AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

APIRA

AUSTRALIAN PETROLEUM SYSTEMS

Exmouth Plateau & Outer Rankin Platform Module

Volume 1

by

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with

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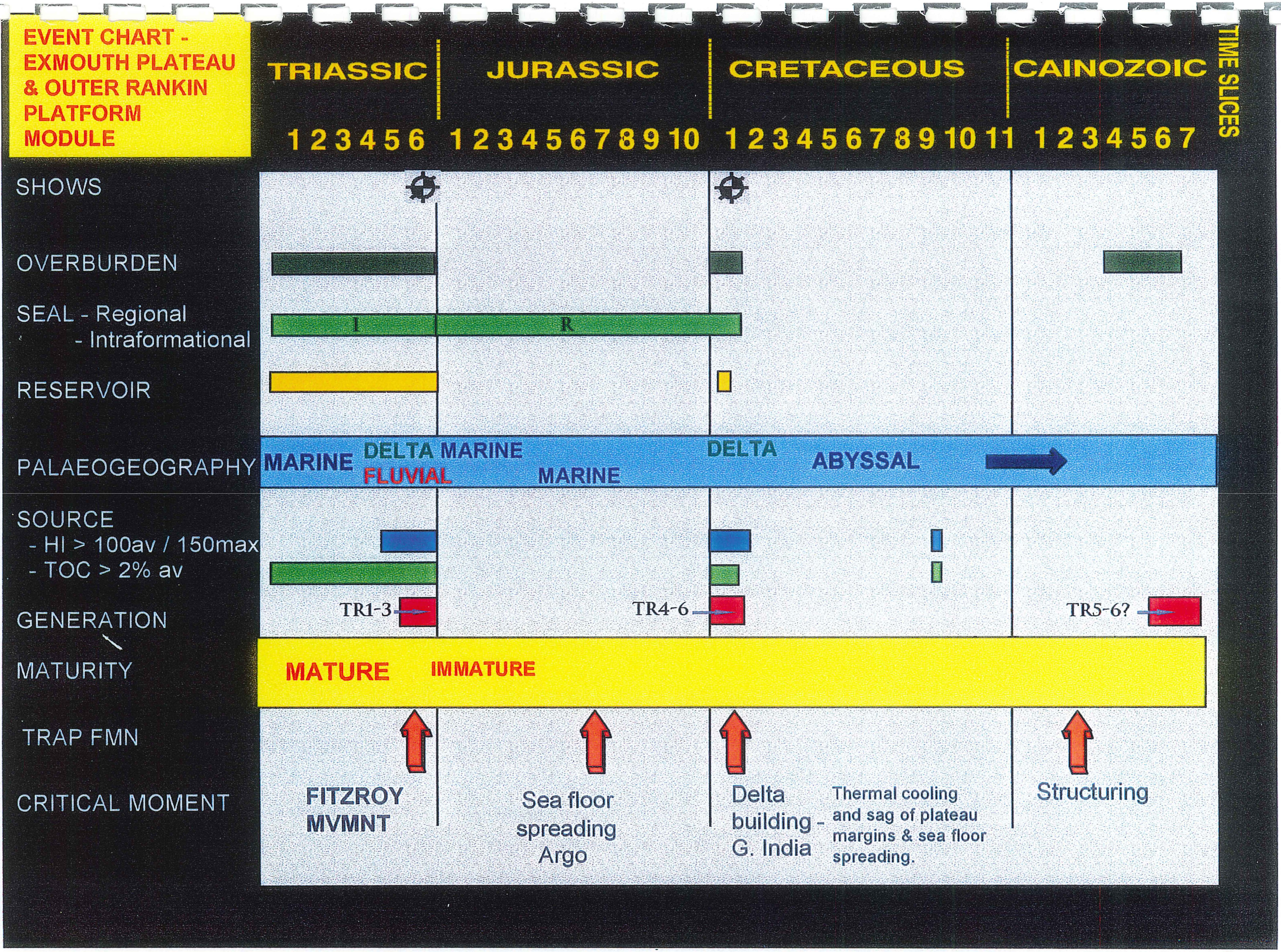
EVENT CHART - EXMOUTH PLATEAU & OUTER RANKIN PLATFORM MODULE
TRIASSIC
JURASSIC
CRETACEOUS
CAINOZOIC
TIME SLICES
1 2 3 4 5 6
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10 11
1 2 3 4 5 6 7
SHOWS
OVERBURDEN
SEAL - Regional
- Intraformational
I
R
RESERVOIR
PALAEOGEOGRAPHY
MARINE
DELTA MARINE
FLUVIAL
MARINE
DELTA
ABYSSAL
SOURCE
- HI > 100av / 150max
- TOC > 2% av
GENERATION
TR1-3
TR4-6
TR5-6?
MATURITY
MATURE
IMMATURE
TRAP FMN
CRITICAL MOMENT
FITZROY MVMNT
Sea floor spreading Argo
Delta building - G. India
Thermal cooling and sag of plateau margins & sea floor spreading.
Structuring

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EXECUTIVE SUMMARY

Of the six recognised petroleum supersystems of the Australian Phanerozoic only the Westralian Supersystem has been drilled in the module area. However it is interpreted that sediments of both the Gondwanan and Larapintine supersystems occur regionally beneath the Westralian Supersystem. All significant hydrocarbon discoveries are within the Westralian Supersystem. These include the large gas reserves in the Triassic both at Gorgon 1 and Echo 1 on the Outer Rankin Platform and the Lower Cretaceous reservoired gas at Scarborough 1 on the Exmouth Plateau.

In adjacent area's oil has been discovered in the Exmouth Sub-basin in the Lower Cretaceous, whilst in the Lewis Trough of the Dampier Sub-basin and in the Barrow Sub-basin, the Upper Jurassic section is an oil prone source rock.

The dominant gas-condensate source in the module area is the Triassic. Thermogenic gas-condensate is produced from the North Rankin Field, sourced almost certainly from the Middle to Upper Triassic. It has been established from previous work that delta front slope sequences are the best gas condensate source facies in the fluvio-deltaic sequences followed by the coaly sequences of the lower delta plain. There are no obvious major palaeoenvironmental differences between the Westralian 1 (Middle & Late Triassic to Early Jurassic) of the Exmouth Plateau and that of the Rankin Trend. There is virtually no significant thickness of Jurassic on the Exmouth Plateau and younger sediments are nowhere mature. It is concluded that the Triassic is the primary source interval for the Exmouth Plateau area, with the Permian as a possible secondary thermogenic source and with a possible component of biogenic source in the Lower Cretaceous. On the Rankin Trend source rocks have been matured by a significant dominantly Cainozoic load (in the order of 2.5 km) as opposed to the Exmouth Plateau where post Triassic loading has been restricted.

The major remaining play on the Exmouth Plateau is the intra-Triassic play, particularly those structures present at or prior to time slice K1. The top Triassic unconformity play has been the main target of the prior drilling effort on the Exmouth Plateau. Almost all wells were targeted on seismically defined direct hydrocarbon indicators, and most wells successfully encountered very dry gas. The dryness of this gas contrasted with the typical gas condensate compositions seen on the Rankin Trend.

Five other major play types have been recognised. They are ranked as follows from highest to lowest probability of success.

A. Middle-Upper Triassic rollovers / fault plays on the Exmouth Plateau:

This play is based on the interpretation that the dry gas accumulations, of the lower Cretaceous structural traps and the Triassic unconformity traps, are a result of an evaporative fractionation process. This process bled off mainly the methane from deeper Lower-Middle Triassic gas-condensate reservoirs interpreted to be present beneath these younger traps. Consequently, the Lower-Middle Triassic reservoirs are thought to be enriched in heavier hydrocarbons. Up to this time gas discoveries on the Exmouth Plateau have been restricted to drilling direct hydrocarbon indicators present at the crest of rotated Triassic horst blocks or domal closures in the Lower Cretaceous.

B. Jurassic-Lower Cretaceous rollovers/fault/stratigraphic plays in the Exmouth Sub-basin:

This is presently an active exploration area in the shallower water depths. It is expected that the Exmouth Sub-basin remains one of the more oil prone sedimentary basins whose potential has not been fully addressed.

C. Lower Cretaceous basin floor fan on the east Exmouth Platform:

A basin floor fan (BFF) play is located 80 km NNW of Minden 1 in the eastern Exmouth Platform. The fan was deposited at the top of the Aptian (time slice K4) in a distal setting, during the Aptian/Albian lowstand. The anomalous thick that is interpreted as the BFF, is estimated from a coarse seismic grid to be in the order of 1000 square kilometres and as such is an attractive play type from its size alone. The BFF lies at the distal end of a major north-south sediment transport axis spanning time slices K3-K10. Potential reservoirs within the BFF are interpreted to be sourced via vertical faults from both a potential Lower Cretaceous oil prone source rock (sub-mature - mature) and or an underlying Triassic gas/light oil prone source rock.

D. Lower-Middle Jurassic rollovers/fault plays in the Victoria Trough:

The Victoria Trough is located to the north of the Rankin Trend and contains a thicker Jurassic sequence with proven source content at Brigadier 1. Potential may remain as it is the only Jurassic depocentre whose potential has not been fully addressed by adequate drilling. Thermal maturation of source rocks is provided by the significant Cainozoic loading at the southern extremity of the trough. Middle Jurassic reservoirs would be regionally sealed by the claystone/calcilutite Cretaceous wedge. The presence of the Upper Jurassic is uncertain.

E. Lower-Middle Jurassic rollovers/fault plays in the north-east Exmouth Platform:

Lower-Middle Jurassic reservoirs may be sourced from the Triassic and sealed by the Cretaceous claystone/calcilutite wedge.

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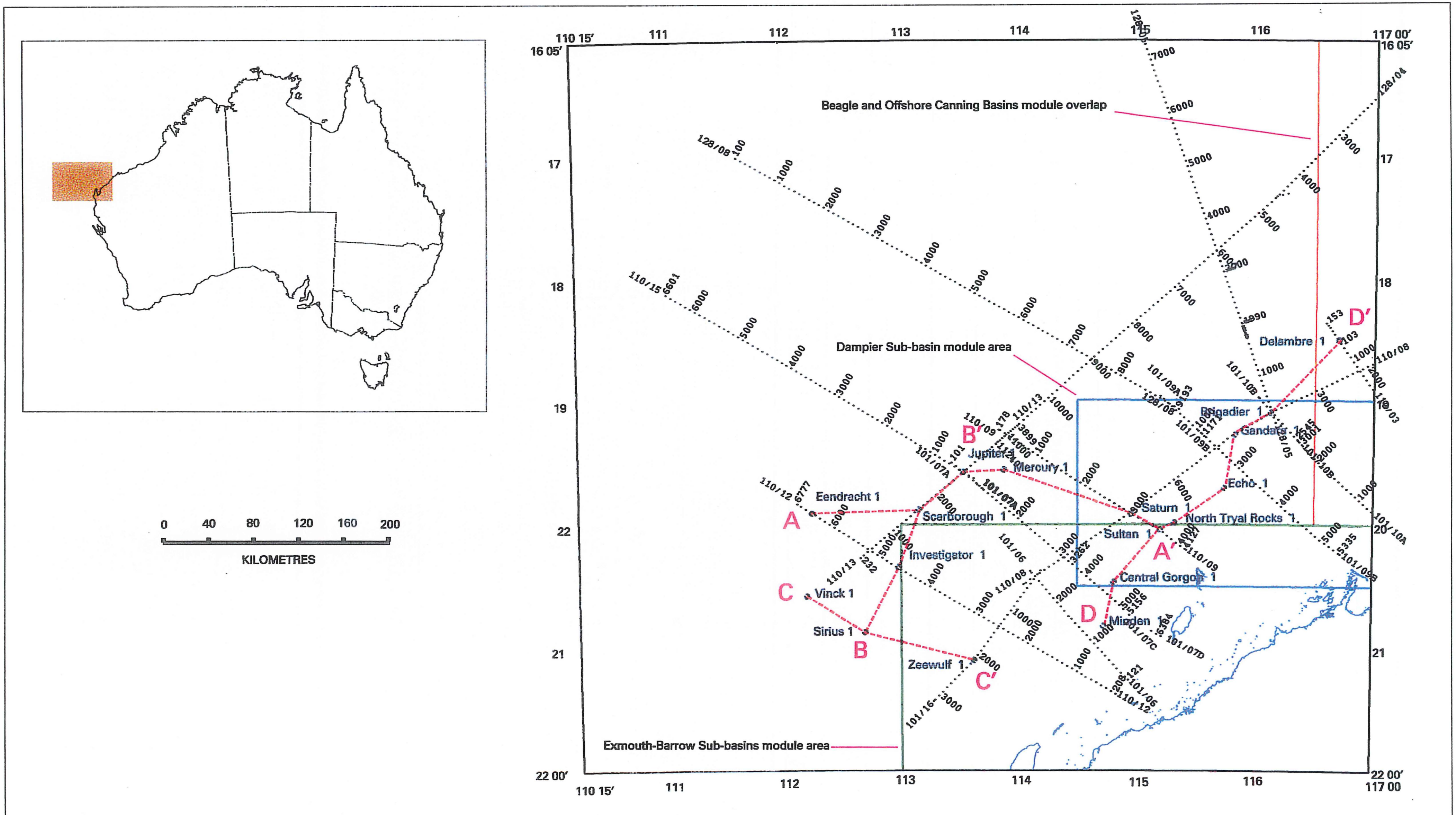


Module Seismic & Cross-Sections Location Diagram Figure 1

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 13 wells and an examination and interpretation of approximately 3000km 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.

Lynton Spencer and Jacques Sayers are the senior authors of this report and were mainly responsible for the geological and geophysical 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 Exmouth Plateau & Outer Rankin Platform 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.

Technical support was provided by Cameron Buchanan, Giuliana Zuccaro, Heike Apps (seconded from CSU set up the Microstation system that produced the palaeogeographic maps) and John Vizy. This support included data collation, the writing of software programs and the generating the various products.

Graham Moss, David Rowland and Kamal Abdelmalek gave support and assistance for all work associated with the STRATDAT and RESFACS databases that they maintain.

Others who provided technical and scientific assistance include: Jim Colwell and Geoff O'Brien who gave an overview of the deep regional structural framework of the Exmouth Plateau & Outer Rankin Platform based on AGSO deep seismic lines.

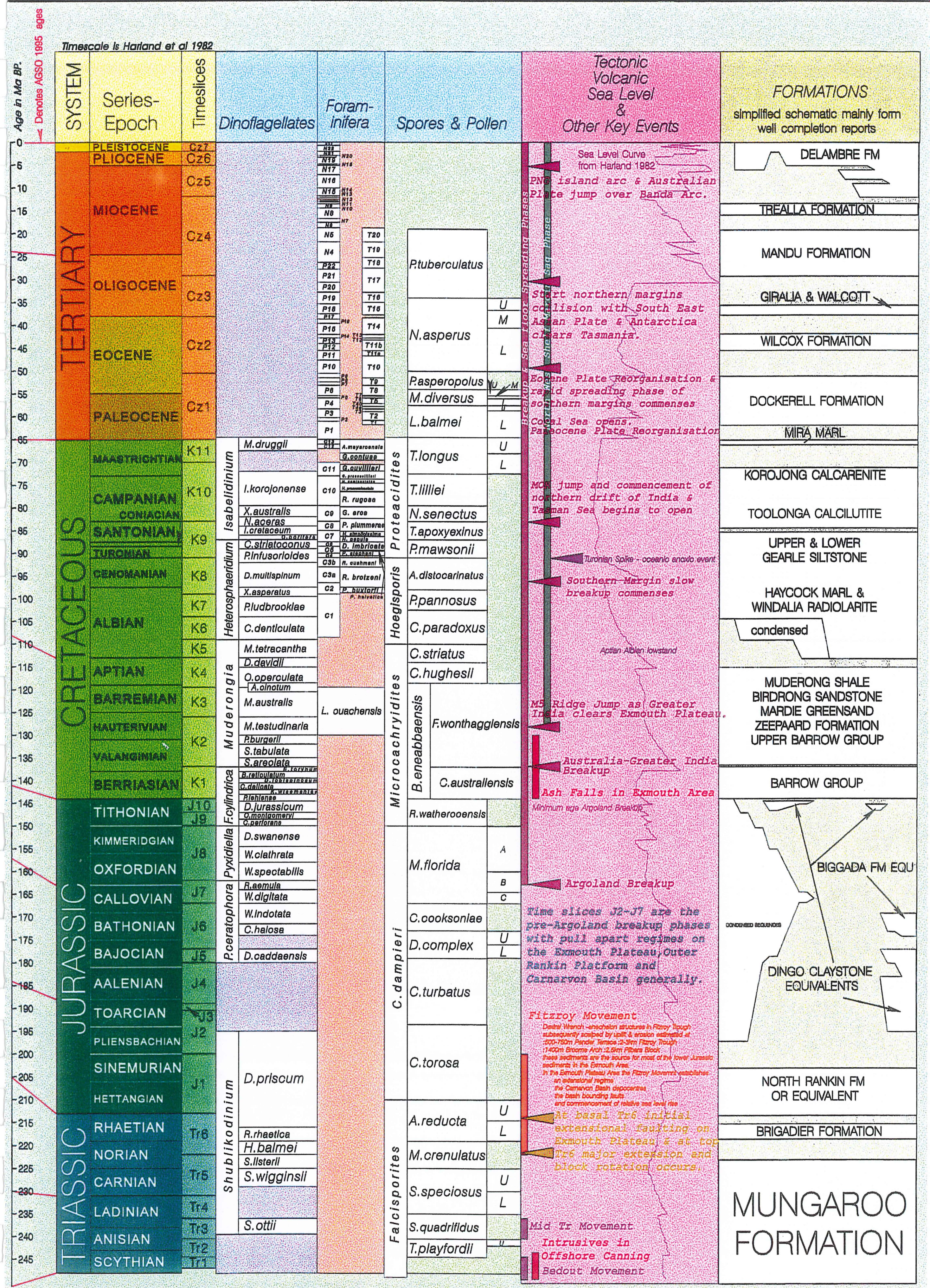
Andrew Murray and Dianne Edwards and Roger Summons provided assistance with geochemical interpretation of the data. In particular Andrew Murray first suggested the possibility of evaporative fractionation or secondary phase migration effects as an explanation of the dry gas accumulations of the Exmouth Plateau.

MODULE AREA and BASIN DEFINITION: *(Figure 1).*

The module area top left corner is 16°05'S & 110°15'E and the bottom right corner is 22°00'S & 117°00'E. This area allows for an overlap with the previously completed modules of the Dampier Sub-basin and Barrow-Exmouth Sub-basins to the east and the Roebuck - Offshore Canning Basin and Beagle Sub-basin module to the northeast. On the advice of the AGSO Cartographic Services Unit it was decided to use a Lambert Conformal Conic Projection for this module. This projection system minimises overall distortion.

Projection details for the Lambert Conformal Conic

Map Projection	: Lambert Conformal Conic Standard parallels:
	:-17° 00' 00"S
	:-21° 00' 00"S
Central Meridian	: 114° 00' 00"E



Summary Stratigraphic Diagram Figure2

Longitude of Origin	: 000° 00' 00"E
Latitude of Origin	: 000° 00' 00"E
Ellipsoid	: World Geodetic System 1984
Equatorial Radius	: 6378137 m
Polar Radius	: 6356752.314 m
Inverse Flattening	: 298.257223563002
Flattening	: 0.00335281066474746
Eccentricity	: 0.081819108426215
Greenwich Offset	: 0 degrees.

Geologically the module area covers the northern end of the Carnarvon Basin on Australia's North West Shelf. Within this area is the Exmouth Plateau and Outer Rankin Platform (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, Barrow-Exmouth Sub Basins and Roebuck - Offshore Canning Basins and Beagle Sub-basin Modules is shown on Figure 1.

DAMPIER SUB-BASIN, BARROW-EXMOUTH SUB-BASINS & ROEBUCK - OFFSHORE CANNING BASINS AND BEAGLE SUB-BASIN MODULES OVERLAP *(see Figure 1).*

Several wells are common to previous models due to the module overlap. These wells are additional to the thirteen 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 palaeoenvironmental interpretations of the Dampier Sub-basin, Barrow-Exmouth Sub-basins and Roebuck and Offshore Canning Basins - Beagle Sub-basin modules with the interpretations for this module. To facilitate a comparison between the overlapping and the current module a brief summary of the previous modules results are occasionally included within the time slice sections of this report.

PETROLEUM SYSTEMS

INTRODUCTION (see Enclosure 3)

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 two of these occur in the module area -- the Westralian and Gondwanan supersystems with only the Westralian being drilled. All the significant hydrocarbon discoveries are within the Mesozoic Westralian Supersystem (Gas-condensate on the Rankin Trend and dry gas on the Exmouth Plateau in Scarborough 1.

LARAPINTINE SUPERSYSTEM

Potentially the Larapintine Supersystem may underlie the area but would be so deep as to not warrent serious consideration as a functional petroleum system. The Larapinitne 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). This is also coincident with the initation of the Westralian Superbasin that holds the pre-Greater India breakup sediments of the Exmouth Plateau. 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 near 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 to very early Triassic reservoirs. These potential source rocks have not been encountered by the drill but can be interpreted to be present across the Exmoth Plateau from seismic correlation. Where encountered (eg the Enderby Terrace) the Locker Shale, although fairly high in TOC is not a good source rock as the organic matter is largely oxidised. Equivalents of the slightly older Kokatea Shale have never been intersected. Todate the Gondwana Supersytem is the only petroleum system thought to be effective on the Exmouth Plateau. The dry gas discoveries on the Exmouth Plateau have been interpreted as the consequence of supermaturation of source rocks or the normal maturation of a particularly gas prone Gondwanan Supersystem source rock (eg the Locker Shale).

There are however younger potential source rocks.

WESTRALIAN SUPERSYSTEM

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 within the time slice TR3 to TR4 interval. 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.

Westralian 1 (see Enclosure 3):

The oldest source interval in the Westralian Supersystem is the Middle to 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 2), defines the top of the Westralian 1, base Westralian 2 subsystem in this area. It has been established from 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. The Triassic palaeoenvirnments recognised on the Exmouth Plateau are very similar to those seen on the Rankin Trend. The late Triassic early Jurassic is transgressive with more marine source rocks developed younger in the section.

Westralian 2 (see Enclosure 3):

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). This is because the tectonism that preceeded 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 Tethyn ocean by the continental fragments of Argoland, and pieces of eastern Indonesia (Bradshaw et al., 1994).

Westralian 3 (see Enclosure 3):

The time interval between the breakup of Argoland and Greater India define the Westralian 3 subsytem. It is the interval of major turbidite reservoir deposition in the deep troughs and the development of the

Barrow Delta. This interval is of major interest on the Exmouth Plateau as it reservoirs the potential enormous Scarborough gas field. However this interval and the younger Westralian 4 subsytem is everywhere immature. Resolution of the source of the dry gas in this interval is a major exploration concern.

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 seals and a thermal blanket of Cainozoic carbonates. Bradshaw (1993) proposed the Westralian Supersystem as a model for the operation of a Petroleum System on the North West 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.

The one exception to the above is the Exmouth Plateau area. Here the Jurassic is thin, the lower Cretaceous only forms a regional seal to the south and the Cainozoic does not significantly load the area. The result is that the dominant focus of attention on the Exmouth Plateau is the Westralian 1 as the only potentially mature thermogenic source interval.

REASSESSMENT OF EXMOUTH PLATEAU PROSPECTIVITY :UPPER TRIASSIC (WESTRALIAN 1) SOURCE ROCKS

EXPLORATION HISTORY OF STUDY 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

TABLE 1: WELLS USED IN STUDY

WELLNAME	OPERATOR	STATUS AT TD DATE	TD (mKB)	TD DATE
BRIGADIER 1	Woodside Petroleum	Dry	4292	[illegible]
DELAMBRE 1	Woodside Petroleum	Dry, minor gas, P & A	5495	Nov 80
ECHO 1	Woodside Petroleum	Condensate suspended	3775	Oct 88
EENDRACHT 1	Esso Expl. & Prod.	Dry, gas show	3410	Jun 80
INVESTIGATOR 1	Esso Expl. & Prod.	Gas discovery	3745.6	Jun 79
JUPITER 1	Phillips	Gas discovery	4946	Oct 79
MERCURY 1	Phillips	Dry, minor shows	3812	Dec 79
MINDEN 1	BHP	Condensate discovery	4022	[illegible]
NORTH TRYAL ROCKS 1	Woodside Petroleum	Gas discovery	3657.6	Aug 72
SCARBOROUGH 1	Esso Expl. & Prod.	Gas discovery	2360	Dec 79
SIRIUS 1	Esso Expl. & Prod.	Gas discovery	3500	Dec 80
SULTAN 1	Woodside Petroleum	Dry, P& A	3620	Mar 79
VINCK 1	Esso Expl. & Prod.	Gas discovery	4600	Mar 80

Palaeogeography Group (1990a), Bradshaw et al (1988, 1993), BMR (1990b), Burger (1994), Colwell et al (1994b), Crawford & Von Rad (1994), Etheridge & O'Brien (1994), Exon & Wilcox (1980), Kaminski et al (1992), Ramsay & Exon (1994), Sager et al (1992), Shafik (1994), Stagg & Colwell (1994), Stanley (1994), Von Rad & Thurow (1992).

UPPER TRIASSIC SOURCE FOR EXMOUTH PLATEAU DRY GAS

Rankin Trend: Mature Upper Triassic Source

The Rankin Trend gas condensates and light oil discoveries are thought to be sourced from the mature Upper Triassic, although some of the oils may be sourced from the Jurassic of the adjacent Lewis Trough. The outer Rankin Platform well Echo 1, in a position where no Jurassic hydrocarbon input is possible, discovered a typical Rankin Trend gas condensate rich accumulation in an Upper Triassic unconformity play. The play flowed 15.5 MMCFPD & 3875 BOCPD. The reservoir temperature is 111 °C and the source appears to be Upper Triassic sediments that are gas condensate and light oil prone. The composition is also representative of the Triassic reservoired hydrocarbons of the Rankin Trend. The geometry of this play is such that any hydrocarbons must be migrating updip and eastward away from the axis of the Kangaroo Syncline. As can be seen from Table 2 the $-\delta^{13}C$ PDB are typical of normal thermogenic hydrocarbon.

TABLE 2: ECHO 1 CONDENSATE COMPOSITION AND $\delta^{13}C$ PDB

Well	Methane %	Ethane %	Propane %	CO_2 %	C3+ %	Formation
Echo 1	64.0	7.0	5.0	2.5	(21.5)	U. Triassic
$\delta^{13}C$‰ PDB	-42.4	-30.1	-28.8	-13.4		TR6

There are good geological and geochemical reasons to believe that the Rankin Trend gas condensate and light oils are sourced from the mature Upper Triassic.

Exmouth Plateau: Dry Gas Discoveries

Exploration on the Exmouth Plateau was originally based on the perceived similarities between the Exmouth Plateau and the Rankin Trend. Exploration on the Exmouth Plateau was fairly successful, in one sense, as there were several large discoveries based on drilling direct hydrocarbon indicators as seen on seismic (Table 3).

TABLE 3: RESULTS OF DRILLING ON THE EXMOUTH PLATEAU.

Well	DHI	Valid Test	Primary Target	Comment	Discovery Formation
Eendracht 1	YES	YES	Triassic Fault Block		*U. Triassic*
Investigator 1	YES	YES	Primary target K1 dome	DHI due to methane in Barrow Group shales ??	*U. Triassic*
Jupiter 1	YES	YES	Rotated Triassic fault block	Seismic gas chimney seen	*U. Triassic* TR6 hot beach sand.
Mercury 1	NO	NO	First Triassic tilted fault block west of the Kangaroo Deep	postulated mature Neocomian source at this location was not present	*U. Triassic* TR5 fluorescence Cretaceous source immature
Scarborough 1	YES	YES	Large K1 dome	Seal is upper K1 shales	*L. Cretaceous* K1-Turbidite facies
Sirius 1	?	?	Top K1 dome -40m * 400sq km.	Upper Triassic was not the primary target	*U. Triassic*
Vinck 1	YES	YES	Faulted K1 anticline 60-120m closure		*U. Triassic*

But the Exmouth Plateau hydrocarbon discoveries are characteristically very dry gas. It is not obvious why this should be the case (Table 4).

TABLE 4: GAS COMPOSITION OF DISCOVERIES ON THE EXMOUTH PLATEAU.

Well	Methane %	Ethane %	Propane %	CO_2 %	Nitrogen %	Formation
Eendracht 1	96.0	?	?	?	?	U. Triassic
Investigator 1	87.0	3.67	1.15	4.3	3.4	U. Triassic
Jupiter 1	96.4	minor			3.1	U. Triassic
Scarborough 1	95.5	0.12	0.01		4.3	L. Cretaceous
Sirius 1	92.8	2.12	0.09		4.6	U. Triassic
Vinck 1	90.0	4.29	2.81			U. Triassic

Some additional comments from the well completion reports.

•In Eendracht 1 time slice TR6 has dry gas with very minor condensate. This condensate is depleted in n-alkanes and aromatics and this is interpreted to be caused by biodegradation and water washing.

•In Sirius 1 analysis shows iC4=0.12% and nC4=0.06% with a comment that there is "dry methane 92.84% with an interesting molecular composition as the branched alkanes are present in higher concentrations than the normal alkanes."

These features, the interpreted biodegradation and water washing, the odd branched versus normal alkane rations and the abundance of dry gas could be a result of the alteration of a normally matured Triassic gas condensate source, such as the one generating the Echo 1 gas condensate, that has been subject to evaporative fractionation. Evaporative fractionation is discussed later in this section. Before detailing this mechanism the source potential of the Exmouth Plateau Upper Triassic will be discussed as well as describing some of the proposed sources for the dry gas of the Exmouth Plateau.

Exmouth Plateau- Upper Triassic Source rocks present

The Upper Triassic on the Exmouth Plateau does have source potential, and would appear to be capable of generating hydrocarbons similar to those found at Echo 1 (Table 5).

TABLE 5: UPPER TRIASSIC SOURCE POTENTIAL OF EXMOUTH PLATEAU WELLS.

Well	Comments on Upper Triassic Source Potential from WCRs
Eendracht 1	Good oil- gas condensate, marine facies but immature
Investigator 1	TOC 2.6%,marine facies oil and gas prone
Jupiter 1	Poor gas-condensate minor oil, above 2400m is good oil source as more marine influence higher in section Below 2400m sufficiently mature to generate oil - but gas prone. Main oil window 3000-3200m -Entered mature section VR=.5% at ~3000m and TD at VR=1.3%~5000m.
Mercury 1	Poor to good source rock
Sirius 1	Very good oil source-immature
Vinck 1	3% average TOC

It appears that ***the upper Triassic is potentially a good gas condensate light oil prone source rock on the Exmouth Plateau with reasonable TOC levels and a favourable increasing marine influence higher in the section***. Nowhere however has this favourable upper section been encountered where it is definitely mature.

Upper Triassic Source Possibly Mature in Early Cretaceous:

Those wells that have intersected the upper Triassic have done so on high blocks, often interpreted as being immature. However it should be noted that current interpretations suggest that Triassic vitrinite levels may be significantly supressed and in the case of Jupiter 1 massive down hole contamination is suspected (Wilkins et al 1992). On this basis the upper Triassic could be currently mature across the Exmouth Plateau. Geohistory modeling suggests that peak maturation levels were reached at the middle of time slice K1 and have stayed frozen at these levels ever since. Jupiter 1 where interpretation of maturity levels is ambiguous (but could be mature in the youngest Triassic) is not buried beneath the thick Barrow Delta (time slice K1) sediments which would definitely push the upper Triassic into the generative window.

There are definite signs that generation from the Upper Triassic is occurring. Most wells which intersected upper Triassic sediments have indications of mature migrating gasoline fraction hydrocarbons. Presumably the gasoline fraction is being expelled from where the section is mature.

TABLE 6: GASOLINE FRACTION COMMENTS FROM WELL COMPLETION REPORTS, EXMOUTH PLATEAU.

Well	Gasoline Fraction comments from well completion reports
Eendracht 1	gasoline fraction in Triassic has all migrated from deeper.
Investigator 1	Definite migrating hydrocarbons.
Jupiter 1	Migrated hydrocarbon high in section.
Mercury 1	Not evident.
Sirius 1	Migrated gasolines in TR5 section.
Vinck 1	C2-C6 increases with depth- result of maturity gradient and migration

The upper Triassic on the Exmouth Plateau appears to have similar source potential to the upper Triassic on the Rankin Trend (liquids rich gas condensate) and has possibly been mature or submature since the middle of time slice K1. The following sections discuss the possible source for the dry gas on the Exmouth Plateau.

Lower Cretaceous - biogenic gas source (Barrow Group - Time Slice K1).

From the gas composition table (Table 4) it is likely that the gas reservoired in the lower Cretaceous in Scarborough 1 (time slice K1-Barrow Group) is derived from the same source that supplied the gas in the Triassic of the other wells. The seal to most of the Triassic traps is time slice K1 basal claystones and the geometry of the traps is such that these seal rocks could have sourced the Triassic reservoirs, usually by face loading across a fault plane, at least in some of the wells.

The time slice K1 sediments do have good gas source potential although they are everywhere immature. Briefly the source rock characteristics of the Barrow Group are:

- 1-2% TOC,
- type III land derived gas prone kerogen,
- older sections contain more reworked organic matter, and
- immature -the present temperature at Scarborough 1 reservoir is ~40°C.

This data suggests a possibility of biogenic gas generation. Further it is also universally recorded that the background methane content is very much higher throughout the Barrow Group shales and claystones in all wells eg

Mercury 1	16,000ppm
Vinck 1	10,500ppm
Echo 1	405,000ppm

However the -$\delta^{13}C$ of the Barrow Group organic carbon is ~-27‰, and for the carbonate carbon it ranges from 0‰ to -22‰ (which is unusually light) whilst the -$\delta^{13}C$ of the condensate in Scarborough 1 is indeterminate, between a biogenic and thermogenic source (pers comm Esso) and is significantly lower than the preceeding figures. Finally the prystane/phytane ratio is greater than 1, which suggests that no methanogenesis has occurred.

In Jupiter 1 where face loading of the Triassic reservoirs from the Barrow Group appears most likely the -$\delta^{13}C$ for the gas is -40‰ which is interpreted as being thermogenic. Perhaps the most significant argument against a biogenic source from the Barrow Group is the result of Investigator 1. This well appears to have drilled a valid dome in Barrow Group sediments, encountered good reservoirs, as well as the characteristically high shale methane, and has similar reservoir temperatures to Scarborough 1, but is dry over this interval. It was however successful in its secondary Triassic target.

In summary the Barrow Group (time slice K1) prodelta facies appears an unlikely source of most of the dry gas, but may be generating some early stage biogenic gas.

TABLE 7: SUMMARY OF GAS SOURCE PROSPECTIVITY SIGNIFICANCE

MAIN CONCEPT	OBSERVATION	IMPLICATIONS	K1	DEEP	U.TR
SINGLE SOURCE FOR GAS- determine the source of the gas, determine the remaining potential.	Gas composition in K1 in Scarborough 1 is the same as Triassic reservoired gas in other wells.	Same source for gas for all the wells.- or absolute fluke (Sayers pers comm 1996).	√	√	√
CRETACEOUS K1 SOURCE- WESTRALIAN SUPERSYSTEM (3) If this is source of all significant hydrocarbons then Exmouth Plateau is dry gas prone. As all major closures with DHIs have been drilled and tested the Exmouth Plateau is consequently an exceptionally poor exploration risk.	•K1 is everywhere immature. •K1 section has anomalously high methane in shales (from mud logs) in most wells. TOCs' >1 % and Type III kerogen. •All Exmouth Plateau Triassic traps could be face loaded or charged by K1. •Investigator 1: valid K1 closure, good reservoirs and high shale methane. Failed in K1 but discovered gas in Triassic. •- $\delta^{13}C$ ‰ values 1. Scarborough 1-mixed 2. Jupiter 1-thermogenic 3. Carbonate carbon in K1-thermogenic.	•gas is biogenic. •Biogenic insitu generation from K1 possible. •gas is biogenic. •K1 biogenic gas not effective or trap leaked or timing of structure wrong. The latter not likely. • •Thermogenic sourced hydrocarbons have migrated through K1 section.	√		
DEEP PERMIAN OR DEEP TRIASSIC SOURCE OF GAS-SUPERMATURE GONDWANAN PETROLEUM SYSTEM - If this is source then exploration risk is high as there is no indication of any good liquids potential associated with the dry gas accumulations.	•Dry gas, nitrogen content and - $\delta^{13}C$ ‰ values could imply supermature or exceptionally gas prone source. •Burial history suggests deep sediments reached approximately current level of maturation by end Tr6. •K1 Barrow Delta forced deeper sediment into gas cracking window.	•Low thermal gradient -top of cracking window reached at 5000m of sediment. • •Deep dry gas and other hydrocarbons escaped during Tr6 extensional rotation and faulting. Deep gas beneath regional K1 seal migrated into upper Tr and K1 traps during fault reactivation associated with Greater India breakup.		√	
UPPER TRIASSIC SOURCE-WESTRALIAN PETROLEUM SYSTEM (1)- If this source is valid then the original primary expelled hydrocarbons would be similar to the condensate of the Rankin Trend. Prospectivity enhanced as liquids rich gas condensate reserves possible in either stratigraphic or structural traps to depth of 4500m subsea on the Exmouth Plateau.	•K1 Barrow Delta forced Upper Triassic gas condensate source into generative window. Source rocks similar to that on Rankin Trend which did not mature until Cainozoic. •Some characteristics of the minor associated condensates eg apparent biodegradation water washing and odd alkane fraction effects can be caused by evaporative fractionation. •Upper Triassic section always has migrated gasoline fraction contamination •Triassic section becomes more marine in younger section and source rock quality improves	•Expelled hydrocarbons should be similar to Rankin trend liquids rich hydrocarbons but are not. •Upper Triassic sourced hydrocarbon modified by evaporative fractionation. Light ends migrate via faults to unconformity traps. •Liquids prone source generative some were down dip. •Liquids rich source potential established.			√
DRILLED TARGETS BIASED The prospectivity of the Exmouth Plateau is enhanced if the upper Triassic can be shown to have source characteristics similar to the Rankin and can be shown to be mature in places.	Most successful wells drilled on DHIs- gas specifically targeted.	•All wells intrinsically favour finding gas. If gas is a unique product of either deep gas source or evaporative fractionation then false impression of prospectivity established. •Other traps without DHIs may be valid but not yet tested			√

Supermature Early Triassic or Permian Sources for the Dry Gas.

If neither time slice K1 nor the upper Triassic are the source of the thermogenic dry gas then by default the early Triassic or older Permian section would have to be.

The Exmouth Plateau has much lower present day temperatures gradients than the Rankin Trend. The top of thermal cracking (~ 150°C) on the Exmouth Plateau is not reached until 5000m of sediment has been penetrated. This has lead to suggestions that the source of the dry gas is very deep supermature Permian or Lower Triassic, neither of which have been encountered by the drill.

The main problem with this concept is that geohistory models suggest that all of the Permian section reached the gas cracking supermaturity phase by the early Triassic and that the lower Triassic section was likewise supermature prior to the main structural fault block rotation and extension during the Fitzroy Movement that occurred at the end of the Triassic. In addition the Lower Triassic Locker Shale in the Carnarvon Basin is not favored as a source rock where it has been intersected.

Escape of any deep supermature hydrocarbons is most likely to have occurred at the end of the Triassic during the Fitzroy Movement, prior to the regional time slice K1 seal being emplaced.

Evaporative Fractionation of Upper Triassic sourced gas-condensate.

Evaporative Fractionation is a mechanism that may possibly explain the exceptionally dry gas accumulations encountered on the Exmouth Plateau and require only the upper Triassic as a necessary source rock. Evaporative fractionation is a process that occurs in the secondary migration of hydrocarbon. It is apparently a major mechanism of secondary hydrocarbon alteration in the US Gulf Coast where 77% of oils are altered by evaporative fractionation (Thompson 1988, p244).

The necessary feature is that a hydrocarbon accumulation be brought below its bubble point by some mechanism that lowers the pressure of the primary expelled hydrocarbon. This can happen by vertical migration of the hydrocarbon along a carrier bed, vertical uplift of an accumulation or most dramatically by pressure release along a fault plane.

Faults provide the main mechanism for rapid depressurisation of deeper reservoirs and if the pressure is reduced below bubble point, gas exsolution is immediate. This immediately establishes a two phase flow, a gas (vapour) phase and a liquids phase. In these circumstances the relative permeability of gas greatly exceeds that of liquids by a factor of up to 10, and as well, gas is 100 times less viscous than liquids. The result is that the gas phase flow rate is a 1000 times that of the liquids phase.

Several subsidary effects occur:

•"the ability of a compound to enter the vapour phase depends on its molecular weight, isomeric structure, hydrocarbon class and composition of the mixture."- this ability is termed the compounds fugacity; *and the fugacity of methane greatly exceeds that of ethane which greatly exceeds that of propane etc.*

•As molecular weight increases the fugacity contrast between isomers decreases meaning that only the light end hydrocarbons will show this effect.

•At any given carbon number iso-alkanes have a greater fugacity than n-alkanes so that iso-alkanes are relatively enhanced in the vapour phase and this effect mimics biodegradation.

•Aromatics tend to remain with the residual reservoir liquids and the migrating vapour phase will be depleted in aromatics particularly benzene and this effect is similar to water washing.

- The result of evaporative fractionation is a vapour phase high in methane with minor light end hydrocarbons showing compound distributions similar to biodegradation and waterwashing.

From the preceding discussion it should be apparent that the Exmouth Plateau ***dry gas accumulations might be due to an evaporative fractionation process operating on normal Upper Triassic sourced gas condensate***. The current project has not been able to pursue this further.

It is possible to distinguish between evaporative fractionation and other gas accumulation mechanisms using compound specific isotopes but this has not yet been done. Samples of condensates from any of the Exmouth Plateau wells appear to be have been used for previous analysis work. recommend it in executive summary.

Maturation Differences - Exmouth Plateau vs Rankin Trend

There are significant differences between the two areas which can be thought of as having a Triassic hydrocarbon drainage divide axis along the axis of the Kangaroo Deep.

1. The Rankin Trend is not loaded by time slice K1 Barrow Group but the southern Exmouth Plateau is (Figure 40). Time slice K1 is
    - Minor to condensed on the Rankin Trend.

- Up to 1700m thick on the Southern Exmouth Plateau.

2. The Exmouth Plateau is not loaded by the very thick Cainozoic deposits but the Rankin Trend is (Figure 57). The Cainozoic is
   - 500m thick on the Exmouth Plateau.
   - 2500m thick on the Rankin Trend.
3. Regional seals were not in place on the Rankin Trend until the earliest time slice K3 and probably younger whilst regional seals were in place across the southern Exmouth Plateau by time slice K1 or possibly older.

A critical event on the Exmouth Plateau therefore appears to be the time slice K1 regional seal and heat flow maxima of time slice K1 related to the Barrow Delta and Greater India Breakup. Consequently although the Triassic section in both areas appears broadly similar, as seismic horizons can be correlated between them, the heat flow history in the areas is different. Geohistory Modeling (BURY) at Jupiter 1 and Sirius 1, shows that the oil window rose to its maximum height at the top of time slice K1. It has remained there ever since. If the vitrinite reflectance levels are being systematically underestimated then most of the upper Triassic has been in the oil window since the early Cretaceous.

Remaining Exploration Potential.

1.Regional seismic shows that large untested intra-Upper Triassic closures are probable.

2.The intra-Upper Triassic section may contain residual condensates that have had a significant portion of their light ends removed by the evaporative fractionation process that sourced the dry gas for the shallower fault block unconformity plays that have DHIs.

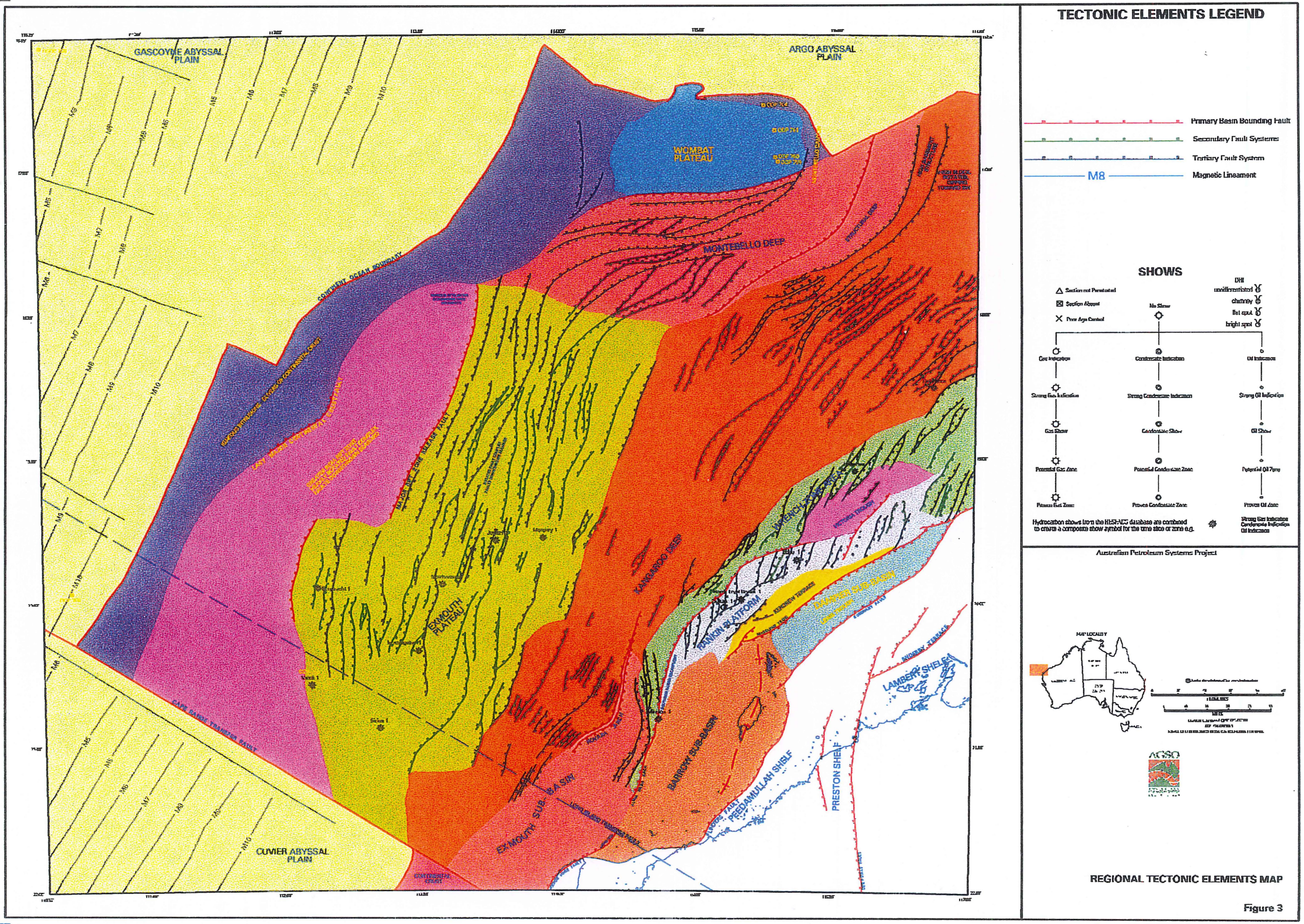
3.Consequently there may be no seismic DHIs associated with deeper accumulations due to loss of the light ends.

4.Depths to 5000m below seafloor are still below oil cracking temperature.

5.The high methane content of the Barrow Group shales could be early biogenic gas or, could be migrated gas. The later possibility is potentially significant. Because the high methane content is restricted to the Barrow Group sediments it would imply that ***the main phase of gas migration occurred during time slice K1.*** This is tectonically consistent as a major structural event, the separation of India-Australia, occurred at this time; the associated fault movement would certainly be conducive to hydrocarbon migration and fractionation from a deeper accumulation.

6.Early hydrocarbon emplacement could reduce porosity-permeability loss at deeper levels.

7.The interpreted biodegradation and water washing is possibly not significant, but rather a result of the evaporative fractionation process.



REGIONAL TECTONIC ELEMENTS MAP

Figure 3

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 4, and an example illustrating age-depth plot interpretation schemes is shown in Figure 5. 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 are shown in Figure 6 and Table 8.

Time slice data maps and palaeogeographic interpretation maps have been constructed over 25 time slices ranging from Carnian to Early Cainozoic. Each time slice data map shows the location of the thirteen wells used in the study. 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), Tmax 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). Figure 12 shows the bottom hole temperatures of all thirteen module wells plotted against total depth and against rock thickness. The plot of bottom hole temperature plotted against rock thickness is more representative due to the deep waters present over the Exmouth Plateau (in excess of 1000 metres) which have negligable bearing on temperature increase with depth.

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.

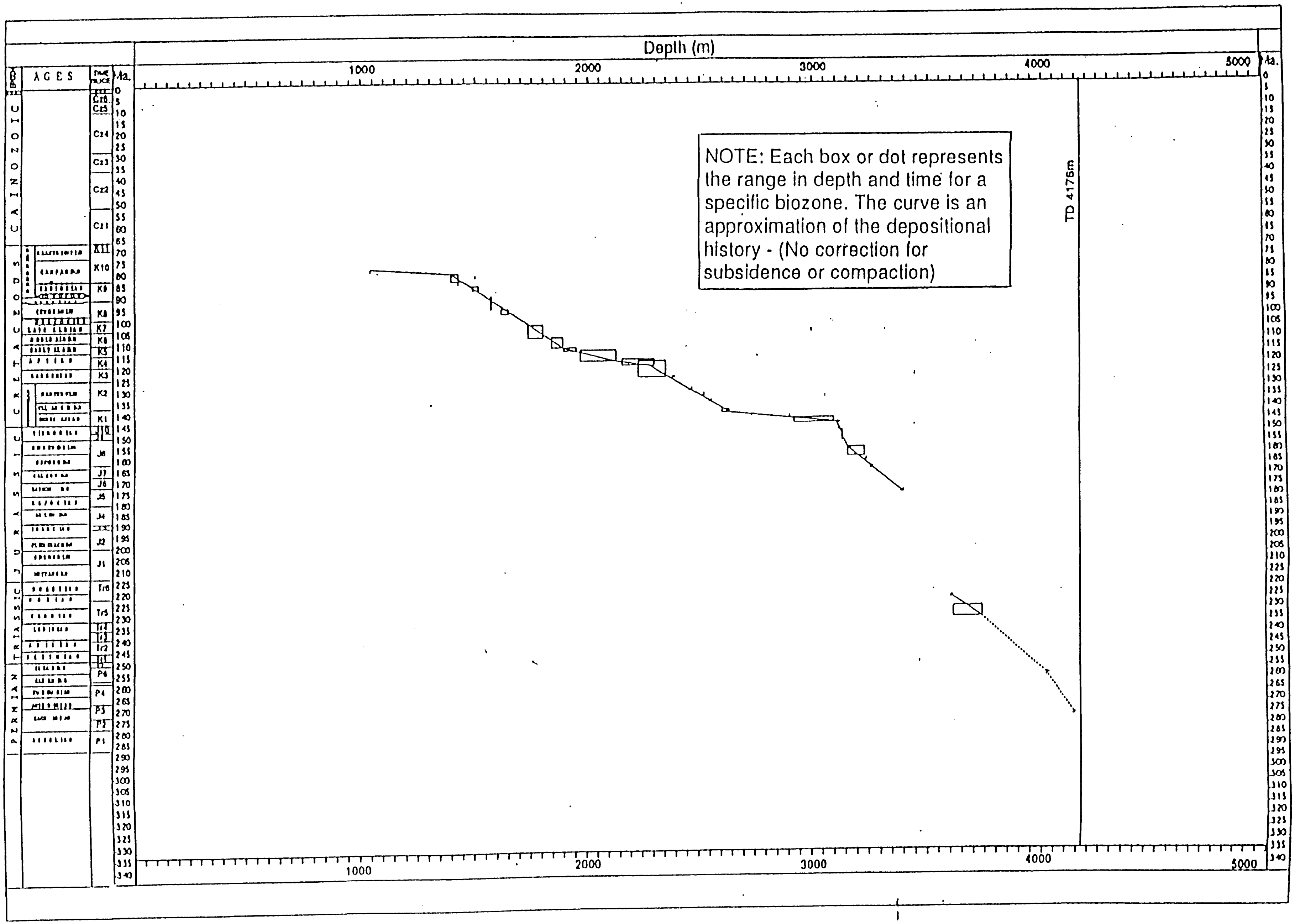


Figure 4: Age/depth plot interpreted example

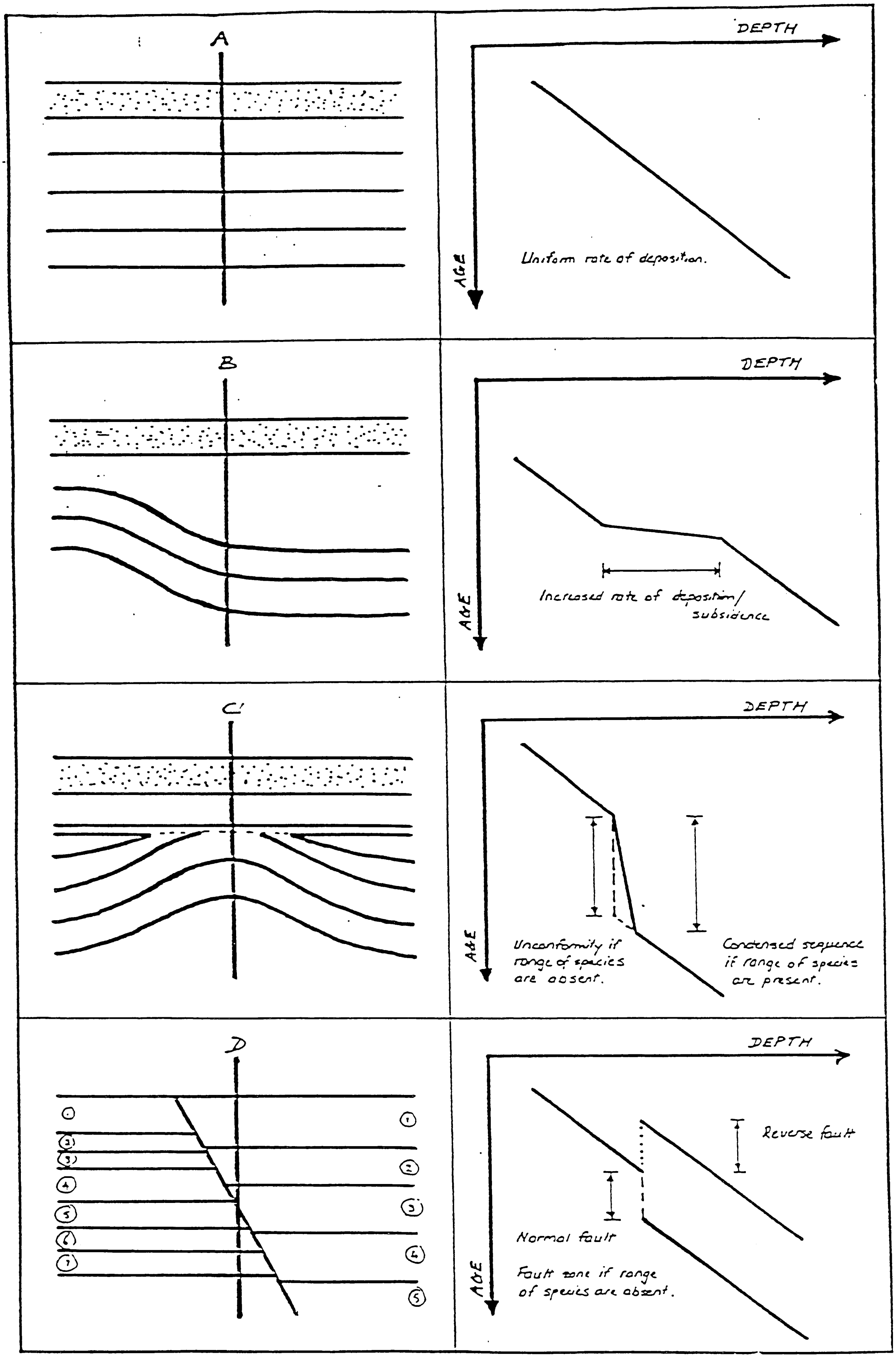
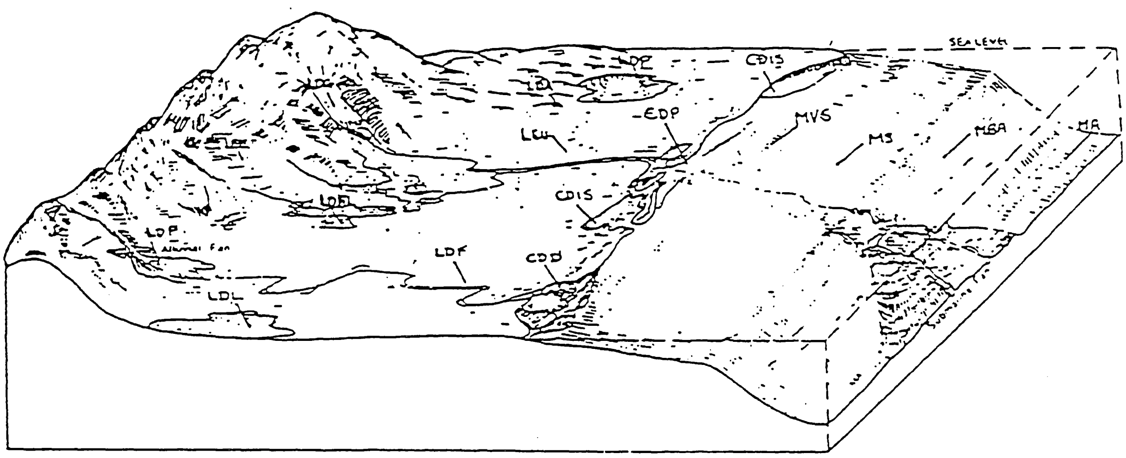


Figure 5: Age/depth plot interpretation schematic.

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 6: Depositional environments classification diagram.

TABLE: 8
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			CDDF	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			MFD	Mixed Fan Distal
					AP	Abyssal Plain		

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

TECHNICAL NOTES AND DEFINITIONS

WELL LOG CROSS-SECTIONS AT 1:7500 SCALE: *(see Figure 1).*

The cross-section set is generated at a scale of 1:7500 (see Enclosures 4 to 7).

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 Cainozoic (Blow, 1969, 1979; Berggren, 1969; Kennett & Srinivasan, 1983), and
- 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. Because of this the details presented in this study can immediately be related to more regional concepts and to maps already produced.

Time slices interpreted in this module range from the Triassic to the Cainozoic. Of the time slices defined within these periods, palaeogeographic data and interpretation maps were made for grouped time slice intervals J3-J6, K5-K7 & Cz1-7. Grouped time slice intervals J3-J6 and K5-K7 are consistent with the data sets from the previous Dampier Sub-basin module.

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 2 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.

Age depth plots are used to differentiate time slices following which depositional environments are assigned to various portions of the time slice (see Figures 4-6, Table 8).

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 Cainozoic 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-Cainozoic and Berggren (1969) for the Cainozoic. 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 Cainozoic time slices is outlined in the Barrow Exmouth Module Report (Spencer et al, 1994).

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, and

5 Very low, low diversity assemblage without key zone species,
6-9 lower, unreliable.

NOTES ON TECTONIC HISTORY: ***(see Figure 3 & Enclosure 1).***

In this report the relevant regional and local tectonic events have been described within the section for the appropriate time slice. On a regional basis, basin provinces include from north to south:

- *Argo, Cuvier and Gascogne Abyssal Plains and oceanic crust areas*: These lie to the extreme north and west of the main module areas,

- *Western and Northern Outer Exmouth Platform*: This area is adjacent to the Abyssal Plains and oceanic crust and consists of a thinned continental crust with igneous intrusions and slivers of continental crust. The sediments are present in discontinuous chaotic rotated fault blocks. Figure 7 shows a boundary between two geological provinces, namely an area of igneous intrusions and slivers of continental crust to the west and a Greater India rift zone area to the east which includes heavily rotated fault complexes where faults are downthrown seaward,

- *Mid Western Outer Exmouth Platform*: This area is landward of the above province and also consists of a thinned crust. Although it contains some igneous intrusions, generally it consists of a series of heavily rotated fault complexes, all faults are downthrown seaward to the west. The western boundary is defined by the last appearance of sedimentary blocks on seismic. Figure 8 shows the boundary between two geological provinces, namely a Greater India rift zone area to the west (which includes heavily rotated fault complexes that are downthrown seaward) and the Exmouth Platform to the east, with a similar style but with a marked reduction in intensity of the rotation. It is postulated that Greater India Breakup faulting is restricted to the western province, as evidenced from the lack of faults truncating the top time slice K1 boundary in the eastern province. Additionally there may be a reduction in dip reversal in the western province. This has implications for seal integrity.

  - *Wombat Plateau*: The Wombat Plateau lies to the very north of the module area. It is a Triassic high block overlain by relatively thin Cretaceous and Cainozoic sediments (Figure 9).

  - *Montebello Deep:* The Montebello Deep lies to the south of the Wombat Plateau. It is thought to have developed during the Lower-Middle Jurassic and become a fully mature deep in the Upper Jurassic-Lower Cretaceous (Figure 10),

- *Main Exmouth Plateau*: This area is landward of the above province and lies within the central part of the module area. No intruding igneous complexes are seen and the sediments are contained within rotated fault complexes, for the most part downthrown to the west. The western boundary is defined by a major rift zone release fault,

- *Kangaroo Deep*: This area lies landward of the above province and contains a less faulted basin sequence with only mild rotation of fault blocks. The intensity of faulting does however increase in the very north and south. The western boundary is defined where there is an increase in rotation on the blocks,

- *Exmouth Sub-basin*: The Sub-basin lies between the Novara Arch to the west and the Southern Rankin Escarpment, Alpha Hilda Arch, Yardie Hinge Fault to the east. It is characterised by a very thick fill of Middle-Upper Jurassic sediments and a much more heavily structured Triassic sequence,

- *Barrow Sub-basin*: The Sub-basin lies to the east of the Southern Rankin Escarpment, Alpha Hilda Arch and Yardie Hinge Fault system and has a substantial Middle-Upper Jurassic fill,

- *Jurassic wrench complex*: This area lies west of the Barrow Sub-basin and Rankin Platform and continues into the Beagle Sub-basin, North Turtle Wrench Zone and west of the onshore extension of the Argo Abyssal Plain transfer (Sayers et al, 1995),

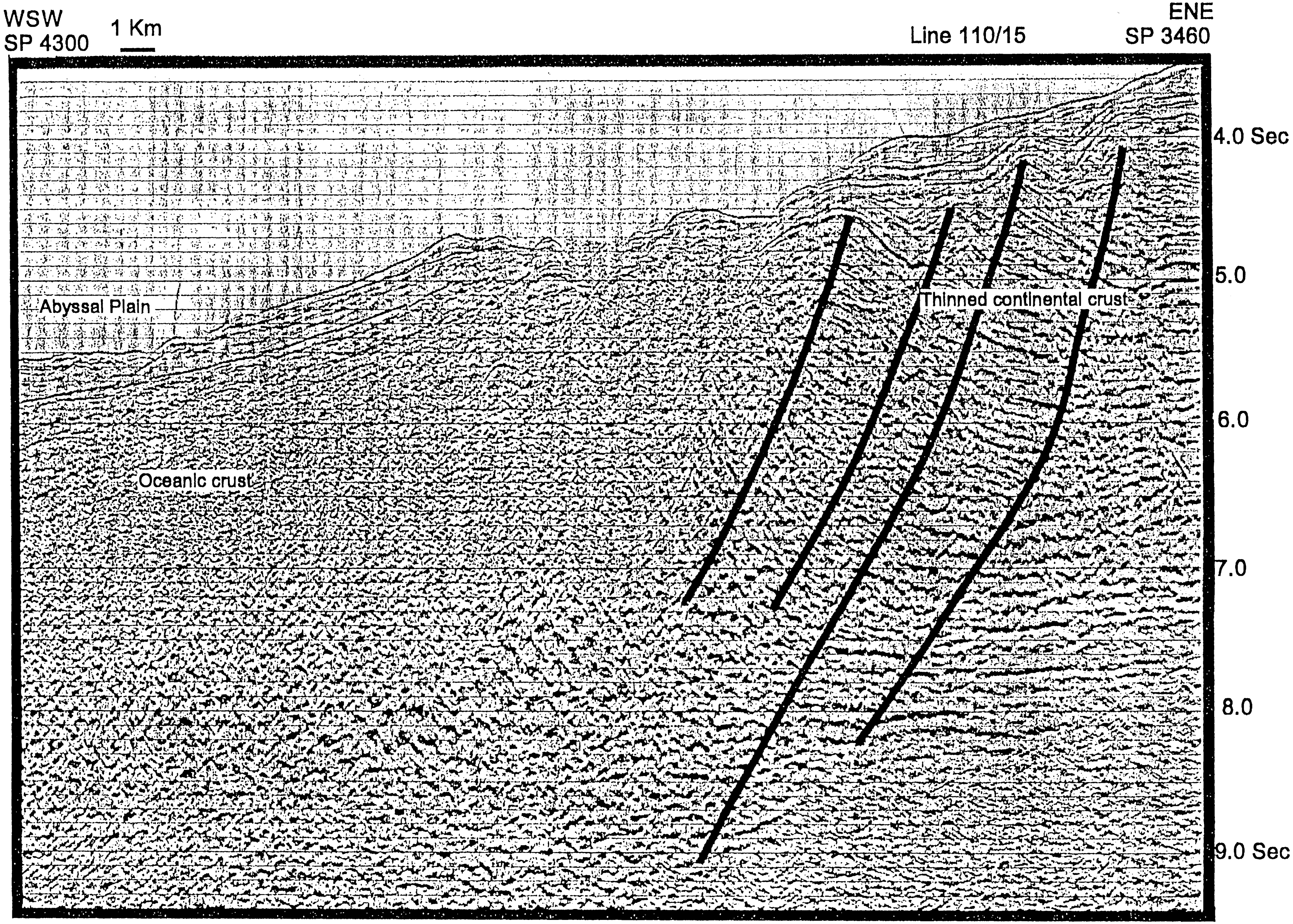


Figure 7: Outer Exmouth Platform, image of igneous provinces and heavily rotated fault block complexes.
See figure 1 for location of line.

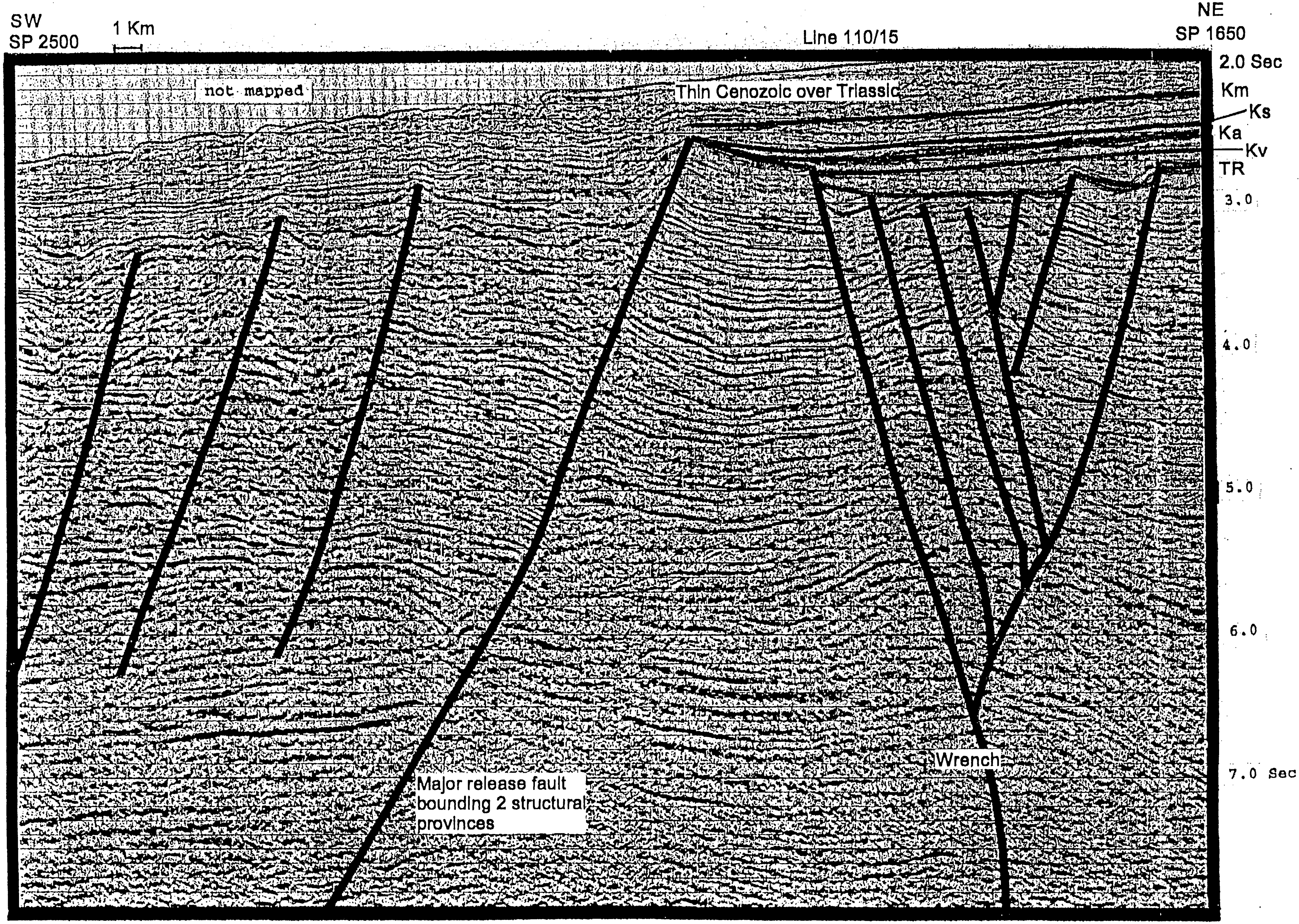


Figure 8: Outer Exmouth Platform, image of a time slice K1 major rift zone release fault and heavily rotated fault block complexes. See figure 1 for location of line. Comprehensive list of seismic horizons in enclosure 2. Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, TR - top time slice Tr5.

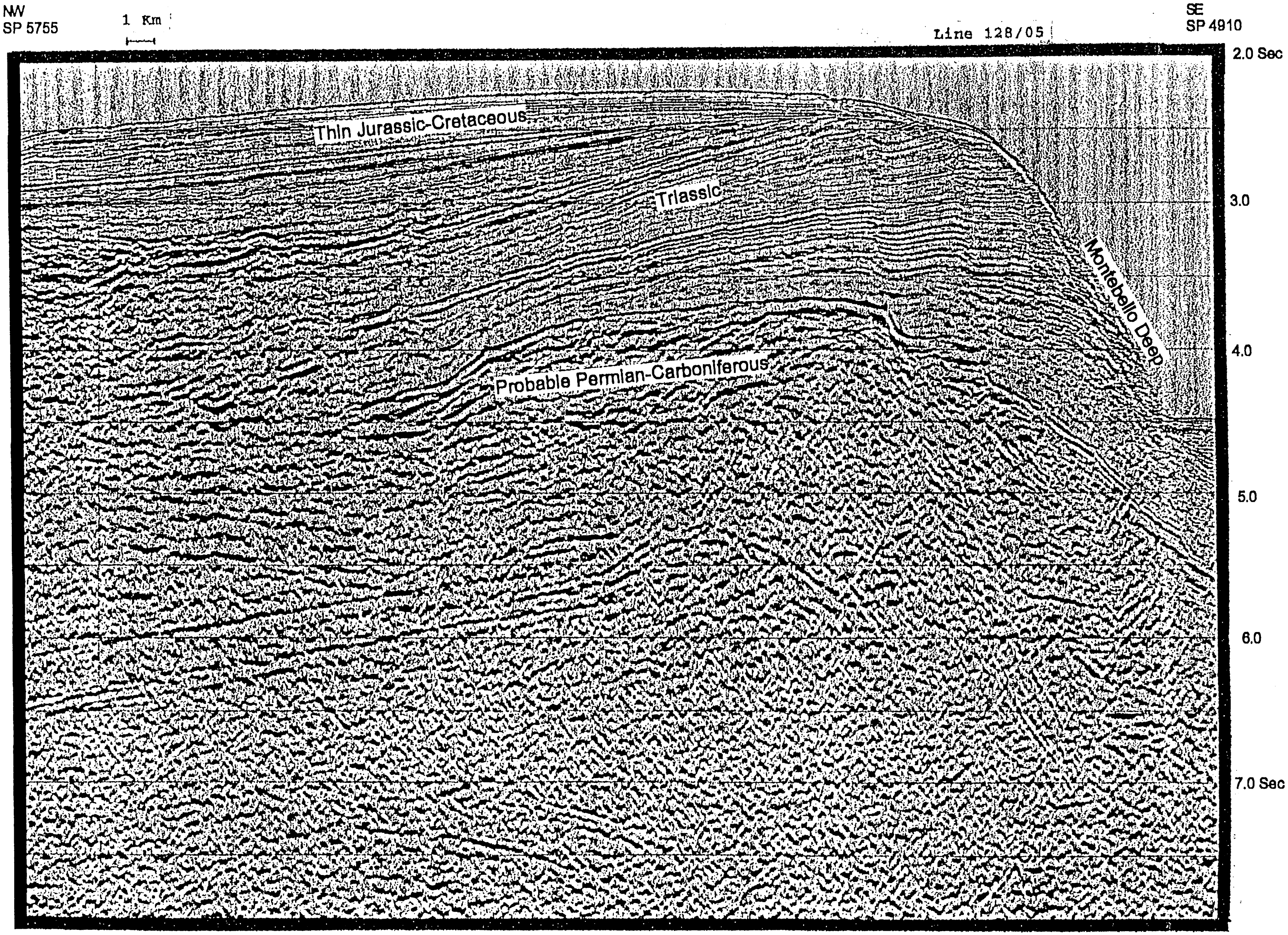


Figure 9: Image of the Wombat Plateau, sub-plateau to the Exmouth Platform. See figure 1 for location of line.

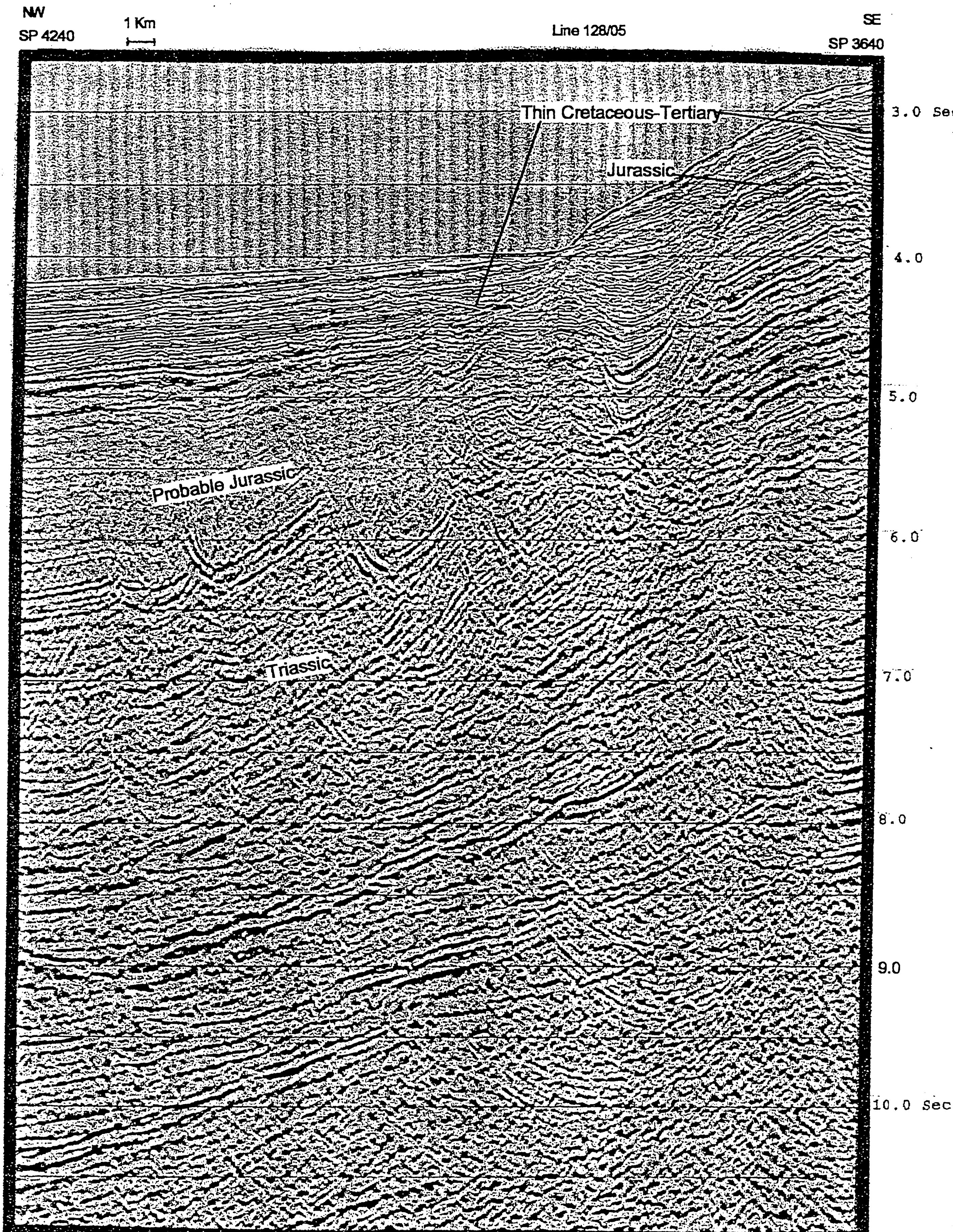


Figure 10: Image of the Montebello Deep, sub-deep to the Exmouth Platform. See figure 1 for location of line.

• *Victoria Trough*: This area lies to the north of the Rankin Trend and east of a number of wrench systems. It contains a thick sequence of Middle-Upper Jurassic sediments as compared to the Kangaroo Deep and Rankin Trend where there are none, and

• *Rankin Trend*: This is the main structural high trend with a major basin bounding fault flanking its northern boundary.

Note 1: The location term *Exmouth Plateau* refers, in this report, to the area of shallower water depth within the closed bathymetric 1150m contour. It is also the area where most of the Exmouth wells were drilled (Investigator 1, Jupiter 1, Scarborough 1, Sirius 1). The location term *Exmouth Platform* refers to areas north of the East Exmouth Continental Fracture Zone and Exmouth Sub-basin, generally including all areas north of the continental shelf break which are also all deeper water areas.

Note 2: The term East Exmouth Continental Fracture Zone (Figure 11): includes the Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone, Argoland Transfer.

Note 3: The term "Fitzroy Movement" is known in different areas of Australia to mean something different in terms of the timing and the effects of the movement. On the North West Shelf the name refers to a late Triassic to Lower Jurassic tectonic event, associated with an extensional event that coincides with the global Pangea event.

Lower-Middle Jurassic pull-apart regime:

A pull apart regime is interpreted to have been active from the Lower Jurassic up to the top of the Callovian, coincident with the breakup of Argoland. This is substantiated from:

- the anchoring of Jurassic depocentres such as the Exmouth Sub-basin, Victoria, Beagle and Cossigny Troughs as well as NNE-SSW wrench fault systems (North Turtle, Beagle, Cossigny wrenchs; Blevin et al, 1993) onto the East Exmouth Continental Fracture Zone (Figure 11). The Fracture Zone became active at the top of the Norian,

- the presence of unconformities during the Toarcian and Bajocian at Brigadier 1 and Delambre 1. These correlate in time with unconformities recorded in the inner Carnarvon Troughs (Lipski, 1993; Delfos, 1994; Rasidi, 1995). The unconformites also correlate in time with transgressive events recorded in the Outer Rowley Sub-basin (Shafik, 1994) which may coincide with structural movements and so be linked to the proposed pull apart movements,

- the presence of isolated fault patterns that resemble wrenchs on the Exmouth Platform, West Roebuck Basin, and

- the absence of some of the Jurassic time slices on the Rankin Trend is a result of movements within the Lower-Middle Jurassic that caused erosion on the Trend. Isolated Jurassic blocks of varying ages are thus preserved. This is characterisitic of a pull-apart mechanism rather than a rift mechanism. In the latter case continuous but retrograde onlap of time slices would occur.

NOTES ON ISOPACH MAPS

Thicknesses for all time slices (TR3-CZ7) within the module area were extracted from the STRATDAT database. The data was brought into Excel for quality control and formatting prior to input into the SURFER contouring package (Golden Software Inc, 1994).

Data control points for the module area are generally very sparse, so the Krigging method for irregularly sparse data control was chosen to perform the griding. Datapoint search and Krigging option parameters are summarised below.

Search Options

Search type:

Octant. The Search obtains data on an eight piece areal pattern which is recommended for sparse irregular data control points.

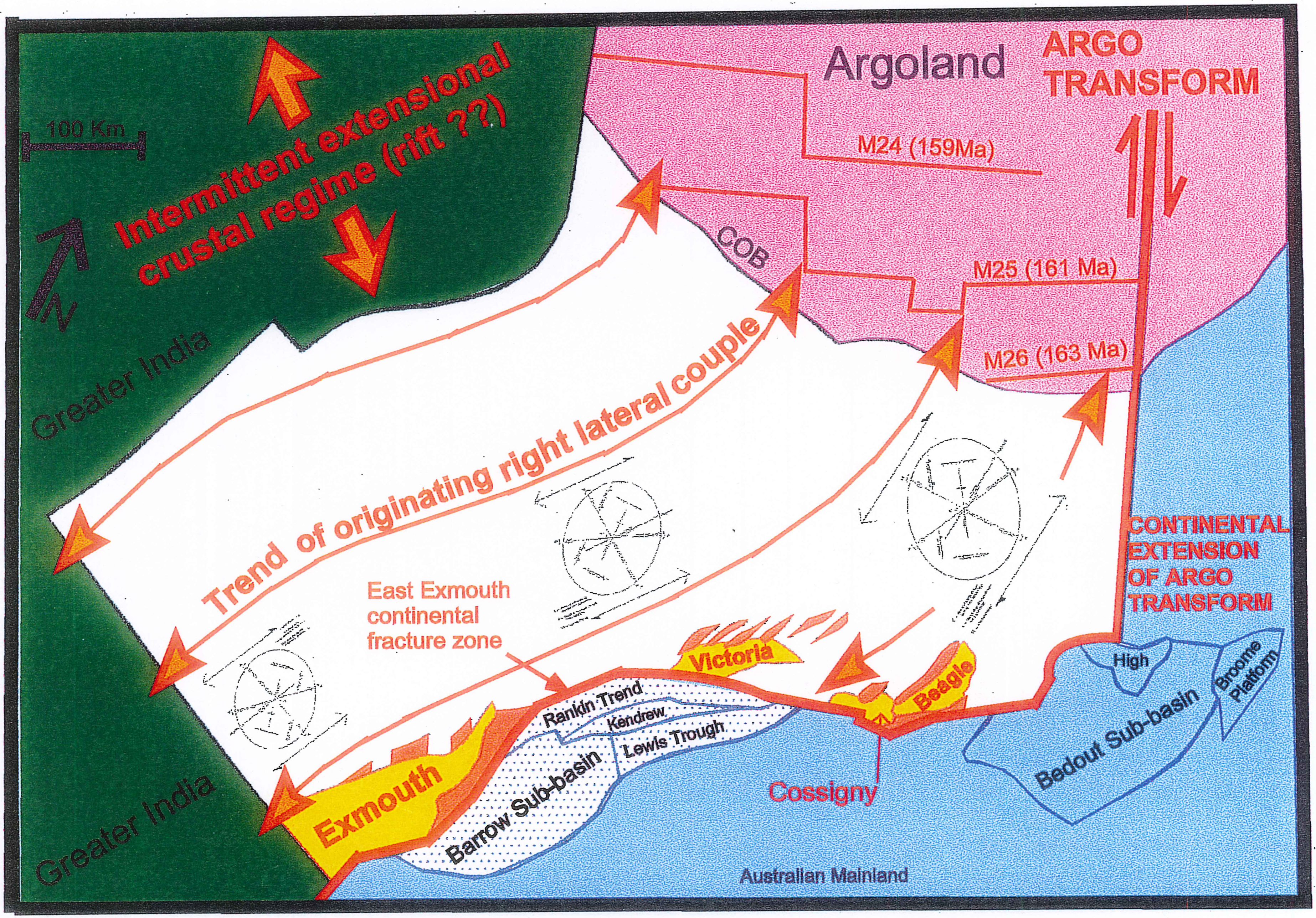


Figure 11: Conceptual diagram of the Jurassic age pull apart system (time slices J2-J7). Orange masses are zones of pull apart defined from seismic.

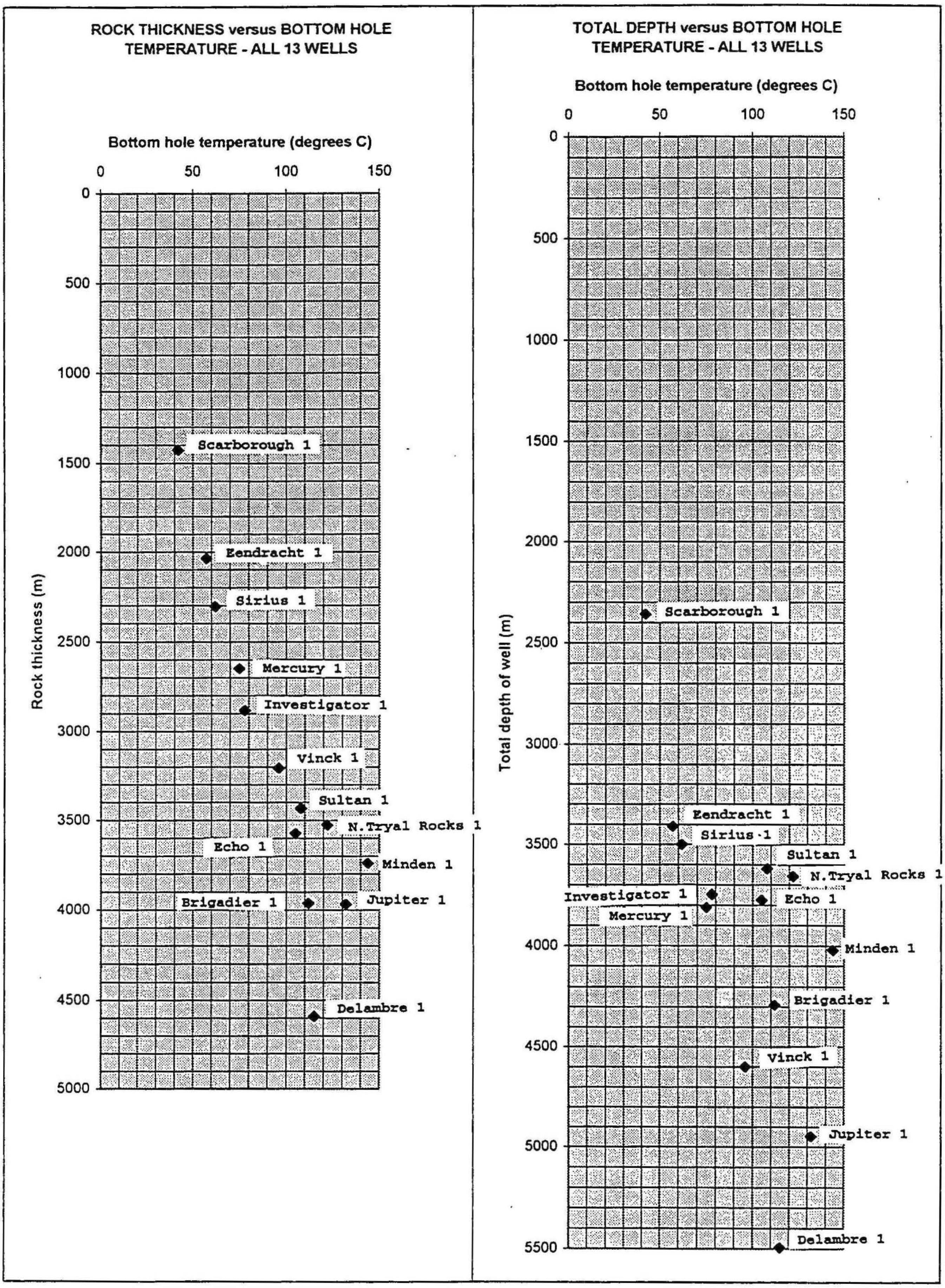


Figure 12: Total rock thickness (excluding water depths) and total depth of well plotted against bottom hole temperature.

Search rules:

Data per sector: 2. The two closest thickness values were deemed sufficient to estimate a none too heavily smoothed value for each of the 8 sectors at each grid point.
Minimum total data: 1. In view of the sparseness of the data and the search radius used, it was necessary to set the lowest value, so as not to create too many holes in the resultant grid.
Max Empty sectors: In view of the sparseness of the data and the search radius used it was necessary to set the highest value so as not to create too many holes in the grid.

Search ellipse:

Radius 1: 1 degree along the maximum radius direction, about 105 km. A smaller value may have created too many holes whilst a larger radius would have resulted in an unrealistic thickness at a particular location.
Radius 2: 0.6 degree along the minimum radius direction, about 65 km. A smaller value may have created too many holes whilst a larger radius would have resulted in an unrealistic thickness at a particular location. The minimum radius is orientated perpendicular to the structural grain of the Mesozoic basins.
Angle: 40 degrees. Estimated from the structural elements map.

Krigging options

Variogram model type: Linear.
Scale: calculated default scale.
Drift type: No drift.
Nugget Effect: none used.
Anisotropy: The following parameters were used to bias the weighting on the datapoints found within the search radius to an accepted structural grain for the Mesozoic sediment basin fill.

Radius 1: 1.0 degree.
Radius 2: 0.6 degree.
Angle: 40 degrees.

Contouring Options

Contouring was done at an interval that reflected the data range as well as the control points distribution.

TRIASSIC TIME SLICES

TIME SLICE Tr3:

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

Petroleum System: Upper Gondwanan 2, lower Westralian 1 (see Enclosure 3).

The Perth Basin is the only place in the Gondwanan Petroleum System where a proven source exists in the earliest Triassic (time slice Tr1 & Tr2), present there in marine sedimentary facies (Locker Shale equivalent). The oldest Triassic has not been penetrated on the Exmouth Plateau. However burial history interpretations suggest the pre time slice TR3 section was mature to supermature at the end of the Triassic. The deeper Permo-Carboniferous sections were supermature at the end of the Triassic.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area: The Mungaroo Formation of the Rankin Trend is the lateral equivalent of the Triassic section on the Exmouth Plateau. The Cossigny Member, the Locker Shale and Keraudren Formation may also be present in the module area.

Regional Definition of Time Slices: (see Figure 2).

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 Enclosures 2, 4-7; Appendices 1-2).

Jupiter 1 is the only well that intersected time slice TR3. Age control is fair. The interpretation is based on the recognition of the *S.quadrifidus* spore pollen zone. The top of the time slice was determined from the age depth curve.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

The Westralian Superbasin was initiated in the late Visean. This is also considered to be the time when the crustal thinning beneath the Exmouth Plateau occurred and is where the Moho is fairly shallow (~25-28km),. Fault block rotation that may have occurred, is not imaged on the seismic. Fairly rapid subsidence was matched by sedimentation and no exceptionally deep water environments are inferred for the interpreted Permo-Carboniferous and early Triassic fill. The module area was part of Pangea (Bailie et al, 1994) and was connected to the Meso Tethys to the north of the Exmouth Plateau.

Local

Mild tectonic activity probably occurred during time slice TR3 (Sayers et al, 1995) as precursor events to the breakup of Pangea during late time slice TR5 and TR6. Colwell & Stagg (1994) also 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. The importance of this event is uncertain in the Exmouth-Outer Rankin area and has not been delineated on seismic. Generally this time slice is interpreted to be a period of rapid basement subsidence with little evidence of any significant faulting or folding.

Lithology: (see Enclosure 2).

Consists of a sequence of interbedded grey-brown siltstones and claystones, with white to grey sandstones and minor coals.

Thickness Variations: (see Figure 14).

A maximum thickness of 765m was intersected in Jupiter 1 which reached total depth within this time slice (Figures 13 and 14). This maximum thickness is also the maximum thickness intersected in the Carnarvon Basin and Exmouth Platform as a whole. It is estimated from seismic that the Triassic is a relatively uniform thickness with substantial thinning occurring towards the mainland basement complexes where onlap occurs. Triassic sedimentation is the result of both erosional and depositional processes consequently a degree of caution is necessary when viewing Figure 14.

Palaeodepositional Environments: (no Enclosure).

Paralic, fluvial to shallow deltaic environments are interpreted. The general coastal energy levels appear to be low, based on the limited Jupiter 1 data and the delta system are correspondingly interpreted to be fluvially dominated.

Globally time slice TR3 is characterised by a relative sea level low and the coastline in the module area is interpreted to have regressed during time slice TR3. Within time slice TR3 there are two globally recognised 3rd

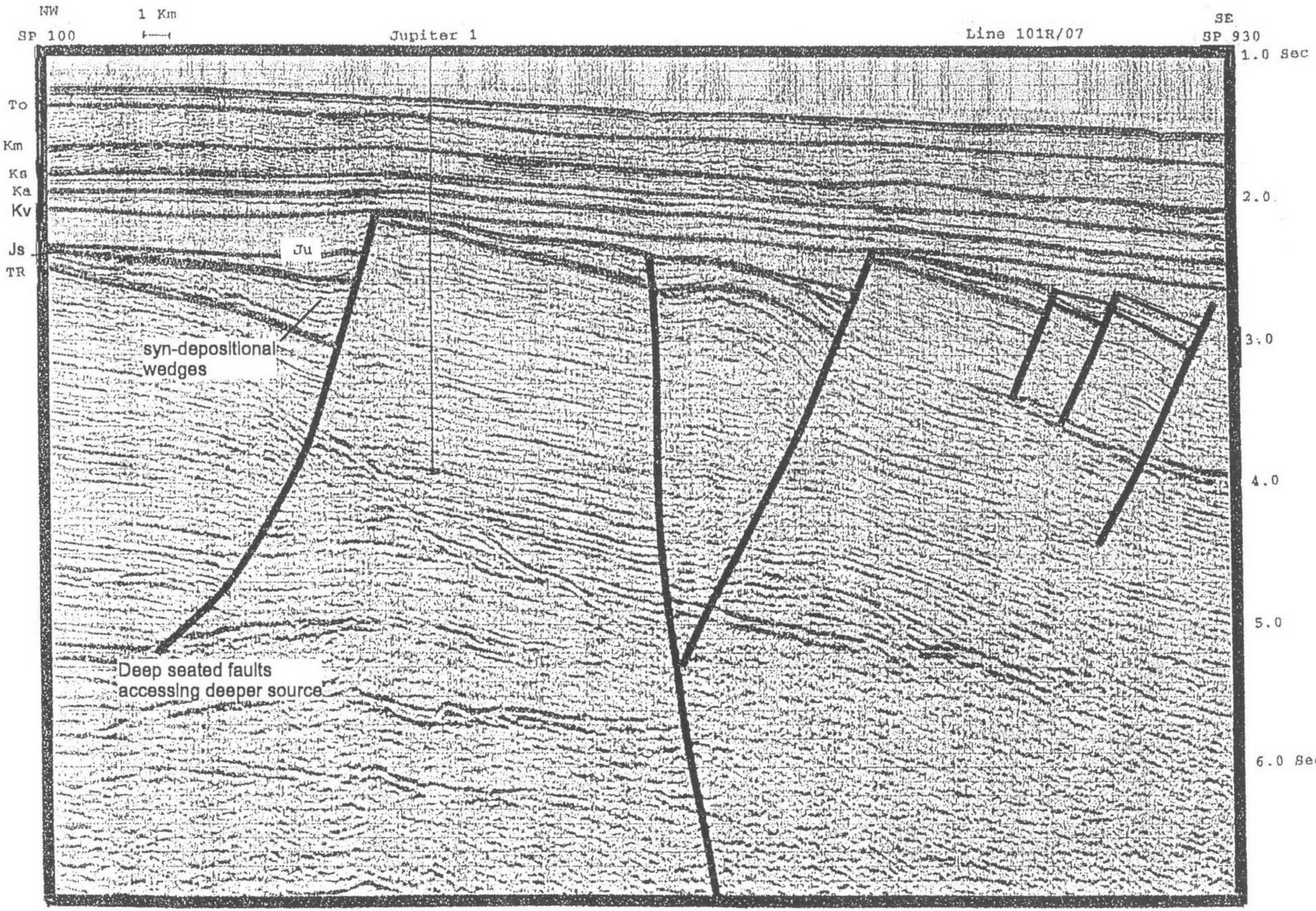


Figure 13: Jupiter 1 location and typical rotated Triassic fault blocks with overlying syn-depositional time slice J1 wedges. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Ju - top Jurassic, Js - top time slice J1, TR - top time slice Tr5.

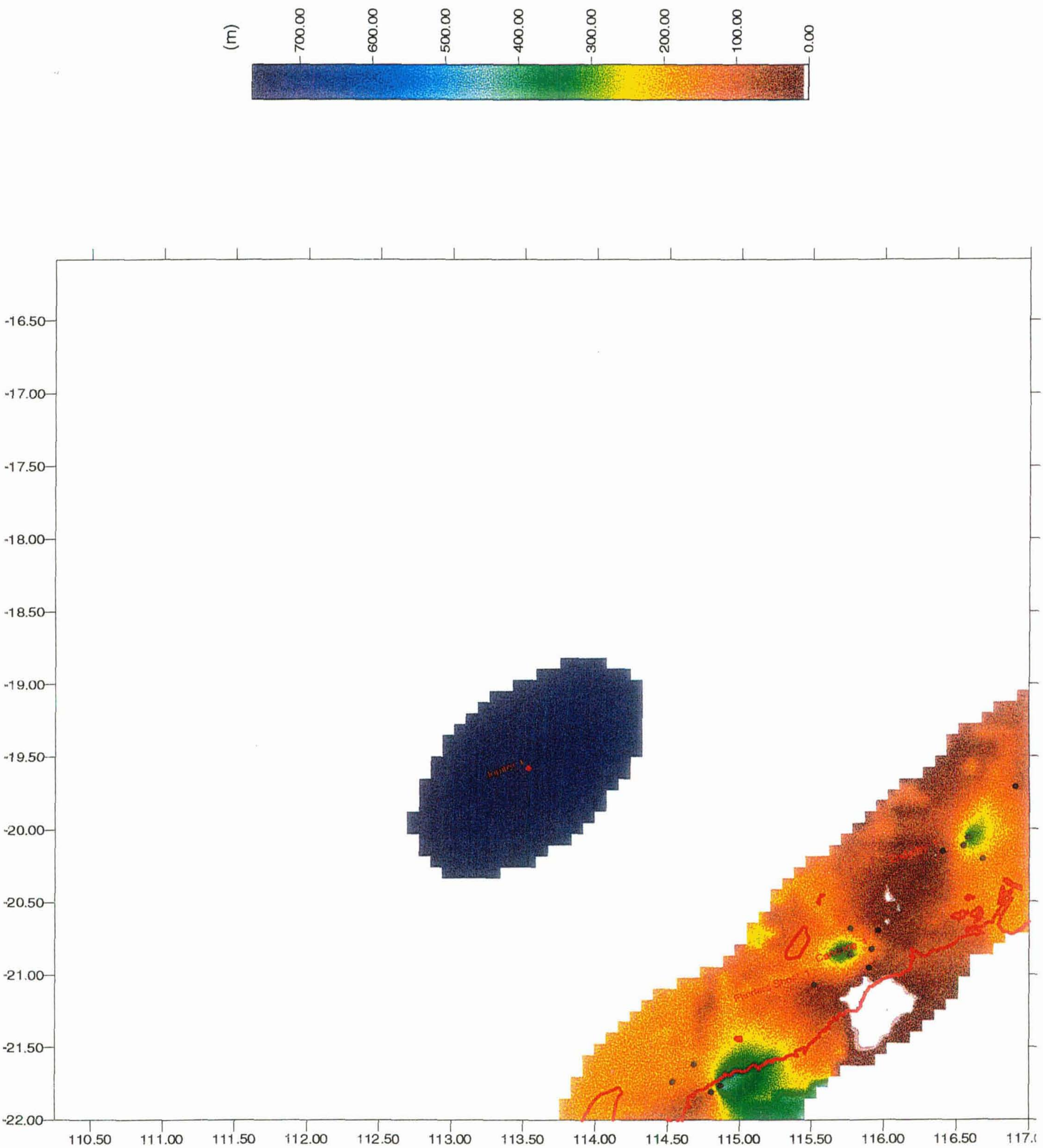


Figure 14: Time slice Tr3 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

order eustatic sea level drops (Haq et al 1987). The Australian inundation curves 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.

Palaeogeography: (no Enclosure).

Because only Jupiter 1 intersected this time slice no palaeoenvironmental interpretation has been attempted. It is interpreted that fluvial low energy deltas prograded mainly from the south, southeast and southwest across a shallow shelf, with some input more directly from the eastern margin of the basin.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

Terrestrial Type I, gas prone source material is interpreted with an average TOC of 3% and a VR=0.9% to 1.3%. The section is in the gas generative window at Jupiter 1, but parts of the section appear to be contaminated by migrating gasoline fraction hydrocarbons.

Shows, Porosity & Permeability: (see Appendix 4).

Minor gas shows were recorded in Jupiter 1, with indications of condensate common. Porosity and permeability appear to be severely degraded below approximately 4000m althought this may be a function of the facies present in Jupiter 1 rather than a regional fact.

Porosity and permeability data summary for the time slice:

Jupiter 1 — 1% < average porosity < 12%, obtained from electrical logs.

Shows summary for the time slice:

Jupiter 1 — G1 obtained from mud logs.

Prospectivity: (GOOD see Enclosure 3).

The Triassic is the only mature section on the Exmouth Plateau, so exploration effort needs to concentrate on the source potential of this interval. At Jupiter 1 time slice TR3 is definitely mature. On the basis of the evaporative fractionation model it is anticipated that much of the methane has been removed from deeper Triassic accumulations. On the Rankin Platform time slice TR3 may be overmature. Seal integrity constitutes the main risk for traps at this level but porosity loss at depth is also a concern, although this could easily be improved if hydrocarbon emplacement predated the major porosity loss.

Traps and plays.

Potentially very large intra-Triassic rollovers have been seen on several of the AGSO lines. Whether these are closed has not been established from this work. No intra Triassic traps have ever been targeted, as top seal is perceived by industry to be a major risk factor. However in Jupiter 1 time slice TR4 appears to have regional seal capacity.

TIME SLICE Tr4:

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

Petroleum System: Westralian 1 (see Enclosure 3).

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, the Victoria Trough being the exception, there are no interpreted thick Jurassic source rocks and the Westralian 1 (see Enclosure 3)source rock interval is the Upper Triassic.

An unconformity may occur 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 in the module area and is an inferred good source rock on this basis.

Formation Synonyms: (see Figure 2).

The Mungaroo Formation of the Rankin Trend is the lateral equivalent of the Triassic section on the Exmouth Plateau.

Regional Definition of Time Slices: (see Figure 2).

The top of time slice TR4 is defined as the top of the Ladinian. In the earliest work it equates to conodont zone *E.mungoensis*. On the North West Shelf the base of time slice TR4 is defined as the top of dinoflagellate zone *S.ottii*. Biostratigraphically it was originally defined by spore pollen zones, uppermost *S.quadrifidus* and lower *S.speciosus*. No dinoflagellate zone is recognised within this interval. 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. On this revised basis *S.speciosus* cannot be time slice TR4 age.

Palaeontology: (see Enclosures 2, 4-7; Appendices 1-2).

Only Jupiter 1 is interpreted to have intersected time slice TR4 aged sediments. The *S.quadrifidus* faunal zones that defines the time slice straddles both time slices TR3 and TR4, whilst *S.speciosus* straddles both time slices TR4 and TR5. The age depth plot was used to estimate the best location for the boundary.

There is a 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 Beagle - Offshore Canning area. It defines the boundary between the Gondwanan and Westralian Petroleum Systems. However no definite unconformity exists on the Exmouth Plateau.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

The module area was part of greater Pangea (Baillie et al, 1994). Pre Norian structural events occur in the Middle Triassic, precursors to the breakup of Pangea. 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

Time slice TR4 is interpreted to be a period of rapid basement subsidence with little evidence of any significant faulting or folding in the module area. The top of time slice TR4 is dolomitic and may represent a soil horizon indicative of an unconformity or exposed delta top.

Lithology: (see Enclosure 2).

Consists of a monotonous sequence of dominantly interbedded grey-brown siltstones and claystones, with secondary white to grey sandstones and minor coals and dolomites.

Thickness Variations: (see Figure 15).

Jupiter 1 intersected 809m, the only well in the module to intersect this time slice. This maximum thickness is also the maximum thickness intersected in the Carnarvon Basin and Exmouth Plateau. It is estimated from seismic that the Triassic is a relatively uniform layer of sediments but substantial thinning does occur towards the mainland basement complexes due to onlap. The Triassic time slice isopach is

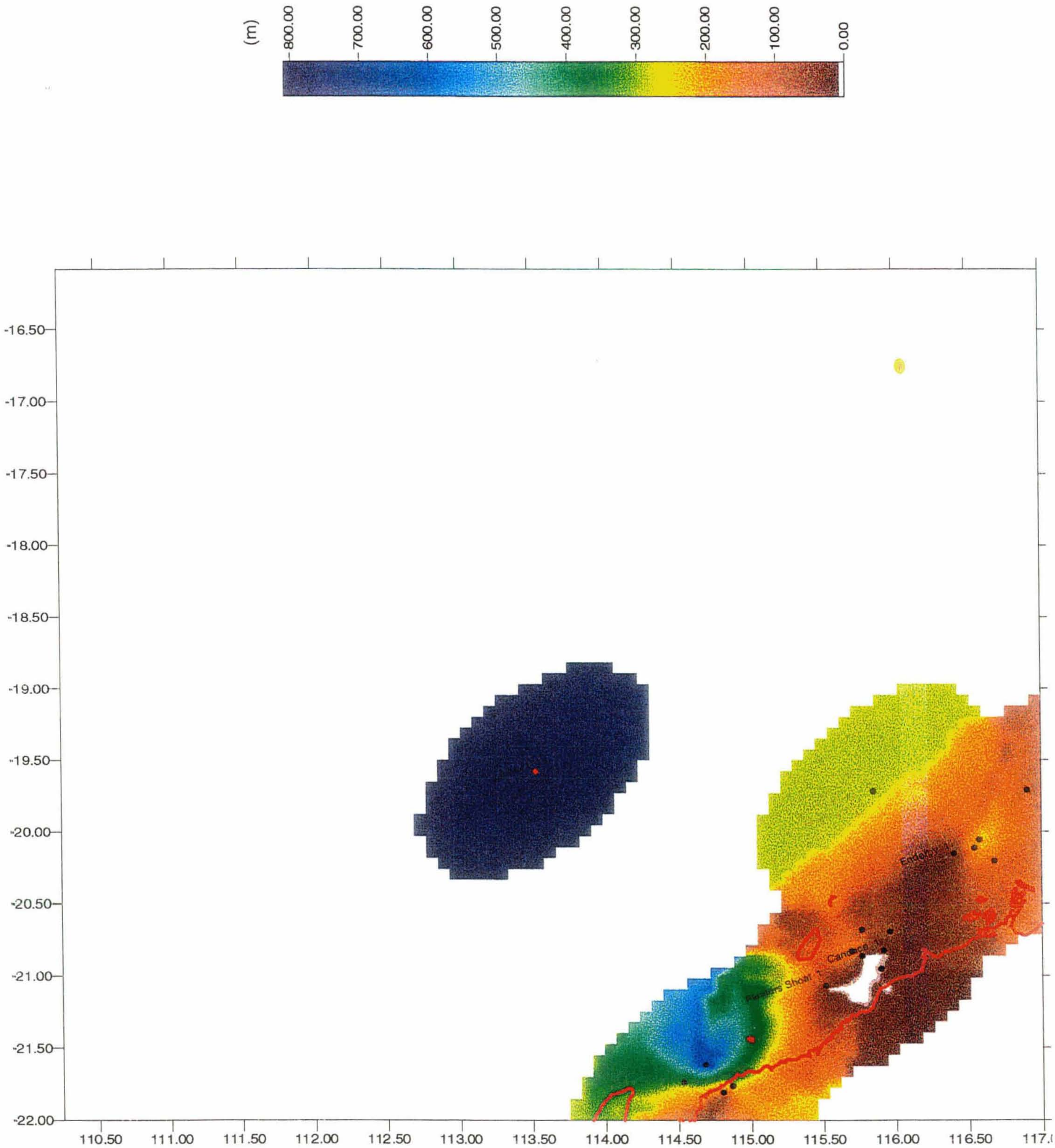


Figure 15: Time slice Tr4 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

the result of both erosional and depositional processes consequently a degree of caution is necessary when viewing Figure 15.

Palaeodepositional Environments: (no Enclosure).

Fluvial, and delta plain environments dominate this section. 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 show a uniform eustatic regime (Struckmeyer & Brown 1990).

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). Regression is interpreted to have occurred in the module area during time slice TR4.

Palaeogeography: (no Enclosure).

Because only Jupiter 1 intersected this time slice no palaeoenvironmental interpretation has been attempted. It is interpreted that fluvial low energy deltas prograded mainly from the south, southeast and southwest across a shallow shelf, with some input more directly from the eastern margin of the basin.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

No geochemistry exists for this time slice. This time slice is poorly sampled, and consequently source rock quality is poorly understood. It is reasonable to expect that the generative potential of the source rock will be similar to that on the Rankin Trend which holds Australia's major gas reserves. The maturation history of the source rock will however be different due to the lack of Jurassic and reduced Cretaceous and Cainozoic loading in the Outer Rankin and Exmouth Platform areas.

Shows, Porosity & Permeability: (see Appendix 4).

Porosities between 15-10% are interpreted for time slice TR4 in Jupiter 1. Permeabilities in clean sands are inferred to be low. Gas peaks associated with coals are common.

Porosity and permeability data summary for the time slice:

Jupiter 1 — 1% < average porosity < 7%, obtained from electrical logs.

Shows summary for the time slice:

Jupiter 1 — G1 obtained from mud logs.

Prospectivity: (GOOD see Enclosure 3).

The time slice is in the peak oil generative window in the vicinity of Jupiter 1. Sands in the Jupiter 1 area are most likely to be fluvial or distributary channel sands. More laterally continuous sands may exist towards the northwest or west where it can be anticipated that delta front, or shoreface sands developed in the transition zone between the fluvial to shallow shelf environments. Porosity may be preserved.

Traps and plays.

Stratigraphic traps could exist in isolated fluvial sands in the Jupiter 1 area and to the north, northeast and northwest where stratigraphic traps may exist in beach sands. The unit as a whole is fairly shaly and intra-time slice Tr4 sub-regional seals are probable.On this basis dip closed structures are viable.

TIME SLICE TR5:

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

Petroleum System: Westralian 1 (see Enclosure 3).

This is one of the most significant time slices of the Westralian System. It is a major source interval as well as a significant reservoir interval for the giant gas condensate accumulations of the Rankin Trend. Many of the major gas accumulations in the Barrow-Exmouth and Dampier Sub-basins, even if not reservoired in the Triassic, can be shown to be sourced from this time slice or the immediately associated time slices. There is no obvious significant difference in the palaeoenvironments found in the module area and those in the Barrow-Exmouth and Dampier Sub-basins. On this basis time slice TR5 is considered to be a source interval over the module area. However the section is generally immature to sub mature where drilled. In nearly all Exmouth Plateau wells there are strong indications of migrated gasoline fractions throughout the section and this is interpreted to indicate downdip generation and maturity. Evaporative fractionation effects are interpreted to have occurred during secondary migration phases of the time slice TR5 sourced hydrocarbon. This effect is thought to upgrade the prospectivity of time slice TR5.

Formation Synonyms: (see Figure 2).

The Mungaroo Formation of the Rankin Trend is the lateral equivalent of the Triassic section on the Exmouth Plateau.

Regional Definition of time slice: (see Figure 2).

The top of time slice TR5 is within the spore pollen zone *M.crenulatus* and equates to the boundary between dinoflagellate zones *H.balmeii* and *S.listeri*. Time slice TR5 is defined by spore pollen zones upper *S.speciosus* and lower *M.crenulatus*.

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. On this basis all of *S.specious* is within time slice TR5. *S.specious* is therefore restricted to the Norian. The Carnian section, although still part of time slice TR5, is not recognisable by dinocysts or spore pollen.

In this project we have adhered to the definition of time slice TR5 that was used in previous modules.

Palaeontology: (see Enclosures 2, 4-7; Appendices 1-2).

Eleven of the module wells encountered this time slice. Palynological control is generally fair. However because of the broad range of the spore-pollen zones used to date this section it is difficult to improve the resolution of the timing of the Fitzroy Movement that commenced in the late Triassic. The interpretation of the timing of episodes of the Fitzroy Movement, as established here, is based on a combination of seismic, previous regional overviews, time depth curve interpretations and the available palaeontology. As the Triassic is the most prospective section on the Exmouth Plateau, additional work to improve age dating of the section is definitely warranted.

A key event is the apparent absence of the dinoflagellate zone *H.balmei* across the module area. This absence is interpreted from fair palynological evidence in Sirius 1, and was extrapolated across the module area through the use of seismic and the age depth plots. The interpretation is consistent with regional events established for the North West Shelf but cannot be considered as fact. This event is thought to mark the commencement of the Fitzroy Movement.

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

- Brigadier 1:	*M.crenulatus* (B2, B5),
- Delambre 1:	*A.reducta* (B3, B5), *M.crenulatus* (B5),
- Echo 1:	*M.crenulatus* (B2), *H.balmei* (B1),
- Eendracht 1:	*M.crenulatus* (B1, B3),
- Jupiter 1:	*M.crenulatus* (B4, B3),
- Mercury 1:	*M.crenulatus* (B5), *S.speciosus* (B5),
- North Tryal Rocks 1:	*M.crenulatus* (A2), U.*S.speciosus* (B2), L.*S.speciosus* (B5),
- Sirius 1:	*M.crenulatus* (B2, B4),
- Sultan 1:	*M.crenulatus* (B3), *S.speciosus* (B3),
- Vinck 1:	*M.crenulatus* (A1, B1).

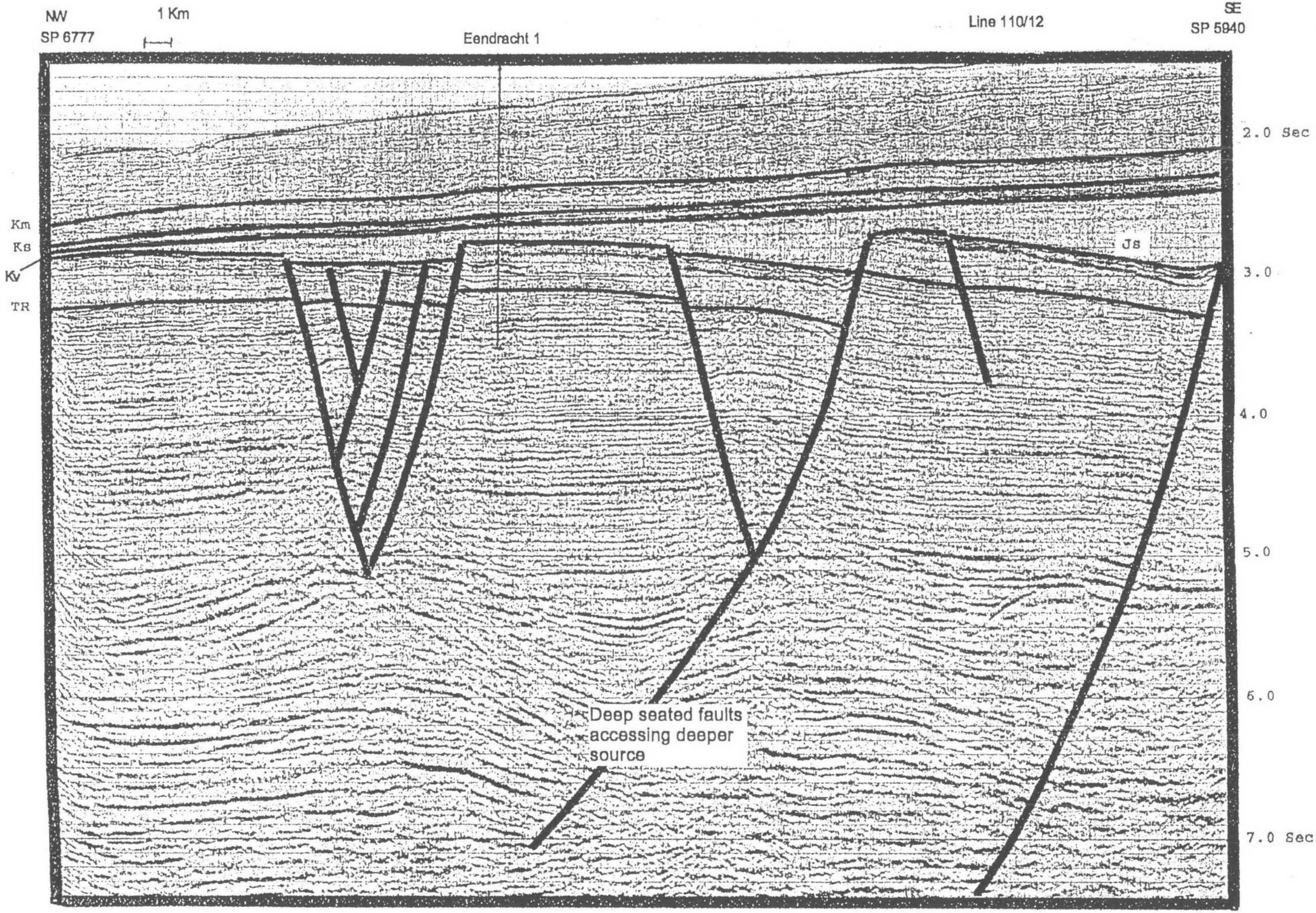


Figure 16: Eendracht 1 location and typical structural and stratigraphic configuration on the Exmouth Plateau. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. Km - top Cretaceous, Ks - intra time slice K9, Kv - top time slice K1, Js - top time slice J1, TR - top time slice Tr5.

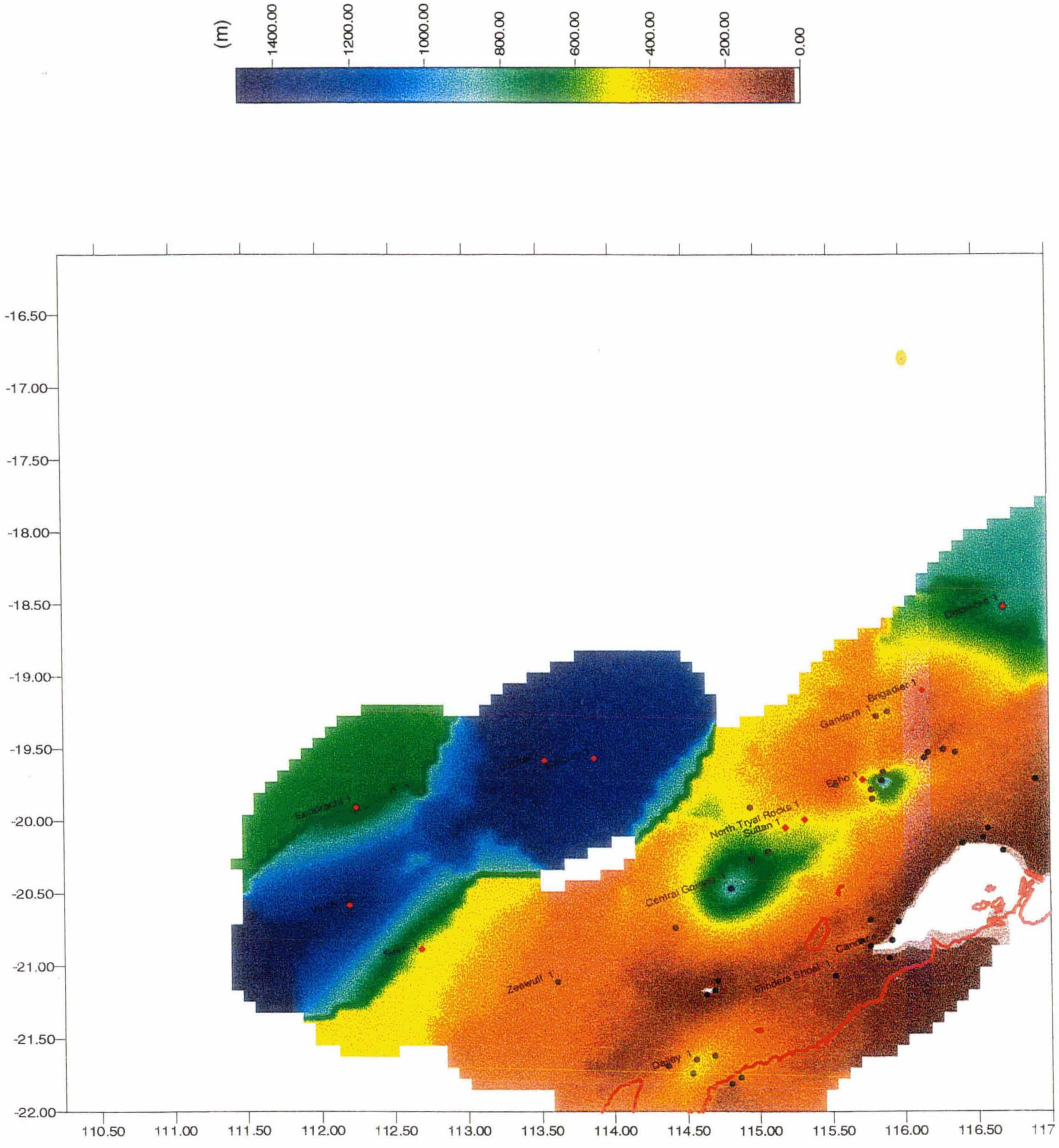


Figure 17: Time slice Tr5 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

The end of time slice TR5 is a period of major structuring with the commencement of the Fitzroy Movement over the entire North West Shelf. Time slice TR5 is bounded at the top by a rift related unconformity but is conformable on time slice TR4. This tectonic event is coincident with the breakup of Pangea and spans time slices TR5 - J1 in the module area. 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). This was also the time when the Chinese terrane blocks collided with Eurasia.

Local

In the module area, the Fitzroy Movement is a major extensional tectonics episode that commenced in uppermost time slice TR5 and concluded in time slice J1. It includes three tectonic pulses: top Norian (intra time slice TR6), top Triassic and intra time slice J1. In general the event is characterised by normal faulting dominantly downthrown to the west. The degree of extension is still substantially less (Beta factors less than 2) than that required for the creation of oceanic crust. This is described more fully under the time slice TR6 section.

The first tectonic pulse ranges from top time slice TR5 to mid time slice TR6 (see Enclosure 2). It has been preferentially placed at top Norian so as to comply with the evidence established in the Roebuck and Offshore Canning Basins-Beagle Sub-basin (Sayers et al, 1995). This event coincides in the Beagle-Offshore Canning Basins module with the Fitzroy Movement onshore and rifting events in the Rowley Sub-basin.

As detailed in the palaeontology section the start of the event is based on the absence of the *H.balmei* zone in the module wells but no clear cut angularity of the top Norian surface (time slice TR5) with overlying time slice TR6 sediments can be substantiated anywhere within the module area. Time slice J1 directly overlies time slice TR5 sediments at North Tryal Rocks 1 where there is clear evidence of strong angularity on the top Norian surface (time slice TR5). This is however not conclusive proof of a structural phase at the top of the Norian since it could have been between the top Norian and top Triassic.

This top Norian structural pulse initiated an extensional regime with the main basin bounding faults forming the East Exmouth Continental Fracture Zone. It was accompanied by a relative sea level rise. It is not however the major uplift event which stripped portions of the Upper Triassic in many areas of the North West Shelf eg the adjacent Roebuck and Offshore Canning Basins-Beagle Sub-basin. The relative sea level rise is substantiated from the presence of the marine sediments (carbonates, marls) in overlying time slices TR6 and J1. Until this event most of the module area was fluvio-deltaic dominated, but after this event a shallow sea transgressed the area.

Figures 16 and 18 show some of the Triassic seismic features observed together with the relatively more transparent seismic signature in the Upper Triassic. This contrast helped pinpoint the stratigraphic level of the top Norian aged unconformity. The Upper Triassic aged faults extend into Mid Carboniferous - Late Permian age rocks thereby accessing potential fractured Permian coals and hence source rocks. It is possible that the Scarborough 1 gas is sourced from these rocks. It is also possible that this faulting allowed the supermature gases of the lower Triassic and Permian sections to escape.

Callovian age faulting on the Exmouth Plateau is possible but cannot be substantiated. This is because almost all faulting is a reactivation of the top Triassic faults, and a major reactivation occurred at time slice K1. On the Exmouth Plateau the Jurassic is thin or condensed and it cannot be determined from seismic if any Callovian aged offset is present, and near Delambre 1 the Cretaceous is thin and only time slice K1 faulting is definite. Figure 20 explains the preferred interpretation of the main faulting event on the Exmouth Plateau.

Both Eendracht 1 and Investigator 1 drilled rotated Triassic horst blocks on the Exmouth Plateau, which have DHIs'. Syn depositional wedges of Mid Carboniferous - Late Permian are interpreted. Similar features were observed in the Rowley Sub-basin (Sayers et al, 1995),

Lithology: (see Enclosure 2).

The time slice contains a mix of sandstone, siltstone, shale and coal.

Thickness Variations: (see Figure 17).

A maximum thickness of 1496m was intersected in Vinck 1 which reached total depth within this time slice. It is estimated from seismic that the Triassic is a relatively uniform layer of sediments with substantial thinning occurring towards the mainland basement complexes where onlap occurs. Triassic time slice thickness is the result of both erosional and depositional processes consequently a degree of caution is necessary when viewing Figure 17.

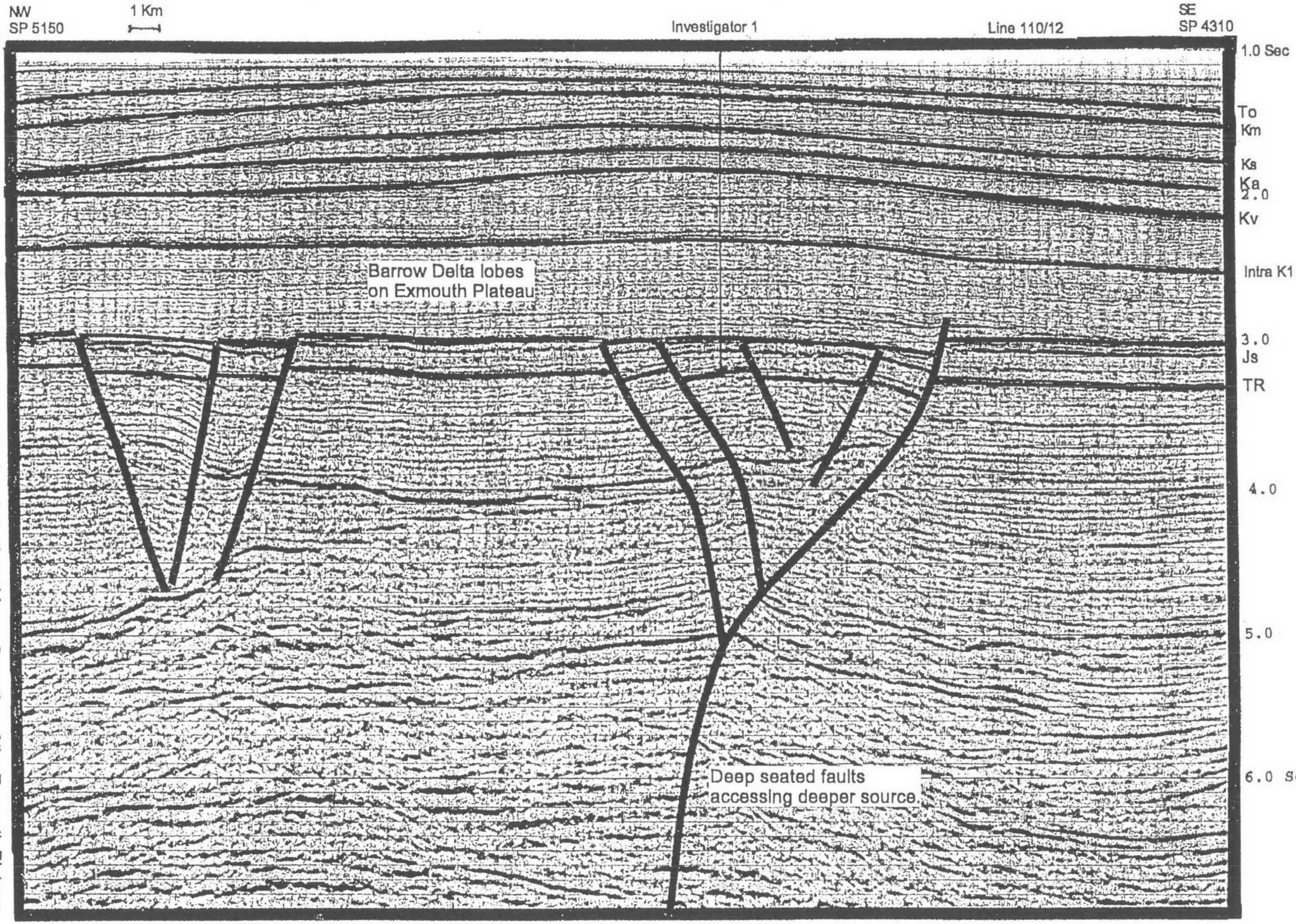


Figure 18: Investigator 1 location and typical structural and stratigraphic configuration of the Exmouth Plateau. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Js - top time slice J1, TR - top time slice Tr5.

Palaeodepositional Environments: (see Enclosure 8).

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) show a uniform eustatic regime (Struckmeyer & Brown 1990). 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 9).

- It has not been possible to substantiate pre-time slice TR5 structure and therefore geomorphological trends, therefore limiting the resolution of the palaeogeographic interpretation.
- Particular palaeogeographic environments have been interpreted to terminate along the boundary of the East Exmouth Continental Fracture Zone as this zone is already thought to have acted as a crustal weakness. Only the main basin bounding faults are interpreted to be present at this time.
- A number of NNE trending blocks including the Sable and Ronsard blocks are interpreted to be present in the later stages of time slice TR5, in the very middle east side of the map. These blocks could possibly be of top Triassic age or even Jurassic in age.
- Sediment supply is interpreted to be coming from the south east off the Australian mainland and from the south west off the Greater India continent.
- The most transgressive part of the time slice is at the top as evidenced from log interpretations.

Reefal marine faunas of probable Norian to Rhaetian age, have been recovered from dredge samples taken from the continental slope near the Continental Ocean Boundary along the northern Exmouth Platform. A shallow warm water reef environment existed in the vicinity of the Wombat Plateau (Stanley, 1994 & Grant-Mackie, 1994). The reefs presumably grow near a palaeocontinental shelf, interpreted to strike roughly parallel to the present day North West Shelf coastline (Nicoll & Foster, 1994). A wide continental shelf seaway existed between this outer reef province and the inner Exmouth-Barrow-Dampier area. These seaways are best interpreted as epicontinental seas (Yeates et al, 1987). The inner area is known from previous modules to be clastic dominated. In the adjacent Dampier Sub-basin the time slice TR5 section includes fluvial and deltaic environments, with meandering rivers dominant in the southeast and extending as far west as the Exmouth Sub-basin and Rankin Platform region. There is evidence of marine inundation and sediment reworking associated with a high energy, possibly tidal, coastal environment, especially near the top of the interval. The fluvial sediments probably prograded into a rising sea level but lobe switching may have allowed localised transgressions. 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. Simultaneous uplift in the Canning Basin to the north (the Fitzroy Movement) provided the dominant sediment source for the continued progradation of sediment in the area.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- 0.7% < average TOC < 3.2% (4 control points),
- 0.6% < average VR< 0.7% (2 control points), and
- HI of 75 at Brigadier 1.

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. It is reasonable to expect that the generative potential of the source rock will be similar to that on the Rankin Trend which reservoirs Australia's' major gas reserves. The maturation history of the source rock will however be different due to the lack of Jurassic and reduced Cretaceous and Cainozoic loading.

Shows, Porosity & Permeability: (see Appendix 4).

Gas and condensate is reservoired in the time slice as determined from FIT/RFT.

Porosity and permeability data summary for the time slice:

Brigadier 1	15% < porosity < 18%, obtained from electrical logs.
Delambre 1	11.1%< average porosity < 20.1%, obtained from density logs.
Echo 1	16.2% < average porosity < 18.6% obtained from density logs.
Eendracht 1	15% < average porosity < 23%, obtained from neutron logs.
Investigator 1	5.9% < average porosity < 14.4%, obtained from neutron logs.
Jupiter 1	8% < average porosity < 25%, obtained from electrical logs.

Mercury 1	8% < spot porosity < 25%, obtained from neutron, density and sonic logs.
North Tryal Rocks 1	5.6% < spot porosity < 21.2%, obtained from core, 16.5% < average porosity < 22% obtained from sonic logs. 20mD < spot K < 130mD, obtained from core. 0.1mD < AvK < 5.4mD, obtained from RFT.
Sirius 1	3% < average porosity < 21%, obtained from electrical logs. 2mD < spot K < 30mD, obtained from RFT.
Sultan 1	13.7% < spot porosity < 26% obtained from core, 23% < average porosity < 27% obtained from sonic logs. 2mD < spot K < 128mD, obtained from core.
Vinck 1	4.5% < average porosity < 20.7%, obtained from density and sonic logs, 6.5% < spot porosity < 13.3% and 2.9% < average porosity < 16.8% obtained from core. 0.1mD < min K < 33mD, obtained from core.

Shows summary for the time slice:

Brigadier 1	G1 obtained from mud logs, L1 obtained from SWC.
Delambre 1	G1 obtained from mud logs, L1 obtained from SWC.
Eendracht 1	L1 obtained from SWC.
Jupiter 1	G4 obtained from FIT, L1 obtained from SWC.
Mercury 1	G1 obtained from mud logs, L1 obtained from SWC.
North Tryal Rocks 1	G4 obtained from FIT, L1 obtained from SWC.
Sirius 1	G3 and C3 obtained from RFT, L1 obtained from cuttings.
Sultan 1	G1 obtained from mud logs, L1 obtained from SWC.
Vinck 1	G4 and C4 from FIT, L1 obtained from SWC and G1 obtained from mud logs.

Prospectivity: (see Enclosure 3).

Exmouth Platform/Plateau

The prospectivity of the Triassic is considered good to excellent for condensate rich to light oil hydrocarbon accumulations. This conclusion requires some explanation as previous drilling on the Exmouth Plateau has encountered only very dry gas that is obviously not commercial at the water depths of the Exmouth Plateau. As briefly as possible, the enhanced estimate of prospectivity is based on the conclusions that:

1) The probable source rocks in the area are not obviously different from the source facies of the gas condensate Rankin Trend. Indications are that the prodelta and lower delta plain backswamp environments are the likely source rocks.
2) The Triassic is overlain by lower Jurassic marls and calcareous claystones that are only poorly lithified and so are considered to form an excellent regional seal rock. Any hydrocarbons, generated post early Jurassic have a good chance of being trapped within the Triassic section and certainly thick regional seals were in place by the earliest Cretaceous.
3) However, where the Triassic has been drilled, the section is generally immature on the Exmouth Plateau; but down dip of most wells the section would be in the generative window. The common occurrence of a migrated gasoline fraction throughout the drilled immature sections is considered evidence of both source potential and maturity of the deeper Triassic sections.
4) The gasoline fraction could also be the residuum of original expelled hydrocarbon
5) Nearly all of the Triassic targeted wells drilled on the Exmouth Plateau were drilled on highs associated with direct hydrocarbon indicators (DHI) as seen on seismic, either bright, dim or flat spots. These DHIs are all associated with dry gas accumulations. This dry gas is believed to be the result of evaporative fractionation effects due to secondary migration of the gas phase that was originally associated with primary gas condensate accumulations (see section Upper Triassic Source For Exmouth Plateau Dry Gas). In effect the DHIs would represent the worst targets for encountering liquids rich accumulations.
6) Not all of the postulated deeper accumulations need have had a loss of the light ends due to the evaporative fractionation mechanism. Any accumulation not accessible by faults, and therefore not subject to a pressure differential, would retain the original charge, presumably similar in composition to that at Echo 1.
7) Presuming the primary gas condensate accumulation was originally of a composition similar to that on the Rankin Trend, it can be inferred that these now methane depleted accumulations will be liquids rich condensate reserves. It is this model that significantly upgrades the hydrocarbon potential of the region.
8) Potentially a variety of large untested closures exist within the Triassic. Single line large scale rollovers are common on the seismic examined for this module. Internal seals may or may not represent a significant risk factor depending upon at what stratigraphic level the closure exists. These closures may reservoir the heavier ends of the evaporative fractionation process.

9) This time slice is shown to have oil and gas source rock potential in Jupiter 1 well, gas source rock potential in Brigadier 1 and inferred sources in most other wells. Marine and coastal reservoirs are present in the Middle-Upper Triassic. Reservoir quality in the Lower-Middle Triassic is as yet not ascertained. Jupiter 1 drilled down to TR2 and found no reservoirs at this level. Regional seals are present in all wells.

Traps and plays.

Exmouth Platform

Structural closures and fault traps in the Lower - Middle Triassic which lie below the 100 degree isotherm may reservoir the heavier ends of the gas fractionation process.

Outer Rankin

Structural closures & fault traps in the Triassic may reservoir gas/condensate/light oil.

Exmouth Sub-basin (Minden 1 closest)

The usual top of Triassic plays exist in the Sub-basin, oil & gas shows are present.

TIME SLICE Tr6:

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

Petroleum System: Westralian 1 (see Enclosure 3).

In the module area this is the most significant time slice of the Westralian System. It is one of the major source intervals and is a major reservoir interval for the giant gas condensate accumulations of the Rankin Trend. It is also the major reservoir unit for the mainly dry gas accumulations encountered over the Exmouth Plateau part of the module area. Most of the wet gas condensate accumulations in the Barrow-Exmouth and Dampier region, if not reservoired in the Triassic, can be shown to be most likely sourced from this or the immediately associated time slices. There is no obvious significant difference in the palaeoenvironments found in this area and those in the Barrow-Exmouth and Dampier Sub-basin. On this basis time slice TR6 is considered to be a source interval over the module area. However the section is generally immature to sub mature where drilled. In nearly all Exmouth Plateau wells there are strong indications of migrated gasoline fractions throughout the section and this is interpreted to indicate downdip generation and maturity. On this basis time slice TR6 is considered to be a viable source within the module area. Evaporative fractionation effects are interpreted to have occurred during the secondary migration of the hydrocarbons reservoired in time slice TR6. This effect is thought to upgrade the prospectivity of the upper Triassic section across the Exmouth Plateau.

Formation Synonyms: (see Figure 2).

The Mungaroo Formation of the Rankin Trend is the lateral equivalent of the Triassic section on the Exmouth Plateau.

The Brigadier Formation overlies the Mungaroo Formation and is interpreted to be bounded by regional unconformities caused by the Fitzroy Movement.

Regional Definition of Time slice: (see Figure 2).

The top of time slice TR6 is the Jurassic-Triassic boundary. It is not defined biostratigraphically but approximates the middle of the overlap zone of *D.priscum* and *A.reducta.* Time slice TR6 is biostratigraphically defined by the lower *A.reducta* and upper *M.crenulatus* spore pollen zones and, the entire *H.balmei* and *R.rhaetica* and lowermost *D.priscum* dinoflagellate zones.

Nicoll and Foster (1994) revised the position of the *S.speciosus* to *M.crenulatus* spore-pollen boundary upwards from the base of the Norian to well within this stage. They also imply that *D.priscum* may be mostly within the Jurassic. On this basis time slice TR6 is virtually equivalent to the Rhaetian.

Palaeontology: (see Enclosures 2, 4-7; Appendices 1-2).

Nine wells intersected time slice TR6 aged sediments. In Sirius 1 the *H.balmei* dinoflagellate zone is probably missing. This is interpreted to coincide with a peak of tectonic activity in the area. In other wells, although not clearly defined on palynological grounds, a major event can be mapped or inferred at this time, either from the logs or from seismic or both. Across this boundary there is always an abrupt palaeo-water depth increase. The base of time slice TR6 is defined by a module wide unconformity. The top is likewise interpreted as a regional unconformity, overlain by unnamed lowermost Jurassic marls.

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

- Brigadier 1:	*A.reducta* (B3), *R.rhaetica* (B3),
- Delambre 1:	*A.reducta* (B3, B5), *R.rhaetica* (B2), *D.priscum* (B2, B3),
- Echo 1:	*M.crenulatus* (B2),
- Eendracht 1:	*R.rhaetica* (B5), A.*reducta* (B3),
- Investigator 1:	*A.reducta* (B3), *M.crenulatus* (B5),
- Jupiter 1:	*M.crenulatus* (B4, B3),
- Mercury 1:	*A.reducta* (B5),
- Sirius 1:	*A.reducta* (B3),
- Vinck 1:	*M.crenulatus* (A1, B1).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

This is a period of intense structuring. West Australia was part of Pangea prior to its breakup in the Norian, following which it became Greater Gondwana (Baillie et al, 1994). The main phase of the Pangea breakup

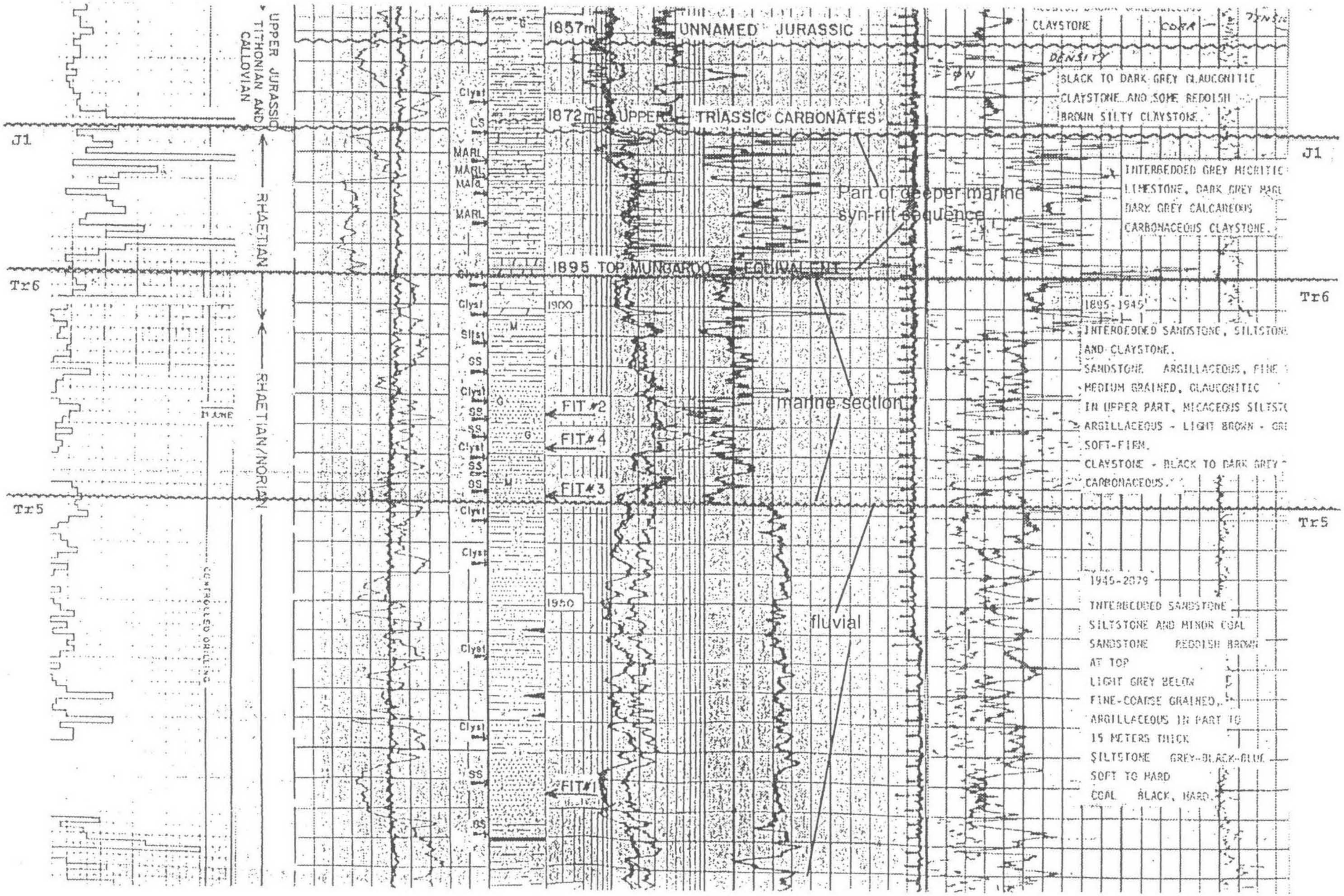


Figure 19: Composite log of Jupiter 1, Upper Triassic-Lower Jurassic section.

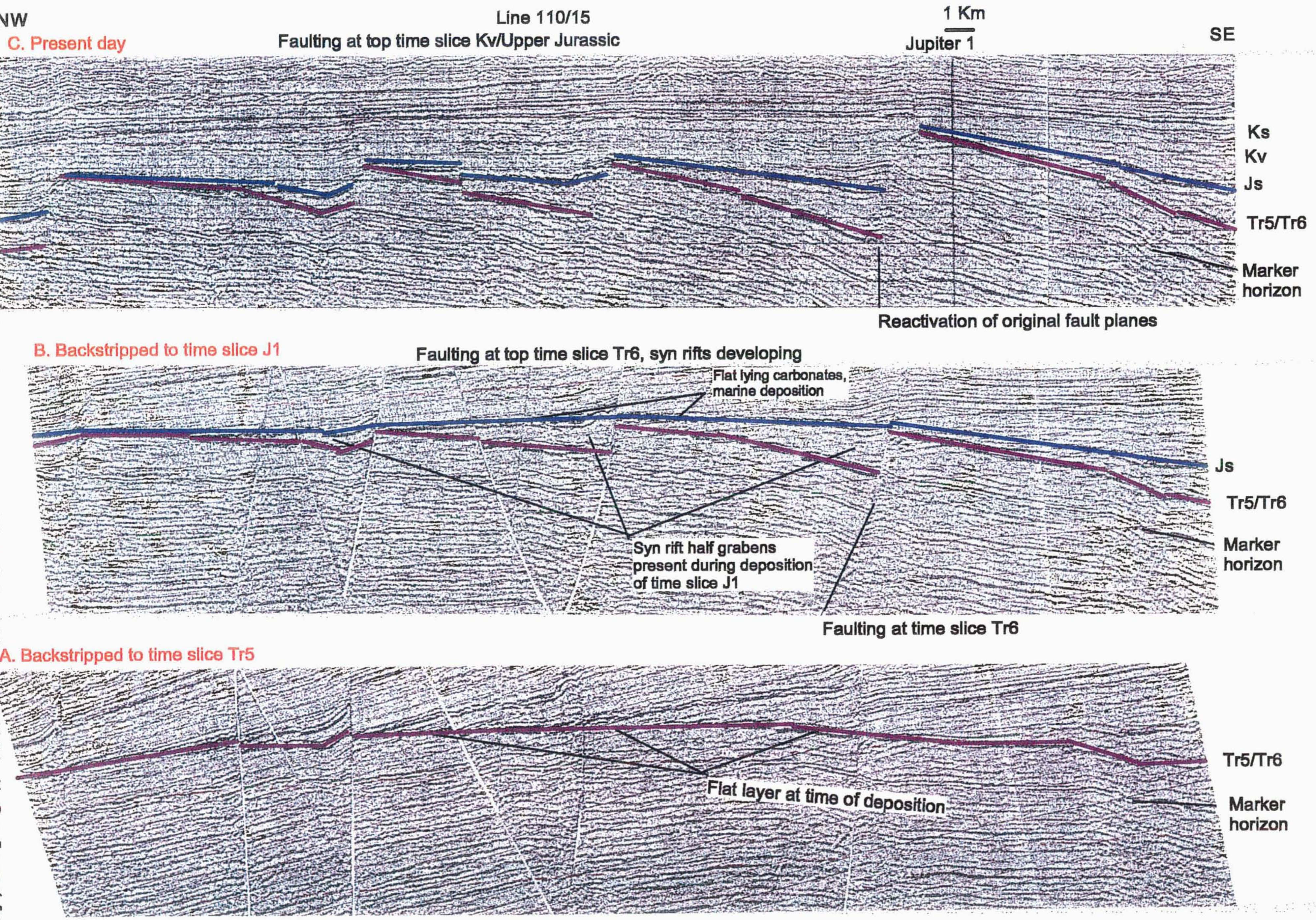


Figure 20: Backstripping of line 110/15 at Jupiter 1 location, differentiation of time slices Tr5 to J1. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. Ks- intra time slice K9, Kv - top time slice K1, Js - top time slice J1.

relative to the module area spans time slices TR5 - J1. This is a time where the Chinese blocks are also colliding with Eurasia.

This is the time of onset of a major tectonic episode across the entire North West Shelf. Regional uplift of 2-3km occurred in the Fitzroy Trough (in the Canning Basin to the north) so the event has been termed the Fitzroy Movement (Wales & Forman, 1981 in Colwell & Stagg, 1994). Suspected salt pillows in the Willara Basin are associated with this event (Colwell & Stagg, 1994) as well as rifting of Asian Terrains and the opening of the Tethyn Ocean. To the north, in the Rowley to Offshore Canning area, the Fitzroy Movement is characterised by the termination of faults and by seismic character changes at the top of time slice TR6. A similar pattern is seen on seismic in this area. In the module area the Fitzroy Movement appears to be a series of imprecisely timed Late Triassic to early Jurassic extensional events.

The timing for the main structuring is placed at the top of time slice TR6 and represents the second pulse referred under the time slice TR5 section. This event is recognised on time-depth curves, where syn depositional wedges of interpreted time slice J1 age overlie a combined time slice TR5-TR6 sediment package on the Exmouth Plateau (near Jupiter 1 and Scarborough 1) and where there is strong truncation erosion of the Upper Triassic on the Rankin Trend (North Tryal Rocks 1, Minden 1, Sultan 1, Echo 1).

Local

The top of time slice TR6 is determined from syn depositional wedges of time slice J1 age overlying combined time slice TR5-TR6 age sediments on the Exmouth Plateau (near Jupiter 1 and Scarborough 1). Backstripping of seismic in the Scarborough 1 - Jupiter 1 region supports the interpretation of episodic faulting at both the end of time slice TR6 and J1 (see Figure 20). Backstripping to the carbonate marker in the time slice J1 (Figure 19) indicated a uniformly deposited carbonate layer within a probable shallow sea. Both Figures 19 and 20 should be viewed together to understand the concept.

The final interpretation on the effects of the top time slice TR6 event is that the event was part of a regional wide extensional phase (top time slice TR5 - J1). Its direct contribution to the overall phase was to initiate major uplift with erosion of the Triassic occurring in the areas east of the East Exmouth crustal fracture (see structural elements map, bounding fault north of the Rankin Trend). Considerable less erosion occurred on the Exmouth Platform which is submerged under a shallow sea. Although no erosion occurred in the submerged areas of the Exmouth Platform, the affect of this movement was one of stretching the crust and rotating the Triassic blocks which were then overlain by syn-depositional time slice J1 wedges.

It is also believed that the East Exmouth Continental Fracture Zone(Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone, Argoland Transfer) was initiated during this time which weakened the crust. This weakness in the crust would later undergo wrenching phases along this zone during the Middle Jurassic and the Argoland breakup. The main evidence for the presence of this lineament at this time comes from the lack of truncational erosion of Triassic horst blocks on the Platform as opposed to the Rankin Trend where blocks are clearly truncationally eroded.

The *H.balmei* dinoflagellate zone marks a major peak of extensional tectonic activity in the module area, characterised mainly by normal faulting. In all wells there is a lower time slice TR6 boundary always marked by an abrupt water depth increase. The faulting may have post dated the sea level rise or be simultaneous with it as there is little evidence on the AGSO regional lines of significant erosion of the fault block apexes. The base of time slice TR6 is defined by a module wide unconformity.

Lithology: (see Enclosure 2).

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: (see Figure 21).

A thickness of 422m was intersected in Brigadier 1, considering only the thirteen module wells. A maximum thickness of 550m is present when considering the Carnarvon Basin and Exmouth Platform as a whole. Restricted maximums exist over the eastern Rankin Trend, Outer Rankin, Barrow and Exmouth Sub-basins. It is estimated from seismic that the Triassic is a relatively uniform layer of sediments with substantial thinning occurring towards the mainland basement complexes where onlap occurs. Triassic time slice thicks are the result of both erosional and depositional processes consequently a degree of caution is necessary when viewing Figure 17.

Palaeodepositional Environments: (see Enclosure 10).

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 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 11).

- The faults shown are interpreted to be top Triassic age.
- Particular palaeogeographic environments have been interpreted to coincide along the boundary of the East Exmouth Continental Fracture Zone which was formed at the top of the Norian and later re-activated at the top of the Triassic. Slightly deeper waters may be prevailing to the north of the boundary.
- A number of NNE trending blocks including the Sable and Ronsard blocks are interpreted to be present in the later stages of time slice TR5, in the very middle east side of the map. These blocks could possibly be of top Triassic age or even Jurassic in age.
- Sediment supply is interpreted to be coming from the south east on the Australian mainland and from the south west off the Greater India continent.
- Evidence of Rhaetian age reefs from dredge samples on the Wombat Plateau clearly point to a relatively open shallow marine environment on the outer Exmouth Plateau.
- The time slice is transgressive.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- 0.7% < average TOC < 4.4% (5 control points),
- 0.5% < average VR< 0.8% (3 control points),
- 120 < average HI < 123 (2 control points),
- 429 < average Tmax < 452 (2 control points).

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. It is reasonable to expect that the generative potential of the source rock will be similar to that on the Rankin Trend which reservoirs Australia's major gas reserves. The maturation history of the source rock will however be different due to the lack of overlying Jurassic sediments and reduced Cretaceous and Cainozoic loading.

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Brigadier 1	18% < porosity < 21%, obtained from electrical logs.
Echo 1	11.2% < spot porosity < 28.7% obtained from core, 19.9% < average porosity < 20.6% obtained from density logs. Permeability 0.7< spot mD< 2520 obtained from core
Eendracht 1	16.3% < average porosity < 25%, obtained from neutron logs.
Investigator 1	5.9% < average porosity < 14.4%, obtained from neutron logs. Av mD=0.1 Core
Jupiter 1	average porosity of 10%, obtained from electrical logs.
Sirius 1	8% < average porosity < 14%, obtained from electrical logs. Spot K=40mD RFT
Vinck 1	12.3% < average porosity < 20.2%, obtained from density logs.

Shows summary for the time slice:

Brigadier 1	G1 obtained from log analysis, L1 obtained from SWC
Delambre 1	L1 obtained from SWC
Echo 1	G5 and C3 from RFT
Eendracht 1	G3 obtained from RFT, L1 obtained from SWC
Investigator 1	G3 obtained from FIT, L2 obtained from FIT
Mercury 1	L1 obtained from SWC
Sirius 1	G3 and C3 obtained from RFT
Vinck 1	G1 obtained from mud logs, L1 obtained from SWC

Echo 1 on the Rankin Trend is the most productive well. It flowed 15.5 MMCFPD of gas & 3875 BOCPD from the uppermost sand of the time slice TR6 section which is sealed by time slice K1 shales. This is a subcrop play on a regionally mappable sand package.

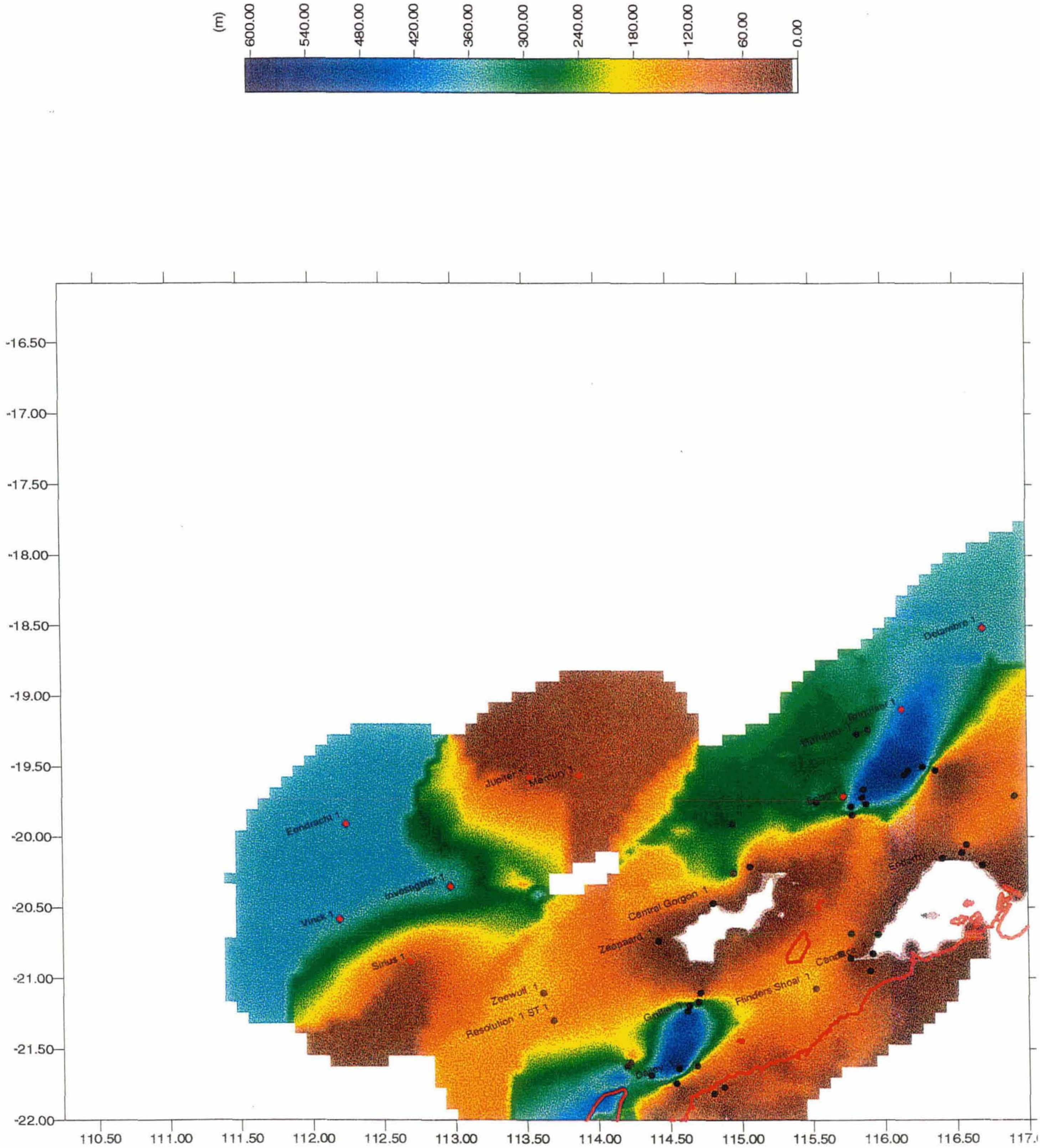


Figure 21: Time slice Tr6 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

Sirius 1 was drilled on a simple domal closure in the lower Cretaceous time slice K1, the Triassic was a poorly defined tertiary target and may not be closed. Time slice TR6 is very thin, clayey and had no shows, though the underlying time slice TR5 had dry gas with minor condensate recoveries.
Eendracht 1 was drilled on the apex of a faulted anticline in the Triassic, that was associated with a direct hydrocarbon indicator (DHI) seen on seismic. The well encountered an interpreted 44m dry gas column at the top of the time slice TR6 interval.
Vinck 1 was drilled on a faulted anticline that had a direct hydrocarbon indicator within the underlying time slice TR5. It encountered gas and a strong oil indication within time slice TR6. The section is interpreted to be affected by migrating liquid hydrocarbons.
Mercury 1 drilled time slice TR6 section that is a thin non reservoir facies, although a gas condensate show was recorded.
Jupiter 1 was drilled on the apex of a Triassic tilted horst block, top sealed and flank sealed by lower Jurassic calcareous marls. The feature is associated with a DHI in the uppermost Triassic. The well encountered dry gas in time slice TR6. The unconformity bounded time slice TR6 is a slightly glauconitic fine grained quartz sandstone with good reservoir characteristics. It is a radioactively "hot" sand probably due to heavy mineral concentrations. It is interpreted as a north south striking beach sand deposit.
Investigator 1 drilled a simple domal closure in the Triassic that was associated with a DHI. It encountered strong gas and oil indications with interpreted migrated gasoline fraction hydrocarbons throughout the section.

Porosity preservation in clean sands appears to be purely depth related. Below 4000m there appears to less than 10% porosity preserved in even the cleanest sands. Permeability is also seriously reduced. High primary porosity is destroyed by pressure solution and the redistribution of quartz as cement, the introduction of kaolinite and the precipitation of carbonate by circulating pore water. Secondary porosity enhancing mechanisms have not been recognised. Most of the porosity destruction with depth can theoretically be reduced by early hydrocarbon emplacement. However the timing of hydrocarbon generation in the Triassic is currently being debated. In essence the major periods of maturation coincide with the major periods of sediment loading. The upper Triassic is the main interval of maturation for the section younger than upper Triassic. Following this event maturation was essentially frozen regionally across the Exmouth Plateau, until the Barrow Delta (time slice K1) loading that pushed the middle and upper Triassic slightly further into the generative window. Subsequently the maturation was again frozen, subject to minor loading from the Cainozoic.

Prospectivity: (see Enclosure 3).

- This time slice is shown to have oil and gas source rock potential in Investigator 1, Brigadier 1 and inferred source rocks in Delambre 1, Echo 1, Eendracht 1 and Jupiter 1.
- Regional seals are interpreted in Brigadier 1, Delambre 1, Eendracht 1, Investigator 1, Jupiter 1 and Mercury 1 whilst local seals are found in Echo 1, Sirius 1 and Vinck 1. Marine and coastal reservoirs are interpreted to be present where the time slice was penetrated.
- The Triassic section is strongly affected by the major tectonic episodes of the Fitzroy Movement. These regional scale events appear to have been associated with episodic submergence on the Exmouth Plateau. Erosion is not clearly evident nor are major angular unconformities. Nevertheless subtle angular unconformities are likely to be present. The regionally extensive marine and prodelta facies of time slice TR6 could form a seal on subcrop plays in the underlying time slice TR5 section.
- Time slice TR6 deposition appears to have the best oil potential of any of the Upper Triassic sections.

Traps and Plays.

Exmouth Platform:

- Plays may exist in the form of structural closures or fault traps in the Lower - Middle Triassic which lie below the 100°C isotherm and where they may reservoir the heavier hydrocarbon residuals of the evaporative fractionation process (see previous sections).
- Samples of Rhaetian reef material have been dredged from the eastern side of the Wombat Plateau. It is possible that seismic anomalies representative of reef buildup may exist in the deeper waters of the outer margin. Rhaetian reef material was also dredged from the outer Rowley Sub-basin hence the regional distribution. Reef plays therefore may exist.

Outer Rankin:

- Structural closures & fault traps in the Triassic may reservoir gas/condensate/light oil.

JURASSIC TIME SLICES

TIME SLICE J1:

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

Petroleum System: Westralian 1 (see Enclosure 3).

On the Rankin Trend time slice J1 is a regional seal facies and minor reservoir unit, that also has some source potential. Time slice J1 probably covered most of the Rankin Trend area until the Callovian, when tilting formed the Rankin Trend, resulting in uplift and erosion of time slice J1. As a petroleum system factor this time slice is mainly important as a seal facies.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include equivalents of the North Rankin Formation.

Regional Definition of Time slice: (see Figure 2).

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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*C.torosa* (B1),
- Delambre 1:	*C.torosa* (B1, B2, B4), *L.tenera* (B3), *D.priscum* (B2, B3),
- Eendracht 1:	*D.priscum* (B4), *A.reducta* (B3), *C.torosa* (B3),
- Investigator 1:	*C.torosa* (B3), *D.priscum* (B4), *A.reducta* (B3),
- Jupiter 1:	*A.reducta* (B5)
- Mercury 1:	*C.torosa* (B3),
- North Tryal Rocks 1:	*D.priscum* (B3), *Falcisporites Sz.* (B4), and
- Sirius 1:	*C.torosa* (B2), *R.rhaetica* (B3).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia was part of greater Gondwana (Baillie et al, 1994). The main phase of the Pangea breakup, the Fitzroy Movement, spans time slices TR5 to J1. Time slice J1 is on the trailing edges on the major tectonic activity.

Local

There is a module wide unconformity extending from top Pliensbachian to top Hettangian. The time depth curves (Appendix 2) show that this unconformity relates to the third and last structural pulse of the Fitzroy Movement at top time slice J1. This unconformity is seen on seismic in the Gandara 1/Brigadier 1 area where time slice J1 faulting terminates on a relatively corrugated surface. The unconformity is also clearly seen on the Exmouth Plateau (near Jupiter 1 and Scarborough 1) where syn-depositional wedges of time slice J1 overlie the highly normal faulted time slice TR5-TR6 sediments. Backstripping and section restoration, using seismic at Jupiter 1, demonstrates that episodic faulting occurred at the end of both time slices TR6 and most probably time slice J1 (see Figure 20). Section restoration to a carbonate marker within time slice J1 indicates a uniformly thick carbonate layer probably deposited in a shallow sea (Figure 19). The faulted time slice K1 sequence that overlies this carbonate layer, implies a post time slice J1 movement prior to deposition of time slice K1.

In summary the top time slice J1 event was the last part of a regional extensional phase that commenced at the top of time slice TR5. This event enhanced the structural relief of already formed structures, mainly by fault reactivation. The event represents 5% of the total extension associated with the Fitzroy Movement.

Lithology: (see Enclosure 2).

The lithology on the Exmouth Plateau comprises marls, calcilutites and calcarenites whilst claystones and calcareous claystones are found on the Rankin Trend. Mixed and coarser clastics are present to the northeast in Delambre 1 and Brigadier 1.

Thickness Variations: (see Figure 22).

Thickness in the thirteen module wells ranges from 0m to 293m in Delambre 1. This is also the maximum thickness encountered in the Carnarvon Basin and Exmouth Platform as a whole. The Kangaroo Deep, Barrow Sub-basin, Enderby Terrace and Outer Rankin Platform all have thick accumulations of sediments. Time slice J1 thicknesses are the result of both erosional and depositional processes hence Figure 22 is not a indication of depositional thickness and a degree of caution is necessary when reviewing this isopach. It is interpreted that the thicks were deposited in half grabens developed during the top Triassic structuring.

Palaeodepositional Environments: (see Enclosure 12).

The Exmouth Platform was block faulted at the end of the Triassic. This resulted in a topographic surface of half graben basins across the Exmouth Platform. However erosion of the sub-aerially upthrown side of the half grabens is minimal and this is interpreted to mean that the fault blocks were not exposed over the Plateau. During the earliest Jurassic the half grabens where filled by continental shelf shallow marine carbonates and marls. However there is potential for the deeper parts of the half grabens to contain restricted marine facies.

Reef material has been dredged from the eastern side of the Wombat Plateau. Although the samples are dated as Rhaetian, time slice J1 contains significant marl and carbonate. As a consequence, reef buildup may still be present on the north Exmouth Platform during this time slice, the main Exmouth Platform would then be a back reef environment.

A deltaic system is interpreted to be sourced from the east. This system built out as far as the outer area of the Rankin trend. Oolitic shoals in the vicinity of Brigadier 1 and Delambre 1 emphasise the generally shoal marine environment of the area.

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) show a uniform eustatic regime (Struckmeyer & Brown 1990). The coastline is regressing in the module area in response to subsidence of the Exmouth Plateau area.

Palaeogeography: (see Enclosure 13).

- The faults shown are interpreted to be top Triassic age but partly reactivated at the top of time slice J1.
- A number of NNE trending blocks including the Sable and Ronsard blocks are interpreted to be present in the later stages of time slice TR5, in the very middle east side of the map. These blocks could possibly be of top Triassic age or even Jurassic in age.
- Low latitudes are inferred from the carbonate dominated shelf environment.
- Clastic sediment supply is interpreted to be coming mainly from the south east off the Australian mainland and from the south west off the Greater India continent.
- Evidence of Rhaetian reefs (time slice TR6) from dredge samples on the Wombat Plateau clearly point to a relatively open shallow marine environment on the outer Exmouth Plateau. It is possible that although increased subsidence would have submerged the reefs, some may still be present in the time slice J1.
- Half grabens developed on the Exmouth Platform during the top Triassic structural phase. These grabens form deeper water marine lows where sediments could be deposited via storm or traction mechanisms. These deeper troughs are interpreted to be present over most of the Exmouth Platform.
- Some palaeogeographic environment boundaries coincide with the boundary of the East Exmouth Continental Fracture Zone which was active during the Upper Triassic. Slightly deeper waters prevailed to the north of this zone.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- 0.6% < average TOC < 1.3% (5 control points),
- 0.3% < average VR < 0.7% (4 control points),
- 14 < average HI < 104 (2 control points),
- 422 < average Tmax < 448 (2 control points).

This time slice is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of

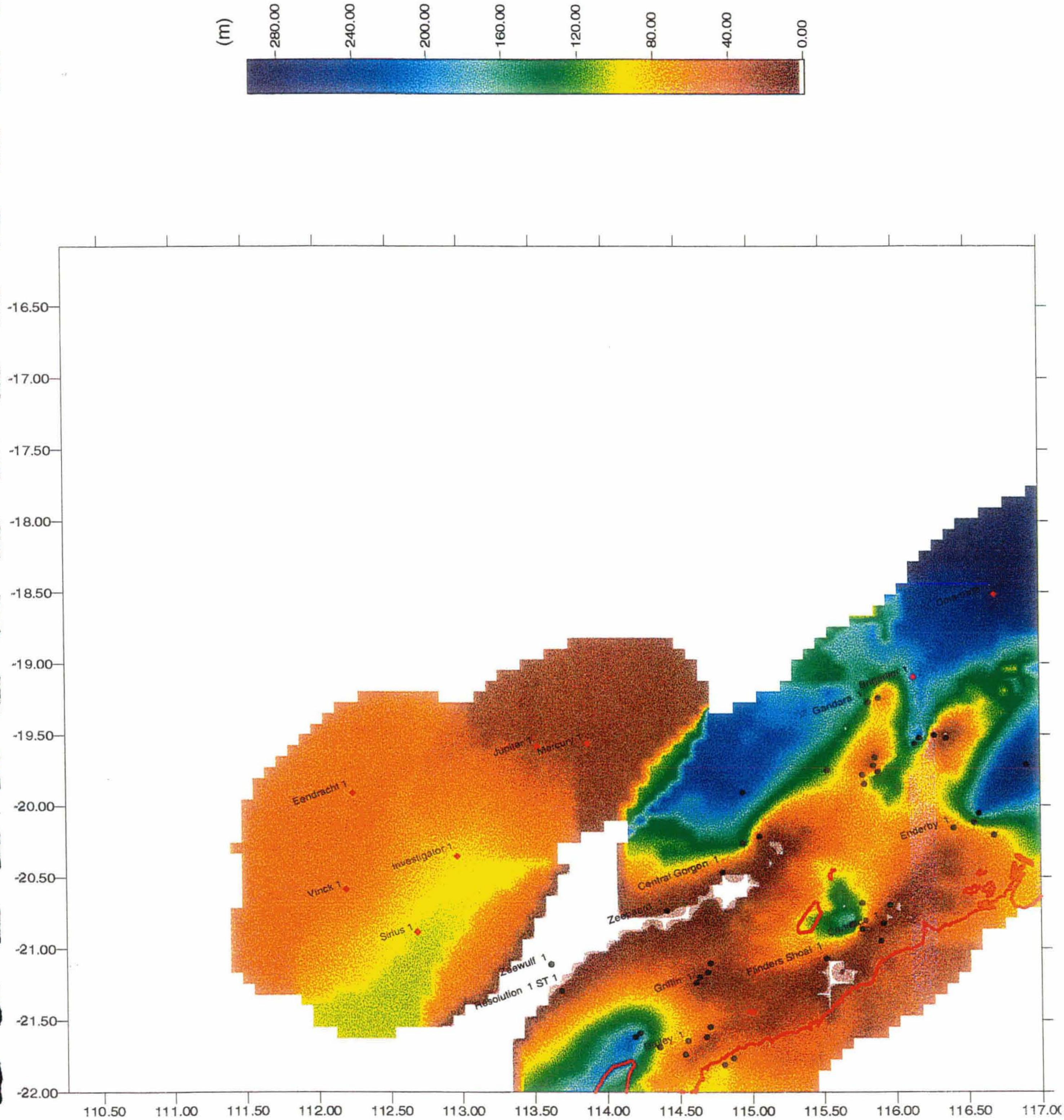


Figure 22: Time slice J1 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Brigadier 1	22.5% < average porosity < 24%, obtained from electrical logs,
Delambre 1	5% < average porosity < 18.5%, obtained from density logs, and
Jupiter 1	average porosity of 28%, obtained from electrical logs.

Shows summary for the time slice:

Brigadier 1, Mercury 1, Sirius 1	G1 obtained from mud logs,
Delambre 1	G1 obtained from mud logs, L1 obtained from SWC, and
North Tryal Rocks 1	L1 obtained from SWC.

Prospectivity: (see Enclosure 3). FAIR

- The time slice is the first potential regional seal on the underlying Triassic section.
- This time slice is generally a particularly poor source rock, with the exception that in Brigadier 1 it may be a potential gas prone source rock. There is some speculative potential for restricted marine source rock facies to develop in the deeper half grabens on the Exmouth Plateau though maturation of any such source is marginal at best.

Marine oolitic and coastal-deltaic clastic reservoirs are interpreted to be present in Brigadier 1, Delambre 1 and the Rankin Trend area. Inferred reservoirs in the form of thin carbonate beds are present in most other wells. These could be sourced from the immediately underlying Triassic section.

Traps and Plays.

Exmouth Platform:

Reef plays may exist. Although the age of the reef samples is dated as Rhaetian, significant marl and carbonate exist in this time slice to substantiate that reef buildup may still be present.

Outer Rankin:

Weak stratigraphic, fault and structural traps may exist where oolitic carbonate reservoirs are intraformationally sealed.

Rankin

Lower Jurassic deltaic sands are reservoirs on the North Rankin trend.

TIME SLICE J2:

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

Petroleum System: Westralian 1 & 2 (see Enclosure 3).

Not well known in this or other areas.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include Dingo Claystone equivalents. A condensed section is present over most of the module area.

Regional Definition of Time slice: (see Figure 2).

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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 fo description of confidence ratings):

- Brigadier 1: *C.turbatus* (B2), and
- Delambre 1: *D.priscum* (B2, B3), *A.reducta* (B3, B5), *C.torosa* (B1, B2, B4).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia was part of greater Gondwana (Baillie et al, 1994). This is a period of general tectonic quiescence.

Local

This time slice is seen as being relatively tectonically quiet but may be influenced by the Lower to Middle Jurassic wrench regime (see time slice J3 section).

Lithology: (see Enclosure 2).

Siltstones, claystones and calcareous claystones are found in Delambre 1 and Brigadier 1.

Thickness Variations: (see Figure 23).

Time slice J2 is condensed or absent in the central and southern Exmouth Platform. It is thicker in the northeast, in the vicinity of the Victoria Trough. Thickness ranges from 0m to 117m in Delambre 1 although a maximum recorded well thickness of 260m occurs on the Enderby Terrace when considering all of the Carnarvon Basin and Exmouth Platform. The main depocentres for the time slice are the Exmouth and Barrow Sub-basins. Jurassic time slice J2 isopach is subject to both erosional and depositional processes hence a degree of caution is necessary when reviewing this isopach.

Palaeodepositional Environments: (see Enclosure 14).

No palaeoenvironmental interpretation was attempted for this time slice. Generally the area is considered to be sediment starved as the Exmouth Plateau subsides to water depths probably in excess of 200m.

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) show a uniform eustatic regime (Struckmeyer & Brown, 1990). 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: (no Enclosure).

•Seismic shows that the Lower Jurassic downlaps to the west of Gandara 1 (Figure 27). A similar pattern is also seen in the Rowley Sub-basin (previous module) where sediments downlapped onto a shallow marine platform (Sayers et al,1995). A condensed section is interpreted west of these continental shelf progrades. Lower Jurassic sediments probably downlapped in a similar manner in the Exmouth Sub-basin, but were subsequently deformed during the Middle Jurassic wrench regime. Consequently no early Jurassic sediments extend beyond this trough onto the Exmouth Platform.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

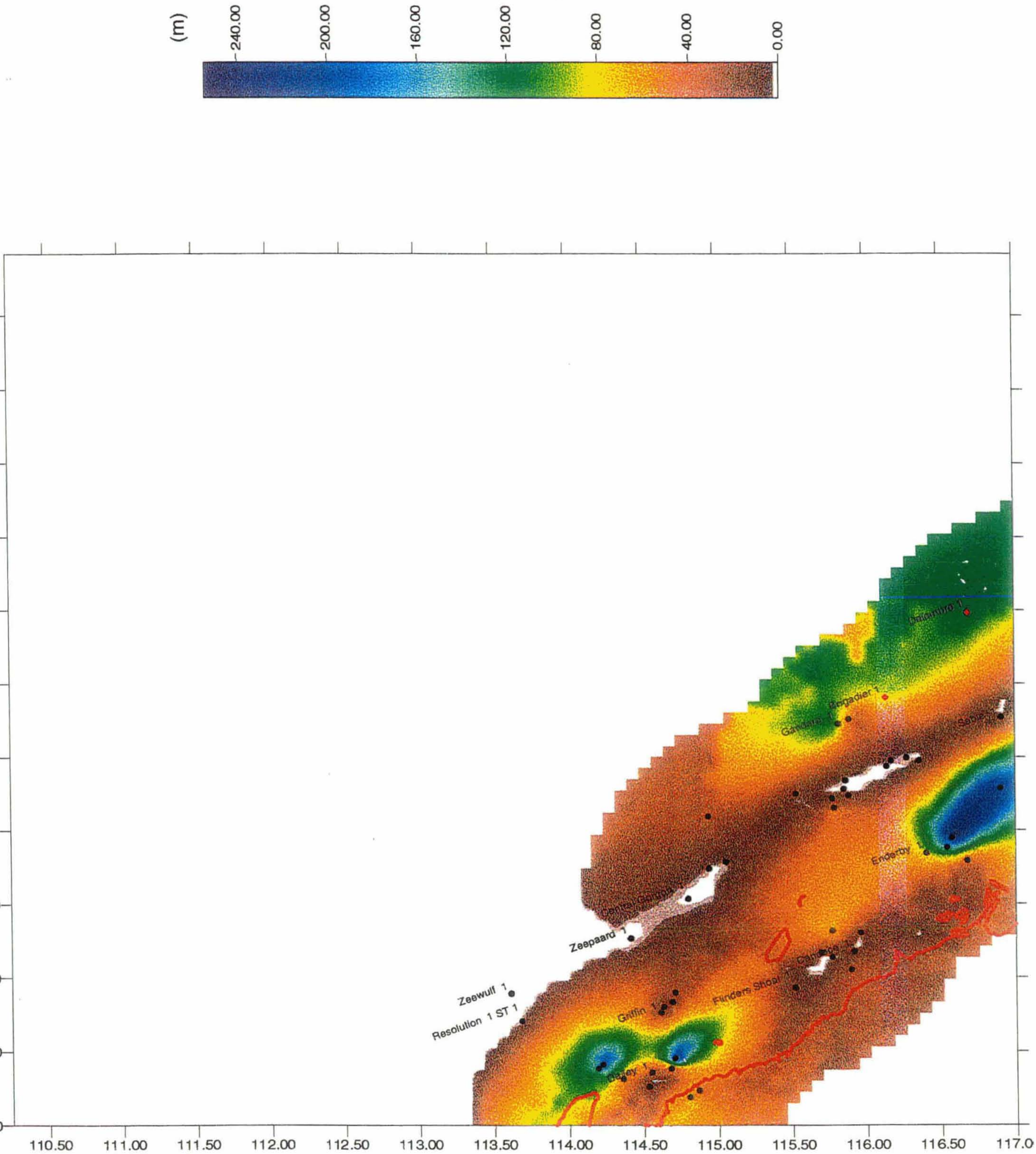


Figure 23: Time slice J2 isopach map based on Stratdat well database. Module wells have red coloured well symbols.

- average TOC = 1.8% at Brigadier 1,
- average VR = 0.5% at Brigadier 1,
- average HI = 144 at Brigadier 1, and
- average Tmax = 426 at Brigadier 1.

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exists for this time slice. Minor gas indications (G1) were recorded in Brigadier 1 and Delambre 1.

Prospectivity: (see Enclosure 3). POOR

- Inferred gas-condensate prone source rocks are present in Brigadier 1 and Delambre 1.
- Minor marine and coastal reservoirs are present in Delambre 1.
- The time slice is thick enough in the northeast to act as a regional seal.

Traps and Plays.

Outer Rankin - Victoria Trough:

Structural closures and minor fault traps may be sourced from potential Lower - Middle Jurassic oil prone source rocks, and/or Triassic gas/light oil prone source rocks.

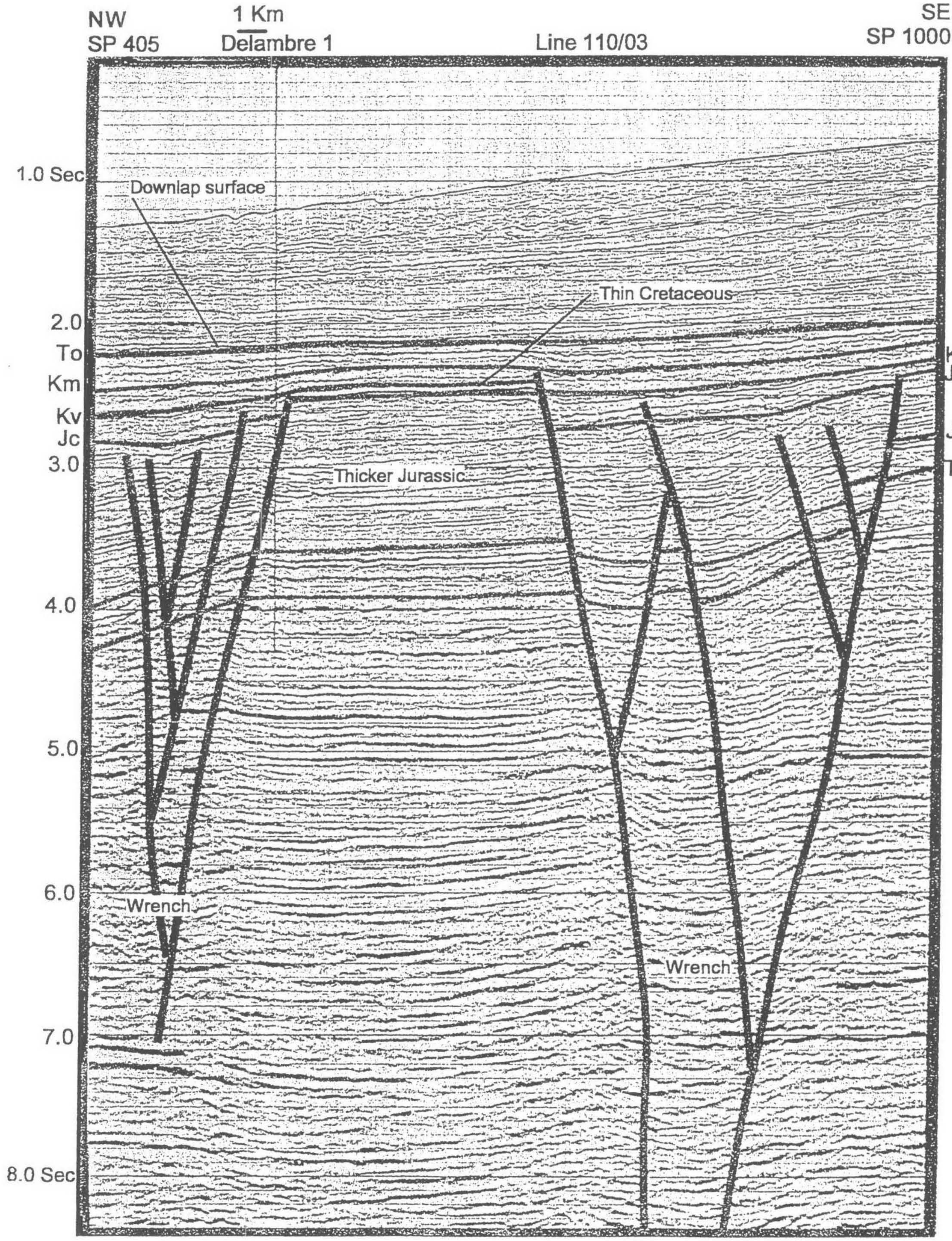


Figure 24: Stratigraphic and structural relationships at Delambre 1 . See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Kv - top time slice K1, Jc - top time slice J7 (Callovian), Js - top time slice J1, TR - top time slice Tr5.

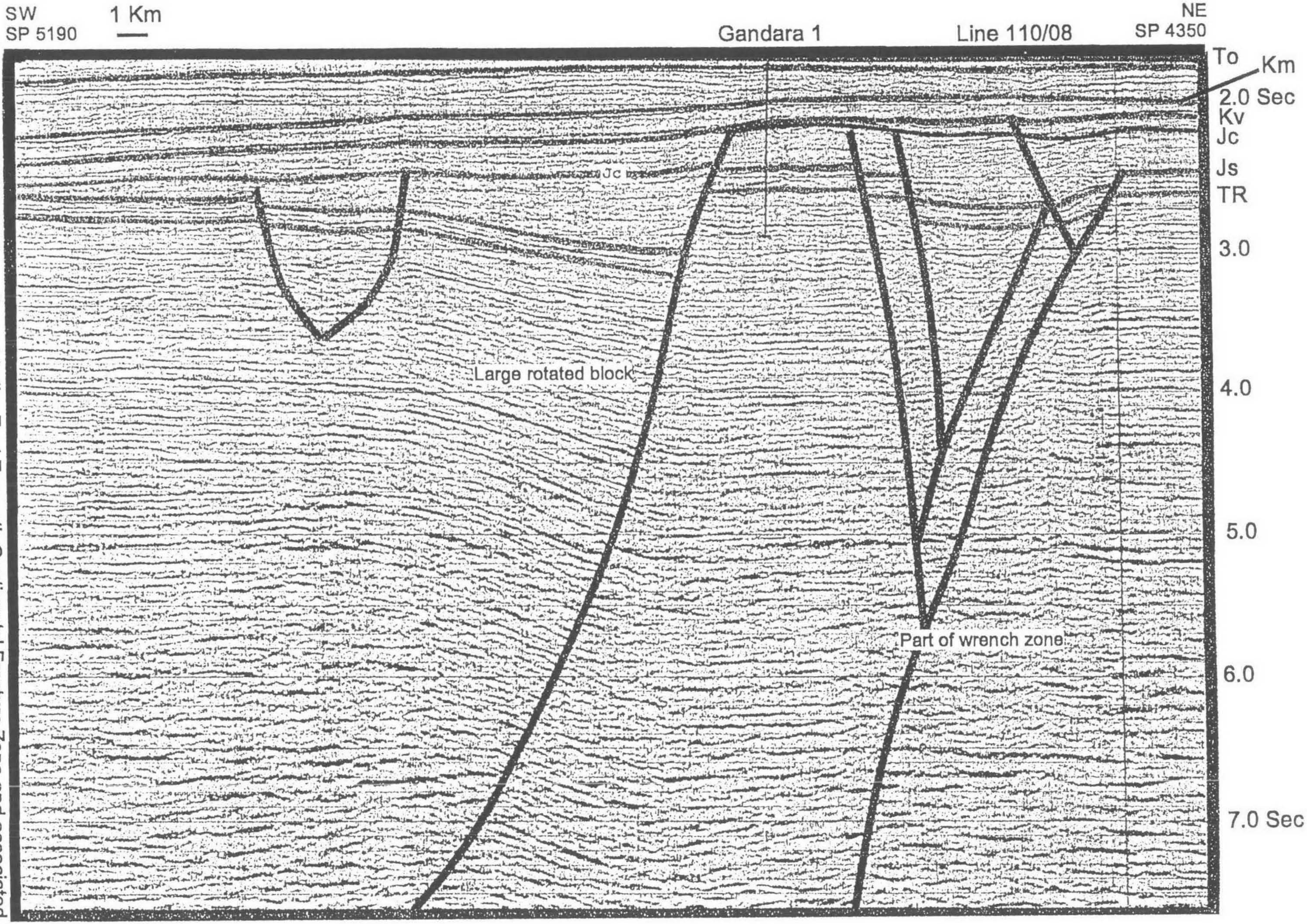


Figure 25: Faulting styles adjacent to the East Exmouth Continental Fracture Zone and associated Middle Jurassic wrench zone. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Kv - top time slice K1, Jc - top time slice J7 (Callovian), Js - top time slice J1, TR - top time slice Tr5.

TIME SLICE J3:

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

Petroleum System: Westralian 2 (see Enclosure 3).

Possibly provides a source facies within the Victoria Trough otherwise the time slice is not particularly significant, is poorly defined and rarely intersected.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Dingo Claystone equivalents. Condensed section is present over most of the module area.

Regional Definition of Time slice: (see Figure 2).

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.

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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*C.turbatus* (B2), and
- Delambre 1:	*C.turbatus* (B5), *L.d'orbignyi* (B3).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

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

Local (see Enclosure 28).

This time slice is interpreted to be influenced by a pull-apart regime related to the breakup of Argoland. Pre-ARGOLAND breakup pull-apart phases are interpreted to have been active since the Lower Jurassic. The evidence comes from unconformities in time slices J3 and J5 seen in Brigadier 1 and Delambre 1 where the Lower-Middle Jurassic section is preserved. Unconformities of this age have also been noted in the Carnarvon Basin (Lipski, 1993; Delfos, 1994; Rasidi, 1995). Marine incursions possibly associated with structural re-adjustment phases occur in the Roebuck and Offshore Canning Basins-Beagle Sub-basin (Sayers et al, 1995; Shafik, 1994). It is also believed that the East Exmouth Continental Fracture Zone (Figure 11: the East Exmouth Continental Fracture Zone includes the Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone, Argoland Transfer) further developed as the area underwent pull apart in the Lower Jurassic. This pull apart system established an extensional regime throughout the Carnarvon Basin that would see substantial depocentres being formed, and filled (Beagle, Cossigny, Exmouth, Victoria) and peaked in the Argoland breakup.

Figures 24 and 25 illustrate this pull-apart mechanism and show:

- the affects of Lower-Middle Jurassic pre-Argoland Breakup faulting, in the form of rotated fault blocks and wrenches in the vicinity of the East Exmouth Continental Fracture Zone and associated wrench zone. The age of maximum deformation would be Toarcian to Callovian culminating in the Callovian,
- that the Lower - Middle Jurassic thins to the southwest towards the Exmouth Platform,
- that Delambre 1 drilled a Triassic and Jurassic horst block in an area that is interpreted to have a reasonable amount of wrench component (Figure 24). The well is located away from the crest of the structural culmination so it is uncertain that this well is a valid structural test, and
- that deep seated faults link up at depth in a pattern indicative of wrench tectonics.

The Exmouth Sub-basin has a substantial fill of Middle - Upper Jurassic sediments (Figure 26). The Sub-basin is interpreted to be a result of the Lower - Middle Jurassic age pull-apart system which in turn is related to wrench movement on the East Exmouth Continental Fracture Zone. The nature of the faulting along this zone is variable but is interpreted to be trans-tensional in the location of the Exmouth Sub-basin.

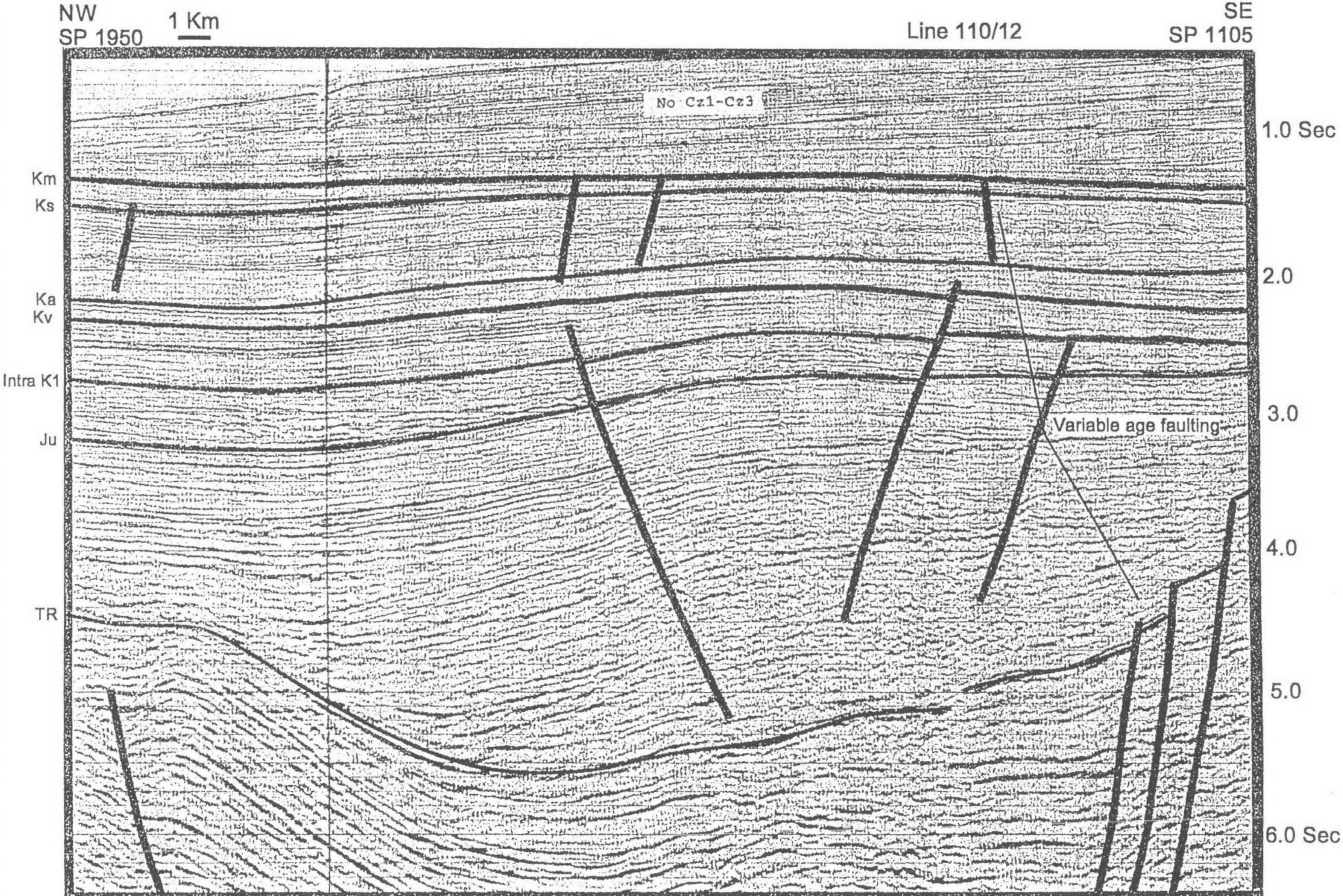


Figure 26: Jurassic depocenter of the Exmouth Sub-basin. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Ju - top Jurassic, TR - top time slice Tr5.

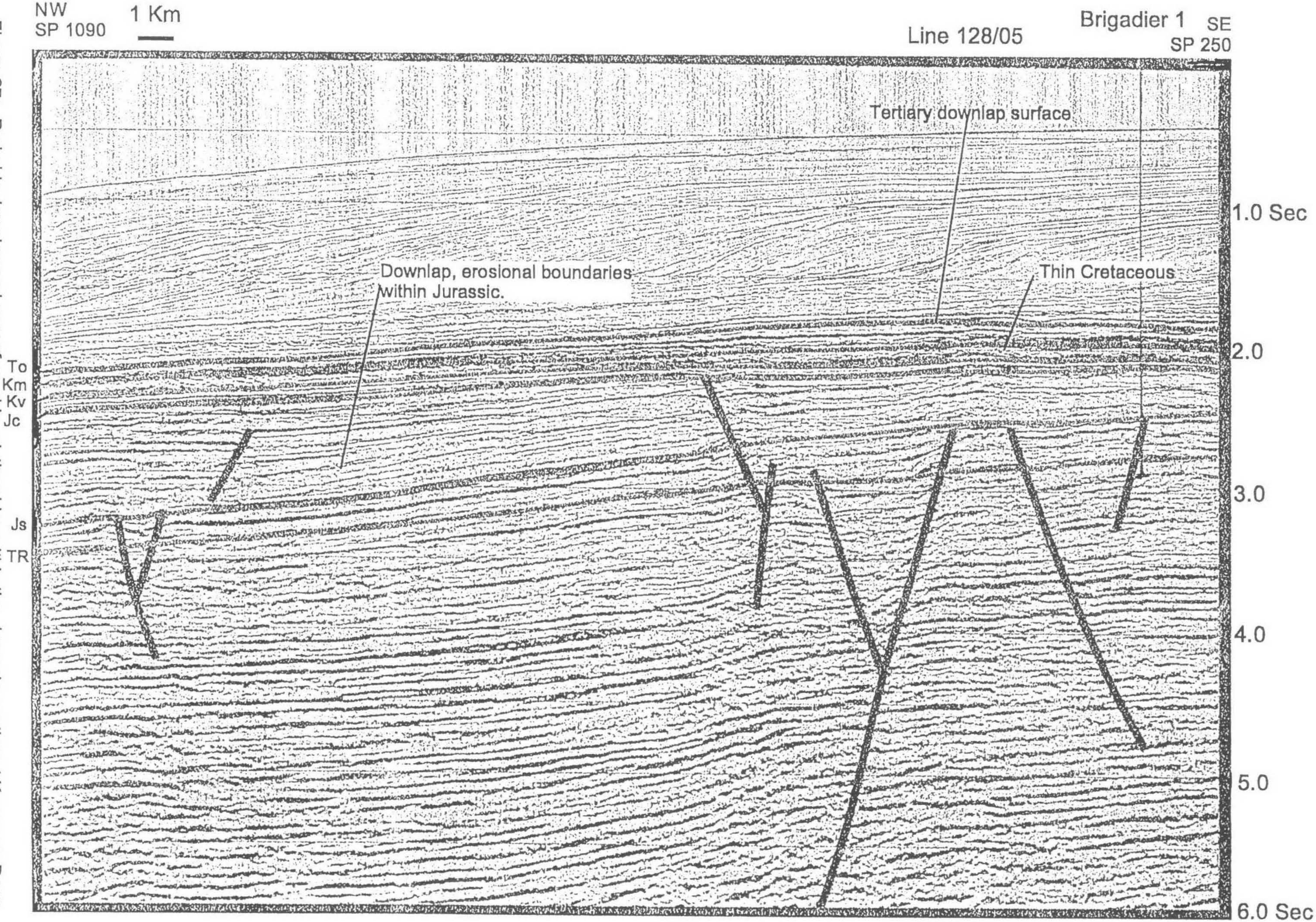


Figure 27: Probable downlap and unconformable relationships within the Jurassic, northeast Kangaroo Deep area. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Kv - top time slice K1, Jc - top time slice J7 (Callovian), Js - top time slice J1, TR - top time slice Tr5.

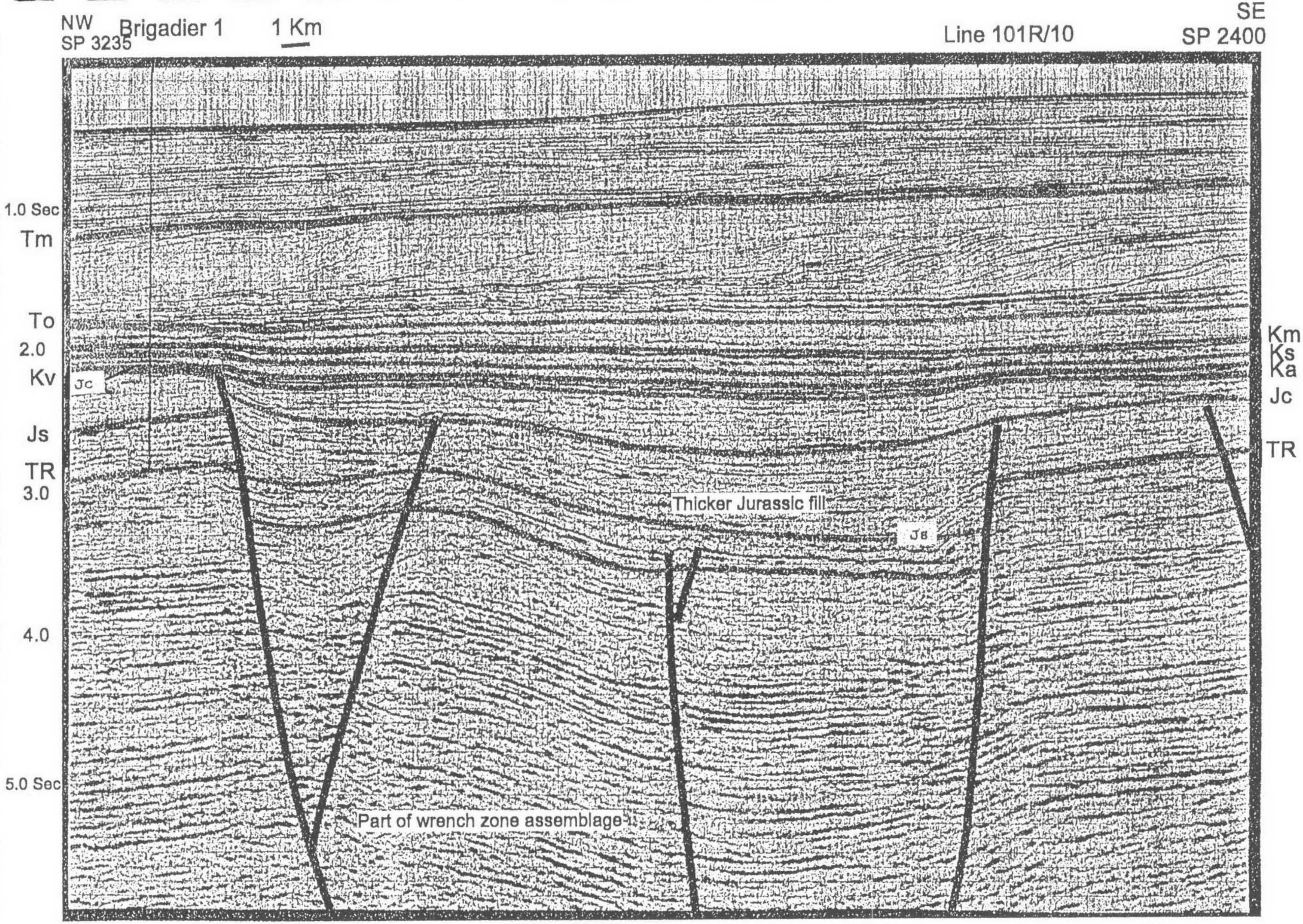


Figure 28: Stratigraphic and structural relationships of the Victoria Trough, implications of a Jurassic source kitchen. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. Tm - top time slice Cz5, To - top time slice Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Jc - top time slice J7 (Callovian), Js - top time slice J1, TR - top time slice Tr5.

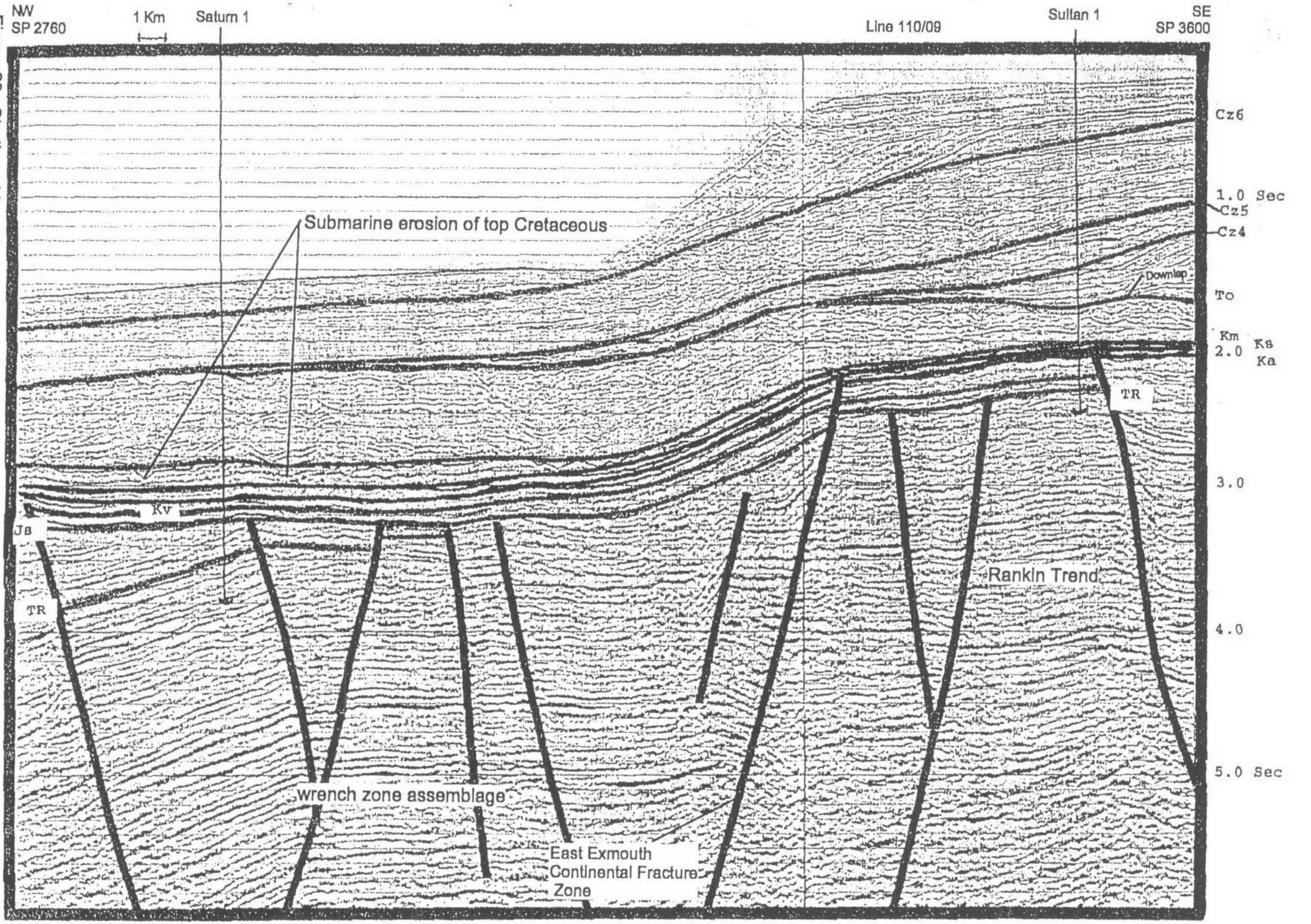


Figure 29: Stratigraphic and structural configurations along the East Exmouth Continental Fracture Zone and associated shelf break. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top of time slice Cz3, Km - top of Cretaceous, Ks - intra time slice K9, Ka - top of time slice K4, Kv - top of time slice K1, Js - top of time slice J1, TR - top of time slice Tr5.

Figure 28 shows:

- the stratigraphic and structural relationships of the Victoria Trough, adjacent to the East Exmouth Continental Fracture Zone and associated Middle Jurassic wrench zone,
- a package of probable Middle Jurassic sediments is preserved in the Victoria Trough. Hydrocarbons generated from these sediments may have been restricted to the Trough due to the juxtaposition of Triassic marine shales against the Jurassic fluvio-lacustrine sands, and
- potential Middle Jurassic source rocks may be mature in the Victoria Trough due to the relatively thick Cainozoic section that overlies the Trough.

Figure 29 shows that Sultan 1 drilled a Triassic horst block on the Rankin Trend whilst Saturn 1 drilled a rotated Triassic horst block. These wells straddle the East Exmouth Continental Fracture Zone and associated Lower - Middle Jurassic wrench zone.

Lithology: (see Enclosure 2).

Siltstones, claystones and calcareous claystones are found in Delambre 1 and Brigadier 1.

Thickness Variations: (see Figure 30).

Time slice J3 is condensed or absent in the central and southern Exmouth Platform but is thicker towards the northeast where the section is more proximal. Thickness range from 0m to 103m in Delambre 1. A maximum thickness for the Carnarvon Basin of 105m occurs in the Outer Rankin Platform. Secondary depocentres are present on the Enderby Terrace and Exmouth Sub-basin. The time slice isopachs are subject to both erosional and depositional processes hence a degree of caution is necessary when reviewing Figure 30.

Palaeodepositional Environments: (see Enclosure 15).

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) show a uniform eustatic regime (Struckmeyer & Brown, 1990).

Palaeogeography: (see Enclosure 16).

- Particular palaeogeography environments boundaries coincide with the boundary of the East Exmouth Continental Fracture Zone. This zone was activated during the intra time slice TR6 structural movement and later at the top of the Triassic. Slightly deeper waters may be prevailing north of the Zone.
- Seismic shows that the Lower Jurassic downlaps to the west of Gandara 1. A similar pattern is also seen in the Rowley Sub-basin (previous module) where sediments downlapped onto a shallow marine platform. A condensed section is interpreted west of these continental shelf progrades. Lower Jurassic sediments probably downlapped in a similar manner in the Exmouth Sub-basin, but were subsequently deformed during the Middle Jurassic wrench regime. Consequently no early Jurassic sediments extend beyond this trough onto the Exmouth Plateau.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- average TOC = 1.8% at Brigadier 1,
- average VR = 0.5% at Brigadier 1,
- average HI = 110 at Brigadier 1, and
- average Tmax = 429 at Brigadier 1.

This time slice is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Platform will be immature. However potential source rocks could be mature in the Victoria Trough.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exist.

The following list summarises the shows:

Brigadier 1	G1 obtained from mud logs, L1 obtained from cuttings, and
Delambre 1	G1 obtained from mud logs.

Prospectivity: (see Enclosure 3). POOR

- Inferred gas-condensate prone source rocks are present in Brigadier 1 and Delambre 1.
- Gas-condensate light oil prone source rocks may be present in the Victoria Trough.
- Minor marine and coastal reservoirs are present in Delambre 1.

• The time slice is thick enough in the northeast to act as a regional seal.

Traps and Plays.

Outer Rankin - Victoria Trough:

• Structural closures and minor fault traps may be sourced from potential Lower - Middle Jurassic oil prone, and/or Triassic gas/light oil prone source rocks in the Victoria Trough.

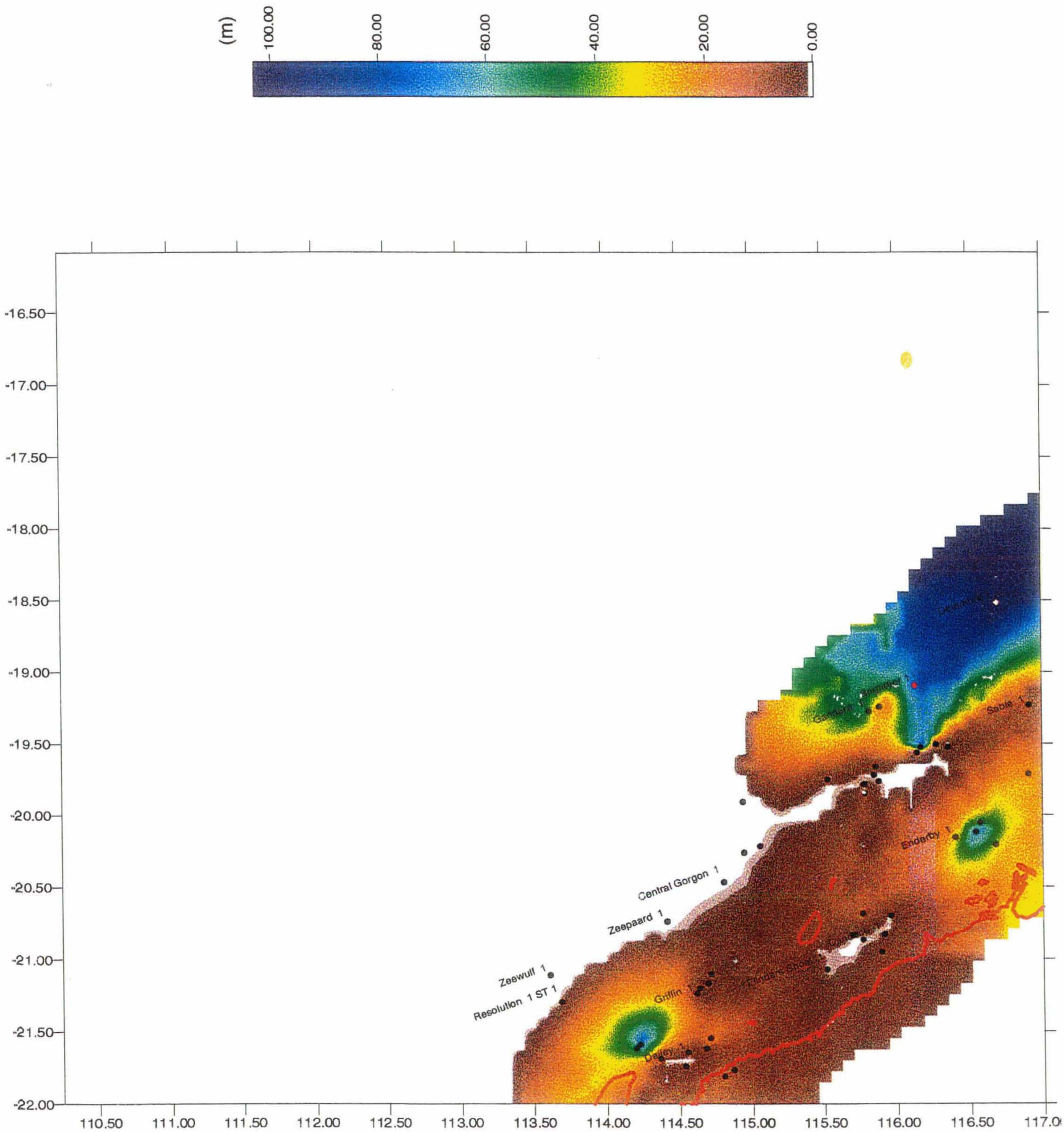


Figure 3[illegible]: Time slice J3 isopach map based on Stratdat well database. Module wells have red coloured well symbols.

TIME SLICE J4:
MIDDLE JURASSIC: LATE TOARCIAN, AALENIAN, EARLIEST BAJOCIAN (189.0 TO 180.0 MA).

Petroleum System: Westralian 2 (see Enclosure 3).
This time slice has been rarely intersected. It may be a good oil condensate source in the Dampier & Barrow Sub-basins.

Formation Synonyms: (see Figure 2).
Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Dingo Claystone. Condensed section is present over most of the module area.

Regional Definition of Time slice: (see Figure 2).
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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*C.turbatus* (B2), and
- Delambre 1:	*C.turbatus* (B3), *L.d'orbignyi* (B3).

Tectonics: (see Enclosure 1, Figures 2 & 3).

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

Local
This time slice is interpreted to be influenced by a pull-apart regime related to the breakup of Argoland. Pre-ARGOLAND breakup pull-apart phases are interpreted to have been active since the Lower Jurassic. The evidence comes from unconformities in time slices J3 and J5 seen in Brigadier 1 and Delambre 1 where the Lower-Middle Jurassic section is preserved. Unconformities of this age have also been noted in the Carnarvon Basin (Lipski, 1993; Delfos, 1994; Rasidi, 1995). Marine incursions possibly associated with structural re-adjustment phases occur in the Roebuck and Offshore Canning Basins-Beagle Sub-basin (Sayers et al, 1995; Shafik, 1994). It is also believed that the East Exmouth Continental Fracture Zone (Figure 11: the East Exmouth Continental Fracture Zone includes the Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone, Argoland Transfer) further developed as the area underwent pull apart in the Lower Jurassic. This pull apart system established an extensional regime throughout the Carnarvon Basin that would see substantial depocentres being formed, and filled (Beagle, Cossigny, Exmouth, Victoria) and peaked in the Argoland breakup.

Lithology: (see Enclosure 2).
Siltstones, claystones and calcareous claystones are found in Delambre 1 and Brigadier 1.

Thickness Variations: (see Figure 31).
Time slice J4 is condensed or absent in the central and southern Exmouth Platform but is thicker towards the northeast where the section is more proximal. Thickness ranges from 0m to 786m in Delambre 1 in the thirteen module wells. A maximum thickness for the Carnarvon Basin of 800m occurs in the Outer Rankin Platform. A secondary depocentre is present in the Exmouth Sub-basin. The time slice thickness is a result of both erosional and depositional processes hence a degree of caution is necessary when reviewing Figure 31.

Palaeodepositional Environments: (see Enclosure 15).
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.

Palaeogeography: (see Enclosure 16).

• Particular palaeogeography environments boundaries coincide with the boundary of the East Exmouth Continental Fracture Zone which was active during the Upper Triassic. Slightly deeper waters are prevailing to the north of this Zone.

• Seismic shows that the Lower Jurassic downlaps to the west of Gandara 1. A similar pattern is also seen in the Rowley Sub-basin (Sayers et al, 1995) where sediments downlapped onto a shallow marine platform. A condensed section is interpreted west of these continental shelf progrades. Lower Jurassic sediments probably downlapped in a similar manner in the Exmouth Sub-basin, but were subsequently deformed during the Middle Jurassic wrench regime. Consequently no early Jurassic sediments extend beyond this trough onto the Exmouth Platform.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- average TOC = 1.6% at Brigadier 1,
- average VR = 0.5% at Brigadier 1,
- average HI = 110 at Brigadier 1, and
- average Tmax = 423 at Brigadier 1.

This time slice is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Platform will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Delambre 1	25% < average porosity < 26%, obtained from electrical logs.

Shows summary for the time slice:

Brigadier 1	G1 obtained from mud logs, and
Delambre 1	G1/L1 obtained from mud logs.

Prospectivity: (see Enclosure 3).

• Inferred gas-condensate prone source rocks are present in Brigadier 1 and Delambre 1.

• Marine-coastal reservoirs are present in Delambre 1.

• The time slice acts as a regional seal in the northeast where it is present.

Traps and Plays.

Outer Rankin - Victoria Trough:

• Structural closures & weak fault traps may be sourced from potential Lower - Middle Jurassic oil prone and/or Triassic gas / light oil prone source rocks. Although the Victoria Trough is not a substantial depocentre, source rock facies are likely to be more distal and more oil prone relative to the inner Carnarvon Troughs.

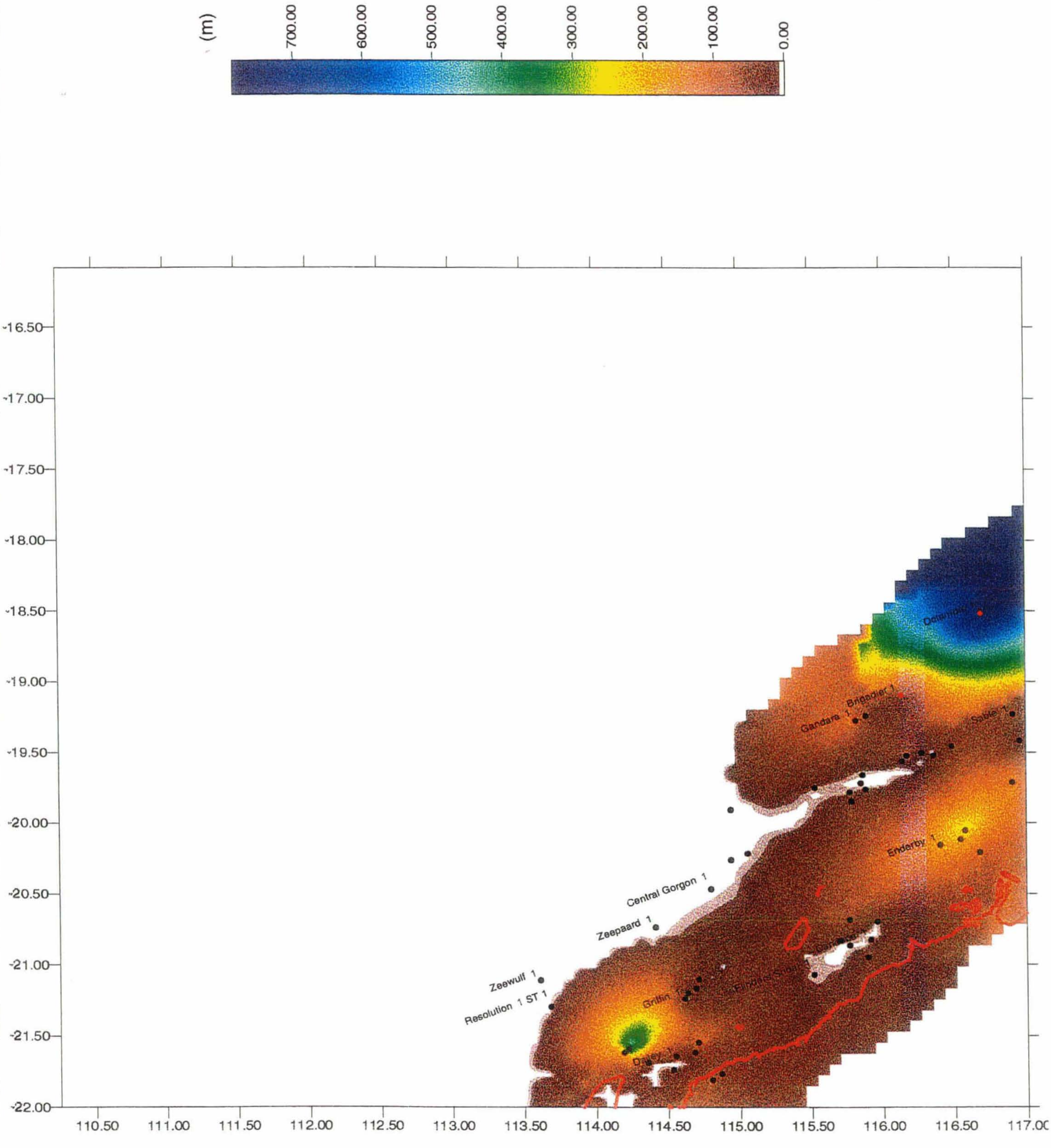


Figure 31: Time slice J4 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

TIME SLICE J5:
MIDDLE JURASSIC: BAJOCIAN (180.0 TO 177.0 MA).

Petroleum System: Westralian 2 (see Enclosure 3).
This time slice has been rarely intersected. It may be a good oil condensate source in the Dampier & Barrow Sub-basins.

Formation Synonyms: (see Figure 2).
Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Dingo Claystone. The time slice is condensed over most of the module area.

Regional Definition of Time slice: (see Figure 2).
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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1: *D.complex* (B2, B5),
- Delambre 1: *D.caddaensis* (B3, B4),
- Eendracht 1: *D.caddaensis* (B3), and
- Investigator 1: *D.complex* (B3).

Tectonics: (see Enclosure 1, Figures 2 & 3).
Regional
This time slice is interpreted to be influenced by a pull-apart regime related to the breakup of Argoland. Pre-ARGOLAND breakup pull-apart phases are interpreted to have been active since the Lower Jurassic. The evidence comes from unconformities in time slices J3 and J5 seen in Brigadier 1 and Delambre 1 where the Lower-Middle Jurassic section is preserved. Unconformities of this age have also been noted in the Carnarvon Basin (Lipski, 1993; Delfos, 1994; Rasidi, 1995). Marine incursions possibly associated with structural re-adjustment phases occur in the Roebuck and Offshore Canning Basins-Beagle Sub-basin (Sayers et al, 1995; Shafik, 1994). It is also believed that the East Exmouth Continental Fracture Zone (Figure 11: the East Exmouth Continental Fracture Zone includes the Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone, Argoland Transfer) further developed as the area underwent pull apart in the Lower Jurassic. This pull apart system established an extensional regime throughout the Carnarvon Basin that would see substantial depocentres being formed, and filled (Beagle, Cossigny, Exmouth, Victoria) and peaked in the Argoland breakup.
Local
Little is known about the tectonic regime present during this time slice in the module area. The depocentres of the Dampier, Exmouth and Barrow Sub-basins were forming coevally with the development of the Argoland rift margin to the north,. 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 Enclosure 2).
Siltstones, claystones and calcareous claystones are found in Delambre 1 and Brigadier 1.

Thickness Variations: (see Figure 32).
Time slice J5 is condensed or absent in the central and southern Exmouth Platform whilst it is more significant in thickness towards the northeast where it varies from a distal basinal section to a more proximal section. The thickness ranges from 0m to 466m (Delambre 1) in the thirteen module wells. The thickness ranges up to 500m in the Outer Rankin when considering all of the Carnarvon Basin and Exmouth Platform. Primary depocentres are also present in the Lewis Trough. Jurassic time slice isopachs are subject to both erosional and depositional processes hence a degree of caution is necessary when reviewing this isopach.

Palaeodepositional Environments: (see Enclosure 15).

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.

Palaeogeography: (see Enclosure 16).

• Particular palaeogeographic environment boundaries coincide with the boundary of the East Exmouth Continental Fracture Zone which was active during the Upper Triassic. Slightly deeper waters prevailed to the north of the Zone.

• The Lower Jurassic is seen to downlap to the west of Gandara 1 as also seen in the Rowley Sub-basin (Sayers et al, 1995) where sediments were downlapping on a shallow marine platform. Sediments are interpreted to be condensed west of these continental shelf progrades. Sediments probably downlapped in the Exmouth Sub-basin at the time of deposition and were then deformed during the Middle Jurassic wrench regime. Consequently no sediments could extend beyond this trough onto the Exmouth Platform.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 6).

The following summarises the geochemistry:
- average TOC = 1.6% at Brigadier 1,
- average VR = 0.5% at Brigadier 1,
- average HI = 96 at Brigadier 1, and
- average Tmax = 426 at Brigadier 1.

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Platform will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Delambre 1	25% < average porosity < 27%, obtained from electrical logs.

Shows summary for the time slice:

Brigadier 1	G1 obtained from mud logs, L1 obtained from SWC, and
Delambre 1	G1 obtained from mud logs.

Prospectivity: (see Enclosure 3).

Marine-coastal reservoirs are present in Brigadier 1 and Delambre 1.
The time slice acts as a regional seal in the northeast where it is present.

Traps and Plays.

Outer Rankin - Victoria Trough:

• Structural closures & weak fault traps may be sourced from potential Lower - Middle Jurassic oil prone and/or Triassic gas/light oil prone source rocks. Although the Victoria Trough is not a substantial depocentre, source rock facies are likely to be more distal and more oil prone relative to the inner Carnarvon Troughs.

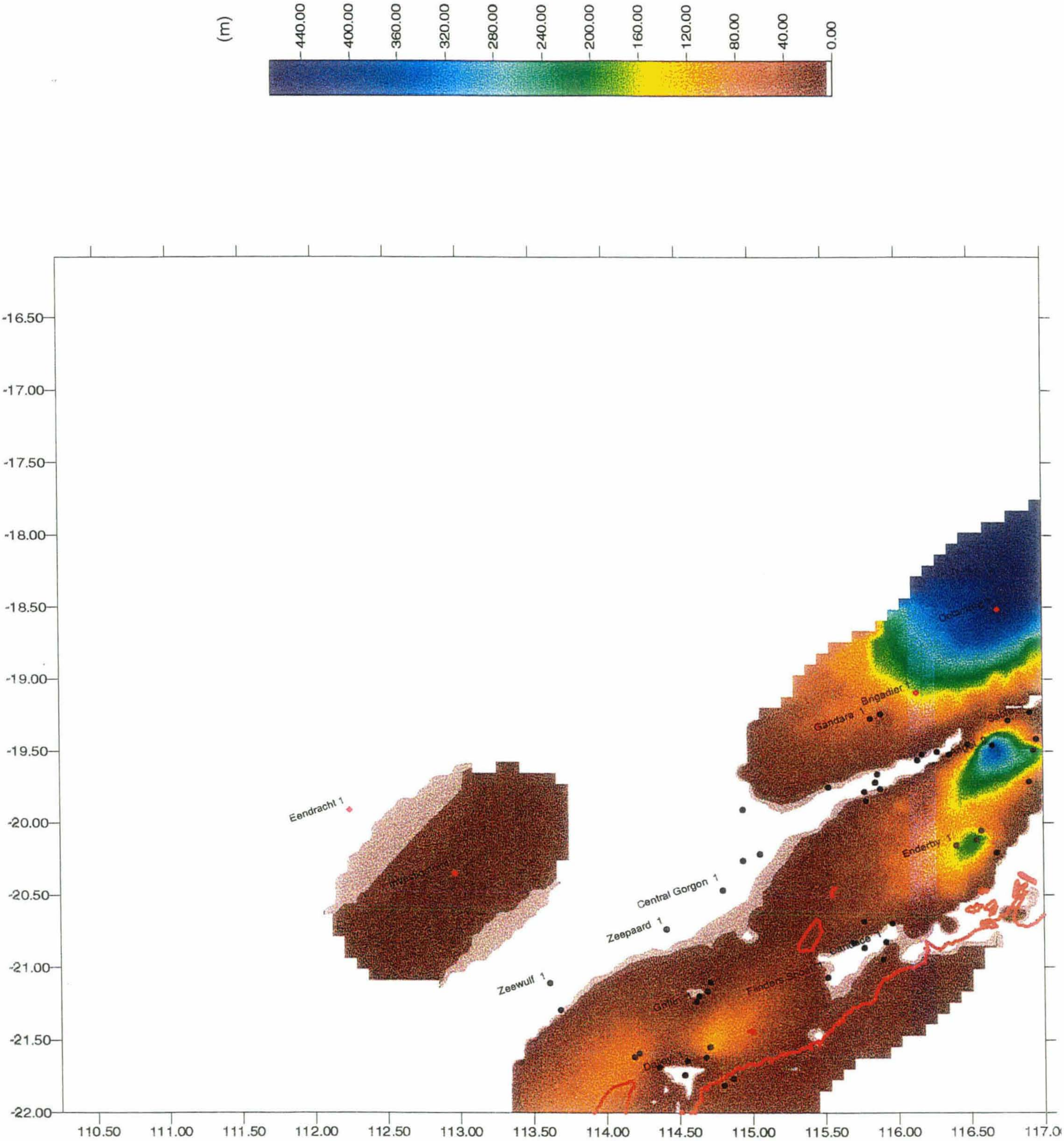


Figure 32: Time slice J5 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

TIME SLICE J6:

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

Petroleum System: Westralian 2 (see Enclosure 3).

This time slice is poorly understood but possibly has good oil-condensate potential in the deeper troughs. The time slice is condensed over the Exmouth Plateau.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, includes the Biggada Formation in Brigadier 1 and Delambre 1.

Regional Definition of Time slice: (see Figure 2).

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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*C.cooksoniae* (B2),
- Delambre 1:	*C.halosa* (B3), *W.indotata* (B3),
- Eendracht 1:	*W.indotata* (B4), and
- Investigator 1:	*W.indotata* (D4), *D.complex* (B3).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia was part of a greater Gondwana (Baillie et al, 1994). At the end of time slice J6 Argoland may have broken from Gondawana along what is now the northern Exmouth Plateau margin.

Local

This time slice is interpreted to be influenced by a pull-apart regime related to the breakup of Argoland. Pre-ARGOLAND breakup pull-apart phases are interpreted to have been active since the Lower Jurassic. The evidence comes from unconformities in time slices J3 and J5 seen in Brigadier 1 and Delambre 1 where the Lower-Middle Jurassic section is preserved. Unconformities of this age have also been noted in the Carnarvon Basin (Lipski, 1993; Delfos, 1994; Rasidi, 1995). Marine incursions possibly associated with structural re-adjustment phases occur in the Roebuck and Offshore Canning Basins-Beagle Sub-basin (Sayers et al, 1995; Shafik, 1994). It is also believed that the East Exmouth Continental Fracture Zone (Figure 11: the East Exmouth Continental Fracture Zone includes the Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone, Argoland Transfer) further developed as the area underwent pull apart in the Lower Jurassic. This pull apart system established an extensional regime throughout the Carnarvon Basin that would see substantial depocentres being formed, and filled (Beagle, Cossigny, Exmouth, Victoria) and peaked in the Argoland breakup.

Very little is known about the local tectonic regime present during this time slice in the module area. The subsiding depocentres of the Dampier, Exmouth and Barrow Sub-basins evolved 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 saw this tear movement on features such as the Bundegi Fault, were it created terraces thereby extending 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 Enclosure 2).

Sandy facies are found in Delambre 1 and Brigadier 1.

Thickness Variations: (see Figure 33).

Time slice J6 is condensed or absent in the central and southern Exmouth Platform whilst it is more significant in thickness towards the northeast where it is varying from a distal basinal section to a more proximal section. In the thirteen module wells thickness ranges from 0m to a maximum 262m in Brigadier 1. A maximum Carnarvon Basin thickness up to 700m occurs in the Lewis Trough. Thickest deposits are restricted to the main Carnarvon Basin Depocentres, namely the Exmouth, Barrow and Dampier Sub-basins. The time slice thickness is a result of both erosional and depositional processes hence a degree of caution is necessary when reviewing Figure 33.

Palaeodepositional Environments: (see Enclosure 15).

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) show a uniform eustatic regime (Struckmeyer & Brown, 1990). The base of time slice J6 is marked by a large sea level fall.

Palaeogeography: (see Enclosure 16).

- Particular palaeogeography environments boundaries coincide with the boundary of the East Exmouth Continental Fracture Zone which was active during the Upper Triassic. Slightly deeper waters are prevailing to the north of this zone.
- The Lower Jurassic downlaps to the west of Gandara 1 as also seen in the Rowley Sub-basin (Sayers et al, 1995) where sediments downlap on a shallow marine platform. Sediments are interpreted to be condensed west of these continental shelf progrades. Sediments probably downlapped in the Exmouth Sub-basin at time of deposition and were then deformed during the Middle Jurassic wrench regime. Consequently no sediments could extend beyond this trough onto the Exmouth Platform.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:
- average TOC = 0.9% at Brigadier 1,
- average VR = 0.5% at Brigadier 1,
- average HI = 91 at Brigadier 1, and
- average Tmax = 418 at Brigadier 1.

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Platform will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Delambre 1 26 < average porosity < 28, obtained from electrical logs.

Shows summary for the time slice:

Brigadier 1, Delambre 1 G1 obtained from mud logs.

Prospectivity: (see Enclosure 3).

- Marine-coastal reservoirs are present in Brigadier 1 and Delambre 1.
- The time slice has poor sealing capacity.
- Prospectivity elements are not expected over the major part of the Exmouth Platform as the time slice is dominantly condensed.

Traps and Plays.

Outer Rankin - Victoria Trough:

- Structural closures & weak fault traps may be sourced from potential Lower - Middle Jurassic oil prone and/or Triassic gas/light oil prone source rocks. Although the Victoria Trough is not a substantial depocentre, source rock facies are likely to be more distal and oil prone relative to the inner Carnarvon Troughs.

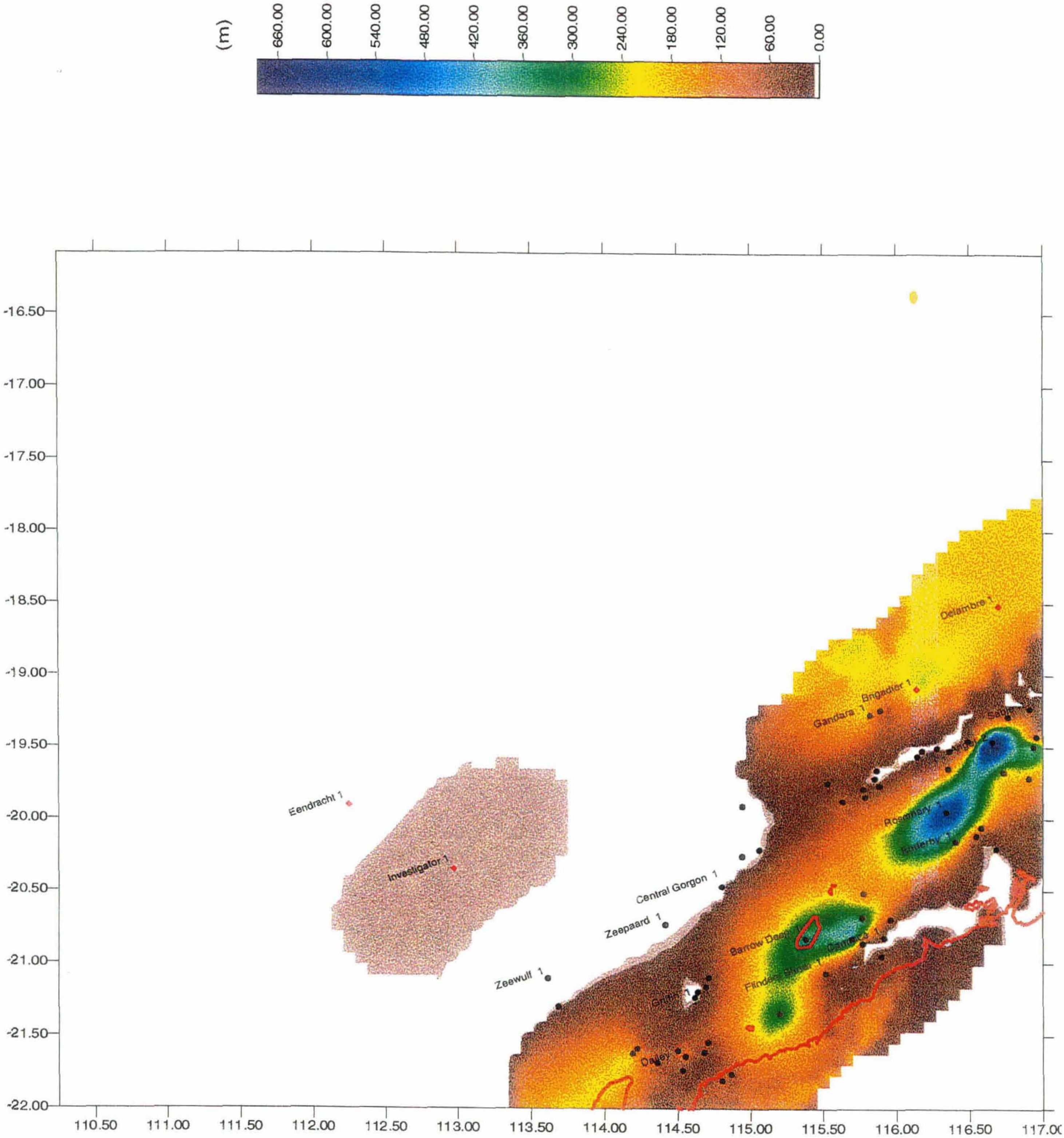


Figure 33: Time slice J6 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

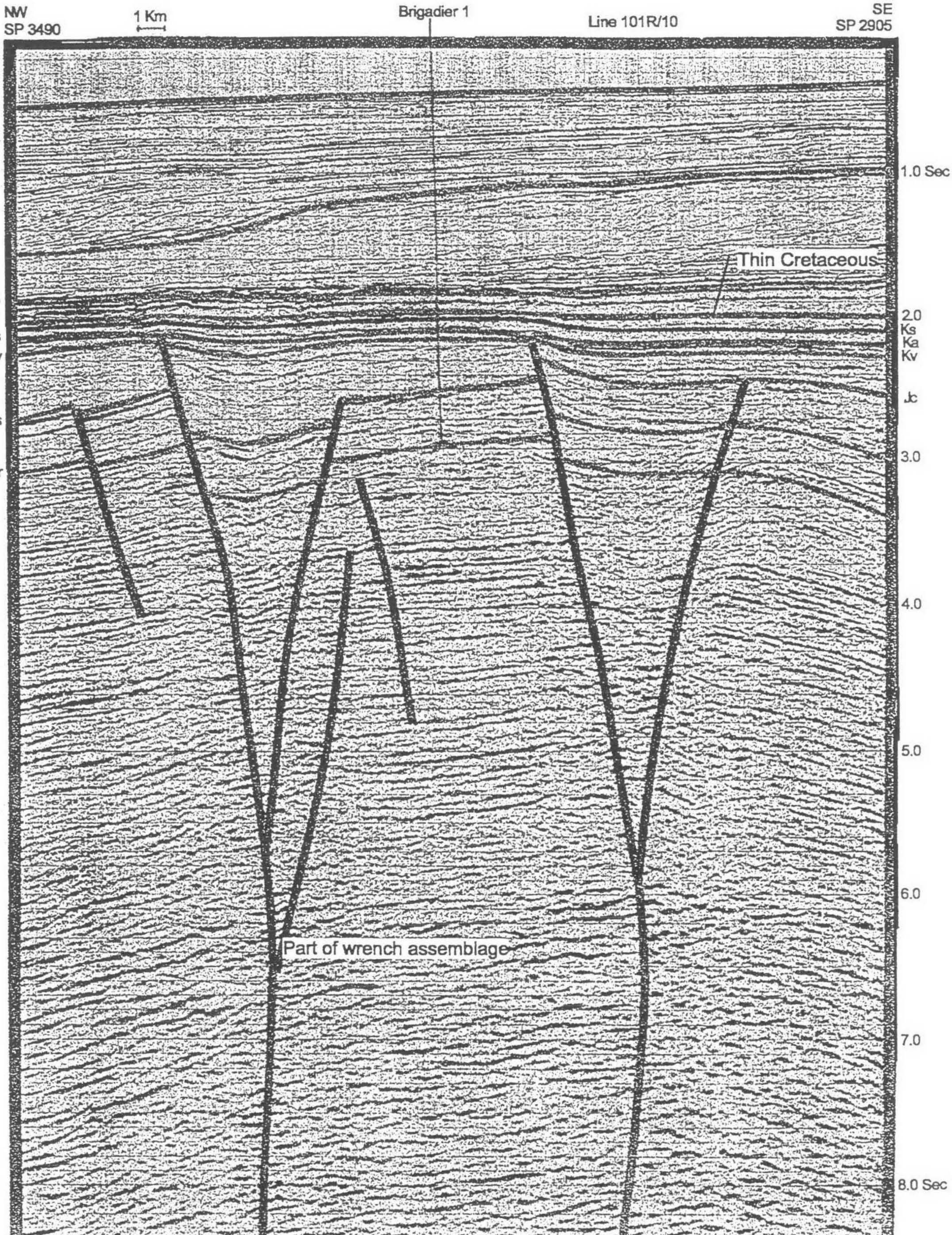


Figure 34: Faulting style at Brigadier 1 and adjacent to the East Exmouth Continental Fracture Zone and associated Middle Jurassic wrench zone. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. Tm - top time slice Cz5, To - top time slice Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Jc - top time slice J7, Js - top time slice J1, TR - top time slice Tr5.

TIME SLICE J7:

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

Petroleum System: Westralian 2 (see Enclosure 3).

This upper part of the time slice is coincident with Argoland breakup. A heat pulse may be associated with this event in the outer Rowley and Dixon Sub-basins. Migration of hydrocarbons may have also coincided with this event although hydrocarbons may have escaped the system.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. An equivalent formation from the offshore Carnarvon Basin, to the southeast of the module area, is the Dingo Claystone. This time slice is condensed for most of the Module area.

Regional Definition of Time slice: (see Figure 2).

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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Investigator 1:	*W.digitata* (D4), and
- Jupiter 1:	*W.digitata* (B5).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia was part of greater Gondwana (Baillie et al, 1994). Through all or most of time slice J7, a trans-tensional 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 north-eastern margin of the Exmouth Platform. The pull-apart nature of this tectonism caused different areas to simultaneously undergo extension and compression. Within the Barrow, Dampier and probably the Exmouth depocentres, there was a hiatus at the start of time slice J7, followed by extensive subsidence and deposition.

Local

This time slice is interpreted to be influenced by a pull-apart regime related to the breakup of Argoland. Pre-ARGOLAND breakup pull-apart phases are interpreted to have been active since the Lower Jurassic. The evidence comes from unconformities in time slices J3 and J5 seen in Brigadier 1 and Delambre 1 where the Lower-Middle Jurassic section is preserved. Unconformities of this age have also been noted in the Carnarvon Basin (Lipski, 1993; Delfos, 1994; Rasidi, 1995). Marine incursions possibly associated with structural re-adjustment phases occur in the Roebuck and Offshore Canning Basins-Beagle Sub-basin (Sayers et al, 1995; Shafik, 1994). It is also believed that the East Exmouth Continental Fracture Zone (Figure 11: the East Exmouth Continental Fracture Zone includes the Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone, Argoland Transfer) further developed as the area underwent pull apart in the Lower Jurassic. This pull apart system established an extensional regime throughout the Carnarvon Basin that would see substantial depocentres being formed, and filled (Beagle, Cossigny, Exmouth, Victoria) and peaked in the Argoland breakup. Figure 34 shows faults adjacent to Brigadier 1 which are interpreted to have initiated during the Lower Jurassic and terminated at the top Callovian at the ARGOLAND breakup stage.

Lithology: (see Enclosure 2).

Time slice J7 is condensed or absent in the central and southern Exmouth Platform. It has not been intersected elsewhere in the wells reviewed in this module.

Thickness Variations: (Figure 35).

Thickness ranges from 0m to 14.5m in Jupiter 1, considering only the thirteen module wells. A maximum thickness of 750m is found in Barrow Deep 1, when considering all of the Carnarvon Basin and Exmouth Platform. The time slice is restricted to the main Carnarvon Basin Depocentres, namely the Exmouth, Barrow and Dampier Sub-basins. Jurassic time slice isopachs are the result of both erosional and depositional processes as opposed to Cretaceous isopachs which are dominantly controlled by depositional processes hence a degree of caution is necessary when reviewing these isopachs.

Palaeodepositional Environments: (see Enclosure 17).

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) show a uniform eustatic regime (Struckmeyer & Brown, 1990). 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.

Palaeogeography: (No Enclosure).

Figures 16 and 18 show the Middle - Upper Jurassic interpreted to be absent or condensed on the Exmouth Plateau.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

An average TOC value of 0.7% at Jupiter 1 is the only analysis available. The module area, consequently, is highly undersampled so there is poor knowledge of the source rock potential of this time slice. The maturation history of the source rock will be different throughout the module area due to the variation of Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity and permeability data exist and no shows were recorded in the module wells.

Prospectivity: (see Enclosure 3).

- Clastic reservoirs are not present in the module wells.
- The time slice acts as a regional seal.
- Oil & gas shows are present in the Upper Jurassic in the Exmouth Sub-basin (Bauer et al, 1994) and quality prospectivity elements are expected.
- The time slice is not prospective on the Exmouth Platform.

Traps and Plays.

No traps or plays recognised.

TIME SLICE J8:

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

Petroleum System: Westralian 3 (see Enclosure 3).

The Westralian 3 Petroleum System is defined as the interval spaning the commencement of drift of Argoland and the commencement of drift of Greater India. The time slice is a major source interval in the inshore Carnarvon Basins but on the Exmouth Plateau is thin or condensed.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. An equivalent formation from the offshore Carnarvon Basin, to the southeast of the module area, is the Dingo Claystone.

Regional Definition of Time slice: (see Figure 2).

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 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 summarises the palaeontological control and species zones confidence ratings (refer to introduction for description of confidence ratings, page iii):

- Eendracht 1:	*W.spectabilis* (B4), *D.swanense* (B1), *W.clathrata* (B4), and
- Investigator 1:	*W.clathrata* (B3, B5).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

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

The breakup along the margin of the Roebuck Basin occurred at approximately the top of time slice J7 to base of time slice J8. Volcanism occurred along an approximately 100km front with Argoland (present day West Burma and NW Sumatra; Metcalf, 1993) drifting northward. At the end of time slice J8, Argoland is estimated from magnetic sea floor lineations to be about 900km to the NNW of the COB. This equates to an average drift rate of about 7mm per year. The continental mass to the west of the Roebuck Basin included the Exmouth Platform. Weakness zones initiated during the Argoland breakup (eg Thouin and Montebello Grabens) further developed to become mature grabens during the Greater India breakup.

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 re-adjustments.

Local

Seismic clearly establishes truncational erosion of the Jurassic strata which is subsequently overlain by the Upper Jurassic and time slice K1 in the inner Carnarvon Basin. The presence of unconformities over the main module area is not clear on time depth curves due to the absence of Middle-Upper Jurassic strata and thus the coalescence of different unconformities. However the boundary is fairly well seen in the Victoria Trough and some outer Rankin Platform wells.

Tectonic deformation along the East Exmouth Continental Fracture Zone (Yardie Hinge, Alpha Hilda Arch, Southern and Northern Rankin Escarpments, West Cossigny Fractures, North Turtle Wrench zone and Argoland Transfer) and associated wrench systems, initiated in the Lower Jurassic and culminated during the Argoland breakup at the top Callovian. Exposure and erosion of the Middle Jurassic off the Rankin Trend occurred as a result.

A pull apart system with substantial Lower-Middle Jurassic deposition in the Dampier, Barrow and Exmouth Sub-basins was now firmly established. The East Exmouth Continental Fracture Zone is the anchor zone for a series of northeast orientated wrench faults and anticlines that developed on its northern edge. The influence of the Argoland breakup on most of the Exmouth Platform appear to be small, as most of the strain is being released along the East Exmouth Continental Fracture Zone (Sayers et al, 1995).

Implications of the Argoland breakup for palaeogeographic reconstruction (Sayers et al, 1995) include;

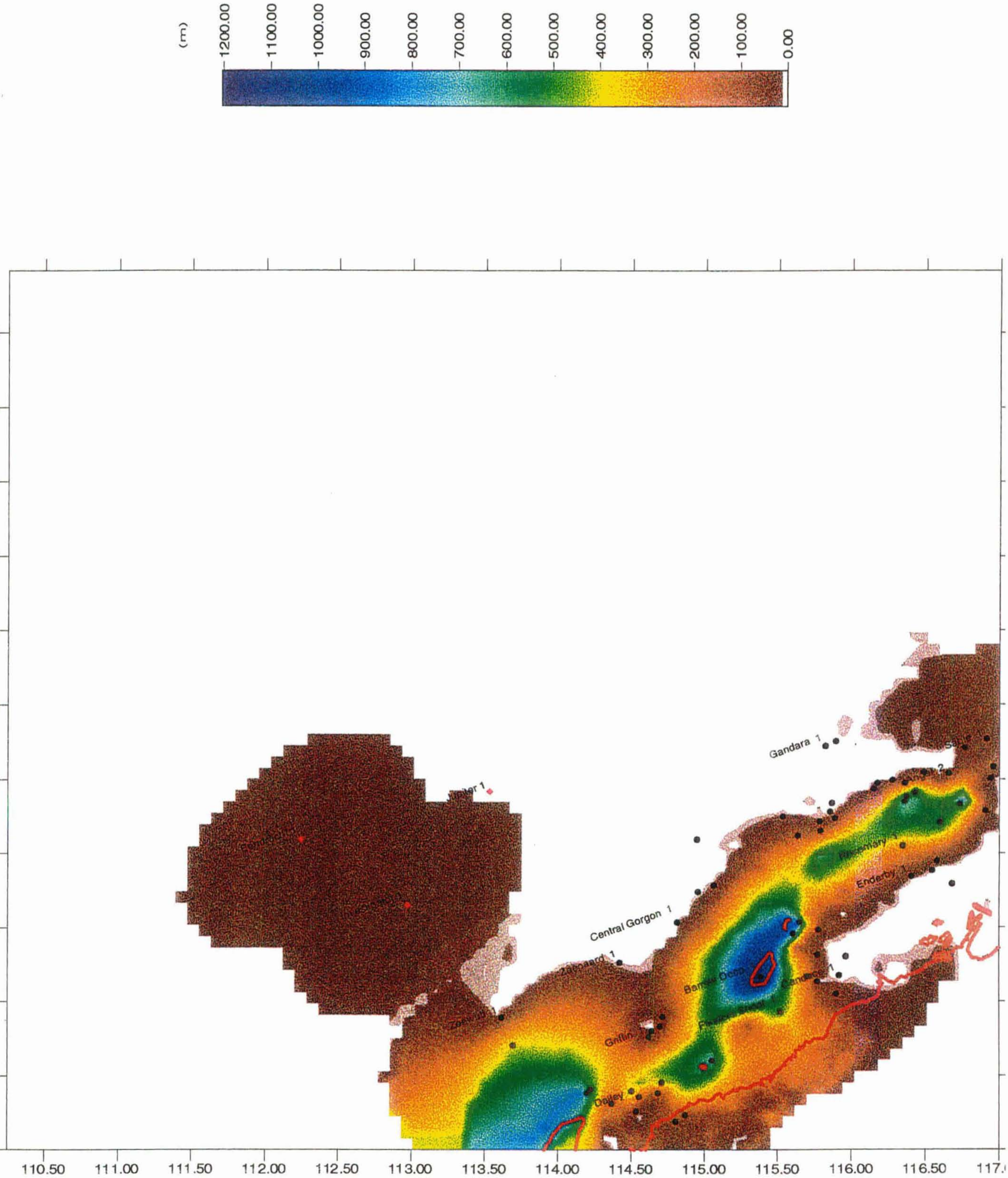


Figure 35: Time slice J7 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

• extension of an Argo Abyssal Plain transfer fault onto the continental crust which is part of a larger weakness zone of the plate (Figure 11), and

• fracture zones present in the developing Thouin and Montebello Grabens. 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. Other smaller scale rift/pull-apart grabens although not mapped in the module area are expected to be present.

Lithology: (see Enclosure 2).

Time slice J8 is condensed or absent in the central and southern Exmouth Platform. It has not been intersected elsewhere in the wells reviewed in this module.

Thickness Variations: (see Figure 36).

This time slice is 18m in Eendracht 1 and 17m in Investigator. In all the other module wells it is absent or condensed. Figure 36 shows that a maximum thickness for the Carnarvon Basin of 1200m when considering all of the Carnarvon Basin and Exmouth Platform. The thicks are restricted to the inshore Carnarvon depocentres; the Exmouth, Barrow and Dampier Sub-basins. Jurassic time slice thicks are the result of both erosional and depositional processes so a degree of caution is necessary to review Figure 36.

Palaeodepositional Environments: (see Enclosure 18).

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 shown not to have shifted significantly since time slice J7.

Palaeogeography: (see Enclosure 19).

• Time slice J8 is a sediment poor interval over most of the Exmouth Platform and Outer Rankin and is mapped as a condensed sequence in most places. Moderate evidence of downlap of the Middle Jurassic is seen to the west of Brigadier 1 providing evidence of non-deposition to condensed section across the platform.

• The Exmouth Sub-basin was a structural low accumulating substantial Middle to Upper Jurassic sediments. Any transport of sediments seaward, beyond the Sub-basin, would have been hindered by reverse palaeo slopes thus providing an explanation for the lack of sediments northwest of the Sub-basin. It is possible that the whole of the Exmouth Platform had a regional tilt to the southeast.

• It is possible that Middle-Upper Jurassic sediments exist on the northeast side of the Cape Range Transform fault as this area would have been closer to the Greater India landmass.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- 0.6%< average TOC < 0.9% (2 control points),
- average HI = 27 at Investigator 1, and
- average Tmax = 443 at Investigator 1.

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Jurassic to Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exists. No shows were recorded in the module wells used.

Prospectivity: (see Enclosure 3).

• Time slice J8 is not a prospective source rock interval on the Exmouth Platform or Outer Rankin as it is in the Exmouth Sub-basin.

• Time slice J8 acts as a local seal with the exception of Investigator 1 where reservoir facies are present.

Traps and Plays.

None interpreted.

TIME SLICE J9:

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

Petroleum System: Westralian 3 (see Enclosure 3).

This is one of the main source rock intervals of the Westralian Petroleum system, particularly in the Dampier, Barrow and Exmouth Sub- Basins. However over the module area it is thin to condensed and cannot be regarded as a potential significant source rock.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. An equivalent formation from the offshore Carnarvon Basin, to the southeast of the module area, include the Dingo Claystone.

Regional Definition of Time slice: (see Figure 2).

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. The 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 slice. The following summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Vinck 1: *O.montgomeryi* (B3).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

Western Australia was part of Greater Gondwana which included Greater India and Antarctica (Baillie et al, 1994).

Local

Time slices J8 and J9 unconformities, established in the Dampier Sub-basin (Spencer et al, 1993), cannot be substantiated in the module area due to the condensed nature and poor sampling of the time slice. These unconformity horizons or their equivalents are likely to be present as crustal stretching prior to the Greater India breakup is believed to be occurring.

Lithology: (see Enclosure 2).

Time slice J9 is condensed or absent in the central and southern Exmouth Platform. It is unknown whether the time slice is present in the northern Exmouth Platform. It is a light grey claystone in Vinck 1.

Thickness Variations: (see Figure 37).

For the thirteen module wells a maximum thickness of 11m occurs in Vinck 1, elsewhere the time slice is absent or highly condensed. Jurassic time slice thickness is the result of both erosional and depositional processes so a degree of caution is necessary when reviewing Figure 37. Figure 37 shows a maximum thickness for the Carnarvon Basin of 550m in the Lewis Trough. The Exmouth Sub-basin is a secondary depocentre.

Palaeodepositional Environments: (no Enclosure).

Palaeodepositional environments are thought to be similar to time slice J8, with deep water present over the Exmouth Platform.

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) show a uniform eustatic regime (Struckmeyer & Brown, 1990).

Palaeogeography: (no Enclosure).

The palaeogeography is thought to be similar to time slice J8, with deep water over the Exmouth Platform (see Enclosure 19). Sediments of this time slice are present in the Exmouth Sub-basin where the main sedimentary fill is restricted in the most part to the east side of the Novara Arch. Some Jurassic sediments have been deposited beyond the Arch to the west, probably initially as progrades.

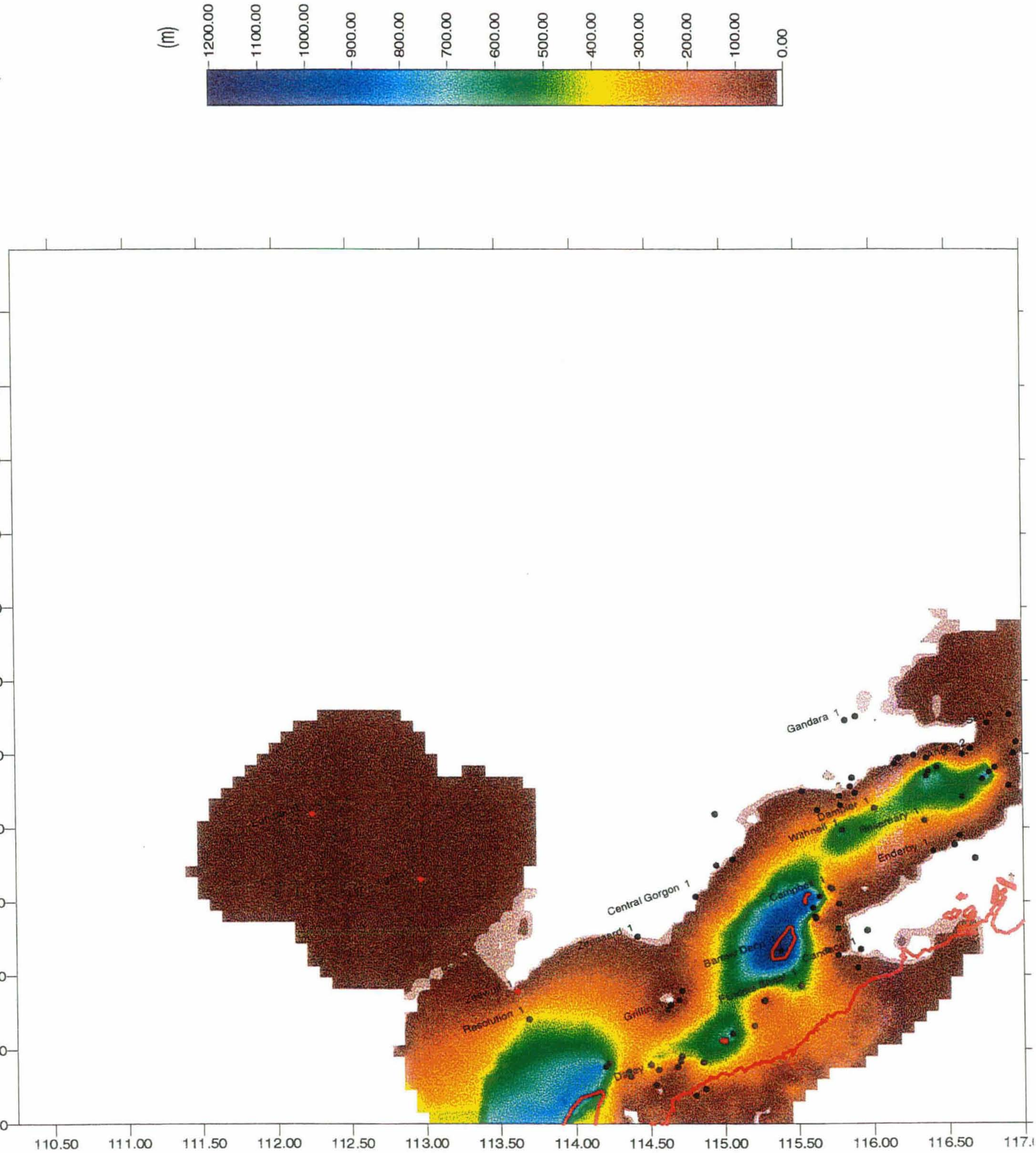


Figure 36: Time slice J8 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

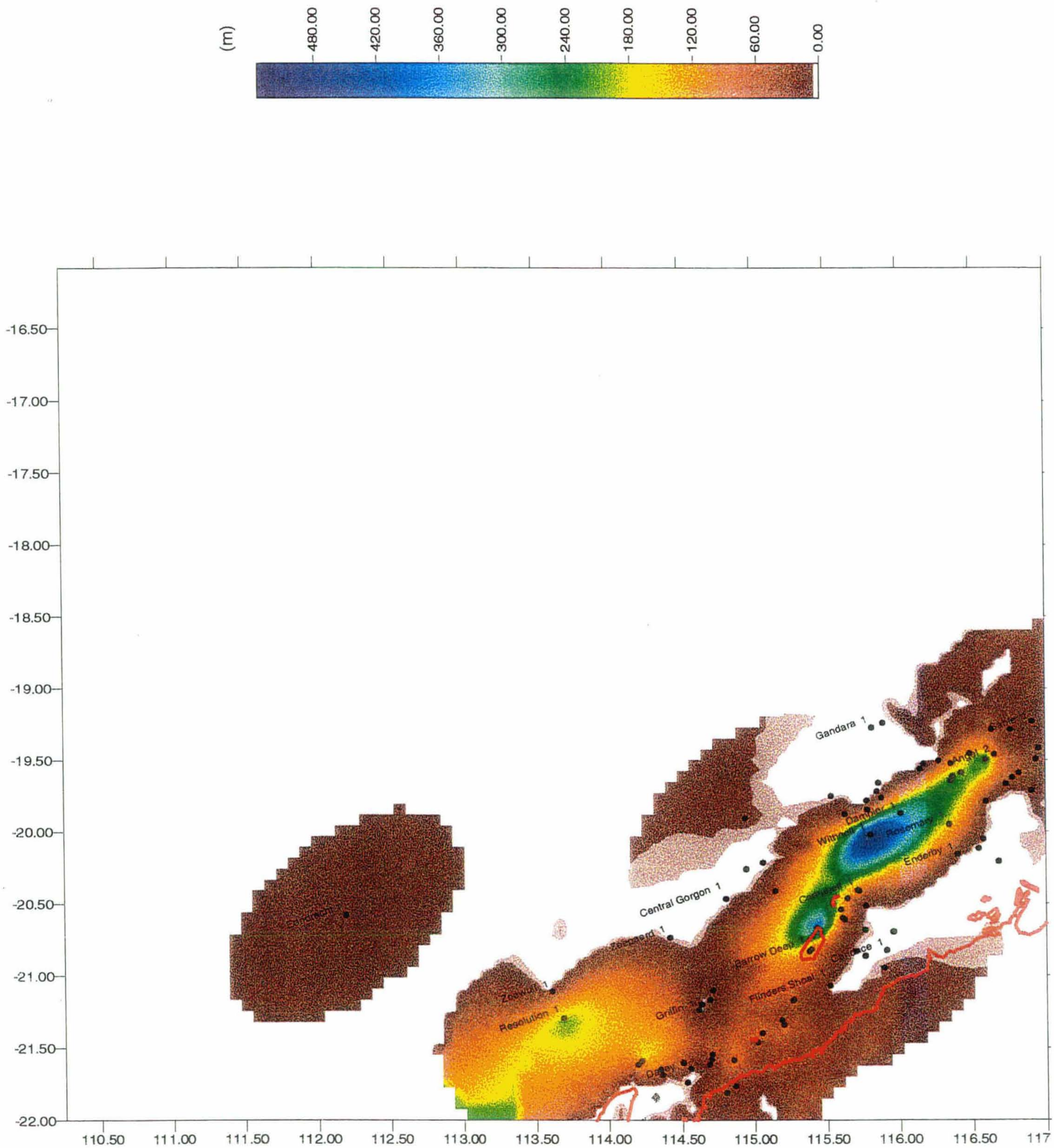


Figure 37: Time slice J9 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

No geochemical analyses are available for this time slice.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exists for this time slice. There are no recorded shows in this time slice from the module wells. .

Prospectivity: (see Enclosure 3).EXTREMELY POOR

Time slice J9 is not a prospective source rock interval on the Exmouth Platform although it is prospective in Exmouth Sub-basin. No reservoirs are expected.

Traps and Plays.

None identified.

TIME SLICE J10:
LATE JURASSIC: LATE TITHONIAN:(147.0 TO 144.0 MA).

Petroleum System: Westralian 3: (see Enclosure 3).
Time slice J10 is the first post Argoland breakup interval to have significant thickness, extent and suitable lithology to provide a local seal on the Main Unconformity surface in the vicinity of Investigator 1. No significant source potential is thought to be present for time slice J10.

Formation Synonyms: (see Figure 2).
Formal stratigraphic names are very loosely defined within the module area. An equivalent formation from the offshore Carnarvon Basin, to the southeast of the module area, is the Dingo Claystone.

Regional Definition of Time slice: (see Figure 2).
Time slice J10 is biostratigraphically defined by the lower *P.iehiense* and all of the *D.jurassicum* dinoflagellate zones. The top of the time slice is 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

-Echo 1:	*D.jurassicum* (B1), and
-Investigator 1:	L. *P.iehiense* (B1), *D.jurassicum* (B3).

The time slice is interpreted to be present in other wells on the basis of lithological or seismic correlations.

Tectonics: (see Enclosure 1, Figures 2 & 3).

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

Local
Uplift along the Cape Range Fracture Zone may have commenced, a precursor to the major movement at the time slice K1-J10 boundary. Weak evidence of an unconformity is also encountered from seismic at this level although it is clearly identifiable in the Dampier Sub-basin (Spencer et al, 1993). Time depth curves of the module wells do not conclusively establish an unconformity, due to lack of time slice J10 sedimentation, although there is weak evidence in Echo 1.

Lithology: (see Enclosure 2).
Claystones and calcareous claystones are present in Investigator 1 and Scarborough 1 whilst siltstones were intersected in Echo 1.

Thickness Variations: (see Figure 38)
For the thirteen module wells thickness to a maximum of 79m occurs in Investigator 1, but in most wells the time slice is thin, absent or condensed. A maximum thickness for the Carnarvon Basin of 500m occurs in the Lewis Trough. Jurassic time slice thickness is the result of both erosional and depositional processes so the maximum present day thickness may not reflect the depositional thickness.

Palaeodepositional Environments: (no Enclosure).
No palaeogeographic interpretation was attempted for this time slice due to the minor thickness of the time slice and the interpreted general similarity to time slice J8 (see Enclosure 19).
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) show a uniform eustatic regime (Struckmeyer & Brown, 1990), towards the lower part of the time slice with regression towards the upper part of the time slice.

Palaeogeography: (no Enclosure).
Sediments of this time slice are present in the Exmouth Sub-basin where the main sedimentary fill is restricted in the most part to the east side of the Novara Arch (Figure 52). Some Jurassic sediments have been deposited beyond the Arch to the west, probably initially as progrades.

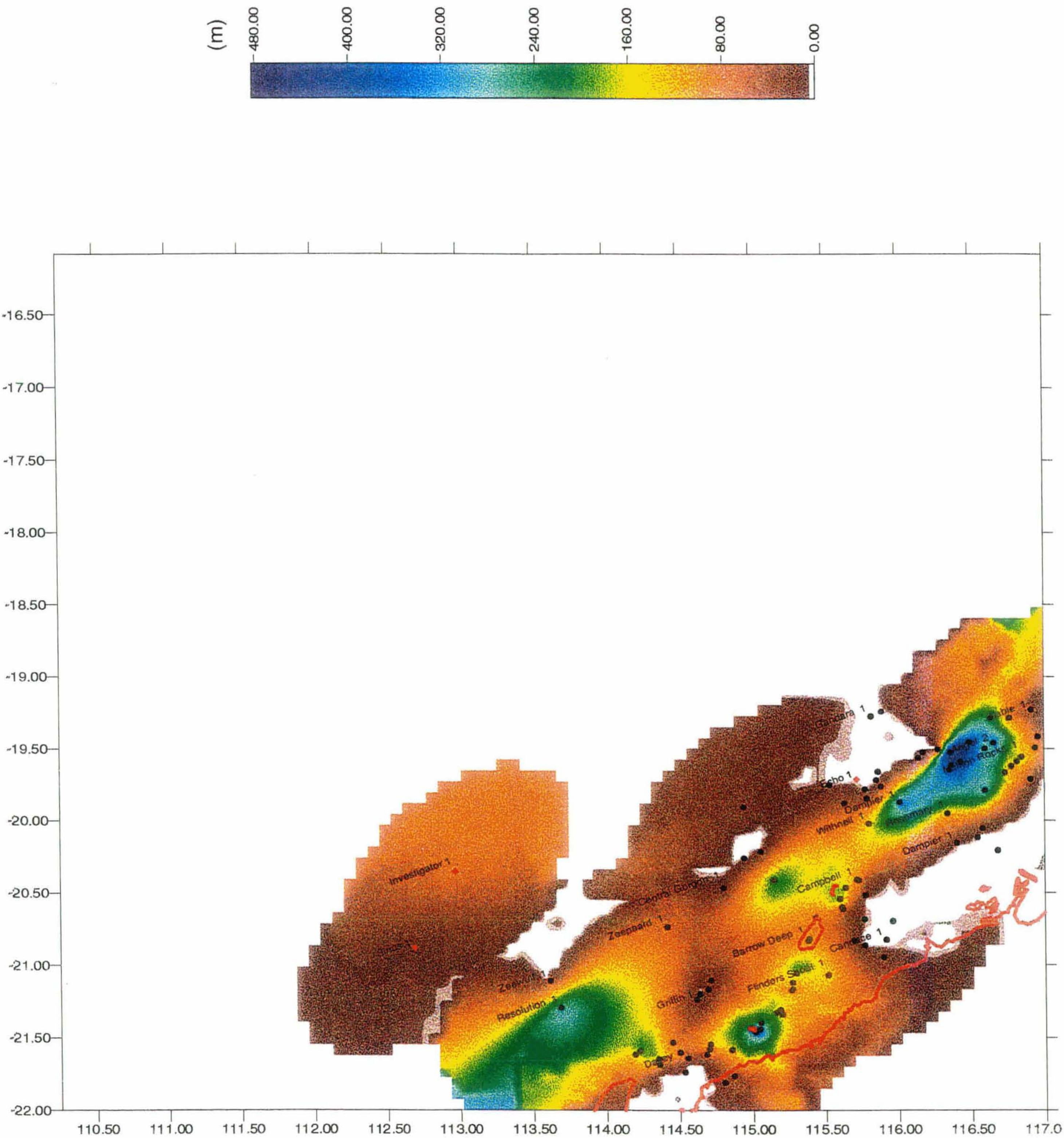


Figure 38: Time slice J10 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- average TOC = 0.9% at Investigator 1.

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exist for this time slice. Gas indications (G1) were recorded in Echo 1 and Sirius 1. The Exmouth Sub-basin also has oil and gas shows in the Upper Jurassic (Bauer et al, 1994).

Prospectivity: (see Enclosure 3).VERY POOR

•Time slice J10 is not a prospective source rock interval on the Exmouth Platform although it is prospective in the Exmouth Sub-basin.

•No reservoirs were identified, the interval is a seal facies.

Traps and plays.

None identified.

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. The Scarborough 1 very dry gas discovery is reservoired in this time slice. It is estimated to contain 10 TCF of gas (1.67 Billion barrels of oil equivalent, Kopsen 1994 p 133). It is the first thick regional seal facies but also has 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. It is a period of expected raised heat flow across the Exmouth Plateau. This effect, and the thick deposits of time slice K1 aged sediments on the southern Exmouth Plateau, may have served to push the underling Middle to Upper Triassic source rocks into the generative zone. Increased tectonic activity in this time slice could also lead to the evaporative fractionation of Triassic gas-condensate accumulations, a mechanism which may explain most of the dry gas on the Exmouth Plateau. Time slice K1 sections, thicker than approximately 100m, are strongly enriched in methane, as recorded by mud logging. This anomalously high gas could be biogenic or could be Triassic thermogenic gas that syn-sedimentarily migrated through the rapidly accumulating but unconsolidated time slice K1 sediments.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area but time slice K1 is the Barrow Group and its equivalents.

Regional Definition of Time slice: (see Figure 2).

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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Delambre 1:	*E.torynum* (B4),
- Echo 1:	*E.torynum* (B2),
- Eendracht 1:	L.*B.reticulatum* (B1), U.*B.reticulatum* (B1), *D.lobispinosum* (B1), *C.delicata* (B4), *K.wisemaniae* (B1),
- Investigator 1:	*E.torynum* (B3), U.*B.reticulatum* (B1), L.*B.reticulatum* (B1), *D.lobispinosum* (B1, B2), U.*C.delicata* (B1), L.*C.delicata* (B1), *K.wisemaniae* (B1), U.*P.iehiense* (B1),
- Jupiter 1:	*E.torynum* (B5), *P.iehiense* (B5),
- Mercury 1:	*E.torynum, C.australiensis,*
- Minden 1:	L.*B.reticulatum* (B1), U.*B.reticulatum* (B1), *D.lobispinosum* (B1), *C.australiensis* (B2), *E.torynum* (B3, B4),
- Scarborough 1:	*E.torynum* (B1), U.*B.reticulatum* (B1), L.*B.reticulatum* (B1), *D.lobispinosum* (D3),
- Sirius 1:	*D.lobispinosum* (B2, B4), *C.delicata* (B3), *K.wisemaniae* (B3),
- Sultan 1:	*E.torynum* (B3), *D.lobispinosum* (B5),
- Vinck 1:	*B.reticulatum* (B1), *D.lobispinosum* (B1, B3), *C.delicata* (B2, B4), *K.wisemaniae* (B1).

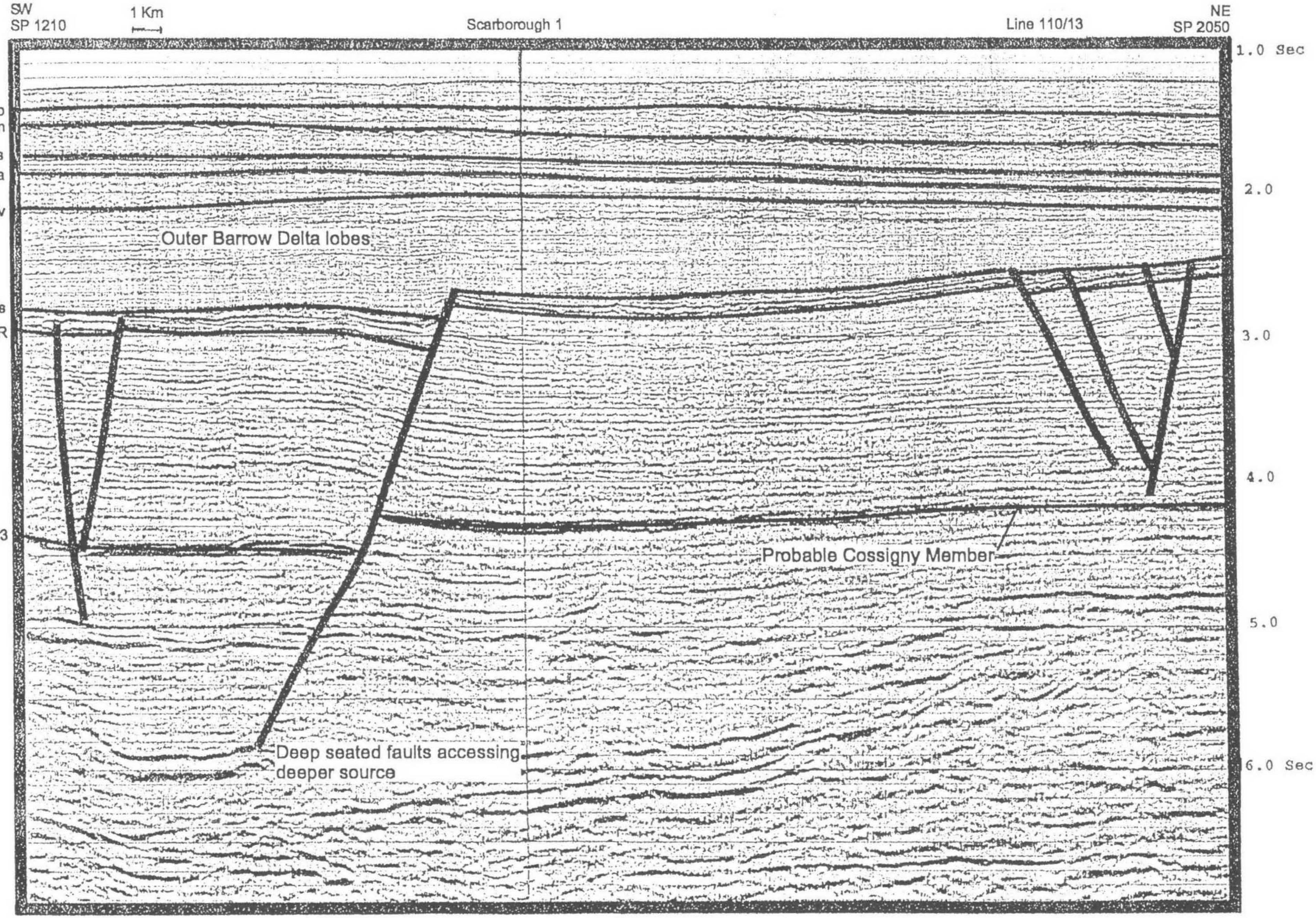


Figure 39: Scarborough 1 location and typical structural and stratigraphic configuration on the Exmouth Plateau. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Js - top time slice J1, TR - top time slice Tr5.

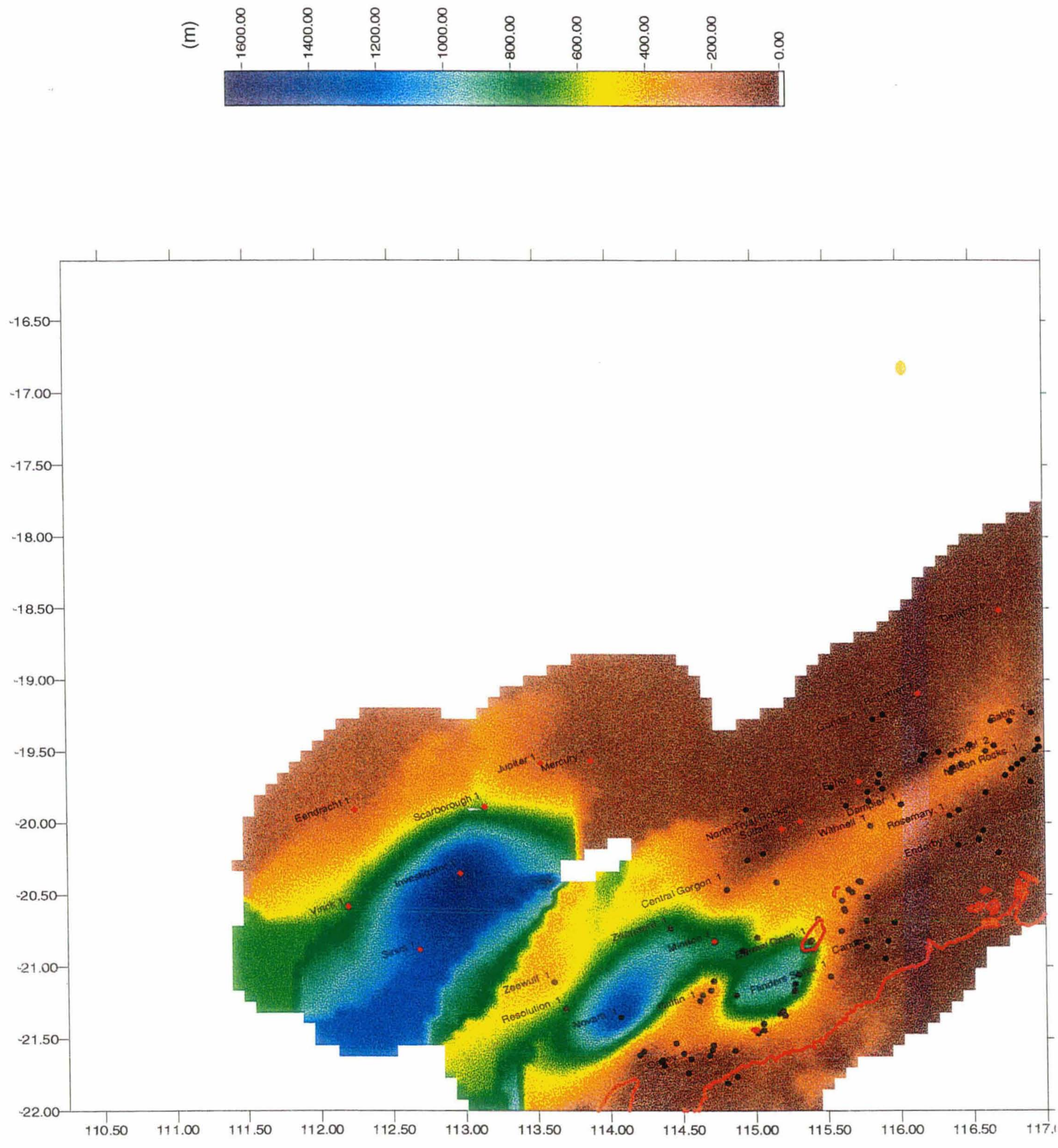


Figure 40: Time slice K1 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

Western Australia was part of Greater Gondwana that included Greater India and Antarctica (Baillie et al 1994). The base of time slice K1 is marked by volcanic ash falls in the inshore Dampier and Barrow Sub-basins. The ash falls coincide with the onset of the breakup tectonic phase. This phase culminates at the end of time slice K1 with the commencement of sea floor spreading and the drift of Greater India. These phases are also defined in the Dampier, Barrow and Exmouth Sub-basins 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

Uplift along the incipient Cape Range Fracture Zone (ie of Greater India south of the present Exmouth Plateau), together with a source to the south of Novara 1, provided massive sediment input along the southern edge of the module area. This resulted in the rapid northern progradation of the Barrow Delta Group during time slice K1. There are two main lobes within the Barrow Delta, substantiated from seismic by the faint downlap seen on the right hand side in Figure 18 and by a seismic character change seen in Figure 25. Figure 39 shows draping of the Barrow Delta lobes over older Triassic structures in an area where time slice K1 faulting does not appear to have been particularly active.

The top of time slice K1 is recognised on seismic from fault termination at this level across the module area and from a cut and fill surface in the Beagle and west Bedout Sub-basins (Sayers et al, 1995). In the Beagle Sub-basin the faults are dominantly normal reactivated Argoland breakup aged faults (Thouin Graben), but there are also faults unrelated to any previous structural event. Fault throws are relatively small and consequently time slice K1 aged faulting can be difficult to differentiate from differential compaction over older fault systems.

The main Greater India breakup, seen over all of the North West Shelf, occurs at the top of time slice K1. The event is clearly evident on all the time depth curves, as well as on the well logs. The effect of the Greater India breakup was to established a much deeper basin, shelf and slope setting for most of the module area. Rejuvenation of pre-existing fault systems occurred with pull apart grabens developing in the majority of the Exmouth Plateau-Outer Rankin. The breakup abruptly terminated sediment supply and consequently any further development of the Barrow Delta.

Lithology: (see Enclosure 2).

Dominantly claystones or calcareous claystones particularly in the basal section. Higher in the section quartz sandstones of turbidite derivation are common and the uppermost section has quartzose fine to coarse grained sandstones deposited in coastal facies.

Thickness Variations: (see Figure 40).

Time slice K1 thickness, in the thirteen module wells, ranges from 15m in North Tryal Rocks 1 to 1650m in Investigator 1. Regionally time slice K1 thicknesses are expected to have a similar range across the entire Carnarvon Basin (Figure 40). Depocentres are present in the Barrow and Exmouth Sub-basins. On the Exmouth Plateau a depositional thick (delta lobe) is centred on Investigator 1.

Palaeodepositional Environments: (see Enclosure 20).

Numerous depositional environments have been interpreted for this time slice. Deep water (>200m) environments covered most of the Exmouth Plateau. The Barrow Delta complex that built into this deep water environment has:

- slope and basin floor claystones deposits,
- Mutti type II & III slope and basin floor turbidite facies,
- delta front environments, apparently wave dominated,
- upper and lower coastal plain environments, and
- probable alluvial fans and fan deltas.

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, reflective of tectonic events and marine incursions associated with the breakup of Greater India. The coastline in the module area is however interpreted to have rapidly regressed from the south in association with the massive sediment input and rapid northern progradation of the Barrow Delta complex.

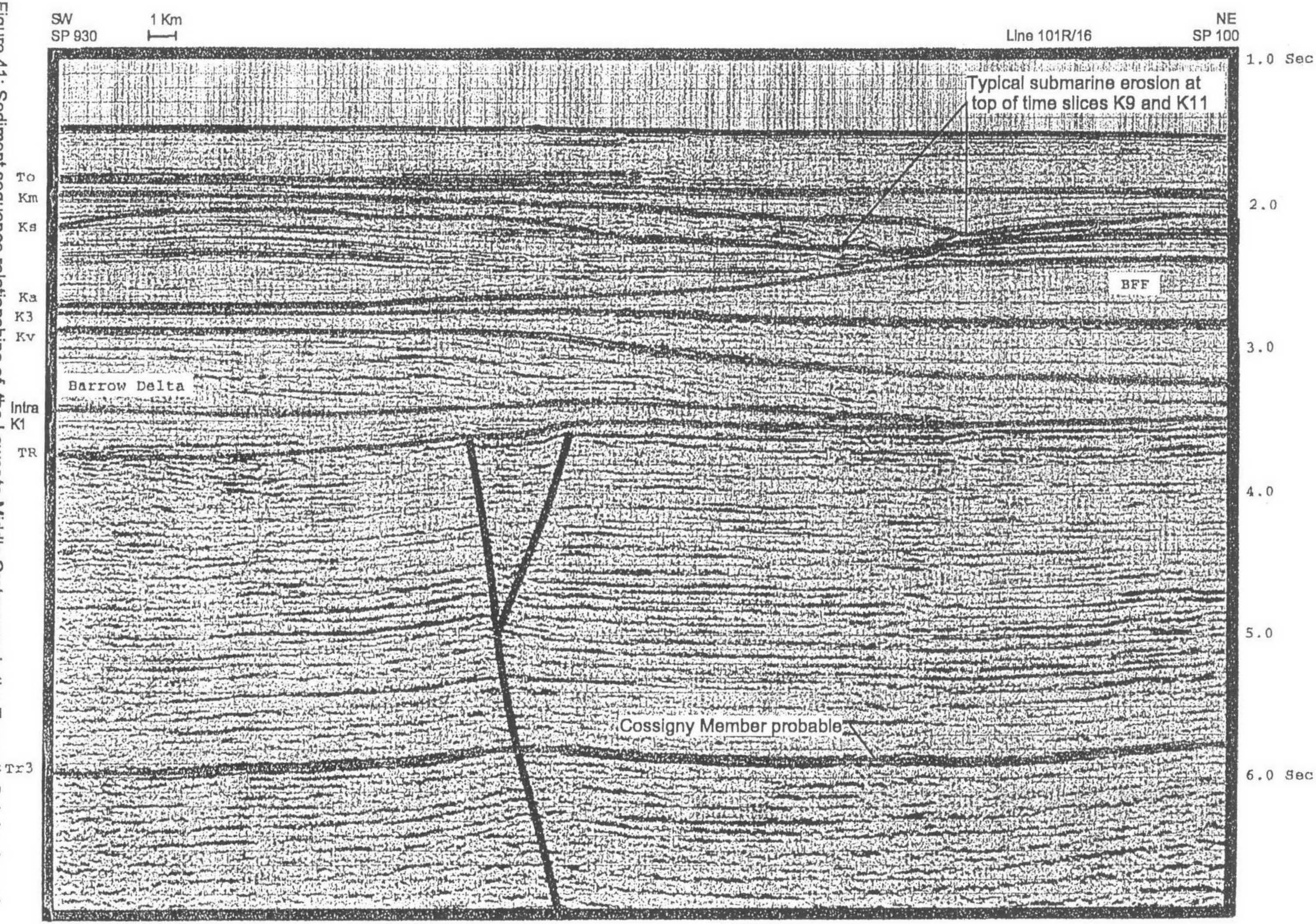


Figure 41: Sediment sequence relationships of the Lower to Middle Cretaceous in the Exmouth Sub-basin and vicinity. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, TR - top time slice Tr5.

Palaeogeography: (see Enclosure 21).

• The Barrow Delta, sourced from the Greater India continent, prograded northeastward, into a deepwater open marine environment. This is clearly seen in Investigator 1 where 1650m of section shows an upward transition from deep to shallow water environments with time. Downlapping of the Barrow Delta sands onto the Triassic is clearly evident on the seismic (see Figure 41). An intra time slice K1 reflector representing the boundary between two major Barrow Delta complex lobes is also clearly seen.

Present day deep sea transform faults are interpreted to extend onto the continental crust of the Exmouth Plateau. These onshore extensions and precursors of the transform fault appear to have been active during deposition of the time slice. Some of the palaeoenvironment boundaries appear to terminate on these bounding fault zones that have re-activated intermittently since the Argoland breakup. How these continental relatives of the oceanic transform faults have offset Carnarvon Basin structural elements is uncertain, with the exception of the Cape Range Transfer Fault.

• Some of the palaeo-environments were made to terminate on older Basin bounding fault zones (the East Exmouth continental fracture zone) which have re-activated intermittently since the Argoland breakup.

• Figure 42 shows the substantial fill of Cretaceous sediments over the Exmouth Sub-basin. Variable heat flow patterns may have existed as a result which may have an effect on the maturation of source rocks.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- 0.5% < average TOC < 2% (5 control points),
- 0.3% < average VR < 0.8% (5 control points),
- 103 < average HI < 206 (3 control points), and
- 445 < average Tmax < 458 (2 control points).

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Nevertheless any potential source rocks within time slice K1 on the Exmouth Plateau will be immature due to insufficient burial depth and low post depositional heat flows. High methane content is characteristic of the time slice K1 fine grained sediments as compared to the remaining section. It is uncertain whether this is a consequence of insitu biogenic methane generation or whether a deeper source of methane permeated these sediments during their deposition. The later explanation is preferred as the methane content appears to be independent of facies type and the prystane/phytane ratio of extracted hydrocarbons is >1 which suggests that no methanogenesis has occurred. It should also be noted that the Barrow Group sediments may have systematically suppressed VR values (Wilkins et al 1992).

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Investigator 1	19.4% < average porosity < 21.9%, obtained from neutron logs.
Scarborough 1	13.8% < average porosity < 25.8%, obtained from electrical logs.

The Exmouth Plateau has proven dry gas, encountered in Scarborough 1. The following list summarises the shows for the module wells:

Brigadier 1, Delambre 1, Echo 1	
Investigator 1, Mercury 1, Sirius 1, Vinck 1	G1 obtained from mud logs.
Minden 1	G1/L1 obtained from mud logs, L1 obtained from cuttings.
North Tryal Rocks 1	L1 obtained from mud logs.
Scarborough 1	G1, G3 obtained from mud logs, L1 obtained from SWC, G3 obtained from RFT. Direct hydrocarbon indications are also present on seismic. A probable major gas field.

Prospectivity: (see Enclosure 3). GOOD TO POOR

•Time slice K1 is a regional seal with the exception of the middle and northern parts of the Rankin Trend where the time slice is thin (eg North Tryal Rocks 1) and in the distal marine settings on the Exmouth Plateau northeast of the Barrow Delta lobes (Figure 40).

•The time slice K1 Barrow Delta Lobe has buried the underlying Triassic source rock section. Consequently in the southern area of the Exmouth Plateau the thick time slice K1 has acted to both seal and increase the maturity of the upper Triassic section beneath it. This is considered a prospectivity plus as the upper parts of the Triassic are more marine influenced and probably more oil prone and could be a viable source beneath the Barrow Delta sediments.

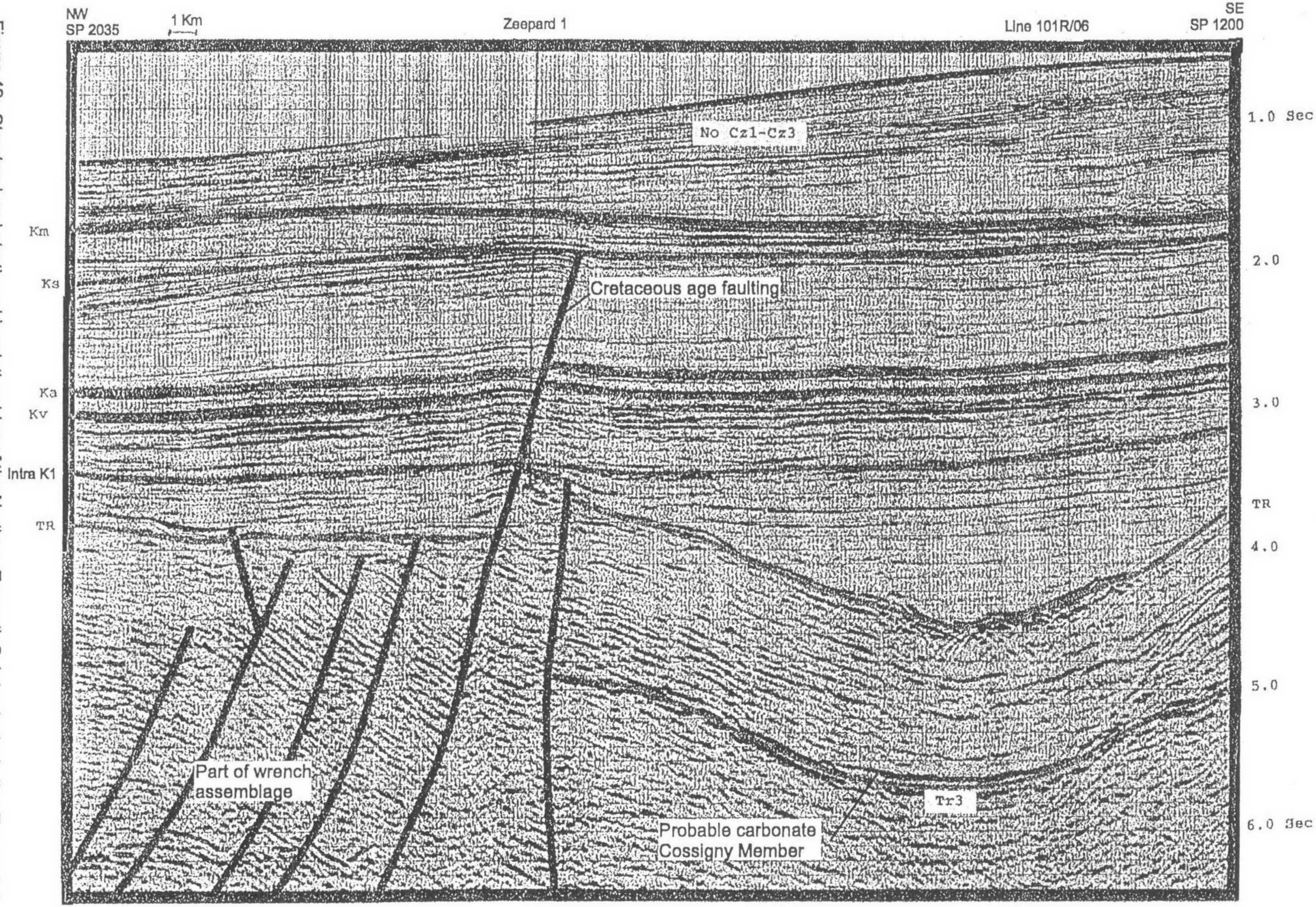


Figure 42: Structural and stratigraphic relationships of the Northern Exmouth Sub-basin, including Zeepard 1 location. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, TR - top time slice Tr5.

•Oil and gas source rocks have been identified in Investigator 1, Vinck 1 and Minden 1. A gas source rock is identified in Eendracht 1 whilst sources are inferred from TOC data alone in Echo 1 and Scarborough 1 but these are immature.

•Good quality marine clastic reservoirs are present in Delambre 1, Eendracht 1, Investigator 1, Minden 1, North Tryal Rocks 1, Scarborough 1, Sirius 1 and Vinck 1.

•Hydrocarbons migrating from deeper in the section are likely to be trapped at this level, in both stratigraphic traps (present since deposition) and structural traps that formed after time slice K2.

•Scarborough 1 tested the major structure within time slice K1 on the Exmouth Plateau. The structure has 70m of closure, is associated with a seismic flat spot, and encountered very dry gas in an upper *B.reticulatum* reservoir. The reservoir is an unconsolidated turbidite channel or fan facies sealed by prodelta facies of the same age. This prodelta facies is an excellent thick regional seal. It is uncertain whether the trap has a strong stratigraphic component, ie the trap was present virtually from the time of deposition, or whether the trap is mainly structural. In the later case it is interpreted that the trap may have formed soon after time slice K1 deposition, by thermal cooling around edges of Exmouth Plateau, or possibly be a later response to Miocene structuring. The 48m gas column extends from 1877m to 1925m below KB. The gas composition is approximately C_1=95.53%, C_2=0.12%, C_3=0.01% & N_2 = 4.34%. RFT pressure gradients show that no hydrocarbon is possible below 1930m KB. There is no evidence to suggest an oil leg or condensate leg exists on this accumulation. The present reservoir temperature is ~40°C which implies that the gas, if locally sourced, could be biogenic. The $-\delta^{13}C$ is indeterminate and suggests a possible mixed biogenic and thermogenic source. A thermogenic source of such dry gas could be from deep supermature Permian or Triassic sources. As noted above the time of trap formation could be anywhere from early Cretaceous to Miocene. Another mechanism to explain the dry gas is that it is a product of evaporative fractionation of a normal Triassic source gas-condensate. This mechanism is discussed elsewhere in the report. A better understanding of the nature of the source, and the mechanism of accumulation of this gas and other similar accumulations across the Exmouth Plateau, is crucial to the evaluation of the prospectivity of the area, which at the moment is perceived as dry gas prone.

Traps and plays.

Exmouth Plateau:

•Substantial potential in the form of variable stratigraphic, roll over plays exists within the main Barrow Group thick on the southern margin of the Exmouth Plateau (eg Scarborough 1, Investigator 1).

TIME SLICE K2:

EARLY CRETACEOUS: NEOCOMIAN: EARLY VALANGINIAN TO LATE HAUTERIVIAN: (137.0 TO 126.0 MA).

Petroleum System: Westralian 4: (see 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 continental breakup 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 seals provided by time slices K1, K2 and K3.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Muderong Shale and potential equivalents of the Mardie Greensand, Birdrong Sandstone, Zeepard Formation and the Upper Barrow Group.

Regional Definition of Time slice: (see Figure 2).

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 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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*M.testudinaria* (B2), *P.burgerii* (B2),
- Delambre 1:	*L.ouachensis* (B1), *P.burgerii* (B2), *M.testudinaria* (B2),
- Echo 1:	*M.testudinaria* (B1), *P.burgerii* 3a (D2),
- Eendracht 1:	*S.areolata* (B3),
- Investigator 1:	*S.tabulata* (B1), *S.areolata* (B1),
- Jupiter 1, Mercury 1:	*M.testudinaria* (B5),
- Minden 1:	*M.testudinaria* (B2, B3), *S.tabulata* (B3), *P.burgerii* (B4),
- North Tryal Rocks 1, Sultan 1:	*S.areolata* (B5),
- Scarborough 1:	*S.areolata* (B1), *S.tabulata* (B4), *M.testudinaria* (B1), *P.burgerii* (B1),
- Sirius 1:	*P.burgerii* (B1), *M.testudinaria* (B1), *S.tabulata* (B3),
- Vinck 1:	*M.testudinaria* (B1).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia was part of Greater Gondwana that at time slice K2 only comprised Antarctica and Australia after the breakup 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 recognised from end of time slice K1 unconformities, deposition of bentonite clays recovered from ODP and exploration wells 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 lineations further constrain the breakup to Valanginian. Initial movement of the Indian Plate away from Australia was along the Cape Range Fracture Zone. In addition 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 Cainozoic section immediately adjacent to the continent ocean boundary. The inference from biostratigraphic and stratigraphic considerations is that breakup occurred at the time slice K1-K2 boundary (top *E.torynum*). Greater India did not clear the Exmouth Platform 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 time slice is bounded at the base by a regional unconformity linked to the Greater India breakup and by a local unconformity at the top. The top time slice K2 unconformity corresponds to Greater India clearing the Exmouth Plateau and the M5 ridge jump in the Gascoyne-Cuvier oceanic crust. This unconformity is local in the sense that it could not be established from all the time-depth curves of the module wells. However the Exmouth Plateau area is the only area studied on the North West shelf were there is a clear biostratigraphic break associated with this event. Once Greater India cleared the Exmouth Plateau, the water sediment interface, at relatively shallow depths over the Barrow Delta Lobes, began to subside to abyssal depths. Any fault movement is also likely to have ceased. On the Rankin Trend erosion occurs in sub-aqueous settings. There is also a change of sediment provenance seen in the Exmouth Sub-basin.

Lithology: (see Enclosure 2).

Dominantly claystones or calcareous claystones and minor sandstones.

Thickness Variations: (see Figure 43).

Considering only the thirteen module wells thickness ranges from 8 meters in Eendracht 1 to 118 meters in Scarborough 1. Figure 43 is a regional isopach map based on the STRATDAT well database. Thicks are present in the Exmouth Sub-basin and part of the Barrow Sub-basins as well as on parts of the Peedamullah Shelf. Thicknesses range up to 1200 metres in the Inner Carnarvon Basin. It is evident that time slice K2 includes reworked time slice K1 sediments. These reworked sediments form the thicker time slice K2 deposits found in the interlobe lows of time slice K1.

Palaeodepositional Environments: (see Enclosure 22).

In the vicinity of the module wells only deep marine environments are apparent, with the exception being Minden 1. The time slice K1 Barrow delta top is probably being reworked during the transgressive event established after Greater India cleared the Exmouth Plateau.

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 started in time slice K1. The coastline east of the Dampier Sub-basin is interpreted to be regressing whilst the coastline in the Exmouth and Barrow Sub-basin areas is transgressing. This coastline transgression is probably short lived or active in the early part of the time slice after which sedimentation rates reduce. This sedimentation rate reduction together with increased continental margin sag established a marine transgressive setting in all areas for the late part of the time slice.

Palaeogeography: (see Enclosure 23).

•Time slice K1 Barrow Delta sands are being reworked providing time slice K2 sediments at the delta front edge. Therefore time slice K2 is still relatively sandy. This includes areas in the Barrow and Exmouth Sub-basins and partly the Kangaroo Deep.

•The Rankin Trend is on the continental slope but is significantly shallower than adjacent bathyal areas reflecting the influence the old Triassic geomorphological highs still have on sedimentation.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- 0.4% < average TOC < 1.5%(5 control points),
- 0.3% < average VR < 0.6% (2 control points), and
- average HI = 48 at Brigadier 1.

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Investigator 1	average porosity of 21.9%, obtained from neutron logs.

Shows summary for the time slice:

Brigadier 1	G1 obtained from mud logs.
Echo 1	G1 obtained from mud logs.
Investigator 1	G1 obtained from mud logs.
Mercury 1	G1 obtained from mud logs.
Minden 1	L1 obtained from cuttings.
North Tryal Rocks 1	L1 obtained from SWC.

Scarborough 1 G3 obtained from mud logs.

The Exmouth Sub-basin also has proven oil and gas at Griffin 1 and West Murion 1 (Mitchelmore & Smith, 1994).

Prospectivity: (see Enclosure 3). POOR OVER THE EXMOUTH PLATEAU

- Inferred sources although immature at the present locations have been identified in Echo 1, Minden 1, North Tryal Rocks 1 and Scarborough 1.
- Marine clastic reservoirs are present in Investigator 1 and have been inferred in Minden 1. There is insufficient data in the Minden 1 well completion report to substantiate reservoirs. It is highly probable that reworking of time slice K1 Barrow Delta quartzose sands deposition during time slice K2 occurred in the Exmouth Sub-basin and the south Exmouth Platform.
- Time slice K2 acts as a regional seal.
- It is highly likely that substantial prospectivity exist in the Exmouth Sub-basin.
- The main risk, in areas with potential reservoirs is the absence of a feasible mechanism to charge the reservoirs.

Traps and plays.

Eastern Exmouth Sub-basin:

Substantial untested potential in the form of variable stratigraphic, roll over and fault trap plays exists.

Outer Rankin:

Plays are unlikely in the northeast Outer Rankin due to the relatively distal setting and lower sedimentation rates present compared to the southwest Outer Rankin. The lack of reservoirs is also substantiated from work done in the Beagle Sub-basin (Sayers et al, 1995).

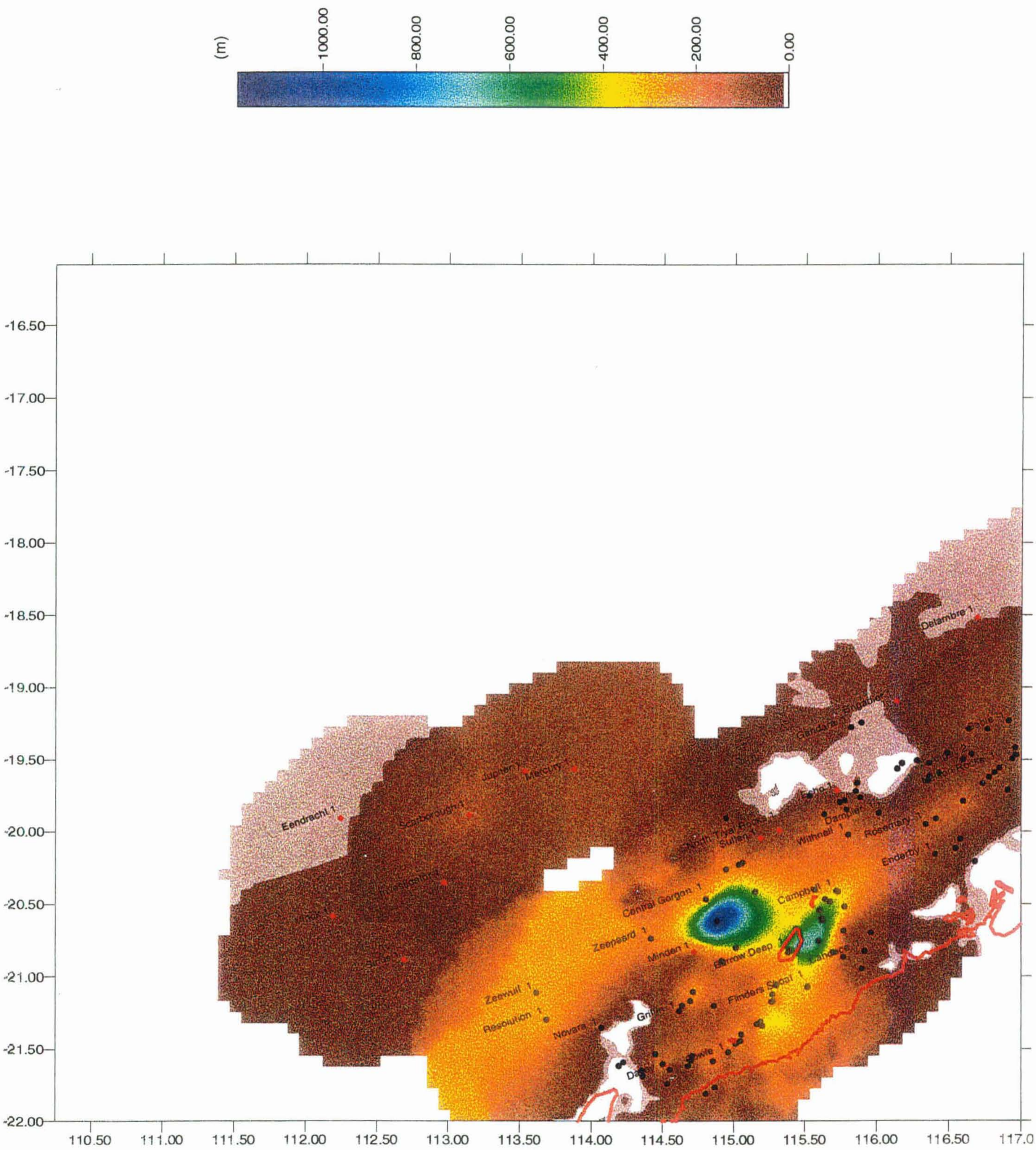


Figure 43: Time slice K2 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

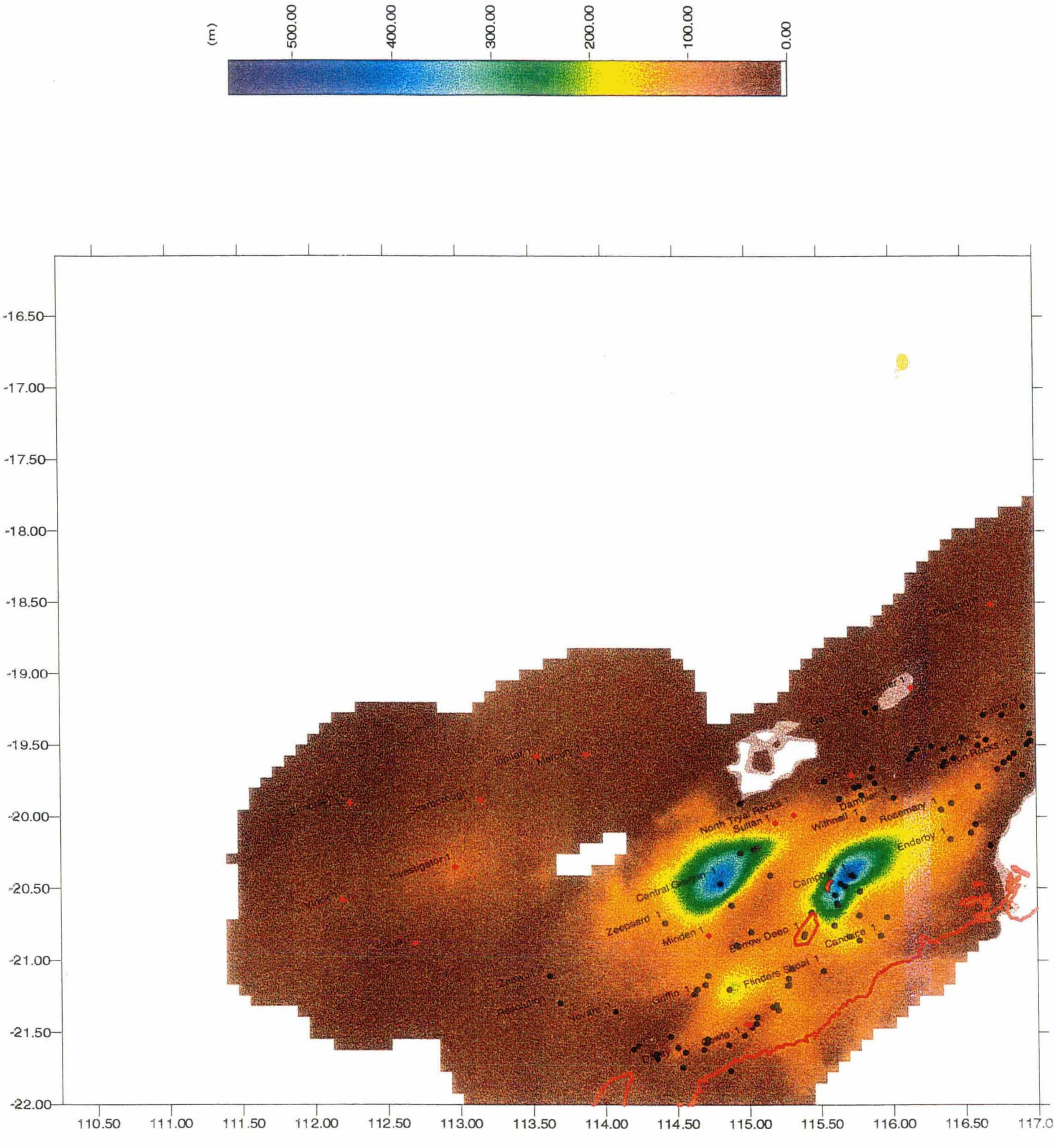


Figure 44: Time slice K3 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

TIME SLICE K3:
MIDDLE CRETACEOUS: NEOCOMIAN: BARREMIAN: (126.0 to 119.5 MA).

Petroleum System: Westralian 4 (see 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 areas of the Exmouth and Barrow Sub-basins.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Muderong Shale, Mardie Greensand and Birdrong Sandstone.

Regional Definition of Time slice: (see Figure 2).

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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Delambre 1:	U.*M.australis* (B2), *L.ouachensis* (B1),
- Echo 1:	U.*M.australis* (D2),
- Eendracht 1:	U.*M.australis* (B1),
- Investigator 1:	U.*M.australis* (B1), L.*M.australis* (B1),
- Jupiter 1:	*M.australis* (B5), *D.multispinum* (B5),
- Mercury 1:	*O.operculata* (B3),
- Minden 1, Sultan 1:	*M.australis* (B3),
- North Tryal Rocks 1:	*M.australis* (B4, B5),
- Scarborough 1:	U.*M.australis* (B4),
- Sirius 1:	*M.australis* (B2),
- Vinck 1:	*M.australis* (B4).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia is part of Greater Gondwana, that now only includes Antarctica after the breakup 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

No tectonic activity is interpreted during this time slice. Time slice K3 is bounded unconformably at the base and is conformable with time slice K4 where the latter has not been removed.

Lithology: (see Enclosure 2).

Dominantly claystones or calcareous claystones.

Thickness Variations: (see Figure 44).

Thicknesses range from 2.5 meters in Brigadier 1 to 120.5 meters in Minden 1, considering only the 13 module wells. Regional thicknesses are expected to be of a similar order of magnitude. Figure 44 shows a regional isopach map based on the STRATDAT well database. There are thicks present on the southern end of the Rankin Trend and northeast Exmouth Sub-basin. These may have been fed from the south via the southern extremity of the Barrow Sub-basin. A maximum thickness for the Carnarvon Basin of 550m occurs in the southern Lewis Trough and southern Rankin Trend.

Palaeodepositional Environments: (see Enclosure 24).

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 regressed, and over the Exmouth Plateau water depth increased.

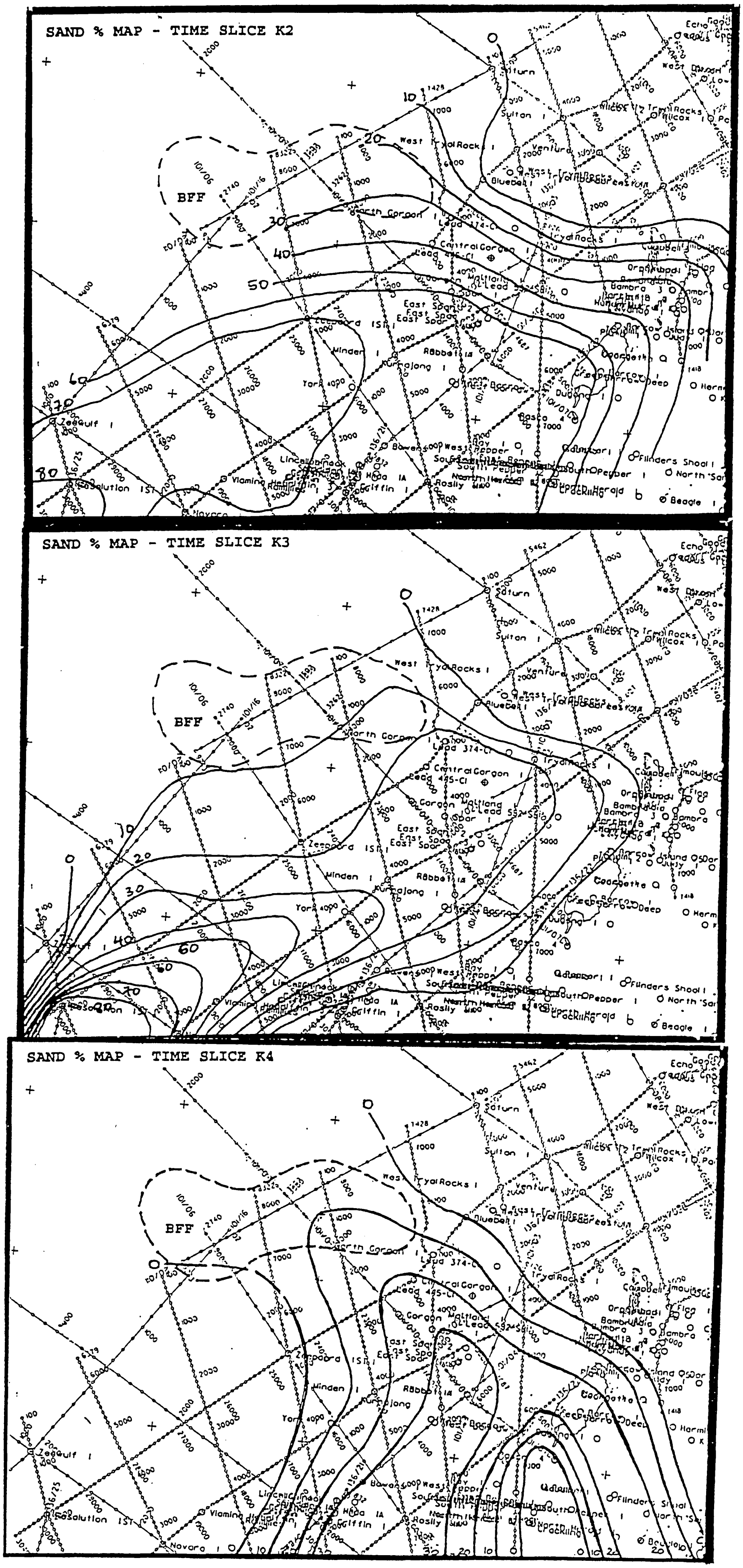


Figure 45: Sand percentage maps of time slices K2-K4 at the location of the basin floor fan (BFF).

Palaeogeography: (see Enclosure 25).
The module area accumulated deep water (continental slope and bathyal depths) sediments.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).
The following summarises the geochemistry:
- 0.4% < average TOC < 2.3% (3 control points),
- average VR = 0.6% at Minden 1,
- 48 < average HI < 258 (2 control points), and
- average Tmax = 437 at Minden 1.

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).
Porosity and permeability data summary for the time slice:
Brigadier 1 average porosity of 24%, obtained from electric logs.
Shows summary for the time slice:
Investigator 1 G1 obtained from mud logs, and
Mercury 1 G1 obtained from mud logs.

Prospectivity: (see Enclosure 3).POOR

- An oil prone source rock is present in Minden 1 whilst an inferred source type occurs in Echo 1, North Tryal Rocks 1 and Sirius 1 on the basis of TOC values. The quality of the source rock is unknown due to the absence of pyrolysis analyses. The above sources are immature at their present locations but may be sub-mature on the Outer Rankin Platform- this could be a viable source for a basin floor fan of overlying time slice K4.
- Clastic reservoirs are inferred in Minden 1 whilst carbonate reservoirs are inferred in Vinck 1.
- Minden 1 is the only module well to have preserved continuous sedimentation throughout time slices K1-K4. It also has an unusually high sedimentation rate throughout time-slices K3-K4 as well as having a moderately well established sand source axis (Figure 45). During time slices K3 and K4, the area to the north of Minden 1, in the Outer Rankin Platform to northeast Exmouth Sub-basin, is most likely to have accumulated distal marine clastic sands. With the exception of this area, no reservoirs are expected in the Outer Rankin Platform or Rankin Trend.
- The sands on the Exmouth Plateau are discontinuous and are unlikely to be a worthwhile target.
- All module wells have substantiated that time slice K3 is a regional seal facies.

Traps and plays.
East Exmouth Platform:

- Reservoirs in basin floor fans dually sourced from the Triassic and a time slice K3 source may be a viable play.

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: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Windalia Sand Member (Minden 1, basin floor fan, see later sections) and the Muderong Shale.

Regional Definition of Time slice: (see Figure 2).

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 slice. The following summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Investigator 1:	*D.davidii* (B4), *O.operculata* (B3),
- Jupiter 1:	*O.operculata* (B1),
- Mercury 1:	*A.cinctum* (B3),
- Minden 1:	*D.davidii* (B4), *O.operculata* (B4),
- Sultan 1:	*A.cinctum* (B5), *D.davidii* (B3), *O.operculata* (B3, B5).

All wells, with the exception of Scarborough 1, have some form of moderate palaeontological control.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia was part of Greater Gondwana that now only includes Antarctica and Australia after the breakup of Greater India at the end of time slice K1 (Baillie et al, 1994). This is a time of regional tectonic quiescence.

Local

The top time slice K4 - basal time slice K5 is part of a global lowstand period, possibly glacially induced, that is also seen on the North West Shelf. There is a disconformity at the top of the time slice over most of the area. Time slice K4 is absent or thin on the Rankin Trend which may be indicative of sub-marine erosion. The hiatus/disconformity ranges up to top time slice K6.

Figure 41 shows the sediment sequence relationships in the Exmouth Sub-basin and vicinity during the Cretaceous. Clastic sediment source provenances are interpreted to change from time slices K1 (from the south and south east) to time slice K6 (from the east) after which it becomes more uniform.

Lithology: (see Enclosure 2).

Dominantly claystones or calcareous claystones with siltstones present in Minden 1.

Thickness Variations: (see Figure 46).

Considering only the thirteen module wells thicknesses range from 0m to 155m in Sultan 1,. Figure 46 shows a regional isopach map based on the STRATDAT well database with thicks being present in the northern end of the Barrow Sub-basin and on the shelves to the southeast. There is also an established thick to the north of Minden 1 (Figures 47-48) based on seismic interpretation which, together with thicks present landward establishes a possible transport direction from the southeast. A maximum thickness of 600m for the Carnarvon Basin occurs in the northern Barrow Sub-basin .

Palaeodepositional Environments: (see Enclosure 26).

Globally this time slice is characterised by an intermediate to maximum relative sea level but 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 with the exception of the short lived lowstand at the very top of the time slice.

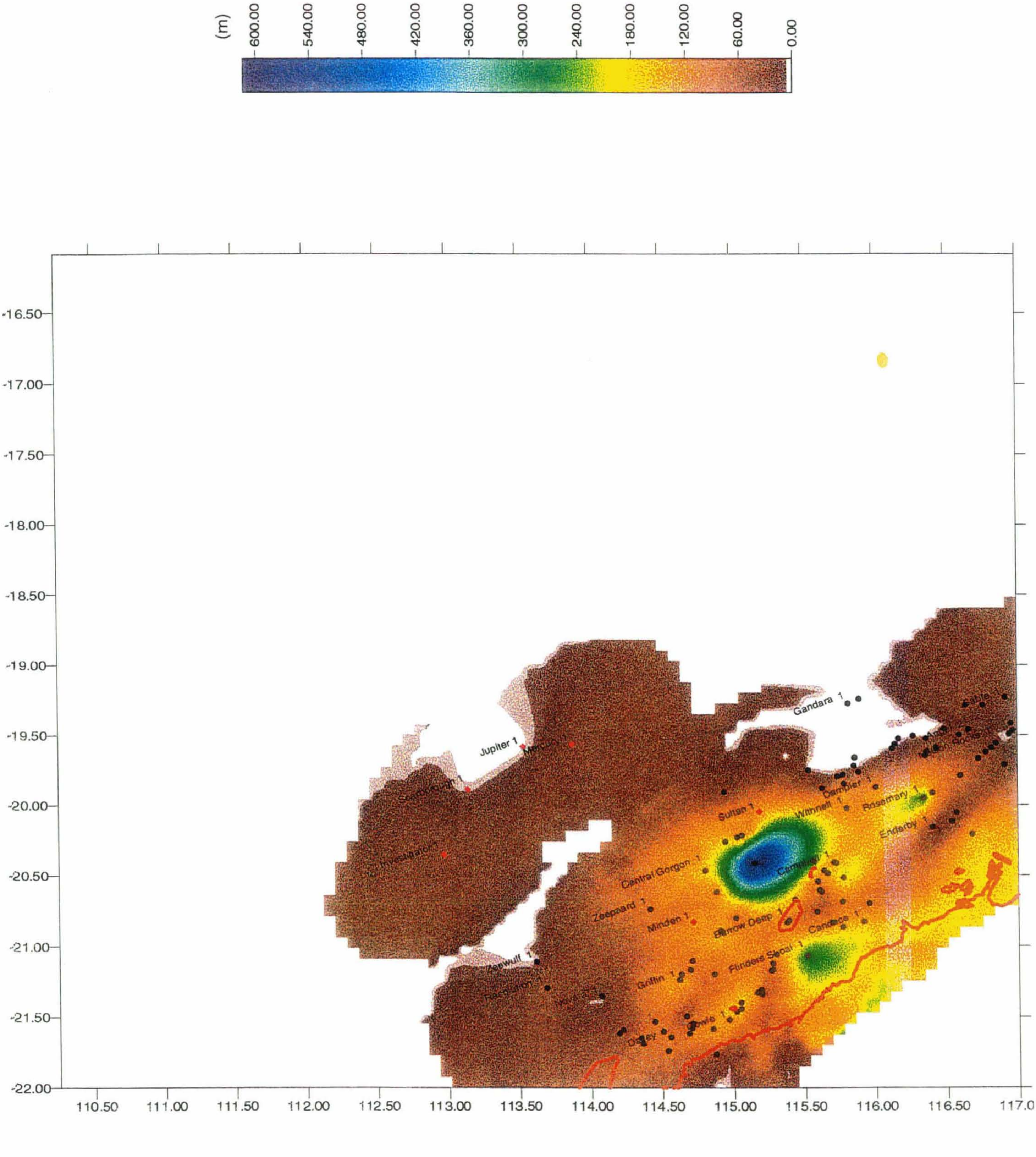


Figure 46: Time slice K4 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

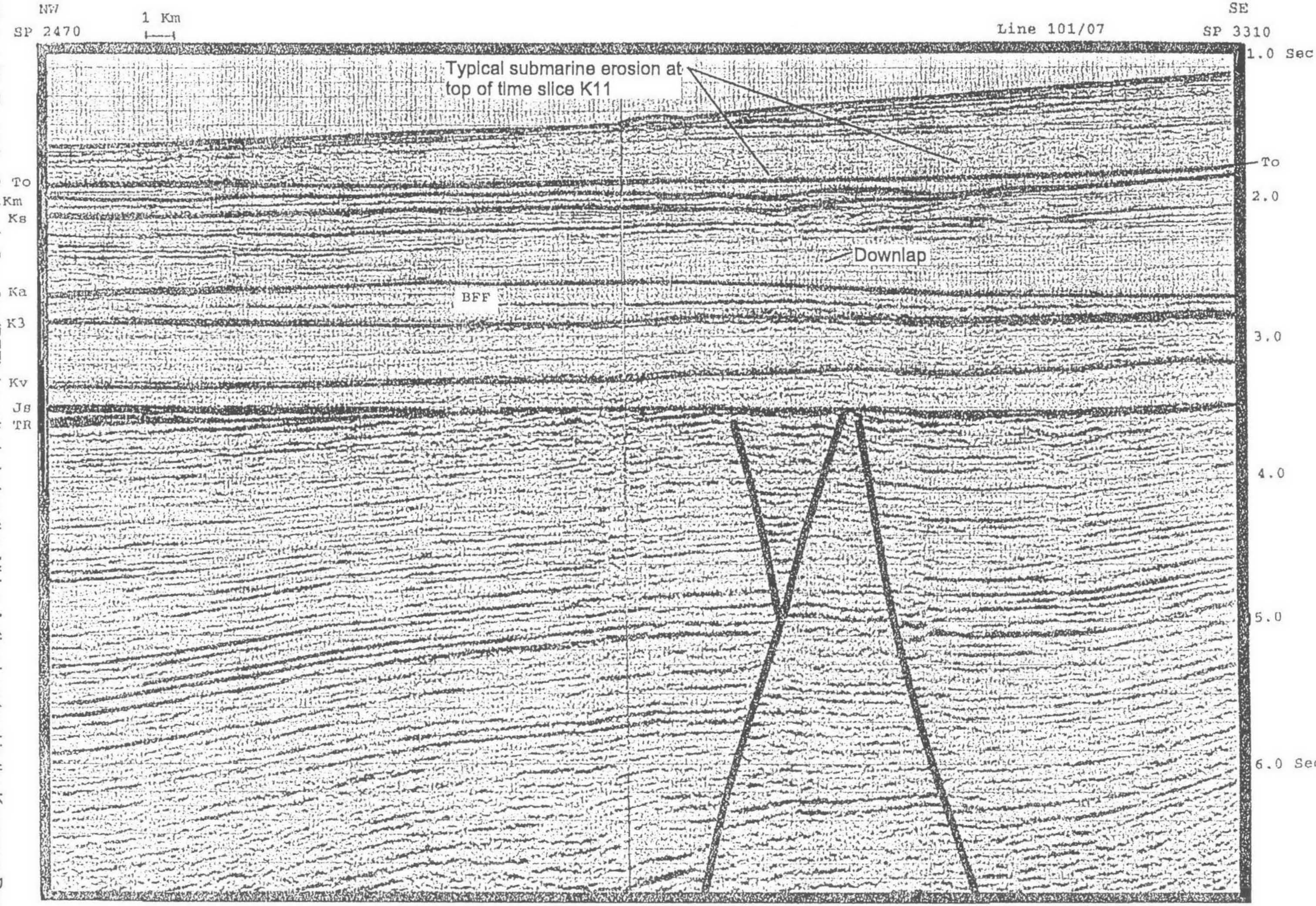


Figure 47: Example of a basin floor fan (BFF) deposited during the Albian-Aptian lowstand in the Kangaroo Deep. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Js - top time slice J1, TR - top time slice Tr5.

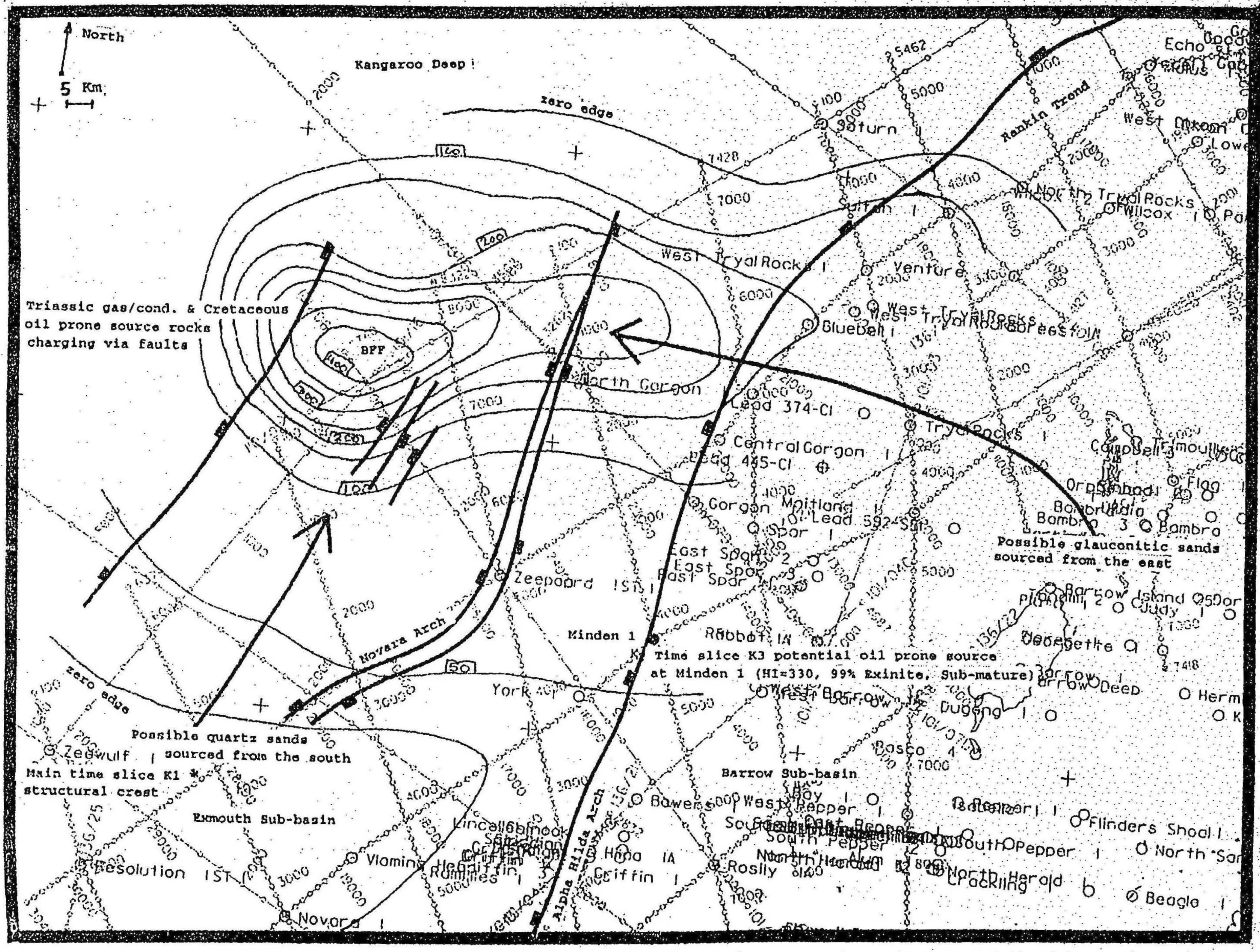


Figure 48: Prospectivity of the basin floor fan, time slice K4.

Palaeogeography: (see Enclosure 27).

- The continental outer shelf and slope boundaries coincide with the boundary of some of the fault systems, in particular the East Exmouth Continental Fracture Zone. Deeper water deposition is present to the north of this fault zone.
- The Rankin Trend is interpreted to be a bathymetric high, as evidenced from the absence of time slice K4 sediments over the high but which onlap around the flanks. This geomorphological high will have acted as a barrier and limited the deposition of sediments being transported from the mainland to the inner troughs of the Carnarvon Basin. However, time slice K4 sediments may have in part been reworked in contrast to not being deposited.
- Reworking of sediments is also possible over the Exmouth Sub-basin, partly as a result of the Barrow Delta lobes of time slice K1 acting as a bathymetric high. This high partly acted as a barrier to distal sedimentation.
- A basin floor fan was deposited north of Minden 1 probably during the end of time slice K4 lowstand. Other deep water fans and turbidite flows may also have been deposited elsewhere. The shaded grey area on Enclosure 27 outlines the fan, the thickest deposition is within the red dashed line. The basin floor fan is interpreted from seismic and correlated to time slice K4 by extrapolation from Minden 1. The very top of the time slice correlation (the Aptian-Albian boundary) is a lowstand and this agrees well with the geological scenario for a fan in a distal location. Facies equivalents of the Windalia siltstone/sandstone (recovered in Barrow Deep 1) are proposed in this distal location.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- average TOC = 0.7% at Minden 1,
- average VR = 0.6% at Minden 1,
- average HI = 126 at Minden 1, and
- average Tmax = 429 at Minden 1.

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exists for this time slice.

Shows summary for the time slice:

Mercury 1	G1 obtained from mud logs, and
Scarborough 1	G1 obtained from mud logs.

Prospectivity: (see Enclosure 3). SPECULATIVE POTENTIAL

- No source potential is interpreted in time slice K4.

Clastic reservoirs are present in Minden 1 and inferred to be present to the north of Minden 1. The inferred clastic reservoirs to the north of Minden 1 are the probable sands within the interpreted basin floor fan. The sands may be quartzose if they are reworked Barrow Delta sands or may be glauconitic marine sands if they are derived from the east.

Time slices K3 and K4 act as a regional seal unit.

Traps and Plays.

East Exmouth Platform:

Basin floor fan:

Reservoirs in a large basin floor fan could be dually sourced from the Triassic and a time slice K3 source rock. The seismic signature of the fan is illustrated in Figures 41 and 47. Figures 45 and 48 illustrate the prospectivity elements for the fan.

Source rock: The source rock for this play may be either time slice K3 and/or the Triassic. The possible time slice K3 source rock was analysed in Minden 1 where HI is 330 and the kerogen composition is 99% exinite. Minden 1 is located 80 km to the southeast of the basin floor structure. This rich source rock could extend in the direction of the play. If any hydrocarbons were generated from this source some would migrate into the basin floor structure.

Maturity: The time slice K3 source rock is interpreted as being mature at Minden 1 but probably sub-mature at the location of the basin floor fan. However the play is large enough to warrant a more comprehensive study of source potential.

Reservoir: The presence of reservoir quality sands is speculative, due to the distal setting of the play. The basin floor fan is interpreted to have been deposited at the top time slice K4 regional North West

Shelf Aptian-Albian lowstand. This enhances the probability of a more proximal depositional setting and of coarser sand being present. Figure 45 illustrates two points. The first is that depositional rates for time slices K3-K4 are highest in this area within an approximate north-south sediment transport fairway. This is unique for all basinal areas south of the Fitzroy Trough. The high depositional rates continue up to time slice K10. The second is the presence of an approximate NNW-SSE sand trend axis in time slice K4 (Figure 45). An approximate estimate of 5-10% sand at the location of the basin floor fan is based on contouring the sand percentage of surrounding wells and biasing the contouring to coalesce with the NNW-SSE sediment transport fairway.

Seal: The time slice K4 sands will be regionally sealed by the time slice K5-K11 claystone/calcilutite wedge.

Outer Rankin:

- Plays are unlikely in the northeast Outer Rankin due to the relatively distal setting and lower sedimentation rates present compared to the southwest Outer Rankin. The lack of reservoirs is also substantiated from work done in the Beagle Sub-basin (Sayers et al, 1995).

TIME SLICES K5-7:

MIDDLE CRETACEOUS: ALBIAN: (113.0 to 99.0 MA).

Petroleum System: Westralian 4 (see 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: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Haycock Marl and Windalia Radiolarite.

Regional Definition of Time slices: (see Figure 2).

•TIME SLICE K5: EARLY ALBIAN (113.0 - 109.0 MA).

Time slice K5 is a time of sea level fall. 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 was transgressive, as well as a global oceanic anoxic event. Biostratigraphically it approximates the *P.ludbrookiae* dinoflagellate zone and encompasses the top of the *C.paradoxa* 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 slice. The following summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

time slice K7:

- Brigadier 1:	*C1* (B1, B2),
- Delambre 1:	*C1* (B2),
- Echo 1, Eendracht 1, Investigator 1, Scarborough 1, Vinck 1:	*C1* (B3),
- Minden 1:	*P.ludbrookiae* (B1, B4), *X.asperatus* (B1),
- North Tryal Rocks 1:	*P.ludbrookiae* (D4, D5),
- Sirius 1:	*C1* (B4).

Time slice K6:

- Brigadier 1:	*C1* (B1, B2),
- Delambre 1:	*C1* (B2),
- Echo 1, Eendracht 1, Investigator 1, Jupiter 1, Scarborough 1, Vinck 1:	*C1* (B3),
- Minden 1:	*C.denticulata* (B1).

Time slice K5:

- Investigator 1, Jupiter 1, Mercury 1:	*M.tetracantha* (B3),
- Minden 1:	*M.tetracantha* (B1).

Most wells have some palaeontological control with confidence ratings varying from poor to good. The absence of palaeontology in some wells for time slices K5-K6 reflects low depositional rates and consequent condensed sequences and subsequent sampling difficulties, or in extreme cases non deposition of the time slice.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

West Australia was part of Greater Gondwana that comprised Antarctica and Australia after the breakup of Greater India at the end of time slice K1 (Baillie et al, 1994). Regionally Greater India began its northward drift. Continental margin sag has been ongoing along the entire western margin of the Australian continent since time slice K2.

Local

No evidence of structural movements have as yet been detected. Time slice K5 is a confirmed disconformity that may extend up to time slice K6.

Lithology: (see Enclosure 2).

Time slice K5: For the most part absent with some siltstone present in Minden 1.

Time slice K6: The lithology reflects the increase in marine conditions. The time slice is absent over the Exmouth Plateau whilst Minden 1 still has a significant siltstone content. Marls, calcilutites and calcarenites are present to the northeast in the Brigadier 1 and Delambre 1 wells.

Time slice K7: Claystones, calcareous claystones, marls, calcilutites and calcarenites dominate whilst some siltstone is present in Minden 1.

Thickness Variations: (see Figures 49-51).

This time slice is condensed. The thickness of time slice K5 is a maximum of 69m (Minden 1) but in most wells it is absent or probably absent. Figure 49 shows a regional isopach map based on the STRATDAT well database with a main thick centred around the Barrow Sub-basin. The maximum thickness for the Carnarvon Basin is up to 120m in the Barrow Sub-basin .

For the 13 module wells the thickness of time slice K6 ranges from 0m to 198m (Minden 1). This thickness range is representative of all of the Carnarvon Basin. Figure 50 shows a regional isopach map based on the STRATDAT well database with a main thick centred around the Barrow Sub-basin. A secondary thick is present on the Exmouth Plateau centred around Mercury 1. This may be indicative of uplift on the Plateau post depositional time slice K5 as Vinck 1 also on the Plateau shows up as a slightly thicker interval.

For the 13 module wells, the thickness of time slice K7 ranges from 0m to 317m in Minden 1. This thickness range is representative of all of the Carnarvon Basin. Figure 51 shows a regional isopach map based on the STRATDAT well database with a main thick centred around the Barrow Sub-basin with lesser thicks extending towards the Lewis Trough.

Palaeodepositional Environments: (see Enclosure 28).

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. The base of time slice K5 is a low stand with a transgressive coastline.

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 (see above - Struckmeyer & Brown (1990) imply the continuation of a regression that started towards the base of time slice K5 but the coastline is not expected to have shifted significantly.

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 (see above- Struckmeyer & Brown (1990) imply the continuation of a regression that started near the base of time slice K5. The coastline is interpreted to have regressed in the module area during time slice K7. This is based on evidence gathered in the Roebuck and Beagle Basins module (Sayers et al, 1995) but no direct evidence for it was found in the module area.

Palaeogeography: (see Enclosure 29).

- Time slices K5-K7 are relatively thin over the module area except in the Minden 1 area. (individual isopach maps Figures 49-51). The Barrow Sub-basin has the thickest accumulation of time slices K5-K7 sediments. Individual time slice downlap edges are seen with kinking of the contours occurring at the vicinity of the time slice K4 basin floor fan. The area north of Minden 1 experienced substantial sedimentation, being sourced from the south (see time slice K4 for comparison).

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry for time slice K5:

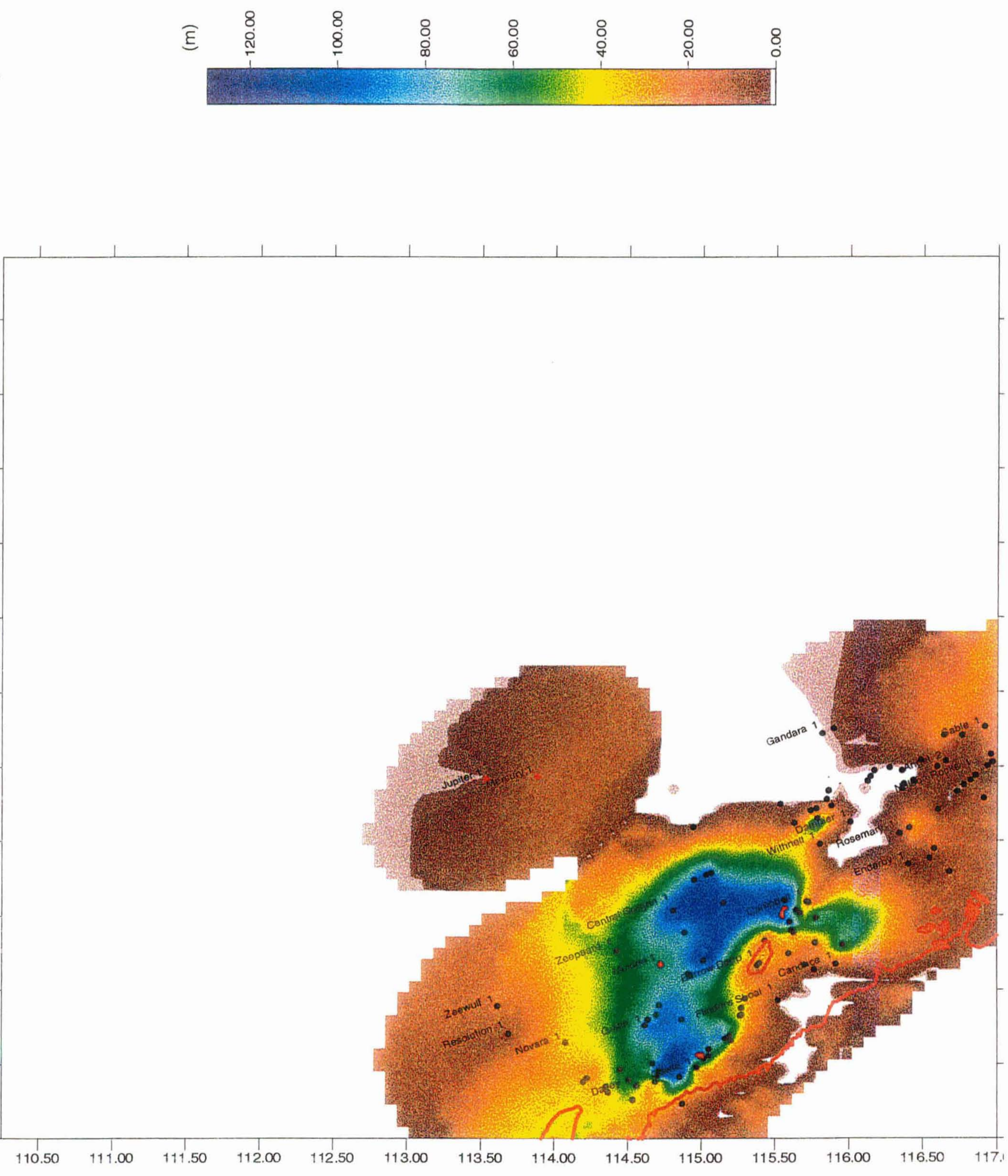


Figure 49: Time slice K5 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

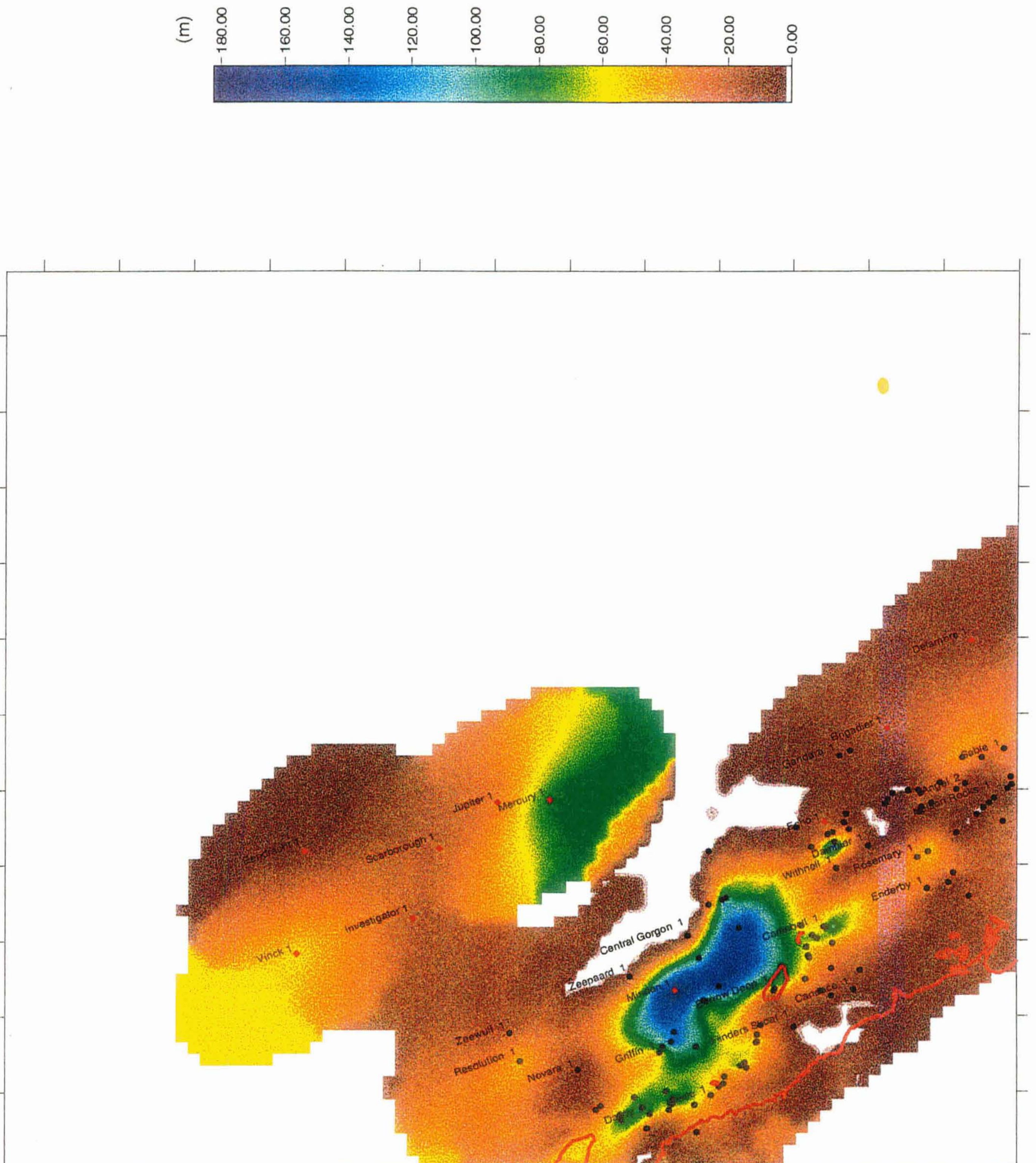


Figure 50: Time slice K6 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

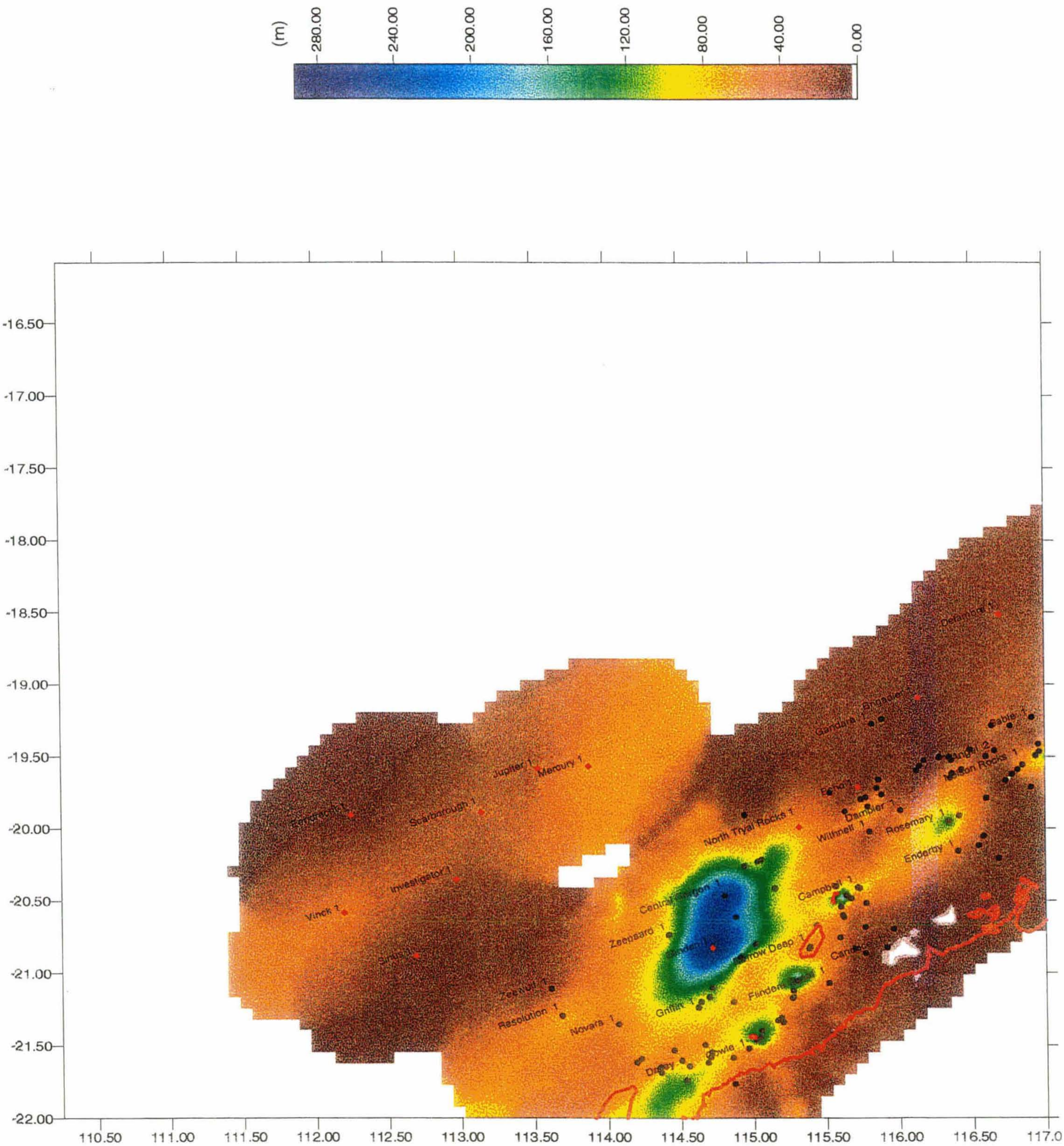


Figure 51: Time slice K7 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

- 0.4% < average TOC < 0.5%(2 control points),
- average VR = 0.6% at Minden 1,
- average HI = 56 at Minden 1, and
- average Tmax = 425 at Minden 1.

The following summarises the geochemistry for time slice K6:
- 0.5% < average TOC < 0.8%(2 control points),
- average HI = 48 at Minden 1, and
- average Tmax = 408 at Minden 1.

The following summarises the geochemistry for time slice K7:
- 0.5%< average TOC < 0.6% (3 control points).

These time slices in the module area are poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Nevertheless any potential source rocks on the Exmouth Plateau will be immature.

Shows, Porosity & Permeability: (Appendix 4).

No porosity or permeability data exists for time slices K5.
The following list summarises the shows for time slice K5:

Mercury 1	G1 obtained from mud logs.

The following list summarises the porosity and permeability data for time slice K6:

Brigadier 1	average porosity of 24%, obtained from electric logs.

The following list summarises the shows for time slice K6:

Brigadier 1, Investigator 1, Mercury 1 & Scarborough 1	G1 obtained from mud logs.

No porosity or permeability data exists for time slices K7
The following list summarises the shows for time slice K7:

Brigadier 1, Investigator 1, North Tryal Rocks 1 & Scarborough 1	G1 obtained from mud logs.

Prospectivity: (see Enclosure 3). POOR

- No source rocks are interpreted for these time slices. Vitrinite values at Minden 1 suggest that the top of time slice K5 is presently mature for oil generation. Younger aged source rocks would be mature immediately east and to the north of this location due to increased depth of burial.
- No reservoirs have been detected within time slices K5-K7 with the exception of weak marine clastic reservoirs in time slice K7 in North Tryal Rocks 1.
- Time slices K5-K7 are major regional seals.

Traps and plays.

It is unlikely that distal sands made it as far as the Outer Rankin Platform area or any of the module area thereby making time slices K5-K7 an unprospective interval. However any possible reservoirs in these time slices are most likely to be present in the eastern Exmouth Sub-basin and western Rankin Trend both of which are within a likely sediment transport fairway. Sedimentation is condensed everywhere else. A siltstone body (Windalia Siltstone) is known to be present at Minden 1 (Enclosure 2) within this fairway and probably extends north into the Outer Rankin Platform area. Additionally younger fault systems are known to be active in the Outer Rankin Platform area thus providing a potential pathway for oil migration from the deeper sections.

TIME SLICE K8:
LATE ALBIAN TO CENOMANIAN (99.0 - 91.0 MA).

Petroleum System: Westralian 4 (see Enclosure 3).
A potential time for the migration of hydrocarbons. The top of time slice K8 coincides with the onset of extension and breakup along the southern margins.

Formation Synonyms: (see Figure 2).
Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Upper and Lower Gearle Siltstone together with the Haycock Marl and Windalia Radiolarite.

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 zones 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. The top of time slice K8 is also associated with the Turonian oceanic anoxic event. This is often seen on well logs as a combined gamma ray high and sonic low. It is considered to be an effective time line and, in the absence of definitive biostratigraphy, to define the top of time slice K8.

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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*C2* (B3), *C3a* (B3), *C3b* (B2),
- Delambre 1:	*C2* (B1), *C3b* (B2),
- Echo 1:	*C2* (B2), *C3a* (B2, D3), *C3b* (D3),
- Eendracht 1:	*C2* (B3), *C3a* (B3), *C3b* (B3, B5),
- Jupiter 1:	*C2* (D3), *C3* (D3),
- Mercury 1:	*C2* (B1, D3), *C3a* (B1, B2), *C3b* (B2),
- Minden 1:	*D.multispinum* (B1, B4),
- North Tryal Rocks 1:	*C2* (B3), *D.multispinum* (B2, B3),
- Scarborough 1:	*C2* (B3), *C3* (B3),
- Sirius 1:	*C2* (B1),
- Sultan 1:	*D.multispinum* (B3).

All wells have some form of palaeontological control with moderate to good confidence ratings.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional
The Australian continent has a similar morphology to the present day continent following the breakup of Antarctica. The timing for this breakup ranges from 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 to slope. General clastic starvation resulted as prograding carbonate wedges formed most of the sediments. Greater India commenced its northward drift at approximately this time.

Local
An intra time slice K8 unconformity is present in the northeast of the module area as well as on the Rankin Trend, and is perhaps a response to distant plate tectonic events. .

Lithology: (see Enclosure 2).
Claystones, calcareous claystones, marls, calcilutites and calcarenites dominate whilst some siltstone is present in Minden 1.

Thickness Variations: (see Figure 52).
For the 13 module wells, thickness ranges from 10.5m in Sirius 1 to 130.2m in North Tryal Rocks 1. Figure 52 shows a regional isopach map based on the STRATDAT well database with a main thick centred around the Barrow Sub-basin. A maximum thickness for the Carnarvon Basin of 300m occurs at Barrow Deep 1.

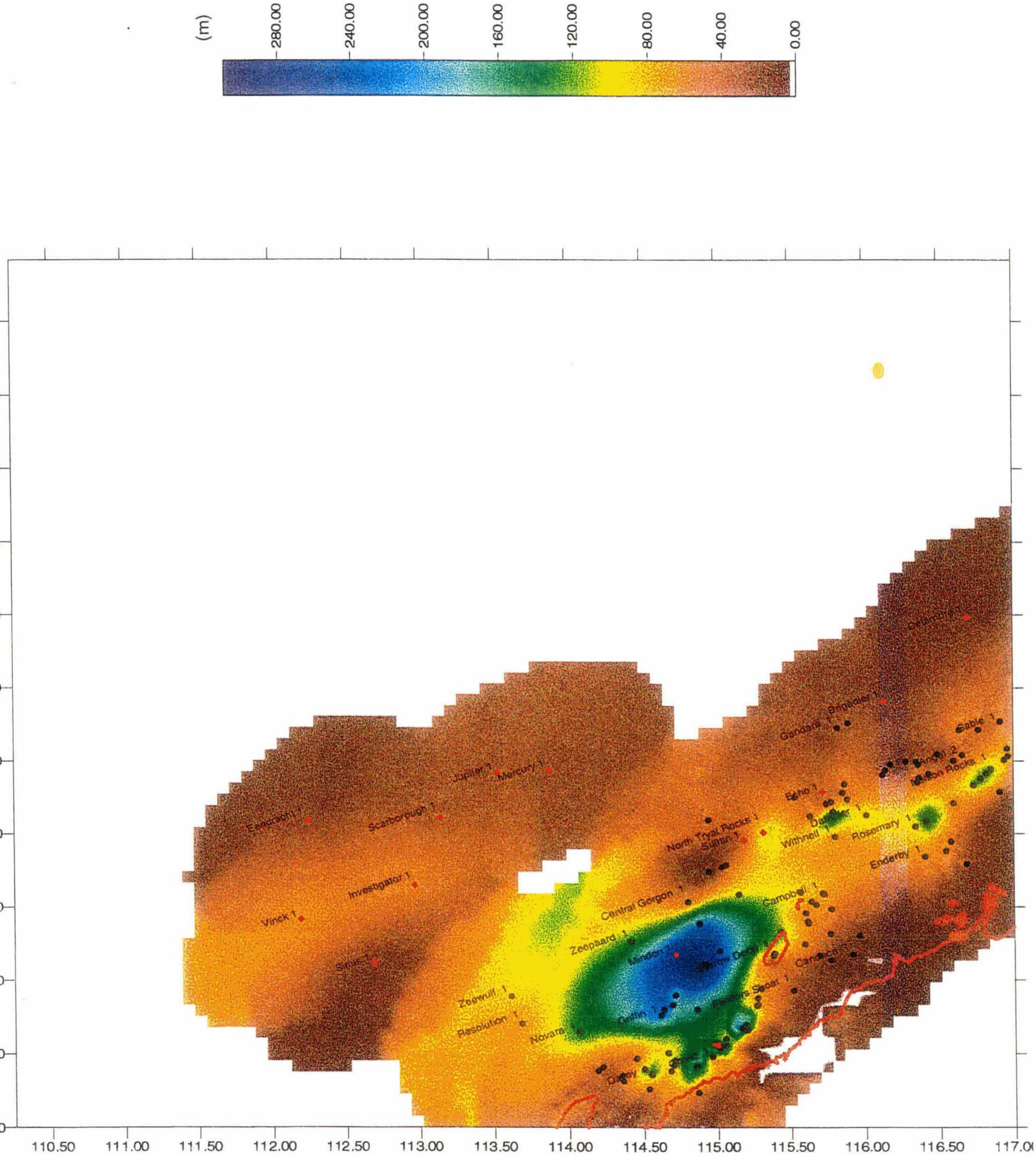


Figure 52: Time slice K8 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

Palaeodepositional Environments: (see Enclosure 30).

Open marine continental shelf, slope and abyssal plain environments are interpreted for the area. 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 regressed.

Palaeogeography: (see Enclosure 31).

- A starved carbonate shelf trends northeast, with a slope environment in the vicinity of the Rankin Trend and deep water over the Exmouth Plateau.
- Time slice K8 is condensed over most of the area. Time-depth curves and seismic reveal a higher sedimentation rate in the Barrow Sub-basin. As with time slices K5-K7, an approximate north-south sediment transport axis is interpreted.
- The upper part of time slice K8 may be absent over part of the Rankin Trend (Sultan 1, North Tryal Rocks 1) since it can be seen on seismic that all of time slice K9 has been removed by truncational erosion.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry for time slice K8:
- 0.1% < average TOC < 0.8% (3 control points), and
- 0.6%< average VR < 0.7% (2 control points).

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. However exceptionally good source rock quality is often associated with the oceanic anoxic layer, Turonian Spike, that occurs at the top of time slice K8. The maturation history of any source rocks will be different throughout the module area due to the variation of Cainozoic loading. However, irrespective of the loading, the oceanic anoxic layer is usually very thin and is not thought to be sufficiently mature anywhere in the module area, to have sourced hydrocarbons.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exists for this time slice.

Shows summary for the time slice:

Scarborough 1	G1 obtained from mud logs, and
Sirius 1	G1 obtained from mud logs.

Prospectivity: (see Enclosure 3).POOR

- No productive source rocks are interpreted.
- No reservoirs have been interpreted. The time slice forms part of a time slices K5-K10 claystone-calcilutite wedge deposited in a distal setting.
- The time slice acts as a regional seal.

Traps and plays.

Time slices K8 is transgressive with deep water prevailing over the area. It is unlikely that distal sands made it as far as the Outer Rankin Platform area or any of the module area thereby making time slices K8 an unprospective interval. **However any possible reservoirs in this time slice is most likely to be present in the eastern Exmouth Sub-basin and western Rankin Trend** both of which are within a likely sediment transport fairway. Sedimentation is condensed everywhere else. A siltstone body (Windalia Siltstone) is known to be present at Minden 1 (Enclosure 2) within this fairway and probably extends north into the Outer Rankin Platform area. Additionally younger fault systems are known to be active in the Outer Rankin Platform area and provide a potential pathway for oil migration from the deeper sections.

TIME SLICE K9:

LATE CENOMANIAN, TURONIAN, CONIACIAN AND LATE SANTONIAN (91.0 - 83.0 MA).

Petroleum System: Westralian 4 (see Enclosure 3).

Time slice K9 appears to be a time of fault reactivation across the North West Shelf and because of this it may be a time of significant fault aided migration of hydrocarbons from deeper mature source or deep pre-existing accumulations into shallower traps.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Upper and Lower Gearle Siltstone.

Regional Definition of Time slice: (see Figure 2).

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 the poorly controlled faunal zones to define the time slice. The following summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*C4* (B2), *C6* (B3), *C7* (B3)
- Delambre 1:	*C5* (D3), *C6* (B3), *C7* (B1), *C8* (B3)
- Echo 1:	*C4* (B2), *C5* (D2), *C6* (D2), *C7* (B4), *C8* (B2)
- Eendracht 1:	*C4* (B3, B4), *C5* (B4), *C6* (B3), *C9* (B3), *C10* (B3), *C11* (B3, B5)
- Jupiter 1:	*C4* (D3), *C7* (B4), *C8* (B1)
- Mercury 1:	*C5* (B2, D5), *C6* (B1, D3), *C7* (B2, D5), *C8* (B4, D3)
- Minden 1:	*P.infusorioides* (B2), *C.striatoconus* (B1)
- Scarborough 1:	*C5* (B3), *C6* (B3), *C8* (B4)
- Sirius 1:	*C4* (B2), *C5* (B3), *C6* (B3, B5)
- Sultan 1:	*I.cretaceum* (B3).

Most wells have some form of palaeontological control with moderate to good confidence ratings.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

Following the breakup of Antarctica during late time slice K8 to early time slice K9, the Australian continent was similar in morphology to the present day continent (Baillie et al, 1994). Time slices K8 and K9 coincide with the initiation of a continent wide subsiding continental margin. Consequently a greater portion of the shelf became outer shelf to slope water depths.

Time slice K9 also corresponds to a mid oceanic ridge jump in the Indian ocean which is associated with the commencement of the northern drift of Greater India. Subduction of the northern Australian Plate beneath the South East Asian Plate may have commenced in the Timor Trough area. The Tasman Sea also started opening during this time. In summary time slice K9 is a time of substantial plate movements which affected the Australia-India Plate.

Local

A near top time slice K9 structural phase and an intra time slice K8 event are interpreted from time depth curves. Truncational erosion is also prominent at this level particularly in the Exmouth Sub-basin where sub-aqueous erosion produced substantial submarine canyons. Truncational erosion can also be seen on the Rankin Trend. Both these events straddle the basal time slice K9 event interpreted in the Roebuck and Offshore Canning Basins-Beagle Sub-basin (Sayers et al, 1995) which was also attributed to the Southern Margins breakup. It is also differentiated from time depth curves and the termination of some faults at this boundary.

Bathymetric relief produced by unknown deep water processes is implied in Figure 18 where the time slice K9 " Ks " unconformity is seen to downcut into older sequences. Figure 41 also shows evidence of a time slice K9 unconformity with incision produced from deep water currents.

Lithology: (see Enclosure 2).

Claystones, calcareous claystones, marls, calcilutites and calcarenites dominate.

Thickness Variations: (see Figure 53).

For the 13 module wells thickness ranges from 25.6m in North Tryal Rocks 1 to 163m in Mercury 1. Figure 53 shows a regional isopach map based on the STRATDAT well database with a main thick centred around the Barrow Sub-basin and Lewis Trough. There are also anomalous thicks centred around Mercury 1 present in deep water settings. It is possible that post time slice K9 uplift may have occurred on the Exmouth Plateau. A maximum thickness for the Carnarvon Basin of 350m occurs in the Lewis Trough.

Palaeodepositional Environments: (see Enclosure 32).

Open oceanic starved shelf, slope and deep water environments dominate this time slice.

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 not to have shifted dramatically during this time slice relative to the previous time slice and relative sea level is interpreted to be at stillstand with deep water prevailing over most of the area.

Palaeogeography: (see Enclosure 33).

- Significant north-south sediment transport axes are present around Minden 1. Depocentres are also present seaward of these axes on the outer continental slope. Non pelagic sediments have potentially been channelling down the submarine canyons present on the western Exmouth Sub-basin and are thought to have contributed to these depocentres.
- Time slice K9 and in part the underlying time slices are absent over part of the Rankin Trend. This, together with the presence of substantial submarine canyons, substantiates that structural movements at this time (effects of the Southern Margins breakup) did occur. As a result slope and basin floor fans may exist seaward of these canyons.
- The continental outer shelf and slope have been extended to the Exmouth Plateau so as to accommodate for sand grains being present in Vinck 1 and coral spicules present in Eendracht 1. This interpretation is also partially supported from seismic which suggests that areas to the northeast were probably deeper water. This could also be explained as a result of uplift of the tectonic block between the Cape Range Fracture Zone (CRFZ) and an unnamed but related feature parallel to the CRFZ but slightly north of Mercury 1. This is an onshore extension of a Gascoyne Abyssal Plain Transfer Fault that parallels the CRFZ.

Geochemistry (TOC, HI and VR): (see Appendix 5).

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. An average TOC of 0.5% at North Tryal Rocks 1 is the only geochemical analysis from the database. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Irrespective of this loading, any potential source rocks throughout the module area are expected to be immature to sub-mature at best.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exists for this time slice. Gas indications (G1) are present in Brigadier 1, Jupiter 1, Mercury 1, Scarborough 1 and Sirius 1.

Prospectivity: (see Enclosure 3).POOR

- No source rocks have been interpreted and the section is immature over the module area.
- No reservoirs have been interpreted, but speculative reservoirs may exist in the southern module area where indications of channelling and coarse clastic and carbonate facies are seen. Generally however the time slice forms part of a time slices K5-K10 claystone-calcilutite wedge deposited in a distal setting.

The time slice acts as a regional seal.

Traps and plays.

In the southern area of the Exmouth Plateau possible stratigraphic traps exist but with a high risk for hydrocarbon charge. The time slice is shown to be neither regressing or transgressing with deep water prevailing over the area. It is unlikely that distal sands were deposited as far as the Outer Rankin area thereby making time slice K9 an unlikely prospective interval. Plays in this time slice have the highest chance of being present in the eastern Exmouth Sub-basin and western Rankin Trend which are within the higher sediment transport fairways (see also this section for time slices K4-K8). Sedimentation is condensed everywhere else. Younger fault systems are known to be active in the above areas thus providing a chance for conduits and oil migration pathways from the deeper sections.

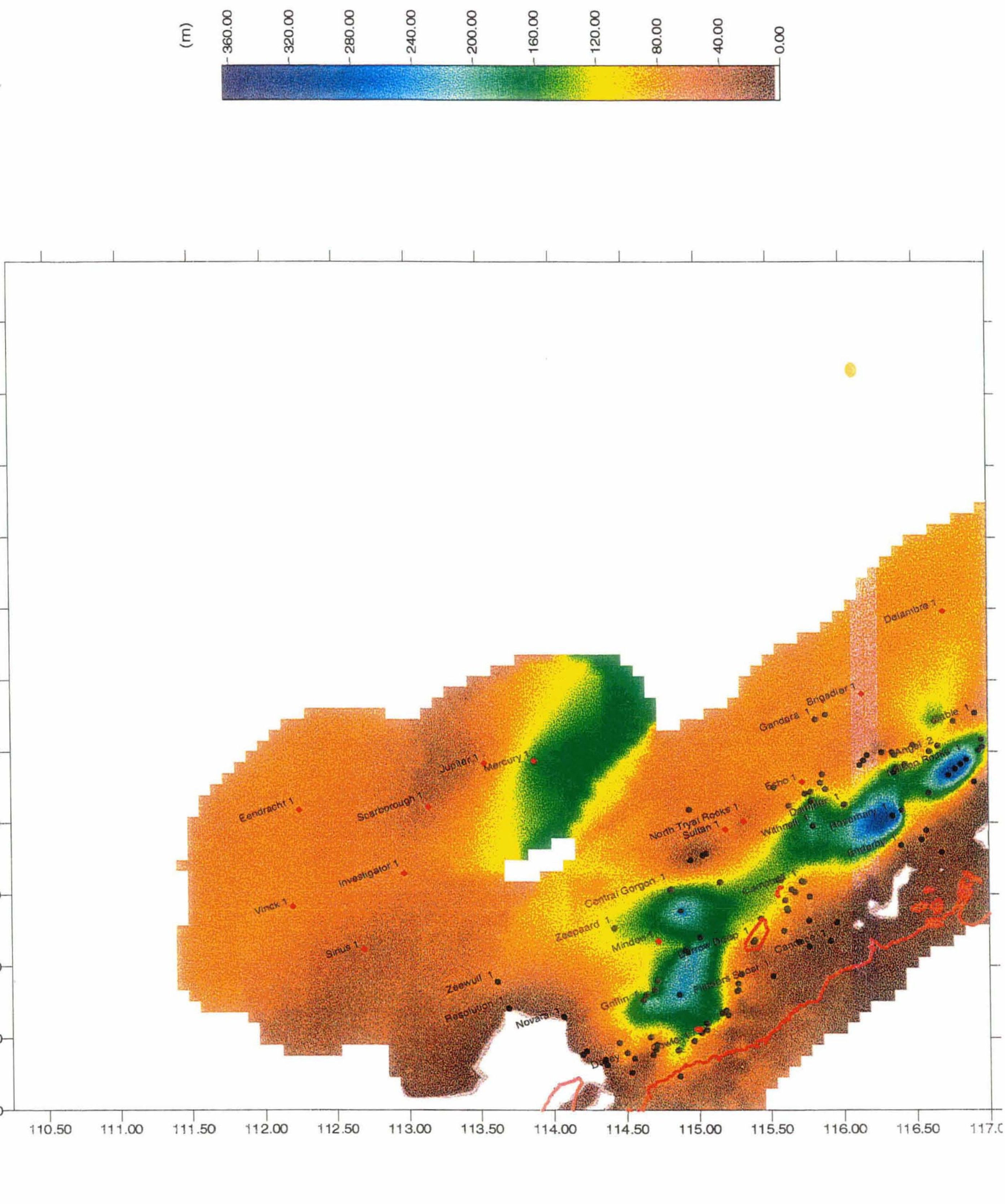


Figure 53: Time slice K9 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

TIME SLICE K10:

LATE SANTONIAN & CAMPANIAN TO EARLY MAASTRICHTIAN (83.0 - 70.0 MA).

Petroleum System: Westralian 4 (see Enclosure 3).

A regional generally thin carbonate dominated seal facies over most of module area. Everywhere immature.

Formation Synonyms: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Korojong Calcarenite and Toolonga Calcilutite.

Regional Definition of Time slice: (see Figure 2).

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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1:	*C9* (B3), *C10* (B2), *C11* (B3), *C13* (B1)
- Delambre 1:	*C10* (B2, B4), *C11* (B2, B4)
- Echo 1:	*C9* (B2), *C10*(B4), *C11*(B2)
- Eendracht 1:	*C9*(B3), *C10*(B3), *C11* (B3, B5)
- Jupiter 1:	*C9*(B2)
- Mercury 1:	*C9* (B2), *C10* (B3), *C11* (B2, D3)
- Minden 1:	*N.aceras* (B2, B3), *C9* (B5), *C10* (B5)
- Scarborough 1, Sirius 1:	*C9* (B3), *C10* (B4).

Most wells have some form of palaeontological control with poor to good confidence ratings.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

Subduction is occurring in the Timor Trough area as the Australian plate drifts north.

Local

A top time slice K10 unconformity is defined solely from time depth curves. The cause of this unconformity is unknown. A time of tectonic quiescence.

Lithology: (see Enclosure 2).

Marls, calcilutites and calcarenites dominate whilst claystones and calcareous claystones were intersected in Echo 1.

Thickness Variations: (see Figure 54).

For the thirteen module wells thickness ranges from 0m to 161m in Scarborough 1. Figure 54 shows a regional isopach map based on the STRATDAT well database with a number of thicks centred around the Dampier and Exmouth Sub-basins but with significant sedimentation present on the Exmouth Plateau. A maximum thickness for the Carnarvon Basin of 600m occurs in the Dampier Sub-basin. It is probable that uplift during time slice K9 initiated slightly higher sedimentation rates in time slice K10.

Palaeodepositional Environments: (see Enclosure 34).

No palaeogeography map was made for time slice K10. The environments and water depths are thought to be similar to those of time slice K9 except that no canyons or coarse clastic are interpreted. 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..

Palaeogeography: (No Enclosure).

- The isopach map (Figure 54) shows that overall time slice K10 is relatively thin but varies from 0-300m over the module area.

• Some of the palaeoenvironmental boundaries coincide with the boundary of the East Exmouth Continental Fracture Zone with deeper water being present to the north. The location of the continental shelf break is based on palaeogeographic interpretations.

• Time slice K10 is absent over parts of the Rankin Trend (Sultan 1, North Tryal Rocks 1).

• Sedimentation rates are higher in the southwest part of the project area, possibly due to sediments being transported via the submarine valleys on the north side of the Exmouth Sub-basin (Enclosures 33 & 51).

• There is a fully open oceanic circulation system with a relatively rapid sagging continental margin. Outer continental shelf and continental slope environments are recognised. The continental shelf break is orientated approximately parallel to the present day coastline.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

The following summarises the geochemistry:

- 0.2% < average TOC < 3.3% (3 control points).

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Irrespective of this loading any potential source rocks throughout the module area are expected to be immature.

Shows, Porosity & Permeability: (see Appendix 4).

No porosity or permeability data exists for this time slice. Gas indications (G1) were recorded in Brigadier 1, Echo 1, Eendracht 1, Jupiter 1, Minden 1 and Sirius 1.

Prospectivity: (see Enclosure 3).VERY POOR

• No source rocks were interpreted.

• No reservoirs were interpreted.

• The time slice acts as a regional seal.

Traps and plays.

No obvious significant plays exist. As the coastline of most of the time slice K8-K11 is regressing, it is unlikely that distal sands made it as far out as the Outer Rankin area thereby making time slice K10 an unlikely prospective interval. Plays in this time slice have the highest chance of being present in the eastern Exmouth Sub-basin and western Rankin Trend which are within the higher sediment transport fairways (see also this section for time slices K4-K9). Sedimentation is condensed everywhere else. The siltstone body at Echo 1 could however provide a possibility for reservoir although poor.

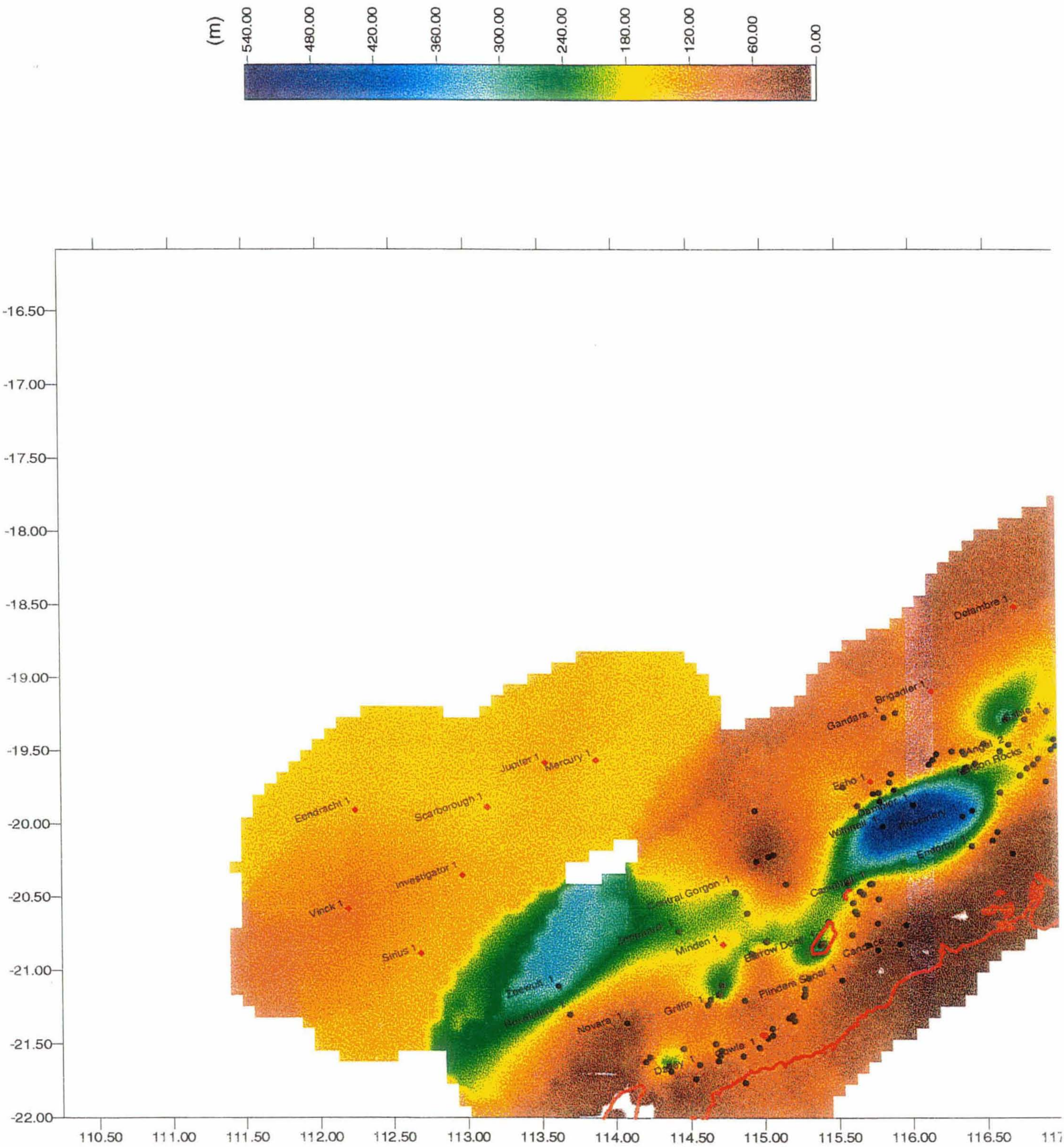


Figure 54: Time slice K10 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

TIME SLICE K11:
UPPER CRETACEOUS: MIDDLE TO LATE MAASTRICHTIAN (70.0 - 65.0 MA).

Petroleum System: Westralian 4 (see Enclosure 3).
A regional generally thin carbonate dominated seal facies over most of module area. Everywhere immature.

Formation Synonyms: (see Figure 2).
Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Mira Marl at the top of the time slice.

Regional Definition of Time slice: (see Figure 2).
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 - Cainozoic boundary.

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 summarises the palaeontological control and species zones confidence ratings (refer to page 2 for description of confidence ratings):

- Brigadier 1, Delambre 1, Eendracht 1, Mercury 1 — *C13* (B1), and
- Minden 1 — *C13* (B5).

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional
The Australian Plate was drifting north whilst subduction was occurring in the Timor Trough area. This time also corresponds to the opening of the Coral sea.

Local
The unconformable nature of the top Cretaceous is defined from time depth curves, logs and seismic and corresponds to a eustatic lowstand with clear evidence of sub-aqueous erosion present, particularly in the Exmouth Sub-basin. This sub-aqueous erosion takes the form of a corrugated surface with major incision in part together with truncational erosion of a set of semi discontinuous reflectors. Faults also terminate at this level which may be indicative of a structural re-adjustment phase. One of the results of the lowstand is the transgression of sands to more distal settings.
Figure 29 shows that sub-aqueous erosion is implied from the corrugated erosional surface of the basal Cainozoic with potential deep water currents scouring out underlying formations.

Lithology: (see Enclosure 2).
Marls, calcilutites and calcarenites dominate.

Thickness Variations: (see Figure 55).
For the 13 module wells thickness ranges from 0m to 83m in Vinck 1. Figure 55 shows a regional isopach map based on the STRATDAT well database with restricted thicks in the Barrow and Dampier Sub-basins. A northeast-southwest trend is prominent on the Exmouth Platform which is primarily based from Saturn 1. Saturn 1 has accumulated thicks at the base of the continental shelf break which may follow the shelf break for some distance. The extent of the thick trend is unlikely to depart from the base of the shelf break and consequently the contouring is in error in this area. A maximum thickness for the Carnarvon Basin of 185m occurs on the Outer Rankin Platform.

Palaeodepositional Environments: (see Enclosure 35).
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 being in about the same location as in time slice K9.

Palaeogeography: (No Enclosure).
- The isopach of time-slice K11 (Figure 55) reveals relatively thin deposition ranging from 0-185m. Isolated thicks such as at Saturn 1 are present immediately north of the East Exmouth Continental Fracture Zone. Sedimentation is thus relatively very poor with the thicker deposits restricted to the base of the continental slope.

• The Exmouth Plateau acts as a bathymetric low area where higher velocity submarine currents have reworked and thinned deposited pelagic sediments relative to landward and seaward areas. This may also be operating on the Rankin Trend.

• Sedimentary rates are higher in the southwest part of the project area, to some degree possibly due to sediments being transported via the submarine valleys on the north side of the Exmouth Sub-basin (Enclosures 33 & 51).

<u>Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).</u>

This time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. An average TOC of 0.1% in Mercury 1 is the only geochemical analysis available from the database. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Irrespective of this loading any potential source rocks throughout the module area are expected to be immature.

<u>Shows, Porosity & Permeability: (see Appendix 4).</u>

No porosity or permeability data exists for this time slice. Gas indications (G1) are present in Eendracht 1.

<u>Prospectivity: (see Enclosure 3). EXTREMELY POOR</u>

• No source rocks were interpreted. Vitrinite values at Minden 1 suggest that the top of time slice K5 is presently mature for oil generation. Younger aged source rocks would be mature immediately east and to the north of this location due to increased depth of burial.

• No reservoirs have been interpreted.

• The time slice acts as a regional seal.

<u>Traps and plays.</u>

No traps are inferred or obvious. The time slice is shown to be neither regressing or transgressing with deep water prevailing over the area. It is unlikely that distal sands were deposited as far as the Outer Rankin area thereby making time slice K11 an unlikely prospective interval. Plays in this time slice have the highest chance of being present in the eastern Exmouth Sub-basin and western Rankin Trend which are within the higher sediment transport fairways (see also this section for time slices K4-K8). Sedimentation is condensed everywhere else. Younger fault systems are known to be active in the above areas thus providing a chance for conduits and oil migration pathways from the deeper sections.

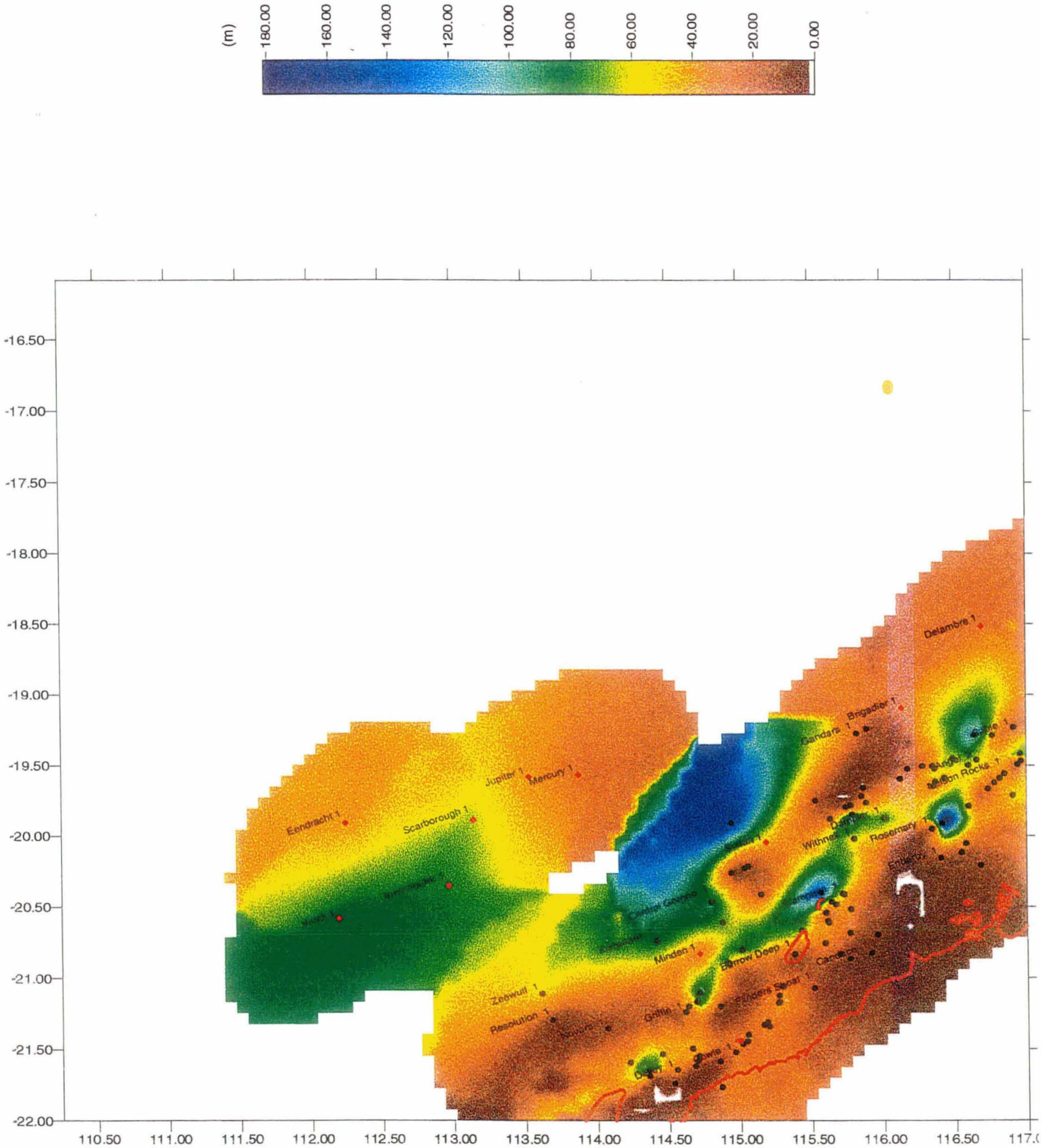


Figure 55: Time slice K11 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

CAINOZOIC TIME SLICES Cz1 to Cz7

CAINOZOIC: PALEOCENE TO RECENT (65.0 TO 0.0 MA).

Petroleum System: Westralian 4 (see Enclosure 3).

The Cainozoic is a significant part of the Westralian system. It is the time of major hydrocarbon generation and migration from the Westralian source rocks in the inshore Carnarvon Basins. Because the Cainozoic is fairly thin on the Exmouth Plateau, in this area the Cainozoic does not constitute a time of major maturation and migration.

The Cainozoic 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 Cainozoic is also a time of significant margin sag due to sediment loading and subsidence. The plate re-organisation during the Cainozoic, as evidenced by the north Australian Plate collision with Timor, has been the initiator of numerous unconformities (Enclosure 2) and reactivated faults from the Oligocene onwards. 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: (see Figure 2).

Formal stratigraphic names are very loosely defined within the module area. Equivalent formations from the offshore Carnarvon Basin, to the southeast of the module area, include the Dockrell formation (CZ1), Wilcox Formation (CZ2), Giralia and Walcott limestones (CZ3), Mandu and Trealla limestones (CZ4), and the Delambre Formation (CZ5-CZ7).

Regional Definition of Time slice: (see Figure 2).

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 the *P9* planktonic foraminiferal zone. This time slice is also associated with 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 the *P17* planktonic foraminiferal zone. This time slice is also associated with increased Australian and Antarctic spreading rate, major transgression along the 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), but induration phenomena, widespread submarine erosion, and or non-deposition, ice development in Antarctica and strengthening of the circum-Antarctic current all occur.

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 Cainozoic 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 Grea 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 page 2 for description of confidence ratings):

CZ1	
- Brigadier 1:	*T4a* (B3), *T4b* (B3), *T5* (B3), *T8* (B2), *T9* (D3, B2),
- Delambre 1:	*T1* (B3), *T3* (B3), *T4a* (B3), *T4b* (B1), *T8* (B2), *T9* (B4), *T10* (B2),
- Echo 1:	*T1* (B3), *T4a* (B1), *T4b* (B1), *T5* (B1), *T8* (B2), *T9* (B2, B4),
- Eendracht 1:	*T1* (B3, B5),
- Mercury 1:	*T2* (D4), *T3* (B4), *T4* (B2),
- North Tryal Rocks 1:	*P4* (B3), *P6* (B3),
- Sultan 1:	*T1* (B5), *T5* (B3).
CZ2	
- Brigadier 1:	*T11* (D3), *T12* (B3),
- Delambre 1:	*T11b* (B1), *T12* (B2), *T13* (B1),
- Echo 1:	*T11b* (B2), *T14* (B3),
- North Tryal Rocks 1:	*P12* (B5),
- Sultan 1:	*T11b* (B5).
CZ3	
- Echo 1:	*T15* (B2),
- North Tryal Rocks 1:	*P14* (B5).
CZ4	
- Brigadier 1:	*P21* (B2), *P22* (B3), *N4* (B2), *N5* (B2), *N8* (B2), *N9* (B2), *N10* (B4),
- Delambre 1:	*N9* (B3), *N10* (B3), *T17* (B3), *T18* (B3), *T19* (B1),
- Echo 1:	*N8* (B3), *N9* (B3, D5),
- Minden 1:	*T18* (B3, B5), *N9* (B5),
- North Tryal Rocks 1:	*P22* (B3), *N4* (B3, B5), *N8* (B3, B4),
- Sultan 1:	*P22* (B3), *N9* (B5).
CZ5	
- Brigadier 1:	*N17* (B3),
- Delambre 1:	*N14* (B1), *N15* (B1, B4), *N16* (B1), *N17* (B1, B3),
- Echo 1:	*N16* (D4, B2), *N17* (B2),
- North Tryal Rocks 1:	*N9* (B3),
- Sultan 1:	*N16* (B5), *N18* (B5).
CZ6	
- Brigadier 1:	*N18* (B3), *N19* (B3, B5),
- Delambre 1:	*N19* (B1), *N21* (B1),
- Echo 1:	*N19* (B1), *N21* (B2),
- Minden 1:	*N20* (B5), *N21* (B5),
- North Tryal Rocks 1:	*N18* (B5), *N19* (B5), *N20* (B5), *N21* (B3),
- Sultan 1:	*N19* (B3), *N20* (B3), *N21* (B3).
CZ7	
- North Tryal Rocks 1:	*N22* (B3),
- Sultan 1:	*N22* (B4).

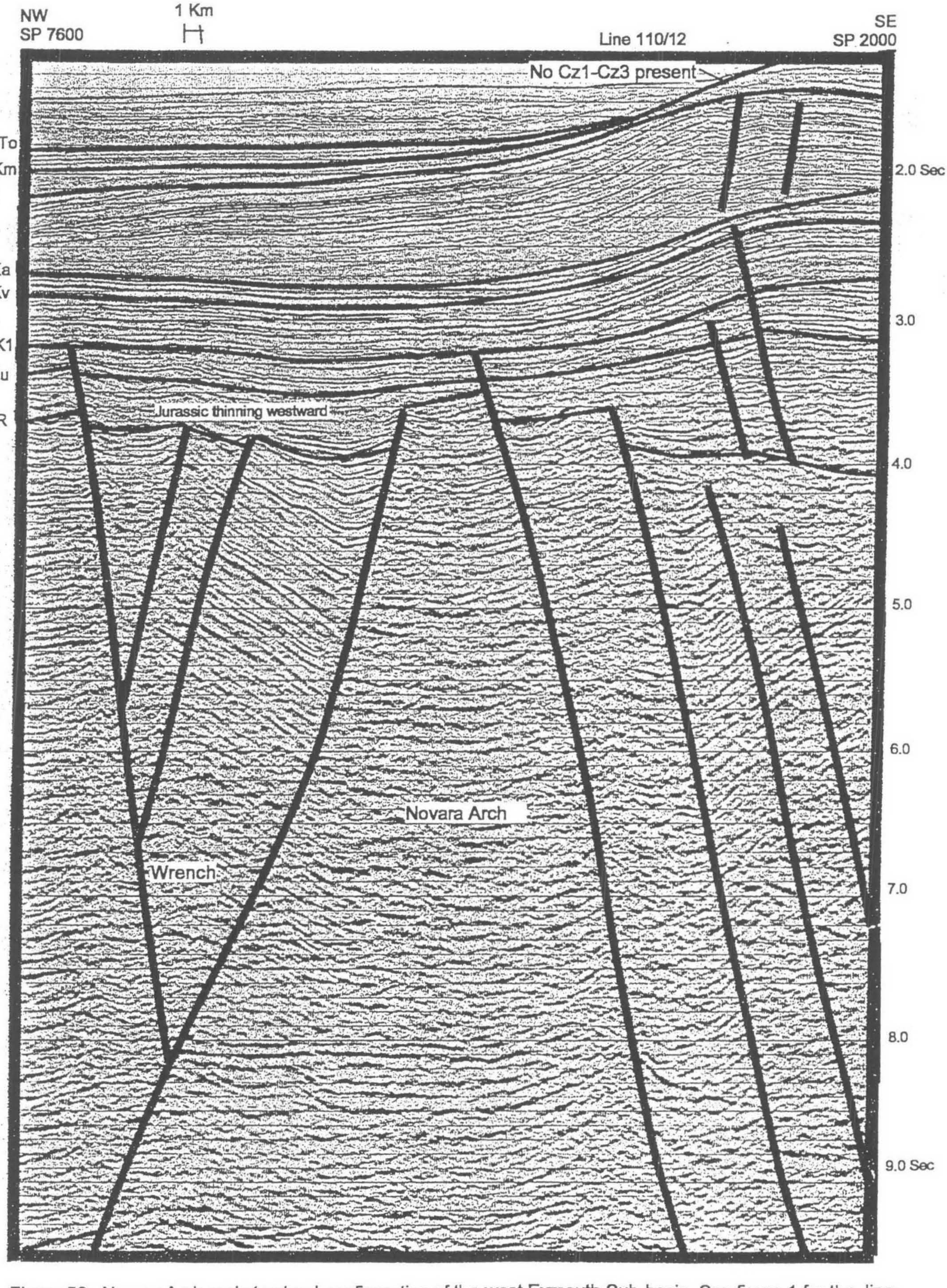


Figure 56: Novara Arch and structural configuration of the west Exmouth Sub-basin. See figure 1 for the line location. Comprehensive list of seismic horizons in enclosure 2. To - top time slice Cz3, Km - top Cretaceous, Ks - intra time slice K9, Ka - top time slice K4, Kv - top time slice K1, Ju - top Jurassic, TR - top time slice Tr5.

Tectonics: (see Enclosure 1, Figures 2 & 3).

Regional

Cainozoic tectonics are dominated by the collision and subduction between the Australian and South East Asian Plates in the area of Indonesia 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. This is thought to reflect the intraplate reorganisation in the Indian Ocean and higher subsidence rates, as well as increased carbonate productivity associated with the Australia-India Plate moving north and entering tropical waters.

Local

A number of unconformities are evident from seismic and chronostratigraphy, some of which relate to prominent structural phases:

- *Top time slice CZ3 (Near top Oligocene):*

The top of this time slice is clearly defined from the time depth curves of all the non Exmouth Plateau wells and is readily recognised on seismic as a downlapping surface. This event corresponds to the initiation of the northern margins collision between the Australian and South East Asia plates.

- *Near top time slice CZ5 (near top Miocene):*

Evidence for the near top time slice CZ5 event is most prominent on seismic on the Rankin Trend and from the time depth curves of Minden 1, Sultan 1 and North Tryal Rocks 1. Truncational erosion is interpreted on the Rankin Trend with a clear sequence boundary present. This event coincides with further northern margins collision between the Australian and South East Asia plates, in particular the development of the Papua New Guinea island arc and Australian Plate jump over the Banda arc. Depositional rates for time slices CZ5 and CZ6 are high which would further mature underlying source rocks. This together with structural movements at the top of time slice CZ5 may have initiated one of the primary oil migration phases in the Carnarvon Basin.

- *Other Tertiary events:*

- Other unconformities have been placed within time slices CZ1, CZ2 and CZ4 (Enclosure 2). These events may correspond to further northern margins collisions between the Australian and South East Asia plates as well as episodic variations in the submergence of the north Australian platforms.
- Time slice CZ1 corresponds to the termination of the Tasman Sea spreading. It is also the time of the India-Asia collision.
- Time depth curves show other sharp offsets which are interpreted to be linked both to potential structural re-adjustment phases and or relative sea level fluctuations causing variable sediment discharge. The result is a series of complex continental shelf prograding sediment packages.
- Figure 29 shows that continual subsidence of the shelf edge occurred through the Cretaceous and Cainozoic at the location of the East Exmouth Continental Fracture Zone. The degree of vertical movement along the length of the fracture system is variable.
- Figure 56 shows the absence of time slices CZ1-CZ3 in the Exmouth Sub-basin the result of probable basin inversion.

Lithology: (see Enclosure 2).

Time slice CZ1: Marls, calcilutites, calcarenites, calcareous claystones and claystones dominate in the inner basin areas. No lithology data exists from the wells drilled on the Exmouth Plateau.

Time slice CZ2: Major chert beds were intersected in Delambre 1 whilst dolomite beds are present on the Rankin Trend together with marls, calcilutites and calcarenites. No lithology data exists from the wells drilled on the Exmouth Plateau.

Time slice CZ3: Marls, calcilutites, calcarenites, calcareous claystones and claystones dominate in the inner basinal areas. No lithology data exists from the wells drilled on the Exmouth Plateau.

Time slice CZ4: Marls, calcilutites, calcarenites, calcareous claystones and claystones dominate in the inner basinal areas. Sandy facies were deposited during the low stand phase at the base of the time slice. No lithology data exists from the wells drilled on the Exmouth Plateau.

Time slice CZ5: Marls, calcarenites and calcilutites are the dominant lithology with prominent sandy facies present in the Brigadier 1 well (Bray sand). No lithology data exists from the wells drilled on the Exmouth Plateau.

Time slice CZ6: Marls, calcarenites and calcilutites are the dominant lithology with prominent sandy facies present in the Brigadier 1 well (Bray sand). No lithology data exists from the wells drilled on the Exmouth Plateau.

Time slice CZ7: Marls, calcarenites and calcilutites are the dominant lithology with prominent sandy facies present in the Brigadier 1 well (Bray sand). No lithology data exists from the wells drilled on the Exmouth Plateau.

Thickness Variations: (see Figures 57-63, Enclosure 52).

Time slice CZ1 ranges in thickness from 0m to 375m in Echo 1, considering only the thirteen module wells. Figure 57 shows a regional isopach map based on the STRATDAT well database where the thickness ranges up to 450m in the Outer Rankin Platform. Features include the presence of restricted thicks in the Dampier Sub-basin, Rankin Trend and Outer Rankin Platform.

Time slice CZ2 ranges in thickness from 0m to 175m in North Tryal Rocks 1, considering only the thirteen module wells. Figure 58 shows a regional isopach map based on the STRATDAT well database where the thickness ranges up to 400m on the Rankin Trend. Localised thicks in the Barrow and Dampier Sub-basins and Rankin Trend are present.

Time slice CZ3 ranges in thickness from 0m to 75m in Brigadier 1, considering only the thirteen module wells. Figure 59 shows a regional isopach map based on the STRATDAT well database where the thickness ranges up to 500m in the Lewis Trough. There are also localised thicks in the Dampier and Barrow Sub-basins and Rankin Trend.

Time slice CZ4 ranges in thickness from 0m to 1139m in Echo 1, considering only the thirteen module wells but is representative of the thickness range for all of the Carnarvon Basin and Exmouth Platform. Figure 60 shows a regional isopach map based on the STRATDAT well database with restricted thicks on the northern side of the Dampier Sub-basin and the Rankin Trend. A prograding sedimentary wedge is clearly seen on seismic downlapping onto the top time slice CZ3 unconformity.

Time slice CZ5 ranges in thickness from 0m to 834.5m in Brigadier 1, considering only the thirteen module wells but is representative of the thickness range for all of the Carnarvon Basin and Exmouth Platform. Figure 61 shows a regional isopach map based on the STRATDAT well database with the main thick restricted to the Rankin Trend and northeast Outer Rankin. This is clearly a result of younger sediments prograding basinward in a NWW direction.

Time slice CZ6 ranges in thickness from 0m to 798m in Sultan 1, considering only the thirteen module wells but is representative of the thickness range for all of the Carnarvon Basin and Exmouth Platform. Figure 62 shows a regional isopach map based on the STRATDAT well database with the main thick restricted to the Rankin Trend and northeast Outer Rankin. This is clearly a result of younger sediments prograding basinward in a NNW direction.

Time slice CZ7 ranges in thickness from 0m to 404m in North Tryal Rocks 1, considering only the thirteen module wells but is representative of the thickness range for all of the Carnarvon Basin and Exmouth platform. Figure 63 shows a regional isopach map based on the STRATDAT well database with thicks present on the Rankin Trend and northeast Outer Rankin as well as a thick developed around Sirius 1. The thickest isopach value on the Exmouth Platform is an artefact of the contouring package.

Palaeodepositional Environments: (see Enclosures 37-41).

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 in the lower part of the time slice followed by a transgression in the upper part of the time slice. The coastline in time slice CZ1 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 (see above) show a gradual transgression in the lower part of the time slice followed by a regression in the upper part of the time slice. The coastline in time slice CZ2 is in about the same location as for time slice CZ1.

Palaeogeography CZ1-CZ7: (see Enclosure 42).

•The Cainozoic isopach shows a thick orientated in a northeast-southwest direction which coalesces with the NE-SW trend found in the Beagle and Roebuck Basins. The thick is a result of progrades stacking on the shelf. The clastic sediment source direction is probably from the south-east-east. This is also illustrated in Enclosure 52 from seismic isochron mapping.

• The continental shelf and slope parallel the present day coastline. The Outer Continental Shelf widens to the south in the vicinity of Minden 1. Time slices CZ1 - CZ3 have not been deposited in the southwest Carnarvon Basin (Figures 25 and 56). It is interpreted that time slices CZ1-CZ3 may either never have been deposited in most of the Exmouth Sub-basin or that the Sub-basin was inverted at top time slice CZ3, coinciding with the initiation of the Australia-South East Asian Plate collision. Time slices CZ4-CZ7 subsequently onlapped this high. Figure 29 shows that time slices CZ4 and CZ5 downlap in the vicinity of Sultan 1, implying that only a condensed sequence is present over the Exmouth Plateau.

• The Cainozoic thins over the Exmouth Plateau but there is a slightly thicker condensed section in the north (also illustrated in Enclosure 52). The older Mesozoic together with the thick time slice K1 Barrow Deltas lobes still provide a bathymetric high where subsequent sedimentation is thinned by higher velocity current flow.

Geochemistry (TOC, HI, S2 and VR): (see Appendix 5).

Average TOCs' vary:

- 0.1% to 0.7% in time slice CZ1,
- 0.3% in time slice CZ2 at North Tryal Rocks 1,
- 0.4% in time slice CZ3 at North Tryal Rocks 1,
- 0.5% in time slice CZ4 at North Tryal Rocks 1,
- 0.4% in time slice CZ5 at North Tryal Rocks 1.

The time slice in the module area is poorly sampled, and consequently source rock quality is poorly understood. The average value of VR is 1.3% in North Tryal Rocks 1 which is highly likely to be contaminated. The maturation history of the source rock will be different throughout the module area due to the variation of Cainozoic loading. Irrespective of this loading any potential source rocks throughout the module area are immature.

Shows, Porosity & Permeability: (see Appendix 4).

Porosity and permeability data summary for the time slice:

Brigadier 1	26% < porosity < 35%, obtained from electric logs,
Delambre 1	5% < porosity < 27%, obtained from sonic logs,
Echo 1	22% < average porosity < 35%, obtained from density logs, and
North Tryal Rocks 1	19% < porosity < 33%, obtained from sonic logs.

Shows summary for the time slice:

Brigadier 1	G1 obtained from mud logs, L1 from SWC,
Echo 1, Eendracht 1, Minden 1, Sultan 1	G1 obtained from mud logs, and
North Tryal Rocks 1	G1 obtained from mud logs, L1 from SWC.

Prospectivity: (see Enclosure 3) POOR to FAIR.

• The Cainozoic does not have significant potential seaward of the main shelf break as only deeper water facies are present. An exception is turbidite, slope and basin floor fans that may have been deposited on the Outer Rankin Platform. At best they may trap biogenic gas. Sands deposited during lowstands may be sourced from faults present in this younger section which were induced from slope instability and from a subsiding shelf break.

• Any potential source rocks of Cainozoic age would be immature to at best sub-mature along the Rankin Trend where a 2500 meter sedimentary column is present.

• Carbonate reservoirs exist throughout the Cainozoic although the quality of reservoir is uncertain. Marine clastic reservoirs have been identified in time slice CZ5 in Echo 1.

• The Cainozoic acts as a regional seal for all wells assessed in this module. Cainozoic aged faults are rare in the main module area thus preventing charging of reservoirs from pre-Cainozoic source rocks with the exception of the shelf break area.

• The Palaeocene gas at Maitland in the Barrow Sub-basin establishes some potential for hydrocarbons in time slices CZ1-CZ7 (Sit et al, 1994).

Traps and plays.

Outer Rankin:

• Turbidite sands, slope and basin floor fans deposited on the shelf break area during lowstands may have potential. Examples of fans are present at the basal time slice CZ4 on the Rankin Trend and eastern Outer Rankin. These could be sourced from depth via intermittent fault systems associated with the subsiding margins but there is a general lack of faulting away from the shelf break area.

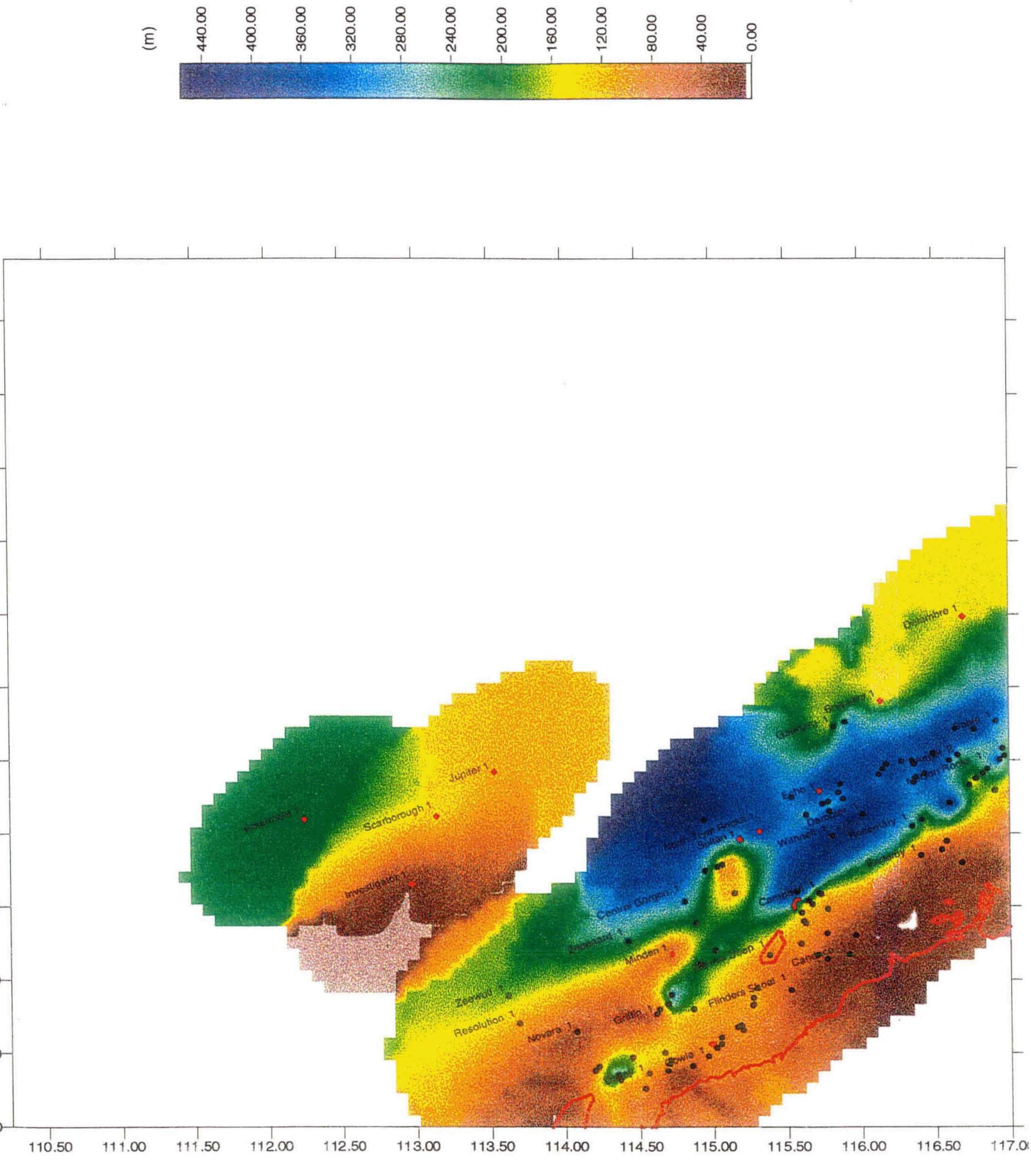


Figure 57: Time slice Cz1 isopach map based on STRATDAT database. Module wells have red coloured well symbols.

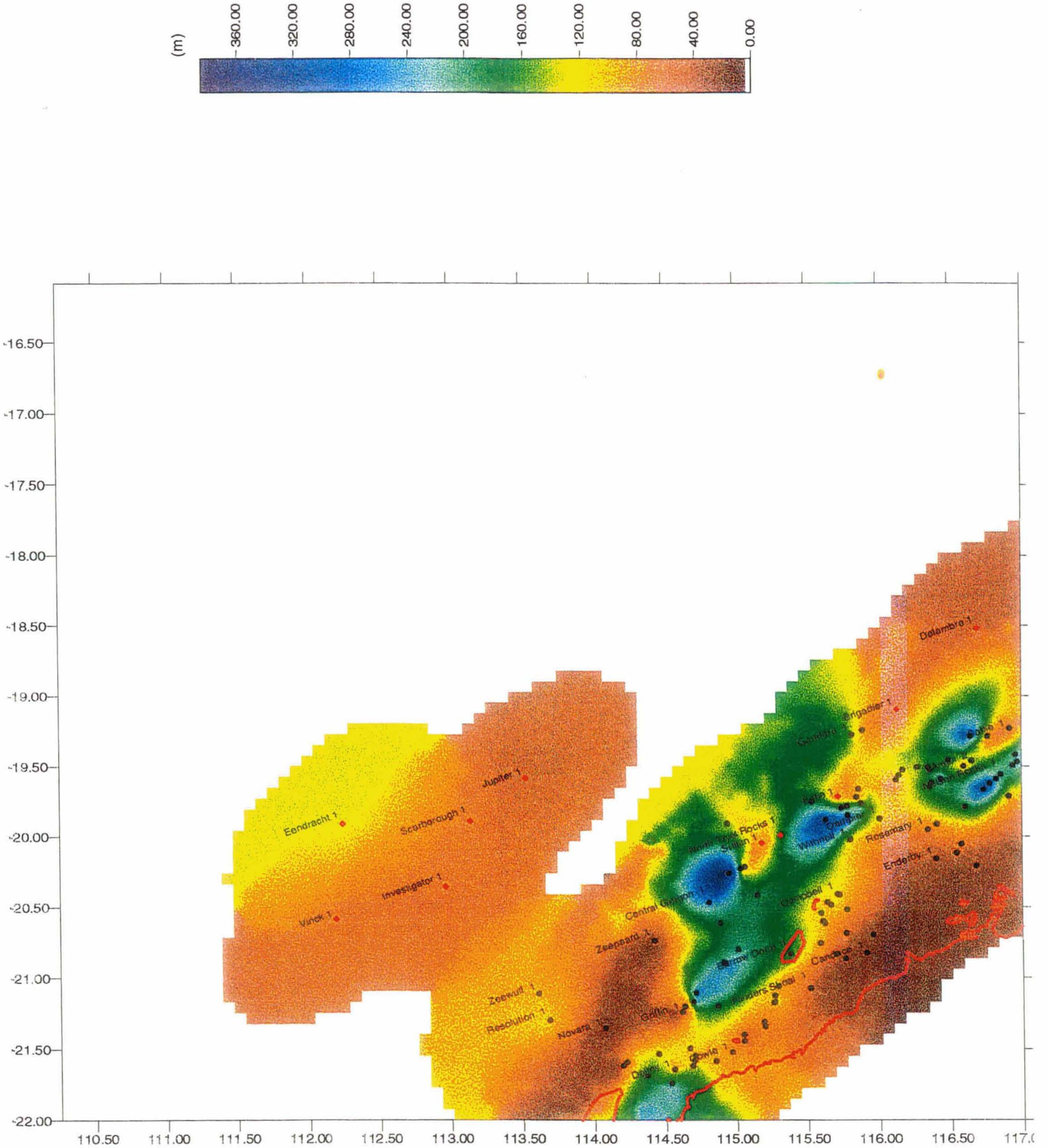


Figure 58: Time slice Cz2 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

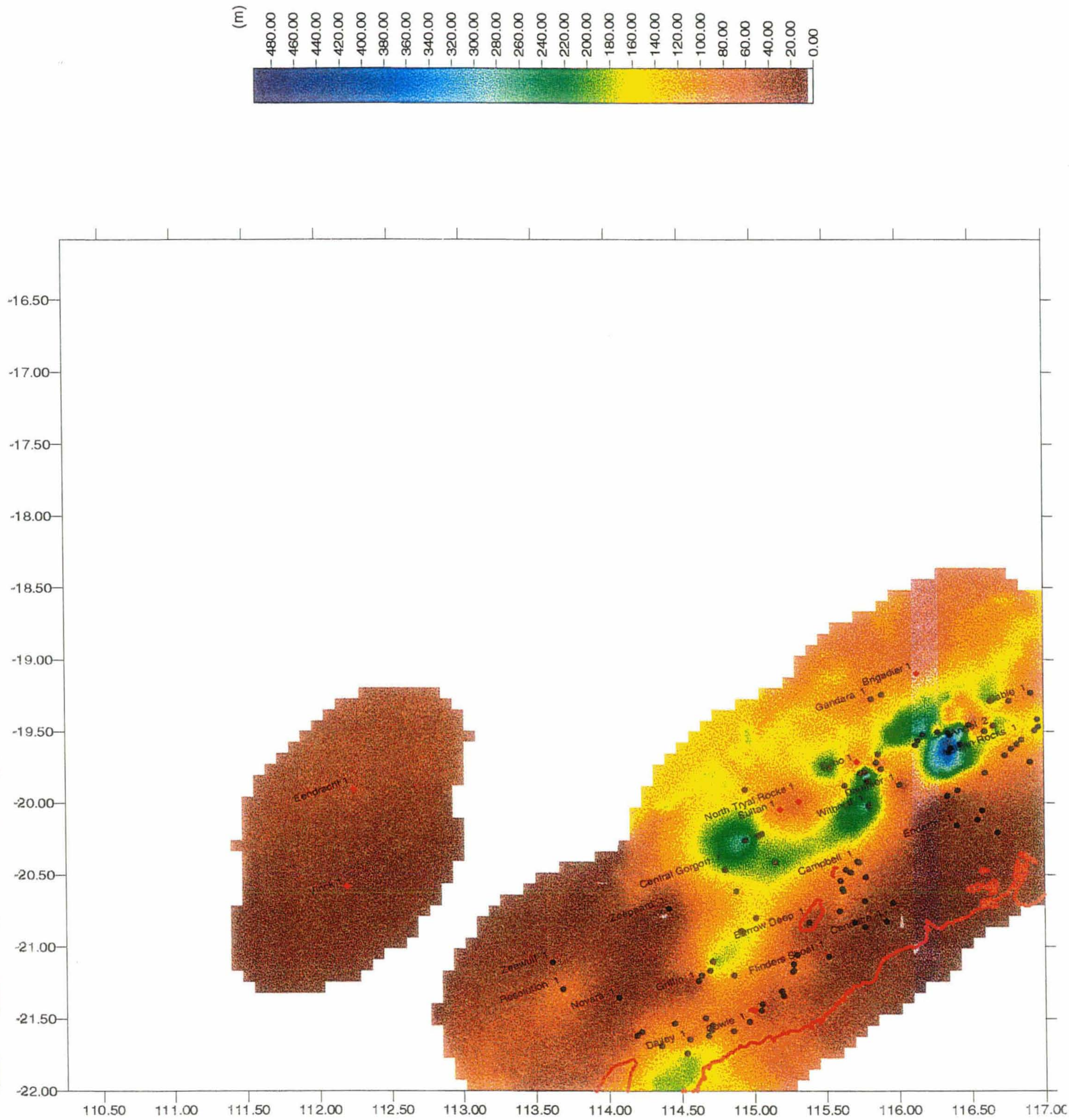


Figure 59: Time slice Cz3 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

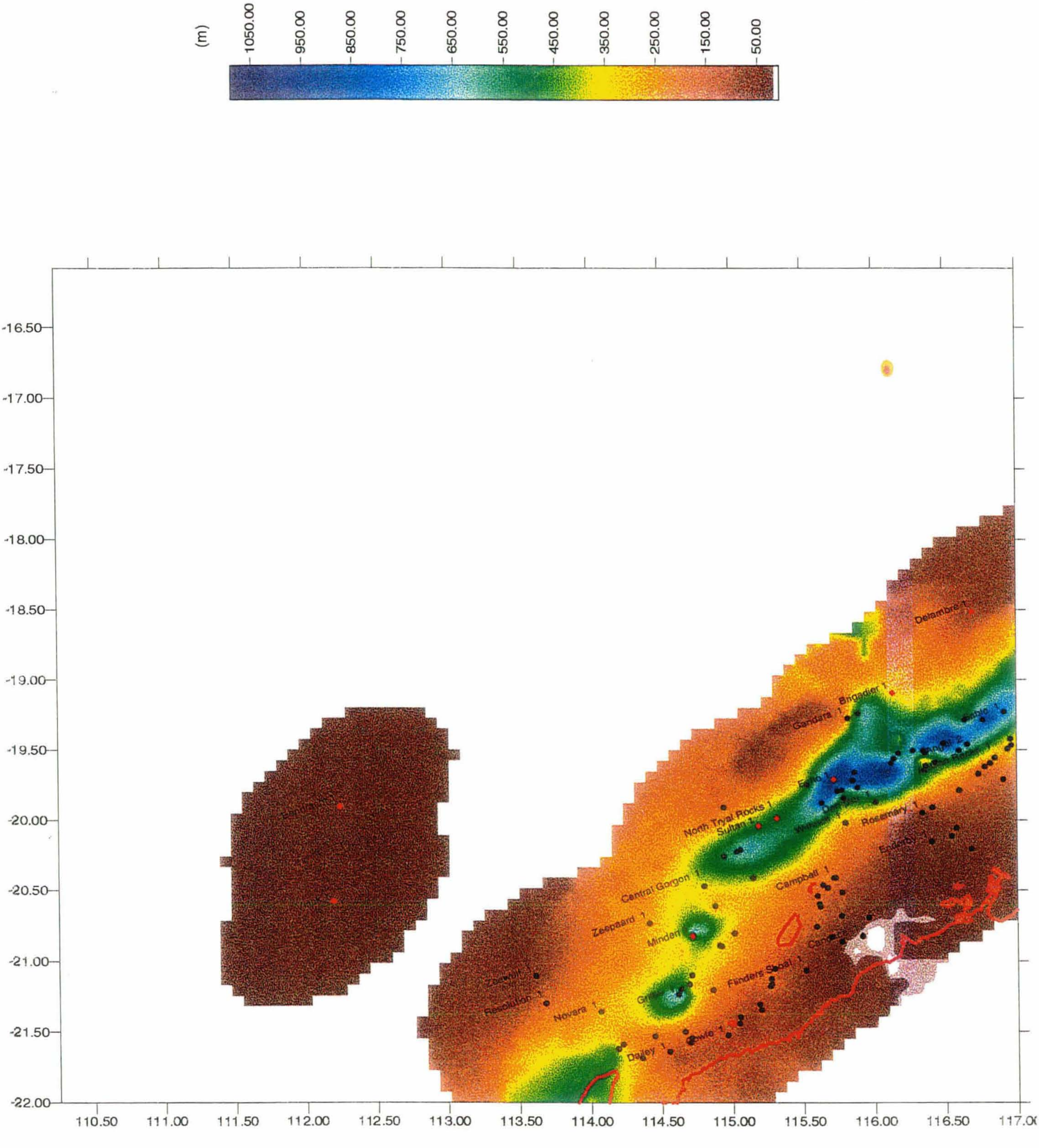


Figure 60: Time slice Cz4 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

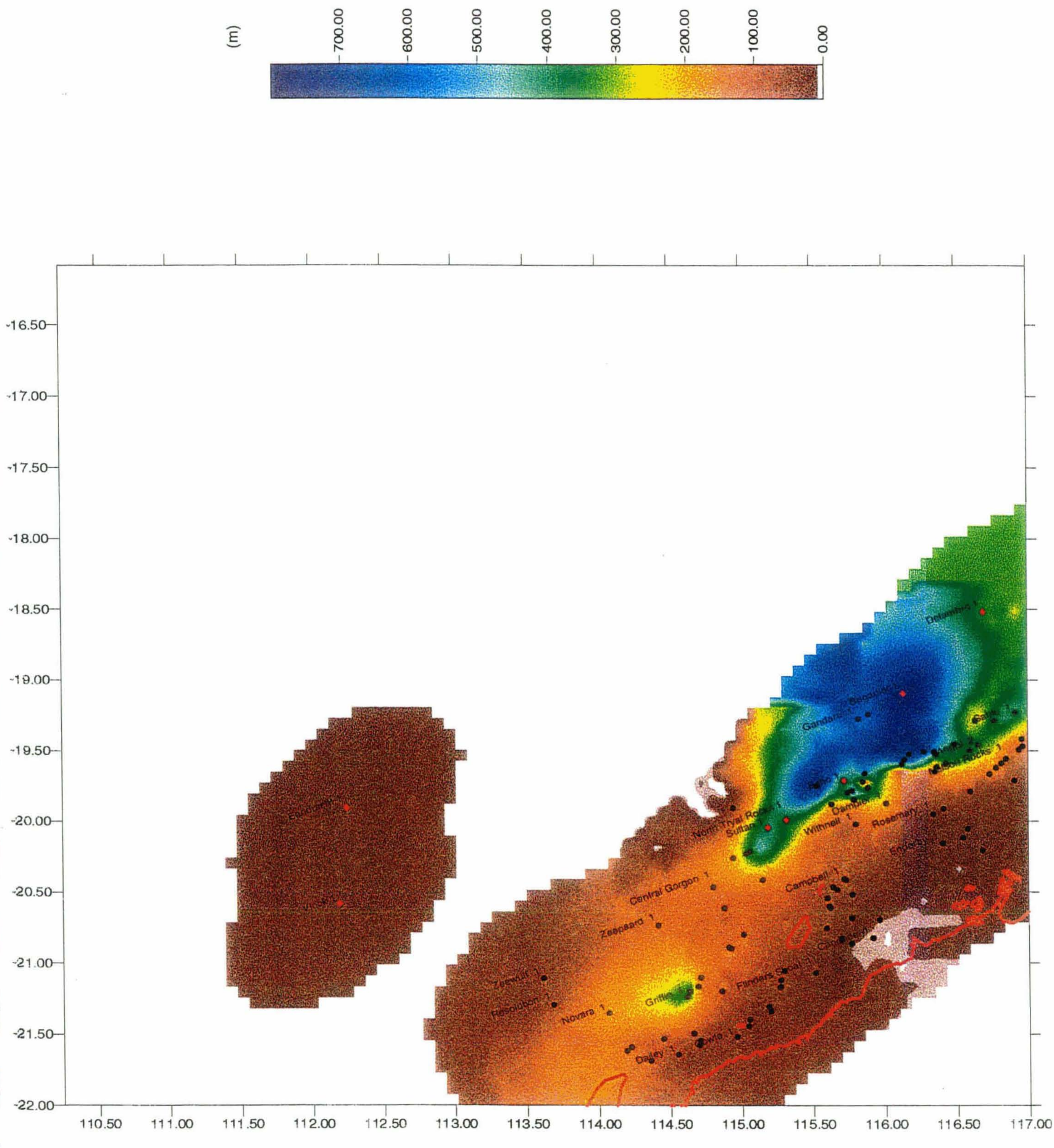


Figure 61: Time slice Cz5 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

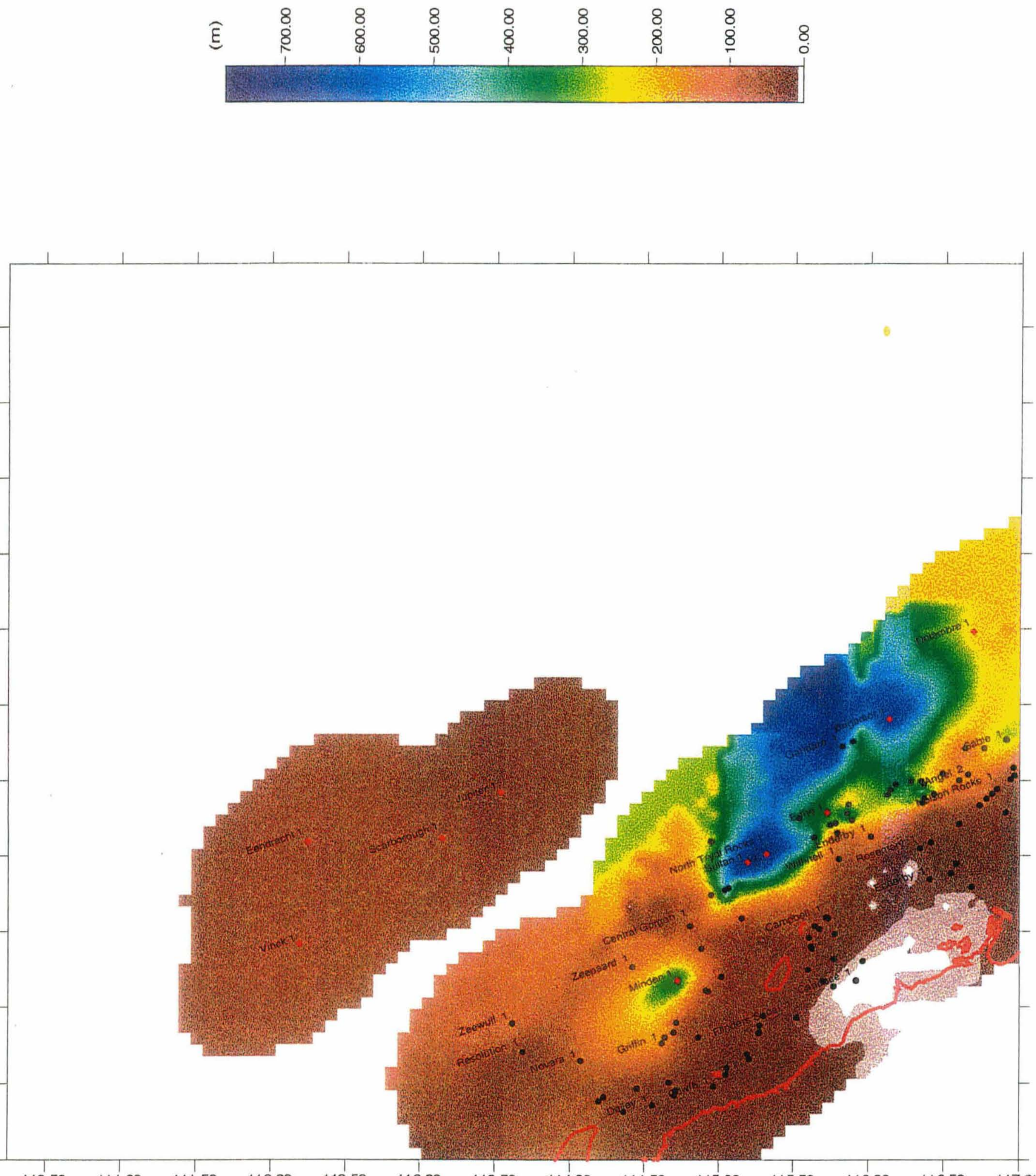


Figure 62: Time slice Cz6 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

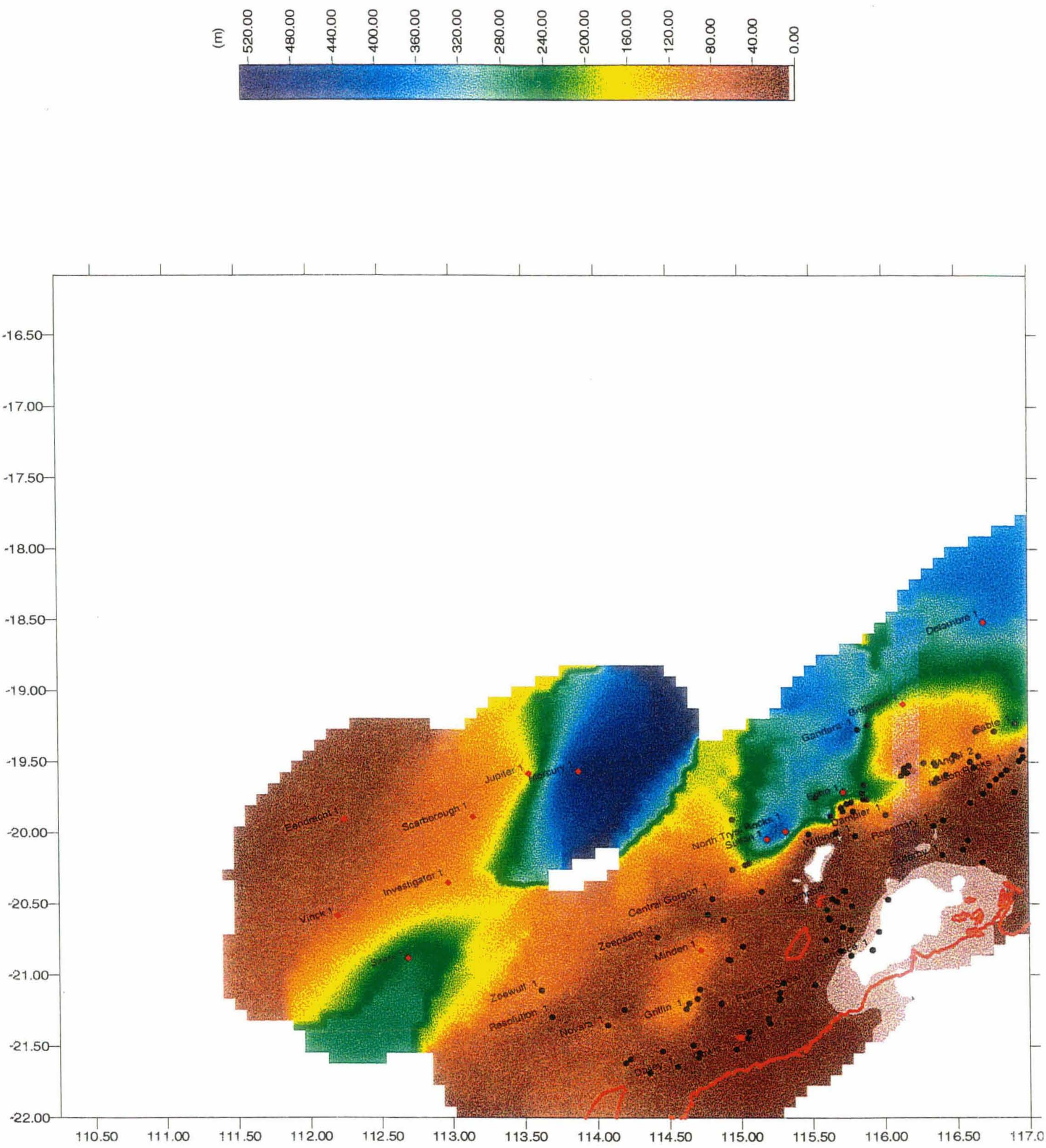


Figure 63: Time slice Cz7 isopach map based on STRATDAT well database. Module wells have red coloured well symbols.

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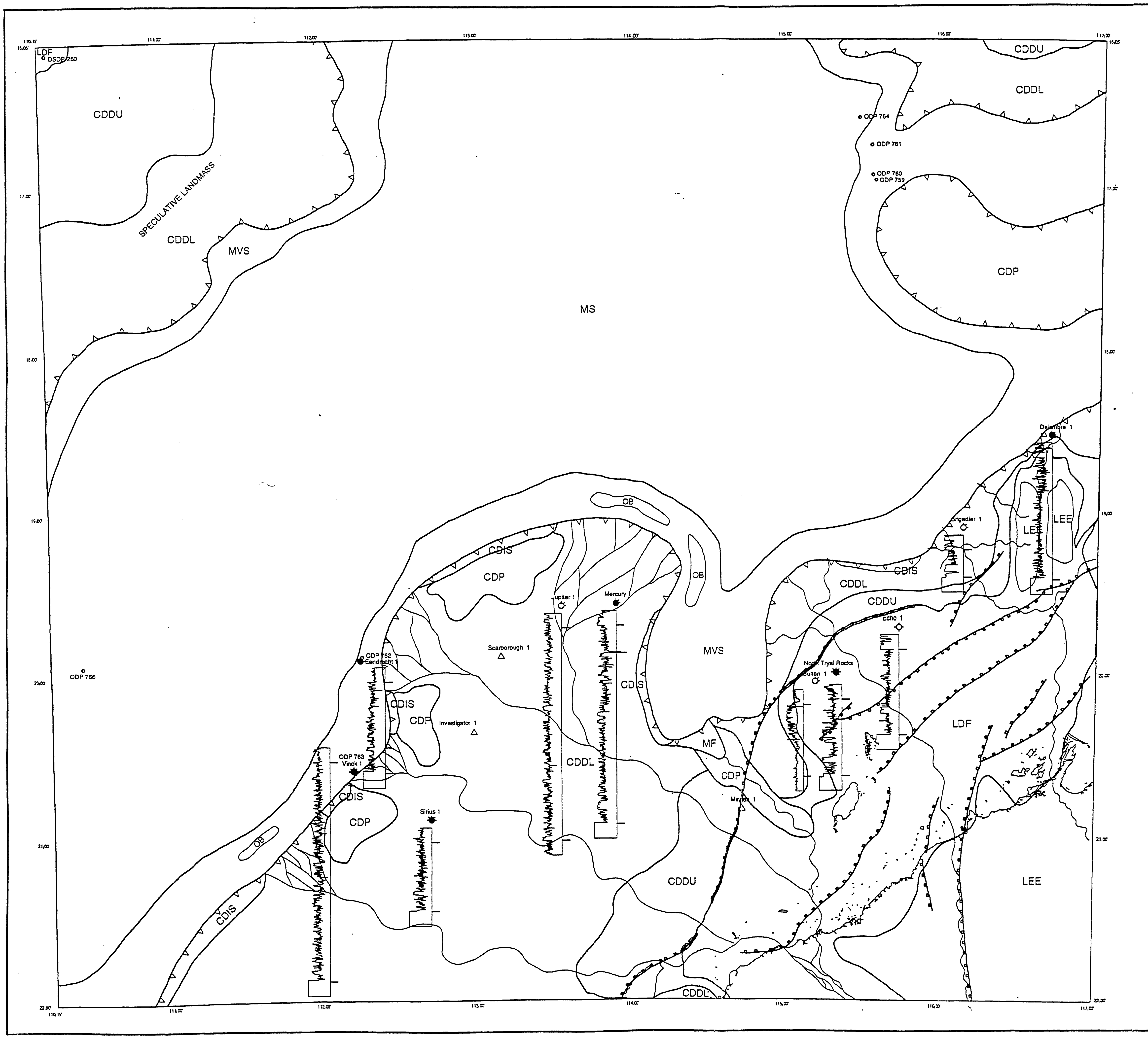
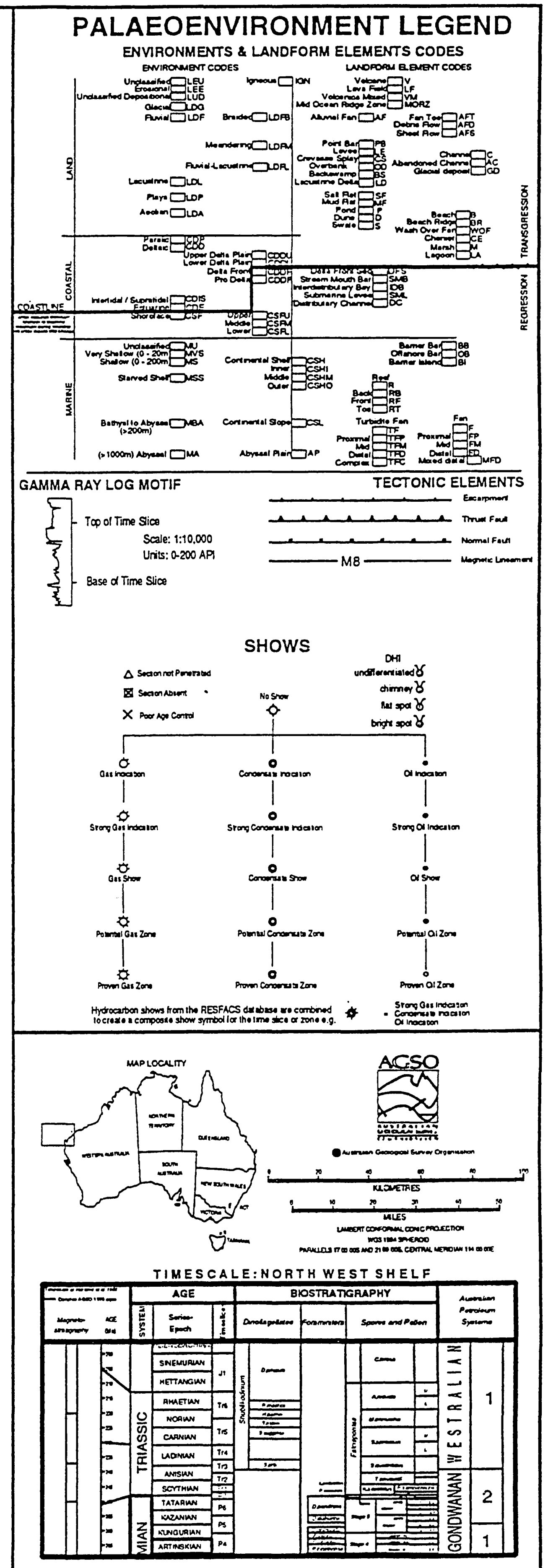


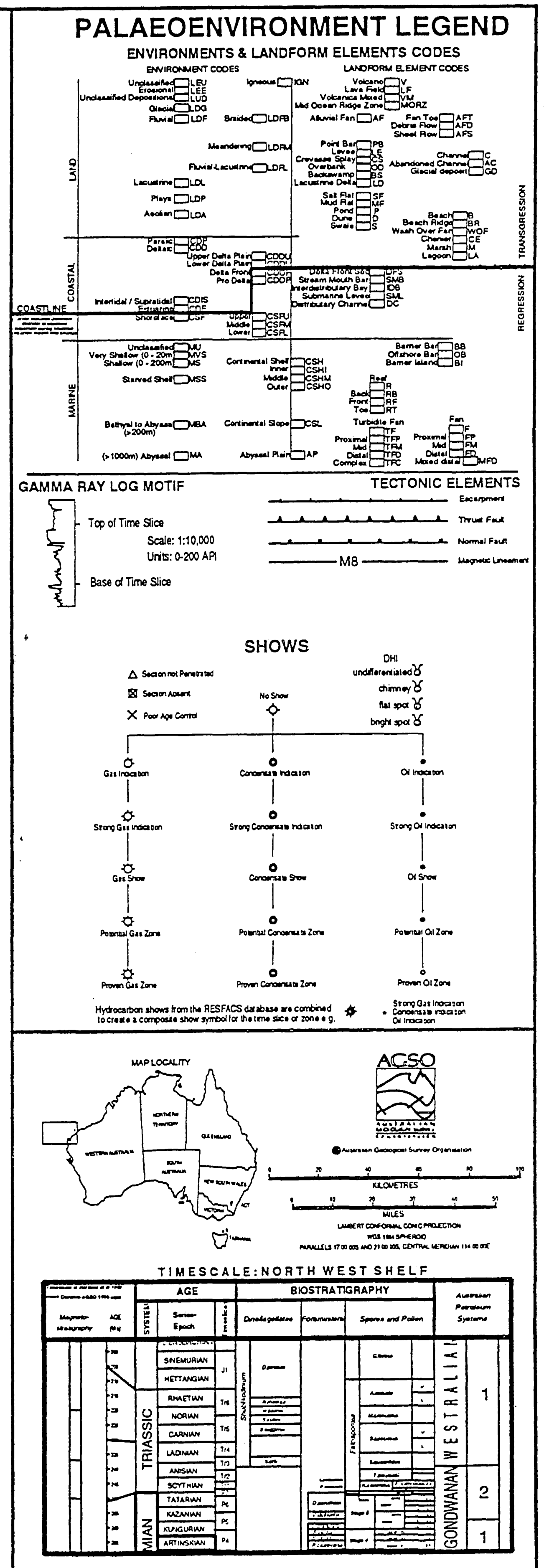


Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *Tr5*

ENCLOSURE 9

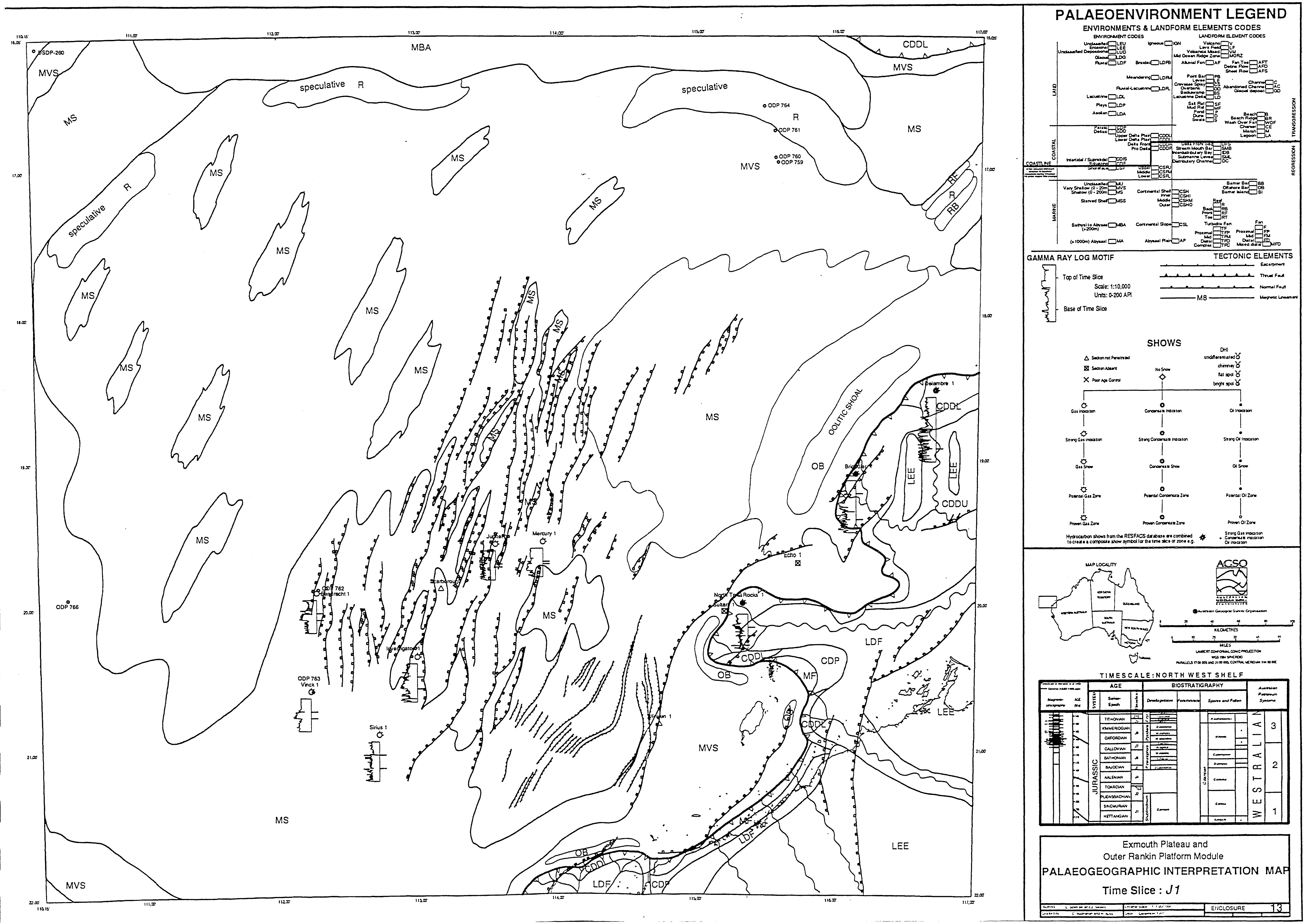


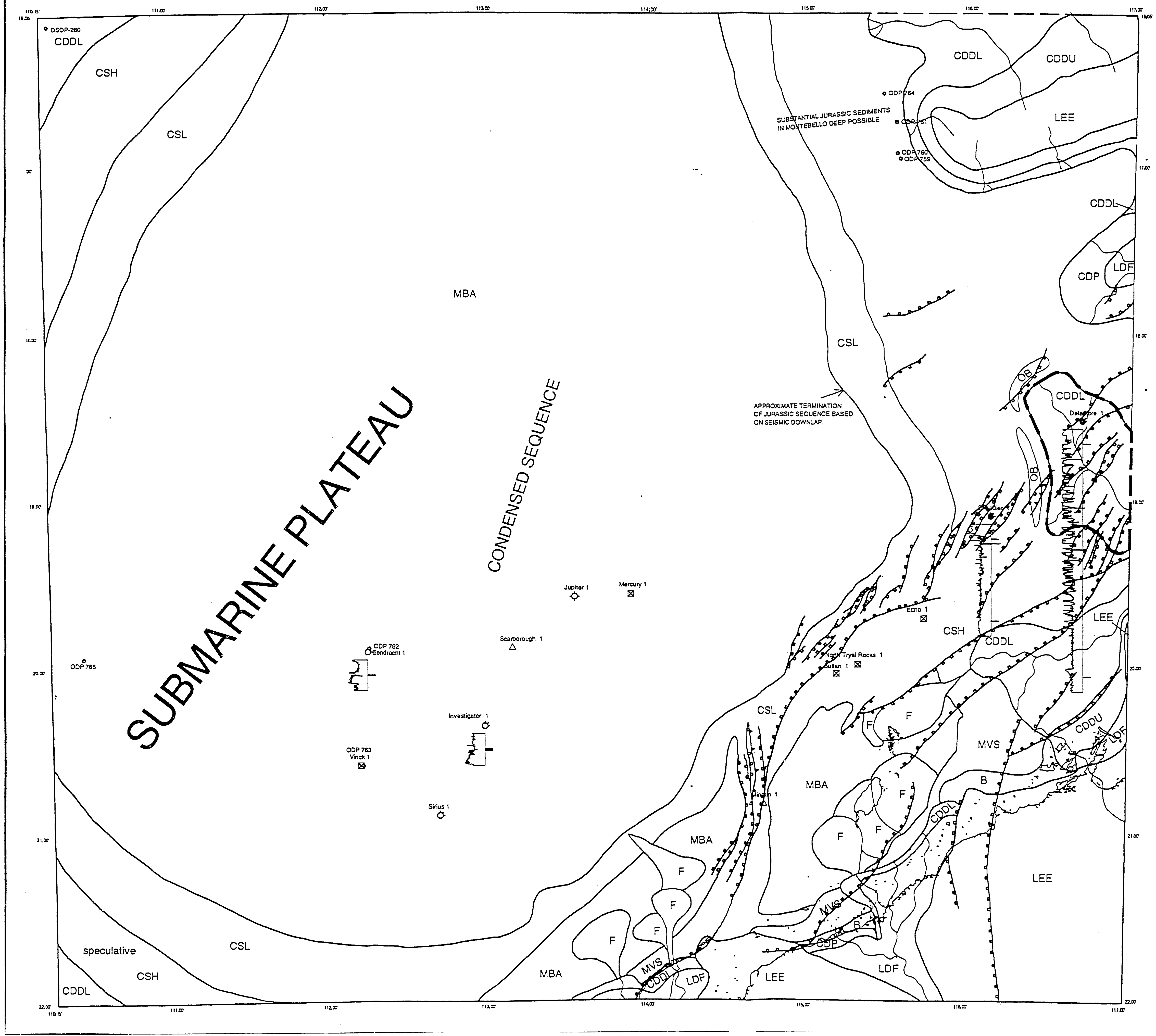
Exmouth Plateau and
Outer Rankin Platform Module

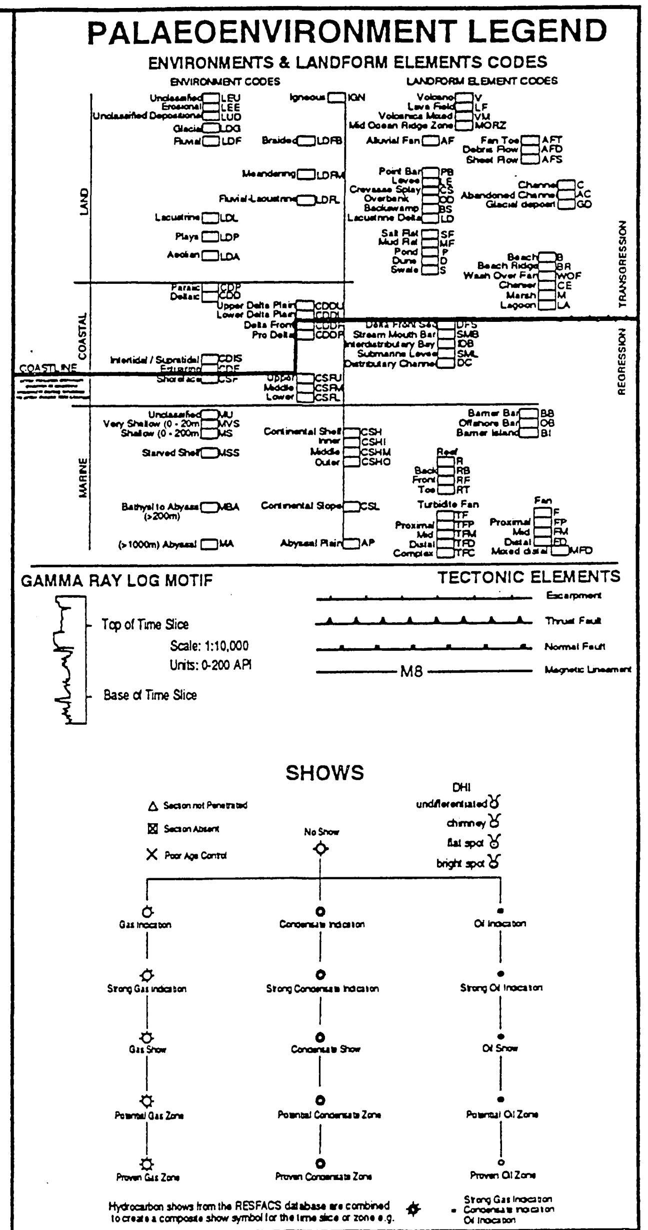
PALAEOGEOGRAPHIC INTERPRETATION MAP

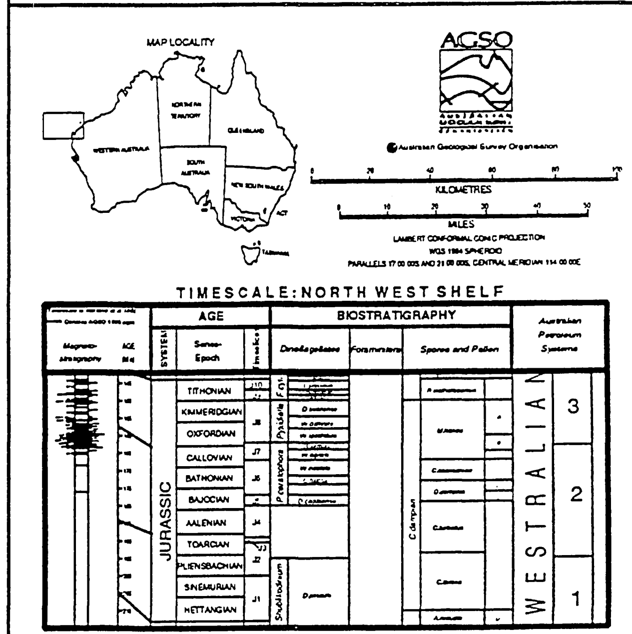
Time Slice : *Tr6*

ENCLOSURE 11


MBA
CDDL
MVS
MS
speculative R
speculative
ODP 764
ODP 761
ODP 760
ODP 759
RF
R
RB
OOLITIC SHOAL
OB
LEE
CDDU
CDP
LDF
MF
CDDL
Delambre 1
Echo 1
North Tryal Rocks 1
Mercury 1
Jupiter 1
Scarborough
ODP 762
Eendracht 1
Investigator 1
ODP 763
Vinck 1
Sirius 1
ODP 766
DSDP-260
PALAEOENVIRONMENT LEGEND
ENVIRONMENTS & LANDFORM ELEMENTS CODES
GAMMA RAY LOG MOTIF
TECTONIC ELEMENTS
SHOWS
TIMESCALE: NORTH WEST SHELF
Exmouth Plateau and
Outer Rankin Platform Module
PALAEOGEOGRAPHIC INTERPRETATION MAP
Time Slice : J1
ENCLOSURE 13





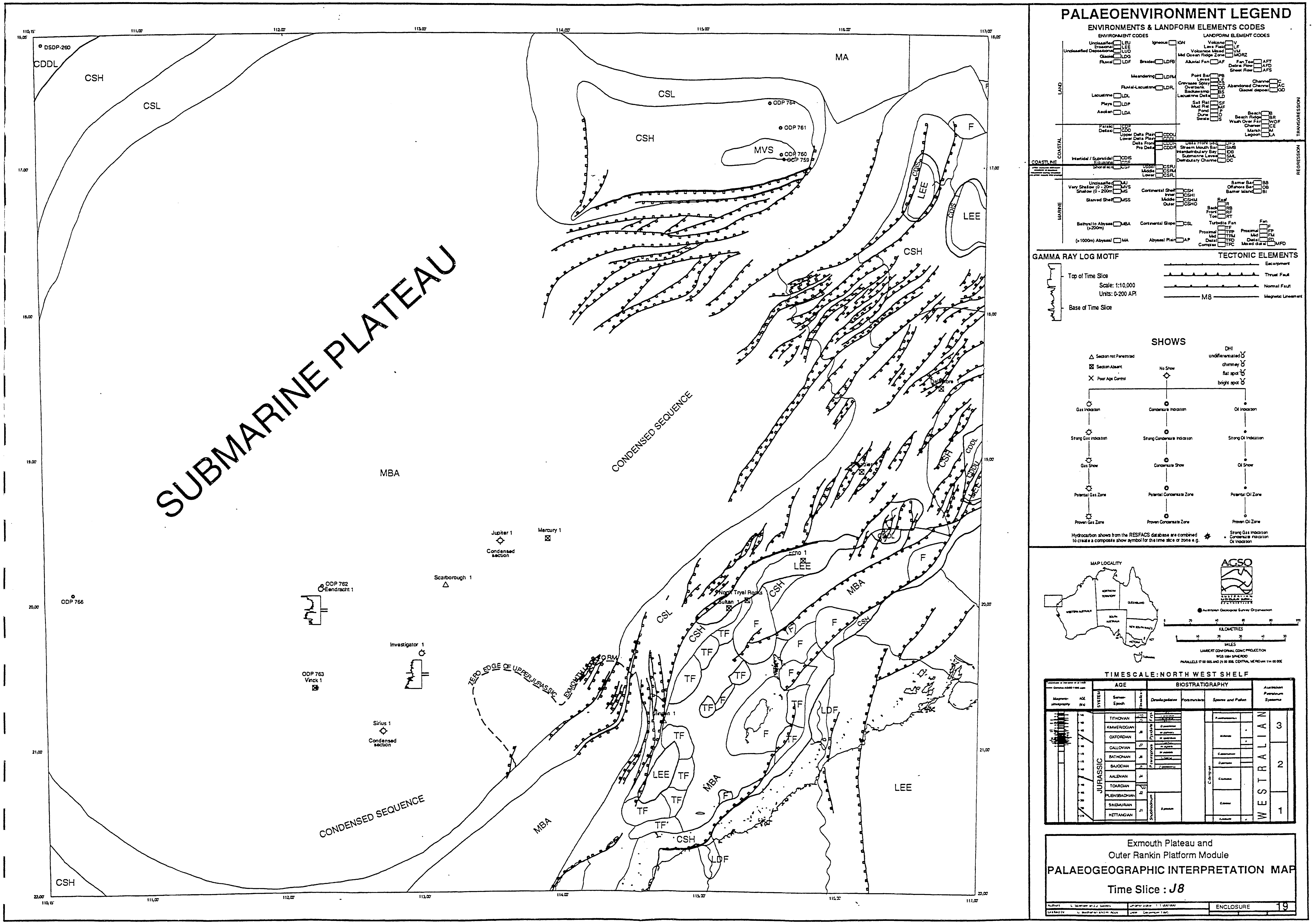


Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *J3-6*

ENCLOSURE 16



Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *J8*

ENCLOSURE 19

PALAEOENVIRONMENT LEGEND

ENVIRONMENTS & LANDFORM ELEMENTS CODES

ENVIRONMENT CODES — LANDFORM ELEMENT CODES

LAND — COASTAL — MARINE — TRANSGRESSION — REGRESSION

GAMMA RAY LOG MOTIF

Top of Time Slice
Scale: 1:10,000
Units: 0-200 API
Base of Time Slice

TECTONIC ELEMENTS

Escarpment
Thrust Fault
Normal Fault
M8 Magnetic Lineament

SHOWS

Gas Indication — Condensate Indication — Oil Indication
Strong Gas Indication — Strong Condensate Indication — Strong Oil Indication
Gas Show — Condensate Show — Oil Show
Potential Gas Zone — Potential Condensate Zone — Potential Oil Zone
Proven Gas Zone — Proven Condensate Zone — Proven Oil Zone

MAP LOCALITY

ACSO

Australian Geological Survey Organisation

KILOMETRES

MILES

LAMBERT CONFORMAL CONIC PROJECTION

TIMESCALE: NORTH WEST SHELF

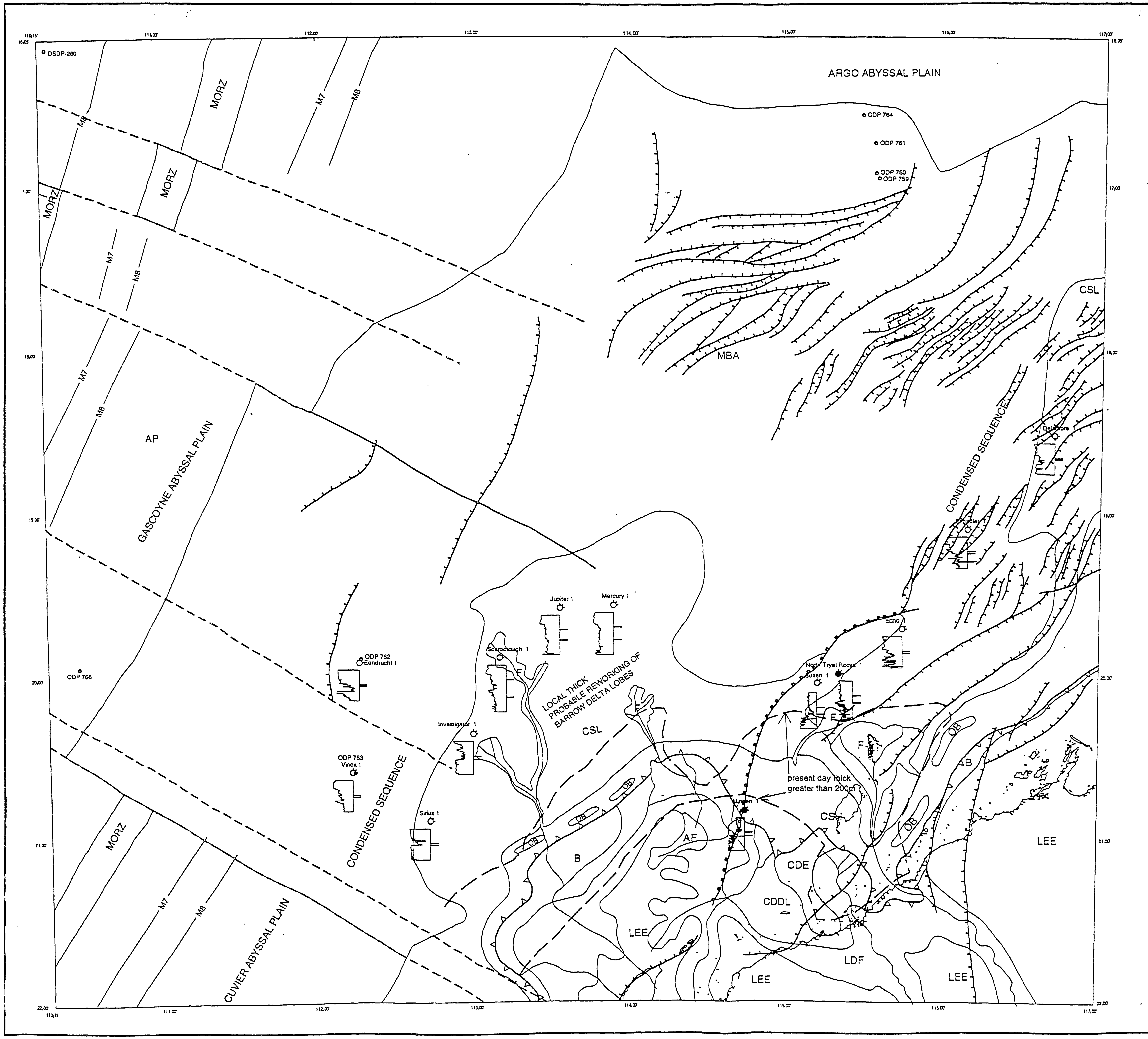
AGE	BIOSTRATIGRAPHY	Australian Petroleum Systems
APTIAN		
BARREMIAN		
HAUTERIVIAN		
VALANGINIAN		
BERRIASIAN		
TITHONIAN		
KIMMERIDGIAN		
OXFORDIAN		
CALLOVIAN		
BATHONIAN		

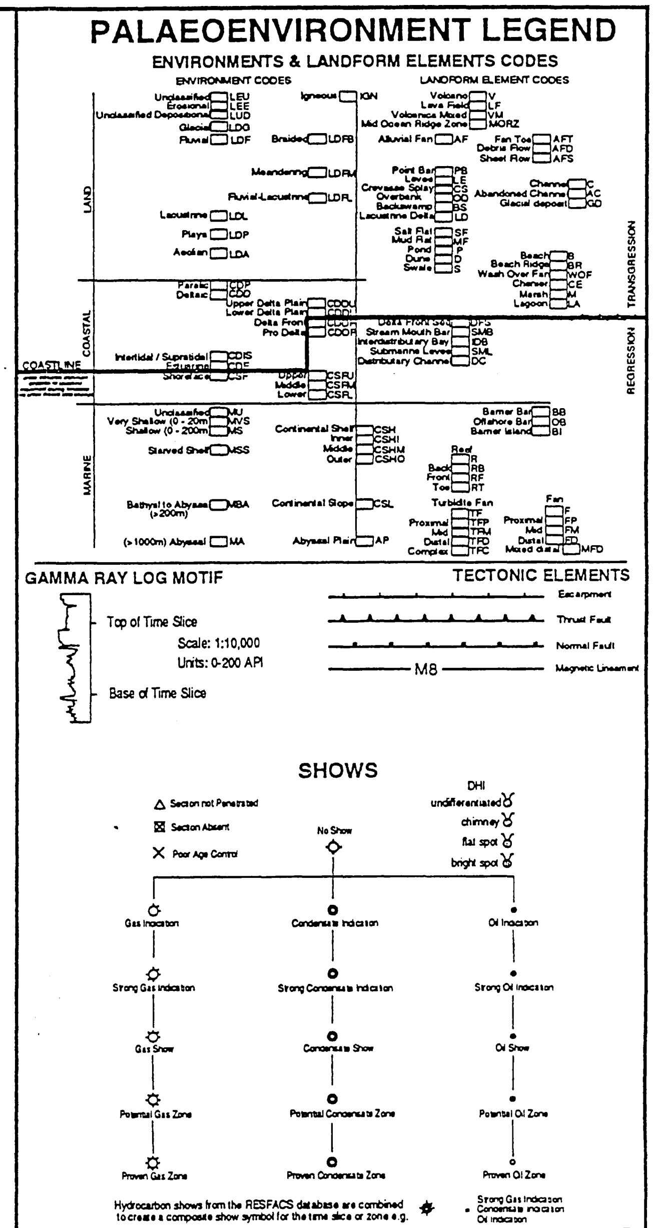
Exmouth Plateau and
Outer Rankin Platform Module

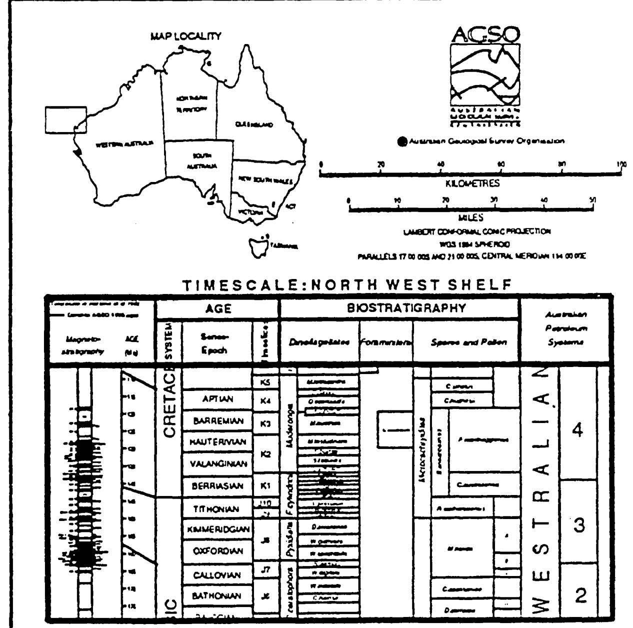
PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *K1*

ENCLOSURE 21





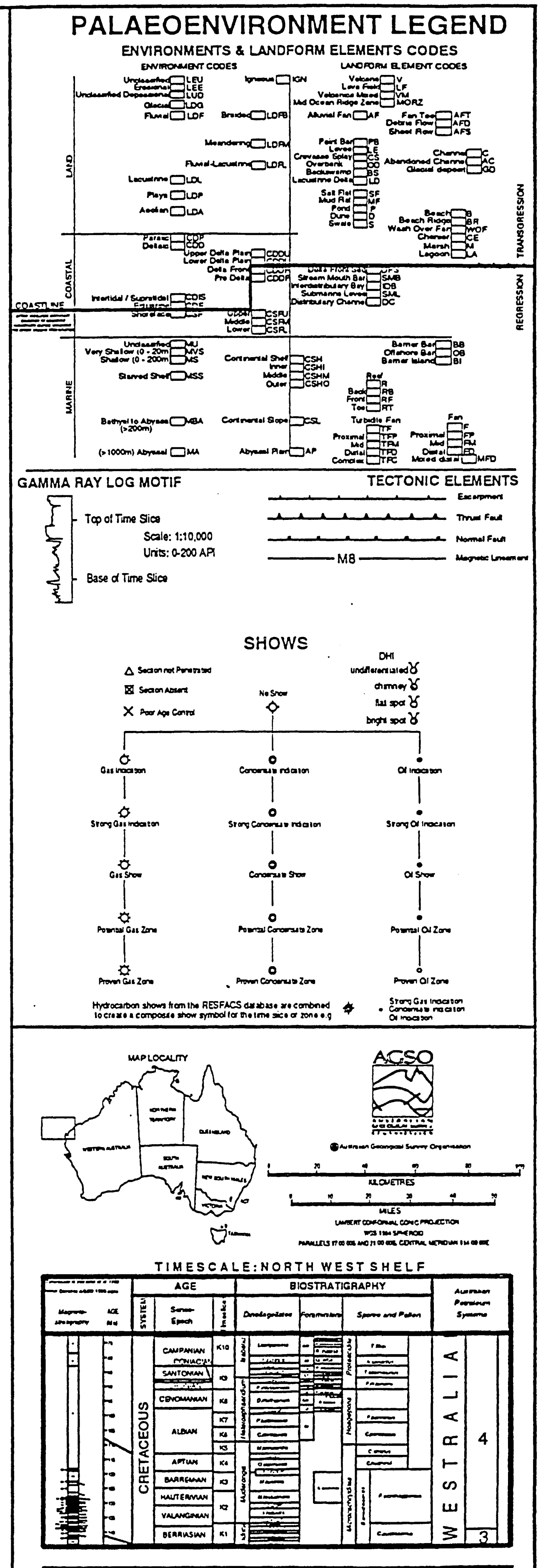


Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *K2*

ENCLOSURE 23

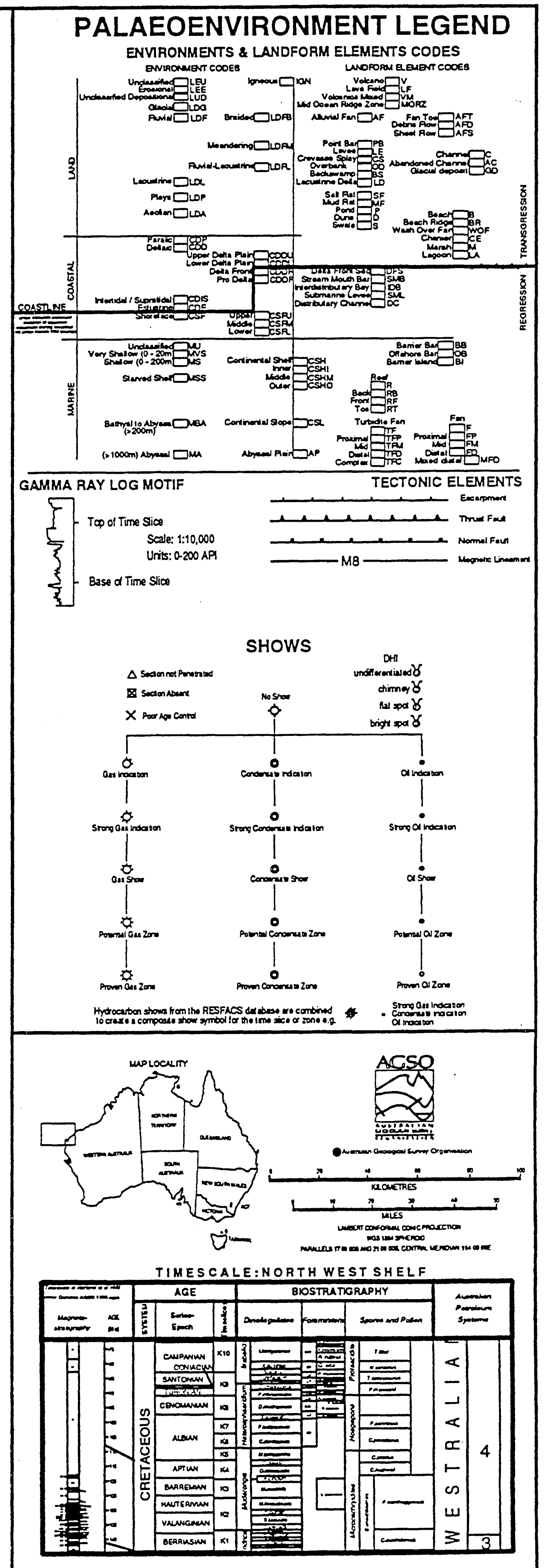


Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *K3*

ENCLOSURE 25

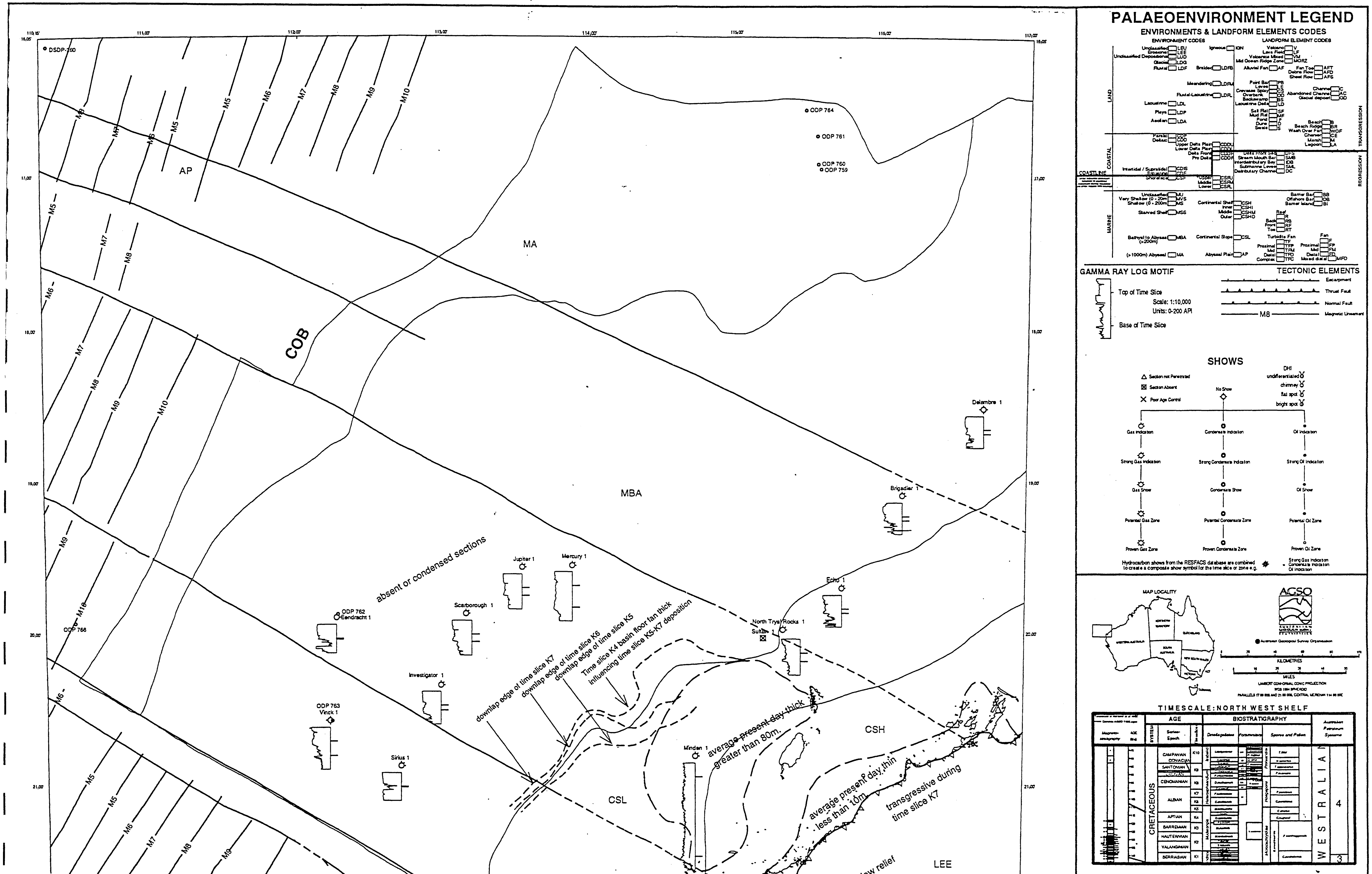


Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *K4*

ENCLOSURE 27

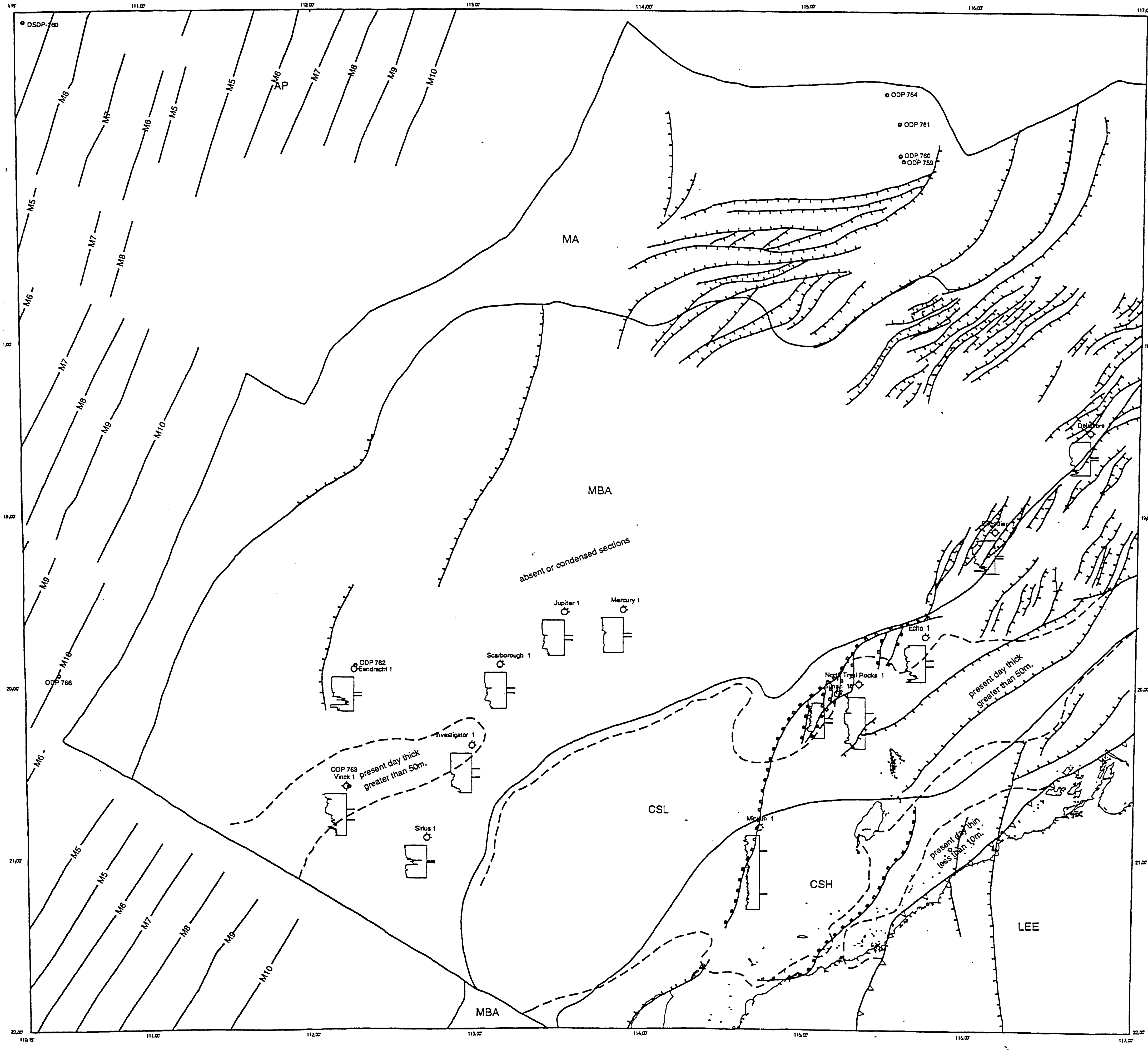


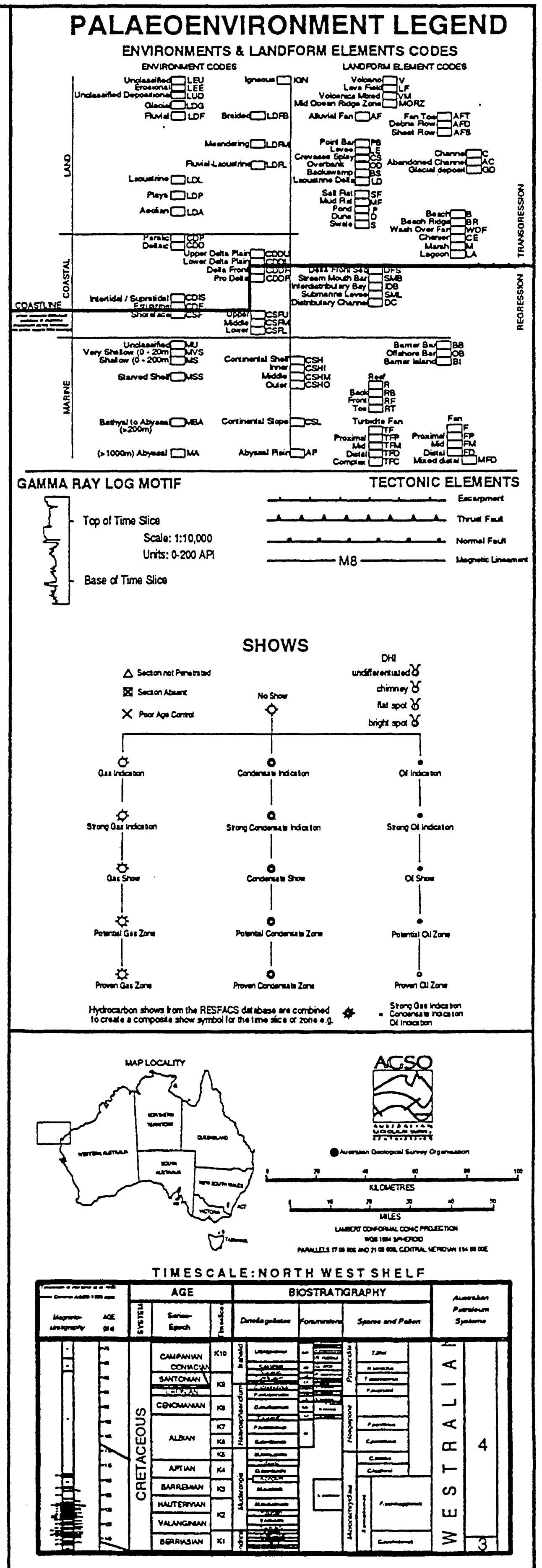
Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *K5-7*

ENCLOSURE 29



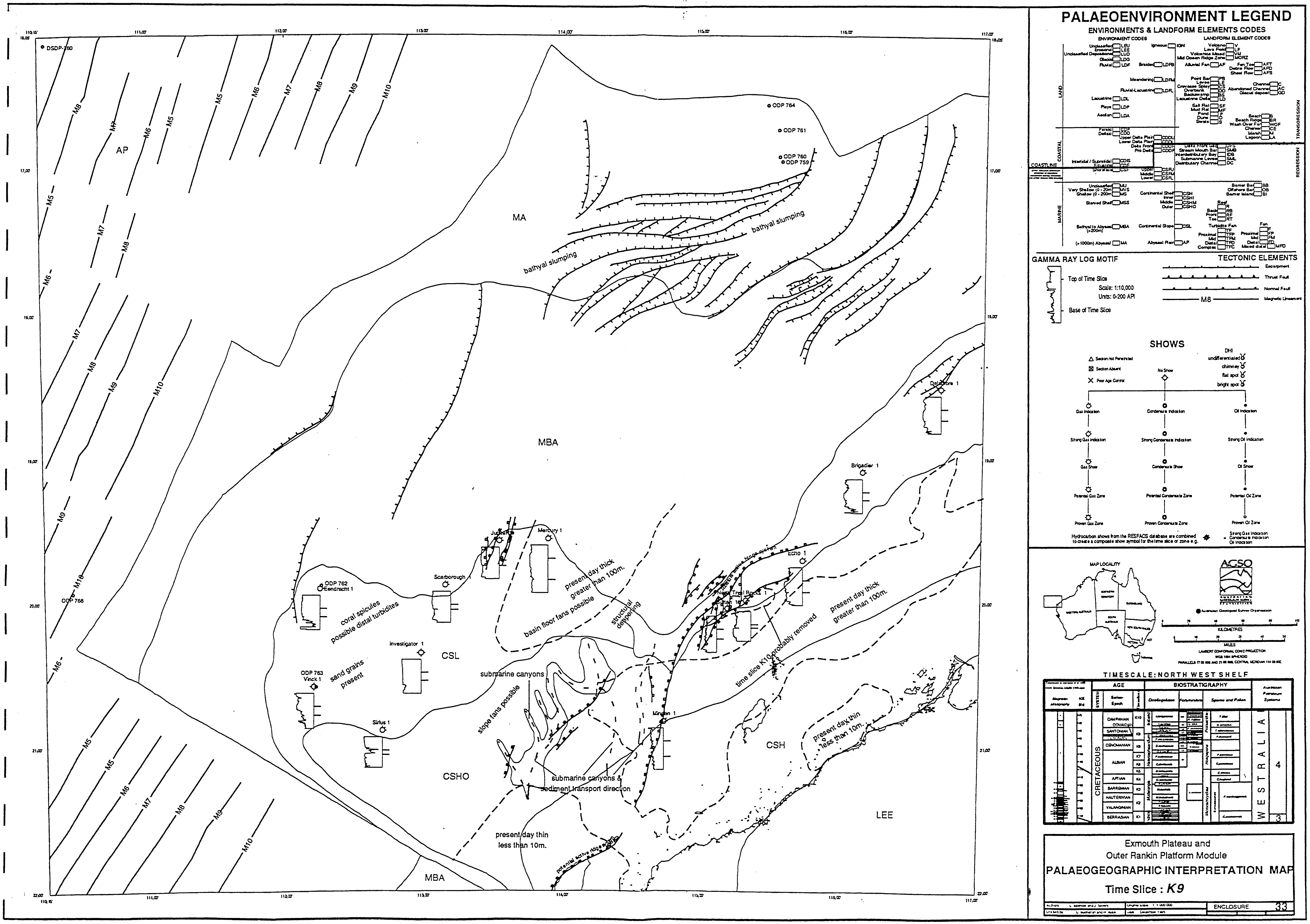


Exmouth Plateau and
Outer Rankin Platform Module

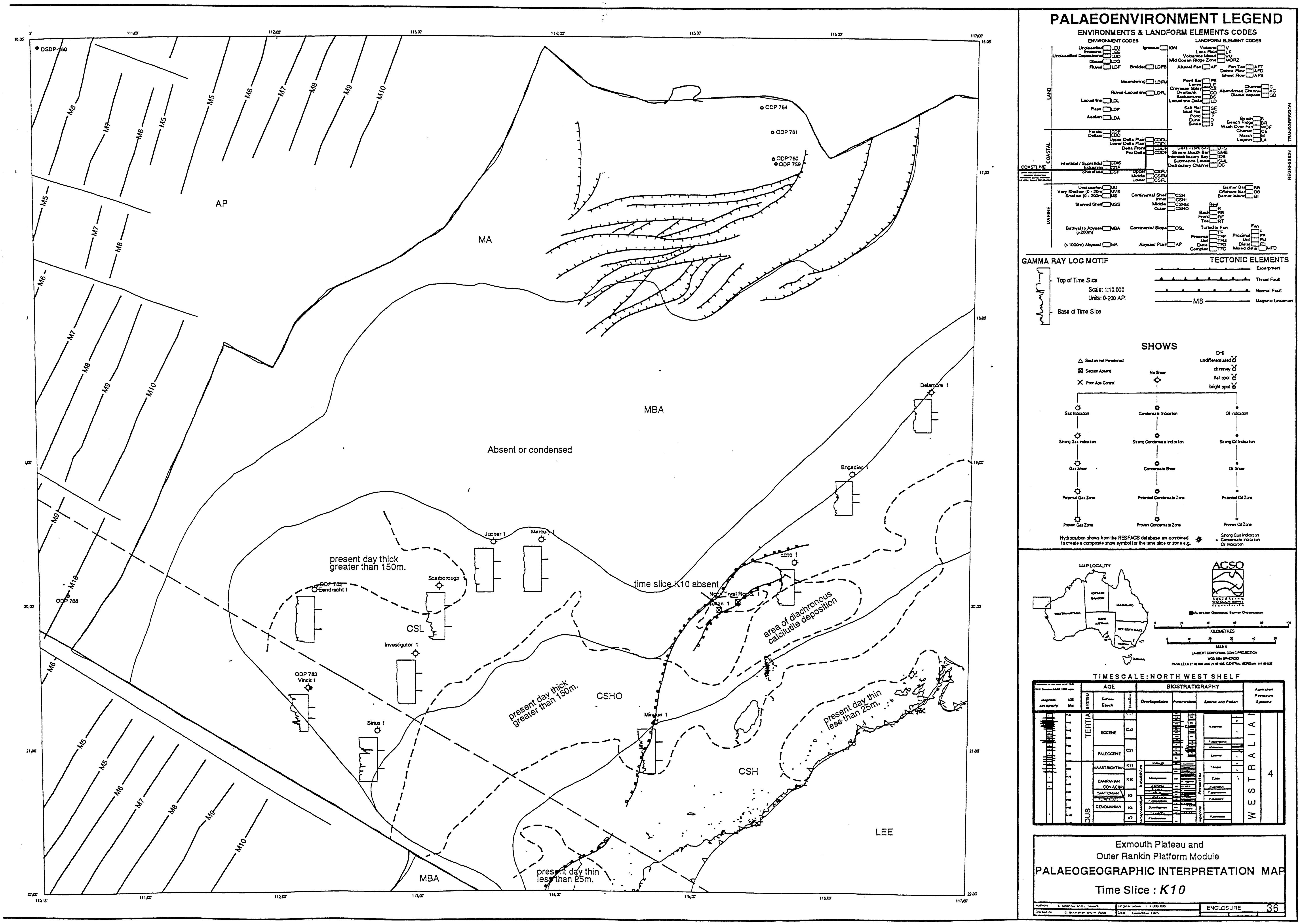
PALAEOGEOGRAPHIC INTERPRETATION MAP

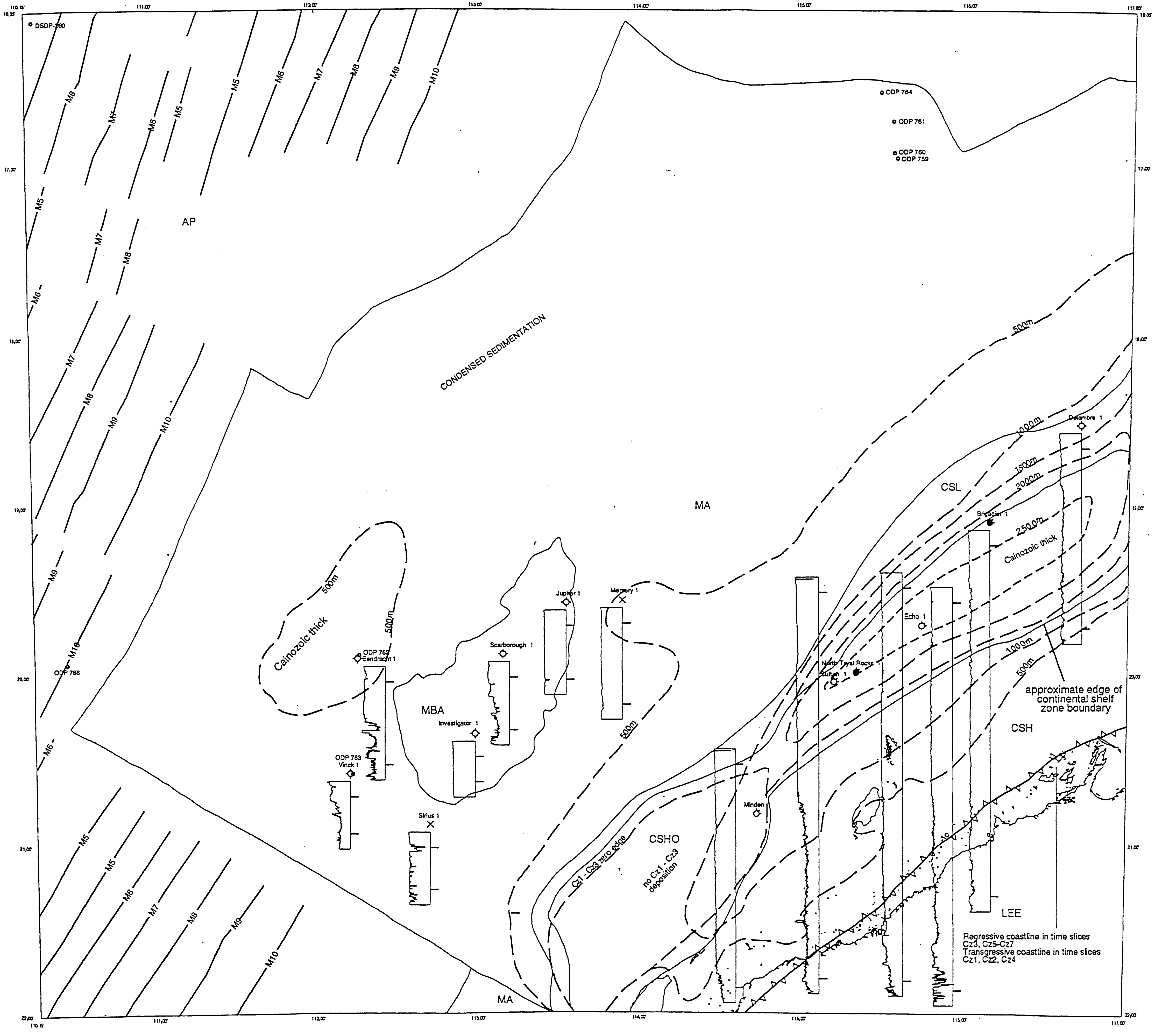
Time Slice : *K8*

ENCLOSURE 31



PALAEOENVIRONMENT LEGEND
ENVIRONMENTS & LANDFORM ELEMENTS CODES
GAMMA RAY LOG MOTIF
Top of Time Slice
Scale: 1:10,000
Units: 0-200 API
Base of Time Slice
TECTONIC ELEMENTS
SHOWS
TIMESCALE: NORTH WEST SHELF
AGE
BIOSTRATIGRAPHY
CRETACEOUS
WESTRALIA
Exmouth Plateau and
Outer Rankin Platform Module
PALAEOGEOGRAPHIC INTERPRETATION MAP
Time Slice : K9
ENCLOSURE
33
AP
MA
MBA
CSL
CSHO
CSH
LEE
bathyal slumping
coral spicules possible distal turbidites
sand grains present
present day thick greater than 100m.
basin floor fans possible
structural deepening
submarine canyons
slope fans possible
submarine canyons & sediment transport direction
time slice K10 probably removed
present day thin less than 10m.
potential active ridge
DSDP-260
ODP 764
ODP 761
ODP 760
ODP 759
ODP 762
Eendracht 1
ODP 766
ODP 763
Vinck 1
Scarborough 1
Investigator 1
Sirius 1
Jupiter 1
Mercury 1
Echo 1
Brigadier 1
Delambre 1
Mindon 1


PALAEOENVIRONMENT LEGEND
ENVIRONMENTS & LANDFORM ELEMENTS CODES
GAMMA RAY LOG MOTIF
Top of Time Slice
Scale: 1:10,000
Units: 0-200 API
Base of Time Slice
TECTONIC ELEMENTS
SHOWS
TIMESCALE: NORTH WEST SHELF
AP
MA
MBA
Absent or condensed
present day thick greater than 150m.
CSL
time slice K10 absent
area of diachronous calcilutite deposition
present day thick greater than 150m.
CSHO
CSH
present day thin less than 25m.
LEE
MBA
present day thin less than 25m.
DSDP-760
ODP 764
ODP 761
ODP760
ODP 759
Delambre 1
Brigadier 1
Jupiter 1
Mercury 1
Scarborough
Echo 1
North Tryal Rocks 1
Investigator 1
ODP 763
Vinck 1
Sirius 1
Minden 1
ODP 766
M5
M6
M7
M8
M9
M10
Exmouth Plateau and
Outer Rankin Platform Module
PALAEOGEOGRAPHIC INTERPRETATION MAP
Time Slice : K10
ENCLOSURE 36



PALAEOENVIRONMENT LEGEND

ENVIRONMENTS & LANDFORM ELEMENTS CODES

ENVIRONMENT CODES / LANDFORM ELEMENT CODES

LAND: Unclassified LEU; Erosional LEE; Undifferentiated Depositional LUD; Glacial LDG; Fluvial LDF; Braided LDFB; Meandering LDFM; Fluvial-Lacustrine LDFL; Lacustrine LDL; Playa LDP; Aeolian LDA; Igneous ION

Volcano V; Lava Field LF; Volcanics Mixed VM; Mid Ocean Ridge Zone MORZ; Alluvial Fan AF; Fan Toe AFT; Debris Flow AFD; Sheet Flow AFS; Point Bar PB; Levee LE; Crevasse Splay CS; Overbank OB; Backswamp BS; Lacustrine Delta LD; Channel C; Abandoned Channel AC; Glacial deposit GD; Salt Flat SF; Mud Flat MF; Pond P; Dune D; Swale S; Beach B; Beach Ridge BR; Wash Over Fan WOF; Chenier CE; Marsh M; Lagoon LA

COASTAL: Paralic CDP; Deltaic CDD; Upper Delta Plain CDDU; Lower Delta Plain CDDL; Delta Front CDDF; Pro Delta CDDP; Delta Front Sand DFS; Stream Mouth Bar SMB; Interdistributary Bay IDB; Submarine Levee SML; Distributary Channel DC; Intertidal / Supratidal CDIS; Estuarine CDE; Shoreface CSF; Upper CSFU; Middle CSFM; Lower CSFL

MARINE: Unclassified MU; Very Shallow (0 - 20m) MVS; Shallow (0 - 200m) MS; Starved Shelf MSS; Continental Shelf CSH; Inner CSHI; Middle CSHM; Outer CSHO; Barrier Bar BB; Offshore Bar OB; Barrier Island BI; Reef R; Back RB; Front RF; Toe RT; Bathyal to Abyssal (>200m) MBA; Continental Slope CSL; Turbidite Fan TF; Proximal TFP; Mid TFM; Distal TFD; Complex TFC; Fan F; Proximal FP; Mid FM; Distal FD; Mixed distal MFD; (>1000m) Abyssal MA; Abyssal Plain AP

TRANSGRESSION / REGRESSION

GAMMA RAY LOG MOTIF

Top of Time Slice
Scale: 1:10,000
Units: 0-200 API
Base of Time Slice

TECTONIC ELEMENTS

Escarpment
Thrust Fault
Normal Fault
M8 Magnetic Lineament

SHOWS

Section not Penetrated
Section Absent
Poor Age Control
No Show

DHI: undifferentiated, chimney, flat spot, bright spot

Gas Indication — Condensate Indication — Oil Indication
Strong Gas Indication — Strong Condensate Indication — Strong Oil Indication
Gas Show — Condensate Show — Oil Show
Potential Gas Zone — Potential Condensate Zone — Potential Oil Zone
Proven Gas Zone — Proven Condensate Zone — Proven Oil Zone

Hydrocarbon shows from the RESFACS database are combined to create a composite show symbol for the time slice or zone e.g. Strong Gas Indication, Condensate Indication, Oil Indication

MAP LOCALITY

ACSO — Australian Geological Survey Organisation

KILOMETRES / MILES

LAMBERT CONFORMAL CONIC PROJECTION

TIMESCALE: NORTH WEST SHELF

AGE		BIOSTRATIGRAPHY			Australian Petroleum Systems
TERTIARY	PLIOCENE Cz6				WESTRALIAN 4
	MIOCENE Cz5, Cz4				
	OLIGOCENE Cz3				
	EOCENE Cz2				
	PALEOCENE Cz1				
	MAASTRICHTIAN K11				

Exmouth Plateau and
Outer Rankin Platform Module

PALAEOGEOGRAPHIC INTERPRETATION MAP

Time Slice : *Cz1-7*

ENCLOSURE 42