace: Bruce 1 has dominantly bell shaped gamma ray log patterns until the top of the section, where funnel shaped patterns are present. Sandstone is 75% of the section and siltstone comprises the remaining 25%. In Poissonnier 1 only a thin portion of the time slice is represented, it is 70% claystone and 30% sandstone. A coal bed is also present.

Bedout Sub-basin: Keraudren 1 has both bell and funnel shaped gamma ray log patterns. Lithology comprises mainly 15% sand at the base, 70% claystone and 15% siltstone in the middle and top. Multicoloured claystones may be indicative of sub-aerial exposure.

West Bedout Sub-basin: Both Phoenix 1 and 2 are similar with about 40% sandstone, 60% claystone and some coal interbeds. Phoenix 1 has both bell and funnel shaped patterns whilst the gamma ray log character in Phoenix 2 is blocky. Multicoloured mudstones in Phoenix 1 and 2 probably indicate sub-aerial exposure.

Offshore Fitzroy Trough: Wamac 1 has dominantly poor bell shaped gamma ray log patterns. There is about 65% siltstone and 35% sandstone present. Coal beds are present at the base of the intersected time slice.

THICKNESS VARIATIONS: (SEE ENCLOSURE 20).

Thicknesses range from 47m in Poissonnier 1 to 455m in Bruce 1. Most wells did not penetrate the Triassic. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from Phoenix 1 on line 120/14 in the Beagle Trough), is 950m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 600m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 21).

Globally this time slice is characterised by a low to intermediate relative sea level. Within time slice TR5 there are two globally recognised 3rd order eustatic sea level drops (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. However in the module area the coastline is interpreted to have transgressed during the later part of time slice TR5.

In the adjacent Dampier Sub-basin module a major delta system was building out with marginal marine and coastal environments (Spencer et al, 1993). Weak evidence suggests an additional sediment source province from the southeast. Fluvial environments predominate on the Rankin and Outer Rankin trend and landform features include point bars, backswamps and channels.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 21).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, rock samples dredged from the outer slope of the Rowley Sub-basin (AGSO, 1994; Blevin et al, 1993), palaeogeographic interpretations from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin and Dampier Sub-basin modules (Spencer et al, 1993: Wilmot, 1993). Secondary sources are from AGSO(BMR), industry and university published work.

Marine to land environments are interpreted in the very northwest part of the palaeogeographic map (future Argoland), directly over what is present day oceanic crust. Argoland is the name given to the landmass that separated from the Australian plate during the late Callovian, and consists of what is today West Burma and northwest Sumatra, with probably other undetected but still preserved landmasses (Metcalfe, 1993).

Triassic and Jurassic marine seaways, when present in the module area, are interpreted to connect to open marine conditions via the Kangaroo Syncline, Dampier and northern Dixon Sub-basins to the west and the Browse Basin to the northeast. The axes of these seaways have been interpreted where possible, to coincide with concurrent structural lows, determined where onlap is visible and biased to a recognised NE-

SW azimuth for the inferred tectonic grain. The restricted marine seaways in time slice TR5 are better thought of as epicontinental seas (Yeates, 1987).

The discovery of probable Norian aged reefal marine fauna in sediments recovered from dredge samples taken from the continental slope near the COB substantiates an open marine environment in this area. The high blocks in the NW corner of the map, established during time slice TR4 structuring, are now interpreted to have reefs growing over them or around them.

Time slice TR5 is interpreted not to have been deposited onshore. Time slices TR4-TR5 aged sediments are believed to have been deposited over the Bedout High and later eroded during the Fitzroy Movement. Truncational erosion is suggested from seismic.

Depositional hinge zones exist west of the Phoenix wells and north of the Bedout High. The area to the east of the northern hinge zone is interpreted to be fluvial whilst probable coastal, and or restricted marine environments are interpreted on the western side. The thinner Triassic sequence is seen to imply a higher chance for fluvial environments being present as opposed to thicker basinal fills establishing coastal environments.

In the adjacent Dampier Sub-basin, the time slice TR5 section includes a fluvial environment, with meandering rivers predominating in the southeast and extending as far west as the Exmouth Sub-basin and Rankin Platform region. These show evidence of marine inundation and sediment reworking associated with high energy coastal environments, especially near the top of the interval. The fluvial sediments prograded into a rising sea level but lobe switching may have allowed transgression in local areas. With massive sediment influx into relatively deep water environments, there was the potential for unstable sediment loads to intermittently flow to the base of slope. Diastrophism to the north provided the sediment source for continued progradation of the sandy Mungaroo facies into time slices TR5 and TR6.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. Ten samples meet these criteria with results that range 2%<TOC<64.4%, 3.41<S2<89.7, 155<HI<280 and 428<Tmax<435. The higher TOC's of up to 64.4% are indicative of coal. These samples establish a dominantly gas, or light oil prone source with very good generative potential, but the samples are sub-mature or immature. The immature samples are from the Offshore Fitzroy Trough and the sub-mature source is from the Phoenix 1 well. Where buried deeper these source rocks would be generative.

One sample from Phoenix 2, analysed in conjunction with this module, gave a low TOC, poor generative potential and low HI.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Oil indications were discovered in Bruce 1 whilst a gas indication was present in Phoenix 2.

The following list summarises the porosity data for this time slice:

Bruce 1	20%<porosity av<30% (logs), and
Phoenix 1	16%<porosity av<23% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas prone source potential exists in the Fitzroy Trough but is unlikely to be mature within the trough.
- Oil and gas source potential exists in the west Bedout Sub-basin and is interpreted to be sub-mature here but probably mature to the west in and adjacent to the Beagle Trough and north in the Inner Rowley Sub-basin.
- Time slice TR5 section is interpreted from seismic in the Beagle Trough. It is sufficiently deep to be presently mature and geochemistry shows it as having high TOC's thereby indicating its potential as an unproven source.
- Reservoir potential is present in the Beagle Trough, west Bedout and Bedout Sub-basins and Fitzroy Trough.
- In the Fitzroy Trough the time slice TR5 section is very sandy. Any hydrocarbons migrating into the time slice are not expected to be trapped until they reach younger Jurassic units that have seal potential.
- Reservoirs within the Bedout Sub-basin will be regionally sealed by time slice TR5 shales, making it prospective if good source rocks can be established for the Bedout Sub-basin.
- Reservoirs within the west Bedout Sub-basin will be regionally sealed by time slice TR5 shales making this area prospective. In other areas some of the time slice TR5 reservoirs are open to time slice TR6 and the

Jurassic. In these areas only a portion of the reservoirs can be expected to be sealed by the regional shales of time slice TR5. Reservoir facies are only confirmed in the Phoenix wells, and on the Bruce Terrace in the Poissonnier 1 and Bruce 1.

- The prospectivity of time slice TR5 is considered good.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **West Bedout Sub-basin:** Triassic time slice TR5 clastic reservoirs sourced by a Lower Triassic source and sealed by time slice TR5 regional seals may be a viable play.
- **Bedout Sub-basin:** Triassic time slice TR5 clastic reservoirs sourced by a Lower Triassic source and sealed by time slice TR5 regional seals may be a viable play. A Lower Triassic source is still at this stage speculative, making this a higher risk play.
- **Outer Rowley and Dixon Sub-basins:** Seismic mounds suspected to be reefs may have play potential. Reefal sediments of this age have been recovered in the Outer Rowley Sub-basin dredge sites. They would be sealed by dominantly marine sequences of time slice TR6 and J1 age and sourced from the Triassic via vertical migration paths. These plays are in deep water and remain untested.

TIME SLICE TR6:

LATE TRIASSIC: LATE NORIAN AND RHAETIAN (222.0 TO 213.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 1.

This is one of the most significant time slices of the Westralian System. It is almost certainly one of the major source intervals as well as a significant reservoir interval for the giant gas condensate accumulations of the Rankin Trend. Many of the gas accumulations in the Barrow-Exmouth and Dampier region, if not reservoired in the Triassic can be shown to have a reasonable probability of being sourced from this or the immediately associated time slices. Timing of maturation of this interval appears to be post Aptian in most places. There is no obvious significant difference in the palaeoenvironments found in this area and those to the south in the Barrow-Exmouth and Dampier Sub-basin. On this basis the time slice TR6 is considered to be a viable source within the module area.

FORMATION SYNONYMS: (SEE FIGURE 2).

Time slice TR6 has not been intersected in the wells but is thought to exist within the module area based on seismic interpretation.

- The Mungaroo and Brigadier Formations are present in the Beagle Sub-basin. The Brigadier Formation, overlying the Mungaroo Formation, is interpreted to be bounded by unconformities caused by the Fitzroy Movement (Blevin et al, 1994).
- The Keraudren and Bedout Formations are present in the Offshore Canning and Roebuck Basins, interpreted as diachronous (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice TR6 is biostratigraphically defined by the lower *A.reducta* and upper *M.crenulatus* spore pollen zones. Enclosure 3 summarises the spore-pollen, dinoflagellate and foraminiferal zones and related time slice boundaries.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

No time slice TR6 intersected; interpreted as present based on seismic.

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Following the breakup of Pangea in early time slice TR6 (Norian), Australia was part of greater Gondwana. The structural phase associated with this breakup is the Fitzroy Movement and here interpreted to be time slices TR6-J1 age. The severity of the movement was greater in the Beagle and Dixon Sub-basins where both depositional and erosional thinning were greater than in the adjacent Roebuck Basin. Depositional hinge zones were present north of the Bedout High and west of the Bedout Sub-basin. No time slice TR6 aged rocks have been identified in the wells although time slice TR6 is expected to be present in the module area. The time slice is substantially more marine than later Jurassic or earlier Triassic time slices, with dominant seaways present in the Kangaroo Syncline and Dixon, Beagle and Outer Rowley Sub-basins. Time slice TR6 is a marine highstand. A range of fluvial to lower shoreface environments is present in time slice TR6. Typical clastic lithology's include sandstone to claystone with minor coal seen in wells and reefal limestones that were recovered from dredge samples. The prospectivity of the time slice is probably good.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of greater Gondwana, now in the process of rifting following the breakup of Pangea during Norian time (Baillie et al, 1994).

Local

The Late Triassic-Early Jurassic structuring event, the Fitzroy Movement, is characterised by the termination of faults at this level and by seismic character changes across the top time slice TR6 boundary. The top Triassic seismic character in most areas, is defined by semi-coherent relatively high frequency reflectors, as opposed to the opaque reflectors of the basal Jurassic. Triassic age faulting is discernible mainly in the Rowley Sub-basin where they are seen to terminate around the top Triassic seismic horizon. It is uncertain how much reactivation may have occurred along these faults during the Argoland breakup (time slice J7 Callovian) as few faults penetrate the Upper Jurassic in the Rowley Sub-basin. The Fitzroy Movement is known to have had a major influence in the Fitzroy Trough (Wales & Forman, 1981 in Colwell & Stagg 1994). Suspected salt pillows in the Willara Basin are also known to be associated with this event (Colwell & Stagg, 1994). The actual timing of this movement is uncertain in the offshore area. It could be as early as the late Norian and so coincides with structural movements seen at this time in other parts of the North West Shelf. It could be as late as the early Jurassic. If the regional marine transgression is partly due to

these structural movements then the time slice TR5-TR6 boundary might be coincident with the main phase of structuring.

The top Triassic TWT structure contour map shows structural deeps in the Rowley and Bedout Sub-basins (Enclosure 58).

The TWT Triassic Isochron map (Enclosure 59) shows:

- the absence of the Triassic on the Leveque and Lambert Shelves, Pender Terrace and Broome Platform. Note that the basal Triassic was deposited in the Wallal Embayment and Offshore Fitzroy Trough (the Blina Shale, BMR, 1981) but has not been mapped in this module,
- a thinning of the Triassic in the Rowley and Bedout Sub-basins. This thinning reflects significant depositional thinning as opposed to erosional thinning, however thinning over the Bedout High is both erosional and depositional. Two major depositional hinge zones comprising of escarpments, embayments and faulted contacts are interpreted to strike north-south, one hinge zone located west and the other north of the Bedout High,
- thinning towards the Lambert Shelf and the Wallal Embayment that is thought to be both erosional and depositional. The thinning onto the Broome Platform is interpreted to be primarily depositional although minor localised erosion has taken place. The thinning onto the Leveque Shelf is interpreted as being depositional,
- that numerous Triassic horst blocks can be expected to be found within the Beagle Sub-basin as evidenced from individual seismic sections, and
- much more gentle thinning within the Rowley Sub-basin relative to the Beagle Sub-basin.

Line 120/01 extends NNW from the Bedout Sub-basin across the Bedout High and Rowley Sub-basin and over the Argo Abyssal Plain. The portion of line 120/01 in Figure 21 shows:

- the Triassic unconformity to the north of the Bedout High where time slices TR4 and TR5 were eroded off during the Fitzroy Movement. The Permian is seen to have also been eroded off or not deposited on the Bedout High, and
- that a basement offset, part of a Triassic aged hinge zone, exists around shotpoint 3600. This would have been active during the Triassic and part of the early Jurassic. It offsets two hinge zones that trend north-south. Major diffraction tails are seen running off this hinge area.

Two probable depositional hinge zones are present NNW of the Bedout High and on the western side of the Bedout Sub-basin (Enclosure 22). These may be reactivated fracture systems of the Bedout Movement, and or reflect a distinct variation in the rheological properties of two basement provinces in the underlying crust (see time slice TR1 section for details).

Syn-rift hinge lines have been interpreted in the area of the Outer Rowley Sub-basin due to time slice TR5 to TR6 age structuring. Their presence is deduced from substantial Jurassic thicks lying on trend to the syn-rift faults in the adjacent Dixon Sub-basin interpreted as deposition in syn-rift structural lows. This would conform to an extensional regime with subtle syn-rift grabens developing within a thinned crust. Reefs are interpreted to have grown on the apex of these blocks. The hinge lines are interpreted to be the distal equivalents of an extensional regime, active on the northern side of Argoland where potential rifting of Asian Terrains and opening of the Tethys ocean occurred during the Fitzroy Movement. As a precaution, the hinge lines are termed as such rather than specific faults or flexures so as to better reflect their distal location relative to the movements that occurred in the terrain (future Argoland) that was present on the present day location of the Argo Abyssal Plain .

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Time slice TR6 has not been intersected but the lithology is expected to be very shale prone due to the known marine conditions prevailing during this time.

THICKNESS VARIATIONS: (NO ENCLOSURE).

Time slice TR6 has not been positively identified but a maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from Phoenix 1 on line 120/14 in the Beagle Trough), is 200m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 200m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 22).

Globally time slice TR6 is characterised by a low relative sea level. Within time slice TR6 there is one globally recognised 3rd order eustatic sea level drop (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a stable eustatic regime. The coastline in the

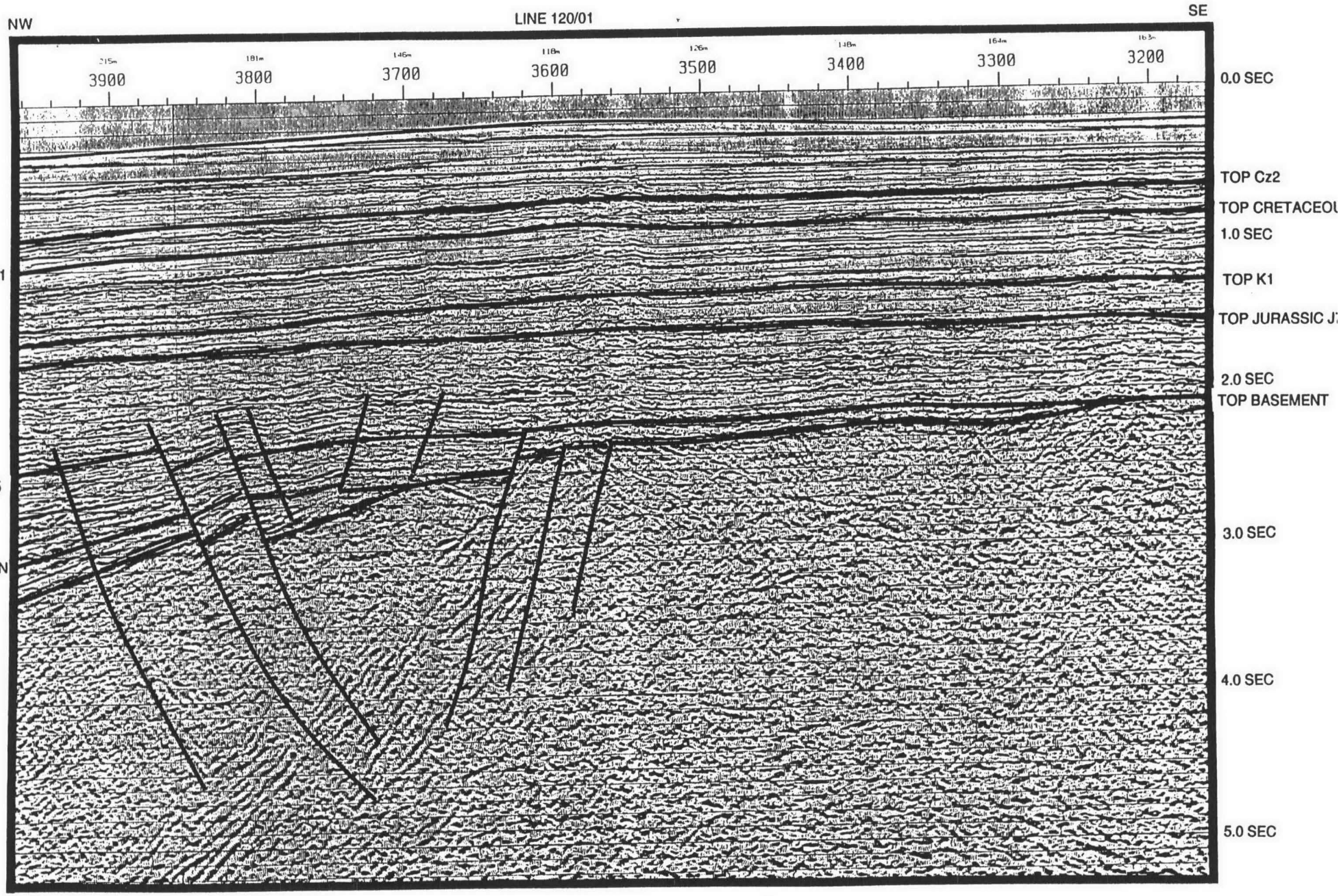


FIGURE 21: SEISMIC REPRESENTATION OF THE NORTHERN CONTACTS OF THE BEDOUT HIGH, ROWLEY SUB-BASIN, LINE 120/01.

module area is interpreted to have transgressed during time slice TR6 continuing the trend that commenced in time slice TR4. In the Offshore Canning Basin erosion probably persisted, with substantial volumes of sediment continuing to be supplied to the Outer Rowley Sub-basin. The rate of sediment supply possibly waned towards the end of this time slice, allowing marine inundation in this area.

In the Dampier Sub-basin, the sea transgressed during this time slice, with fluvial, and or deltaic environments (such as interdistributary bays, distributary channels and backswamps) yielding to shoreface and marine environments.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 22).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, rock samples dredged from the outer slope of the Rowley Sub-basin (AGSO, 1994; BMR 1990(b); Blevin et al, 1993), 6200km of mapped seismic sections, the known absence of time slice TR6 in both onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

Time slice TR6 aged rocks have not been positively identified offshore. The spore pollen zones that define time slice TR6 straddle both time slice J1 (*A. reducta*) and time slice TR5 (*M.crenulatus*). Dinoflagellate faunal zones like *R.rhaetica* and *H.balmei* also characteristic of time slice TR6 were not identified in any wells.

Time slice TR6 is interpreted to be present in the module area but has a higher proportion of land, relative to time slice TR5, due to uplift associated with the late Triassic Fitzroy Movement. A number of conceptional landmasses have been drawn to illustrate this.

Marine to land environments are interpreted in the very northwest part of the palaeogeographic map (future Argoland), directly over what is present day oceanic crust. Argoland is the name given to the landmass that separated from the Australian plate during the late Callovian, and consists of what is today West Burma and northwest Sumatra, with probably other undetected but still preserved landmasses (Metcalfe, 1993).

A shallow marine platform, with intermittent emerging landmasses, was present in the outer Rowley Sub-basin. This interpretation is based on the observed seismic downlap, and or onlap, of time slices J1 to J3 seen in this area (Figure 17). After time slice J3 this platform was fully submerged. The southern edge of it can be identified on two seismic lines whilst the northern edge is placed to fit in with the model that reefs have built up on the shallow narrow shelf behind the platform.

Marine seaways for the Triassic and Jurassic periods, when present in the module area, have been taken to originate from the Kangaroo Syncline, Dampier Sub-basin, northern Dixon Sub-basin (all lying west of the module area) and from the Browse Basin to the northeast. The location of these seaways have been highgraded where possible at the location of present structural lows, sometimes where onlap is visible and biased to a recognised NE-SW azimuth for tectonic grain originating at this time. Restricted marine seaways in this interval may still be representative of epicontinental seas (Yeates, 1987) although the discovery of probable Rhaetian aged marine fauna in reefal sediments recovered from dredge samples substantiates a more open marine environment. Seaways with reefal buildups are interpreted on the present location of the continental slope but also to the west of longitude 117°E where reefs have been interpreted from seismic (Exon and Wilcox, 1980).

No rocks of time slice TR6 age are thought to have been deposited onshore. It is possible that time slice TR6 rocks were layed down in the Offshore Fitzroy Trough during this interval however a reworked lowland deposition interpretation is favoured with thin deposition possibly preserved.

In the Dampier Sub-basin, marine inundation over a very large peneplain produced a complex shifting mosaic of marine, paralic and fluvial environments. There were periods of local regression and resumption of fluvial deposition, but marine environments finally prevailed. Diastrophism provided the sediment source for continued progradation of the sandy Mungaroo facies into time slices TR5 and TR6.

GEOCHEMISTRY (TOC, HI, S2 AND Vr):

No geochemistry is available for time slice TR6.

SHOWS, POROSITY & PERMEABILITY.

No time slice TR6 has as yet been drilled within the module area.

PROSPECTIVITY.

Backswamp and lacustrine landforms are interpreted to still be present in the Rowley Sub-basin are and may provide source areas. The top Triassic TWT structure contour map (Enclosure 58) shows that many

structural prospects are likely to be found within the wider spaced contours in and adjacent to the main depocenters where isolated horsts exist. Individual prospects cannot be confirmed at this scale.

TRAPS AND PLAYS.

- **Outer Rowley and Dixon Sub-basins:** Seismic mounds suspected to be reefs may have play potential(Exon and Wilcox, 1980). Reefal sediments of this age have been recovered in the Outer Rowley Sub-basin dredge sites thus increasing the probability of the seismic mounds being reefs. They would be sealed by dominantly marine sequences of time slice TR6 and J1 age and sourced from the Triassic via vertical migration paths. These plays are in deep water but remain untested.
- **Beagle and West Bedout Sub-basins:** Sands present in the interpreted lower and upper delta plain environments and sealed regionally by time slices TR6 and J1 will probably form good traps where they can be more directly sourced from Triassic source rocks.

JURASSIC TIME SLICES

TIME SLICE J1:

EARLY JURASSIC: HETTANGIAN TO SINEMURIAN:(213.0 TO 200.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 1.

In the area of the present day Rankin Trend time slice J1 is a regional seal facies and minor reservoir unit that also has source potential. It probably covered most of the area of the Rankin Trend until the Callovian when the Rankin Trend was formed by tilting, uplift and erosion. As a petroleum system factor time slice J1 is mainly important as a source and seal facies.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The North Rankin Formation in the Beagle Sub-basin is interpreted as being bounded by unconformities (Blevin et al, 1994). The diachronous Athol and Legendre Formations may be present at the top of the time slice.
- The Bedout Formation is bounded by an unconformity at the top in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994). The Depuch Formation may be present at the top of the time slice.

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J1 is biostratigraphically defined by the middle *D.priscum* dinoflagellate zone and the lower *C.torosa* and upper *A.reducta* spore pollen zones. The Jurassic - Triassic boundary is not marked biostratigraphically. It occurs within the *A.reducta* spore-pollen zone and the *D.priscum* dinoflagellate zone. The upper boundary of this time slice is within the *C.torosa* spore-pollen zone and the *D.priscum* dinoflagellate zone.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *C.torosa* (B4),
- East Mermaid 1: *C.torosa* (B5),
- Keraudren 1/Lagrange 1/Phoenix 1/Picard 1: *C.torosa* (B2),
- North Turtle 1: *C.torosa* (B2/B3), and
- Phoenix 2: no palaeontological control.

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Gondwana during this time slice. It was probably a tectonically quiescent time following the breakup of Pangea in the Norian. Time slice J1 is conformable with time slice J2 but unconformable on a Triassic surface. The time slice is substantially more marine than later Jurassic time slices, with dominant seaways interpreted in the Kangaroo Syncline, Dixon and Outer Rowley Sub-basins. A range of fluvial to lower shoreface environments is present. Time slice J1 has clastic lithology's ranging from sandstone to claystone with minor coal. Oil and gas indications have been recorded in Picard 1 and Lynher 1. Time slice J1 is both a reservoir and seal unit, with both intraformational and regional seals. Mature source exists in the Beagle Trough and areas of the Inner and Outer Rowley Sub-basins. However, due to the sandy nature of the time slice in these areas, any migrating hydrocarbons may bypass time slice J1 and not be trapped until they encounter time slice J7 sediments. In other areas hydrocarbons may have been trapped in time slice J1.

TECTONICS: (SEE ENCLOSURES 1, 2 & FIGURE 2).

Regional

West Australia was part of a greater Gondwana (Baillie et al, 1994).

Local

Two probable depositional hinge zones are present NNW of the Bedout High and on the western side of the Bedout Sub-basin (Enclosure 24). These may be rejuvenated from fracture systems of the Bedout Movement, and or reflect a distinct variation in the rheological properties of the underlying crustal provinces (see time slice TR section for details).

Syn-rift hinge lines have been interpreted in the Outer Rowley Sub-basin following the Fitzroy Movement during time slices TR5 to TR6. Their presence is speculative rather than being substantiated from seismic. Substantial Jurassic thicks lie on trend in the adjacent Dixon Sub-basin suggesting deposition in structural

lows (Exon & Willcox, 1980). The lows are interpreted as products of syn-rift tectonics. This implies an extensional regime with syn-rift horsts and grabens developing within a thinned crust. Reefs are interpreted to have grown on the apex of the horst blocks. The hinge lines are interpreted to be the distal equivalents of an extensional regime, active on the northern side of Argoland where potential rifting of Asian Terrains and opening of the Tethys ocean occurred during the Fitzroy Movement. The hinge lines are termed as such, rather than faults or flexures so as to better reflect their distal location relative to the movements that occurred in the terrain (future Argoland) that was present on the present day location of the Argo Abyssal Plain .

Line 120/01 extends NNW from the Bedout Sub-basin across the Bedout High and Rowley Sub-basin and extends to the Argo Abyssal Plain. The portion of line 120/01 in Figure 21 shows the Jurassic downlapping on a submerged Triassic age platform.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

Beagle Trough: North Turtle 1 gamma ray log signature is blocky whilst Picard 1 has dominantly funnel shaped patterns with some bell shape and blocky signatures. Sandstone and claystone is respectively 30% and 70% of the section in Picard 1 and 55% and 45% of the section in North Turtle 1.

West Bedout Sub-basin: Both Phoenix wells have blocky gamma ray log signatures with some bell shaped patterns. Sandstone and claystone is respectively 30% and 70% of the section.

Bedout Sub-basin: Keraudren 1 gamma ray log signature is blocky with subtle funnel shaped patterns. One shale bed is present within an overall sandy sequence.

Bedout High: Bedout 1 contains both bell and funnel gamma ray log patterns whilst Lagrange 1 has a massive bell shaped pattern overlain by a blocky signature. The lithology in Lagrange 1 is dominantly claystone overlain by a sandstone. Sandstone and claystone is respectively 40% and 60% of the section in Lagrange 1. Bedout 1 is dominantly siltstone with 25% of the section sandstone with some coal streaks.

THICKNESS VARIATIONS: (SEE ENCLOSURE 23).

Thicknesses range from 120m in Keraudren 1 to 272m in Lagrange 1. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from North Turtle 1 on line 110/01 in the Beagle Trough), is 900m. A maximum thickness for the time slice, estimated from the seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 350m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 24).

Globally this time slice is characterised by a relative sea level low. Within time slice J1 two global 3rd order eustatic sea level drops are recognised (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. In the module area, the coastline is interpreted to have been in a similar position to time slice TR6.

In the adjacent Dampier Sub-basin module shallow marine shelf deposition is interpreted in the west and deltaic deposition in the east (Spencer et al, 1993). Generally this area formed part of a transgressive sequence. A source from the northeast is possible. In the Dampier Sub-basin, drowning of the fluvial Mungaroo Formation sediments continued within the study area.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 24).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, rock samples dredged from the outer slope of the Rowley Sub-basin (AGSO, 1994; BMR, 1990b), 6200km of mapped seismic sections, palaeogeography interpretations from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin modules (Spencer et al, 1993). Secondary sources are from AGSO(BMR), industry and university published work.

The following summarises the palaeogeography map:

- Marine to land environments are interpreted in the very northwest part of the map, directly over what is present day oceanic crust and what became Argoland. Argoland is the name given to a landmass that separated from the Australian plate during the late Callovian and consisted of what is today, west Burma and northwest Sumatra, and probably other undetected but still preserved landmasses (Metcalfe, 1993).
- A shallow marine platform with intermittently emerging landmasses has been identified in the Outer Rowley Sub-basin. This interpretation is based on the seismic downlap of time slices J1-J3. It is only after time slice J3 that the platform is interpreted to be submerged. The southern edge of the platform can be identified on two lines whilst the northern edge is conceptionally placed to fit in with the model that reefs

have built up on a shallow narrow shelf behind the platform. (See Figure 17 and seismic line 120/01 sp7500-6500).

- All onlap edges on the southeast side of the map are phantomed using the discontinuous reflectors present in the Jurassic as a guide. Additionally a reasonable amount of well control is provided from Lynher 1, East Mermaid 1, Lagrange 1 and Keraudren 1. The confidence attributed to the onlap edges in the southeast is considered good throughout the Jurassic, as the edges can be correlated to onshore rocks of known age. The southern extent of the Jurassic onto the Lambert Shelf and Pilbara Block is much more interpretative as it is difficult to differentiate between onlap or depositional limits as opposed to erosional edges on the seismic.
- Triassic and Jurassic marine seaways, when present in the area, have been interpreted to be connected to the open sea via the Kangaroo Syncline, Dampier and northern Dixon Sub-basins (all lying west of the module area) and the Browse Basin to the northeast. The seaways have been interpreted, where possible, to have axes coincident with structural lows. Sometimes onlap is visible and biased to a recognised NE-SW azimuth coincident with the tectonic grain and depositional axes. Restricted marine seaways in this interval have been interpreted as epicontinental seas (Yeates, 1987). However the discovery of late time slice TR5 to J1(Rhaetian) aged marine fauna in reefal sediments recovered from dredge samples near to COB (continent ocean boundary) implies a more open marine environment. This more open marine conditions may have extended into the Lower Jurassic. On this basis seaways with reefal buildups are inferred at the present location of the continental ocean boundary in the Outer Rowley Sub-basin and also to the west of longitude 117°E where reefs have been interpreted from seismic (Exon and Wilcox, 1980).
- Emergent landmasses existed north of the Dampier Sub-basin and Cossigny Trough after the structuring caused by the Fitzroy Movement (Blevin et al, 1993). These landmasses are interpreted to be still emergent in time slice J1. Fluvial environments persisted from the late Triassic into the earliest Jurassic. As the transgression progressed, silty and sandy influx lessened, resulting in widespread shale deposition within a possibly deepening marine environment over most of the northern Carnarvon Basin.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few samples where 0.5%<TOC<1.0%, the bulk of the samples having a TOC > 1.0%. Only one sample met the selection criteria with TOC=3.3, S2=5.51, HI=166 and Tmax=429 indicating a gas and light oil prone source for time slice J1.

Two samples from Picard 1 were analysed in conjunction with this module (Appendix 5 part 3). They have TOCs' of 2.61% and 1.63% but poor generative potential and low HI.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

A gas indication was present in Lynher 1 whilst Picard 1 had oil and gas indications. The following list summarises the porosity and permeability data for this time slice:

North Turtle 1	13%<porosity av<17% (logs),
Phoenix 1	porosity av = 21% (logs), and
Picard 1	0.3%<porosity av<14%, 0.6<permeability<1.8 mD (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas source potential exists in the Beagle Trough and the Inner Rowley Sub-basin where time slice J1 is presently mature.
- Reservoir potential exists in all areas where time slice J1 is present.
- The seal quality of time slice J1 is better than that of the younger Jurassic units. Over both the Bedout High and the Inner Rowley Sub-basin, time slice J1 is a regional seal whilst in the Beagle Trough and the west Bedout Sub-basin the seal is interpreted as intraformational.
- Time slice J1 immediately overlies the potentially good source rocks of time slices TR5 and TR6.

The prospectivity of time slice J1 is considered fair to good.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Bedout High:** Time slice J1 clastic reservoirs, could be sourced from Triassic sources and sealed by time slice J1 regional seals. The hydrocarbon charge would be from the Inner Rowley Sub-basin or the west Bedout Sub-basin as no identified local source is known from the Bedout High.
- **Inner Rowley Sub-basin:** Time slice J1 clastic reservoirs could be sourced by a Triassic or time slice J1 source and sealed by time slice J1 regional seals.

- Higher risk plays in the **Beagle Trough** and **west Bedout Sub-basin** exist where intraformational seals are a significant risk factor.
- **Outer Beagle Platform** plays may exist within the delta plain environments interpreted.
- Reefs, present in the **Outer Rowley and Dixon Sub-basins,** spanning time slices late TR5 to J1 remain untested. These plays are in deep water.

TIME SLICE J2:

EARLY TO MIDDLE JURASSIC: PLIENSBACHIAN TO EARLY TOARCIAN (200.0 TO 190.5 MA).

PETROLEUM SYSTEM: WESTRALIAN 1 & 2.

Not well known in this or other areas.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The diachronous Athol and Legendre Formations are present in the Beagle Sub-basin (Blevin et al, 1994).
- The Depuch Formation and unnamed units are present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J2 is biostratigraphically defined by upper *D.priscum,* upper *C.torosa* to lower *C.turbatus*. Time slice J2 corresponds to the *N.vallatus* datum. It is marked by a facies change in many basins and by the commencement of deposition in others.

PALAEONTOLOGY (SEE ENCLOSURE 2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *C.torosa* (B3/B4), *C.turbatus*(B3),
- Depuch 1: *C.turbatus* (B1),
- East Mermaid 1: *C.torosa* (B3/B5),
- Keraudren 1/Lagrange 1/Phoenix 1: *C.torosa* (B2),
- North Turtle 1: *C.torosa* (B2), *C.turbatus* (B2),
- Phoenix 2: *C.torosa* (B4),
- Picard 1: *C.torosa* (B2/B4),
- Ronsard 1: *C.torosa* (B2/B3/B4), and
- Trafalgar 1: *C.turbatus* (B2).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Gondwana during time slice J2. This was a tectonically quiescent period. Time slice J2 appears conformable with time slices J1 and J3. Open marine areas are interpreted in the Kangaroo Syncline, Dampier and Outer Rowley Sub-basins. A range of fluvial to lower shoreface environments is present elsewhere. Time slice J2 has dominantly clastic lithology's ranging from sandstone to claystone with minor coal. Oil and gas indications have been recorded in Picard 1, North Turtle 1, Depuch 1, Lynher 1 and Cossigny 1. Time slice J2 is dominantly a reservoir unit with some local seal potential. Mature source exists in the Beagle Trough and areas of the Inner and Outer Rowley Sub-basins and sub-mature source rocks occur in the Cossigny Trough. Because of the dominantly sandy nature of the time slice any migrating hydrocarbons would probably bypass it and be trapped in time slice J7.

TECTONICS: (SEE ENCLOSURES 1, 2 & FIGURE 2).

Regional

West Australia was part of greater Gondwana (Baillie et al, 1994).

Local

Speculative syn-rift hinge lines have been interpreted from the seismic in the area of the Outer Rowley Sub-basin, these are a result of the Fitzroy Movement (time slices TR5 and TR6). Substantial Jurassic thicks lie on trend to these faults in the adjacent Exmouth Plateau suggesting deposition in structural lows (Exon and Wilcox, 1980). The hinge lines are interpreted to be the distal equivalents of an extensional regime, active on the northern side of Argoland where potential rifting of Asian Terrains and opening of the Tethys ocean occurred during the Fitzroy Movement. As a precaution, the hinge lines are termed as such rather than specific faults or flexures so as to better reflect their distal location relative to the movements that occurred in the terrain (future Argoland) that was present on the present day location of the Argo Abyssal Plain . This model conforms to an extensional regime with the subtle syn-rift grabens developing within a thinned crust. Their expression, during time slice J2 is reduced as sedimentation proceeded to fill up the lows.

In the Dampier Sub-basin, accelerated subsidence and faulting along the basin margins, defined the central Lewis Trough of the Sub-basin (Spencer et al, 1993). Towards the Barrow Sub-basin the Rosemary and Flinders Fault Systems became active or reactivated; and possibly also the Rankin Trend faults. As a result

subsidence in the Barrow and Dampier depocenters was enhanced. Faulting here has a transtensional appearance with steep normal faults and little bedding rotation implying only minor extension.

In the Exmouth Sub-basin, there was subsidence adjacent to the Rough Range and Bundegi Faults (Spencer et al, 1994).

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Ronsard 1 gamma ray log patterns are blocky with minor funnel shaped patterns (claystone) present. Sandstone and claystone are respectively 25% and 75% of the section. Trafalgar 1 has blocky gamma ray log patterns. The section is 75% sandstone and 25% claystone.

Beagle Trough: Depuch 1 has a mainly mild serrated blocky character, bell and funnel gamma ray log patterns. North Turtle 1 has dominantly funnel shaped and serrated patterns. Picard 1 has a uniform serrated pattern at the base (claystone) with dominantly funnel and blocky signatures in the middle and top of the time slice. Sandstone and claystone is respectively 40% and 60% of the section in Picard 1, 45% and 55% of the section in Depuch 1 and 55% and 45% of the section in North Turtle 1.

West Bedout Sub-basin: Phoenix 2 gamma ray log signature patterns include funnel shaped and blocky patterns whilst Phoenix 1 has funnel patterns at the base overlain by bell shaped patterns. Sandstone and claystone to siltstone are each 50% of the section in Phoenix 2 and 40% and 60% respectively of the section in Phoenix 1.

Bedout Sub-basin: Keraudren 1 gamma ray log signature patterns consist of both bell and funnel shaped patterns. The section is 80% sandstone and 20% siltstone.

Bedout High: Bedout 1 gamma ray log signature patterns include a blocky base with bell and funnel patterns in the middle and serrated patterns at the top. Lagrange 1 has a blocky base with a funnel gamma ray log pattern. Sandstone and claystone to siltstone both are 50% of the section in Lagrange 1.

Rowley Sub-basin: East Mermaid 1 gamma ray log patterns include a blocky base (siltstone) and a blocky top (sandstone). Siltstone and sandstone are respectively 65% and 35% of the section.

THICKNESS VARIATIONS: (SEE ENCLOSURE 24).

Thickness range from 140m in East Mermaid 1 to 434m in Picard 1. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from North Turtle 1 on line 110/01 in the Beagle Trough), is 350m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 700m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 25).

Globally time slice J2 is characterised by a low relative sea level. Within time slice J2 there are three globally recognised 3rd order eustatic sea level drops (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. The coastline is interpreted to have regressed during time slice J2. Time slice J2 marks the end of the general transgressive phase initiated at the end of time slice TR4.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 25).

The primary sources for the palaeogeographic interpretation include all wells with interpreted time slice palaeogeography, 6200km of mapped seismic data, rock samples dredged from the outer slope of the Rowley Sub-basin (AGSO, 1994; BMR, 1990), palaeogeographic interpretations from onshore Canning Basin wells and outcrop and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

The following summarises the palaeogeographic map:

- Marine to land environments are interpreted in the very northwest part of the map, directly over what is present day oceanic crust and what will become Argoland. Argoland is the name given to a landmass that separated from the Australian plate during the late Callovian and consisted of what is today, west Burma and northwest Sumatra, and probably other undetected but still preserved landmasses (Metcalfe, 1993).
- A shallow marine platform with intermittently emerging landmasses has been identified in the Outer Rowley Sub-basin. This interpretation is based on the seismic downlap of time slices J1 to J3. The platform is interpreted to be submerged after time slice J3. The southern edge of the platform can be identified on two lines whilst the northern edge is conceptionally placed to fit in with the model that reefs have built up on a shallow narrow shelf behind the platform (See Figure 17 and seismic line 120/01 sp 6500-7500).

- Emergent landmasses existed north of the Dampier Sub-basin and Cossigny Trough after the structuring caused by the Fitzroy Movement (Blevin et al, 1993). These landmasses are interpreted to be still emergent in time slice J2.
- All onlap edges on the southeast side of the map are phantomed using the discontinuous reflectors present in the Jurassic as a guide. Additionally, a reasonable amount of well control is provided from Lynher 1, East Mermaid 1, Lagrange 1 and Keraudren 1. The reflectors are more continuous basinward providing a reasonably well defined downlap edge to the shallow marine platform in the Outer Rowley Sub-basin. The confidence attributed to the onlap edges in the southeast is considered good throughout the Jurassic as the edges agree with the absence of Lower Jurassic rocks onshore. The southern extent of the Jurassic onto the Lambert Shelf and Pilbara Block is more interpretive, as it is difficult to differentiate onlap, and thus depositional limits, as opposed to erosional edges from the seismic.
- The restricted marine seaways in this interval have been interpreted as epicontinental seas (Yeates, 1987). These epicontinental seas regressed during time slice J1.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few samples where 0.5%<TOC<1.0%, the bulk of the samples having a TOC > 1.0%. Fifty six samples, from wells in the Beagle Trough, Bedout High and west Bedout Sub-basin, meet these criteria and ranged 1.4%<TOC<64.9%, 0.74<S2<238, 152<HI<366 and 421<Tmax<440. This indicates gas and oil prone source rock with very good generative potential. The samples are immature to mature.

Two samples from Picard 1, analysed in conjunction with this module, have TOC's of 0.56% and 2.21%, with poor generative potential and low HI. Another sample from Lagrange 1 has a low TOC and HI and poor generative potential (see Appendix 5 part 3).

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

A gas indication was present in Lynher 1 whilst oil indications were recorded in Cossigny 1. Oil and gas indications were present in North Turtle 1, Depuch 1 and Picard 1.

The following list summarises the porosity data for this time slice:

Depuch 1	11%<porosity av<12%(logs),
North Turtle 1	13%<porosity av<17%(logs),
Phoenix 1	porosity av = 21%(logs), and
Picard 1	porosity av = 8%(logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas source potential exists in the Beagle and Cossigny Troughs, Bedout High, west Bedout and Inner Rowley Sub-basins. The source in the Cossigny Trough, West Bedout Sub-basin and the Bedout High is immature.
- Reservoir potential exists in all basinal elements with the exception of the Pender and Jurgurra Terraces and Fitzroy Trough. Reservoirs depths range from 2100m in Keraudren 1 to 4220m in North Turtle 1.
- Intraformational seals exist in the Cossigny and Beagle troughs, Bedout High, west Bedout and Inner Rowley Sub-basins.
- Time slice J2 is considered to have fair prospectivity.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Bedout High:** Time slice J2 clastic reservoirs sourced from older source rocks and sealed by time slice J3 regional seals may be a viable play. The source charging the reservoirs would have to be from the Inner Rowley or west Bedout Sub-basins as no identified local source exists on the Bedout High.
- **Inner Rowley Sub-basin:** time slice J2 clastic reservoirs sourced from older source rocks or time slices J1-J2 source rocks and sealed by time slice J3 regional seals may be a viable play.
- Higher risk plays in the **Cossigny and Beagle Troughs** and west **Bedout Sub-basin** exist however the seals are intraformational and are considered a significant risk factor.
- **Beagle Sub-basin:** Intertidal and supratidal sandy reworked fringes around the Sable, Ronsard, Picard and Depuch blocks and other secondary blocks may create viable reservoirs. As the blocks are submerged, these fringes could form potential stratigraphic traps. The reservoir quality is uncertain as the sediment eroded off the blocks, Late Triassic to time slice J1 in age, has a high proportion of calcareous material that may reduce porosity.

TIME SLICE J3:

MIDDLE JURASSIC: LATE TOARCIAN (190.5 TO 189.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 2.

Time slice J3 is currently mature (VR ≥ 0.6%) within the Beagle Trough and Inner and Outer Rowley Sub-basins. Oil and gas source rocks, of fair to very good generative potential have been encountered in other areas of the module. Maximum thickness of the section is in the vicinity of 200m.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The diachronous Athol and Legendre Formations are present in the Beagle Sub-basin (Blevin et al, 1994) .
- The Depuch Formation and unnamed units are present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J3 is marked by a distinct change in lithology and depositional environment in the Surat and other eastern basins. It corresponds to the appearance of *Applanopsis spp*, and is marked by the development of ironstone oolite beds within the Evergreen Formation and its equivalents.

The spore pollen zones for the different time slices are listed on the left and the dinoflagellate zones on the right. Time slice J3 is wholly within spore pollen zone *C.turbatus*. There are no dinoflagellate zones recorded on the North West Shelf during this time slice.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page v).

Because of the poor palaeontological constraints on this time slice it has mostly been defined from the age depth plots. The *C.turbatus* zone straddles time slice upper J2 and all of time slices J3 and J4. In the absence of evidence to the contrary it is assumed that the *C.turbatus* zone represents an interval of continuous sedimentation.

- Bedout 1, Lagrange 1 & Ronsard 1: *C.turbatus* (B3),
- Depuch 1: *C.turbatus* (B1),
- East Mermaid 1: *C.turbatus* (B4),
- Keraudren 1,Phoenix 1 and 2: no palaeontological control,
- North Turtle 1 and Trafalgar 1: *C.turbatus* (B2), and
- Picard 1: *C.turbatus* (B2/B4).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Gondwana. A pre-rift structural phase of the Argoland breakup occurred within the time slice which was coincident with a short lived transgression. Time slice J3 is seen to be the time of the first pre-rift movement prior to Argoland breakup. Time slice J3 appears conformable with time slices J2 and J4. The more marine areas within the module area are interpreted in the Kangaroo Syncline, Dampier Sub-basin and the very northern part of the Outer Rowley Sub-basin. A range of fluvial to lower shoreface environments is represented in the time slice. Time slice J3 has clastic lithology's including sandstone to claystone with minor coal. Oil and gas indications have been recorded in Picard 1. Time slice J3 is mainly a local seal unit with poor reservoir potential. It is a mature source in the Beagle Trough and areas of the Inner and Outer Rowley Sub-basins and a sub-mature source within the Cossigny Trough.

TECTONICS:(SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of a greater Gondwana (Baillie et al, 1994).

In the Dampier Sub-basin, in time slices J3 to J5, the western Exmouth and Rankin Plateaus probably remained high in response to the Argoland pre-rift movements. These areas possibly created a source of sediment from the west. There is no incontrovertible evidence for this proposition, but significant volumes of sediment were deposited in the depocenters whilst on the high blocks of the plateaus this was a time of non-deposition or of deposition with subsequent erosion. Condensed intervals may be preserved in the localised lows on the plateaus.

Local (see Enclosure 28).

Speculative syn-rift hinge lines, not based on seismic, have been interpreted in the area of the Outer Rowley Sub-basin following time slice TR5 and TR6 structuring. Substantial Jurassic thicks lie on trend in the

adjacent Exmouth Plateau (Exon and Wilcox, 1980), suggesting deposition in structural lows interpreted as syn-rift here. The hinge lines are interpreted to be the distal equivalents of an extensional regime, active on the northern side of Argoland where potential rifting of Asian Terrains and opening of the Tethys ocean occurred during the Fitzroy Movement. As a precaution, the hinge lines are termed as such rather than specific faults or flexures so as to better reflect their distal location relative to the movements that occurred in the terrain (future Argoland) that was present on the present day location of the Argo Abyssal Plain . This would conform to an extensional regime with subtle syn-rift grabens developing within a thinned crust. The most southwestern hinge line is shown to have disappeared since time slice TR5.

The Dampier, Exmouth and Barrow Sub-basins were subsiding depocenters, coevally with the rift margin development. Malcolm et al (1991, pp168) identified significant block rotation related to oblique-slip movement in the Exmouth Sub-basin.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Trafalgar 1 gamma ray log patterns include mild smooth bells (sandstone). Ronsard 1 section is 100% claystone.

Beagle Trough: Picard 1 gamma ray log patterns consist of multiple moderately serrated funnels at the base and middle with serrated patterns at the top (siltstone and claystone). Sandstone and claystone are respectively 45% and 55% of the section in Picard 1. Depuch 1 gamma ray log patterns are serrated (interbedded sandstone and claystone). Sandstone and claystone are respectively 30% and 70% of the section in Depuch 1. North Turtle 1 gamma ray log patterns includes a massive serrated bed at the base (claystone) with smooth cylinder and serrated patterns at the top (claystone beds). Sandstone and claystone are respectively 40% and 60% of the section in North turtle 1.

West Bedout Sub-basin: Phoenix 1 has serrated cylinder gamma ray log patterns that merged into smooth bell patterns. Phoenix 2 has serrated gamma ray log patterns at the base (claystone) with multiple bell shaped patterns further up. Sandstone and claystone are respectively 35% and 65% of the section in Phoenix 2.

Bedout Sub-basin: The gamma ray log character is smooth in Keraudren 1 (sandstone).

Bedout High: Bedout 1 has interbedded claystone and sandstone. Sandstone and claystone are respectively 20% and 80% of the section in Bedout 1. Lagrange 1 has interbedded sandstone and claystone are respectively 40% and 60% of the section.

Rowley Sub-basin: East Mermaid 1 gamma ray log patterns is dominantly serrated with a moderate serrated funnel top. Sandstone and claystone are respectively 10% and 90% of the section.

THICKNESS VARIATIONS: (SEE ENCLOSURE 27).

Thicknesses range from 19m in Ronsard 1 to 168m in North Turtle 1. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from North Turtle 1 on line 110/01 in the Beagle Trough), is 300m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 200m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 28).

Globally this time slice is characterised by a low relative sea level. Within time slice J3 there are no globally recognised 3rd order eustatic sea level drops (Haq et al, 1987), partly due to the fact that this time slice spans only 2 million years. The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. The coastline is interpreted to have transgressed in the module area during time slice J3.

A continuation of the transgression with marine shallow continental shelf environment is envisaged for the adjacent Dampier Sub-basin as evidenced from limestones on the Enderby Terrace (Spencer et al, 1993). Some volcanic activity may also be taking place as evidenced from the increase in feldspar content. Fluvial to near shore sedimentation is proceeding in the Browse Basin (Wilmot, 1993).

PALAEOGEOGRAPHY: (SEE ENCLOSURE 28).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, rock samples dredged from the outer slope of the Rowley Sub-basin (AGSO, 1994; BMR, 1990b), the known absence of time slice J3 rocks from both wells and outcrop in the onshore Canning Basin (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

The following summarises the palaeogeographic map:

- Marine to land environments are interpreted in the very northwest part of the map, directly over what is present day oceanic crust and what will become Argoland. Argoland is the name given to a landmass that separated from the Australian plate during the late Callovian and consisted of what is today, west Burma and northwest Sumatra, and probably other undetected but still preserved landmasses (Metcalfe, 1993).
- The shallow marine platform developed in the Outer Rowley Sub-basin during the late Triassic Fitzroy Movement is still present, based on the downlap of time slices J3 (see time slice J2 for a complete discussion).
- An additional landmass (part Argoland, part Australian continent) has been interpreted in the present Argo Abyssal Plain area coinciding with the M26 magnetic lineament (see enclosure 1). It is assumed that the influx of marine conditions could be partially linked to a pre-time slice J7 breakup phase so that the emergence of land here would reflect a thermal arching phase. It may be one of several pre-time slice J7 breakup rift phases and lies within about 35 million years of the main breakup. Peripheral arch lows lie either side of it.
- All onlap edges on the southeast side of the map are phantomed using the discontinuous reflectors present in the Jurassic as a guide. Additionally a reasonable amount of well control is provided from Lynher 1, East Mermaid 1, Lagrange 1 and Keraudren 1. The reflectors are more continuous basinward providing a clearer downlap edge location on the shallow marine platform in the Outer Rowley Sub-basin. The confidence attributed to the location of the onlap edges in the southeast is considered good throughout the Jurassic, as the edges agree with what is interpreted by the BMR (BMR, 1981). The southern extent of the Jurassic onto the Lambert Shelf and Pilbara Block is much more interpretative as it is difficult to differentiate onlap from erosional edges.
- Restricted marine seaways in this interval are interpreted as epicontinental seas (Yeates, 1987). A short lived transgression, as suggested by calcareous nannofossils, may have occurred in the outer Rowley Sub-basin during the Toarcian (Shafik, 1994). Late Toarcian foraminifera suggest, together with lithology's recovered from dredge samples, that deltaic and marine environments occurred in the outer Rowley Sub-basin during time slice J3 (Exon and Wilcox,1980; AGSO,1994).

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few samples where 0.5%<TOC<1.0%, the bulk of the samples having a TOC > 1.0%. The samples meeting these criteria ranged 1.9%<TOC<21.9%, 2.99<S2<79.7, 155<HI<364 and 424<Tmax<434. These results indicate oil and gas sources, of fair to very good generative potential. The analysed samples were immature to sub-mature, but would be generative if buried deeper.

One sample from Ronsard 1, analysed in conjunction with this module, has a TOC of 2.42%, but poor generative potential and a low HI (Appendix 5 part 3).

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Oil and gas indications were present in Picard 1. The following list summarises the porosity data for this time slice:

Depuch 1	11%<porosity av<12% (logs),
North Turtle 1	13%<porosity av<17% (logs), and
Phoenix 1	porosity av = 22% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas source potential is present in the Beagle Trough, Bedout High, west Bedout and Inner Rowley Sub-basins. Sources are presently mature in the Beagle Trough and the Inner Rowley Sub-basin. An unconfirmed source (TOC > 1.0% but no rock-Eval data) exists in the Cossigny Trough that can be expected to be mature in some areas.
- Reservoirs are present in all areas with the exception of the Fitzroy Trough, Jurgurra and Pender Terraces. It is difficult to subjectively assess the trapping potential of time slice J3 as it is on average more shale prone and so more likely to act as a seal for hydrocarbons. Leakage of hydrocarbons up into younger Jurassic reservoirs cannot be discounted.
- Time slice J3 acts as a regional seal on the Bedout High and in the Inner Rowley Sub-basin. Intraformational seals can be found in the Cossigny and Beagle Troughs.
- Time slice J3 is considered to have fair potential.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Bedout High:** Time slice J3 clastic reservoirs sourced by an older source and sealed by time slice J3 regional seals may be a viable play. The source would have to be from the Inner Rowley or the west Bedout Sub-basins as no identified local source as yet exists on the Bedout High.
- **Inner Rowley Sub-basin:** Time slice J3 clastic reservoirs sourced by an older source or time slices J1-J3 source and sealed by time slice J3 regional seals may be a viable play.
- Higher risk plays in the **Cossigny and Beagle Troughs** and west **Bedout Sub-basin** exist where intraformational seal is a significant risk factor.
- **Beagle Sub-basin:** Intertidal and or supratidal fringes around the Sable, Ronsard blocks and other secondary blocks may be viable as the blocks are progressively being submerged and therefore form stratigraphic traps. As the sediments eroded off the blocks is Late Triassic, with a high proportion of calcareous material, the reservoir quality is uncertain.

TIME SLICE J4:

MIDDLE JURASSIC: LATE TOARCIAN, AALENIAN, EARLIEST BAJOCIAN (189.0 TO 180.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 2.

Time slice J4 is the youngest good source rock section that is currently mature (VR ≥ 0.6%) within the module area. It is mature in the Beagle Trough, Inner and Outer Rowley Sub-basins. All younger sections everywhere are immature to sub-mature. Oil and gas source rocks with very good generative potential have been encountered, a high percentage of which are from interpreted lower delta plain sediments.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The diachronous Athol and Legendre Formations are present in the Beagle Sub-basin (Blevin et al, 1994) .
- The Depuch Formation and unnamed units are present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J4 corresponds to the commencement of deposition of the Hutton Sandstone in the Eromanga and Surat basins, the Algebuckina Sandstone in the Poolowanna Trough, the Cattamarra Coal Measures in the Perth Basin, and the expansion of deposition in the Papuan Basin. Biostratigraphically it is loosely defined as the upper part of the *C.turbatus* zone. Their are no dinoflagellate zones defined for time slice J4 on the North West Shelf.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1, East Mermaid 1 and Keraudren 1 Ronsard 1: *C.turbatus* (B3),
- Depuch 1: *C.turbatus* (B1),
- Lacepede 1A: *C.turbatus* (B2/B5),
- Lagrange 1: no palaeontological control,
- North Turtle 1: *C.turbatus* (B2),
- Phoenix 1: *C.turbatus* (B4),
- Picard 1: *C.turbatus* (B2/B4),
- Poissonnier 1: *C.torosa* (B5), *C.turbatus* (B5), and
- Trafalgar 1: *C.turbatus* (B2), *M.florida* (B3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Gondwana. This was a tectonically quiescent time. Time slice J4 appears conformable with time slices J5 and J3. More marine areas are interpreted in the Kangaroo Syncline, Dampier Sub-basin and the very northern part of the outer Rowley Sub-basin. A range of fluvial to lower shoreface environments is represented throughout the time slice. Time slice J4 is the most terrestrially dominated time slice of all the interpreted Jurassic time slices. Typical clastic lithology's include sandstone and claystone with minor coal. Oil and gas indications have been recorded in Picard 1 and North Turtle 1. Time slice J4 is a reservoir unit with some local seal potential. Mature source exists in the Beagle Trough and areas of the Inner and Outer Rowley Sub-basins and sub-mature source rocks are found in the Cossigny Trough. Any migrating hydrocarbons would probably bypass the time slice and not be trapped until time slice J7 level.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of greater Gondwana (Baillie et al, 1994).

In the Dampier Sub-basin, during time slices J3 to J5, the western Exmouth and Rankin Plateau areas were probably high, in response to the development of the Argoland rift. They probably provided a source of sediment from the west. Although there is no incontrovertible evidence for this scenario, significant volumes of sediment were deposited in the depocenters, and non-deposition or subsequent erosion occurred in these areas. Condensed time slice J4 intervals may be preserved in localised lows on these highs.

Local (see Enclosure 29).

NE-SW trending syn-rift hinge lines are interpreted in the area of the outer Rowley Sub-basin, created during time slices TR5 and TR6 structuring. Their presence is speculative rather than substantiated from seismic. Substantial Jurassic thicks lie on trend in the adjacent Exmouth Plateau suggesting deposition in structural lows (Exon and Wilcox, 1980) here interpreted as being present on the northern side of syn-rift hinge lines. The hinge lines are interpreted to be the distal equivalents of an extensional regime, active on the northern side of Argoland where potential rifting of Asian Terrains and opening of the Tethyan ocean occurred during the Fitzroy Movement. The hinge lines are so termed, rather than called specific faults or flexures, to best reflect their distal relationship to the movements that were occurring in the future Argoland. The most southwestern hinge line is interpreted to have disappeared since time slice TR5 as this hingeline does not correspond to the location of the present day continent ocean boundary where plastic deformation occurred at Argoland breakup. The last hinge line may still be depositionally active as it is likely to remain a weakness zone within the crust as it is coincident with the present day continent ocean boundary.

In the Carnarvon Basin, coevally with the rift margin development, the Dampier, Exmouth and Barrow Sub-basins were subsiding depocenters. Malcolm et al (1991, pp168) identified significant block rotation related to oblique-slip movement in the Exmouth Sub-basin.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Ronsard 1 gamma ray log patterns include smooth beds at the base (claystone), mild funnel and smooth cylinder patterns (sandstone) with dominantly mild serrated funnel at top. Sandstone and claystone are both 50% of the section in Ronsard 1. Trafalgar 1 has mild serrated cylinder and bell shape gamma ray log patterns. Sandstone and claystone are respectively 90% and 10% of the section in Trafalgar 1.

Beagle Trough: Depuch 1 gamma ray log patterns are serrated at the base (claystone), smooth cylinder and serrated funnel in the middle with dominantly serrated funnel at the top. Sandstone and claystone are respectively 55% and 45% of the section in Depuch 1. North Turtle 1 gamma ray log patterns consist of a serrated funnel at the base, smooth cylinder in the middle and is serrated at the top (claystone). Sandstone to claystone are respectively 60% and 40% of the section in North Turtle 1. Picard 1 has both serrated bell and funnel patterns. Sandstone and claystone are respectively 55% and 45% of the section in Picard 1. Poissonnier 1 consists of 10% claystone with interbedded sandstone and siltstone.

West Bedout Sub-basin: Phoenix 1 contains mild serrated funnel gamma ray log patterns at the base whilst Phoenix 2 has dominantly serrated cylinder, mild serrated bell and funnel gamma ray log patterns. Sandstone represents respectively in Phoenix 1 and Phoenix 2 95% and 85% of the section.

Bedout Sub-basin: Keraudren 1 contains 100% sandstone.

Bedout High: Bedout 1 gamma ray log patterns include dominantly smooth cylinders with mild serrated bells and are serrated (claystone). Claystone and sandstone are respectively 30% and 70% of the section in Bedout 1. Lagrange 1 has mild serrated cylinder gamma ray log patterns at the base with serrated bells towards the top. Claystone and sandstone are respectively 30% and 70% of the section in Lagrange 1.

Rowley Sub-basin: East Mermaid 1 gamma ray log patterns are serrated (claystone) with dominantly smooth cylinder and mild smooth bells. Sandstone and claystone are respectively 55% and 45% of the section .

Offshore Fitzroy Trough: Lacepede 1 contains a smooth cylinder gamma ray log pattern (dominantly sandstone, 10% interbedded claystone).

THICKNESS VARIATIONS: (SEE ENCLOSURE 27).

Thicknesses range from 93m in Poissonnier 1 to 350m in North Turtle 1. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from North Turtle 1 on line 110/01 in the Beagle Trough), is 400m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 450m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 29, 31).

Globally time slice J4 is characterised by low to intermediate relative sea levels. There are within time slice J4 five globally recognised 3rd order eustatic sea level drops (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a stable eustatic regime in the lower part of the time slice with a mild transgression in the upper part of the time slice. During time slice J4 the coastline is interpreted to have regressed in the module area.

A continuation of a transgressive sequence, is envisaged for the adjacent Dampier Sub-basin with deltaic environments in the eastern half and offshore shallow marine in the western half (Spencer et al, 1993). A fluvial to near shore environment is interpreted in the Browse Basin (Wilmot, 1993).

PALAEOGEOGRAPHY: (SEE ENCLOSURES 29, 31).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, some rock samples dredged from the outer slope of the Rowley Sub-basin (AGSO, 1994; BMR, 1990), palaeogeographic interpretations from onshore Canning Basin wells and outcrop and palaeogeographic interpretations from the adjacent Browse and Dampier Basin modules (Wilmot, 1993; Spencer et al, 1993). Secondary sources are from AGSO(BMR), industry and university published work.

The following summarises the palaeogeography map:

- Marine to land environments are interpreted in the very northwest part of the map, directly over what is present day oceanic crust and what will become Argoland. Argoland is the name given to a landmass that separated from the Australian plate during the late Callovian and consisted of what is today, west Burma and northwest Sumatra, and probably other undetected but still preserved landmasses (Metcalfe, 1993).
- An additional landmass, formed during time slice J3, has been interpreted in the present Argo Abyssal Plain coinciding with the M26 magnetic lineament (see enclosure 1). It is assumed that the influx of marine conditions in time slice J3 could have been partially linked to a pre-time slice J7 rift onset phase, so that the emergence of land here would reflect thermal arching during time slice J3. It may be one of several pre-time slice J7 structural phases as it lies within 35 million years of the main Argoland breakup. Peripheral arch lows, lie either side of the arch, in time slice J4 are interpreted to be the location of marine seaways. The landmass has reduced in size since time slice J3 with fluvial deposits building up either side of the arch during time slice J4.
- All onlap edges on the southeast side of the map are phantomed using the discontinuous reflectors present in the Jurassic as a guide. Additionally a reasonable amount of well control is provided from Lynher 1, East Mermaid 1, Lagrange 1 and Keraudren 1. The southern extent of the Jurassic onto the Lambert Shelf and Pilbara Block is more interpretative as it is difficult to differentiate onlap and depositional limits as opposed to erosional edges.
- Restricted marine seaways in this interval are thought of as epicontinental seas (Yeates, 1987). Seaways are interpreted to be retreating during this time, with a high proportion of the area containing terrestrial fluvial environments. Dredge samples, of possible Middle Jurassic age, from adjacent to the present COB on the edge of the outer Rowley Sub-basin, are interpreted as probably being deposited in deltaic environments (Exon, 1990).

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few samples where 0.5%<TOC<1.0%, the bulk of the samples having a TOC>1.0%. The samples meeting these criteria ranged 0.51%<TOC<49.1%, 2.68<S2<94.6, 151<HI<340 and 419<Tmax<435. These results indicate potential oil and gas source rocks with very good generative potential, however they are immature to sub-mature in samples analysed. A high percentage of samples are from interpreted lower delta plain sediments.

Ten samples from the East Mermaid 1 well, analysed by Rock-Eval as part of this module, gave encouraging results (Appendix 5 part 3). HIs' ranged from 58 to 262 with the bulk of the values above 150. These are oil and gas prone source rocks. TOCs' range from 0.92% to 8.39%, whilst S2 ranges from 0.53 to 22, with the bulk of the S2 values showing fair to good generative potential.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Oil and gas indications were recorded in North Turtle 1 and Picard 1. The following list summarises the porosity data for the time slice:

Depuch 1	11%<porosity av<15% (logs),
Phoenix 1	porosity av = 22%(logs), and
Poissonnier 1	porosity av = 24% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

Oil and gas source potential exists in all areas with the exception of the Jurgurra and Pender Terraces. These source rocks are presently mature in the Beagle Trough and the Inner Rowley Sub-basin and are likely to be mature in areas of the Cossigny Trough.

Reservoir potential exists in all areas with the exception of the Pender and Jurgurra Terraces. As only intraformational seals exist within time slices J4 to J7, leakage of hydrocarbons from J4 reservoirs right up into Upper Jurassic reservoirs is likely.

Intraformational seals are found in the Beagle and Cossigny Troughs, Bedout High, west Bedout and Inner Rowley Sub-basins.

The prospectivity of time slice J4 is considered fair to poor.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

Only high risk plays are present in the **Cossigny and Beagle Troughs**, **west Bedout** and **Inner Rowley Sub-basins** and **Bedout High** where intraformational seals are a significant risk factor.

TIME SLICE J5:

MIDDLE JURASSIC: BAJOCIAN (180.0 TO 177.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 2.

FORMATION SYNONYMS: (SEE FIGURE 2).

The Legendre Formation is present in the Beagle Sub-basin (Blevin et al, 1994).

The Depuch Formation and unnamed units are present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J5 is marked by a marine transgression in the Perth Basin. It is biostratigraphically defined by the *D.caddaensis* dinoflagellate zone. Ammonites contained within sediments of time slice J5 in the Perth Basin allow direct correlation with the European stages.

The spore pollen zones for the time slice is listed on the left and the dinoflagellate zone on the right.

Time slice J5: *C.turbatus* & lower *D.complex*. . . . . .*D.caddaensis*.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings.(refer to introduction for description of confidence rating, page iii):

- Bedout 1: *D.caddaensis* (B5),
- Depuch 1: *D.caddaensis* (B1), *D.complex* (B1),
- East Mermaid 1: *C.turbatus* (B5), D.complex (B5),
- Keraudren 1/Lagrange 1/Phoenix 1: no palaeontological control,
- Lacepede 1A: *C.turbatus* (B3),
- Minilya 1: *D.complex* (B4),
- North Turtle 1: *D.complex* (B3),
- Perindi 1: *C.torosa* (B5),
- Picard 1: *D.caddaensis* (B3), and
- Wamac 1: *C.turbatus* (D6/B3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Gondwana. A pre-rift structural phase of Argoland breakup occurred within this time slice coincident with a short lived transgression (Shafik, 1994). The final breakup with the formation of the Argo Abyssal Plain is thought to have occurred at the end of time slice J7 potentially extending into lower time slice J8. Time slice J5 appears conformable with time slices J6 and J4. Marine areas within the module area are interpreted in the Dixon and Beagle Sub-basins and the very northern part of the Outer Rowley Sub-basin. A range of fluvial to lower shoreface environments is represented in the time slice. Time slice J5 has clastic lithology's including sandstone to claystone with minor coal. Oil and gas indications have been recorded in Picard 1 and Depuch 1. Time slice J5 is a reservoir unit with some local seal potential, whilst a sub-mature source exists in the Beagle Trough and areas of the Inner to Outer Rowley Sub-basins where further potential may exist in the more deeply buried sediments.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of greater Gondwana (Bailie et al, 1994). In time slices J3 to J5, the western Exmouth and Rankin Plateau probably remained high in response to the development of the Argoland rift, and possibly created a source of sediment from the west. There is no incontrovertible evidence for this proposition, but significant volumes of sediment were deposited in the depocenters, and this time was one of non-deposition or subsequent erosion on the high blocks of the plateau. Condensed intervals may also be preserved in localised lows.

Local

Very little is known about the local tectonic regime present during this time slice in the module area. Coevally with the rift margin development, were the subsiding depocenters of the Dampier, Exmouth and Barrow Sub-basins. Malcolm et al (1991, pp168) identified significant block rotation related to oblique-slip movement in the Exmouth Sub-basin. They saw this tear movement on features such as the Bundegi Fault

creating terraces and thereby extending the boundary of the Exmouth Sub-basin eastwards. In time slice J6 local subsidence continued, as did the Argoland rift development. Associated trans-tensional faulting intensified along the margins of the Barrow, Dampier and Exmouth Sub-basins.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Beagle Trough: Picard 1 gamma ray log patterns include alternating highs and lows (sandstone and claystone) with smooth bell patterns at the base. Alternating highs and lows (claystone and sandstone) and overall bell shaped patterns in the middle and the top are also present. Sandstone and claystone are respectively 40% and 60% of the section in Picard 1. Depuch 1 gamma ray log patterns include alternating highs and lows (claystone and sandstone), a serrated funnel at the base, serrated bells in the middle and interbedded patterns (sandstone and claystone) at the top. Sandstone and claystone are respectively 60% and 40% of the section in Depuch 1. North Turtle 1 gamma ray log patterns have serrated funnels at the base, alternating highs and lows (sandstone and claystone) in the middle and serrated funnels at the top. Sandstone and claystone both are 50% of the section in North Turtle 1.

West Bedout Sub-basin: Phoenix wells and Keraudren 1 gamma ray log patterns include continuous mildly serrated cylinders. Phoenix 2 in addition has one smooth bell pattern. Minilya 1 has mild gamma ray log serrated bell patterns. In the Phoenix wells and Keraudren 1, the lithology is dominantly sandstone with very occasional claystone beds, representing respectively 95% and 5% of the section. Sandstone and claystone represents respectively 75% and 25% of the section in Minilya 1.

Bedout High: Bedout 1 gamma ray log patterns include a smooth cylinder that merges into a serrated bell at the base. Alternative high and low patterns (claystone and sandstone) are found in the middle with a smooth cylinder at the top. Lagrange 1 gamma ray log patterns include a moderate serrated bell pattern at the base (claystone), top and the middle (sandstone). Sandstone and claystone are respectively 85% and 15% of the section in Lagrange 1.

Rowley Sub-basin: East Mermaid 1 gamma ray log patterns have alternating highs and lows (claystone and sandstone) at the base with mild serrated bells in the middle and the top. Sandstone and claystone are respectively 85% and 15% of the section.

Offshore Fitzroy Trough: Wamac 1 gamma ray log patterns are alternating highs and lows (sandstone and claystone) and have serrated funnel patterns at the base, smooth cylinder and serrated pattern (claystone) in the middle and serrated funnels at the top. Sandstone and claystone are respectively 65% and 35% of the section.

Pender Terrace: The Perindi 1 gamma ray log pattern comprises a serrated cylinder (95% sandstone).

THICKNESS VARIATIONS: (SEE ENCLOSURE 27).

Intersected intervals range from 77m in Perindi 1 to 284m in East Mermaid 1. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from North Turtle 1 on line 110/01 in the Beagle Trough), is 250m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 400m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 30, 31).

Globally this time slice is characterised by a relative sea level low. Within time slice J5 there is one globally recognised eustatic sea level drop representing a 3rd order cycle (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a very mild regression. The marine seaways are interpreted to have transgressed landward for the module area relative to time slice J4 making time slice J5 a marine transgressive unit.

A continuation of a transgressive sequence with marine shallow continental shelf environment is envisaged for the adjacent Dampier Sub-basin peaking during this time slice with deltaic in the eastern half and offshore shallow marine in the western half (Spencer et al, 1993). Fluvial to near shore environments are suggested in the Browse Basin (Wilmot, 1993).

PALAEOGEOGRAPHY: (SEE ENCLOSURES 30, 31).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, rock samples dredged from the outer slope of the Rowley Sub-basin (AGSO, 1994; BMR, 1990), palaeogeographic interpretations from onshore Canning Basin wells and outcrop (BMR, 1981), palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

The following summarises the palaeogeographic map:

Marine to land environments are interpreted in the very northwest part of the map, directly over what is present day oceanic crust and what will become Argoland. Argoland is the name given to a landmass that separated from the Australian plate during the late Callovian and consisted of what is today, west Burma and northwest Sumatra, and probably other undetected but still preserved landmasses (Metcalfe, 1993).

An additional landmass has been interpreted in the present Argo Abyssal Plain coinciding with the M26 magnetic lineament (see enclosure 1). It is assumed that the influx of marine conditions in time slices J3 and J5 could be partially linked to two pre-time slice J7 breakup rift phases with the emergence of land reflecting thermal arching. These may be one of several pre-time slice J7 breakup rift phases which lie within about 35 million years of the main breakup. Peripheral arch lows lie either side of the thermal arch during time slice J5 and are interpreted to be the location of marine seaways. Fluvial environments have been replaced by upper delta plain environments since time slice J4.

Emergent land on the Broome Platform may be present, formed as a result of pre-time slice J7 rift movement or caused by abandonment or avulsion of time slice J4 upper delta plain sediment source.

All onlap edges on the southwest side of the map are phantomed using the discontinuous reflectors present in the Jurassic as a guide. Additionally a reasonable amount of well control is provided from Beagle Sub-basin wells. Bajocian rocks are found onshore, implying that possible subsidence, transgression or structural readjustments far inland, resulted in the sourcing of sediments to the onshore and Offshore Canning Basin.

Restricted marine seaways in this interval are thought of as epicontinental seas (Yeates, 1987). A short lived transgression during the Bajocian may have occurred in the offshore Rowley Sub-basin as suggested from calcareous nannofossils (Shafik, 1994). The Cadda Formation in the Perth Basin is also evidence of this transgression on a regional scale (Yeates, 1987). Forams and nannofossils of this age together with dredge samples indicating marine to deltaic environments in the Outer Rowley Sub-basin (Exon, 1990(b)).

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 6).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few samples where 0.5%<TOC<1.0%, the bulk of the samples having a TOC>1.0%. Samples meeting the selection criteria revealed 0.85%<TOC<60.61%, 2.3<S2<113, 159<HI<385 and 419<Tmax<440 indicating the potential of oil and gas prone source within this time slice with fair to very good generative potential with maturity ranging from immature to mature.

One sample was analysed by Rock-Eval as part of this module in the East Mermaid 1 and gave encouraging results (Appendix 5 part 3). Results are a HI of 384, TOC of 14% and an S2 of 53.72, probably indicative of a coaly source rock.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

A gas indication is present in Depuch 1 whilst oil and gas indications are recorded in Picard 1. The following list summarises the porosity data for the time slice:

Depuch 1	porosity av = 15% (logs),
Phoenix 1	porosity av = 22% (logs),
Picard 1	porosity av = 13% (logs), and
Lacepede 1A	3.9% < porosity av < 38% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

Potential oil and gas source rocks exist in the Beagle Trough, west Bedout Sub-basin, Bedout High, Fitzroy Trough and Pender Terrace.

Potential oil source rocks exist in the Inner Rowley Sub-basin.

Reservoir potential exists in all areas with the exception of the Cossigny Trough and Jurgurra Terrace. As only intraformational seals exist within time slices J5-J7, leakage of hydrocarbons from time slice J5 reservoirs is likely.

Intraformational seals exist in the Beagle Trough, Inner Rowley Sub-basin and Fitzroy Trough.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- Only high risk plays are present in the **Beagle Trough, west Bedout and Inner Rowley Sub-basins** where intraformational seal is a significant risk factor.
- **Beagle Sub-basin:** Intertidal and supratidal fringes around the Sable, Ronsard, Picard and Depuch blocks and other secondary blocks may be viable as stratigraphic traps. As the sediments eroded off the blocks are Middle Jurassic age and have a high proportion of sand, the reservoir quality is expected to be reasonable.

The blocks are interpreted to have been rejuvenated during time slice J5 pre-rift phase tectonism prior to the Argoland breakup.

TIME SLICE J6:

MIDDLE JURASSIC: BAJOCIAN, BATHONIAN AND EARLY CALLOVIAN (177.0 TO 167.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 2.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Legendre Formation is present in the Beagle Sub-basin (Blevin et al, 1994).
- Depuch Formation and unnamed units are present in the Roebuck and Offshore Canning Basins. Although these are absent through erosion (Colwell & Stagg, 1994), they have been interpreted to be present in this module.

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

The base of time slice J6 equates with the top of *D.caddaensis* dinoflagellate zone. Stratigraphically, the base of the time slice coincides with the end of the Cadda transgression in the Perth Basin and the top of the time slice equates to the regional "Callovian Unconformity" seen in several basins on the North West Shelf. The top of the time slice is defined as the top of the *C.cooksoniae* spore pollen zone, and or the top of the *W.indotata* dinoflagellate zone. The *C.halosa* dinoflagellate zone is within time slice J6 as is the upper part of the *D.complex* spore pollen zone.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *W.indotata* (B4),
- Depuch 1: *D.complex* (B1), *C.cooksoniae* (B1/B6),
- East Mermaid 1: *C.cooksonaie* (B5),
- Jarman 1/Kambara 1/Lagrange 1 Minjin 1/Pearl 1/Perindi 1: no palaeontological control,
- Keraudren 1: *D.complex* (B5), *C.cooksoniae* (B5),
- Lacepede 1A: *D.complex* (B3/B6),
- Minilya 1: *D.complex* (B4), *C.cooksoniae* (B3/B4),
- North Turtle 1: *C.cooksonaie* (B2), *W.indotata* (B2/B4),
- Phoenix 1: *C.cooksoniae* (B3/B5),
- Phoenix 2: *C.cooksoniae* (B3/B4),
- Picard 1: *D.complex* (B2/B3/B6), *C.cooksoniae* (A3/B2), and
- Wamac 1: *C.turbatus* (D6/B3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Gondwana with the pre-breakup structural phases of the Argoland breakup dominating the time slice. Time slice J6 appears conformable with time slices J5 and J7. Marine areas within the module area are interpreted in the Dixon and Beagle Sub-basins with fluvial to lower shoreface environments presented in the time slice. Time slice J6 has typical clastic lithology's including sandstone to claystone with minor coal. Oil and gas indications have been recorded in Lacepede 1A, Cossigny 1, Depuch 1 and Picard 1. Time slice J6 is dominantly a reservoir unit with some local seal potential. A sub-mature source exists in the Beagle Trough and areas of the Inner and Outer Rowley Sub-basins and further potential source may exist in the more deeply buried sediments.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of a greater Gondwana (Baillie et al, 1994). In time slices J3 to J5, the western Exmouth and Rankin Plateau probably remained high in response to the development of the Argoland rift, and possibly created a source of sediment from the west. There is no incontrovertible evidence for this proposition, but significant volumes of sediment were deposited in the depocenters, and this time was one of non-deposition or subsequent erosion on the high blocks of the plateau. There may also be preserved condensed intervals in the localised lows.

Local

Very little is known about the local tectonic regime of this time slice in the module area. The subsiding depocenters of the Dampier, Exmouth and Barrow Sub-basins developed coevally with the rift margin development. Malcolm et al (1991, pp168) identified significant block rotation related to oblique-slip movement in the Exmouth Sub-basin. They identified this movement on features such as the Bundegi Fault, where it created terraces and extended the boundary of the Exmouth Sub-basin eastwards. In time slice J6 subsidence continued, as did the Argoland rift development. Associated transtensional faulting intensified along the margins of the Barrow, Dampier and Exmouth Sub-basins.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Jarman 1 gamma ray log pattern is a smooth cylinder (sandstone).

Beagle Trough: Picard 1 gamma ray log patterns include a smooth cylinder at the base, alternating lows and highs (sandstone and claystone), a smooth cylinder towards the middle and a smooth cylinder and alternative lows and highs (sandstone and claystone) at the top. Sandstone and claystone are respectively 70% and 30% of the section in Picard 1. Depuch 1 gamma ray log patterns portray alternating lows and highs and cylinders (sandstone and claystone). Sandstone and claystone are 55% and 45% of the section in Depuch 1. North Turtle 1 gamma ray log patterns have dominantly alternating lows and highs (sandstone and claystone) with occasional serrated beds throughout.

West Bedout Sub-basin: Phoenix 1 gamma ray log pattern consists of mild serrated bells. Sandstone and siltstone are 75% and 25% of the section in Phoenix 1. Phoenix 2 in addition has one funnel pattern (sandstone percentage of 90%). Minilya 1 gamma ray log patterns include moderately serrated funnels towards the base and middle with alternating highs and lows towards the (sandstone and claystone) top. Sandstone and claystone are respectively 60% and 40% of the section in Minilya 1.

Bedout Sub-basin: Keraudren 1 gamma ray log patterns are all mild serrated bell patterns (sandstone).

Bedout High: Bedout 1 gamma ray log patterns include a serrated cylinder at the base with smooth cylinder, funnel and bell in the middle and top. Sandstone and claystone are respectively 85% and 15% of the section in Bedout 1. Lagrange 1 gamma ray log patterns have dominantly serrated bells with two serrated funnels. Sandstone and claystone are respectively 90% and 10% of the section in Lagrange 1.

Rowley Sub-basin: East Mermaid 1 gamma ray log patterns have alternating serrated bells and funnels. Sandstone and claystone are respectively 40% and 60% of the section.

Offshore Fitzroy Trough: Lacepede 1A has mild serrated gamma ray log patterns (sandstone). Wamac 1 has mild serrated bell patterns. Sandstone and claystone are respectively 95% and 5% of the section in Wamac 1.

Pender Terrace: Kambara 1 has continuous sandstone with more siltstone towards the top. Minjin 1 gamma ray log patterns are serrated (sandstone with more siltstone towards the top). Sandstone and claystone are respectively 90% and 10% of the section in Minjin 1. Perindi 1 has continuous sandstone.

Jurgurra Terrace: Gamma ray log patterns in Pearl 1 are mild serrated. Sandstone and claystone are respectively 95% and 5% of the section.

THICKNESS VARIATIONS: (SEE ENCLOSURE 27).

Intersected intervals range from 112m in Minilya 1 to 892m in Depuch 1. A maximum thickness for the time slice, estimated from seismic in the Beagle Sub-basin (extrapolating from North Turtle 1 on line 110/01 in the Beagle Trough), is 900m. A maximum thickness for the time slice, estimated from seismic in the Roebuck Basin (extrapolating from Lagrange 1 on line 120/01 in the Rowley Sub-basin), is 450m.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 31, 32).

Globally this time slice is characterised by an intermediate to low relative sea level. Within time slice J6 there are two globally recognised eustatic sea level drops representing 3rd order cycles (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. The base of time slice J6 is marked by a large sea level fall. An increase in the distribution of lower and upper delta plain environments is interpreted in this time slice.

PALAEOGEOGRAPHY: (SEE ENCLOSURES 31, 32).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, rock samples dredged from the outer slope of the Rowley Sub-basin, palaeogeography interpretations from the onshore Canning Basin wells and outcrop and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin

(Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

The following summarises the palaeogeography map:

Marine to land environments are interpreted in the very northwest part of the map, directly over what is present day oceanic crust and what will become Argoland. Argoland is the name given to a landmass that separated from the Australian plate during the late Callovian and consisted of what is today, west Burma and northwest Sumatra, and probably other undetected but still preserved landmasses (Metcalfe, 1993).

An additional landmass formed during time slice J3 has been interpreted in the present Argo Abyssal Plain area coinciding with the M26 magnetic lineament (see enclosure 1). It is assumed that the influx of marine conditions in time slices J3 and J5 could be partially linked to two pre-time slice J7 breakup rift phases and the emergence of land here would reflect thermal arching. Several pre-breakup rift phases are likely to have occurred within about 35 million years of the main breakup. Peripheral arch lows lie either side of the arch and are interpreted to be the location of marine seaways.

All onlap edges on the southwest side of the map are phantomed using the discontinuous reflectors present in the Jurassic as a guide. Additionally a reasonable amount of well control is provided from Beagle Sub-basin wells.

Restricted marine seaways are shown to be still present.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few samples where 0.5%<TOC<1.0%, the bulk of the samples having a TOC>1.0%. The 44 samples meeting the selection criteria revealed 0.58%<TOC<50.49%, 0.97<S2<112, 151<HI<389 and 422<Tmax<438, indicating an oil and gas prone source with poor to very good generative potential that range from immature to marginally mature.

Three Rock-Eval analyses were undertaken as part of this module, two in the East Mermaid 1 well and one in the Bedout 1 well. The Bedout 1 sample gave a HI of 208, a TOC of 7.88% and an S2 of 16.37 suggesting a possible coal source. The two East Mermaid 1 samples gave HIs' of 110 and 274, TOCs' of 5.52% and 4.21% and S2s' of 6.08 and 11.55, and reflect a gas prone source.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

A gas indication was present in Lacepede 1 with an oil indication present in Cossigny 1. Oil and gas indications were present in Depuch 1 and Picard 1. The following list summarises the porosity and permeability data for the time slice:

Depuch 1	15%<porosity av<20%(logs),
Perindi 1	porosity av = 24.9% (logs),
Phoenix 1	porosity av = 24% (logs), and
Picard 1	porosity av = 13% (logs), 9.4%<porosity av<28.2%(core), 2.0<permeability<742 mD (core),

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas prone source rocks are found in the Beagle Trough, west Bedout Sub-basin, Bedout High, Inner Rowley Sub-basin and Pender Terrace. These are presently sub-mature but are likely to be mature in some areas of the Beagle Trough and some areas of the Inner and Outer Rowley Sub-basin.
- J6 reservoirs are found in all areas. Leakage of hydrocarbons into younger reservoirs is unlikely in the Inner Rowley Sub-basin, Bedout High and Cossigny Trough whereas leakage up to at least time slice J9 would probably occur in the remaining area.
- Intraformational, but no regional, seals exist in the Beagle Trough, west Bedout Sub-basin and Inner Rowley Sub-basin.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Bedout Sub-basin:** Time slice J6 clastic reservoirs sourced by an older source and sealed by time slice J9 regional seals may be a viable play.
- **Bedout High:** Time slice J6 clastic reservoirs sourced by an older source and sealed by time slice K1 regional seals may be a viable play. A Triassic or older source would have to be from the adjacent west Bedout and Inner Rowley Sub-basins.
- **Inner Rowley Sub-basin**: Time slice J6 reservoirs sourced by Triassic or Jurassic (time slices J1 to J5) source rocks.

- High risk plays in the **Beagle Trough** and west **Bedout Sub-basin** with intraformational seals as a significant risk factor.

TIME SLICE J7:

MIDDLE JURASSIC: MIDDLE CALLOVIAN TO EARLY OXFORDIAN (167.0 TO 162.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 2.

This time slice is coincident with a major structural phase on the north west shelf as Argoland commenced to breakup. A heat pulse may be associated with this event in the outer Rowley and Dixon sub-basins. It may also be a time of migration of deeper mature source although the intensity of the tectonics, with faults reaching the surface, implies that hydrocarbons may have escaped the system.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Calypso Formation is present in the Beagle Sub-basin (Blevin et al, 1994). Hocking (1994) defines it as a fine-grained sedimentary rocks that were deposited between the onset and the completion of the Callovian-Oxfordian rifting episode. Its ranges from the base of *W.digitata* to the top of *W.spectabilis*. The Emma Member is a sandy interval at the base of the Calypso Formation found in the eastern Barrow and Dampier Sub-basins.
- The Depuch Formation and unnamed units are present in the Offshore Canning and Roebuck Basins even though these are shown to be absent due to erosion in Colwell & Stagg (1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J7 is defined by dinoflagellate zones *W.digitata* and *R.aemula* and spore pollen zone lowermost *M.florida*. The base of time slice J7 equates with the base of the *M.florida* spore-pollen zone and the *W.digitata* dinoflagellate zone. It incorporates the *R.aemula* zone, and the top is defined by the base of the dinoflagellate zone *W.spectabilis*. It is a time of uplift and erosion, prior to the commencement of sea floor spreading on the North West Shelf, and coincides with the transition from Hutton Sandstone deposition to a lower energy shale prone Birkhead Formation fluvial-lacustrine regime in the eastern Australian Eromanga Basin.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Jarman 1: *W.digitata* (B3), *M.florida* (B5),
- Minilya 1: *W.digitata* (B2/B5),
- North Turtle 1: *W.digitata* (B2/B4), *R.aemula* (B3), and
- Trafalgar 1: *W.digitata* (B2), *M.florida* (B3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of greater Gondwana. Breakup with the formation of the Argo Abyssal Plain is thought to have occurred at the end of time slice J7 potentially extending into lower time slice J8. Time slice J7 is bounded at the top by a regional unconformity (the Main Unconformity, breakup Unconformity or Jc seismic horizon), but appears conformable with time slice J6. More marine areas within the module area are interpreted in the Dixon and Beagle Sub-basins whilst fluvial to lower shoreface environments dominate elsewhere in the time slice. Lithology's range from sandstone to claystone. The Nebo 1 well discovered oil in the Calypso Formation in the Beagle Sub-basin, proving the generative potential of the local source rocks. Nebo 1 is the only discovery in the module area. Time slice J7 is a dominantly reservoir unit although sub-mature source exists in the Beagle and Cossigny Troughs and west Bedout Sub-basin. Additional potential mature source rocks may exist in more deeply buried areas.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part of greater Gondwana (Baillie et al, 1994). Through all or most of time slice J7, a transtensional regime initiated distal rifting and caused possibly as much as 1 to 2 kilometres of uplift along the major platforms (Kopsen and McGann, 1985. pp159). This is the time of the Argoland break-up, with the first oceanic crust being generated by the end of this time slice. Breakup and drift occurred along the northern margin of the Exmouth Platform, and there is also major tectonic activity on the western and southern boundaries of the Exmouth Plateau along the future rifting margin of Greater India. The strike-slip nature of this tectonism caused different areas to simultaneously undergo extension and compression.

Within the Barrow and Dampier and probably the Exmouth depocenters, there was a hiatus at the start of time slice J7, followed by extensive subsidence and deposition.[1]

Local

The top Jurassic Breakup TWT structure contour map (Enclosure 61) shows:

- localised highs and lows that are the outcome of higher intensity structural regimes in the Beagle Sub-basin during the Argo and Greater India breakups than found in the adjacent Roebuck Basin,
- a uniform NW-SE structural gradient in the Roebuck Basin, and
- a structural deep in the Outer Beagle Platform representing the Thouin Graben.

The top Jurassic breakup (Jc) to top Triassic (TR) isochron map (Enclosure 62) shows:

- thicks within the Outer Rowley and Bedout Sub-basins and a trough to the SE of Minilya 1 well. These reflect depocenters established at the time of deposition as the Jurassic is known to be less affected by uplift and erosion here than in the adjacent Beagle Sub-basin,
- very localised thicks and thins that reflect deep seated troughs and highs within the Beagle Sub-basin. Features within the Beagle Sub-basin include:
  - E to NE trending features such as the Beagle and Cossigny synclinal troughs and basin margin fault,
  - N to NE intra basin features such as the Picard, Ronsard blocks and others on the Outer Beagle Platform, and
  - N to NNW trending transfer faults that offset the other trends.

Many of these features are not observed on this map due to its regional nature but are outlined in Blevin et al (1993). The Beagle Sub-basin is known to have been substantially affected by the main Jurassic breakup phase that included wrench tectonics, and

- the pull-apart within the Thouin Graben (Swan Canyon) has produced a series of rotated Triassic and Jurassic blocks that show up as sedimentary thins.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Jarman 1 gamma ray log patterns include a cylinder at the base overlain by a massive serrated funnel shape (claystone). Lithology consists of some claystone, siltstone and minor dolomite. Sandstone and claystone are respectively 80% and 20% of the section.

Beagle Trough: North Turtle 1 has a massive partly serrated gamma ray log pattern (claystone). A sandstone bed is present towards the top overlain by a uniform claystone. Sandstone and claystone are respectively 20% and 80% of the section.

West Bedout Sub-basin: Minilya 1 section consists of one relatively smooth gamma ray log funnel pattern. Sandstone and claystone percentage are respectively 75% and 25% of the section.

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[1] There is some evidence to suggest that the initiation of seafloor spreading in the Argo Abyssal Plain could be younger than presently accepted. The bulk of the evidence suggests that ODP Site 765 lies on magnetic anomaly M26, but it is possible that the site could be as young as magnetic anomaly M20. If so, this would suggest a two stage breakup to Argoland with the most northerly block (containing the DSDP Site 261) drifting slightly before the southerly region.

Magnetic Anomaly M26 has an estimated age of approximately 147 Ma (Haq et al , 1987) or 164 Ma (Harland et al, 1982). In either case it is Oxfordian: time slice J7 or J8. As the site is only 75km from the COB it is thought that seafloor spreading in the Argo Abyssal Plain commenced about 3 to 4Ma earlier. Veevers & Li (1991) calculate the breakup at 158.6 Ma interpreting the ODP 765 site to be on magnetic anomaly M26. A minimum age of the oldest oceanic crust is 155Ma ± 3.4 MA based on a K/Ar age of celedonite in basaltic basement in ODP Site 765.

Dumoulin & Bown (1990) describe the basal sediment that overlies the basalt as a silty claystone with some angular quartz. This would indicate fairly rapid sedimentation except for the presence of manganese micronodules that indicate a low sedimentation rate of 2.5m/Ma. The quartz is interpreted to be aeolian and could have been sourced from either Greater India or Australia or Argoland. Sediments that immediately overlie the basalt are estimated to be 149MA (late Tithonian) based on nannofossil and dinoflagellate evidence, as well as an estimated slow depositional rate of 2m/MA. This implies a minimum time gap of 10MA between the basalt extrusion and initial sedimentation, a situation that would appear unlikely, given the proximity to the COB at this time; unless the ODP Site 765 was somehow positioned that it was bypassed by sedimentation.

Gillis et al (1992, p197-198) interprets that the mineralogical alterations of the basalt in ODP 765 indicate that low temperature alteration by oxygenated normal seawater was short lived and was followed by a conductive heating event. The implication is that the basalt was quickly sealed from seawater (by sedimentation) and subsequently heated by fluids migrating from a near by juvenile spreading centre. In which case the basalt would not be much older than the overlying sediments. The oldest interpreted magnetic anomaly in ODP Site 765 is M17r which is interpreted for the sediment layer that directly overlies the oceanic basalt (Ogg et al 1992 fig 5 p 536).The available evidence for the age of ODP Site 765 is therefore conflicting but appears to be within the range M20 to M26.

THICKNESS VARIATIONS: (APPENDIX 1).

Thickness ranges from 1m in Trafalgar 1 to 142m in North Turtle 1. These thicknesses may not be representative of the module area due to the poor palynological and well control however a similar order of magnitude is expected.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 32).

Globally this time slice is characterised by a low relative sea level. Within time slice J7 there are two globally recognised eustatic sea level drops representing 3rd order cycles (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. A marine regression is interpreted in the adjacent Dampier Sub-basin with deltaic conditions in the eastern half and shallow marine in the western half (Spencer et al, 1993). Major tectonism commenced during this time slice. A source area from the northeast is envisaged. Fluvial to near shore sedimentation prevails in the western Browse Basin (Wilmot, 1993).

PALAEOGEOGRAPHY: (SEE ENCLOSURE 32).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, rock samples dredged from the outer slope of the Rowley Sub-basin, palaeogeography interpretations from onshore Canning Basin wells and outcrop, palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Basin modules (Spencer et al, 1993). Secondary sources are from AGSO(BMR), industry and university published work.

The following summarises the map:

- Marine to land environments are interpreted in the very northwest part of the map, directly over what is present day oceanic crust and what will become Argoland. Argoland is the name given to a landmass that separated from the Australian plate during the late Jurassic and consisted of what is today, west Burma and northwest Sumatra, and probably other undetected but still preserved landmasses (Metcalfe, 1993).
- An additional landmass has been interpreted in the present Argo Abyssal Plain area coinciding with the M26 magnetic lineament (see enclosure 1).
- All onlap edges on the southwest side of the map are phantomed using the discontinuous reflectors present in the Jurassic as a guide and well control.
- Restricted marine seaways are present.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%. The 4 samples meeting the selection criteria revealed 1.05%<TOC<3%, 1.83<S2<6.43, 174<HI<277 and 427<Tmax<435 indicating a light oil and gas prone source with poor to good generative potential and maturity ranging from immature to sub-mature.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

The Nebo 1 well tested a maximum flow of 1840 BOPD of 42° API oil through a ½ inch choke from the Calypso Formation. It remains the only DST and discovery within the module area. The well was not reviewed in this module due to its confidential status.

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas prone source rocks are found in the Beagle and Cossigny Troughs and gas prone source rocks in the west Bedout Sub-basin. These are presently sub-mature but are likely to be mature in the some areas of the Beagle Trough.
- J7 reservoirs are found in the Cossigny and Beagle Troughs and the west Bedout Sub-basin.
- No regional seals exist but intraformational seals are present in the Beagle and Cossigny Troughs and west Bedout Sub-basin.
- Numerous structural highs and structural noses are interpreted to occur within the Beagle Sub-basin. Many structural prospects are likely to be found within the areas of wider spaced contours where isolated horst blocks could exist.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

Only high risk plays exist in the **Beagle and Cossigny Troughs** as poor intraformational seals are a significant risk factor.

TIME SLICE J8:

LATE JURASSIC: EARLY OXFORDIAN TO KIMMERIDGIAN: (162.0 TO 150.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 3.

The Westralian 3 Petroleum System is defined by the interval spaning the commencement of drift of Argoland and the drifting of Greater India.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Dingo Claystone is present in the Beagle Sub-basin (Blevin et al, 1994). The Angel Sandstone may be present in the western part of the Beagle Sub-basin. It is interpreted to be diachronous.
- The Baleine Formation is present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J8 is biostratigraphically defined by dinoflagellate zones *D.swanense, W.clathrata, W.spectabilis.* Time slice J8 is the time of maximum transgression in the Jurassic. The top boundary coincides with an unconformity on the North West Shelf, the Papuan and Laura Basins. It also coincides with a facies change in many other basins. Biostratigraphically, the base of the time slice equates to the base of the *W.spectabilis* dinoflagellate zone and the top corresponds to major zonation boundaries in both dinoflagellate (top *D.swanense)* and spore-pollen (top *M.florida)* schemes.

PALAEONTOLOGY: (SEE ENCLOSURE 2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- East Mermaid 1: *Pyxidiella* (B4), and
- Jarman 1: *W.spectabilis* (B3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of Gondwana that included Antarctica and Greater India following the breakup of Argoland and the formation of the Argo Abyssal Plain. An Argo Abyssal Plain transfer fault may have an onshore correlative in the Rowley Sub-basin that acted as a depositional hinge zone. Time slice J8 deposition is thin and patchy. It was deposited unconformably on pre Argoland breakup Middle Jurassic aged rocks. The thickest unit of Upper Jurassic rocks is found within the western side of the Cossigny Trough where it onlaps and where the top is truncationally eroded towards the east. Only thin units of Upper Jurassic are present east of the Cossigny Trough. Time slice J8 is interpreted as a marine highstand unit with environments varying from short lived delta systems off the coast, to islands with intertidal sand fringes and a starved inner shelf. Lithology's comprise dominantly claystone to sandstone with minor dolomite. Generally the time slice, where present, acts as a local and regional seal. An unproven source in the Inner Rowley Sub-basin may be mature in the Outer Rowley Sub-basin.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

West Australia was part Gondwana that included Greater India and Antarctica (Baillie et al, 1994).

The breakup along the margin of the Roebuck Basin occurred at approximately top of time slice J7 to base of time slice J8. Volcanism occurred along an approximately 100km front with Argoland (present day W Burma and NW Sumatra, Metcalf, 1993) drifting off on the northern side of the rift zone. At the end of time slice J8 the continent was estimated from magnetic sea floor anomalies to be about 900km to the NNW of the COB, a drift rate average of about 7mm per year. The continental mass to the west of the Roebuck Basin included the Exmouth Plateau and was still in place although weakness zones would have been initiated during the Argoland breakup (eg Swan Canyon). A very shallow sea with a predominance of exposed land masses is envisaged for the early part of this period. The breakup may have been a multi phase event starting off at top time slice J7 and continuing possibly up to top time slice J8.

The main breakup event of Middle Jurassic age is seen in the Dampier Sub-basin as an instantaneous event across the basin at the boundary of time slices J7 and J8 (Spencer et al, 1993). This event is pinpointed particularly from the Wanaea 1 and Walcott 1 wells where time slices J7 and J8 age sediments are identified. Unconformities within the Dampier Sub-basin during time slices J8 and J9 exist but are not seen to be synchronous basinwide events but rather localised structural readjustments. The Upper Jurassic is poorly preserved within the Roebuck Basin such that these unconformities cannot be distinguished. Complex tectonic activity continued to occur in the Late Jurassic but at lesser intensity, although this area

was affected by the last stages of Argoland break-up, and the pre-breakup phase of the rift to the southwest.

Local

Implications of the Argoland breakup for palaeogeographic reconstruction include the:

- Extension of an Argo Abyssal Plain transfer fault into the continental crust. This feature may have influenced deposition.(see time slice J7 section for a more detailed description). This implies possible variations in water depth and thus different shallow water environments are possible. Focusing of specific palaeoenvironments on a north-south corridor may have implications for petroleum exploration. Reworking along this hinge zone may have created cleaner sands and thus higher quality reservoirs, at least in some areas, and
- Fracture zones that had developed in the location of the future Thouin Graben and the canyon between the Echidna and Emu Spurs. It is speculated that these fracture zones acted as corridors for deeper water sedimentation such as feeder channels, turbidites and slump or gravity flow deposits.

The main continental breakup phase is best illustrated in the Beagle and Dixon Sub-basins where large scale, very well resolved Callovian to Oxfordian aged faults are seen to truncate the bulk of the Triassic and Jurassic strata. Some of these are probably reactivated Triassic faults, many being absorbed in the Lower Triassic shales, and or Permian strata in the trough areas. The faulting style includes pull-apart normal and a pull-apart wrench fault systems. Normal pull-apart faults appear listric with depth within the Beagle Sub-basin (Beagle Outer Platform, Beagle and Cossigny Troughs). Pull apart wrench fault systems show classic flower structures with reversal of the dip direction. Numerous sub faults are found within larger scale bounding faults. It may be that the faults combine with a detachment surface on the outer shelf although absorption of the faults at deeper levels within Triassic and Permian shales is also likely.

It is thought that there may be a system of northeast trending wrenchs, that are not recognised on seismic, but are associated with the Argo Abyssal Plain Transfer. These unrecognised wrench fault systems would be found within an approximate N-S corridor or transition zone east of the Beagle Trough, west of the Phoenix and Minilya highs, east of the Swan Canyon and west of the extension of the Argo Abyssal Plain transfer. Examples of recognised wrench systems are present on the North Turtle Wrench Zone, Cossigny Trough, outer Beagle Trough and Platform and the southern extent of the Beagle Trough and Bruce Terrace and within the Thouin Graben (Figures 22, 23 and 24). Seismic sections 110/5, 110/3 (sp 300-500, sp 700-1000), 110/1 (sp 3100-3400, sp 1300-2200, sp 900-1600) illustrate some of the wrench style faults observed with the Beagle Sub-basin.

Line 120/01 extends NNW from the Bedout Sub-basin across the Bedout High and Rowley Sub-basin and extends to the Argo Abyssal Plain. The portion of line 120/01 in Figure 25 shows the continental shelf break and Tertiary to Post-Tithonian pelagic to hemipelagic sediments overlying oceanic crust. The age of the sediments was determined from ODP 765 in the Argo Abyssal Plain.

note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

East Mermaid 1 and Jarman 1 lithology's include sandstone to claystone, the claystone in East Mermaid 1 contains dolomite.

THICKNESS VARIATIONS: (NO PALAEOGEOGRAPHY DATA MAP).

Jarman 1 and East Mermaid 1 are the only wells that intersected time slice J8 and have 24m and 17m respectively. These thicknesses are considered representative of the module area.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 33).

Globally this time slice is characterised by a low relative sea level in the lower part of the time slice followed by an intermediate relative sea level in the middle and upper part of the time slice. Within time slice J8 there are five globally recognised eustatic sea level drops representing 3rd order cycles (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a transgression towards the lower part of the time slice. The coastline is interpreted to have transgressed in the module area.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 33).

The primary sources include the Jarman 1 well with interpreted time slice palaeogeography, 6200km of mapped seismic sections, palaeogeography interpretations from onshore Canning Basin wells and outcrop (BMR, 1981), palaeogeography interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier

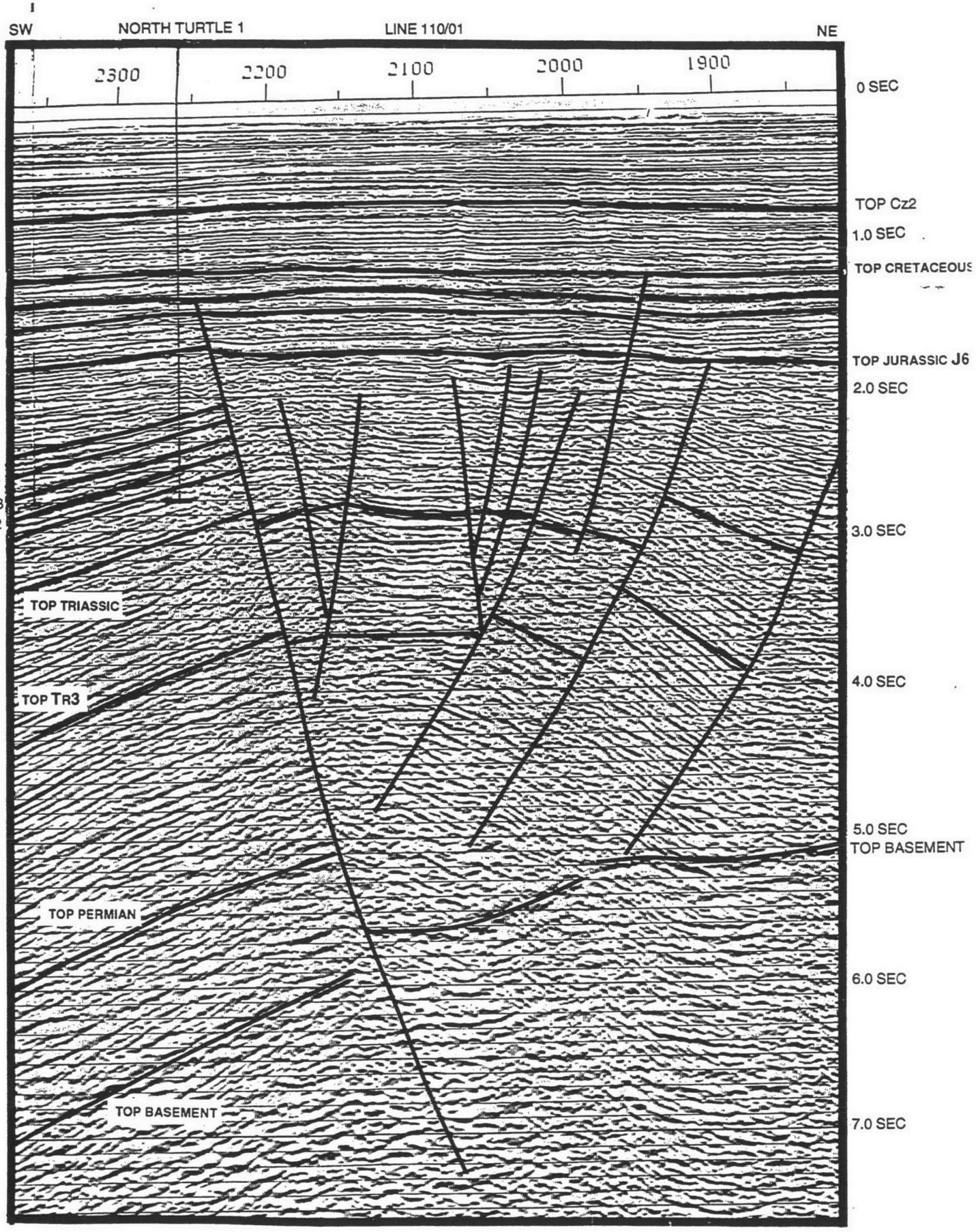

FIGURE 22: SEISMIC REPRESENTATION OF THE NORTH TURTLE WRENCH ZONE & NORTH TURTLE 1, BEAGLE SUB-BASIN, LINE 110/01.

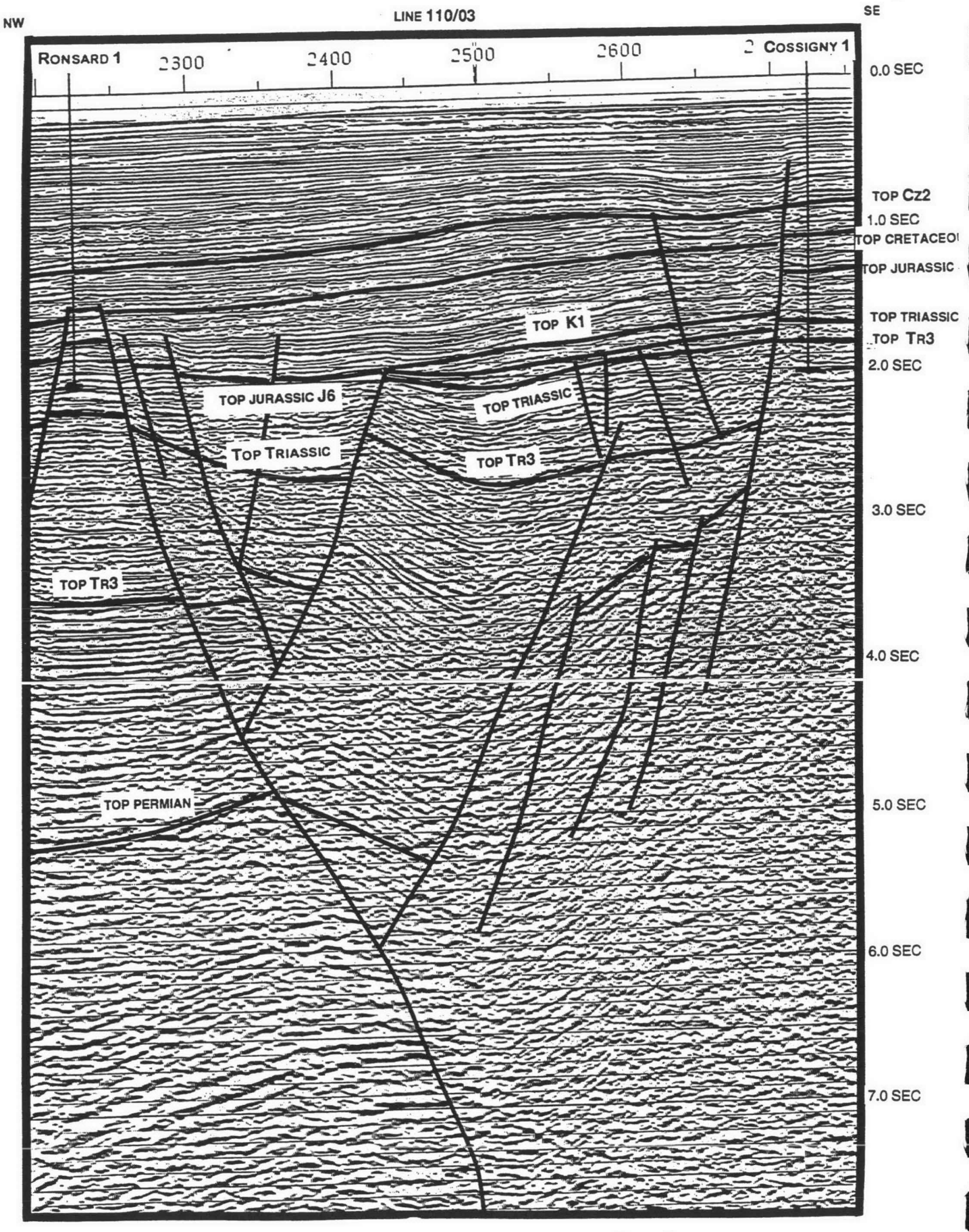

FIGURE 23: SEISMIC REPRESENTATION OF THE COSSIGNY TROUGH, COSSIGNY 1 & RONSARD 1, BEAGLE SUB-BASIN, LINE 110/03.

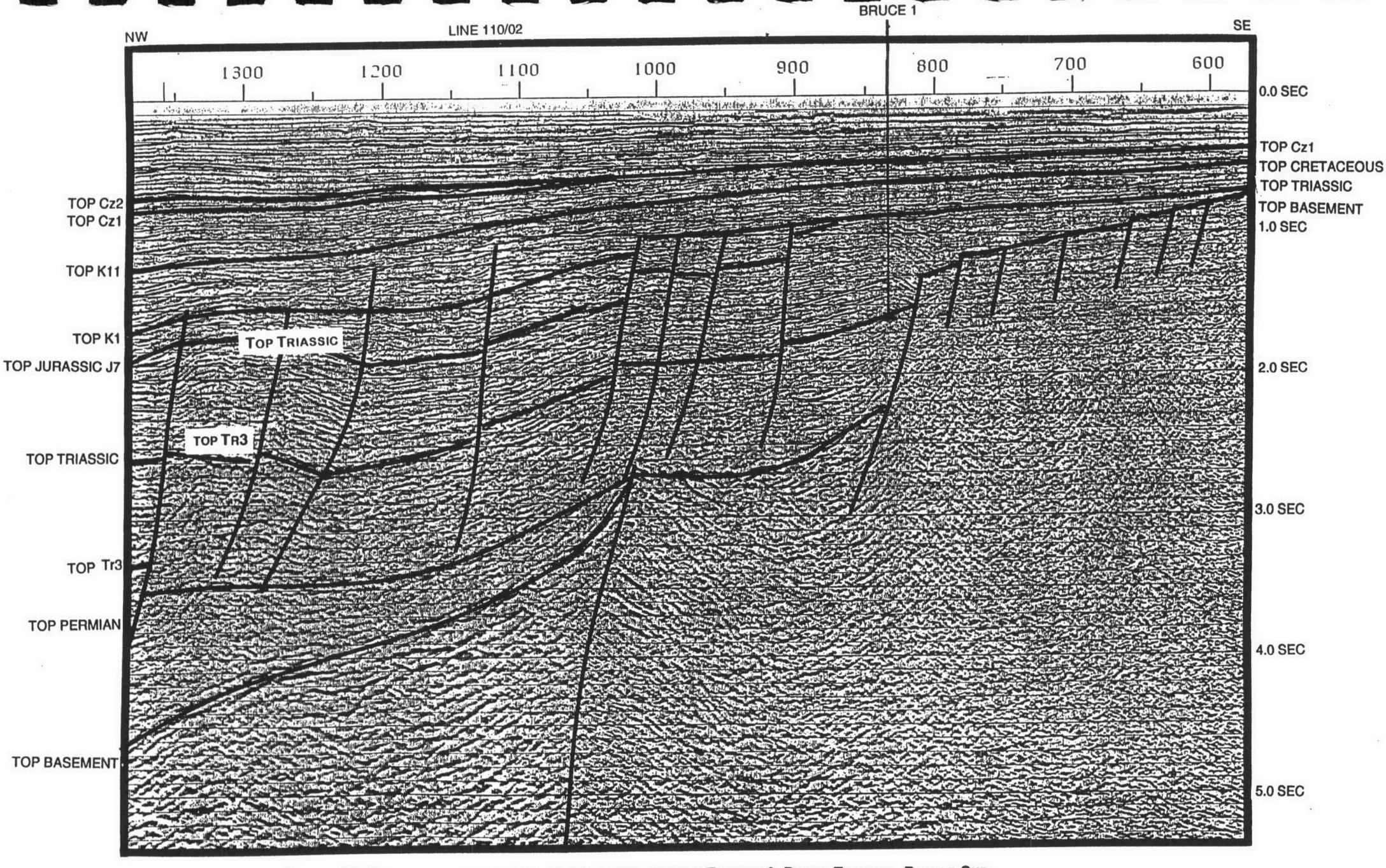

FIGURE 24: SEISMIC REPRESENTATION OF THE SOUTH BEAGLE TROUGH & BRUCE TERRACE, BEAGLE SUB-BASIN, LINE 110/02.

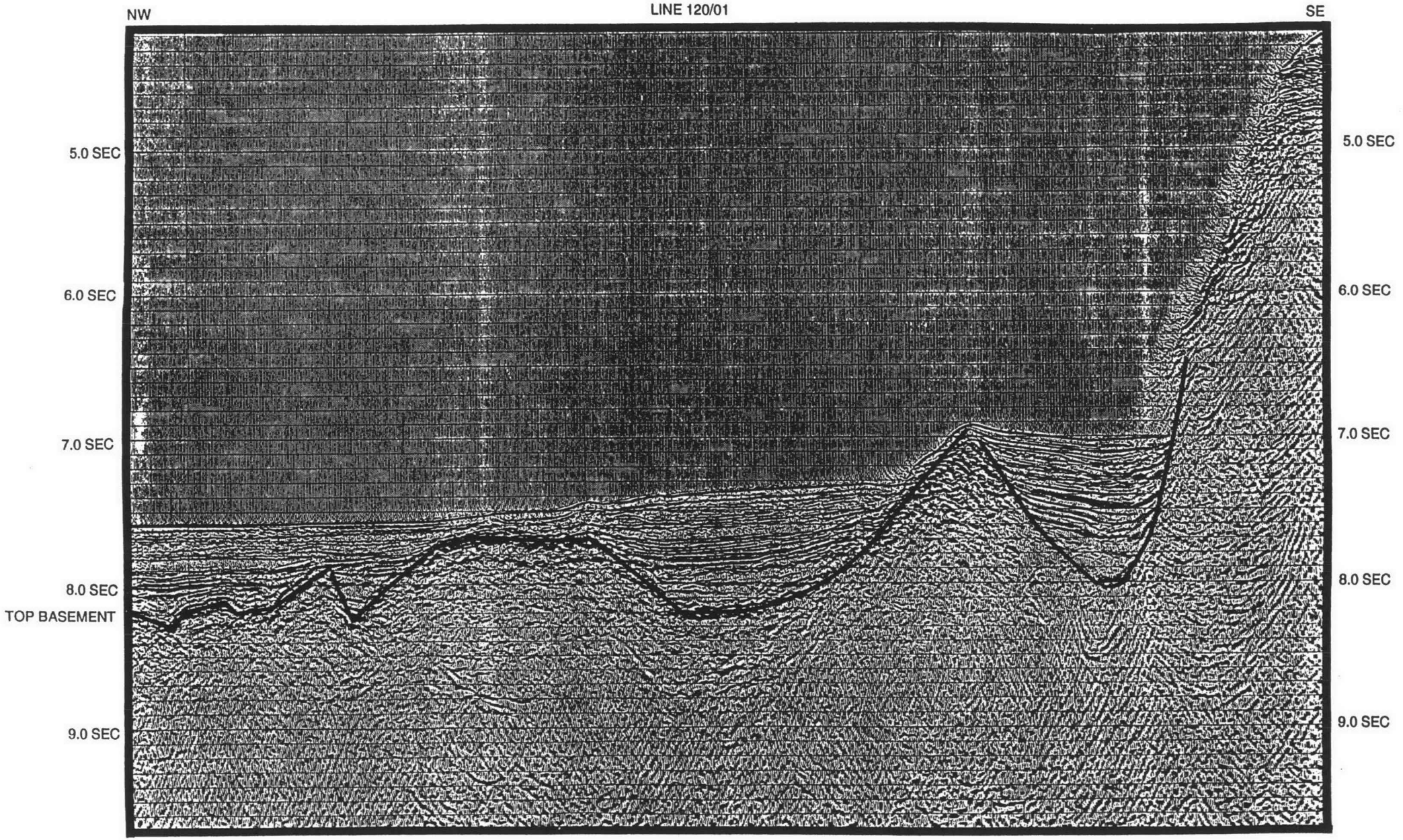

FIGURE 25: SEISMIC REPRESENTATION OF THE CONTINENTAL-OCEAN BOUNDARY, OUTER ROWLEY SUB-BASIN, LINE 120/01.

Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

The following is shown on the map:

- A starved inner shelf is interpreted over a major part of the area.
- Up to 200m of sediment is present in the onshore Canning Basin (Wallal Embayment, Broome Platform, Fitzroy Trough) and is interpreted to extend offshore on the Broome Platform and Fitzroy Trough (BMR, 1981).
- Topographic relief is portrayed by the number of conceptional landmasses interpreted. Some minor structural readjustment may have occurred on the Bedout High and east of it during time slice J8. The Bedout High and adjacent area is shown to be emergent with potentially good beach sand deposits on its outer fringe.
- Landmasses interpreted in the Beagle Trough include the Sable, Ronsard and Picard blocks and a high on the Depuch structure (Blevin et al, 1993).
- No downlap or onlap edges can be substantiated due to the very thin nature of time slice J8 in the offshore areas.
- The presence of time slice J8 on the Argo Abyssal Plain is unsubstantiated from the sediments recovered in ODP 765 (Kaminski, A.M., et al, 1992). The oldest sediments confirmed are of Tithonian age (time slices J10 and J9). Kaminski et al (1992) state that the deep ocean drilling penetrated sediments of Tithonian age or older prior to penetrating the oceanic crust igneous rocks.
- A source area from the northeast in the adjacent Dampier Sub-basin module is suggested (Spencer et al, 1993). A marine environment is envisaged during time slice J8.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

No significant source potential has as yet been determined for this time slice and because it is thin it is unlikely to have significant unrecognised potential.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

No shows have been detected

PROSPECTIVITY: (SEE ENCLOSURE 3).

- No reservoir potential has been detected within time slice J8. As portrayed in the palaeogeography map, sands deposited within the intertidal fringe may have significant reservoir potential.
- When present time slice J8 acts as a regional seal in the Inner Rowley Sub-basin and local seal in the Cossigny Trough.
- Time slice J8 may be prospective, but is difficult to map. Lows on the *Jc* surface would be the most likely places to find time slice J8 sediments.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

Stratigraphic traps may be present in intertidal fringes around landmasses, for example around the Sable, Ronsard and Picard blocks and Bedout High.

TIME SLICE J9:

LATE JURASSIC: EARLY TITHONIAN:(150.0 TO 147.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 3 (ENCLOSURE 3).

This is one of the main source rock intervals of the Westralian Petroleum system, particularly in the Carnarvon Basin. It is however not well developed in the module area and cannot be regarded as a source rock.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Dingo Claystone and Angel Sandstone in the Beagle Sub-basin are interpreted to be diachronous (Blevin et al, 1994).
- The Egret Formation is present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J9 is defined biostratigraphically by the *C.perforans* and *O.montgomeryi* dinoflagellate zones and is within the lower part of the *R.watherooensis* spore pollen zone. Time slice J9 - J10 boundary occurs at the top of *O.montgomeryi* zone. Time slice J9 represents a phase of relative regression on the North West Shelf that corresponded to a shift in the Eromanga Basin from low energy Birkhead Formation deposition to the higher energy sandsheet regime of the Adori Sandstone. The base is marked by a regional unconformity that is also observed in the Papuan and Bonaparte basins.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Jarman 1	*C.perforans* (D3/D5), *O.montgomeryi* (D5),
- Kambara 1/Minilya 1/Minjin 1 Pearl 1/Perindi 1/Phoenix 1	no palaeontological control,
- Keraudren 1	*O.montgomeryi* (B2), and
- Phoenix 2	*O.montgomeryi* (B3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of Greater Gondwana that included Antarctica and Greater India. The Argo Abyssal Plain transfer extended across the Rowley Sub-basin (Enclosure 35) where it may have acted as a depositional hinge zone. Time slice J9 is not greatly developed but is conformable with time slice J8 where time slice J8 is present and lies unconformably on older sequences elsewhere, the bulk of these older sequences being pre Argoland breakup Middle Jurassic aged rocks. The thickest unit of Upper Jurassic rocks is found on the western side of the Cossigny Trough where they onlap and where the top is truncationally eroded towards the east. Only thin units of Upper Jurassic are present east of the Cossigny Trough. Time slice J9 is interpreted as a marine highstand unit, palaeoenvironments vary from short lived delta systems off the coast, turbidites, islands with intertidal sand fringes and a starved inner shelf. Lithology's comprise dominantly claystone to sandstone with minor dolomite and limestone. Good quality channel sands within a delta system are found in the Cossigny Trough, but generally the time slice acts more like a local seal with variable quality sand reservoir.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

Western Australia was part of Greater Gondwana that included Greater India and Antarctica (Baillie et al, 1994). Unconformities found in the Dampier Sub-basin during time slices J8 and J9 are seen, but they are not basinwide events but rather localised structural readjustments. The Upper Jurassic is very thin in the Roebuck Basin so these unconformities cannot be distinguished although they may exist. Unconformities can be seen in the Beagle Sub-basin.

Local

An extension of the Argo Abyssal Plain transfer onto the continental crust is shown in Enclosure 35 where it may have influenced deposition.

Fracture zones developed in the location of the future Swan Canyon and the canyon between the Echidna and Emu Spurs. Speculatively, they would have acted as corridors for deeper water sedimentation such as feeder channels, turbidites and slump and gravity flow deposits.

note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Jarman 1 gamma ray log show a moderately serrated pattern (sandstone). The sandstone has traces of glauconite.

West Bedout Sub-basin: The gamma ray log in Phoenix 1 includes one funnel pattern (dominantly all sandstone). Phoenix 2 is dominantly argillaceous sandstone with trace calcite and claystone. Minilya 1 has interbedded claystone and sandstone.

Bedout Sub-basin: Keraudren 1 has uniform dark to olive grey claystone all through with minor siltstone.

Offshore Fitzroy Trough: Both Wamac 1 and Lacepede 1A have a uniform smooth cylinder gamma ray log pattern (sandstone).

Pender Terrace: Kambara 1 gamma ray log patterns show a moderately smooth cylinder (80% sandstone and 20% siltstone). Minjin 1 has interbedded claystone and sandstone at the top with a siltstone base. Perindi 1 has dominant sandstone and claystone interbeds.

Jurgurra Terrace: Pearl 1 has a sandstone base with interbedded siltstone and sandstone in the middle and a higher percentage of claystone at top, the dominant lithology is sandstone.

THICKNESS VARIATIONS: (SEE ENCLOSURE 34).

Time slice J9 is a thin unit. Thickness ranges from 15m in Phoenix 2 to 83m in Pearl 1. A similar order of magnitude is expected across the module area.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 35).

Globally this time slice is characterised by an intermediate relative sea level. Within time slice J9 there are two globally recognised eustatic sea level drops representing 3rd order cycles (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime. The coastline is interpreted to have slightly regressed in the module area indicating similar relative sea level changes. Time slices J8 to J10 are marine transgressive units relative to time slices J6-J7 and K1 making them marine highstands.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 35).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, palaeogeography interpretations from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

A starved inner shelf is interpreted. Time slice J9 is generally thin. Topographic relief is portrayed by the number of conceptional landmasses although many of these have submerged since time slice J8. No downlap or onlap edges can be substantiated due to the thinness of time slice J9. Time slice J9 is interpreted to be present as a condensed sequence up to the continental-ocean boundary and beyond.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

No significant source has as yet been identified in this time slice.

SHOWS, POROSITY & PERMEABILITY:(SEE APPENDIX 4).

No shows have been detected. The average porosity for Phoenix 1, the only well with porosity data, is 23% as determined from logs.

PROSPECTIVITY: (SEE ENCLOSURE 3).

- An unconfirmed source (TOC > 1.0% but no Rock-Eval) may be present in the west Bedout Sub-basin but is not mature.
- Reservoirs are found in the Cossigny and Fitzroy Troughs, west Bedout Sub-basin and Jurgurra and Pender Terraces.
- Sands have been intersected in the Jarman 1 well. The sands are very fine to very coarse, sub-angular to sub-rounded, poorly sorted with good visual porosity. They are interpreted as distributary channels within a lower delta plain system. They should be adequately sealed on a local scale and thus are a significant exploration target. The sands will need to be charged by Lower Jurassic or Triassic source via faults.
- Reservoirs are present on the Jurgurra and Pender Terraces, however there are no adequate shale seals.
- Within the Fitzroy Trough, the single most important reservoir within the Mesozoic is time slice J9 as it is connected to all other Jurassic aged reservoirs and migrated hydrocarbons could be sealed by time slices J10 or K1 regional seals.

- Time slice J9 has a regional seal in only the Bedout Sub-basin whilst local seals are interpreted in the Cossigny Trough and Jurgurra Terrace.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Cossigny Trough, west Bedout Sub-basin:** Time slice J9 clastic reservoirs sourced by a Triassic or Lower Jurassic source and sealed by time slice J10 regional or intraformational seals may be a viable play.
- **Jurgurra and Pender Terraces, Offshore Fitzroy Trough:** Time slice J9 clastic reservoirs sourced by a pre-Permian source and sealed by time slice J10 regional seals may be a viable play.
- **Bedout High/Beagle Sub-basin:** Intertidal and supratidal fringe sands (Ronsard, Jarman, Ronsard blocks and others) sourced by Triassic or time slices J1 to J4 source, and sealed by time slice J10 to Lower Cretaceous intraformational seals and time slice K2 regional seal may be a viable play.

TIME SLICE J10:

LATE JURASSIC: LATE TITHONIAN:(147.0 TO 144.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 3

Time slice J10 is the first post Argoland breakup interval to have significant thickness, extent and suitable lithology to provides a regional seal on the Main Unconformity surface.

FORMATION SYNONYMS: (SEE FIGURE 2).

- The Dingo Claystone and the diachronous Angel Sandstone are present in the Beagle Sub-basin (Blevin et al, 1994).
- The Egret Formation is present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice J10 is biostratigraphically defined by the lower *P.iehiense* all of the *D.jurassicum* dinoflagellate zones. The top of the time slice represents the Jurassic - Cretaceous boundary that lies within the *P.iehiense* dinoflagellate zone. The first appearance of the *C.australiensis* spore pollen zone is used as the biostratigraphic definition of the base Cretaceous in Australia. Time slice J10 also represents a transgressive phase following the regression of time slice J9.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Jarman 1, Kambara 1,Minjin 1 North Turtle 1, Pearl 1: no palaeontological control,
- Keraudren 1: *P.iehiense* (B2),
- Lacepede 1A, Phoenix 1, Trafalgar 1: *D.jurassicum* (B3),
- Minilya 1 & Perindi 1: *D.jurassicum* (B2),
- Poissonnier 1: *D.jurassicum* (B5), and
- Wamac 1: *D.jurassicum* (D3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Australia was part of Gondwana that included Antarctica and Greater India. The Argo Abyssal Plain transfer extended across the Rowley Sub-basin where it may have acted as a depositional hinge zone. Time slice J10 is bounded at the top by a regional unconformity caused by pre-rift movements associated with the breakup of Greater India. Time slice J10 is conformable on time slice J9 but unconformable with pre Argoland breakup Middle Jurassic aged rocks where time slice J9 is absent. The thickest unit of Upper Jurassic rocks is found within the western side of the Cossigny Trough where it onlaps and the top is truncationally eroded towards the east. Only thin units of Upper Jurassic are present east of the Cossigny Trough. Time slice J10 is regarded as a marine highstand unit, palaeoenvironments vary from short lived delta systems off the coast, turbidites, islands with intertidal sand fringes and a starved inner shelf. Lithology's comprise dominantly claystone to sandstone with minor dolomite and limestone. Good quality shoreface sands are found in the west Bedout Sub-basin. These may provide primary reservoir targets. Weak secondary targets are also found in the Beagle Trough. Generally time slice J10 has variable quality sands with both regional and local seals present.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

Western Australia was part of Greater Gondwana that included greater India and Antarctica (Baillie et al, 1994). The top time slice J10 structural event of the Dampier Sub-basin is a basin wide event identified in most of the wells of the Dampier Sub-basin (Spencer et al, 1993).

Local

An extension of an Argo Abyssal Plain transfer onto the continental crust is interpreted that may be influencing deposition (see Enclosure 35). The top Jurassic boundary is a regional mappable seismic horizons along the North West Shelf. It is clearly identified on the western edge of the Cossigny Trough where the top of the Late Jurassic is identified on seismic. This top Jurassic unconformity is a pre-rift event associated with the breakup of Greater India and the formation of the Cuvier and Gascoyne Abyssal Plains. It is inferred that the impact of this structuring decreased to the east away from the Australia - Greater India

Rift Zone. This reduced effect ties with what is seen in the Roebuck Basin to the east of the onshore extension of the Argo Abyssal Plain Transfer (Enclosure 35).

Fracture zones developed in the location of the future Swan Canyon and the canyon between the Echidna and Emu Spurs. These zones may have acted as corridors for deeper water sedimentation such as feeder channels, turbidites and slump and gravity flow deposits

NB: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Jarman 1 has 100% uniform sandstone lithology. Trafalgar 1 consists of interbedded, intergradational siltstone and sandstone with minor claystone and thin streaks of dolomite.

Beagle Trough: Sandstone and claystone are respectively 25% and 75% of the section, calcareous cement is found in the sandstone. Poissonnier 1 has 100% uniform claystone lithology.

Bedout Sub-basin: Keraudren 1 has a uniform 100% serrated claystone lithology.

West Bedout Sub-basin: Phoenix 1 gamma ray log patterns reveal one funnel. The lithology consists of 100% sandstone and siltstone. Minilya 1 has 100% uniform claystone lithology.

Offshore Fitzroy Trough: Wamac 1 has a mild uniform claystone lithology with minor limestone. Lacepede 1A gamma ray log patterns include a uniform mild serrated pattern at the base and interbedded patterns (siltstone) in the middle and top. Sandstone and siltstone are respectively 40% and 60% of the section in Lacepede 1A.

Pender Terrace: Kambara 1 has mild serrated gamma ray log patterns uniform in magnitude at the base. Lithology's include the Jarlemai Siltstone and continuous sandstone and siltstone for the middle and top. Sandstone and siltstone are respectively 60% and 40% of the section in Kambara 1. Both Perindi 1 and Minjin 1 gamma ray log patterns consist of mild serrated uniform base (glauconitic claystone). Dominant sandstone lithology with interbeds of claystone are found in the middle and top. Sandstone represents 50% of the section.

Jurgurra Terrace: Pearl 1 has sandstone at the base and middle with secondary siltstone and claystone. There is one gamma ray log funnel pattern at the top of the time slice (sandstone).

THICKNESS VARIATIONS: (SEE ENCLOSURE 34).

Time slice J10 is a thin unit ranging from 13m in Jarman 1 to 219m in Wamac 1. Thickness variations across the module are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 35).

Globally time slice J10 is characterised by an intermediate relative sea level. Within time slice J10 two globally recognised eustatic sea level drops are developed representing 3rd order cycles (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a uniform eustatic regime towards the lower part of the time slice with regression towards the upper part of the time slice. The coastline is interpreted to have regressed slightly in the module area.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 35).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic sections, palaeogeographic interpretations from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

A starved inner shelf environment is interpreted. Seismic cannot resolve downlap or onlap edges due to the thinness of time slice J10. The shelf sea floor is interpreted to have high topographic relief, following the tectonic activity of Argoland breakup. Time slice J10 accumulated in the lows and gradually onlapped and buried this topography. Time slice J10 is interpreted to be present as a condensed sequence up to the continental-ocean boundary and beyond.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI>150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. The four analyses meeting the selection criteria have 0.89%<TOC<2.4%, 1.3<S2<5.02, 167<HI<211 and Tmax=421 to 427. These results indicate a light oil to gas prone source rock of poor to good generative potential. The samples are immature.

One sample from Poissonnier 1, analysed by Rock-Eval in conjunction with this module, gave a TOC of 2.14%, but poor generative potential and low HI (Appendix 5 part 3).

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

A gas indication is present in Kambara 1. The following lists summarises the porosity data for the time slice:

Phoenix 1 porosity av = 23% (logs), and

Poissonnier 1 35%< porosity av < 40% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Oil and gas prone source rocks are present in the west Bedout Sub-basin, Fitzroy Trough and Pender Terrace but are unlikely to be mature.
- Reservoirs are found in the Cossigny and Beagle Troughs, west Bedout Sub-basin, Jurgurra and Pender Terraces.

The following is a reservoir description summary:

- In the Beagle Trough, only Poissonnier 1 and North Turtle 1 have intersected sands. In North Turtle 1, sands are thin (about 5m), white, occasionally very fine grained, sub-angular to sub-rounded, moderately well sorted, have low porosity and are interpreted as channels within a coastal-estuarine system. These sands would not stand up as a primary exploration target on their own accord but could be a secondary weak target when located on major depositional hinge zones. The sandstone in Poissonnier 1 is multicoloured, very fine to granule, poor to moderately well sorted, angular to sub-rounded with poor to fair porosity with minor greensand. These sands are interpreted as part of a pro-delta system.
- Within the Cossigny Trough, thin time slice J10 sands were intersected within the Trafalgar 1 well. The sands are light olive grey, very fine, well sorted with nil to very poor porosity and are interpreted as sands deposited on the marine shelf. These time slice J10 sands may develop laterally in other parts of the basin.
- Within the west Bedout Sub-basin, time slice J10 sands are also present in the Phoenix 1 well. The sands here are medium grey, fine grained to granule, moderate to well sorted, sub-angular to sub-rounded with good visual porosity. They are interpreted as shoreface and are therefore likely to be attractive exploration targets. These time slice J10 reservoirs will probably leak hydrocarbons possibly as high as K2 where they can be sealed by overlying claystones
- In the Jurgurra and Pender Terraces, time slice J10 reservoirs are present but with no shales to seal them adequately.

- Time slice J10 is a regional seal in the Bedout Sub-basin, Jurgurra and Pender Terraces and Fitzroy Trough but only a local seal in the Cossigny and Beagle Troughs and west Bedout Sub-basin.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Cossigny Trough**: Jurassic time slice J10 clastic reservoirs sourced by Triassic or Lower Jurassic source and sealed by time slice J10 and Lower Cretaceous intraformational seals could be a viable play.
- **Beagle Trough:** Jurassic time slice J10 clastic reservoirs sourced by Triassic or Jurassic time slices J1-J4 source and sealed by time slice J10 intraformational seals and Lower Cretaceous regional seals could be a viable play.
- **West Bedout Sub-basin:** Jurassic time slice J10 clastic reservoirs sourced by a Lower Triassic source and sealed by time slice J10 and Lower Cretaceous intraformational seals could be a viable play.
- **Jurgurra and Pender Terraces:** Jurassic time slice J10 reservoirs sourced by Pre-Permian source rocks and sealed by time slice J10 seal could be a viable play.
- **Bedout High/Beagle sub-basin:** Intertidal/supratidal fringe sands (Ronsard/Jarman/Ronsard blocks and others) sourced by Triassic or Jurassic time slices J1-J4 source, and sealed by Lower Cretaceous intraformational seals and time slice K2 regional seal could be a viable play.

CRETACEOUS TIME SLICES

TIME SLICE K1:

EARLY CRETACEOUS: NEOCOMIAN: BERRIASIAN TO EARLY VALANGINIAN: (144.0 to 137.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 3 (ENCLOSURE 3).

Time slice K1 may be the most prospective interval in the module area. It provides the first thick regional seal facies within which are good reservoir horizons. These could be the first well sealed reservoirs to be encountered by vertically migrating hydrocarbons sourced from deeper in the section. It is the time slice during which breakup of Greater India occurs, the end of the time slice being marked by the drift of Greater India.

FORMATION SYNONYMS: (FIGURE 2).

- The Forestier Claystone is found in the Beagle Sub-basin, it is interpreted to have an unconformable top and base (Blevin et al, 1994).
- The formations are unnamed in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice K1 is defined by dinoflagellate zones *E.torynum, B.reticulatum, D.lobispinosum, C.delicata, K.wisemaniae* and upper *P.iehiense*. The base of time slice K1 is the Jurassic - Cretaceous boundary. This is within the *P.iehiense* dinoflagellate zone and at the base of the *C.australiensis* spore-pollen zone. The top is defined as the top of the *E.torynum* dinoflagellate zone and the *C.australiensis - F.wonthaggiensis* spore-pollen boundary. The top of time slice K1 represents a major unconformity on the western margin of the Australian continent and may correspond to a major sea level fall, associated with the breakup and drift of Greater India.

PALAEONTOLOGY: (SEE ENCLOSURE 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with poorly controlled faunal zones to define time slice K1. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *E.torynum* (B4), *D.lobispinosum* (B2), *C.delicata* (B2), *K.wisemaniae* (B3),
- Bruce 1: *C.australiensis* (B3),
- Depuch 1: *E.torynum* (B5),
- East Mermaid 1: *E.torynum* (B4), *B.reticulatum* (B2), *D.lobispinosum* (B2/B4),
- Jarman 1: U & L *B.reticulatum* (B3/D3), *D.lobispinosum*(B3), *P.iehiense* (B5),
- Kambara 1, Minjin 1, Pearl 1 & Wamac 1: no palaeontological control,
- Keraudren 1: *E.torynum* (B5),
- Lacepede 1A: *D.lobispinosum*(A1/B3), *B.reticulatum*(B3), *C.delicata* (B5), *K.wisemaniae*
- Lagrange 1: *D.lobispinosum* (D3), *C.delicata* (D5),
- Minilya 1: *C.delicata* (B4), *D.lobispinosum* (B2), *E.torynum* (B2),
- North Turtle 1: *D.lobispinosum* (B3), *B.reticulatum* (B3/D3),
- Perindi 1: *K.wisemaniae* (B2),
- Phoenix 1: *D.lobispinosum* (B3),
- Phoenix 2: *D.lobispinosum* (B3), *C.australiensis* (B3),
- Picard 1: *B.reticulatum* (B2/B3),
- Poissonnier 1: *E.torynum* (B5), *D.lobispinosum* (B5), and
- Trafalgar 1: *P.iehiense* (B2), *C.australiensis* (B4), *D.lobispinosum*(B1/B4), *B.reticulatum* (B4), *E.torynum* (B1).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Time slice K1 is dominated by pre-drift tectonic phases of the Greater India breakup. Both the base and the top of this time slice are bounded by regional unconformities. These are very marked on the age-depth plots (Appendix 3). The base of time slice K1 is coincident with the onset of recognisable volcanic ash falls in the Dampier Sub-basin, coincident with the onset of breakup. The top of time slice K1 unconformity is coincident with the onset of drift of Greater India, and also appears to be coincident with a major sea level fall. The basal unconformity is often difficult to define, due to the thinness of Upper Jurassic present, and

the merging of multiple unconformity surfaces, but the *P.iehiense* is rarely identified and when it is, it is never very thick. The extension of the Argo Abyssal Plain Transfer fault onto the shelf was still influencing sedimentation in the Roebuck Basin. Time slice K1 is a time of regression.

Palaeoenvironments include delta systems coming off the continent, possible turbidite fans and incised valley fills. There are also islands with intertidal sand fringes around them in the Beagle Sub-basin area. The eastern side of the Rankin and Exmouth Platforms were still shedding sediments into the Outer Beagle Sub-basin. Lithology's range from claystone to sandstone with secondary dolomite, limestone and calcilutite. Time slice K1 contains both reservoirs and seals throughout. The best potential lies in the west Bedout Sub-basin and around the north side of the Bedout High. Oil and gas indications have been recorded in Depuch 1 in the Beagle Sub-basin.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

Western Australia was part of Greater Gondwana that included Greater India and Antarctica (Baillie et al 1994). Time slice K1 includes in it pre-drift breakup tectonic phases prior to the Greater India drift phase. These phases are best defined in the Dampier Sub-basin and Barrow Exmouth areas where the base of the time slice is coincident with the onset of breakup and the top is thought to mark the commencement of drift.

Local

The top of time slice K1 is recognised on seismic from the termination of faults at this level and from a cut and fill surface in the Beagle and west Bedout Sub-basins (line 120/11, sp 800-1650). This cut and fill surface is best illustrated on lines 110/02 (sp 1300-2800), 110/05 (sp1700-2700), 120/07 (sp 219-1600) and 120/14 (sp 1900-2900). In the Beagle Sub-basin the faults are dominantly normal and related to reactivated Argoland breakup aged faults but there are also faults unrelated to any previous structural events. Fault throws are relatively small and as a consequence time slice K1 aged faulting can be difficult to differentiate from differential compaction over the older fault systems.

An example of reactivation is the Thouin Graben (Figure 18), that seaward becomes the Swan Canyon. The graben was initiated during the main continental Argoland breakup and was reactivated during late time slice K1 and early time slice K2 (Valanginian) with intermittent movements after that. The fault geometry of the graben is a pull-apart system displaying both lateral and vertical movement. Basement involvement is apparent, with a wrench component being present. Substantial Cretaceous fill exists within the graben with the potential for Late Jurassic sediments in all of the graben, but particularly downdip (see lines 110/5 and 110/3).

In the Dampier Sub-basin the time slice K1-K2 boundary is an abrupt basinwide event that was of sufficient intensity to preclude deposition of sediments up to time slice K3 on the structurally higher points of the basin.

NB: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

Cossigny Trough: In both Trafalgar 1 and Jarman 1 the gamma ray log pattern is a mild serrated curve reflecting a dominantly continuous claystone lithology, although traces of glauconite are found within the claystone at Jarman 1. In Trafalgar 1 the section has interbedded to gradational claystone to siltstone, with thin streaks of dolomite towards the base whilst massive claystone with interlaminated siltstone and thin streaks of dolomite and rare limestone dominates the top of the section.

Beagle Trough: Picard 1 and Depuch 1 have a moderately serrated gamma ray curve, both reflecting a claystone lithology. North Turtle 1 has two large scale serrated funnel shaped gamma ray log patterns. Claystone dominates the section and grades into siltstone and sandstone (about 5%). Bruce 1 has a continuous serrated gamma ray log signature. The underlying lithology is slightly calcareous and glauconitic claystone. Poissonnier 1 gamma ray log signature includes two large scale funnels. The section is about 60% sandstone with a well developed sandstone horizon at the top.

West Bedout Sub-basin: Phoenix 1 gamma ray log signature includes a blocky section at the base (sandstone and claystone lithology), with one blocky (sandstone bed) and one serrated funnel in the middle and two serrated bells (sandstone with minor limestone interbeds) at the top. The section is about 80% sandstone. Phoenix 2 gamma ray log signature is serrated at the base (claystone and sandstone), with one large scale funnel in the middle and top (dominantly sandstone but dolomite in part). The section is about 80% sandstone. Minilya 1 gamma ray log signature is continuously serrated and reflects the claystone with minor argillaceous calcilutite.

Bedout Sub-basin: The gamma ray log patterns of Keraudren 1 include four serrated funnels. The section is about 20% sandstone.

Bedout High: Lagrange 1 gamma ray log pattern is dominantly a continuous highly serrated curve (claystone) with mild funnels present. Sandstone represents about 60% of the lithology where it also contains glauconite mineralisation and dolomite beds present in part. Bedout 1 has a continuous serrated curve at the base (claystone with two isolated sands) while the middle consists of one large scale funnel and the top contains one more funnel. The section is approximately 20% sandstone. The sands have good intergranular porosity in part. The claystone is dark grey to olive black with occasional glauconite.

Rowley Sub-basin: East Mermaid 1 gamma ray log is a continuous serrated curve, the section is a medium dark grey claystone that contains occasional siltstone and dolomite.

Offshore Fitzroy Trough: Wamac 1 gamma ray log signature includes a continuous serrated curve at the base (claystone), with funnels in the middle and top (minor limestone and interbedded sandstone and siltstone). The sandstone is about 55% of the section. In Lacepede 1A, the gamma ray log curve is continuous serrated at the very base (claystone, medium grey with trace of glauconite), overlain by one funnel and a later smooth cylinder. The middle section is sandstone with interbeds of siltstone whilst the top is argillaceous siltstone (a continuous serrated gamma ray curve).

Pender and Jurgurra Terraces: Pearl 1 and Kambara 1 gamma ray log curves are continuous and smooth (sandstone lithology). Perindi 1 section is dominantly sandstone with secondary interbedded claystone and siltstone. Minjin 1 gamma ray log curve is continuous serrated (interbedded siltstone and sandstone).

THICKNESS VARIATIONS: (SEE ENCLOSURE 36).

Time slice K1 thickness ranges from 9m in Bruce 1 to 485m in East Mermaid 1. These thicknesses may not be representative of the module area due to the poor well control and limited seismic used in mapping time slice K1 however regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 37).

Globally this time slice is characterised by an intermediate relative sea level. Within time slice K1 there are four global eustatic sea level drops (Haq et al, 1987). The base and top of time slice K1 coincide with sea level falls. The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show the beginning of a continent-wide transgressive event, reflecting possible uplifts due to tectonic events associated with the breakup of Greater India. The coastline is interpreted to have regressed in the module area.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 37).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic data, the established absence of time slice K1 age rocks onshore (BMR, 1981), and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

The following points relate to the palaeogeographic interpretation:

- the rate of sedimentation increased significantly in this time slice following the thin sequences and starved sediment sequences of the Late Jurassic. Land appears to coincide approximately with the present day landmass and the edge of the Lambert Shelf,
- the NE-SW striking downlap edge of time slice K1 was identified from seismic in the Rowley Sub-basin. It is seen to skew in the vicinity of the shelf extension of an Argo Abyssal Plain Transfer Fault. This edge then links up to incised valley fills in the Beagle Sub-basin and then goes down the Thouin Graben,
- sediments of this age have been recovered in ODP site 765 on the Argo Abyssal Plain (Kaminski et al, 1992). Time slice K1 is therefore interpreted to be present as a condensed sequence beyond the mapped seismic downlap edge, out to the continental-ocean boundary and beyond,
- the inner-middle shelf boundary is approximately located using the palaeogeographic interpretation from the most basinward wells,
- the incised valley fills are interpreted from the well data, particularly Phoenix 1 & 2, and are also apparent on seismic sections
- land is interpreted to be present on the Sable-Ronsard-Picard Blocks, with intertidal to supratidal rims around each of the high grounds. It is possible that time slice K1 was deposited on these highs, maybe in the form of condensed sequences, and later eroded. These high block are interpreted to have been decreasing in size since the main Argoland breakup phase, and

- shallower water conditions still prevailed in the western Beagle Platform where delta systems were feeding off the elevated land to the west. The western Beagle Platform was not finally inundated until early in time slice K2, after Greater India commenced to drift.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI >150, TOC>1.0% or 100<HI<150, TOC>0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. Six analyses meet the criteria (range 1.1%<TOC<1.55%, 2<S2<4.07, 151<HI<232 and 424<Tmax<434) indicating a light oil and gas prone source with poor to fair generative potential. All samples are immature to sub-mature.

One sample from Poissonnier 1, analysed by Rock-Eval for this module, gave a low TOC and HI and has poor generative potential (see Appendix 5 part 3).

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

An oil and gas indication has been recorded in Depuch 1. The following list summarises the porosity data for time slice K1:

Phoenix 1	14%<porosity av<27% (logs),
Poissonnier 1	35%<porosity av<40% (logs), and
Lacepede 1A	22%<porosity av<45% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Time slice K1 is considered to have good prospectivity.
- Oil and gas prone source rocks are found in the Cossigny and Beagle Troughs, the west Bedout Sub-basin and Fitzroy Trough but are unlikely to be mature anywhere.
- An unproven source (TOC>1.0%, no rock-Eval analyses available) on the Jurgurra Terrace is unlikely to be mature anywhere.
- Reservoirs are found in the Beagle and Fitzroy Troughs, west Bedout and Bedout Sub-basins, Bedout High, Jurgurra and Pender Terraces.
- Substantial sands have been intersected on the Bedout High in both Bedout 1 and Lagrange 1. They are grey to olive grey, very fine to coarse, moderately sorted, sub-angular to sub-rounded with poor to very good intergranular porosity. They are in the order of 200 feet thick and are interpreted as turbidite fans. Isolated beds occur in earlier time slice K1, with the same lithological description as above, but are interpreted as channels in a lower delta plain setting.
- The sands in Lagrange 1 would need to be charged via vertical migration pathways from the Early Triassic source rocks of the Bedout Sub-basin or, potentially from the Lower Jurassic and Triassic of the Inner Rowley Sub-basin. Old hinge zones exist around the edges of the Bedout High, and reactivation of these faults is highly probable during the Greater India breakup (time slice K1) thus providing a potential vertical migration pathway. Reservoirs would be sealed by regional time slice K1 aged seals and local time slice K2 aged seals.
- Large thicknesses of sand have been intersected in Keraudren 1 in the Bedout Sub-basin. The sands are light grey, very fine to very coarse, moderately sorted, sub-rounded to rounded and have good porosity. They are interpreted as continental shelf sands or potentially turbidite sands. Again vertical migration pathways would be needed to charge these sands from a Jurassic or Triassic source. This play type is less attractive considering the lower intensity of faulting and the uncertainty of mature source in the Bedout Sub-basin.
- Large thicknesses of sand have been encountered in both the Phoenix wells. The sands are light grey, predominantly medium grained, moderately sorted, sub-angular to sub-rounded with moderate to good porosity. They are interpreted as shoreface and channel deposits in a coastal-estuarine system, the back fill of an inner continental shelf, incised valley. These sands would need to be charged via vertical migration pathways from the Lower Jurassic and Triassic of the Inner Rowley Sub-basin. Old hinge zones exist to the west of Minilya 1 and Phoenix wells. The reactivation of hinge zone faults is highly probable during the Greater India breakup (time slice K1) and would provide potential vertical migration pathways. Reservoirs would be sealed by local seals of time slices K1 and K2.
- The only significant time slice K1 sands on the Bruce Terrace are in Poissonnier 1. The sand is multicoloured, very fine to granule, dominantly fine to coarse, poor to moderately well sorted, angular to sub-rounded with poor to fair porosity. It is interpreted as channels within a coastal estuarine system. The sand does not present itself as a potential exploration target as there is no significant seal.

- Reservoirs on the Pender and Jurgurra Terraces are unlikely to be prospective as there are no Cretaceous or Tertiary seals.
- Reservoirs of the Offshore Fitzroy Trough are unlikely to hold hydrocarbons as there is no effective regional seal until time slice K3.
- Regional seals are found in the Beagle and Fitzroy Troughs, Bedout High and Inner Rowley Sub-basin. Local seals are found in the Cossigny Trough and west Bedout - Bedout Sub-basins.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Beagle Trough:** Cretaceous time slice K1 clastic reservoirs sourced by a Triassic or Jurassic time slices J1-J4 source and sealed by Lower Cretaceous time slices K1-K2 regional seals.
- **west Bedout Sub-basin:** Cretaceous time slice K1 clastic reservoirs sourced by a Lower Triassic source and sealed by Lower Cretaceous intraformational seals.
- **Bedout Sub-basin:** Cretaceous time slice K1 clastic reservoirs sourced by a Lower Triassic source and sealed by Lower Cretaceous intraformational seals.
- **Bedout High:** Cretaceous time slice K1 clastic reservoirs sourced by a Lower Triassic source and sealed by Lower Cretaceous intraformational seals and time slice K1 regional seal.
- **Beagle Sub-basin**: Intertidal or supratidal fringe sands (Ronsard, Jarman, Ronsard and other blocks) sourced by Triassic or Jurassic time slices J1-J4 source, and sealed by Lower Cretaceous intraformational seals and time slice K2 regional seal.

NB: Migration conduits may have formed between the sandy pre-Argoland breakup Jurassic reservoir sequence and the lower Cretaceous reservoirs in the east Beagle and west Bedout Sub-basins and on the Bedout High. Consequently hydrocarbons may have accumulated in these lower Cretaceous reservoirs. Drilling appears to have been focussed on the structural culmination of tilted Jurassic horst blocks and structural traps at the lower Cretaceous may not have been tested adequately. This is because there are numerous unconformities between the lower Cretaceous and the pre-Argoland breakup Jurassic level and structural closure is not vertically coincident. Regionally time slices K1 and K2, and in part time slice K3, are highly prospective, as these time slices have good reservoir quality sands enclosed in seal facies, as well as being overlain by the regional seal facies of time slice K3.

Palaeodepositional environments interpreted for the sands include: incised valley fills, channels in a coastal estuarine system and upper shoreface sands. These reservoirs would need to be sourced from the Lower Jurassic and Triassic source rocks of either the Beagle Trough, and or from the southwest part of Inner Rowley Sub-basin. From east, near the west Bedout Sub-basin, to west, near the west Beagle Sub-basin, there is a decrease in gross sand thickness and probably average grain size within the lower Cretaceous time slices.

There is a distinct reduction of faulting intensity from the west to the east within the Beagle and Rowley Sub-basins. The higher intensity fault areas (Argoland and Greater India breakup age) in the western Beagle Sub-basin could provide conduits for hydrocarbons to migrate past the Upper Jurassic and Lower Cretaceous reservoir horizons. As an example Picard 1, a valid closure, recorded shows all the way up to the Cainozoic but did not reservoir any hydrocarbons. This is interpreted to imply seal breaching by the faults that also acted as migration pathways. The lower intensity fault areas (in places no faulting at all) in the Bedout Sub-basin do not provide migration pathways into the Upper Jurassic-Lower Cretaceous reservoirs. Because of this fault distribution the east Beagle and west Bedout Sub-basins and outer northwest Bedout High are believed to be the best location for this time slice K1 play. Here the faults extend approximately up to the top of the lower Cretaceous providing a terminating migration path into time slice K1 or K2 or K3 reservoirs.

TIME SLICE K2:

EARLY CRETACEOUS: NEOCOMIAN: EARLY VALANGINIAN TO LATE HAUTERIVIAN: (137.0 TO 126.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

This is the first time slice in the youngest of the Australian Petroleum Systems. Although good quality source rocks have been identified throughout the time slice, nowhere are they mature. The main significance of this time slice is as a regional seal to the underlying time slice K1. It is also the last phase of major tectonic deformation of the area. By late time slice K2 Greater India had moved past the Exmouth Platform (Plateau) and the main margin sag phase along the West Australian coast commenced. Not until time slice K9 would there be any signs of significant tectonics. Any faults active during time slice K2, that were connected to deep areas of then mature source, are potential migration pathways for hydrocarbons up to the regional seal provided by time slices K1, K2 and K3.

FORMATION SYNONYMS:(FIGURE 2).

- Muderong Shale in the Beagle Sub-basin is interpreted to have an unconformable base (Blevin et al, 1994).
- Unnamed in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE:(SEE ENCLOSURE 3).

Biostratigraphically the base is defined by the *E.torynum - S.areolata* dinoflagellate zone boundary and the *C.australiensis - F.wonthaggiensis* spore-pollen boundary. It covers the *M.testudinaria, P.burgerii, S.tabulata* and *S.areolata* dinoflagellate zones. It contains the M10 magnetic anomaly and equates to the start of major phase of sea floor spreading along the western margin in the Perth, Cuvier and Gascoyne Abyssal Plains. The base of time slice K2 represents a major unconformity in many basins, particularly on the western margin of the Australian continent. It also corresponds to a major sea level fall on the Haq et al (1987) chart.

PALAEONTOLOGY: (SEE ENCLOSURE 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *P.burgerii* (B3),
- Depuch 1: *P.burgerii* (B5),
- East Mermaid 1: *P.burgerii* (B3), *M.testudinaria* (B2), *S.tabulata* (B3),
- Jarman 1: *P.burgerii* (B5), *M.testudinaria* (B3/D3),
- Kambara 1/Minjin 1/Perindi 1 Wamac 1/Phoenix 2: no palaeontological control,
- Keraudren 1: *S.areolata* (B3),
- Lacepede 1A: *P.burgerii* (B5), *M.testudinaria* (B4),
- Lagrange 1: *M.testudinaria* (D3),
- Minilya 1: *M.testudinaria* (B3),
- North Turtle 1: *P.burgerii* (D5),
- Phoenix 1: *M.testudinaria* (B3),
- Picard 1: *P.burgerii* (B2/B4), *M.testudinaria* (B2/D3),
- Poissonnier 1: *P.burgerii* (B5), *M.testudinaria* (B5),
- Ronsard 1: *M.testudinaria* (B1), and
- Trafalgar 1: *P.burgerii* (B1), *M.testudinaria* (B1).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

The base of time slice K2 coincides with the commencement of drift of Greater India and the initiation of the Gascoyne and Cuvier Abyssal Plains. As a result, within the present area, the palaeoshelf and slope include numerous horsts and grabens. These are prevalent in the Beagle and Dixon Sub-basins but less extensive in the Roebuck and Offshore Canning Basins. The most prominent graben is the Thouin Graben that extends basinward. Its bathymetric expression is the Swan Canyon. An Argoland Abyssal Plain Transfer Fault extended onto the continental crust and acted as a significant topographic feature. Time slice K2 is bounded at the base by a regional unconformity but is conformable with the overlying time slice K3. Palaeoenvironments range from coastal-estuarine, inner shelf to slope with incised valley fills, carbonate banks and islands with intertidal sand fringes. Lithology's range from claystones to sandstones and greensands, with secondary dolomite, calcilutite and minor coal. Oil and gas indications were recorded in

Picard 1. Significant plays may exist in the west Bedout Sub-basin. Generally time slice K2 is favourable for stratigraphic traps that have both local or regional seals.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

West Australia was part of Greater Gondwana that now only comprises Antarctica and Australia after the breakoff of Greater India at the base of time slice K2 (Baillie et al, 1994). The timing of the breakup and drift of Greater India and the opening of the Gascoyne and Cuvier Abyssal Plains is correlated using end of time slice K1 unconformities, deposition of bentonite clays and dredge samples as well as ocean floor magnetic field lineations. On the Wombat Plateau evidence suggests a late Berriasian to late Valanginian age for the breakup (Von Rad & Thurow, 1992). Magnetic seafloor lineation further constrain the breakup to Valanginian. Initial movement of the Indian Plate away from Australia was along the Cape Range Fracture Zone. The oldest known oceanic crust adjacent to the Exmouth Plateau is M10 age (late *S.tabulata*), however it is probable that older crust exists beneath the Tertiary section immediately adjacent to the continent ocean boundary. The inference from biostratigraphic and stratigraphic considerations is that breakup occurred at time slice K1-K2 boundary (top *E.torynum*). India did not clear the Exmouth Plateau until magnetic reversal anomaly M5 (mid *M.testudinaria*) coincident with a mid oceanic ridge jump. Following this event the area entered a continental margin sag phase that is coincident with the commencement of a major transgression (Veevers, 1988). Time slice K2 is characterised by a continuous reduction in clastic input.

Local

The extension of an Argoland Abyssal Plain Transfer fault onto the continental crust may have influenced deposition. This transfer fault appears to be coincident with mapped Triassic aged hinge zones that have acted as weakness lines within the crust. Two probable Triassic depositional hinge zones are located NNW of the Bedout High and on the western side of the Bedout Sub-basin. These may possibly be associated with fracture systems created during the Bedout Movement or reflect distinct variations in the rheological properties between two basement provinces (see time slice J7 section for a more detailed description).

Commencing in time slice K2, fracture zones initiated during the Argoland breakup, in the location of the Swan Canyon and the canyon between the Echidna and Emu Spurs, finally developed into grabens (eg. the Thouin Graben). These grabens may have acted as corridors (feeder channels), for deeper water sedimentation such as turbidites and slump, and or gravity flow deposits.

Numerous horst and graben structures were formed during the Greater India breakup (Valanginian). These were still remnant as palaeo features throughout the Cretaceous. It is not possible to map all these palaeo-troughs and highs from the available seismic although their presence is inferred during time slice K2 and a sample of the fault trends can be seen in the Dixon Sub-basin in Enclosure 39.

Line 110/05 extends WNW from the Minilya 1 well, across the Outer Beagle Platform and out to the Thouin Graben. The portion of line 110/05 in Figure 18 shows the Thouin Graben flanks are a system of pull apart faults. The faults are not purely extensional as they have been shown to have a wrench component on them. Some of these faults are rejuvenated Jurassic and probably Triassic aged faults. A number of these pull apart fault systems were mapped in the Beagle Sub-basin. They are important for petroleum exploration, if they were initiated at Argoland breakup time. This is because the pull-apart regime may provide potential localised deeps, in which Upper Jurassic source rocks, similar to those found in the Dampier Sub-basin could accumulate. Better source potential may result due to restricted circulation in these deeps and possible dysoxic conditions. The grabens are filled by time slices K2-K11 sediments. The presence of sediments of time slices J8-J10 age is uncertain.

NB: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

Cossigny Trough: Jarman 1, Trafalgar 1 and Ronsard 1 sections are continuous claystone. The claystone in Jarman 1 is glauconitic in part with calcilutite and dolomitisation present. In Trafalgar 1 the claystone has minor siltstone with thin streaks of dolomite. Two coal interbeds were intersected towards the base of Ronsard 1.

Beagle Trough: Picard 1 has a serrated bell shaped gamma ray log signature at the base, a serrated funnel signature in the middle and a serrated bell at the top. The section is claystone. Both Depuch 1 and Poissonnier 1 have a very mild serrated gamma ray log signature. The lithology is claystone that is locally glauconitic. North Turtle 1 has a smooth bell shape gamma ray log pattern at the base, a mild serrated pattern in the middle and top, reflecting a sandstone base and dominantly claystone top with siltstone interbeds.

West Bedout Sub-basin: Phoenix 1 and 2 gamma ray log patterns are dominantly moderately serrated. Phoenix 1 has claystone and limestone lithology's with more sand content towards the base whilst Phoenix 2 has interbedded claystone and siltstone with massive sand at base. Minilya 1 gamma ray log pattern is serrated. The lithology is claystone with minor calcilutite.

Bedout High and Bedout Sub-basin: Keraudren 1, Lagrange 1 and Bedout 1 all have continuous serrated gamma ray log signatures. The lithology is claystone. Occasional beds of very fine greensand are found in both Bedout 1 and Lagrange 1.

Rowley Sub-basin: The gamma ray log signature in East Mermaid 1 is a serrated curve with mild bells and funnels. The lithology is claystone. No sandstone was encountered but some siltstone and dolomite are present.

Offshore Fitzroy Trough: Lacepede 1A gamma ray log patterns include a smooth section at the base (sandstone) with serrated bells in the middle and top (sandstone). Minor interbeds of claystone are present. Wamac 1 gamma ray log patterns include mild funnels and one mild bell in the middle and base, with a continuous mildly serrated pattern at the top. The section is dominantly sandstone (90%) with secondary claystone and siltstone.

Pender and Jurgurra Terraces: Kambara 1, Perindi 1 and Pearl 1 sections are all sandstone. Minjin 1 section is dominantly sandstone with isolated claystone beds throughout.

THICKNESS VARIATIONS: (SEE ENCLOSURE 38).

Thickness ranges from 15m in Keraudren 1 to 265m in Perindi 1. Regional thickness is expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 39).

Globally time slice K2 is characterised by an intermediate to low relative sea level. Six global eustatic sea level drops occur during time slice K2 (Haq et al, 1987). The base of time slice K2 is characterised by a major sea level drop. The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a gradual transgression that started in time slice K1. However during most of time slice K2 the coastline in the module area is in about the same location as for time slice K1.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 39).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of interpreted seismic data, palaeogeographic interpretations from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

Enclosure 39 shows that:

- the rate of sedimentation increased significantly in this time slice following the thin sequences and starved sediment sequences of the Late Jurassic. Land appears to coincide approximately with the present day landmass and the edge of the Lambert Shelf,
- the NE-SW striking downlap edge of time slice K2 (identified from seismic) is seen to prograde only slightly basinward relative to time slice K1, suggesting a similar average sea level prevailed during both time slices,
- sediments of this age have been recovered in ODP site 765 on the Argo Abyssal Plain (Kaminski et al, 1992). Time slice K2 is therefore interpreted to be present as a condensed sequence beyond the mapped seismic downlap edge, out to the continental-ocean boundary and beyond,
- the approximate location of the continental shelf break is inferred using the palaeogeographic interpretations from the most basinward wells, a number of shallower water landforms, like the estuarine tidal ridges in the Bedout Sub-basin, were probably deposited during marine lowstands, and
- land is interpreted to be present on the Sable and Picard Blocks and Jarman horst with intertidal and supratidal rims around each of these high grounds. Figure 26 shows an example of time slice K2 sedimentation in the Beagle Trough and adjacent to the Picard Block. It is possible that time slice K2 was deposited on these highs maybe in the form of condensed sequences, and later eroded. These high block are interpreted to have been decreasing in size since the main Argoland breakup phase.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI >150, TOC > 1.0% or 100<HI<150, TOC > 0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. Three analyses meet these criteria (1.6%<TOC<3.93%, 3.12<S2<29, 201<HI<737 and Tmax=430 and 432) and indicate an oil

and gas prone immature source with fair to very good generative potential. One sample from Ronsard 1, analysed for Rock-Eval in conjunction with this module, gave a TOC of 1.75% but poor generative potential and low HI (Appendix 5 part 3).

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

An oil and gas indication was recorded in Picard 1. The following list summarises the porosity data for the time slice:

Poissonnier 1	35%<porosity av<40%(logs), and
Lacepede 1A	26%<porosity av<42%(logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

Enclosure 3 shows that:

- gas prone source rocks are present in the west Bedout Sub-basin but are immature,
- oil prone source rocks are present in the Offshore Fitzroy Trough but are immature,
- oil and gas prone source rocks are present in the Cossigny Trough but are immature,
- potential source rocks although unproven, are interpreted in the Beagle Trough and Jurgurra Terrace. These source rocks are immature,
- potential reservoirs are interpreted in the Beagle and Fitzroy Troughs, west Bedout Sub-basin, Jurgurra and Pender Terraces,
- reservoirs in the west Bedout Sub-basin are substantial units, especially in Phoenix 2, and to a lesser extent in Phoenix 1. The are unconsolidated quarztose, silt to coarse grained sands, moderately sorted, subangular to subrounded and have high visual porosity. They are interpreted as both channel sands in a coastal estuarine system and lower shoreface sands. They are expected to be excellent reservoirs that are sealed by time slice K3 regional seals. These reservoirs require sourcing via faults from Lower Triassic source rocks of the Bedout Sub-basin or potentially from Lower Jurassic source rocks of the east Beagle Trough,
- the only sands present within the Beagle Trough are found at North Turtle 1. This well is located on a depositional hinge line. The sands are unconsolidated, coarse grained, colourless, poorly sorted, sub-angular to sub-rounded and are interpreted as incised valley fill. They may also be shoreface sands reworked along the depositional hinge lines,
- reservoirs of the Jurgurra and Pender Terraces are not prospective as there is no adequate Upper Cretaceous or Tertiary seal,
- reservoirs of the offshore Fitzroy Trough are unprospective as the top of the reservoir section is within time slice K3 before being sealed by time slice K3 regional seals, and
- regional seals are confirmed in the Cossigny and Beagle Troughs and Inner Rowley Sub-basin whilst local seals are likely in the west Bedout and Bedout Sub-basins and Bedout High.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

Identified plays include in the:

- **Beagle Trough:** Time slice K2 clastic reservoirs sourced by Triassic or Jurassic (time slices J1-J4) source, and sealed by Lower Cretaceous intraformational seals and time slice K2 regional seal.
- **west Bedout Sub-basin:** Time slice K2 clastic reservoirs sourced by a Lower Triassic source and sealed by Lower Cretaceous intraformational seals and time slice K3 regional seal.
- **Beagle Sub-basin**: Intertidal to supratidal fringe sands around the Ronsard, Jarman, Ronsard and other blocks, sourced by Triassic or Jurassic (time slices J1-J4) source, and sealed by Lower Cretaceous intraformational seals, and or time slice K2 regional seal.
- **General module area**: Incised valley fills sourced by Triassic or Jurassic (time slices J1-J4 source), and sealed by Lower Cretaceous intraformational seals and time slice K2 regional seal.

NB: Migration conduits may have formed between the sandy pre-Argoland breakup Jurassic reservoir sequence and the lower Cretaceous reservoirs in the east Beagle and west Bedout Sub-basins and on the Bedout High. Consequently hydrocarbons may have accumulated in these lower Cretaceous reservoirs. Drilling appears to have been focussed on the structural culmination of tilted Jurassic horst blocks and structural traps at the lower Cretaceous may not have been tested adequately. This is because there are numerous unconformities between the lower Cretaceous and the pre-Argoland breakup Jurassic level and structural closure is not vertically coincident. Regionally time slices K1 and K2, and in part time slice K3, are highly prospective, as these time slices have good reservoir quality sands enclosed in seal facies, as well as being overlain by the regional seal facies of time slice K3.

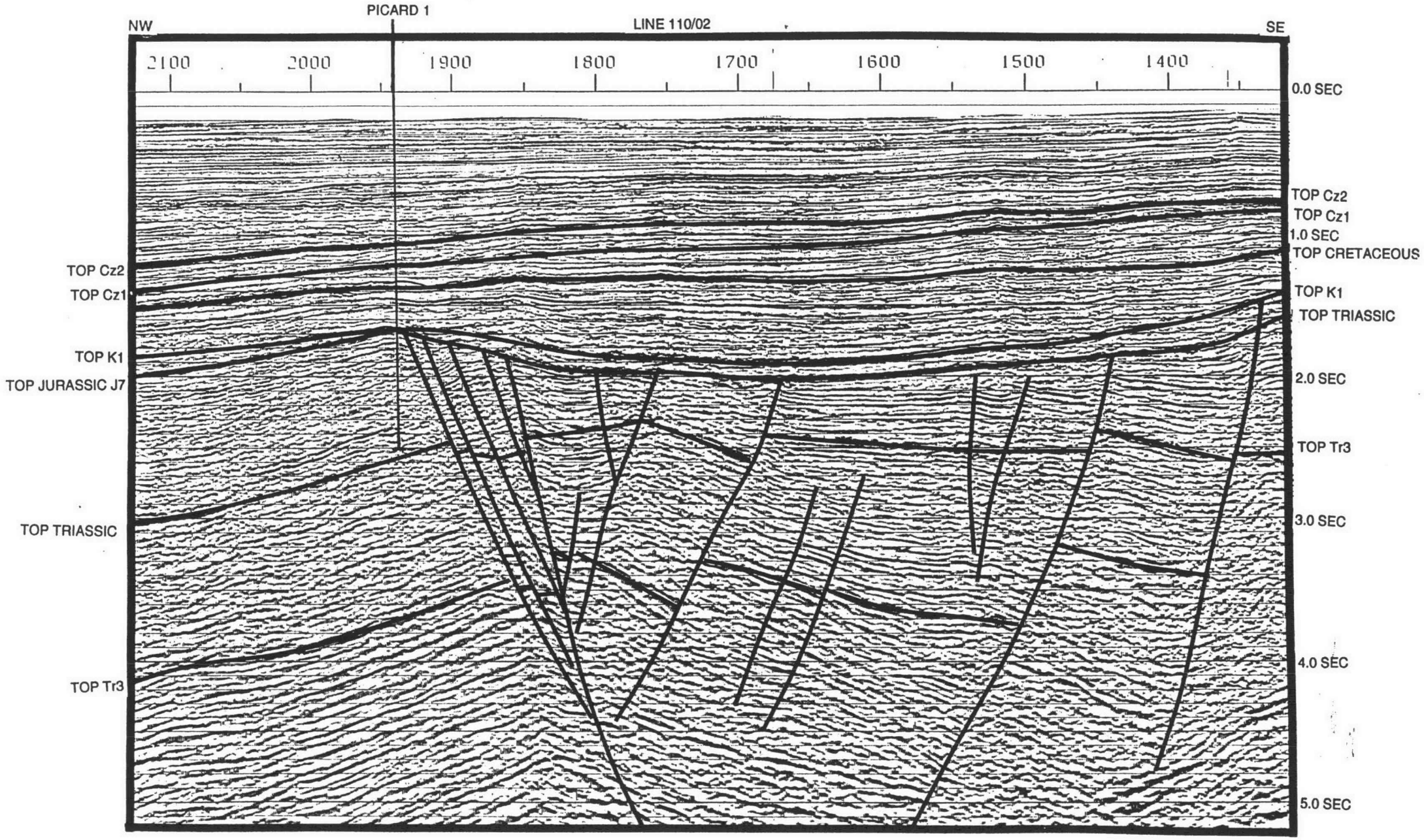

FIGURE 26: SEISMIC REPRESENTATION OF THE BEAGLE TROUGH & PICARD 1, BEAGLE SUB-BASIN, LINE 110/02.

Palaeodepositional environments interpreted for the sands include: incised valley fills, channels in a coastal estuarine system and upper shoreface sands. These reservoirs would need to be sourced from the Lower Jurassic and Triassic source rocks of either the Beagle Trough, and or from the southwest part of Inner Rowley Sub-basin. From east, near the west Bedout Sub-basin, to west, near the west Beagle Sub-basin, there is a decrease in gross sand thickness and probably average grain size within the lower Cretaceous time slices.

There is a distinct reduction of faulting intensity from the west to the east within the Beagle and Rowley Sub-basins. The higher intensity fault areas (Argoland and Greater India breakup age) in the western Beagle Sub-basin could provide conduits for hydrocarbons to migrate past the Upper Jurassic and Lower Cretaceous reservoir horizons. As an example Picard 1, a valid closure, recorded shows all the way up to the Cainozoic but did not reservoir any hydrocarbons. This is interpreted to imply seal breaching by the faults that also acted as migration pathways. The lower intensity fault areas (in places no faulting at all) in the Bedout Sub-basin do not provide migration pathways into the Upper Jurassic-Lower Cretaceous reservoirs. Because of this fault distribution the east Beagle and west Bedout Sub-basins and outer northwest Bedout High are believed to be the best location for this time slice K2 play. Here the faults extend approximately up to the top of the lower Cretaceous providing a terminating migration path into time slice K1 or K2 or K3 reservoirs.

TIME SLICE K3:

MIDDLE CRETACEOUS: NEOCOMIAN: BARREMIAN: (126.0 to 119.5 MA).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

Time slice K3 has some source potential throughout the area but is nowhere mature. Its main significance is as a sealing facies. It is the first regional seal over the area of the Exmouth and Barrow Sub-basins.

FORMATION SYNONYMS: (FIGURE 2).

- The Muderong Shale in the Beagle Sub-basin (Blevin et al, 1994).
- Unnamed in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

This time slice is equivalent to the *M.australis*, basal *A.cintum*, and *L.ouachensis* dinoflagellate zones. The *F.wonthaggiensis* spore and pollen zone is common to both time slices K2 and K3. The time slice is characterised by a major transgression of the sea into central and western Australia.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1, Minilya 1 & Phoenix 1: *M.australis* (B3),
- Bruce 1: *M.australis* (B5),
- Depuch 1: *M.australis* (B5), *L.ouachensis* (B3),
- East Mermaid 1: *L.ouachensis* (B3),
- Jarman 1, Keraudren 1, Lacepede 1A Lagrange 1/Phoenix 2: no palaeontological control,
- North Turtle 1: *M.australis* (D4),
- Picard 1: *M.australis* (B3/B5),
- Poissonnier 1: *M.australis* (B2),
- Ronsard 1: *M.australis* (B4),
- Trafalgar 1: *M.australis* (B1), and
- Wamac 1: *M.australis* (D3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Continental margin sag occurred along the west Australia margin following the clearing of Greater India from the Exmouth Plateau in late time slice K2. Time slice K3 is a transgressive unit. The shelf and slope topography reflected numerous horst and graben features, particularly in the Beagle and Dixon Sub-basins and, to a lesser extent, in the Roebuck and Offshore Canning Basins. The base of time slice K3 is conformable on time slice K2. The top is mainly disconformable but some evidence for an unconformable contact exists (figure 10). The top of time slice K3 corresponds in places to the base time slice K5 lowstand since time slice K4 is for the most part eroded away. Palaeo-environments include continental shelf to slope with incised valley fills. Lithology's range from claystones to sandstones and greensands with secondary limestone, dolomite and fossiliferous beds. Significant plays are likely in the Beagle Trough with secondary targets on the Bedout High. Generally the time slice is a regional seal.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

West Australia is part of Greater Gondwana, that now only includes Antarctica after the breakoff of Greater India at the end of time slice K1 (Baillie et al, 1994). The North West Shelf entered a continental margin sag phase as the adjacent juvenile ocean floor cooled and commenced to submerge to abyssal depth. Volcanic activity has ceased and this is a time of general tectonic quiescence.

Local

The shelf extension of the Argo Abyssal Plain Transfer fault, interpreted to be an active feature during time slice K2, is thought not to be influencing sedimentation during time slice K3. Following the Valanginian breakup, there were numerous graben and horst structures formed that were still remnant at this time. It is not possible to map all these features from the available seismic although their presence can be inferred during time slice K3. Continental shelf fracture zones often developed into grabens towards the continental margin (eg the Thouin Graben). These grabens may have acted as feeder channels for deeper water

sedimentation, such as turbidites and slump and gravity flows. The portion of line 120/03 in Figure 10 shows that time slice K3 is truncationally eroded.

note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

The gamma ray log patterns in most wells (Jarman 1, Trafalgar 1, Ronsard 1, Picard 1, Bruce 1, Depuch 1, East Mermaid 1, Keraudren 1, Minilya 1, North Turtle 1, Phoenix 1 and 2) are dominantly serrated. The lithology is claystone.

Cossigny Trough: Trafalgar 1 has massive claystone with minor siltstone and thin streaks of dolomite. Ronsard 1 lithology's include claystone with interbeds of sandstone. Jarman 1 also has glauconite present.

Beagle Trough: North Turtle 1 lithology includes interbedded claystone and siltstone. The claystone in Bruce 1 is slightly calcareous and glauconitic. Poissonnier 1 has one sand bed and one claystone bed.

West Bedout Sub-basin: Phoenix 1 and 2 have interbedded sandstone, siltstone and claystone and is glauconitic in part. Minilya 1 has 100% claystone.

Bedout Sub-basin: Keraudren 1 has significant fossiliferous sandstone towards the top.

Bedout High: The gamma ray log patterns for Bedout 1 and Lagrange 1 are very serrated and form an overall large scale funnel patterns. The lithology is dominantly claystone. The claystone in Bedout 1 is dark grey to olive black, with minor glauconite with occasional thin beds of very fine greensand whilst beds of sandstone, limestone and dolomite are present in the middle of the unit.

Rowley Sub-basin: East Mermaid 1 is slightly calcareous and glauconitic with siltstone beds also encountered.

Offshore Fitzroy Trough: Wamac 1 gamma ray log patterns include a continuous serrated base (greensands, siltstone and claystone) with mild bells in the middle and top (claystone) . Lacepede 1A has dominantly interbedded and interlaminated claystone and siltstone towards the top grading to interbedded siltstone and sandstone towards the base.

THICKNESS VARIATIONS: (SEE ENCLOSURE 40).

Thicknesses range from 17m in Ronsard 1 to 313m in Lacepede 1A. Regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 41).

Globally this time slice is characterised by an intermediate relative sea level. Within time slice K3 there are three global eustatic sea level drops amounting to four 3rd order cycles (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a gradual transgression that started in time slice K1. In the module area the coastline is interpreted to have transgressed.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 41).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic data, palaeogeography interpretations from onshore Canning Basin wells and outcrop (BMR, 1981), palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

Important points to note in Enclosure 41 are that:

- the seismically mapped downlap edge progrades basinward relative to time slice K2
- sediments of this age have been recovered in ODP site 765 on the Argo Abyssal Plain (Kaminski et al, 1992). Time slice K3 is therefore interpreted to be present as a condensed sequence beyond the mapped seismic downlap edge, out to the continental-ocean boundary and beyond,
- a number of incised valley fills are postulated. These are deduced from the presence of sandy intervals and dolomitic beds interpreted to be related to sea level drops,
- the shoreline is believed to have been located east of the present day shoreline and land is interpreted to the southeast. The general trend of the shelf break approximates the present day shoreline's northeast to southwest strike,
- only minor fluvial input is interpreted that is limited, mainly, to the valleys of the fluvial systems adjacent to a narrow band of coastal deposits,
- the starved shelf has glauconitic sands that gradually become finer and more argillaceous towards the shelf edge and slope, and

- the palaeosubmarine topography is thought likely to have reflected compaction within the underlying time slice K2 sediments.

GEOCHEMISTRY (TOC, HI, S2 AND VR): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI >150, TOC > 1.0% or 100<HI<150, TOC > 0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. The two analyses meeting the selection criteria revealed TOC = 1.84%-1.92%, S2= 2.3-3.1, HI = 155-163, indicating a gas prone source of fair generative potential.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

No shows have been detected. The following list summarises the porosity data for this time slice:

Poissonnier 1 35%<porosity av<40%(logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- The Pender and Jurgurra Terraces may have had time slice K3 sedimentation but this was subsequently eroded. In this area time slice K3 cannot be expected to be prospective.
- Oil and gas prone source rocks are present in the west Bedout Sub-basin, Bedout High and Fitzroy Trough but are not mature,
- Reservoir potential has been identified within the Beagle and Fitzroy Troughs, west Bedout Sub-basin and Bedout High,
- Within the Beagle Trough area, only the Poissonnier 1 well shows any substantial thickness of sandstone. The sandstone is very fine to granule, dominantly very fine to coarse, angular to rounded and well sorted with fair to good porosity. The sand is interpreted as a channel within a coastal estuarine system. The regional extent of this sand is unknown but is probably limited to the terraces beyond the main basin margin fault. Seals may be lacking on the basin margins,
- On the Bedout High, only the Lagrange 1 well intersected sands. The sand is colourless, medium to coarse grained, well rounded, poorly sorted and has been interpreted as channels within a coastal estuarine system. The sands are likely to have been deposited during a short lived lowstand and are expected to be sealed by overlying transgressive shales.
- Within the west Bedout Sub-basin, only Phoenix 1 and 2 intersected sands. Phoenix 1 intersected interbedded greensands in the order of 20m thick deposited on the middle shelf. Phoenix 2 intersected massive sands also deposited on the middle shelf. In Phoenix 2 the sands are very fine to coarse and generally unconsolidated. These may be offshore sand bars or sandwaves. The stratigraphic trap potential of these sands is good as overlying seals are present. However they require complicated migration pathways up faults from potential Triassic source rocks in the Inner Rowley Sub-basin to charge them. Plays based on this concept are likely to be present around the Bedout High as Late Cretaceous-Tertiary tectonism is reactivating older Bedout High Palaeozoic hinge zones and these may provide migration pathways from deeper source into time slice K3 reservoirs.
- The sands in the Fitzroy Trough are interbedded within continental shelf shales and may be poor exploration targets as migration pathways from Carboniferous and older rocks are complex.
- Time slice K3 is a regional seal on the Cossigny and Fitzroy Troughs, west Bedout, Bedout and Inner Rowley Sub-basins and Bedout High. Time slice K3 has been interpreted to be a local seal for the Beagle Trough.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- **Beagle Trough:** Cretaceous time slice K3 clastic reservoirs sourced by a Triassic or Jurassic time slices J1-J4 source and sealed by Lower Cretaceous intraformational seals may be a viable play.
- **Bedout High:** Cretaceous time slice K3 clastic reservoirs sourced by a Lower Triassic source and sealed by Lower Cretaceous time slices K3 and K4 regional seals may be a viable play.

NB: Migration conduits may have formed between the sandy pre-Argoland breakup Jurassic reservoir sequence and the lower Cretaceous reservoirs in the east Beagle and west Bedout Sub-basins and on the Bedout High. Consequently hydrocarbons may have accumulated in these lower Cretaceous reservoirs. Drilling appears to have been focussed on the structural culmination of tilted Jurassic horst blocks and structural traps at the lower Cretaceous may not have been tested adequately. This is because there are numerous unconformities between the lower Cretaceous and the pre-Argoland breakup Jurassic level and structural closure is not vertically coincident. Regionally time slices K1 and K2, and in part time slice K3, are

highly prospective, as these time slices have good reservoir quality sands enclosed in seal facies, as well as being overlain by the regional seal facies of time slice K3.

Palaeodepositional environments interpreted for the sands include: incised valley fills, channels in a coastal estuarine system and upper shoreface sands. These reservoirs would need to be sourced from the Lower Jurassic and Triassic source rocks of either the Beagle Trough, and or from the southwest part of Inner Rowley Sub-basin. From east, near the west Bedout Sub-basin, to west, near the west Beagle Sub-basin, there is a decrease in gross sand thickness and probably average grain size within the lower Cretaceous time slices.

There is a distinct reduction of faulting intensity from the west to the east within the Beagle and Rowley Sub-basins. The higher intensity fault areas (Argoland and Greater India breakup age) in the western Beagle Sub-basin could provide conduits for hydrocarbons to migrate past the Upper Jurassic and Lower Cretaceous reservoir horizons. As an example Picard 1, a valid closure, recorded shows all the way up to the Cainozoic but did not reservoir any hydrocarbons. This is interpreted to imply seal breaching by the faults that also acted as migration pathways. The lower intensity fault areas (in places no faulting at all) in the Bedout Sub-basin do not provide migration pathways into the Upper Jurassic-Lower Cretaceous reservoirs. Because of this fault distribution the east Beagle and west Bedout Sub-basins and outer northwest Bedout High are believed to be the best location for this time slice K3 play. Here the faults extend approximately up to the top of the lower Cretaceous providing a terminating migration path into time slice K1 or K2 or K3 reservoirs.

TIME SLICE K4:

MIDDLE CRETACEOUS: APTIAN (119.5 to 113.0 MA).

PETROLEUM SYSTEM: WESTRALIAN (ENCLOSURE 3).

This time slice is significant as the maximum transgressive phase for the regional seal facies.

FORMATION SYNONYMS: (FIGURE 2).

- The Muderong Shale is present in the Beagle Sub-basin (Blevin et al, 1994).
- Formations are as yet unnamed in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice K4 records the peak of a marine transgression across the Australian continent. It is biostratigraphically defined by the dinoflagellate zones upper *A.cinctum*, *O.operculata* and *D.davidii,* and the *C.hughesii* and basal *C.striatus* spore-pollen zones. Time slice K4 corresponds to a change in stratigraphy in many basins with the deposition of marine shales over sandstones in offshore basins.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *D.davidii* (B3),
- Bruce 1/Keraudren 1: *O.operculata* (B5),
- East Mermaid 1: *D.davidii* (B5), *O.operculata* (B3),
- Lacepede 1A: *O.operculata* (B3),
- Lagrange 1: no palaeontological control, and
- Wamac 1: *O.operculata* (D5).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Continental margin sag occurred along west Australia margins following the clearing of Greater India. Regionally this was a time of tectonic quiescence. The disconformable-unconformable top of time slice K3 is best illustrated from the age-depth plots (see Appendix 3; Bedout 1, East Mermaid 1, Jarman 1, Keraudren 1, Minilya 1, North Turtle 1 and Ronsard 1). There is weak evidence of an unconformable base that can be seen from the age-depth plot of East Mermaid 1(Appendix 3). Time slice K4 has in part been eroded away during the base K5 lowstand, it is also interpreted to be condensed in a few of the wells. Time slice K4 is a marine transgressive unit. Lithology's range from claystone, marl with secondary sandstone, siltstone with minor limestone and fossiliferous beds. In summary the time slice is a dominant regional seal with some reservoir potential within the Bedout Sub-basin.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

West Australia was part of Greater Gondwana that now only includes Antarctica and Australia after the breakoff of Greater India at the end of time slice K1 (Baillie et al, 1994). This is a time of regional tectonic quiescence.

Local

Following the Valanginian breakup, there were numerous graben and horst structures formed that were still remnant at this time. It is not possible to map all these features from the available seismic although their presence can be inferred during time slice K4. In particular continental shelf fracture zones in the location of the Swan Canyon and the canyon between the Echidna and Emu Spurs developed into grabens towards the continental margin (eg the Thouin Graben). These grabens may have acted as feeder channels for deeper water sedimentation, such as turbidites and slump and gravity flows.

Note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Beagle Trough/Bruce Terrace: Mild to moderately serrated gamma ray log patterns (claystone) are found in Bruce 1. The claystone in Bruce 1 is slightly calcareous and glauconitic.

Bedout Sub-basin: Mild to moderately serrated gamma ray log patterns (claystone) are found in Keraudren 1.

Bedout High: Both Lagrange 1 and Bedout 1 have continuous mild serrated gamma ray log patterns. The lithology in Lagrange 1 is mudstone with trace of limestone whilst Bedout 1 consists of claystone with minor sandstone. There is significant fossiliferous sandstones and claystones in Keraudren 1.

Rowley Sub-basin: East Mermaid 1 has mild serrated gamma ray log patterns (medium grey partly fossiliferous lithology).

Offshore Fitzroy Trough: Lacepede 1A lithology consists of marl grading downwards to claystone with interbedded siltstone. Wamac 1 has marl at its base overlain by a claystone bed. Mild to moderately serrated gamma ray log patterns (claystone) are found in Wamac 1.

THICKNESS VARIATIONS: (SEE ENCLOSURE 42).

Thicknesses range from 22m in Bruce 1 to 58m in Keraudren 1. Regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 43).

Globally this time slice is characterised by an intermediate to maximum relative sea level, and as well the top of time slice K4 is characterised by a major sea level drop (Haq et al, 1987). This is substantiated from the Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990). Within time slice K4 there are six global eustatic sea level drops (Haq et al, 1987). In the module area the coastline is interpreted to have transgressed.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 43).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic data, palaeogeographic interpretations from the onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

Enclosure 43 shows that:

- at the peak of the transgression the coastline was significantly inland of the present coastline, but emergent land is interpreted to the south and the northeast,
- the western downlap edge of time slice K4 as identified from seismic, is landward of the time slice K3 edge suggesting a relative sea level high. This is further evidenced from the presence of marine sediments inland. Additionally, an increase in subsidence may have activated instability of the shelf,
- sediments of this age have been recovered in ODP site 765 on the Argo Abyssal Plain (Kaminski et al, 1992). Time slice K4 is therefore interpreted to be present as a condensed sequence beyond the mapped seismic downlap edge, out to the continental-ocean boundary and beyond, and
- there may be a clastic depocenter in the Keraudren area at this time, possibly feeding sediment to the outer shelf.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

No high quality source rocks have been identified in this time slice. It is considered unlikely that time slice K4 has high quality source rock potential, as well it is unlikely to be mature anywhere within the module area.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

A gas indication was recorded in Lynher 1. No porosity or permeability data exist.

PROSPECTIVITY: (SEE ENCLOSURE 3).

- An unconfirmed (TOC >1% but no Rock-Eval) oil and gas prone source rock is present in the Beagle Trough but is unlikely to be mature anywhere within the module area.
- Some reservoir potential has been identified within the Bedout Sub-basin. The sands are very fine to coarse, dominantly subangular to subrounded, moderately well sorted and have poor to good porosity. They are interpreted as having been deposited on the continental shelf possibly as sheet sands during short lived lowstands. Their regional extent is not known. There may be a trap if the sands can be sourced from Lower Triassic source rocks via migration up Cretaceous aged faults. Intraformational and regional seals are provided by overlying time-slices K6-K10 sediments.
- Time slice K4 is a regional seal for the Bedout and Inner Rowley Sub-basins, Bedout High and the Offshore Fitzroy Trough. Time slice K4 would act as a local seal for the Beagle Trough.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- Stratigraphic traps exist in the Bedout Sub-basin. The sands in Keraudren 1 may form part of a sand apron that extends to the west Bedout Sub-basin and possibly onto the Bedout high. There may be a good chance for hydrocarbon accumulations if the Basal Jurassic, and or Triassic has sourced these reservoirs.

- Incised valley fill in the east Rowley Sub-basin, seen on seismic to have cut and fill internal facies patterns, may have hydrocarbon potential. The feature could form a large scale stratigraphic trap. Similar features may also be present elsewhere in the module area.

TIME SLICES K5-7:

MIDDLE CRETACEOUS: ALBIAN: (113.0 to 99.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

In the Dampier Sub-basin, these time slices mark the onset and development of a significant thickness of regional seal, resulting in initial thermal blanketing and the first significant burial of the Jurassic source rocks of the earliest Westralian Petroleum Systems.

FORMATION SYNONYMS: (FIGURE 2).

- The Haycock Marl with an unnamed siltstone unit, interpreted as diachronous, is present in the Beagle Sub-basin (Blevin et al, 1994). The Haycock Marl has an erosional base.
- Stratigraphy in the Offshore Canning and Roebuck Basins remains unnamed (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICES: (SEE ENCLOSURE 3).

- TIME SLICE K5: EARLY ALBIAN (113.0 - 109.0 MA).

Time slice K5 is a time of sea level retreat. It equates to the *C.striatus* spore-pollen zone and approximates the *M.tetracantha* dinoflagellate zone.

- TIME SLICE K6: MIDDLE ALBIAN (109.0 -104.0 MA).

Regression continued during Time slice K6. The base of the time slice equates to the base of *C.paradoxa* spore-pollen zone and the top equates to the top of *C.denticulata* dinoflagellate zone.

- TIME SLICE K7: LATE ALBIAN (104.0 - 99.0 MA).

Time slice K7 is a transgressive episode, as well as a global oceanic anoxic event. Biostratigraphically it approximates the *P.ludbrookiae* dinoflagellate zone and encompasses the top of the *C.paradoxus* spores and pollen zones.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1(K5):	*M.tetracantha* (B3),
- East Mermaid 1 (K6):	*C1*(B2), *C.denticulata*(B3),
- Ronsard 1 (K6):	*C1*(B3),
- Jarman 1 (K6/K7):	*C1*(B5),
- Bedout 1 (K6/K7), Depuch 1 (K6/K7):	*C1*(B3),
- East Mermaid 1 (K7):	*C1*(B5), *P.ludbrookiae*(B2),
- Keraudren 1 (K7):	*P.ludbrookiae*(B2, B3),
- Minilya 1 (K7):	*C1*(B3),
- North Turtle 1 (K7):	*C2*(D5), *C6*(D5), *P.ludbrookiae*(D3),
- Picard 1 (K7):	*C1*(B5), and
- East Mermaid 1(K5), Keraudren 1 (K6), Lagrange 1 (K7), Phoenix 1 (K7), Phoenix 2 (K7), Trafalgar 1 (K6/K7):	no palaeontological control.

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Continental margin sag occurred along the west Australia margin following the clearing of the Greater India continent. Time slices K5, K6 and in part K7 were lowstands with very little deposition in any of the wells. The base of time slice K5 is a well recognised regional disconformity on the North West Shelf. Depositional environments include both starved shelf and slope. The Bruce Terrace was emergent and some shelf incision is interpreted. Lithology's range from calcilutite, marl and claystone with secondary siltstone, sandstone and coal. A relative sea level drop is interpreted from the presence of dolomite and fossiliferous beds. In summary these time slices act as local and regional seals.

TECTONICS:(SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

West Australia was part of Greater Gondwana that comprised Antarctica and Australia after the breakoff of Greater India at the end of time slice K1 (Baillie et al, 1994). Regionally the drifting Indian Sub-continent effectively cleared Australia and continental margin sag commenced along the entire western margin of the Australian continent.

Following the Valanginian breakup there were numerous graben and horst structures formed that were still remnant at this time. It is not possible to map all these features from the available seismic although their presence can be inferred during time slices K5-7. In particular onshore fracture zones in the location of the Swan Canyon and the canyon between the Echidna and Emu Spurs developed into grabens towards the continental margin (eg the Thouin Graben). These grabens may have acted as feeder channels for deeper water sedimentation, such as turbidites and slump and gravity flows.

Local

Line 120/07 extends SW from the western extremity of the Browse Basin across the Rowley Sub-basin and terminates in the Outer Beagle Platform. The portion of line 120/07 in Figure 27 shows a downcut landform that may have originated from slumping but is interpreted to be shelf or slope incision during the time slice K5 lowstand. The fill occurred during time slices K5 to K11 and was then overlain by Tertiary progrades.

Line 110/06 extends NNE from the Lambert Shelf across the western part of the Bedout Sub-basin and the Phoenix high and terminates at the southern extremity of the western part of the Inner Rowley Sub-basin. The portion of line 110/06 in Figure 28 shows some of the unconformities that can be picked up from seismic such as the base time slice K5 unconformity where truncational erosion is evident. Part of the erosional surface could be a response to minor structural movement, but a major marine transgression during time slice K4 followed by a regression during time slice K5 downcutting appears the most likely mechanism. In other areas the base of time slice K5 is a disconformity, particularly well seen towards the Dampier Sub-basin. The disconformity appears to be a result of massive sediment starvation.

Note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

Time slice K5:

Bedout and Rowley Sub-basins: Gamma ray log patterns in Bedout 1 and East Mermaid 1 include very mild serrated patterns. These are continuous medium grey fossiliferous claystones.

Time slice K6:

Cossigny Trough: Gamma ray log patterns are cylindrical in Ronsard 1. The lithology includes calcilutite and claystone with secondary marl and rare coal. Jarman 1 gamma ray log patterns include serrated half bells (siltstone) and a dominantly serrated pattern (calcisiltite/marl/dolomite). Trafalgar 1 has calcareous claystone with minor marl.

Beagle Trough: Depuch 1 gamma ray log patterns include a smooth cylinder (claystone and calcilutite).

Bedout Sub-basin: Keraudren 1 has two serrated funnels (fossiliferous claystone).

Bedout high and Rowley Sub-basin: Bedout 1 and East Mermaid 1 gamma ray log patterns are very mildly serrated. The lithology comprises continuous medium grey fossiliferous claystones.

Time slice K7:

Cossigny Trough: Gamma ray log patterns are serrated in Trafalgar 1 (siltstone and claystone) and smooth half bells in Jarman 1 (marl and claystone). Trafalgar 1 lithology's include calcareous claystone, minor marl at the base, marl with interbedded and intergradational calcareous claystone, minor claystone with siltstone lamina and sandstone with thin dolomite streaks.

Beagle Trough: Both Depuch 1 and North Turtle 1 have smooth continuous log patterns. Depuch 1 lithology includes calcilutite.

West Bedout Sub-basin: The gamma ray log patterns in the Phoenix wells are serrated cylinders (dominantly calcareous claystone). Phoenix 2 has dominant claystone with glauconite and dolomite present and a sandstone bed at the base. Minilya 1 gamma ray log patterns consist of two mild bells (claystone and marl).

Bedout Sub-basin: The gamma ray log patterns in Keraudren 1 are serrated. The lithology consists of continuous claystones containing *Inoceramus* and pelecyopod fragments towards the top together with forams and glauconite mineral.

Bedout High: The gamma ray log pattern in Lagrange 1 consists of serrated half bells whilst Bedout 1 has very mild serrated patterns. The lithology in Lagrange 1 is all claystone with trace of glauconite whilst Bedout 1 has continuous calcareous, olive grey to olive black claystone.

Rowley Sub-basin: East Mermaid 1 has very mild serrated gamma ray log patterns. The lithology consists of continuous medium grey fossiliferous claystone.

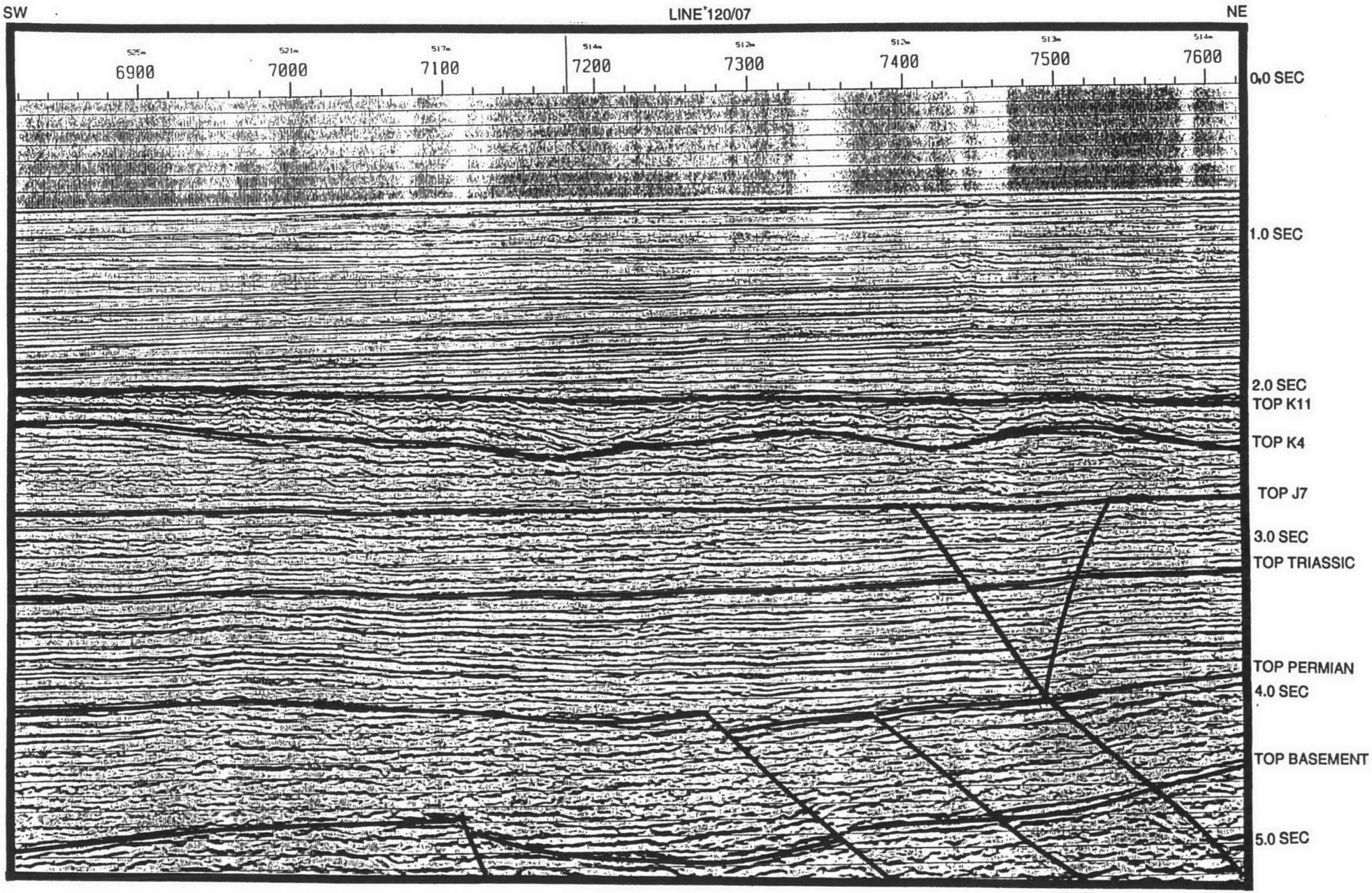

FIGURE 27: SEISMIC REPRESENTATION OF A CUT & FILL FEATURE, ROWLEY SUB-BASIN, LINE 120/07.

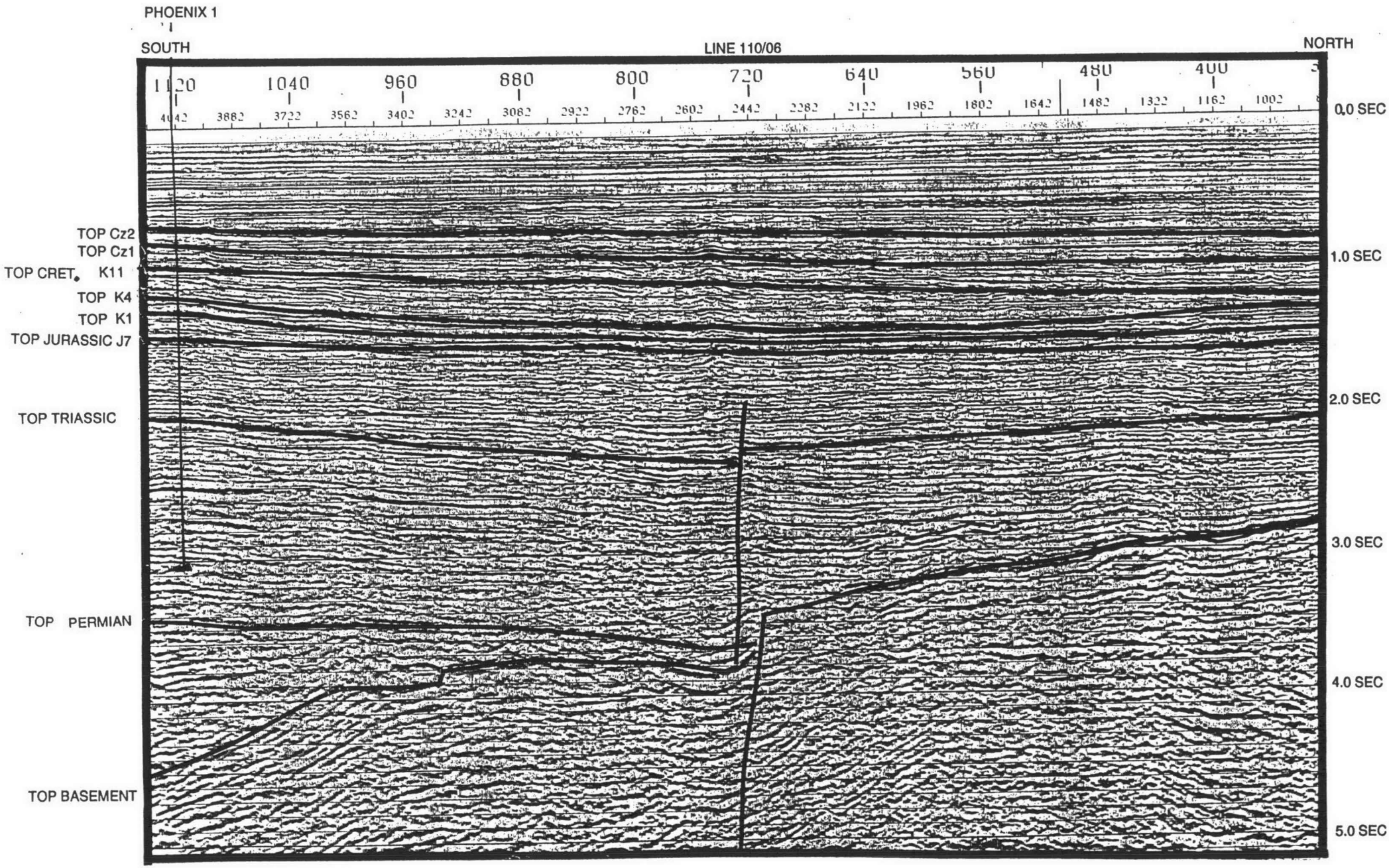

FIGURE 28: SEISMIC REPRESENTATION OF WEST BEDOUT SUB-BASIN & MIDDLE CRETACEOUS UNCONFORMITIES, LINE 110/06.

THICKNESS VARIATIONS: (SEE ENCLOSURE 44).

Overall time slice K5 is very thin. Two wells penetrated this time slice. Bedout 1 intersected 9m and East Mermaid 1 intersected 11m. In some of the other wells time slice K5 is interpreted to be present as a condensed sequence. Thicknesses for time slice K6 range from 17m in Bedout 1 to 55m in Keraudren 1. Thicknesses for time slice K7 range from 2m in Picard 1 to 188m in Keraudren 1. Regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 45).

Time slice K5: Globally this time slice is characterised by an intermediate to maximum relative sea level. Within time slice K5 there is one global eustatic sea level drop (Haq et al, 1987). The base of time slice K5 is coincident with a major relative sea level drop. The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply the start of a regression. However within the module area the coastline is interpreted to be at a low stand throughout time slice K5.

Time slice K6: Globally this time slice is characterised by an intermediate to maximum relative sea level. Within time slice K6 there are three global eustatic sea level drops (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply the continuation of a regression that started towards the base of time slice K5. However within the module area the coastline is interpreted to have started transgressing during the later part of time slice K6.

Time slice K7: Globally this time slice is characterised by a relative sea level high with two global minor eustatic sea level drops present (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply the continuation of a regression that started towards the base of time slice K5. Within the module area the coastline is interpreted to have transgressed during time slice K7. Middle to outer shelf, slope and base of slope environments are recognised. The shoreline position is very poorly constrained but is thought likely to be parallel to the present. The lack of abundant planktonic foraminifera in the sediments of this interval implies restricted oceanic circulation.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 45).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, 6200km of mapped seismic data, palaeogeographic interpretations from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

Enclosure 45 reveals that:

- overall, the area was a restricted to open marine starved shelf with slope deposition associated with margin sag. Significant sedimentation did not occur until time slice K7 when Greater India finally cleared Australia and significant margin sag commenced. The shelf edge trended approximately parallel to the current orientation. Clastic input shoreward of the recognised shelf area is possible but has not been clearly recognised,
- time slice K5-K7 was a time of low or nondeposition, although time slice K7 had significant proximal marine sedimentation. Land was present west of the present coastline,
- evidence of downlap for time slices K5 and K6 is seen on line 120/03 to the north of East Mermaid 1, but cannot be reliably mapped. The location of the continental shelf break is based mainly on palaeogeographic interpretations from wells, whilst the onlap edges to the southeast are based on seismic.
- sediments of this age have been recovered in ODP site 765 on the Argo Abyssal Plain (Kaminski, A.M., et al, 1992). Time slice K5-7 is therefore interpreted to be present as a condensed sequence beyond the mapped seismic downlap edge, out to the continental-ocean boundary and beyond,
- the cut and fill feature, in the eastern Outer Rowley Sub-basin, generated during the base time slice K5 lowstand, is still be an active landform during time slices K5-K7 (Figure 27). It was continuously filled with time slice K5-K10 sediments, and
- No time slices K5-K7 are interpreted in Bruce 1 and Poissonnier 1. This implies that:

  - time slices K5-K7 sediments were not deposited on the Bruce Terrace, because the terrace lay beyond a major basinal margin fault, or

  - time slices K5-K7 sediments were deposited on the Bruce Terrace as a substantial unit or condensed sequence and later removed, sometime between time slices K5-K9. There is regional evidence showing localised structural movements during time slices K8-K9, although the evidence is not substantial

enough to conclude a regional event (see Enclosure 2). This erosion may have taken place during late time slice K8, as this is also the time of the Australian-Antarctic breakup, when regional plate readjustments were occurring.

GEOCHEMISTRY (TOC, HI, S2 AND Vr):

No high quality source rocks have yet been detected in the time slice K5-K7 interval.

SHOWS, POROSITY & PERMEABILITY:

No shows have been detected and no porosity or permeability data exists.

PROSPECTIVITY: (SEE ENCLOSURE 3).

- The Pender and Jurgurra Terraces did not have any time slices K5-K7 sedimentation and hence cannot be expected to be prospective.
- Oil and gas prone source rocks are present in the West Bedout Sub-basin but are unlikely to be mature anywhere within the module area.
- Some reservoir potential has been identified within the west Bedout Sub-basin. The sands are however thin and cannot be substantiated as an exploration target at present.
- Time slice K7 is a regional seal for the Bedout and Inner Rowley Sub-basins, and Bedout High and a local seal for the Beagle and Cossigny Troughs and west Bedout Sub-basin. Time slice K6 is condensed or not deposited in the west Bedout Sub-basin and Bedout High. Time slice K6 regional seals are found within the Inner Rowley Sub-basin and Cossigny Trough whilst local seals are interpreted for the Beagle Trough and Bedout Sub-basin. Time slice K5 is interpreted only in the Inner Rowley Sub-basin where it is a regional seal.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- A play exists in the **west Bedout Sub-basin** where time slice K7 reservoirs may be sourced by Lower Triassic source and sealed by Upper Cretaceous regional seals.
- The incised valley fill with cut and fill internal facies patterns in the **east Rowley Sub-basin** may have hydrocarbon potential. The feature would form a large scale stratigraphic trap if there is enough sand content. Similar landforms may also be present elsewhere in the module area.

TIME SLICE K8:

LATE ALBIAN TO CENOMANIAN (99.0 - 91.0 Ma).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

A potential time for the migration of hydrocarbons. Time slice K8 coincides with the onset of extension and breakup along the southern margins.

FORMATION SYNONYMS: (FIGURE 2).

- The Haycock Marl and an unnamed siltstone unit, interpreted as diachronous, are present in the Beagle Sub-basin (Blevin et al, 1994).
- The formations are as yet unnamed in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

This time slice is biostratigraphically defined by the *C2*, *C3a* and *C3b* foram zones and it approximates the *D.multispinum*, upper *X.asperatus* and *P.infusoroides* dinoflagellate zone and the *A.distocarinatus* spore-pollen zone. During this time slice the sea retreated from the centre of the continent, but there was a rise in relative sea level on the western margin.

PALAEONTOLOGY:(SEE ENCLOSURES 2, 4-7, APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *C2*(B3), *D.multispinum* (B5),
- Depuch 1: *C2*(B2), *C3*(B3, D3),
- East Mermaid 1: *C2*(D2), *C3*(B2),
- Jarman 1: *C2*(B3), *C3*(B2, B3),
- Keraudren 1: *D.multispinum*(B3),
- Lagrange 1, Phoenix 2 & Trafalgar 1: no palaeontological control,
- Minilya 1: *C2*(D3), *C3*(D3),
- Phoenix 1: *C3*(D3), *D.multispinum*, and
- Picard 1: *C1*(B5), *C3*(D3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Greater India previously drifting west relative to the Australian continent commenced its northward drift during Late time slice K8 to Early time slice K9. The Antarctic-Australian Plate breakup was initiated on the southern margins during the same time. These events may be reflected in some of the wells in the module area where there is evidence of localised unconformities mainly at the top of the time slice, but also in the middle (Enclosure 2). Time slice K8 is a transgressive time slice with open marine inner shelf and slope environments interpreted. Lithology's range from claystone, calcilutite and marl with secondary bioclastic sediments, siltstone and dolomite. This time slice is much less calcareous than time slice K9. The North Turtle Wrench Zone and Bruce Terrace areas may not have received sediments or the sediments may have been reworked. Time slice K8 is a regional seal with the exception of the offshore Canning Basin where it was not deposited.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

The Australian continent has similar morphology to the present day continent following the breakoff of Antarctica during late time slice K8 (Baillie et al, 1994) to early time slice K9 (Veevers et al, 1991, p 379). Time slices K8 and K9 coincide with the initiation of a continent wide subsiding continental margin. This caused a significant deepening of the water on the margin and resulted in a greater portion of the shelf being outer shelf. General clastic starvation resulted in prograding carbonate wedges forming the shelfs. India commences its northward drift at approximately this time.

Local

Following the Valanginian breakup there were numerous graben and horst structures formed that were still remnant at this time. It is not possible to map all these features from the available seismic although their presence can be inferred during time slices K8. In particular continental shelf fracture zones in the location of the Swan Canyon and the canyon between the Echidna and Emu Spurs developed into grabens towards the continental margin (eg the Thouin Graben). These grabens may have acted as feeder channels for deeper water sedimentation, such as turbidites, slumps and gravity flows.

As well a few cut and fill features, or equivalents that have scoured the underlying formations, have been interpreted in the Bedout Sub-basin.

In the Dampier Sub-basin, unconformities ranging from time slice K8 to lower time slice K10 have been identified in about half of the wells. Ages for these are not consistent and it is thought likely that the unconformities reflect localised structural movements or are eustatically controlled. Some authors have postulated these unconformities to be either the result of Southern Margins Antarctic breakup or movements within the Australian-Asian Plates.

note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Smooth gamma ray log patterns were encountered in Bedout 1, Depuch 1, East Mermaid 1, Jarman 1 and Minilya 1 whilst moderate to mild serrated patterns are present in Keraudren 1, Lagrange 1, Phoenix 1 and 2, Picard 1 and Trafalgar 1. The latter has a claystone lithology.

Beagle Trough: The lithology in Depuch 1 is calcilutite with minor marl. Lithology's for Picard 1 include marl at the base overlain by claystone.

Cossigny Trough: The lithology in Jarman 1 is dominantly marl containing glauconite with secondary claystone and calcilutite. Trafalgar 1 comprises marl with interbedded to intergradational calcareous claystone with minor claystone with siltstone laminae, sandstone and thin dolomite streaks.

West Bedout Sub-basin: The lithology in Phoenix 1 and 2 is claystone. Minilya 1 lithology's include claystone and marl.

Bedout Sub-basin: The claystone in Keraudren 1 is calcareous in part, with trace of glauconite, *Inoceramus* and pelecyopod fragments.

Bedout High: Bedout 1 comprises calcareous olive grey to olive black claystone with trace of glauconite.

Rowley Sub-basin: The lithology in East Mermaid 1 has a medium grey claystone, fossiliferous with forams and cephalopods, calcareous in part with a bed of partly dolomitic lime wackestone.

THICKNESS VARIATIONS: (SEE ENCLOSURE 46).

Thicknesses range from 14m in Lagrange 1 to 55m in Depuch 1. These thicknesses may not be representative of the module area due to the poor well and seismic control however regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 47).

Globally time slice K8 was characterised by a maximum relative sea level. Within time slice K8 there are six minor global eustatic sea level drops (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply the continuation of a regression that started towards the base of time slice K5. In the module area, the coastline is interpreted to have transgressed slightly during time slice K8, although this cannot be substantiated from the seismic due to poor resolution.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 47).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, palaeogeographic interpretations from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

The following deductions shown on enclosure 47 are that:

- time slice K8 has a downlap edge located on the outer continental slope. The deposition of time slice K8 in the western Outer Rowley Sub-basin was influenced by the Thouin Graben, as the downlap edge is skewed against the western fault that bounds this graben,
- time slice K8 is interpreted to be present as a condensed sequence up to the continental-ocean boundary and beyond. The presence of this time slice on the Argo Abyssal Plain is verified from the sediments recovered in ODP 765 (Kaminski et al, 1992),
- no time slice K8 has been recovered from Bruce 1, Poissonnier 1 and North Turtle 1 suggesting that either time slice K8:

-was not deposited on the North Turtle Wrench Zone (Terrace) and Bruce Terrace but was deposited in the Beagle and Cossigny Troughs, or

-was deposited on the North Turtle Wrench Zone (Terrace) and Bruce Terrace as either a substantial unit or condensed sequence but later eroded, sometime between upper time slice K8 and lower time slice K9.

There is regional evidence of localised structural movements within time slices K8 and K9, although the evidence is not strong enough to establish a regional event (see Enclosure 2). However time slice K8 is the time of the Australian-Antarctic breakup and a high level of plate readjustments is expected, or

-the preferred interpretation is that time slice K8 was deposited on the North Turtle Wrench Zone(Terrace) and later eroded but was never deposited on the Bruce Terrace, beyond the main basin bounding fault. Time slice K8 was deposited in the Beagle and Cossigny Troughs, and

- the cut and fill feature in the eastern Outer Rowley Sub-basin, generated during the base time slice K5 lowstand, is still an active feature during time slice K8. It has been continuously filling with sediment since time slices K5.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI >150, TOC > 1.0% or 100<HI<150, TOC > 0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. Three analyses meet the selection criteria and established 2%<TOC<9.8%, 3.06<S2<47.1, 153<HI<479 and 417<Tmax<430, indicating an immature oil and gas prone source of fair to very good generative potential.

SHOWS, POROSITY & PERMEABILITY:

No shows have been detected and no porosity or permeability data exist.

PROSPECTIVITY: (SEE ENCLOSURE 3).

- The Pender and Jurgurra Terraces did not receive any time slice K8 sedimentation and is not prospective for this time slice.
- An oil and gas prone source rock is present in the West Bedout Sub-basin but is unlikely to be mature anywhere within the module area.
- No potential reservoirs have been identified within the module area. Time slice K8 is however a regional seal for the west Bedout and Bedout Sub-Basins, Bedout High and Inner Rowley Sub-basin but a local seal for the Beagle and Cossigny Troughs.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- Short lived marine lowstands may have resulted in incised valley fills that could provide sealed reservoir. Although theoretically possible, no incised valley fill features of this age have been recognised in this study.
- The incised valley fill, with cut and fill internal facies patterns, in the east Rowley Sub-basin may have hydrocarbon potential. The feature could form a large scale stratigraphic trap if there is enough sand content. Similar landforms may also be present elsewhere in the module area.

TIME SLICE K9:

LATE CENOMANIAN, TURONIAN, CONIACIAN AND LATE SANTONIAN (91.0 - 83.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

Time slice K9 appears to be a time of fault reactivation across the North West Shelf. This may be a time of significant migration of hydrocarbon from deeper mature source or accumulations into shallower traps.

FORMATION SYNONYMS: (FIGURE 2).

- The Haycock Marl is separated unconformably from the younger, Toolonga Calcilutite in the Beagle Sub-basin (Blevin et al, 1994).
- Unnamed units are separated unconformably from the younger Toolonga Calcilutite in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

The time slice is biostratigraphically defined by the *C4* to *C8* foram zones, the *P.mawsonii* and *T.apoxyexinus* spore-pollen zones, and approximates the *P.infusorioides* to *I.cretaceum* dinoflagellate zones.

PALAEONTOLOGY: (SEE ENCLOSURE 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and confidence ratings for the identified species zones (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *C5*(B4, D5), *C6*(B2), *C7*(B2), *C8*(B2),
- Bruce 1: *C6*(B3), *C7*(D3), *N.aceras*(B5), *C.striatoconus*(D4),
- Depuch 1: *C4*(B3), *C5*(B5), *C6*(B2, B5), *C7*(B3), *C8*(D3),
- East Mermaid 1: *C6*(D3), *C7*(D3), *C8*(B3, D2),
- Jarman 1: *C4*(D3), *C5*(B3), *C6*(D2), *C7*(D3), *C8*(D5), *P.infusoriodes*(B3),
- Keraudren 1: *C8*(B2),
- Lacepede 1A: *C.striatoconus*(B3),
- Lagrange 1, Phoenix 2 Trafalgar 1, Wamac 1: no palaeontological control,
- Minilya 1: *C5*(B3), *C6*(B3), *C8*(B3),
- North Turtle 1: *C7*(D5), *C8*(D5),
- Phoenix 1: *C5*(D4), *C6*(D3), *C8*(B3), *C.striatoconus*(B5),
- Picard 1: *C4*(D3), *C5*(D3, D5), *C6*(D3), *C7*(D3), *C8*(D3),
- Poissonnier 1: *C4*(B1), *C5*(B5), *C6*(B2), *C7*(B2/B3), *C8*(B3), *C.striatoconus*(B5),
- Ronsard 1: *C6*(B2), *C7*(B2), *C8*(D3, B2).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Regionally the area was part of a subsiding continental margin. The southern margins breakup occurred in late time slice K8 to early time slice K9 and Greater India started drifting north (Veevers et al, 1991, p 379). This is reflected in some of the wells where evidence of localised unconformities occurs, mainly at the base of the time slice but also in the middle (Appendix 3). Time slice K9 was a marine regressive unit with open marine and continental slope environments interpreted. Lithology's range from claystones, marl, calcilutite, calcisiltite and limestone with secondary dolomite and bioclastic sediments. This time slice is more calcareous than time slice K8. Time slice K9 is a seal unit for the bulk of the module area with the exception of the Offshore Canning Basin where it is only locally deposited.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 2).

Regional

The Australian continent was, following the breakoff of Antarctica during late time slice K8 to early time slice K9, similar in morphology to the present day continent (Baillie et al, 1994). Time slices K8 to K9 coincide with the initiation of a continent wide subsiding continental margin. Consequently a greater portion of the shelf became outer shelf, with deeper water, that accumulated prograding carbonate wedges. Subduction of the Australian Plate beneath the South East Asian Plate may have commenced in the Timor Trough area (Howell, 1988).

Local

Following the Valanginian breakup there were numerous graben and horst structures formed that were still remnant at this time. It is not possible to map all these features from the available seismic although their

presence can be inferred during time slices K9. In particular continental shelf fracture zones developed into grabens towards the continental margin (eg the Thouin Graben). These grabens may have acted as feeder channels for deeper water sedimentation, such as turbidites and slump and gravity flows.

In the Dampier Sub-basin, time slice K9 is a time of tectonic activity, possibly as a result of right lateral wrenching along the basin margins. It is also the time of reactivation of the Lowendal Fault (Howell 1988) and South Pepper Faults (William & Poynton, 1985).

note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

Cossigny Trough: Trafalgar 1 gamma ray log patterns have a large scale serrated funnel at the base. The lithology there comprises interbedded to intergradational calcareous claystone, minor claystone and siltstone lamina and sandstone with thin dolomite streaks. A massive gamma ray log half bell pattern is found at the top (calcilutite). Jarman 1 gamma ray log patterns include a serrated half bell pattern. Jarman 1 lithology's include calcilutite, calcisiltite with trace of forams and marl with claystone towards the base with trace of glauconite. Ronsard 1 gamma ray log patterns include mild serrated funnels (calcilutite).

Beagle Trough: Picard 1 gamma ray log patterns are mildly serrated. The lithology comprises claystone at the base and calcilutite at the top. The gamma ray log pattern in Depuch 1 consists of a half smooth funnel whilst North Turtle 1 has a mild serrated pattern. Both wells have a calcilutite lithology. Bruce 1 gamma ray log patterns is serrated (calcilutite) whilst Poissonnier 1 is serrated with smooth half bells (calcilutite).

West Bedout Sub-basin: Minilya 1 gamma ray log patterns include a smooth cylinder (calcilutite and marl). The gamma ray log pattern in Phoenix 1 is mildly serrated and consists of funnels (interbedded calcilutite and claystone) whilst Phoenix 2 has serrated patterns (silty limestone and claystone).

Bedout Sub-basin: Gamma ray log patterns in Keraudren 1 are serrated at the base (claystone) whilst half funnel patterns are found towards the middle and top (marl). Traces of forams and pelecyopod fragments are found at the base.

Bedout High: Bedout 1 gamma ray log patterns comprise a smooth cylinder pattern (calcilutite and marl). Lagrange 1 has mild serrated bells gamma ray log patterns. The lithology consists of limestone overlain by dolomite and than mudstone.

Rowley Sub-basin: East Mermaid 1 gamma ray log patterns comprise serrated funnels. Lime mudstones grade to bioclastic packstone-grainstone with forams also being identified.

Offshore Fitzroy Trough: Lacepede 1A lithology's comprise argillaceous siltstone with some glauconite present.

THICKNESS VARIATIONS: (SEE ENCLOSURE 48).

Thickness ranges from 13m in Trafalgar 1 to 121m in North Turtle 1. These thicknesses may not be representative of the module area due to the poor well and seismic control however regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 49).

Globally this time slice is characterised by a maximum relative sea level. There are six minor global eustatic sea level drops within time slice K9 (Haq et al 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply the continuation of a regression that started towards the base of time slice K5. The coastline is interpreted to have regressed during time slices K9. Open marine continental shelf and slope environments are interpreted.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 49).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, the known absence of time slice K9 rocks in the onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

Note that:

- there is evidence from seismic of time slice K9 downlap just to the north of Minilya 1. This may imply a local palaeogeographic feature such as a slope fan or delta toe,
- time slice K9 is interpreted to be present as a condensed sequence up to the continental-ocean boundary and beyond. The presence of this time slice on the Argo Abyssal Plain is verified from the sediments recovered in ODP 765 (Kaminski, et al, 1992). The cut and fill feature in the eastern Outer Rowley Sub-

basin, initiated during the base time slice K5 lowstand, has been continuously filling with sediment since time slice K5. It is still an active landform during time slice K9.

GEOCHEMISTRY (TOC, HI AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI >150, TOC > 1.0% or 100<HI<150, TOC > 0.5% and S2>5. The one analysis meeting the selection criteria shows, TOC = 3.3%, S2= 9.7, HI = 294 and VR = 0.35. This is an oil and gas prone immature source with good generative potential.

SHOWS, POROSITY & PERMEABILITY: (SEE APPENDIX 4).

Gas indications were recorded in Poissonnier 1 and North Turtle 1. In Poissonnier 1, the only well with available porosity data, porosity ranges from 35% to 40% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Time slice K9 is a regional seal for the Cossigny and Beagle Troughs, west Bedout Sub-basin and Bedout High and a local seal for the Bedout and Inner Rowley Sub-basins and the Offshore Fitzroy Trough. An oil and gas prone source rock is present in the West Bedout Sub-basin but is unlikely to be mature anywhere within the module area. No definite reservoirs have as yet been identified for this time slice. Time Slice K9 is considered to be of low prospectivity as it requires migration of deeper sourced hydrocarbons to supply unverified reservoirs.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- Short lived marine lowstands may have resulted in incised valley fills that could provide sealed reservoir. Although theoretically possible, no incised valley fill features of this age have been recognised in this study.
- The incised valley, with cut and fill internal facies patterns, in the east Rowley Sub-basin may have potential. The feature couid form a large scale stratigraphic trap if there is enough sand content. Similar landforms may be present elsewhere in the module area.

TIME SLICE K10:

LATE SANTONIAN & CAMPANIAN TO EARLY MAASTRICHTIAN (83.0 - 70.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

A regional generally thin carbonate dominated seal facies over most of module area. Everywhere immature.

FORMATION SYNONYMS: (FIGURE 2).

- The Toolonga Calcilutite is unconformably overlain by the Withnell Formation, both are present in the Beagle Sub-basin (Blevin et al, 1994).
- The Toolonga Calcilutite is overlain by the Miria Formation, both are present in the Offshore Canning and Roebuck Basins (Colwell & Stagg, 1994).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice K10 is biostratigraphically defined by the *C9* to *C11* foram zones, the *N.senectus* and *T.lilliei* spore-pollen zones, and approximates the *N.aceras* to *I.korojonense* dinoflagellate zones. The top of the time slice is marked with breaks in both the foram and dinoflagellate zones. It corresponds to the commencement of sea floor spreading in the Tasman Sea.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slice. The following list summarises the palaeontological control and confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1: *C9*(B2), *C10*(B3), *C11*(B3),
- Bruce 1/Lagrange 1/Phoenix 2: Trafalgar 1: no palaeontological control,
- Depuch 1: *C10*(D5/B3),
- East Mermaid 1: *C9*(B5, D5), *C10*(B4), *C11*(B5),
- Jarman 1: *C9*(D2, D5), *C10*(D3/D5), *C11*(B5),
- Keraudren 1: *C9*(D5), *C10*(B4), *C11*(D3),
- Minilya 1: *C9*(B3/D4), *C10*(B3/B4),
- North Turtle 1: *C9*(D3), *C10*(D5), *C11*(D5),
- Phoenix 1: *C9*(B2/B4/D3), *C10*(B2/D5), *C11*(B2/D3),
- Picard 1: *C9*(B2), *C10*(D3), *C11*(D2/D3),
- Poissonnier 1: *C9*(B3/B5), *C10*(B3), *C11*(B3), and
- Ronsard 1: *C9*(B3/D3).

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Regionally, the Australian Plate is subducting under the Timor Trough, as Australia drifts north from Antarctica in response to sea floor spreading along the southern margins. The top of time slice K10 is bounded by a regional unconformity in the module area, this unconformity is also evidenced on the age-depth plots of some of the wells including Bedout 1, Depuch 1, Jarman 1, Minilya 1, North Turtle 1, Phoenix 1, Picard 1 and Ronsard 1 (Appendix 3). The age-depth plots also show evidence for higher depositional rates in Depuch 1, Keraudren 1, Jarman 1, Phoenix 1 and Picard 1. A relative sea level rise during time slice K10 is inferred from the inland distribution of sediments. The lithology's are dominantly claystone, calcilutite, marl and limestone with secondary sandstone and siltstone. Open marine shelf and slope environments are interpreted for this time slice and some shelf incision has occurred. Poorly developed reefs and offshore bars are present. In summary, time slice K10 is a regional seal for the bulk of the module area with the exceptions of the Offshore Canning Basin where it was not deposited.

TECTONICS: (SEE ENCLOSURES 1, 3 & FIGURE 3).

Regional

Subduction is occurring in the Timor Trough area as the Australian plate drifts north.

Local

Following the Valanginian breakup there were numerous graben and horst structures formed that were still remnant at this time. It is not possible to map all these features from the available seismic although their presence can be inferred during time slices K10. They are however expected to be more subdued than in time slice K2. In particular onshore fracture zones developed into grabens towards the continental margin

(eg the Thouin Graben). These grabens may have acted as feeder channels for deeper water sedimentation, such as turbidites, slumps and gravity flows.

Note: Please refer also to comments in the local tectonics section of time slice K11.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

Cossigny Trough: Jarman 1 gamma ray log patterns comprise a serrated mild bell (claystone). Jarman 1 claystones are olive black with abundant *Inoceramus* and secondary marl, with trace of dolomite at the base. Trafalgar 1 has a bell shaped gamma ray log signature at the base. The lithology comprises marl, interbedded calcareous claystone with minor argillaceous calcilutite and thin dolomite streaks. The gamma ray log pattern is mildly serrated. Claystone is found at the top with rare siltstone and bioclastic calcilutite. Ronsard 1 has a serrated gamma ray log pattern. The lithology is claystone being calcareous in part with fragments of *Inoceramus* and interbeds of marl.

Beagle Trough: Picard 1 gamma ray log patterns comprise a bell shaped pattern at the base (calcilutite overlain by marl), that is overlain by a serrated gamma ray log pattern (claystone with marl at top). Gamma ray log patterns in Depuch 1 includes a half funnel at the base, overlain by a serrated pattern (calcilutite grading to marl and claystone). North Turtle 1 has a mild serrated gamma ray log pattern (calcilutite with minor claystone). The gamma ray log patterns in Poissonnier 1 are smooth half bells (calcilutite). Bruce 1 lithology is uncertain due to a lack of recovered drill cuttings in this time slice.

West Bedout Sub-basin: Minilya 1 has a serrated gamma ray log pattern. The lithology comprises claystone and sandstone with occasional marl. Phoenix 1 gamma ray log signature includes a smooth to mild serrated large scale bell at the base and middle. The dominant calcilutite lithology is overlain by interbedded calcisiltite and claystones. Phoenix 2 gamma ray log signature is a smooth bell at the base (limestone and claystone) overlain by a continuous serrated pattern (fossiliferous claystone).

Bedout Sub-basin: Keraudren 1 gamma ray log patterns include a basal smooth half funnel and an upper serrated pattern. The lithology comprises calcilutite at the base with siltstone and secondary claystone in the middle and top.

Bedout High: Bedout 1 has interbedded claystone and marl. The claystone in Bedout 1 is calcareous, yellowish brown with *Inoceramus* prisms and shell fragments. Lagrange 1 has a mudstone base with fossiliferous units towards the top.

Rowley Sub-basin: gamma ray log patterns in East Mermaid 1 include mainly a smooth lime mudstone lithology with lime mudstone and claystone funnels. The lime mudstone is fossiliferous with forams grading to bioclastic lime packstone-grainstone.

THICKNESS VARIATIONS: (SEE ENCLOSURE 50).

Thicknesses range from 38m in Depuch 1 to 269m in Trafalgar 1. Regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 51).

Globally time slice K10 is characterised by a maximum relative sea level. Six global relative sea level drops occur within time slice K10 (Haq et al, 1987). Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply the continuation of a regression that started towards the base of time slice K5. The coastline is interpreted to have transgressed in the module area. Open marine continental shelf and slope environments are interpreted.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 51).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, the known absence of time slice K10 rocks from onshore Canning Basin wells and outcrop (BMR, 1981) and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

Important points to note from Enclosure 51 are that:

- there is a fully open oceanic circulation system. There is a relatively rapid continental margin sag occurring, with outer continental shelf and continental slope environments recognised. The continental shelf break is oriented approximately parallel to the present day coastline. Because the interior continent was peneplained, only minor clastic deposition occurred onshore resulting in a clastic starved, carbonate dominated offshore environment,
- the Australian continent is at about the same latitude as it was in the previous time slice,

- the location of the continental shelf break is based solely on palaeogeographic interpretations whilst the onlap edges to the southeast are based from seismic,
- sediments of this age have been recovered in ODP site 765 on the Argo Abyssal Plain (Kaminski et al, 1992). Time slice K10 is therefore interpreted to be present as a condensed sequence beyond the mapped seismic downlap edge, out to the continental-ocean boundary and beyond, and
- the cut and fill feature in the eastern Outer Rowley Sub-basin initiated during the base time slice K5 lowstand has been continuously filling with sediment since time slices K5. It is still an active landform during time slice K10.

GEOCHEMISTRY (TOC, HI, S2 AND Vr): (SEE APPENDIX 5).

Appendix 5 part 2 summarises the best Rock-Eval results for the module area. Two sets of criteria were used to define source rocks, either HI >150, TOC > 1.0% or 100<HI<150, TOC > 0.5% and S2>5. There are only a few values of TOC where 0.5%<TOC<1.0%, the bulk of the values being > 1.0%. The three analyses meeting these criteria revealed 1.31%<TOC<1.43%, 2.54<S2<3.3, 194<HI<235 and Tmax 426 and 432. This is a light oil and gas prone immature source with fair generative potential.

SHOWS, POROSITY & PERMEABILITY:

No shows have been detected and no porosity or permeability data exist.

PROSPECTIVITY: (SEE ENCLOSURE 3).

- Time slice K10 is a regional seal for the Cossigny and Beagle Troughs, west Bedout, Bedout and Inner Rowley Sub-basins, Bedout High but is a local seal for the Offshore Fitzroy Trough.
- Although potential gas source rocks exist in the Cossigny Trough and oil and gas source rocks exist in the Beagle Trough, west Bedout and Bedout Sub-basins these sources are unlikely to be mature anywhere within the module area.
- No reservoirs have been recognised within this time slice.
- Time slice K10 is considered to have low prospectivity.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

- Short lived marine lowstands may have resulted in incised valley fills that could provide sealed reservoir. Although theorectically possible, no incised valley fill features of this age have been recognised in this study.
- The incised valley fill, with cut and fill internal facies patterns, in the east Rowley Sub-basin may have hydrocarbon potential. The feature could form a large scale stratigraphic trap if there is enough sand content. Similar landforms may also be present elsewhere in the module area.

Note: Any plays also require access to migrating hydrocarbons generated deeper in the section.

TIME SLICE K11:

UPPER CRETACEOUS: MIDDLE TO LATE MAASTRICHTIAN (70.0 - 65.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

This time slice has some minor reservoir potential, but is nowhere mature, irrespective of any minor source potential. It acts, for the most part, as a thin discontinuous carbonate seal facies.

FORMATION SYNONYMS: (FIGURE 2).

- The Miria Marl is present in the Beagle Sub-basin (Blevin et al, 1994).
- The Miria Formation is present in the Offshore Canning and Roebuck Basins. Although Colwell & Stagg (1994) interpreted time slice K11 to be absent due to erosion, it has been shown to be present from work done in this module.

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

Time slice K11 is biostratigraphically defined by the *C12* and *C13* foram zones, the *M.druggii* dinoflagellate zone and the *T.longus* spore-pollen zone. Its top represents the Mesozoic - Tertiary boundary.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with poorly controlled faunal zones to define the time slices. The following list summarises the palaeontological control and species zone confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1 & Depuch 1:	*C13*(B3),
- East Mermaid 1:	*C12*(B4), *Isabelidinium Sz*(B3),
- Jarman 1:	*C12*(D4), *C13*(B2),
- Keraudren 1, Lagrange 1 & Phoenix 2 Trafalgar 1:	no palaeontological control,
- Minilya 1:	*C12*(B4), *C13*(B2),
- Phoenix 1:	*C13*(D2), and
- Ronsard 1:	*C13*(B1, B5),

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

Subduction of the northern margin of the Australian Plate occurred in the Timor Trough area. Time slice K11 is interpreted to be bounded at the top and base by regional unconformities (Enclosure 2). These unconformities are substantiated from the age-depth plots of Bedout 1, Depuch 1, Jarman 1, Minilya 1, North Turtle 1, Phoenix 1, Picard 1 and Ronsard 1(Appendix 3). Time slice K11 sedimentation rates were low and the time slice is relatively thin or condensed. Time slice K11 corresponds to a marine highstand. Carbonate sediments were deposited in starved continental shelf and slope environments. Lithology's include marl, limestone, claystone, calcilutite and calcarenite with some fossiliferous beds within the limestone units. Time slice K11 is a regional seal and is not considered to have play potential.

TECTONICS:(SEE ENCLOSURES 1, 3, 63, 64 & FIGURE 3).

Regional

The Australian Plate was drifting north. Subduction was occurring in the Timor Trough area.

Local

Seismic mapping provides the basis for interpreting the gross architecture of the Cretaceous.

The Top Cretaceous TWT Structure Contour Map (Enclosure 64) shows:

- a NW-SE relatively uniform structural gradient with the top Cretaceous shallowing towards the southeast,
- older topographic highs that are still acting as structural hinge zones. Examples include the Bedout High and the Pender Terrace, and
- the deepening of the TWT Structure in the Outer Beagle Platform where there is a structural low coincident with the Thouin Graben. The low merges into the present day Swan Canyon basinward.

The Top Cretaceous (Km) to Top Jurassic Breakup (Jc) TWT Isochron Map (Enclosure 63) shows:

- the influence of pre-Argoland breakup features on Late Jurassic, and or Cretaceous sedimentary deposits. In particular, the Kimberley and Pilbara Blocks, Broome Platform and Lambert Shelf were highs that were onlapped. The Offshore Fitzroy Trough, Bedout and eastern Inner Rowley Sub-basins, Cossigny and Beagle Troughs were Late Jurassic, and or Cretaceous depocenters. However areas within the Beagle Sub-basin are known to be influenced by erosional thinning during these times,

- a W-E trending thickness variation across a NNW-SSE trend in the Outer Rowley Sub-basin that coincides with the projection of an Argoland Abyssal Plain Transfer Fault onto the shelf. Across the NNW-SSE trend, the sediments thicken eastward into the Rowley Sub-basin. In the Rowley Sub-basin, the Late Jurassic-Cretaceous interval is more uniform than in the Beagle Sub-basin, where thins reflect a greater degree of uplift and erosion.

This thickness variation implies:

- the probability of the transfer fault extending onto the continental shelf,
- the influence of the transfer fault as a depositional hinge zone during the Late Jurassic, and or Lower Cretaceous,

- that the Cretaceous fill within the Beagle Trough and Outer Beagle Platform is thinner than the fill in the Offshore Fitzroy Trough and Bedout Sub-basin deeps. The thins in the Outer Beagle Platform reflect erosion from tectonic uplift during the Greater India breakup (Valanginian) and associated structural re-adjustments as well as depositional thinning in a distal setting, and
- that the thin in the Outer Rowley Sub-basin is due to the Cretaceous being downcut and therefore is a reflection of erosion rather than deposition.

The top Cretaceous basal Tertiary boundary is an unconformity, clearly defined on seismic by cut and fill features that are particularly prevalent in the Rowley and Beagle Sub-basins (see line 120/14 sp 2000-2250). This unconformity together with the associated structural re-adjustments has also been interpreted by Colwell and Stagg (1994).

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III)

Cossigny Trough: Ronsard 1 has a mild serrated gamma ray log pattern (dominantly marl and secondary claystone lithology's). Trafalgar 1 has a smooth funnel gamma ray log pattern (marl and calcareous claystone lithologies). Jarman 1 gamma ray log signatures are mild serrated. The lithology's are dominantly marl with secondary claystone and limestone.

Beagle Trough: Depuch 1 has a mild serrated gamma ray log pattern (calcilutite and marl lithology's).

West Bedout Sub-basin: Minilya 1 has a calcareous claystone base and a limestone top. The Phoenix wells have mild serrated gamma ray log patterns. The lithology in Phoenix 1 consisting of limestone and calcarenite whilst Phoenix 2 has dominant claystone with secondary limestone.

Bedout Sub-basin: Keraudren 1 section is all sandstone.

Bedout High: Bedout 1 has a mild serrated gamma ray log pattern (claystone) whilst Lagrange 1 has a serrated bell gamma ray log pattern at the base. The basal part includes fossiliferous limestone overlain by calcareous mudstone. The gamma ray log patterns include a serrated pattern. Claystone lithology in the middle grades to a siltstone and mudstone at top. The claystone in Bedout 1 is yellowish, brown to olive black, glauconitic with *inoceramus* prisms and trace shell fragments in the lower part. Thin beds of siltstone and minor calcilutite are also present.

Rowley Sub-basin: East Mermaid 1 lithology includes olive black claystone, calcareous beds, fossiliferous zones with forams and beds rich in *Inoceramus* valves.

THICKNESS VARIATIONS: (SEE ENCLOSURE 52).

Thicknesses range from 5m in Keraudren 1 to 221m in Bedout 1. Regional thicknesses are expected to have a similar order of magnitude.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURE 53).

Globally time slice K11 is characterised by a maximum relative sea level. Within time slice K11 there are two global relative sea level drops (Haq et al, 1987). Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) imply the continuation of a regression that started towards the base of time slice K5. The coastline is interpreted as having approximately the same location as it had during time slice K10, with the exception of the Broome Platform. On the Broome Platform the coastline may have transgressed further inland than it was in time slice K10. Open marine continental shelf and slope environments are interpreted, in an area starved of clastic sediments.

PALAEOGEOGRAPHY: (SEE ENCLOSURE 53).

The primary sources of information used to compile the palaeogeographic interpretations include all wells with interpreted time slice palaeogeography, the absence of time slice K11 onshore (BMR, 1981) and palaeogeography interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO (BMR), industry and university published work.

The following summarises the palaeogeography:

- This is a fully open oceanic circulation system, clastic starved, continental sag margin, with shelf and slope environments recognised. The continental margin is oriented approximately parallel to the present coastline. Carbonate deposition dominates, the interior continent being peneplained and low clastic deposition occurring onshore, locally if at all.
- The landmass interpreted in the present day offshore, is also partly substantiated by absence of time slice K11 in the more landward wells (Kambara 1, Minjin 1, Perindi 1, Pearl 1, Bruce 1, Poissonnier 1) as well as not being present onshore (BMR, 1981).
- Time slice K11 is interpreted to be present as a condensed sequence up to the continental-ocean boundary and beyond. The presence of this time slice on the Argoland Abyssal Plain is verified from the sediments recovered in ODP 765 (Kaminski, et al, 1992).
- The approximate location of the continental shelf break is based solely on palaeogeographic interpretations whilst the location of the onlap edge to the southeast is based from seismic.
- No time slice K11 is present in Bruce 1, Poissonnier 1, North Turtle 1, Cossigny 1 and Picard 1. All these wells lie within the same region implying a number of possibilities where time slice K11:

  -was not deposited on the Picard High, North Turtle Wrench Zone and Terrace and Bruce Terrace whilst being deposited in the Beagle Trough and Cossigny Trough, or

  -was deposited on the Picard High, North Turtle Wrench Zone and Terrace and Bruce Terrace as a substantial unit or condensed sequence and later removed during the basal Tertiary lowstand, or

  -was deposited on the Picard High, North Turtle Wrench Zone and Terrace and never deposited on the Bruce Terrace that lies beyond the main basin bounding fault. Either a substantial unit or condensed sequence was later removed from the Picard High and North Turtle Wrench Zone and Terrace during the basal Tertiary lowstand. This is the favoured option.

GEOCHEMISTRY (TOC, HI, S2 AND Vr):

No geochemistry data exists.

SHOWS, POROSITY & PERMEABILITY:

No shows have been detected and no porosity or permeability data exist.

PROSPECTIVITY: (SEE ENCLOSURE 3).

- It is interpreted that the Pender and Jurgurra Terraces including the landward end of the offshore Fitzroy Trough did not receive any time slice K11 sedimentation and hence cannot be expected to contribute any prospectivity elements.
- Time slice K11 is not considered to have source potential for any of the module areas as the time slice is everywhere immature.
- Time slice K11 is not considered to have reservoir potential in any of the module areas with the exception of the Bedout Sub-basin where some reservoir potential is present in Keraudren 1. Generally Keraudren 1 is sandier during time slices K11-CZ2 than other locations. Reservoir potential may be localised to the vicinity of the well but could also be more extensive within the Sub-basin. Migration from older source rocks up late stage faults of probable Mid-Miocene to Oligocene age would be required to source these reservoirs. At best one could expect intraformational seals of time slices CZ1 and CZ2 to seal time slice K11 reservoirs. This play is extremely high risk due to the thinness of the seals, their sandy nature in part and the relatively complicated migration pathway.
- Time slice K11 is a regional seal in the Cossigny Trough, West Bedout and Inner Rowley Sub-basins and Bedout High.
- Time slice K11 is thought to have poor prospectivity.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

The Top Cretaceous TWT Structure Contour Map (Enclosure 64) shows areas in the Bedout Sub-basin where contours are non parallel and have shallower gradients. These areas may potentially indicate topographic highs, where dip closed prospects could exist.

CAINOZOIC TIME SLICES Cz1 TO Cz7

CAINOZOIC: PALEOCENE TO RECENT (65.0 TO 0.0 MA).

PETROLEUM SYSTEM: WESTRALIAN 4 (ENCLOSURE 3).

The Tertiary is a significant part of the Westralian system. It is the time of major hydrocarbon generation and migration from the Westralian source rocks.

The Tertiary section is a prograding dominantly calcareous wedge that provides an axial load to further mature older source rocks. It dominantly acts as a seal but also has potential reservoir facies. These reservoirs need to be charged from older source rocks via faults. The Tertiary is also a time of significant margin sag due to sediment loading and subsidence. The north Australian Plate collision with Timor, from the Oligocene onwards, has resulted in numerous unconformities (Enclosure 2) and reactivated faults. Additionally, seaward tilting of earlier formed closures may have progressively spilt any previously accumulated hydrocarbons from the structure. In the Dampier Sub-basin similar age events caused reactivation of faults and growth on several features (Spencer et al, 1993). These movements may also be correlated with a second phase of significant oil migration from deeper sources.

FORMATION SYNONYMS:

Stratigraphy is undefined within the module area. The formations from the offshore Carnarvon Basin, to the southwest of the module area, include the Lambert, Dockrell, Wilcox, Walcott, Bare & Delambre Formations and Mandu and Trealla Limestones going from oldest to youngest (BMR, 1990).

REGIONAL DEFINITION OF TIME SLICE: (SEE ENCLOSURE 3).

TIME SLICE CZ1: CAINOZOIC: PALAEOCENE TO EARLY EOCENE. (65.0 TO 50.5 MA).

Biostratigraphically defined by foraminiferal Zones *T1* to middle *T10. T6* is generally considered to be absent and a time of submarine disconformity on the North West Shelf (Apthorpe 1988). The top is defined as the top of *P9* planktonic foraminiferal zone. This time slice is also associated with an cessation of rifting along the eastern margin, restricted marine conditions along the southern and western margin and widespread carbonaceous sedimentation.

TIME SLICE CZ2: CAINOZOIC: MIDDLE TO LATE EOCENE (50.5 TO 38.1 MA).

Biostratigraphically defined by foraminiferal Zones *P10* to *P17* and *T10* to *T14*. The top is defined as the middle of *P17* planktonic foraminiferal zone. This time slice is also associated with increased Australian and Antarctic spreading rate, major transgression along southern and western margin and widespread calcareous sedimentation.

TIME SLICE CZ3: CAINOZOIC: EARLY OLIGOCENE (38.1 TO 29.2 MA).

Biostratigraphically defined by foraminiferal Zones *P17* to *P21* and *T15* to *T17*. The top is defined as the boundary between *P21a* and *P21b* planktonic foraminiferal zones. There is an apparent paucity of continental deposition (except in the southeast), induration phenomena, widespread submarine erosion, and or non-deposition, ice development in Antarctica and strengthening of the circum-Antarctic current.

TIME SLICE CZ4: CAINOZOIC: LATE OLIGOCENE TO LATE MIDDLE MIOCENE (29.2 TO 11.9 MA).

Biostratigraphically defined by foraminiferal Zones *P21b* and *P22* and *T17* to *T20* and nannofossils zones *N4* to *N14*. The top is defined as the middle of nannofossil zone *N14*. This time slice is also associated with the resumption of continental deposition, highest Tertiary sea level, widespread carbonate deposition, reef development in northern Australia and collision with New Guinea (New Guinea Orogen).

TIME SLICE CZ5: CAINOZOIC: LATE MIOCENE (11.90 TO 5.1 MA).

Biostratigraphically defined by nannofossil zones *N14* to *N17*. The top is defined as the top of nannofossil zone *N17*. Continent wide regression and induration features on land are also features associated with this time slice.

TIME SLICE CZ6: CAINOZOIC: PLIOCENE (5.1 TO 2.0 MA).

Biostratigraphically defined by nannofossil zones *N18* to *N21*. The top is defined as the top of nannofossil zone *N21*. This time slice is also associated with a transgressive period, widespread sedimentation, collision with Banda Arc and Antarctic glaciation.

TIME SLICE CZ7: QUATERNARY: PLEISTOCENE (2.0 TO 0.0 MA).

Biostratigraphically defined by nannofossil zones *N22* and *N23*. The top is defined as 10kybp. This time slice is also associated with a major sea level rise and climatic fluctuations, development of the modern Great Barrier Reef and development of continental dune fields.

PALAEONTOLOGY: (SEE ENCLOSURES 2, 4-7; APPENDICES 1-2).

Log character was used in conjunction with the poorly controlled faunal zones to define the time slices. The following summarises the wells, time slices, palaeontological control and species zones confidence ratings (refer to introduction for description of confidence rating, page iii):

- Bedout 1(CZ1): *T1*(B3), *T4*(B3/B5), *T5*(D3), *T9*(B5),
- Bruce 1(CZ1), Keraudren 1(CZ1)
  Lagrange 1(CZ1), Trafalgar 1(CZ1)
  Bedout 1(CZ2), Keraudren 1(CZ2)
  Lagrange 1(CZ2), Phoenix 2(CZ2)
  Trafalgar 1(CZ2-CZ5): no palaeontological control,
- Depuch 1(CZ1): *T1*(D3), *T2*(B3), *T4*(D3), *T5*(D3), *T6*(D3), *T9*(D4),
- Depuch 1(CZ2): *T10*(B4), *T11*(B3), *T12*(B5), *T13*(B5), *T14*(B3),
- East Mermaid 1(CZ1): *T4*(B2), *T5*(B3), *T8*(B3), *T9*(B3),
- East Mermaid 1(CZ2): *T11*(B2), *T12*(B5),
- Jarman 1(CZ1): *T1*(B2), *T2*(D5), *T3*(D5), *T4*(D3), *T5*(D3), *T6*(D3), *T7*(D3), *T8*(D3), *T9*(D4), *T10*(D4),
- Jarman 1(CZ2): *T11*(D3), *T12*(F3),
- Jarman 1 (CZ3): *P18*(D2),
- Jarman 1 (CZ4): *L.badjiiaensis*(D3),
- Jarman 1 (CZ5): *N14*(D5), *N17*(D3),
- Minilya 1(CZ1): *T1*(B4), *T2*(B4), *T3*(B4), *T4/5*(B4), *T6*(D4/B4), *T9*(B4),
- Minilya 1(CZ2): *T11*(D4), *T12*(B4),
- North Turtle 1(CZ1): *T1*(D3), *T2*(D3), *T4*(D3), *T5*(D3), *T8*(D3),
- Phoenix 1(CZ1): *T1*(D3), *T2*(D3), *T3*(B3), *T4*(D3,D4), *T5*(D3,D4), *T6*(D3), *P6*(D3/D5), *T8*(D3), *P7*(D4), *T9*(D3), *P8*(D4), *P9*(D5),
- Phoenix 1(CZ2): *P12*(D3), *P14*(D4), *P15*(B4), *P16*(B5),
- Phoenix 2(CZ1): *T7*(D4),
- Picard 1(CZ1): *T3*(B2), *T4*(D3), *T5*(B2), *T6*(D2), *T8*(D3), *T9*(B4),
- Ronsard 1(CZ1): *T1*(B1), *T2*(B4), *T3*(B4), *T4*(B3), *T5*(D3), *T6*(D3,D5), *T8*(B3,D2), *T9*(B5),
- Ronsard 1(CZ2): *T13*(D3), *T14*(D2/D3),
- Ronsard 1(CZ3): *P18*(D3), *P19*(D3),
- Ronsard 1(CZ4): *N11*(B5), *P22*(D3), *L.badjiiaensis*(B2), *N5*(B3), and
- Ronsard 1(CZ5): *N16*(B5).

The palaeontological control after CZ2 is exceptionally poor or non existent and only a few wells have had time slices CZ3 - CZ6 defined.

ROEBUCK AND OFFSHORE CANNING BASINS - BEAGLE SUB-BASIN SUMMARY:

The tectonic regime during the Tertiary is a result of the collision of the Australian Plate with the South-East Asia Plate. The transferred stress, resulted in numerous unconformities and reactivation faulting. A carbonate-clastic wedge, trending NE-SW, prograded seaward in response to margin sag and clastic starvation.

Substantial time offsets on some of the age-depth plots (Bedout 1, Bruce 1, Depuch 1, East Mermaid 1, Jarman 1, Minilya 1, Phoenix 1, Picard 1 and Ronsard 1) clearly point to multiphase structural re-adjustment events throughout the Tertiary. Relative sea level changes are clearly evident from the presence of low stand sands, thin rich fossiliferous beds and shallow water dolomite deposition within dominant claystone, calcilutite to calcarenite lithology's. Sediment depositional rates were slow but continuous. Sediments were deposited in a continental shelf setting. Reefs probably grew near the continental shelf break. Shelf incision, due to sea level falls is evident in places. Nowhere is the Tertiary interpreted to be mature. Potential stratigraphic traps exist but require migration pathways, eg via faults, to link the older mature source rocks to the Tertiary reservoirs.

TECTONICS: (SEE ENCLOSURES 1, 3, 65 & FIGURE 3).

Regional

Tertiary tectonics are dominated by the collision and subduction of the Australian Plate with the South East Asian Plate in the area of Indonesia, Timor and New Guinea. The regional stresses have been transmitted through the Australian Plate with varied local responses in the module area. Climatically, Australia drifted northward into temperate and tropical waters. The Middle Eocene time slice CZ2 marks a change from moderate rates of shelf progradation to fairly rapid progradation. It is thought to reflect the intraplate reorganisation in the Indian Ocean and higher subsidence rates.

Local

The Tertiary TWT Isochron Map (Enclosure 65) shows:

- a thick orientated on a NE-SW axis that reflects the thicker parts of the sigmoids of the prograding Tertiary carbonate sequences. The sigmoids tail off both basinward and landward. Line 110/05 extends WNW from the Minilya 1 well across the Outer Beagle Platform and over the Thouin Graben. The portion of line 110/05 in Figure 18 shows the Tertiary prograding carbonate wedge, representing deposition on a passive submerging continental margin shelf,
- that the Tertiary has been deposited over the whole module area, although the presence of the Tertiary in the nearshore has not yet been substantiated,
- that some of the older topographic highs and lows are still acting as depositional hinges. Examples can be seen on the DeGrey Nose (Cossigny Trough), the western end of the Bedout Sub-basin, Bedout High, Fitzroy Trough and the Pender Terrace,
- mild evidence of the effect of Late Miocene-Oligocene tectonism. Uplift and possible wrenching is the probable cause of the thins in the northern flank of the Offshore Fitzroy Trough. The contour trend is seen to change from a NE-SW orientation to a N-S orientation and then resume NE-SW. A number of fault systems have been defined in the Offshore Fitzroy Trough, southern Browse Basin and Leveque Shelf (line 120/08 sp 2100-2800). These faults appear to have wrench affinities and help in defining the boundary between the Browse and Roebuck Basins within the upper Tertiary section,
- substantial thickening west of the Bedout Sub-basin in the Outer Beagle Platform. As well a higher contour gradient is present. The thicker section reflects a higher sedimentation rate and the higher contour gradient may reflect a steeper depositional slope, and or a possible response to a higher rate of submergence of the passive margin platform in the Beagle Sub-basin. This higher rate of submergence may be linked to potentially different crustal rheologies, and
- a thin NW of East Mermaid 1 that, if reflective of an intra-Tertiary topographic high, has implications for potential oil migration from older reservoirs into Tertiary reservoirs.
- The top Cretaceous TWT structure contour map (Enclosure 64) shows a topographic high implying that any Tertiary topographic high, if present, must have been formed at a late stage possibly during the Mid-Miocene-Oligocene Timor plate movements.

The portion of line 120/03 in Figure 10 shows Tertiary faulting over older depositional hinge zones and escarpments. The Tertiary movements probably reactivated older fault systems in other areas. There appears to be several stages of faulting within the Tertiary that may be continuous to intermittent from time slice CZ3 onwards. Unconformities are recognised within time slice CZ1, top of time slices CZ1 and CZ2 (Enclosure 2). The unconformity at the time slice CZ1 to CZ2 boundary in the Dampier Sub-basin is thought to be a result of a simultaneous and short lived tectonic event throughout the Sub-basin (Spencer et al, 1993).

A time slice CZ4 event is differentiated on line 110/03 between the Cossigny 1 and Ronsard 1 wells (figure 23) where time slice CZ3 is absent in the Cossigny 1 well and is seen to be truncationally eroded between the wells. Other evidence includes cut and fill erosional surfaces with onlapping sediments (line 110/5 sp 1750-2600, line 110/4 sp 3500-3700).

A time slice CZ6 event is identified from the level at which faults appear to terminate. Colwell and Stagg (1994) identify the basal Tertiary and time slice CZ4 stages but not the younger time slice CZ6 stage. The time slice CZ6 age faults around the East Mermaid high appear to overlie an older basement suite of faults (line 120/03, sp 5000-5100, Figure 10). Unconformities ranging from time slices CZ5-CZ6 boundary are also inferred in some of the age-depth plots and seismic. This cannot be substantiated more fully due to the lack of abundant age records in the near shallow section so that correlation of unconformities is problematic. It is likely however that these events reflect both structural readjustment movements, and or relative sea level changes resulting in ravinement surfaces.

LITHOLOGY: (SEE 'NOTES ON LITHOLOGY' SECTION FOR DESCRIPTIVE TERMS, PAGE III).

Cossigny Trough: Jarman 1 gamma ray log signature patterns for time slice CZ1 include a mild serrated pattern (siltstone). Both Ronsard 1 and Trafalgar 1 have a greater claystone content than in Jarman 1. Jarman 1 and Ronsard 1 have calcilutite lithologies with secondary calcisiltite and chert for time slices CZ1 and CZ2. There is also secondary marl in time slice CZ2 and secondary claystone for time slice CZ1. Trafalgar 1 has calcareous claystone for time slice CZ1 with minor calcilutite and marl. Lithology's in time slice CZ2 for Trafalgar 1 comprise massive siliceous calcilutite with minor dolomite and rare marl. Jarman 1 lithology's in time slice CZ2 include calcisiltite, calcilutite with major chert beds. A gradation towards marl at the base is also evident whilst time slice CZ1 lithology's comprise mainly marl with secondary siltstone, claystone and calcilutite.

Beagle Trough: Picard 1, Depuch 1 and North Turtle 1 have all mild serrated gamma ray log patterns in time slice CZ1. The lithology in North Turtle 1 is all claystone whilst Picard 1 ranges from marl and calcilutite at the base to claystone in the middle overlain by marl and fossiliferous limestone. Picard 1 has a mild serrated gamma ray log pattern in time slice CZ2.The lithology in Picard 1 is dominantly calcilutite with interbeds of calcarenite, marl, siltstone, minor sandstone and calcisiltite. Depuch 1 has a smooth gamma ray log pattern with lithology's ranging from calcilutite, calcarenite, marl with minor claystone and traces of chert for both time slices CZ1 and CZ2. North Turtle 1 has a moderate serrated gamma ray log pattern in time slice CZ2. The lithology in North Turtle 1 consists of calcarenite grading to calcsiltite downwards with chert and glauconite present. Bruce 1 lithology is uncertain due to lack of drill cuttings.

West Bedout Sub-basin: Minilya 1 gamma ray log patterns for time slice CZ1 include smooth patterns at the base (non fissile claystone with secondary marl, calcilutite) and a smooth gamma ray log pattern at the top and middle (calcilutite and marl). Both Phoenix 1 and 2 have mild serrated gamma ray log patterns in time slice CZ1. The lithology in Phoenix 1 includes claystone at the base overlain by calcilutite and calcarenite, all containing glauconite. The time slice CZ2 lithology's in Phoenix 2 include dominant calcarenite with secondary claystone, phosphatic nodules and calcisiltite beds at the base. Time slice CZ1 lithology's include non calcareous sand and calcareous claystone. Minilya 1 has a smooth time slice CZ2 gamma ray log pattern. The lithology comprises calcilutite and dolomite with secondary calcisiltite, calcarenite, marl, claystone and chert. Gamma ray log patterns in Phoenix 1 are large scale moderately serrated funnels with lithology's consisting of dominant fossiliferous limestone, calcarenite and sands at the base representing a probable lowstand. Phoenix 2 has a mild serrated funnel gamma ray log pattern (sandstone).

Bedout Sub-basin: Keraudren 1 lithology's in time slice CZ2 include calcarenite with trace of gypsum and glauconite grading to multicoloured claystone at the base with trace of limonite. Time slice CZ1 lithology is sandstone with limonite and glauconite minerals included.

Bedout High: Time slice CZ1 in Bedout 1 has a serrated base (claystone) and a mild serrated gamma ray log pattern at top and middle. Time slice CZ2 lithology in Bedout 1 consists of calcilutite with secondary dolomite and skeletal fragments. Lagrange 1 has mild serrated siltstone and sandstone in time slice CZ1.

Rowley Sub-basin: East Mermaid 1 lithologies for time slice CZ1 include smooth claystone at the base and bioclastic lime packstone and siltstone in the middle and top. A smooth continuous bioclastic lime packstone is interpreted for time slice CZ2, cherty and glauconitic in part with siltstone also present.

THICKNESS VARIATIONS: (SEE ENCLOSURES 54, 56).

Time slice CZ1 ranges in thickness from 25m in Keraudren 1 to 349m in Minilya 1. These thicknesses may not be representative of the module area due to the poor well and seismic control however a similar order of magnitude is expected.

Time slice CZ2 ranges in thickness from 25m in Keraudren 1 to 297m in Minilya 1. These thicknesses may not be representative of the module area due to the poor well and seismic control however a similar order of magnitude is expected.

PALAEODEPOSITIONAL ENVIRONMENTS: (SEE ENCLOSURES 54, 56).

The basal Tertiary saw a relative sea level fall within the module area, as evidenced from cut and fill features that are best represented on line 110/2 (sp 1400-2900), line 110/5 (sp 1750-2400), line 110/7 (sp 3000-1200). Open marine continental shelf and slope environments are interpreted.

Globally time slice CZ1 is characterised by a maximum relative sea level. Within time slice CZ1 there are nine globally recognised eustatic sea level drops (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a regression towards the lower part of the time slice followed by a transgression in the upper part of the time slice. However during most of time slice CZ1 the coastline in the module area is in about the same location as for time slice K11.

Globally time slice CZ2 is characterised by a maximum to intermediate relative sea level. There are within the time span of time slice CZ2 ten globally recognised eustatic sea level drops (Haq et al, 1987). The Australian inundation curves (constructed by plotting the percentage of the continent covered by marine environments for seventy Phanerozoic time slices) of Struckmeyer & Brown (1990) show a gradual transgression in the lower part of the time slice followed by a regression in the upper part of the time slice. However during most of time slice CZ2 the coastline in the module area is in about the same location as for time slice CZ1.

PALAEOGEOGRAPHY CZ1:(SEE ENCLOSURE 55).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography and palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work.

The degree of certainty regarding the exact location of the downlap and onlap edges of time slice CZ1 on a local scale is problematic although the regional geometry of the edges is thought to be correct. It is uncertain whether the inner shelf southeast of the onlap edge has received any sedimentation. A starved inner shelf is suggested with a high proportion of this shelf being potentially emergent although this has not been substantiated. The location of the onlap edge is more problematic than the location of the downlap edge due to the lower aggradation to encroachment ratio involved with an inner shelf. The elongate and narrow stratigraphic sequence interpreted is representative of a subsiding regional platform with probable low relief inland and low sedimentation rates.

PALAEOGEOGRAPHY CZ2: (SEE ENCLOSURE 57).

The primary sources for the palaeogeographic interpretation are all wells with interpreted time slice palaeogeography, palaeogeography interpretations from onshore Canning Basin wells and outcrop (BMR, 1981), palaeogeographic interpretations from the adjacent Browse Basin (Wilmot, 1993) and Dampier Sub-basin (Spencer et al, 1993) modules. Secondary sources are from AGSO(BMR), industry and university published work. There is uncertainty in mapping the exact top of time slice CZ2 basinward when following the progrades downslope whereas the exact position of the onlap edge is interpretive due to the thin sequence landward and high encroachment distances.

Additionally it is uncertain whether the starved inner shelf interpreted southeast of the onlap edge may have received any sedimentation locally. A starved inner shelf is suggested with a high proportion of this shelf being probable landmass although this has not been substantiated.

GEOCHEMISTRY (TOC, HI, S2 AND Vr):

There is no available geochemical data for the Tertiary section.

SHOWS, POROSITY & PERMEABILITY:(SEE APPENDIX 4).

An oil and gas indication was recorded in Picard 1 in time slice CZ1. Common lost circulation problems establish that adequate porosity and permeability also exist, presumably as primary porosity in calcarenites or perhaps as secondary porosity in carbonates exposed to fresh water. The following list summarises the porosity data for the time slice:

Picard 1	CZ1	porosity av = 25%(logs), and
Picard 1	CZ2	23%<porosity av<40% (logs).

PROSPECTIVITY: (SEE ENCLOSURE 3).

No generative source rocks are expected within time slice CZ2 due to the time slice being a prograding dominantly carbonate sequence with some clastics, with low organic content and insufficient depth of burial.

Potential reservoirs have been identified in the Beagle Trough and Bedout Sub-basin. The reservoirs within the Beagle Trough may be charged from Lower Jurassic or Triassic sources if suitable migration pathways exist up late stage faults of mid-Miocene to Oligocene age. There is sufficient reactivation and density of faults within the Beagle Sub-basin for this to occur. Seal would be provided by time slices CZ3-CZ7 that are dominantly very fine grained calcareous sediments. It is unlikely that potential reservoirs within the Bedout Sub-basin could be sourced from the Triassic due to the low density of late stage faults. There would also be a lack of seal in the Bedout Sub-basin.

No substantial thickness of time slice CZ2 aged sediment is present on the Jurgurra and Pender Terraces or in the Fitzroy Trough and the time slice is considered unprospective in this area.

The CZ2 time slice, with the exception of the Offshore Canning Basin, acts as a regional seal in the Cossigny and Beagle Troughs, West Bedout, Bedout and Inner Rowley Sub-basins and Bedout High. The time slice acts as a local seal within the Bedout Sub-basin where it is thin and in places sandy.

TRAPS AND PLAYS: (SEE ENCLOSURE 3).

Stratigraphic traps and combined traps dominate exploration within the Tertiary carbonates and have been recognised in the Beagle Trough. Exploration needs to focus on periods of sea level fall and the reworking of glauconitic and carbonate sands that might occur. They could be present either as strandlines or if sea level fall is sufficient as incised shelf edge channels and associated slope turbidites. The older time slices CZ1 and CZ2 have significant amounts of quartz and siltstone detritus associated with them to substantiate the presence of reservoirs.[2]

[2]There is a distinct reduction of faulting intensity from the west to the east within the Beagle and Rowley Sub-basins. The higher intensity fault areas (Argoland and Greater India breakup age) in the western Beagle Sub-basin could provide conduits for hydrocarbons to migrate past the Upper Jurassic and Lower Cretaceous reservoir horizons. As an example Picard 1, a valid closure, recorded shows all the way up to the Cainozoic but did not reservoir any hydrocarbons. This is interpreted to imply seal breaching by the faults that also acted as migration pathways. The lower intensity fault areas (in places no faulting at all) in the Bedout Sub-basin do not provide migration pathways into the Cretaceous or Cainozoic. Because of this fault distribution it is believed that the lower Tertiary reservoirs have a higher chance of accumulating hydrocarbons in the west Beagle Sub-basin. Here the faults extend into the the lower Cainozoic.

PETROLEUM SYSTEMS

INTRODUCTION

A petroleum system as defined by Magoon & Dow (1991) is a mature source rock and all its generated hydrocarbon accumulations. The system includes all the play elements – source, reservoir, seal, trap, overburden (required for maturation), and migration pathways – and the actual processes and linkages involved, from source to trap, and including the preservation of the accumulation. The system operates successfully, and hydrocarbons are accumulated, when all the crucial elements are present and occur in the correct order.

The petroleum system concept can be applied to Australia at a number of different scales. At the continent-wide scale, Bradshaw (1993) established a framework that linked together basins of similar age, facies, structural history and hydrocarbon potential into petroleum systems, now more correctly termed supersystems. These groupings are much broader in scope than the original Magoon & Dow (1991) definition in that they extend through many basins, encompass a family of similar source rocks, rather than a single pod, and include numerous individual petroleum systems.

The supersystems provide generalised models of how an individual petroleum system may operate at the basin-scale, but detailed analysis is necessary to 'test' the model. The key elements of reservoir, seal, source and trap need to be mapped and the processes of generation, migration, accumulation and preservation considered. Successful operation of the system in one basin points to prospective intervals in less well explored parts of the supersystem, and the insights gained can be used predictively.

Six petroleum supersystems are recognised in the Australian Phanerozoic (Bradshaw, 1993) and potentially three of these occur in the Roebuck and Offshore Canning Basins - Beagle Sub-basin module area – the Westralian, Gondwanan and Larapintine supersystems. All the significant hydrocarbon discoveries are within the Mesozoic Westralian Supersystem (oil at Nebo 1 and gas in the Phoenix wells, some hydrocarbon shows occur within the Gondwanan Supersystem (on the Pender Terrace) and some petroleum potential can be speculated about in the Larapintine interval as it is a proven source in the adjacent onshore Canning Basin.

LARAPINTINE SUPERSYSTEM

The Larapintine Supersystem is characterised by lower Palaeozoic marine facies, including carbonates, evaporites and several intervals of organic rich marine rocks (Bradshaw, 1993), deposited during a tropical regime between the glacially influenced epochs of the late Precambrian and the Permian-Carboniferous. The key episodes of source rock deposition were the result of marine transgression in the Middle Cambrian, Early Ordovician and Late Devonian to Early Carboniferous.

The boundary between the Larapintine and Gondwanan Supersystems is marked by a time of continent-wide tectonism in the Carboniferous coinciding with the peak of the Alice Springs Orogeny (Enclosure 3). In the few basins (Fitzroy Trough and Petrel Sub-basin), where significant thicknesses of source rocks were deposited during the Mid Carboniferous, a separate petroleum system is now recognised as transitional between the Larapintine and Gondwanan regimes (Bradshaw et al, 1994).

GONDWANAN SUPERSYSTEM

The Gondwanan Supersystem includes those sequences dominated by the late Carboniferous early Permian glaciation. In comparison with the Larapintine Supersystem, terrestrial environments are better represented and the facies are predominantly clastic. Proven source facies tend to be gas prone, terrestrial organic facies such as the coals and carbonaceous shales in the basins of eastern Australia (eg the Cooper Basin). Marine shales with a significant terrestrial component are the dominant source rocks on the western margin.

The Early Triassic Locker Shale is distributed throughout the study area. It is a time equivalent of the Kockatea Shale, which is a proven oil and gas source in the Perth Basin, and an effective seal over late Permian and early Triassic reservoirs. The source characteristics of the Early Triassic marine shales

are inferior to the Permian shales, but the successful Gondwanan petroleum system is in this interval where there is a coincidence of reservoir, seal and trap (Bradshaw, 1994).

The pragmatic boundary between the Westralian and Gondwanan supersystems is the top of the diachronous Locker Shale. In this study, the boundary is taken as being within the time slice TR3 to TR4 interval.

WESTRALIAN SUPERSYSTEM

The Westralian Supersystem links together basins, from the Exmouth Sub-basin to the Papuan Basin, that share a history of extension and eventual break-up and sea floor spreading in the Late Jurassic to Early Cretaceous. They have a similar stratigraphy of Triassic to Cretaceous reservoirs, Jurassic marine oil source rocks, Cretaceous regional seal and a thermal blanket of Tertiary carbonates. The focus of the basin modules studied to date in the AGSO-APIRA Australian Petroleum Systems Project (Browse, Dampier, Barrow-Exmouth Beagle & offshore Canning and Papuan) has been the prolific Westralian Supersystem.

The oils from the entire Westralian Supersystem are very similar geochemically, indicating deposition of the source rock in marine anoxic conditions, with the input of a significant amount of terrestrial organic matter (Murray et al, 1993). Tectonism related to continental break-up in the Late Jurassic, produced a palaeogeography of restricted, deep-marine troughs bordered by emergent highland areas, ideal for the deposition of such source rocks. The marine environments of Australia's northern margin were partially barred from the Tethyan ocean by the continental fragments of Argoland, and pieces of eastern Indonesia (Bradshaw et al., 1994).

Another source interval in the Westralian Supersystem is the Late Triassic fluvial-deltaic sequences that have sourced the giant gas and condensate fields of the North West Shelf (Woodside Offshore Petroleum, 1988). The unconformity within Time slice J2 (Figure 3), provides a convenient place to subdivide the Westralian Supersystem into two petroleum systems, both of which operate successfully in the study area but have distinctly different source rock facies.

In the Beagle Sub-basin the Nebo oil discovery shows that at least one viable petroleum system is present. In the Westralian system of the North West Shelf the oil source rocks are late Jurassic shales, deposited in deep troughs formed or deepened during tectonism related to sea floor spreading in the Argo Abyssal Plain. However, in contrast to the other oil occurrences, to the north and south in the Barrow Dampier Sub-basins and the Timor Sea, in the Beagle Sub-basin the Late Jurassic is thin with the exception of the west Cossigny Trough. It is also probably immature over most of the area but again in the west Cossigny Trough it may just enter the oil window. In the Beagle Sub-basin petroleum system the source is in the pre-Argoland breakup sequence of the Late Triassic and or Early Jurassic fluvio-deltaics. It has been established from our previous work (Spencer et al 1993) that the delta front slope sequences are the best source facies in the fluvio-deltaic sequences and perhaps some of the coaly sequences are sources as well. These are the source for the gas condensate of the Rankin Trend.

Bradshaw (1993) proposed the Westralian Super System as a model for the operation of a Petroleum System on the NW Shelf extending to the Papuan Basin. All shared similar features; Late Jurassic source revealed in very similar oils; Cretaceous and Triassic sandstone reservoirs and Cretaceous regional seal (Westralian 2). Variants recognised on the basis of the age of the source rocks are Westralian 1, where the source from the Triassic is gas and condensate prone and Westralian 2 where Late Jurassic is oil and gas prone. The small gas accumulation at Phoenix proves a mature petroleum system is active, in this case the pre-Argoland breakup source rock is the Westralian 1.

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