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GEOLOGICAL CROSS-SECTION ACROSS THE WESTERN TIMOR SEA, BONAPARTE BASIN

JOHN BRADSHAW

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

ONSHORE SEDIMENTARY &
PETROLEUM GEOLOGY

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JOHN BRADSHAW

Bureau of Mineral Resources, Geology and Geophysics &
Australian Petroleum Industry Research Association

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SUMMARY

The western Timor Sea area of the Bonaparte Basin comprises up to 13 km of Permo-Carboniferous to recent sediment (Westralian Superbasin) and up to 5 km of sediment older than Permo-Carboniferous (proposed new name - Roebuck Superbasin). It is an area of proven hydrocarbon reserves (> 130 Mill Bbl - Jabiru/Challis/Cassini), with hydrocarbon shows occurring throughout the section from the Permian to the Cainozoic. Existing fields are reservoired in Triassic and Jurassic sands that have excellent porosity and permeability characteristics overlain by a regional seal of Cretaceous claystone. Reservoir potential also exists in both the Permian and Cainozoic. Seismic resolution in the area of the Jabiru Terrace is poor between the Cretaceous and the Permian, making structural interpretation of the data and accurate prospect delineation exceedingly difficult. Considerable differences exist between the interpretation of the regional tectonics and structural style of the region, which is partly due to different analyses of the Deep Sea Drilling and Ocean Drilling Project results. DSDP 261 and ODP 765 encountered sediments above oceanic crust of late Kimmeridgian to early Tithonian and Late Berriasian to Valanginian ages respectively. The "mid-Valanginian" event is examined in detail and is not believed to represent a period of widespread uplift and erosion in this region, as has been previously stated. Numerous new plays remain to be adequately tested in the area, including thick upper Jurassic sands, Cainozoic carbonates, and deep tests of the Permian along the Jabiru Terrace.

INTRODUCTION

DATA SET

WHIMBREL 1 (ARCO, 1974)
OSPREY 1 (ARCO, 1972)
CHALLIS 1 (BHP PETROLEUM, 1984)
RAINIER 1 (BHP PETROLEUM, 1988)
JABIRU 1A (BHP PETROLEUM, 1983)
POLLARD 1 (BHP PETROLEUM, 1984)
SAHUL SHOALS 1 (BOCAL, 1970)

WHIMBREL MARINE SEISMIC SURVEY (AMPOL EXPLORATION, 1986 - AB86A)
HJ9 MARINE SEISMIC SURVEY (BHP PETROLEUM, 1987 - HJ9)
NT/P26 SEISMIC SURVEY (CITCO AUST. PETROLEUM, 1981 - 8126)
H2683A MARINE SEISMIC (BHP PETROLEUM, 1984 - H2683A)

SCALE

The cross-section has been drawn at 1:100,000 scale with a vertical to horizontal exaggeration of 1. The total length of the line is 260 km and has a maximum depth of approximately 11 km.

HORIZONS DRAWN

A total of 11 horizons were carried on the seismic and drawn on the cross-sections (Plate 1) ;

1) Tertiary - Base Late Oligocene - base Cz4
2) Tertiary - Lower Eocene - top Cz1
3) Cretaceous - Top Maastrichtian - top K11
4) Cretaceous - Top Cenomanian - top K8
5) Jurassic - Top Tithonian - top J10
6) Triassic - Top of the Triassic section present
7) Triassic - Base Carnian - base T5
8) Triassic - near base Anisian - intra T2 reflector
9) Permian - Top Tatarian - top P7
10) Pre-late Permian - Permo-Carboniferous - Grant unconformity?
11) Pre-late Permian - Intra Palaeozoic - Devonian/Carboniferous?

TIME DEPTH PLOTS

Time/depth plots have been drawn for the seven wells (Plate 2). These plots are not burial history curves, but simply represent the palaeontological dating performed in each well, and show the precise nature of the biostratigraphic control which exists for the cross-section. The boxes drawn on the time/depth curves are the actual depth range of the palaeontological zones assigned in the well completion report.

The age dating is reliable for all wells. The dating in the older wells have been updated from reports where resampling was undertaken. The dating in the modern wells was derived from interpretation of Open File basic data (species lists and range charts). Some of the above was provided by G. Chapronier (BMR), TCPL Resources Ltd (Sydney) and from Morgan and Ingram (1988).

SEISMIC QUALITY

Modern seismic was utilised where possible along the cross-section and to tie adjacent wells. Considerable difficulties were encountered along the Jabiru Terrace in tieing from wells along strike lines (NE-SW) to the regional dip line (NW-SE) of 8126-25. In many instances using the 1981 seismic data, it was impossible to tie horizons between the Cretaceous and the Permian along the 1981 strike lines to Jabiru 1A, Challis 1, Cassini 1, and Rainier 1. More modern data was not available. As such the confidence in this interval is very poor. More modern lines were available to tie Pollard 1 and Sahul Shoals 1. On the Londonderry High the seismic is reliable down to the high amplitude Permian horizon, but the sequence beneath this interval is masked by multiples and ringing. Thus only limited interpretation was possible beneath the Permian, where "windows" into the pre-Permian occurred.

RESULTS

DATING OF HORIZONS

Pre-late Permian

At the southeastern end of Section F-G (Plate 1) an angular unconformity (late Palaeozoic) is evident beneath the late Permian sequence. The age of this unconformity may be either Permo-Carboniferous, or by analogy with the Offshore Canning (Bradshaw, 1990a) and the Petrel Sub-basin (Bradshaw, 1990b) be Devonian (?) to Carboniferous. The latter would equate it with the Base Grant Unconformity in the onshore Canning Basin (Goldstein, 1989). The late Palaeozoic unconformity surface dips to the west (basinward), but the stratal geometry of the unconformity is not apparent in that direction due to multiples masking the event. Sequences of Carboniferous and older ages probably also underlie the Vulcan Sub-basin, and Ashmore Platform.

Permian

Permian sediments were penetrated in Whimbrel 1 (100 m), Osprey 1 (340 m) and Sahul Shoals 1 (30 m). Dating of the marine section in Sahul Shoals 1 has been reviewed by Archbold (1988) which has been integrated with the dating from Morgan and Ingram (1988). Only the latest Permian is penetrated (time slices P6 and P7 - Kazanian and Tatarian) in these wells, but at least 4 km of sediment occurs beneath the latest Permian and above the late Palaeozoic unconformity in this region. This thickness is similar to that which occurs in the Permian and Carboniferous in the Petrel Sub-basin in a similar basin location (Bradshaw, 1990b - Plate 1 section H-I).

Triassic

Triassic sediments occur in all seven wells, comprising time slices T1 to T5 (Scythian to Carnian). Possible time slice T6 sediments occur in Jabiru 1A, although by comparison with Rainier 1, where better dating control exists, the undated section in Jabiru 1A is most likely Jurassic in age.

Jurassic

Jurassic sediments only occur in Rainier 1 (260 m) and Jabiru 1A (≈50 m) wells, comprising time slices J1 to J4 (Hettangian to Aalenian) and J8 to J10 (Oxfordian to Tithonian). The age control in the lower Jurassic in Jabiru 1A is poor. On the cross-section, a considerable thickness of Jurassic occurs down dip from the Jabiru Terrace within the Cartier Trough, but probably represents different facies to that which occurs in Rainier 1. MacDaniel (1988) infers that a thin upper Jurassic interval (timeslice J8) occurs in Jabiru 1A wedged between two unconformities (MacDaniel (1988) - W. Spectabilis sand 1590 - 1605 m Fig. 9) but is not delineated on the current dating (Plate

2). Presumably this upper Jurassic unit has been derived from log correlation and age control in nearby appraisal wells on the Jabiru field.

Cretaceous

Cretaceous sediments occur in all seven wells, comprising time slices K1 to K11 (Berriasian to Maastrichtian). The upper part of the Cretaceous (K8 to K11) is extremely poorly constrained in Jabiru 1A and Rainier 1. The lower part of the Cretaceous is absent from Sahul Shoals 1 (K4 to K1) and Pollard 1 (K8 to K1) where the sequence is comparatively thin.

Cainozoic

Cainozoic sediments occur in all seven wells, comprising time slices Cz1 to Cz7 (Palaeocene to Quaternary). There is no dating for Jabiru 1A or Rainier 1, whilst the upper part of the Cainozoic is poorly constrained in Challis 1. The Oligocene unconformity is well defined by dating in Sahul Shoals 1 and Pollard 1, but poorly constrained in the other wells where its position has been inferred from logs and seismic.

TIME AND FACIES DIAGRAMS

Time and facies correlation diagrams were drawn by extrapolating the time/depth plots for each well to produce time space, time slice correlation and time slice - facies diagrams (Plate 2). All three diagrams essentially portray similar data, except that the time space diagram is plotted against time and the time slice correlation and time slice facies diagrams are plotted against depths using the base of the Cretaceous as a datum. The reliability of the extrapolations can be directly assessed by examining the data points on the time depth plots of each well.

Time Space

This diagram shows the regional breaks in deposition (unconformities and unrecognised condensed intervals) evident from the well data along the cross-section. They include;

Late Triassic (Rhaetian - timeslice T6),
Middle to Late Jurassic (Bajocian to Oxfordian - timeslices J5 to J8),
Earliest Cretaceous (Berriasian - timeslice K1)
Early Cretaceous (Aptian to Albian - timeslice K4 to K6)
Cainozoic (Oligocene - timeslice Cz3)

Condensed intervals occur in the Early Cretaceous between the Berriasian and Aptian (K1 to K4) being identified from dating in Rainier 1 (23 m = 30 Ma), Challis 1 (40 m = 30 Ma), and probably Whimbrel 1 (100 m = 20 Ma). This condensed interval may be present in other wells but is so thin that sampling is inadequate to determine its presence. Such a conclusion is evidenced by cavings of Berriasian age (timeslice K1) occurring in the Triassic in Osprey 1, that have not been recognised in place in the well.

An Aptian break in deposition probably occurs in Whimbrel 1, but could not be resolved from the dating available.

Time Slice Correlation

Late Permian sediments occur on the southeastern and northwestern ends of the section, and can be reliably correlated on seismic as a high amplitude event into the centre of the Cartier Trough. The depth to the top of the Permian beneath each well has been estimated from seismic and shown on this diagram. Rapid thickening of the latest Permian (timeslices P7 and P6) appears to occur between Osprey 1 and Whimbrel 1. Although this may be solely due to the level of the control provided by age dating, seismic data tends to support westward thickening in this interval (seismic line 86A138). In Sahul Shoals 1 where the late Permian is accurately dated, timeslices P7 and P6 are relatively thin.

Within the Triassic, it is difficult to estimate thickness changes because of incomplete sections for most of the timeslices along the section, and the poor seismic resolution in this interval. In the southeast on the Londonderry High (Osprey 1 and Whimbrel 1), only timeslices T1 and T2 (Scythian & Anisian) are present. The remaining wells contain up to timeslice T5 (Carnian), with a slight possibility of T6 (?) in Jabiru 1A (see Dating of Horizons - Triassic discussion above).

Only Rainier 1 and Jabiru 1A contain any Jurassic sediment. Rainier 1 contains a thick upper Jurassic section (Oxfordian to Tithonian - timeslices J8 to J10) and a relatively condensed lower Jurassic (Hettangian to Aalenian - timeslices J1 to J4). Whilst Jabiru 1A has no upper Jurassic dates (see Dating of Horizons - Jurassic - discussed above), it contains a relatively condensed lower Jurassic (Hettangian to Aalenian - timeslices J1 to J4). Along the cross-section the Jurassic sequence rapidly thickens from the high blocks of the Jabiru Terrace down into the Cartier Trough.

All seven wells contain Cretaceous sediments, which thin offshore in a northwest direction. The well data suggests that the lower Cretaceous is thin relative to the upper Cretaceous, but the cross-section indicates that down dip off the structural highs they appear to be of comparable thickness.

The well data indicates that the Tertiary thickens appreciably in an offshore direction. The cross-section indicates that the greatest thickness is confined to the Cartier Trough, with the largest variations in thickness occurring in the Miocene to Recent (timeslice Cz4 to Cz7) sequence.

Time Slice Facies

Marine and paralic facies were dominant in the latest Permian and early Triassic (Kazanian to Anisian - timeslice P6 to T2), followed by paralic and then fluvial sedimentation in the late Triassic (Ladinian to Carnian - timeslices T3 to T5). Both the inshore and offshore wells (Whimbrel 1 and Sahul Shoals 1) show slight variation to these regional trends. Fluvial facies dominate both the lower and upper Jurassic (Hettangian to Aalenian - timeslices J1 to J4, and Oxfordian to Tithonian - J8 to J10), although more marine affinities probably occur within the Cartier Trough. In the Cretaceous marine facies dominated (as condensed intervals in the lower Cretaceous), except for some paralic sediments on the flank of the basin. Marine sedimentation continued throughout the Tertiary except during the Oligocene when there was a major drop in sea level, and resultant unconformity. Straddling this time break, are paralic facies in Challis 1 and Pollard 1. Following this period, marine sedimentation resumed through until the Recent.

HYDROCARBON PROSPECTIVITY

Reservoir

The Permian limestones usually have very low porosity and permeability, but Osprey 1 when tested flowed 5950 barrels of water per day of gas cut saltwater from fractured Permian limestone. The Permian interbedded sands and shales have ranges in porosity of 2 to 28%, with an average of around 5 to 15%.

There are excellent reservoir characteristics in the Triassic and Jurassic. Primary porosity in the Triassic ranges from 10 - 29% with an average of 20%, whilst secondary porosity ranges from 20 - 36% with permeabilities of 1.1 to 5.2 D. The lower Jurassic has porosities of 16 - 25%, with permeabilities of 0.1 - 15 D with an average of 2 - 3 D. The upper Jurassic has porosities ranging from 13 - 24% with permeabilities of 1.1 D.

The Cretaceous has moderate to poor reservoir characteristics due to high clay and glauconite content resulting in porosities of up to 22% with permeabilities of 16 to 897 mD. In the early Cainozoic, porosities range from 23 - 35% with 10 - 108 mD, and in the Miocene porosities range from 10 - 34 % with 133 - 188 mD.

Source and Maturation

Permian to Middle Jurassic aged rocks, exhibit source rock characteristics and maturation levels adequate for the generation of hydrocarbons (Kraus and Parker, 1979). MacDaniel (1988) believes that the most important source rocks in the western Timor Sea region are Jurassic sediments, with 1 to 2% total organic carbon (TOC) contents occurring in the upper Jurassic in the Swan Graben. The upper Triassic is an organically lean gas prone sediment, whereas the lower Triassic being less oxidised and with TOC's up to 0.5%, has marginal to moderate oil generative potential (MacDaniel, 1988).

The APIRA/BMR source rock data base (Haji-Taheri & Powell, 1990) indicates that there are higher TOC's in the inshore Triassic (Whimbrel 1 and Osprey 1 : 1.4 - 0.4%) than in the offshore (Sahul Shoals 1 : 0.2 - 0.6%), and that the Permian has good source potential with up to 3.4% TOC (Osprey 1). Localised zones of good source potential occur in Osprey 1 in the Cretaceous with up to 5.0% TOC, but in this location is immature.

Seal

The regional seal over Jurassic and Triassic reservoirs is claystones in the lower Cretaceous, which can operate as a lateral seal in structures which are fault dependant (MacDaniel, 1988 - Figs 10 & 12). Intra-formational seals occur in the Permian, where gas accumulations are restricted to the fractured zones of the Permian limestones. Intra-formational seals also occur in the claystones and carbonates of the Cretaceous and Cainozoic.

Shows

Hydrocarbon shows and indications occur in the Cainozoic, Cretaceous, Jurassic, Triassic and Permian, with the oil fields of Jabiru and Challis occurring in the Jurassic and Triassic respectively (Plate 2 - Hydrocarbon Shows).

Osprey 1 tested 5950 barrels of water per day of gas cut saltwater from fractured limestone in the Permian. Jabiru 1A flowed oil at 7500 barrels per day with a net pay of 53 m from the Oxfordian (? - See MacDaniel, 1988) and the Aalenian to Hettangian (timeslices J8(?), and J1 to J4). Challis 1 flowed oil at 6730 barrels per day with a net pay of 21 m from the Carnian (timeslice T5).

Pollard 1 had oil and gas indications in the Miocene and Eocene (timeslices Cz4 & Cz1), Jabiru 1A had gas indications in the Santonian (timeslice K9) and Whimbrel 1 had gas indications in the Aptian and Valanginian (timeslices K4 & K2). Rainier 1 had oil indications from the Oxfordian to Tithonian section (timeslices J8 to J10) and from the Hettangian to Aalenian (timeslices J1 to J4). Pollard 1, Jabiru 1A and Rainier 1 had gas or oil indications from the Ladinian to Carnian section (timeslice T4 to T5).

STRUCTURE AND TECTONICS

Considerable differences occur in the interpretation of the regional tectonics and structural style of the Timor Sea and North West Shelf. The most recent publications include; Veevers (1988) and Pattillo and Nicholls (1990) for regional tectonics, and Woods (1988) and Nelson (1989) for structural style.

Pre-Permian

The structure and tectonics prior to the Permian are summarised by Veevers (1988) as changing from a period of dextral shear in the early Cambrian to plate divergence off northwest Australia. In the mid-Carboniferous there was considerable compression in central and eastern Australia, with correlative unconformities in the northwestern and northern Australia (Bradshaw and others, 1990 - Fig. 13). This orogenic period may have been the precursor to the initiation of the Westralian Superbasin which contains thick Permian and Mesozoic sediments along the western margin of Australia (Bradshaw and others, 1988). It is proposed to refer to the older sequences (pre-late Carboniferous) beneath the late Palaeozoic unconformity in the offshore Bonaparte to Carnarvon Basins as the Roebuck Superbasin.

The oldest recognisable sequence on the cross-section can only be dated as pre-Permian in age (Plate 1 - Section F-G), but probably represents Carboniferous, Devonian and older sediments. The top of the sequence is bounded by an angular unconformity which by comparison with the Offshore Canning and the Petrel Sub-basins (Bradshaw, 1990a & 1990b) may be mid-Carboniferous in age, equivalent to the Base Grant Unconformity and the Alice Springs Orogeny (Goldstein, 1989). This sequence contains some normal faulting down to the east, opposite that of the overlying Westralian Superbasin. As the faults do not penetrate into the overlying sequence, and because of the evidence of widespread truncation, significant changes in the stress regime probably occurred between the two superbasins, and a considerable time break may be involved across this unconformity. This period equates with the change over from the Uluru to the Innamincka regime described by Veevers (1984).

Permian

Following the initiation of the Westralian Superbasin and truncation of the lower Palaeozoic sequences of the Roebuck Superbasin, thick Permian sedimentation onlapped the late Palaeozoic unconformity, culminating in the deposition of late Permian carbonates and clastics. Localised structuring of these sequences is evident prior to the transgression of Triassic sediments, shown on the southeastern end of Section F-G (Plate 1) and on seismic line AB86A-138 at shotpoint 1200-1000 (not provided). It is difficult to resolve on the seismic data the sequence beneath the Permian, and thus it is not clear whether the faulting prior to the Triassic sedimentation is located along deeper pre-existing structures or represents a new tectonic fabric produced by a changed stress regime.

Mesozoic

The major differences between Veevers (1988) and Pattillo and Nicholls (1990) involves analysis of the Mesozoic tectonics of rifting and break-up. Their differences revolve around the interpretation of the Deep Sea Drilling Project and Ocean

Drilling Project (DSDP/ODP) results from the Argo Abyssal Plain, principally sites 261, and 765 (Plate 2 - Regional Location Map), which are summarised below.

Age of Oceanic Crust and Overlying Sediments

In **DSDP 261** the oldest sediments above oceanic crust were described by Veevers and others (1974) as:

Tithonian, Kimmeridgian and Oxfordian (based on nannoplankton),
Upper Jurassic or Lower Cretaceous (based on non-diagnostic foraminifer),
Kimmeridgian to Tithonian (based on a poor dinoflagellate assemblage).

Ages of no younger than Early Tithonian, and late Kimmeridgian to early Tithonian have been determined after re-analysis of the samples in DSDP 261 by Brown (in press), utilising the presence of three nannofossils *Stephnolithion bigotii*, *Watznaueria britannica* and *Watznaueria manivitae*.

In contrast, sampling from **ODP 765** indicated that the oldest sediments above oceanic crust were dated as latest Berriasian to Valanginian (Leg 123 shipboard scientific party, 1989; Gradstein, Ludden and others, 1990). However, the lowest dated sediments in this well occur 5 m above the top of the basalt, and the dinoflagellate zone *E.Torynum* (latest Berriasian to earliest Valanginian (Helby and others, 1987) and traditionally older than the "mid-Valanginian" event) occurs ≈ 30 m above the basalt.

Fullerton and others (1989) analysed the magnetic anomalies of the eastern Indian Ocean over sites DSDP 261 and ODP 765 on the Argo Abyssal Plain and found that the magnetic isochrones include M26 to M16 (Plate 2 - Magnetic Isochron Map). Thus they believe that sea floor spreading in the Argo Abyssal Plain commenced at or prior to M26 time, which is early Oxfordian in age (162 Ma - Harland, 1982). The magnetic anomalies were analysed prior to ODP 765 data being available, but even with later consideration of that data Fullerton and others (1989) believe that spreading began at or before M26 time (N. Exon BMR, personal communication, November 1990).

The study of the magnetic anomalies appears to corroborate the older biostratigraphic dates in DSDP 261, whilst the ODP 765 site must be assumed to be more complex than originally recognised. The alternative is that both of the two biostratigraphic age datings in DSDP 261 are spurious, and that the interpretations of the magnetic anomalies is similarly flawed. At this stage, this seems to be the least likely scenario, **and thus the age of the onset of sea floor spreading is assumed to be Oxfordian or Kimmeridgian.**

Rifting and Break-up models

As suggested above, the major differences in the competing models for the timing of rifting and break-up revolve around interpretation of the age of sea floor spreading. Veevers (1988) uses the earlier date of early Oxfordian whereas Pattillo and Nicholls (1990) use a date of mid-Valanginian. Pattillo and Nicholls (1990) refer to Gradstein and Ludden (1988) as indicating that ODP 765 revised the onset age of sea floor spreading in the Indian Ocean to middle Valanginian. However, both Gradstein, Ludden and others (1990) and (Leg 123 shipboard scientific party, 1989) state that latest Berriasian to Valanginian overlie sea floor in ODP 765. These discrepancies result in the following timing for each model (Tables 1a & b).

RIFTING EVENT TERMINOLOGY

VEEVERS (1988) AGE	VEEVERS (1988) EVENT	PATTILLO & NICHOLLS (1990) EVENT	PATTILLO & NICHOLLS (1990) AGE
LATE TRIASSIC	RIFTING	PRIOR TECTONIC EPISODE TO LATE JURASSIC / EARLY CRETACEOUS RIFTING	PRE-CALLOVIAN
LATE JURASSIC OXFORDIAN breakup III	SEA FLOOR SPREADING	SYN RIFT	CALLOVIAN - INTRA-VALANGINIAN
E. CRETACEOUS HAUTERIVIAN / VALANGINIAN breakup IV	INDIA/AUSTRALIA SEPARATION	POST RIFT	INTRA-VALANGINIAN - PRESENT
EARLY OXFORDIAN **DSDP 261 ***	OLDEST SEDIMENT ON SEA FLOOR		LATE BERRIASIAN - VALANGINIAN **ODP 765 #**

* Revised date from Brown (in press) of late Kimmeridgian to early Tithonian.
# Pattillo & Nicholls (1990) quote this age as mid-Valanginian.

RIFTING EVENT AGE COMPARISON

VEEVERS (1988) AGE	EVENT	PATTILLO & NICHOLLS (1990) AGE
TRIASSIC	RIFT ONSET	CALLOVIAN
CALLOVIAN	BREAKUP	VALANGINIAN
POST CALLOVIAN	POST RIFT	POST VALANGINIAN

TABLE 1A & B - Comparison of the terminology for rifting events and their age designation for Veevers (1988) and Pattillo & Nicholls (1990).

Triassic - Jurassic Unconformities

Along the cross-section, the most obvious Mesozoic unconformity is above the Triassic and below the Cretaceous. This is displayed in Rainier 1 where there are several marked changes in the dipmeter log between and within the Jurassic and Triassic intervals. More specifically in Rainier 1, there are dipmeter changes between the upper and lower Jurassic (timeslice J8 to J4), the lower Jurassic and Triassic (timeslice J1 to T5), and within the upper Triassic (timeslice T5) (Table 2). These dip changes can not be resolved on the seismic data over Rainier 1. Age dating and seismic data suggests that the intra-Triassic dip change may be due to faulting rather than represent an angular unconformity.

DEPTH (M)	DIP TREND (AVERAGE)	FACIES	AGE	TIMESLICE
1900-2015	10° W	FLUVIAL - BRAIDED STREAM, FAN	KIMMERIDGIAN - OXFORDIAN	J8
2015-2040	20° SW	FLUVIAL - PARALIC?		
2040-2080	15° SSW			
2080-2118	8° W			
2118-2185	30° NNW	FLUVIAL - BRAIDED & MEANDER STREAMS	AALENIAN - HETTANGIAN	J1 - J4
2185-2230	25° W	FLUVIAL - MEANDER STREAMS	NORIAN - CARNIAN	T5
2230-2240	40° SE	FLUVIAL MEANDER CHANNEL		
2240-2290	6° SSW	PARALIC - STREAM MOUTH BARS & CHANNELS		

TABLE 2 - Dipmeter trends in Rainier 1

The dipmeter logs for Jabiru 1A show several changes in dip direction over the same interval as in Rainier 1, however they are non-conclusive as there are no abrupt changes in dip magnitude (which are all comparatively shallow), and thus any interpreted tectonic signature could easily be overprinted by facies controls. The Rainier 1 data indicates that there is a tectonic component to the depositional break between the Triassic and Jurassic (Rhaetian - timeslice T6) and between the lower Jurassic and upper Jurassic (Bajocian to Callovian - timeslice J5 - J7). These respectively correspond to the Triassic event of Veevers (1988) and the Callovian events of Veevers (1988) and Pattillo and Nicholls (1990) (Table 1A & B), albeit given different significance.

Late Jurassic - Early Cretaceous Unconformities

Examination of Rainier 1 age dating in the late Jurassic and early Cretaceous suggests that there is an unconformity in the latest Jurassic to earliest Cretaceous (timeslices J10 to K1), and above this either a period or a series of condensed intervals occurs, as 22 m of sediment composed of glauconitic claystones represents 34 Ma (Table 3).

The latest Jurassic to earliest Cretaceous unconformity is represented by major changes in facies and lithology, the absence of K.Wisemaniae and P.Iehiense dinoflagellate zones (Table 3), and a slight change in dipmeter values and trends. This break has not been recognised as a regional event by previous workers as this sequence is rarely intersected, and thus has not been incorporated into the tectonic framework. As it represents a major change from a thick sequence of clean upper Jurassic sands up into thin glauconitic claystones, it is believed to be a significant event. The homogeneous and thick nature of the upper Jurassic sands, is a reflection of the source and proximity of the sediment, and its rate of accumulation. The presence of marine microfossils may indicate marine affinities, however the yield and diversity was very low. Because of the lack of other marine indicators such as glauconite, the absence of any fine grained component to the 450 m thick sand interval, and its resultant blocky log character, this unit is believed to have been deposited in a fluvial or perhaps paralic environment . On seismic data, a single mound like feature was identified within the upper Jurassic interval, which may indicate alluvial to nearshore fan developments.

As Rainier 1 is located on the down side of the Challis horst block, the upper Jurassic sands may be a syn-tectonic deposit shed off Triassic highs and infilling the graben lows. The absence of this age sediment in other wells (especially the younger Tithonian section - timeslice J9 & J10), suggests that a syn-tectonic origin is exceedingly likely, indicating that the faults along the Jabiru Terrace were active during the Oxfordian to Tithonian. An intra-Kimmeridgian break is also possible in Rainier 1 (≈ 1920 m), where a facies change occurs and a change in the depositional rate can be postulated. This would correlate with the intra Kimmeridgian event of Pattillo and Nicholls (1990).

The overlying condensed interval extends from the Berriasian to the Aptian, but has been suggested by Pattillo and Nicholls (1990) to incorporate several unconformities at Aptian and mid-Valanginian level. Eclipse 1 is cited by Pattillo and Nicholls (1990 - Fig. 17) as the type example in this region for their "intra-Valanginian disconformity", however as shown (Table 3) there is scant age dating to support this premise, and thus neighbouring wells need to be analysed. Only Rainier 1 provides a detailed examination of this interval (Table 3), and shows that with closely spaced sampling, the majority of the zonations could be present, especially as lithologies suggestive of low rates of

PERIOD	AGE	DINOFLAGELLATE ZONE	RAINIER 1 (K/Jur. -1672m)	CHALLIS 1 (K/Tri. -1387m)	ECLIPSE 1 (K/Jur. -2330m)	OSPREY 1 (K/Tri. -1256m)	WHIMBREL 1 (K/Tri. -1128m)
EARLY CRETACEOUS	ALBIAN	M.TETRACANTHA	1650-1653 (3)			caved	
	APTIAN	D.DAVIDII			2288	1247	
		O.OPERCULATA					
	----------	{A.CINCTUM					
	BARREMIAN	M.AUSTRALIS	1653-1662 (9)	1375			1036-1079 (43)
	HAUTERIVIAN	M.TESTUDINARIA		1380	2307		
	----------	P.BURGERI	1662-1665 (3)				
		S.TABULATA	1667-1668 (1)				1096
	VALANGINIAN	S.AREOLATA					
	----------	E.TORYNUM					
		B.RETICULATUM	1669-1671 (2)				
		D.LOBISPINOSUM					
	BERRIASIAN	C.DELICATA				caved	1102-1114 (12)
		K.WISEMANIAE			2328?		
....	----------	P.IEHIENSE					
JURASSIC	TITHONIAN	D.JURASSICUM	1672-1782 (110)				
		O.MONTGOMERYI					
THICKNESS BETWEEN M.AUSTRALIS - M.TESTUDINARIA AND JURASSIC/TRIASSIC UNCONFORMITY			10	12	23	< 9	49

TABLE 3 - Dinoflagellate zonations for wells with glauconitic claystones above the Jurassic/Triassic unconformity.

marine deposition are present. As these lithologies are present in the other wells above the Jurassic/Triassic unconformity but lack the detailed age control, the likelihood of similar condensed intervals is high. Thus condensed intervals in the early Cretaceous, are also suggested for Challis 1, Eclipse 1 and Whimbrel 1. In Osprey 1, caved samples of early Cretaceous age appear to have been missed in the sample gap of nine metres between the Aptian and Triassic.

The most important aspect of the detailed dating and inferred condensed intervals, is how it relates to the oft quoted **"mid-Valanginian unconformity"**. This event has variously been referred to as;

> "intra-Valanginian disconformity ... ... is represented by a highly condensed section containing subtle non-depositional hiatii (hardgrounds) with no evidence for significant erosion. ... towards the Browse Basin .. .. the event appears to approach close conformity." (Pattillo and Nicholls, 1990 - p. 41).
>
> "The regional Valanginian unconformity which interrupts the post- breakup sequence is represented by a small hiatus in the Vulcan Sub-basin, but considerable erosion took place over elevated areas, such as the Londonderry High and Ashmore Platform." (Mory, 1988 - p. 294).
>
> "This (Flamingo Group) was followed by a period of widespread uplift and erosion during the Early Cretaceous (Valanginian Unconformity), during which time there was some rejuvenation of the earlier faulting." (Whibley and Jacobson, 1990 - p. 12)

As illustrated above, most prior work references the widespread nature of this event, its tectonic significance and the erosion which took place. However, along the cross-section the tectonic and erosive characteristics of this event are seriously questioned because;

- If widespread erosion of the Londonderry High and Ashmore Platform took place, where is the sediment that was eroded? Only thin early Cretaceous intervals have been penetrated in this region.
- If the erosion and uplift were significant, why are there both above and below the Valanginian, intervals which appear continuous and which comprise similar lithologies and facies?
- If widespread uplift occurred, why are there thin intervals of Berriasian aged sediments (usually C. Delicata dinoflagellate zone) preserved beneath the unconformity, that comprise fine grained glauconitic intervals, that should have been removed in such a major tectonic event?

Several explanations could be invoked to explain these problems, some of which include, sediment starvation and sediment bypass, but neither answer all of the problems. The data from Rainier 1 needs to be fully incorporated into the tectonic framework, which includes the recognition that;

- There is no angular unconformity in the Valanginian.
- There is an almost complete continuity of sedimentation in this area (albeit with slow rates of deposition).
- Condensed intervals occur in most wells but are poorly sampled, including on the high blocks (Challis 1), in the grabens (Rainier 1) and on the basin margins (Whimbrel 1 and Osprey 1).

Thus whilst in areas such as the Perth Basin (Seggie, 1990) the mid-Valanginian event is a period of major erosion due to the onset of sea-floor spreading , in the Timor Sea it has another expression (albeit probably tectonically related), and does not represent a period of "widespread uplift and erosion". It may be a period of subsidence following the extrusion of ocean floor basalts and thermal cooling in the Argo Abyssal Plain as suggested from both the condensed intervals in the Timor Sea, and from data in the southern Exmouth where up to 2 km of subsidence occurred in the Early Cretaceous (Boyd and others, in press). Two periods of rifting on the North West Shelf may have been felt in the Timor Sea region, thus complicating the sedimentology and biostratigraphy on the shelf, the DSDP/ODP results on the oceanic crust and the subsequent analysis of the tectonic history of the Jurassic and Cretaceous in this region.

Cretaceous and Cainozoic Unconformities

Most of the wells in this region document the depositional break in the Aptian (Plate 2 & Table 3). This period represents the "Aptian Gap" that was a period of high sea levels worldwide, producing a general pattern of sediment starvation (Ingram and Morgan, 1988).

The only other major break identified along the cross-section occurred in the Oligocene, and can be seen both in the dating of several wells, and on seismic in the vicinity of Pollard 1. Paralic facies are associated with this unconformity with coals occurring in Challis 1 and Pollard 1. This unconformity is principally the product of a major drop in sea level as shown in the Offshore Canning Basin (Bradshaw, 1990b).

Along the cross-section, faults often penetrate up into the Miocene, which is considered to be the result of collision of the Australian plate with the Eurasian Plate. It is interesting to note that there is clear evidence of Miocene reactivation in the Ashmore Platform, Cartier Trough and Jabiru Terrace. However, on the Londonderry High, the majority of the faults do not penetrate above the Triassic. This suggests that the more mobile blocks of the Cartier Trough and Ashmore Platform reacted to the Miocene convergence whereas the stable older crust of the Londonderry High was not affected. The intervening zone of the Jabiru Terrace may have been a zone of accommodation between the mobile and stable areas where tangential stress was taken up, and could account for the complexity of structures and poor seismic resolution in that area.

PLAYS

The current plays being explored for in the western Timor Sea are Triassic and lower Jurassic sands in horst blocks overlain by Cretaceous seals with Jurassic source. The data from this cross-section indicates that several less conventional plays exist and warrant testing in the future.

Inshore there are numerous areas of older targets within the Roebuck Superbasin where large structural highs of Devonian and Carboniferous are overlain by the Westralian Superbasin (Maung and others, 1990). Permian targets have not been adequately explored either on the Londonderry High or as deep tests in areas along the Jabiru and Montara Terrace (see deep structure below Challis 1 - Plate 1 section C-D and along the boundary between the Londonderry High and Jabiru Terrace). Following the encouraging results from the Petrel Sub-basin where oil has been encountered in these older sequences (Barnett), the conventional wisdom of the "gas prone" nature of these sediments should be seriously reassessed. The high TOC's documented above in the Triassic could provide adequate source material for face loading into these structures, as well as migration from deeper Palaeozoic sources.

The most exciting new play is that associated with the thick upper Jurassic sands discovered in Rainier 1. Whilst it is possible that these sands are very localised syn-tectonic features, their thickness and homogeneity indicates that they should be explored for further down dip into the Cartier Trough where the Jurassic section thickens. In this region, more adequate seals may be encountered, and shorter source migration pathways would occur. As oil has managed to migrate into the structurally higher horst blocks of Jabiru, Challis and Cassini, these structurally lower thick reservoir units must have high potential to trap migrating hydrocarbons. High resolution seismic may help in identifying associated mound features within the grabens and on the flanks of the Cartier Trough.

Pollard 1 encountered a good show of oil within the Cainozoic sequence, although with further testing it was not believed to be significant. Due to the normal drilling practices of drilling "blind" in this interval and not necessarily on structure, the real potential of these younger units is unknown. If older prospects are not drilled because it is believed that the trap has leaked along reactivated faults which extend into the Miocene, then Cainozoic traps should be seriously considered and explored for. If the Aptian and early Cretaceous are condensed intervals, they should act as rich source rocks in the deeper parts of the basin where they may be mature and could be migrating up into the Cainozoic sequences.

Undoubtedly the most important key to new and existing plays in this region will continue to revolve around advances in seismic acquisition and processing technology, which will help to accurately delineate the tectonic history of the region, and can only be achieved by utilising the whole data set.

POST SCRIPT :

1) The dinoflagellate zonation near the base of ODP 765 has now been revised to B.Reticulatum rather than E.Torynum (pers. comm. Robin Helby, January 1991). However this still suggests from biostratigraphy that the age of the oldest dated sediments in this well are Upper Berriasian to Valanginian (Helby & McMinn, 1990). (See pages 11 & 12 of this report and Table 1A).

2) A provisional age dating of the hyaloclastic volcanic breccia at the base of the sedimentary section in ODP 765 has been determined as 155 ± ? m.y. using K/Ar methods (pers. comm. Neville Exon, BMR, January 1991). This result suggests that the older Jurassic age for commencement of sea floor spreading indicated from DSDP 261 is correct. However, because of the vagaries of the different radiometric time scales currently in use, this age could vary from the Kimmeridgian to the Callovian. As it is a K/Ar age, this number most likely represents the minimum age of the basalt. This determination raises numerous questions of resolving the age of sea floor spreading from the first fossil determination in the overlying sediment.

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WESTERN TIMOR SEA-BONAPARTE BASIN STRUCTURAL CROSS-SECTION.

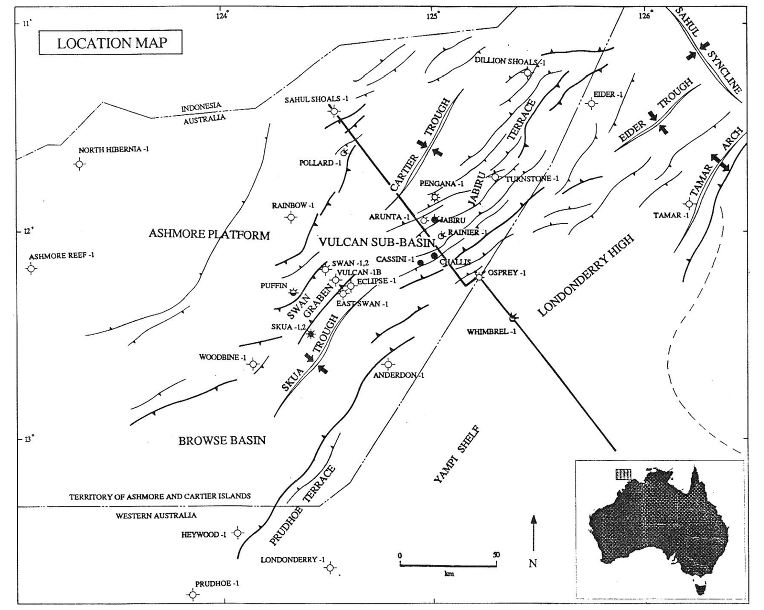
JOHN BRADSHAW

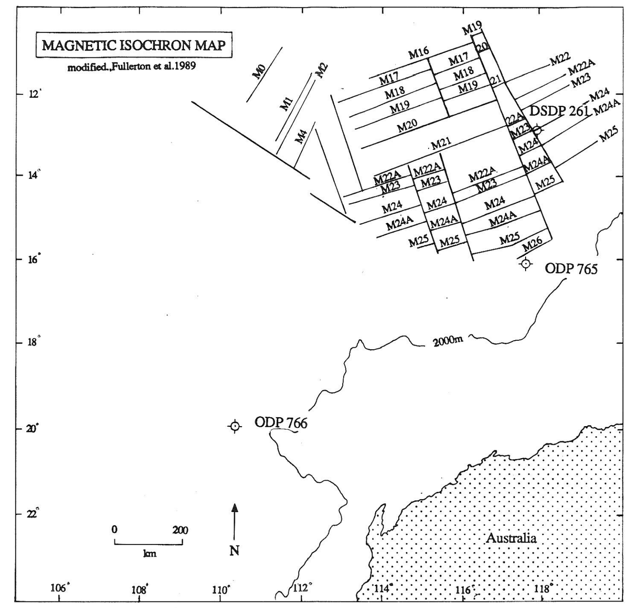
Plate 1

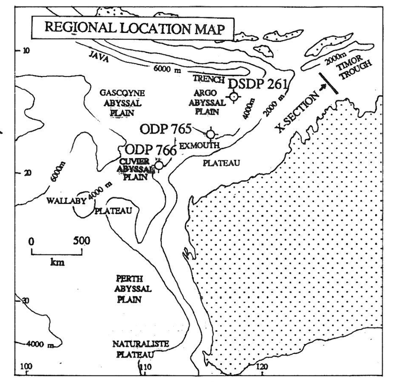
WESTERN TIMOR SEA-BONAPARTE BASIN BIOSTRATIGRAPHY.

JOHN BRADSHAW

Plate 2



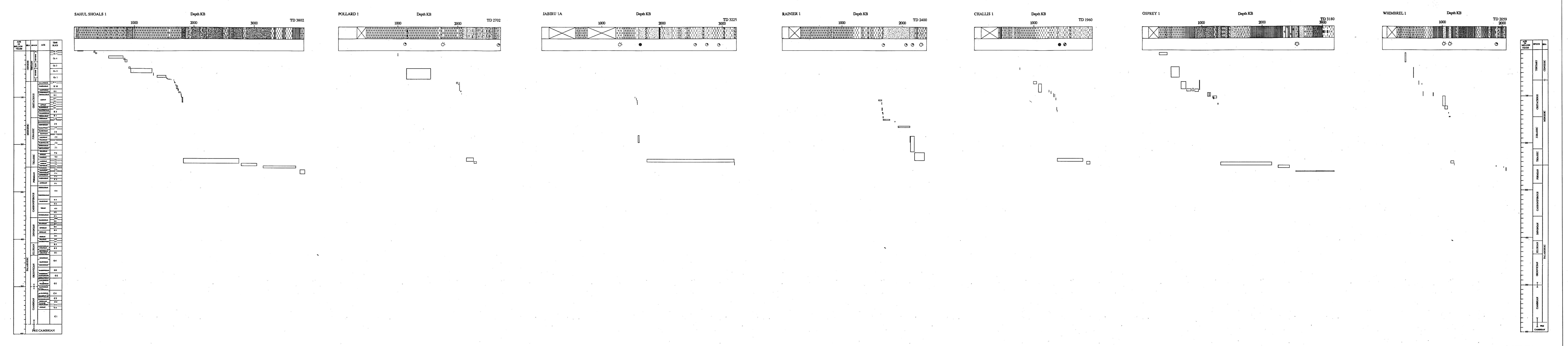




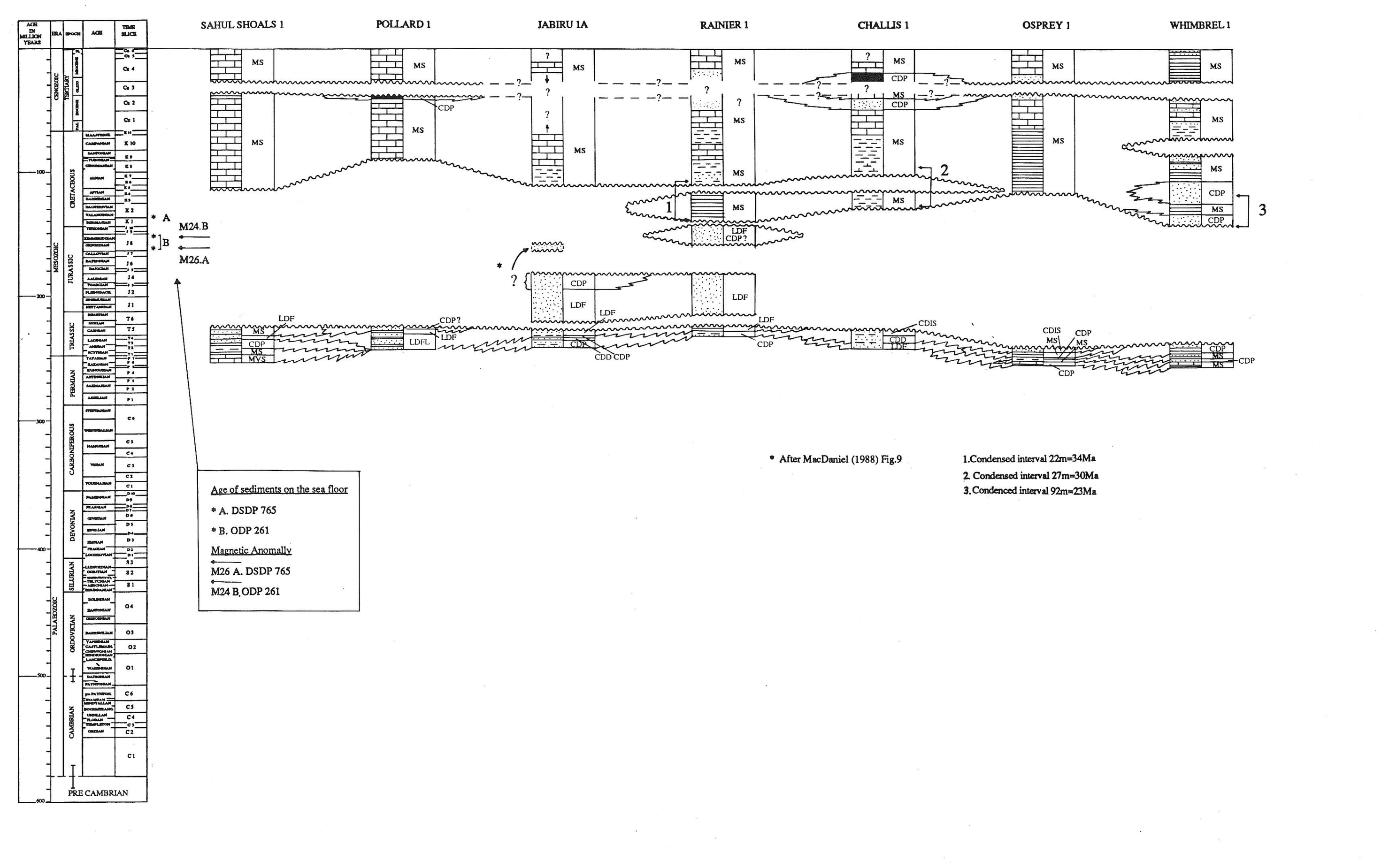
KEY

	No hydrocarbon indication	LDF	Land Deposition Fluvial		Shale/Mudstone
	Oil indication	LDFL	Land Deposition Fluvial Lacustrine		Siltstone
	Strong oil indication	CDP	Coastal Depositional Paralic		Sandstone
	Proven oil zone	CDIS	Coastal Depositional Intertidal-Supratidal		Marl
	Gas indication	CDD	Coastal Depositional Deltaic		Dolomite
	Gas show	MVS	Marine Very Shallow		Limestone
	Potential gas zone	MS	Marine Shallow		Coal
	Gas and oil indication				
	Gas and oil show				
	Proven gas and oil zone				

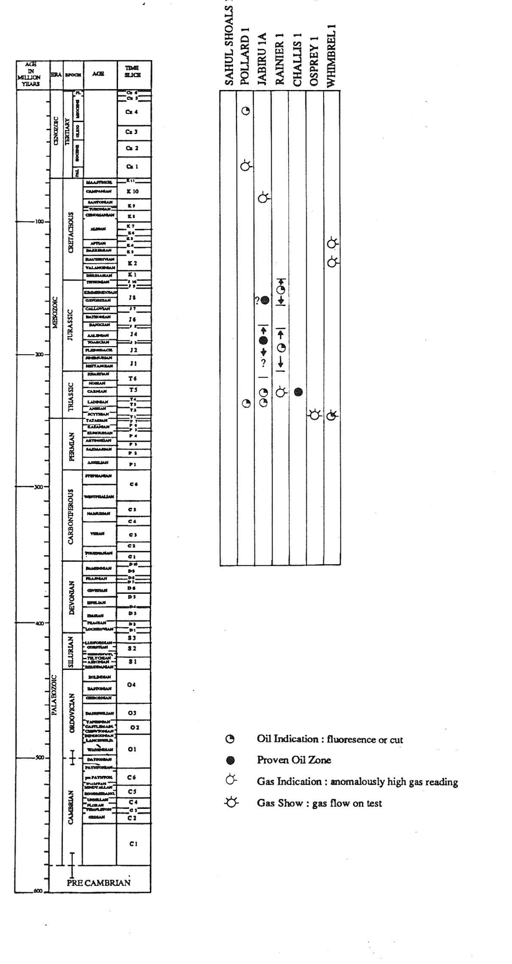
TIME/DEPTH PLOTS



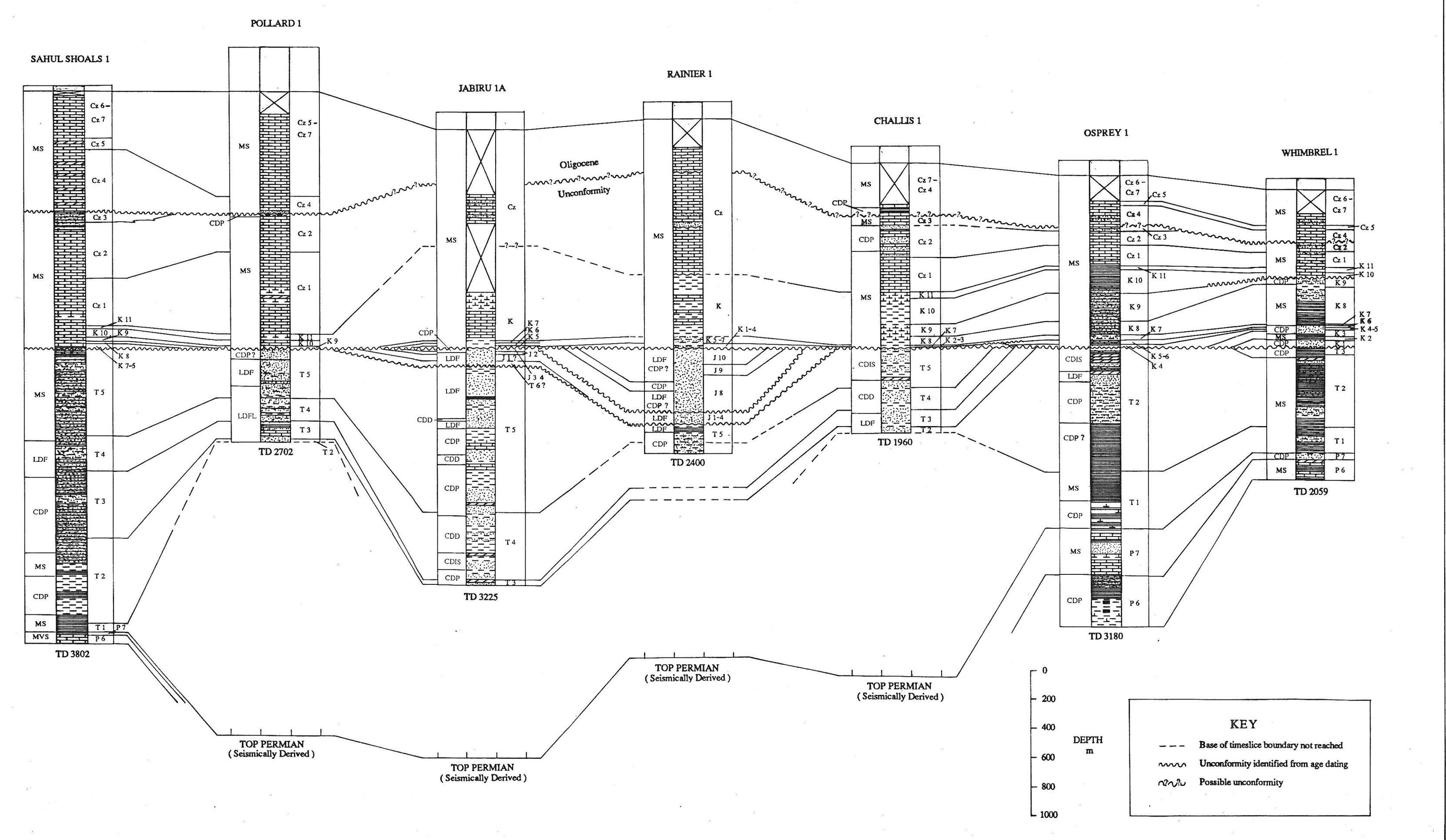
TIME SPACE



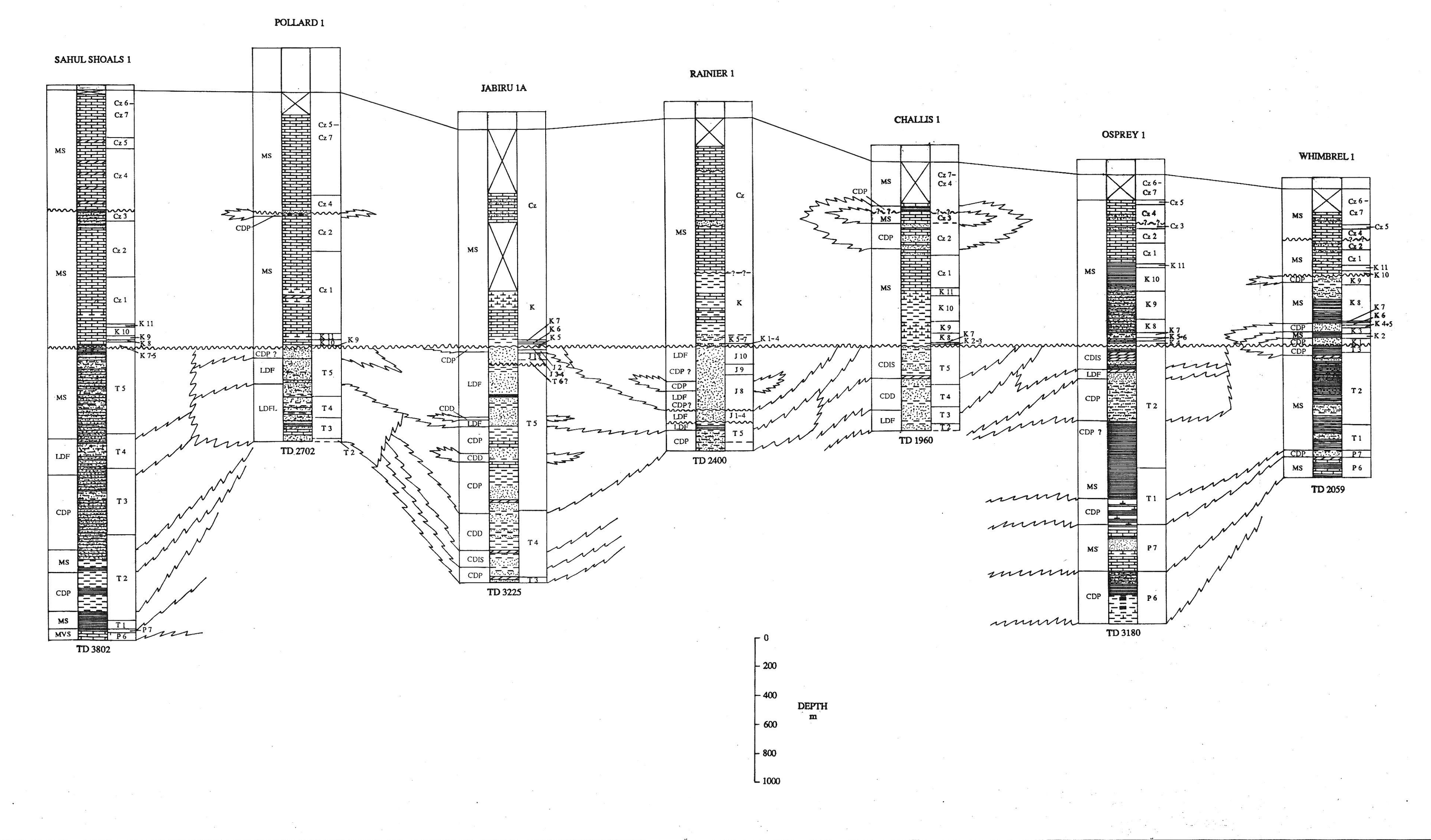
HYDROCARBON SHOWS



TIME SLICE CORRELATION



TIME SLICE FACIES



Drafted by John Vizy
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Phanerozoic History of Australia
Project 175A

WESTERN TIMOR SEA - BONAPARTE BASIN LINE 8126-25 Plate 3

B

WESTERN TIMOR SEA - BONAPARTE BASIN LINE 8126-25 Plate 4

C

SE

CITIES SERVICE AUSTRALIA
AREA NT/P26
LINE 8126-25
SHOTPOINTS 1-4

WAVE E
FINITE D

FIELD DATA

CREW - WESTERN GEOPHYSICAL PTY.
DATE -

CABLE
GROUP INTERVAL 25 M
DEPTH AVG. 34
LENGTH 2400 m
NO. OF GROUPS 96

SOURCE
TYPE AIRGUN
DEPTH 6m.
SHOTPOINT INTERVAL 25 M.
CAPACITY
OFFSET

SYSTEM
TYPE DFS V 9 TRACK
RECORD TIME 6.0 SEC
FILTER Hi 128 Hz db/oct
Lo OUT Hz 18 db/oct
FORMAT SEG
SAMPLING 2 MSEC.

PROCESSING

1 DEMULTIPLEX 96 CHANNELS
EXPONENTIAL GAIN RATE 4 db/sec.
GATE 0 - 3.0 sec
2 STATICS SHIFT 11 ms (SOURCE & CABLE DEPTHS)
3 RESAMPLE TO 4 ms
4 COMMON DEPTH POINT GATHER
5 DECONVOLUTION
SP ALL, NO OF FILTERS 2
WHITE NOISE 1 %
FILTER LENGTH 200 ms.
GAP LENGTH 24 ms
6 VELOCITY ANALYSIS
7 ZMULT
8 VELOCITY ANALYSIS
9 NORMAL MOVEOUT
10 MUTING
11 CDP SUM 48 FOLD
12 DECONVOLUTION (GAPPED)
SP ALL, NO OF FILTERS 3
WHITE NOISE 1 %
FILTER LENGTH 200 ms
GAP LENGTH 10 ms

13 TIME VARIANT FILTERING

TIME (SEC)	FILTER (HZ)
0.0	12 - 50

SCALE
14 TIME VARIANT SCALING (250ms. gate)
DIGISTAK
MIGRATION: LAYER THICKNESS = 60 ms.
WATER REPLACEMENT STATICS Vr = 6986ft/sec.
V = VELOCITY ANALYSIS LOCATION
STATICS SHIFT ms
DISPLAY

HORIZONTAL SCALE 48 tr./inch
VERTICAL SCALE 3.75 ins/sec.

PROCESSED BY
digicon
SINGAPORE

DATE 19TH. JANUARY 1982

QUALITY CONTROL CHECK
DISPLAY & DRAFTING
SEISMIC
PARTY CHIEF
INDEX NO.