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BROWSE BASIN PETROLEUM PROSPECTIVITY STUDY

by

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The Browse Basin Petroleum Prospectivity Study owes much to many people. Authorship of individual sections in the text is labelled throughout. Elements of style and grammar and scientific content are the responsibility of individual authors. The compilers take responsibility for formatting and grammatical inconsistencies, but have not attempted to resolve scientific inconsistencies in the text or conflicting interpretations on Plates and Figures.

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1. INTRODUCTION

The Browse Basin forms part of Australia's North West Shelf. It is generally an underexplored area of the Shelf and has historically been perceived as a gas province. Since 1963, when exploration commenced, most of the exploration acreage in the basin has been subject to several renewals, relinquishments and subsequent re-gazettals.

Recent relinquishments within the basin have allowed the Designated Authorities, the Australian Commonwealth Government and the Western Australian State Government, to release five large vacant areas for petroleum company and consortia exploration. Areas recommended by the Bureau of Mineral Resources (BMR) are shown in Figure 1. At the time of this study, the Designated Authorities had not determined the final boundaries of the areas for release. Therefore, the limits of the areas offered in Release 2 of 1991 may be slightly different from those shown on Figure 1.

The Petroleum Resource Assessment Branch (PRAB) of the BMR undertook a study of the petroleum prospectivity of the Browse Basin, with particular emphasis on the five areas to be released in 1991. The study area covers the continental shelf and slope off Western Australia that lie between 13^{o}30' and 16^{o}30' latitude and 120^{o} and 125^{o} longitude, but excludes the Territory of the Ashmore and Cartier Islands. However, data from some wells to the north of the study area have been included in this package.

The study summarises the regional geology, geophysics, structure, stratigraphy, palaeogeography, exploration history and hydrocarbon discoveries of the basin. A regional representation of the basin is given on the structure and bathymetry maps (Plates 3 to 6), the basin tectonic elements maps (Plates 1 and 77), the well log cross-sections (Plates 7 to 9), the seismic cross-sections (Plates 10 to 12), and the stratigraphic cross-sections (Plates 78 and 79). Reservoir, source and seal, as well as maturation and timing of generation are discussed on a regional level, and the main plays in the basin are summarised. Each of the proposed release areas was studied in more detail and prospects and leads were delineated (Plates 28 to 73). Maps at 1:000 000 scale (structure and leads (Plates 13 to 17), bathymetry (Plates 18 to 22) and seismic line location (Plates 23 to 27) are available for each area. The text is complemented by approximately 200 plates and figures.

This multidisciplinary Record provides an overview for explorationists interested in acquiring petroleum acreage in this generally underexplored area.

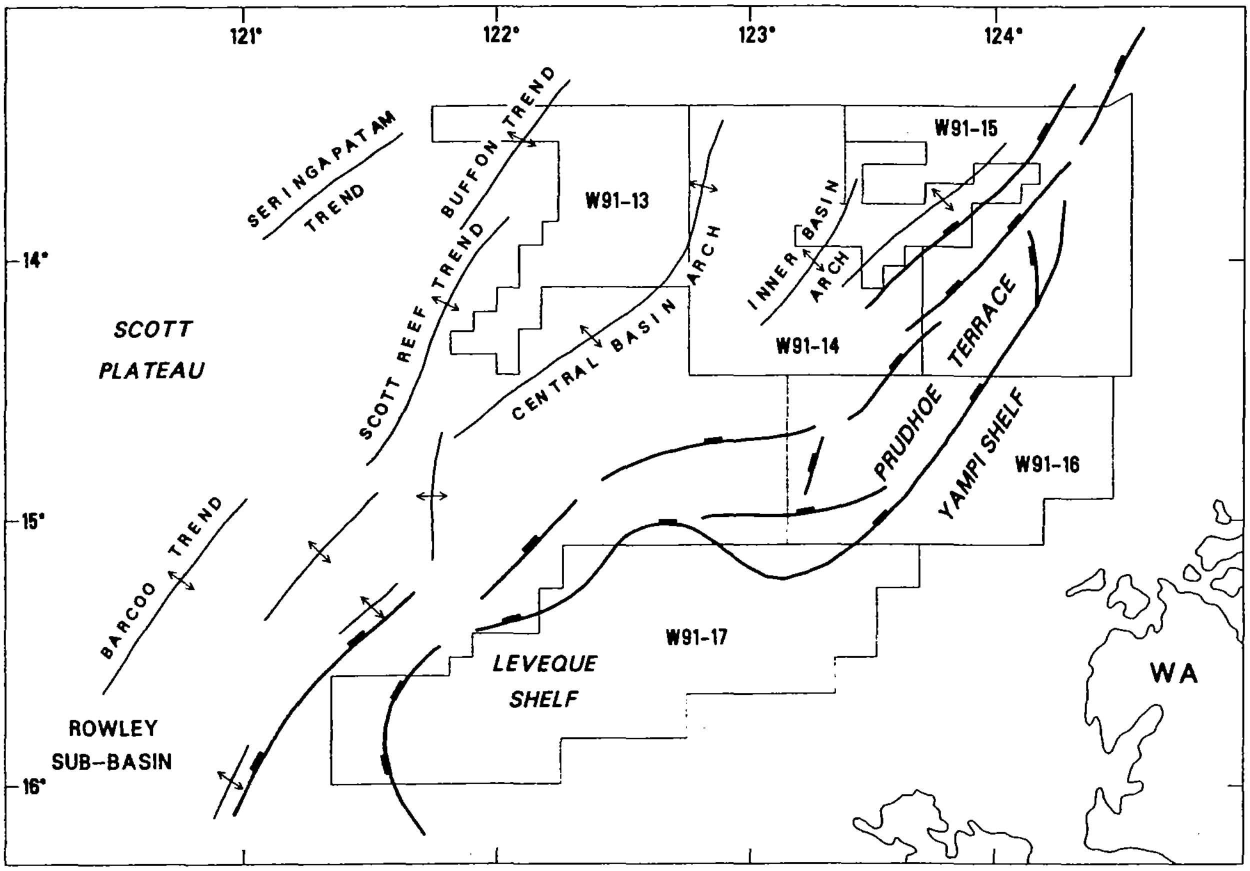


Figure 1. Tectonic elements, gazetted acreage Release No.2, 1991, Browse Basin.

2. REGIONAL GEOLOGY

(S.J. Cadman)

2.1 BASIN SETTING

The Browse Basin is a northeast-southwest trending offshore sedimentary basin underlying approximately 100 000 square kilometres of Australia's western continental shelf and slope between latitudes 12°15' and 16°00' and longitudes 120°00' and 124°45' (Plate 1). Most of the basin lies in water depths in excess of 200 metres (Plate 3). Water depths increase to the west and exceed 2000 metres along the western basin margin.

The Browse Basin is bounded to the east by the Kimberley Block. Its seaward expression (the Yampi and Leveque Shelves and the Prudhoe Terrace) (Figure 1) lies within the basin. The Scott Plateau controls the western limits of the basin and the Ashmore Platform its northern extent. The southern boundary of the basin with the adjacent Rowley Sub-basin of the Canning Basin is less well defined and, for the purposes of this study, the southern limit of the Browse Basin has been taken at 16° latitude.

2.1.1 Kimberley Block

The Kimberley Block is a stable shield area consisting of Archaean and Proterozoic plutonics and metamorphics overlain by locally deformed sediments and minor volcanics (Veevers, 1967). These rocks have been faulted down to the west in a series of terraces and plunge beneath the Phanerozoic Browse Basin sediments. Regionally, they represent economic basement and are thought to have been a major source area for Browse Basin sediments (Allen & others, 1978). They form the ultimate eastern boundary to the Browse Basin.

2.1.2 Yampi Shelf

The Yampi Shelf forms the eastern limit of the Browse Basin and consists of a seaward thickening wedge of Permian, Cretaceous, and Tertiary sediments directly overlying Precambrian basement. The Yampi Shelf links to the Londonderry Arch to the north and to the Leveque Shelf to the south.

2.1.3 Leveque Shelf

The Leveque Shelf is considered to be a southern extension of the Yampi Shelf and Prudhoe Terrace. Here, basement is overlain by Upper Jurassic and Cretaceous sediments (Leveque No.1 provides the only well control in this area). The southern boundary of the Leveque Shelf is controlled by the seaward extent of the northwest-southeast fault systems, which define the onshore Canning Basin. The seaward edge of the shelf is defined by major down-to-the-basin normal faults. Both the Leveque and Yampi Shelves exhibit a virtual absence of faulting or structural relief.

2.1.4 Prudhoe Terrace

The Prudhoe Terrace is separated from the Yampi Shelf to the east by a hinge zone, and the central Browse Basin to the west by a series of major down-to-the-basin normal faults. It is underlain by steeply dipping Precambrian basement onlapped by a wedge of block faulted Permian sediments. These northeast-trending Upper Palaeozoic horst blocks are onlapped by Upper Jurassic sandstones, siltstones and claystones (Prudhoe No.1). Up to 3500 metres of Mesozoic sediments may be present on the Prudhoe Terrace.

2.1.5 Scott Plateau

The western limit of the Browse Basin is defined by the Scott Plateau and its northeast extension, the Seringapatam rise (Lofting & others, 1975; Warris, 1973). Seismic data suggest that the plateau consists of uplifted, relatively shallow Palaeozoic and Precambrian rocks overlain by thin Cretaceous and Recent sediments. Permian through Jurassic sediments pinchout on its eastern flank, although fault controlled structural lows could contain Triassic and possibly Jurassic rocks (Powell, 1976). Throughout most of the Permian to Jurassic, the Scott Plateau was probably above sea level, providing a source of clastic sediments for the Browse Basin (Stagg, 1978).

2.1.6 Ashmore Platform

The Ashmore Platform defines the northern limit of Browse Basin sedimentation. It consists of a large uplifted block of Triassic sediments underlain by an unknown thickness of Palaeozoic rocks. The Triassic is unconformably overlain by Cretaceous claystones, although the Ashmore Reef No.1 well, drilled on the southern margin of the plateau, encountered a Triassic section overlain by volcanics of indeterminate age followed by an Upper Jurassic sequence.

2.1.7 Central Browse Basin

The central Browse Basin is bounded to the east by the down-to-the-basin faults delineating the Prudhoe Terrace, and to the west by the Scott Plateau. Up to 11 000 metres of Mesozoic and Cainozoic sediments may have accumulated in the central basin (Allen & others, 1978). Faulting is generally subparallel to the northeast-southwest structural grain and appears to have been active until at least the Early Cretaceous (Allen & others, 1978). The main structural elements of the central Browse Basin are the northeasterly-trending Inner and Central Basin Arches whose complexities have yet to be elucidated (Williams, 1991).

2.2 BASIN EVOLUTION

The pre-Permian history of the Browse Basin is speculative. However, Powell (1976) considers that, in the Late Carboniferous to Early Permian, regional uplift of the Archaean-Proterozoic shield area, accompanied by rifting, was responsible for the opening of an elongate trough near the coastline of present-day Western Australia. The formation of this intracratonic basin is related to an early extensional phase associated with the breakup of Gondwana (Bradshaw & others, 1988).

Permian sediments have been encountered in a number of wells on the eastern Basin margin (Rob Roy No.1, Lynher No.1, Prudhoe No.1 and Yampi No.1) (Plate 1). In Rob Roy No.1, Permian sediments directly overlie eroded Precambrian basement. Well and seismic evidence indicate that a maximum of 4000 meters of Late Carboniferous to Permian sediments may be present in the central basin (Powell, 1976).

Tensional movements at the end of the Permian led to an episode of block faulting on the eastern Browse Basin margin and uplift of the Scott Plateau to the west (Figure 2). On the eastern basin margin, this produced an erosional wedge of Permian and Triassic sediments overlying Precambrian basement.

The Late Permian movements were accompanied by subsidence. Few wells encountered an Early to early Middle Triassic section in the Browse Basin. In the Bonaparte Basin to the north, Early to early Middle Triassic marine shale and silt are overlain by a late Middle and early Upper Triassic fluvio-deltaic to shallow marine sequence, and a similar sequence may be present in the Browse Basin. Well and seismic data show that Triassic sedimentation is largely confined to the central basinal area between the Prudhoe Terrace and the Scott Plateau (Allen & others, 1978).

While a decrease in water depth in the Late Triassic (Rhaetian) led to the deposition of a regressive paralic sequence over most of the basin at this time, fluvio-deltaic sandstone and claystone characterised the Late Triassic along the eastern and southern basin margins (Lynher No.1, Yampi No.1). The adjacent Kimberley Block to the east is the probable source of these sediments, although dipmeter logs from the Scott Reef wells indicate that sediments may also have been supplied from the Scott Plateau area (Powell, 1976).

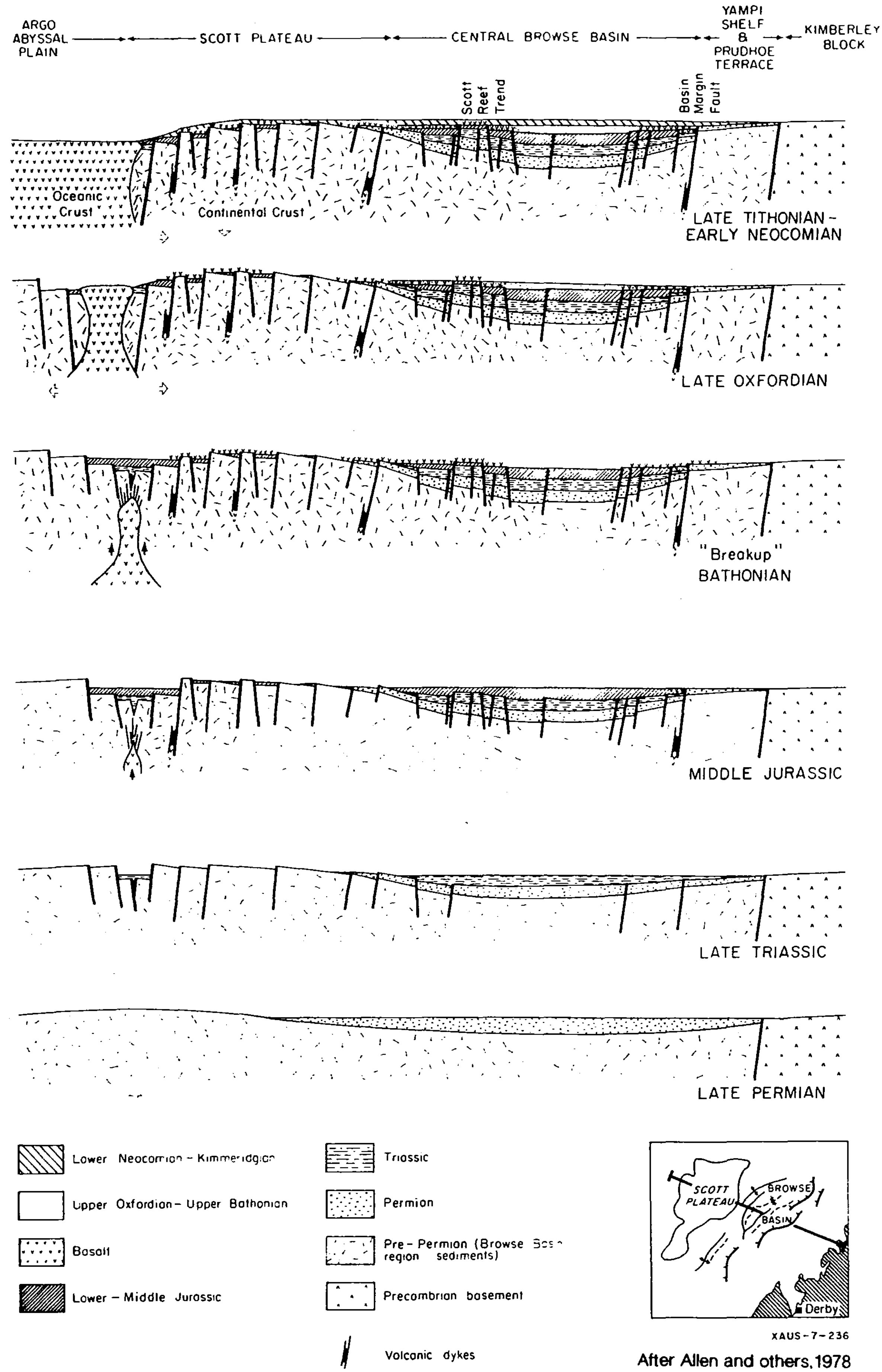


Figure 2. Structural evolution, Browse Basin.

Near the end of the Triassic, tensional stress associated with rifting resulted in extensive block faulting and terminated Triassic sedimentation over much of the Browse Basin. This Late Triassic event imparted a northeast-southwest structural grain on the Browse Basin and probably caused uplift of the Ashmore Platform to the north at this time. On the eastern basin margin, a stratigraphic break between the Late Triassic and Early Jurassic in the Yampi No.1 well is taken as evidence for this tectonism. An angular discordance overlying a block-faulted sequence (observed in seismic data over most of the basin) is thought to correlate with this Late Triassic/Early Jurassic tectonic event (Allen & others, 1978).

Typical rift valley sedimentation ensued, with the deposition of a Early Jurassic 'red bed' sequence in Lombardina No.1), overlain by Early to Middle Jurassic fluvio-deltaic clastics and minor coal. A number of local marine incursions have also occurred within this sequence. Early to Middle Jurassic sediments are thought to be present between the outer edge of the Prudhoe Terrace and the eastern margin of the Scott Plateau.

One of the wells drilled by the Glomar Challenger in 1972 (DSDP 261), as part of the Deep Sea Drilling Project (DSDP), indicates that new oceanic crust was being created along a spreading ridge to the west of the Scott Plateau during the late Middle to early Upper Jurassic (Powell, 1976). Widespread basaltic outpourings and pyroclastics associated with this rifting event are found in the Middle to Late Jurassic in a number of Browse Basin wells (Scott Reef No.1, Yampi No.1, Lombardina No.1, Buffon No.1, Brecknock No.1) (Plate 1).

In the late Middle Jurassic, an episode of block faulting associated with this volcanism marked the end of the rifting phase. A basinwide unconformity developed at this time and is referred to as the 'breakup' (Jb) unconformity (Crostella, 1976; Powell, 1976; Willis, 1988). A stratigraphic break seen in most of the Browse Basin wells at this time, indicates significant uplift took place. The precise effects of this uplift are uncertain, although it is interpreted that there was at least some rejuvenation of Triassic block faulting (Allen & others, 1978).

Post-breakup or drift phase sedimentation commenced in the central Browse Basin in the late Middle Jurassic. Transgressive marine shale and claystone, initially deposited in the central basin, eventually onlapped areas of high relief and the basin margin. By Late Tithonian times, the Scott Reef structure had been covered by marine claystone, and sediments had onlapped much of the Prudhoe Terrace and the southern margin of the Ashmore Platform (Allen & others, 1978). On the eastern basin margin, deltaic to marginal marine sedimentation prevailed through most of the Late Jurassic. Late Jurassic sediments encountered in Prudhoe No.1, Adele Island No.1, Yampi No.1 and Heywood No.1 typically comprise interbedded sandstone, siltstone and claystone.

At the end of the Jurassic, a regressive sequence of estuarine and deltaic sandstone, siltstone and claystone of Early Neocomian age was deposited on the eastern flank of the basin (Yampi No.1, Adele Island No.1, Leveque No.1, Rob Roy No.1). Lack of well control in the central Browse Basin has made it difficult to determine the basinward extent of these sediments. Near the end of the Early Cretaceous, subsidence of the Ashmore Platform and the Scott Plateau was complete and a free-circulating, open oceanic system had been established in the Browse Basin (Powell, 1976). Rejuvenation of some of the pre-breakup faults in the Late Jurassic and Early Cretaceous may have been due to stresses associated with the sinking of the outer basin margin and a general northwest tilting of the shelf (Allen & others, 1978).

Transgressive conditions returned at the end of the Neocomian with the deposition of shelf claystone and hemi-pelagic carbonates over much of the Browse Basin. At this time, transgressive nearshore sandstones onlapped the Yampi Shelf on the eastern basin margin. In Londonderry No.1, Early Cretaceous sandstone directly overlies Precambrian basement. A regression in the Campanian led to the deposition of a thick sequence of prograding nearshore sandstone on the eastern flank of the basin (Brewster No.1A, Heywood No.1, Rob Roy No.1, Prudhoe No.1, Yampi No.1 and Adele Island No.1).

Sandstone deposition on the eastern margin of the Browse Basin is virtually continuous from the Late Cretaceous to the end of the Eocene. The presence of coal and inner shelf or lagoonal carbonates interbedded with these sands, suggests a non-marine to inner shelf depositional environment (Allen & others, 1978). Elsewhere in the basin, shelf carbonate deposition predominates.

In the Oligocene, uplift and erosion occurred over most of the inner shelf, and a pronounced stratigraphic break is seen in all wells (with the exception of those on Scott Reef) at this time. Carbonate sedimentation continued in the Late Tertiary with the subsidence of the outer shelf, leading to the deposition of a series of thick, prograding carbonate wedges (Willis, 1988). Tensional forces in the late Tertiary have established a pattern of young faulting in the northern Browse Basin (Allen & others, 1978).

3. EXPLORATION HISTORY

(S.J. Cadman)

Exploration of the Browse Basin commenced in 1963 when an aeromagnetic survey of the area undertaken by Woodside (Lakes Entrance) Oil Company N.L. revealed the presence of a sedimentary basin seaward of the Kimberley Block. Initially, Exploration Permit 213H (Figure 3a), covering an area of approximately 164 000 square kilometres (including the Browse Basin), was granted to the above company under the Petroleum Act (1936). In 1964, Woodside successfully sought farmin partners to explore the acreage and, in that year, the 'Northwest Shelf Joint Venture' was formed - a consortium of companies comprising Woodside (Lakes Entrance) Oil Company N.L., BOC of Australia Ltd, Shell Development (Australia) Pty Ltd, California Asiatic Oil Company and Mid-Eastern Oil N.L.

Between 1964 and 1968, seismic surveys totalling approximately 4100 line kilometres were shot. The initial reconnaissance surveys used a dynamite energy source, although some semi-detailed coverage was acquired over the Scott Reef area using the Aquapulse system. Additional coverage was provided by BMR gravity, magnetic and seismic (sparker) surveys (Whitworth, 1969).

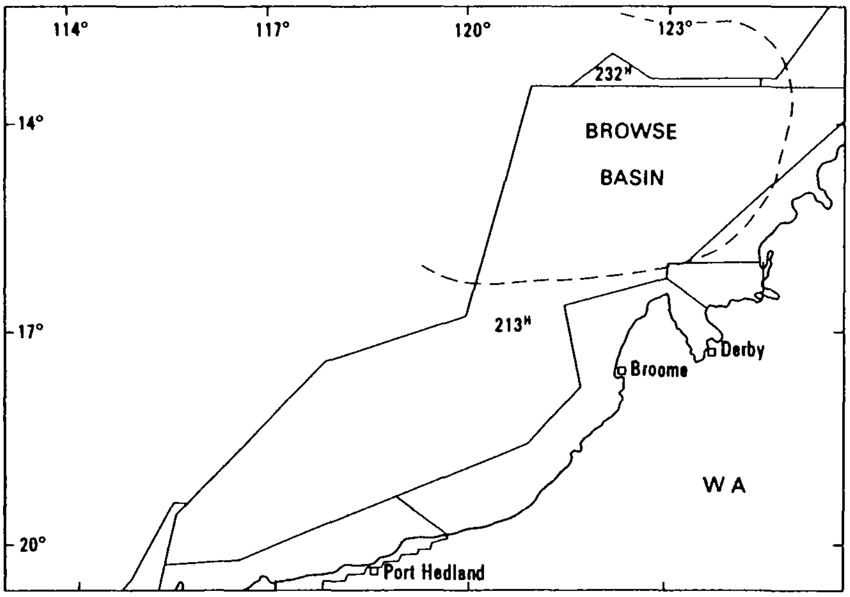
New legislation proclaimed in September 1969 saw the conversion of existing tenements held by the Joint Venture (213H) into several new permits (WA-32-P, WA-33-P, WA-34-P, WA-35-P and WA-37-P) (Figure 3a). Over the following five years, a total of approximately 22 000 line kilometres of seismic data of varying quality was acquired using predominantly airguns and 24-fold coverage.

The first well drilled in the Browse Basin proper was Leveque No.1. Drilled in 1970 as a stratigraphic test of the eastern Browse Basin margin, it was plugged and abandoned with no significant hydrocarbon shows after reaching a total depth of 899 metres in Precambrian basement. The following year in 1971, Lynher No.1 tested an anticlinal structure on the outer margin of the Leveque Shelf and was also plugged and abandoned without encountering hydrocarbons.

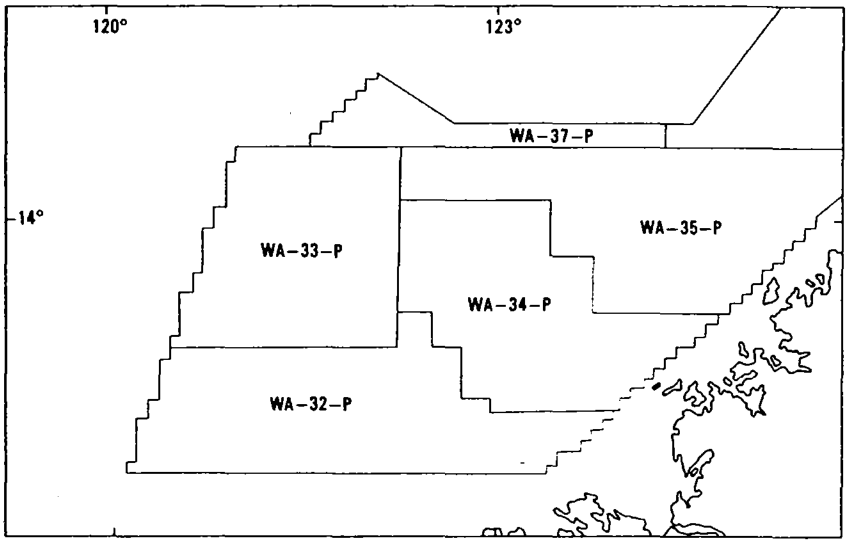
That same year, the most significant hydrocarbon discovery in the Browse Basin to date was made. Scott Reef No.1, drilled on the culmination of the Scott Reef Trend, encountered gas and condensate in Lower to Middle Jurassic and Upper Triassic sandstones.

Between 1972 and 1975, a further six wells were drilled by the joint venture. Rob Roy No.1 and Londonderry No.1 were drilled as stratigraphic tests of the northeastern basin margin, while Heywood No.1, Prudhoe No.1 and Yampi No.1 (located on, or near the Prudhoe Terrace) were

AT 31st DECEMBER 1964



AT 31st DECEMBER 1968



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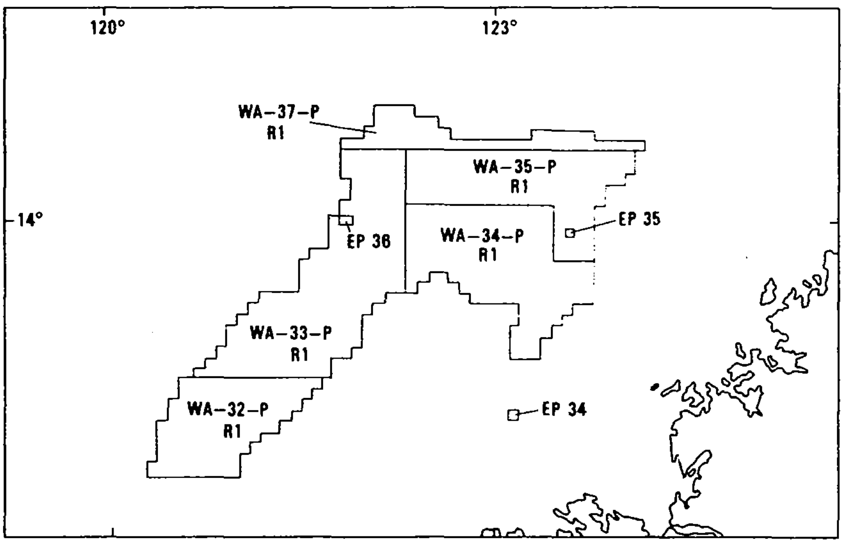


Figure 3a. Permit status 1964-1975.

subsequently found not to have tested valid closures. However, traces of residual oil were extracted from a core taken in Early to Middle Jurassic sandstones in Yampi No.1. Fluorescence with a trace of live oil in the drilling mud was noted while drilling Late Jurassic sandstones in Heywood No.1.

Lombardina No.1, drilled in 1974 to test an anticlinal feature with some fault-dependent closure on the margin of the Leveque Shelf, encountered minor fluorescence in Middle to Late Jurassic sandstones.

In 1975, at the end of the initial permit terms, approximately 60 % of the original permit areas was relinquished and the remaining acreage renewed for a further five years (Figure 3a). During this first renewal period a further six wells were drilled (excluding those drilled on the northern margins of the basin in the Territory of the Ashmore and Cartier Islands), and a further 6700 line kilometres of seismic data acquired.

Scott Reef No.2A, drilled in 1977 as a stepout well on the Scott Reef accumulation, was plugged and abandoned after encountering gas in a transition zone in Middle Jurassic sandstones.

Caswell No.1, located in the central Browse Basin, did not reach its programmed Jurassic objectives but encountered live oil and gas in what were interpreted to be thin, overpressured Early Cretaceous sands.

Brecknock No.1, spudded in 1979 as a test of a drape anticline south of the Scott Reef discovery, recovered gas in a DST conducted in Early to Middle Jurassic sandstones. Encouraging gas shows were also noted in Buffon No.1, a faulted drape anticline drilled to the northeast of Scott Reef in 1980. Here, high gas readings were recorded in a thick volcanic sequence of probable Middle Jurassic age. However, RFTs and a DST conducted within this interval indicated tight formation with probable fracture porosity.

In that same year, Brewster No.1A, (also drilled as a test of a drape anticline) encountered gas in sands of Late Jurassic age. Gas was found to be bleeding from a core cut in this interval, although porosity was generally poor (4.4 to 12.7 %). Barcoo No.1, spudded in 1980 (drilled in the southern Browse Basin), was plugged and abandoned and has been subsequently interpreted not to have tested a valid structure.

During 1976, some of the Browse Basin acreage relinquished by the Joint Venture in 1975 at the conclusion of the first term of the permit, was re-permitted and released to the exploration industry. Oberon Oil Pty Ltd successfully applied for acreage on the southeastern basin margin

(WA-104-P) and Oxoco International Inc took up WA-68-P in the northeastern Browse Basin (Figure 3b).

At the end of the First Renewal Term, in 1980, further acreage was relinquished. In the decade that followed, most of the Browse Basin vacant acreage was re-permitted (Figures 3b, 3c).

Since 1980, a further seven wells have been drilled in the Browse Basin. North Scott Reef No.1 (1982) tested a drape anticline north of the Scott Reef No.1 gas/condensate discovery. Gas and condensate were recovered in an RFT tool from Jurassic sandstones in this well.

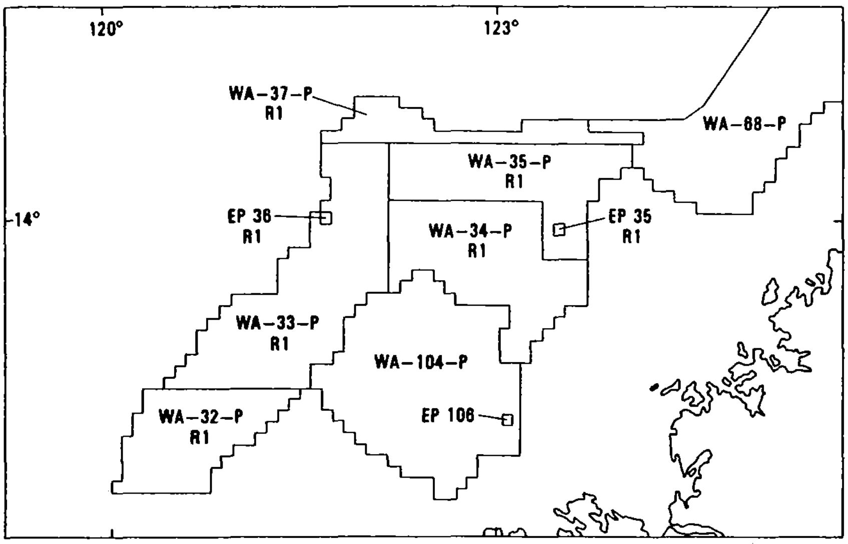
Caswell No.2, a step-out well to the Caswell No.1 oil discovery was drilled in 1983. Oil and gas were recovered from a Campanian sandstone, although the Jurassic objective was thought to be outside structural closure.

Echuca Shoals No.1, drilled in the same year, tested a fault block with minor drape at Jurassic and Early Cretaceous levels. High gas readings were noted while drilling the Early Cretaceous, Jurassic and Permian sections and the presence of a gas accumulation in Jurassic sandstones has been inferred from logs.

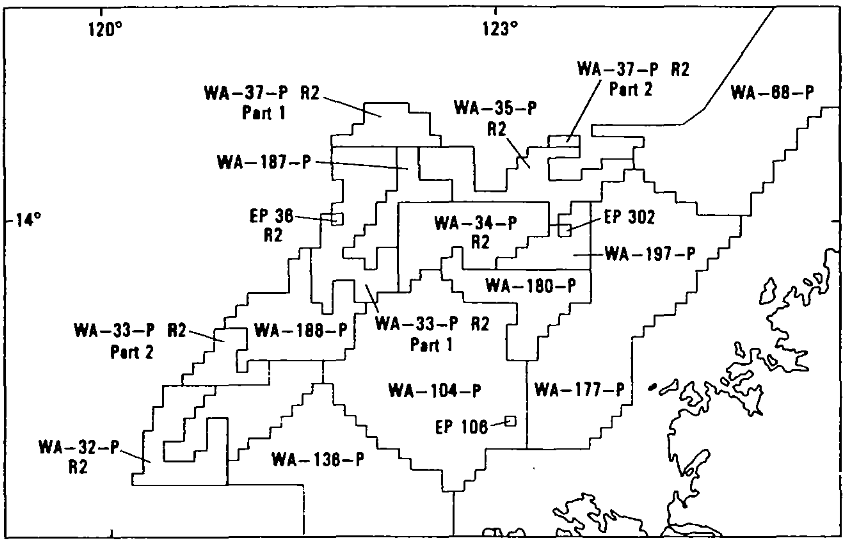
The two most recent wells drilled in the Browse Basin (Trochus No.1 and Buccaneer No.1) were both plugged and abandoned without encountering significant hydrocarbon shows.

Table 1 summarises the wells drilled in the Browse Basin, and Table 2 lists the exploration activities carried out in each of the permits held in the basin. The hydrocarbon discoveries and the wells with significant shows in the basin are discussed in more detail in Chapter 7 and Appendix 1.

AT 1st JANUARY 1979



AT 1st JANUARY 1983



AT 1st JANUARY 1989

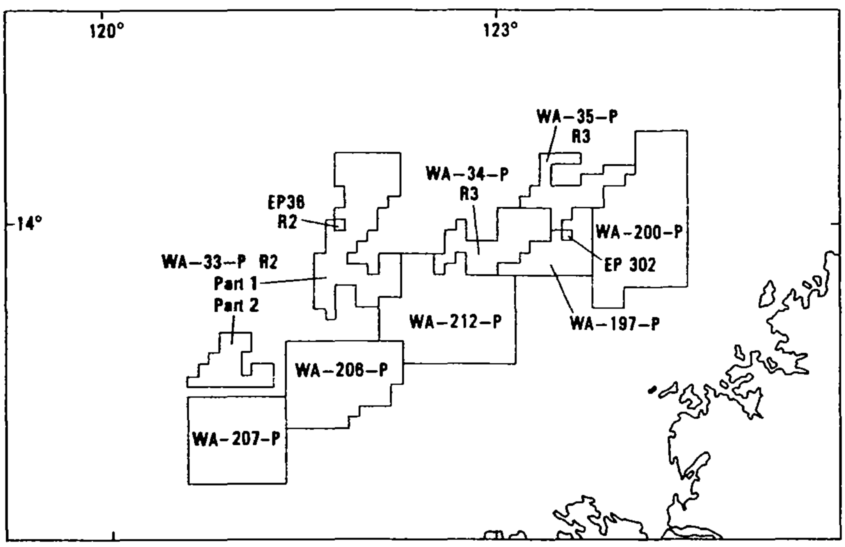
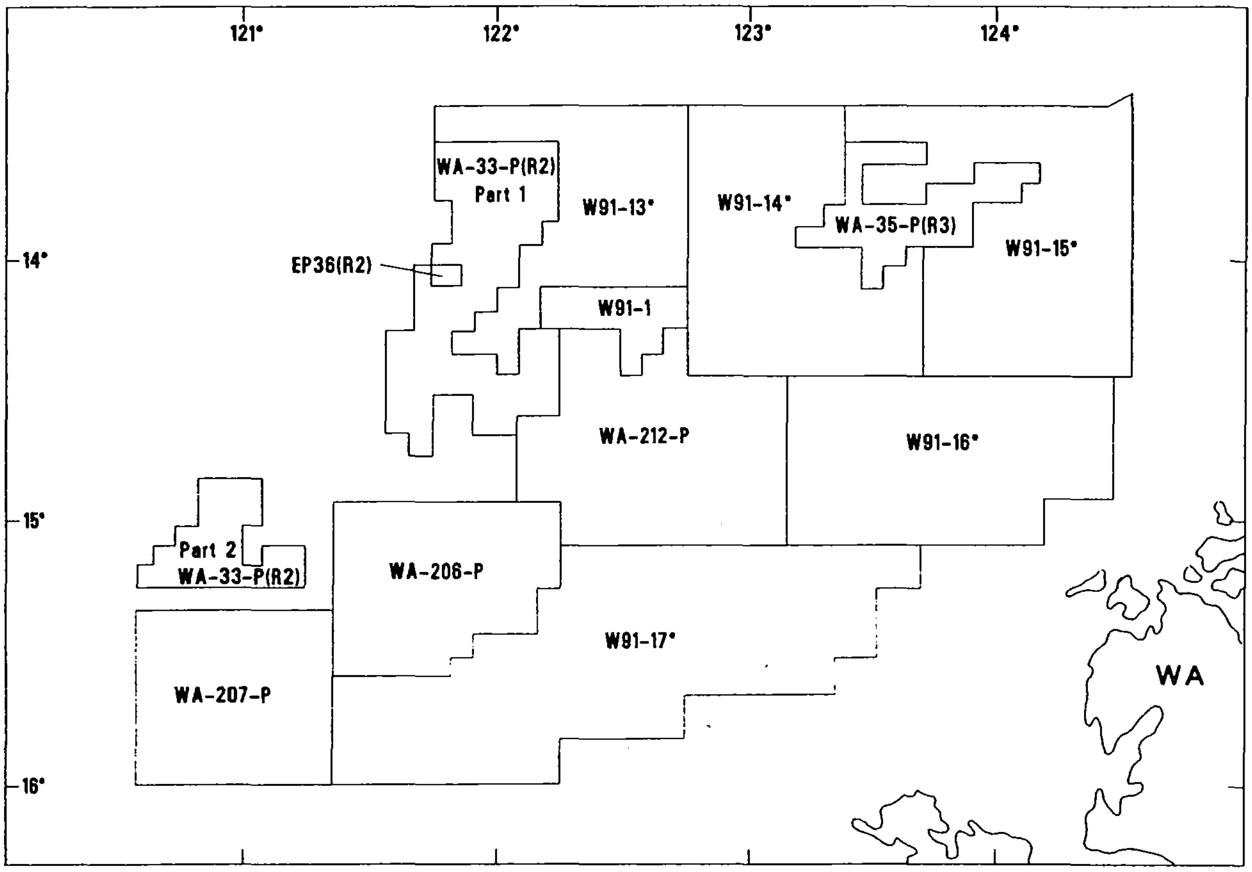


Figure 3b. Permit status 1979-1989.



* Gazetted acreage, Release No.2, 1991

Figure 3c. Current permit status Browse Basin, November 1991.

Table 1. Exploration wells drilled inBrowse Basin study area

WELL	TD DATE	OBJECTIVES	STRUCTURE	HYDROCARBON INDICATIONS	REMARKS
Leveque No. 1	1970	Mesozoic	None	None	Stratigraphic test of eastern Browse Basin margin.
Lyner No. 1	1970	L. Cretaceous	Faulted Anticline	None	Structure considered to be very young feature.
Scott Reef No. 1	1971	Tertiary	Drape Anticline	Middle Jurassic/Upper gas sands	Drilled on culmination of Scott Reef Structural trend. Gas Discovery.
Rob Roy No. 1	1972	U. Jurassic	None	None	Drilled to test postulated carbonate buildup (subsequently found to be pre-Jurassic erosion surface).
Yampi No. 1	1973	Triassic	None	Residual oil extracted from core in L-M Jurassic. High gas readings throughout section.	Subsequently found not to have tested valid structural closure.
Londonderry No. 1	1973	L. Cretaceous	None	None	Stratigraphic test of eastern Browse Basin margin.
Heywood No. 1	1974	Triassic	None	Live oil in mud and fluorescence in U. Jurassic section	Drilled on what was interpreted to be a Triassic horst block. No structural closure.
Lombardina No. 1	1974	L. Jurassic	Faulted Anticline	Minor fluorescence in M-U Jurassic	Young structure, formed by NW tilting of basin in Tertiary.
Prudhoe No. 1	1974	M.-L. Jurassic	None	None	Drilled on fault-bounded structure on inner basin margin. No structural closure.
Scott Reef No. 2A	1977	M. Jurassic	Drape Anticline	Gas in M. Jurassic section	Step-out well. Gas transition zone encountered in M. Jurassic.
Caswell No. 1	1977	M.-L. Jurassic	Drape Anticline	Free oil in mud and fluorescence in Albian sandstones	Did not penetrate Jurassic section due to mechanical problems.
Brecknock No. 1	1979	M.-L. Jurassic	Drape Anticline	Gas recovered from DST in L. Jurassic sandstones	Gas discovery.

WELL	TD DATE	OBJECTIVES	STRUCTURE	HYDROCARBON INDICATIONS	REMARKS
Barcoo No. 1	1979	M.-L. Jurassic	None	None	No structural closure.
Buffon No. 1	1980	Triassic-M. Jurassic	Faulted Drape Anticline	High gas readings over M. Jurassic volcanics	DST/RFTs indicate tight reservoir (volcanics) with probable fracture porosity and permeability.
Brewster No. 1A	1980	U.-M. Jurassic	Drape Anticline	Gas bleeding from core in L. Jurassic sandstone	Gas discovery inferred from logs. Tight reservoir.
Adele Island No. 1	1982	Jurassic	None	None	Drilled to test possible closed structure centred on Adele Island.
North Scott Reef No. 1	1982	U. Jurassic	Drape Anticline	Gas/condensate recovered from RFT in Jurassic sandstone	Gas discovery.
Caswell No. 2	1983	M.-L. Jurassic	Drape Anticline	Oil and gas recovered in RFT from Campanion sandstone	Outside structural closure at Jurassic level. Step-out well to Caswell No. 1.
Echuca Shoals No. 1	1983	Jurassic/Triassic	Fault block with minor drape	High gas readings in E. Cretaceous, Jurassic and Permian	Gas accumulation (Jurassic) inferred from logs.
Browse Island No. 1	1986	Stratigraphic well	None	None	Drilled to determine thickness and interval velocity of a surface reef at Browse Island.
Buccaneer No. 1	1989	E.-M. Jurassic	Fault, with some dip closure		Drilled to test fluvio-deltaic and marine sandstones of Early Jurassic age.
Trochus No. 1	1990		Updip test of Lynher No. 1	None	Plugged and abandoned. (Dry)

Table 2. Permit status - Browse Basin

PERMIT	PERMIT TERM	OPERATOR	PERMIT SIZE (Graticular blocks)	SEISMIC SURVEYS	LINE KILOMETRES SEISMIC	WELLS
213H	1963-1968	'Northwest Shelf Joint Venture'		Montebello-Mermaid BMR (Record 1969/99)	4100 km (total)	
WA-32-P	1969-1975	Bocal, Woodside, Shell		Adele-Scott (1969) Legendre-Marie (1969) Tryal-Evans (1970) Trimouille-Dillon (1971) Prudhoe-Hibernia (1972) Mermaid-Cartier (1973) Kendrew-Cootamundra (1974)	NOTE: Most surveys completed 1969-1975 also covered permits WA-33, 35 and 37-P	Lynher No. 1 (1970) Leveque No. 1 (1970) Lombardina No. 1 (1974)
WA-32-P(R1)	1975-1980	Bocal, Woodside, Shell	100	Tessa-Troubadour (1976) Woodbine-Victovia (1979)	298 km 70 km	Barcoo No. 1 (1980)
WA-32-P(R2)	1980-1985	Woodside	50	Dampier-Broome (Project 81D) (1981) (Project 82D) (1982)	151 km 215 km	
WA-33-P	1969-1975	Bocal, Woodside, Shell		See WA-32-P		Scott Reef No. 1 (1971)
WA-33-P(R1)	1975-1980	Bocal, Woodside, Shell	194	Tessa-Troubadour (1976) Hermite-Barton (1979) Woodbine-Victoria (1979)	672 km 121 km 417 km	Scott Reef No. 2 (1977) Scott Reef No. 2A (1977) Brecknock No. 1
WA-33-P(R2)	1980-1985	Woodside	97	Dampier-Broome (1981)] 1982/2DW (1982) Lewis-Brecknock (1983)	1084 km 434 km 291 km	North Scott Reef (1977)
WA-33-P (R3)*	1985-?	Woodside	48	Permit not yet renewed pending boundary decision		

Table 2. Permit status - Browse Basin (cont'd)

PERMIT	PERMIT TERM	OPERATOR	PERMIT SIZE (Graticular blocks)	SEISMIC SURVEYS	LINE KILOMETRES SEISMIC	WELLS
WA-34-P	1969-1975	Bocal, Woodside, Shell		See WA-32-P		Yampi No. 1 (1973)
WA-34-P(1)	1975-1980	Woodside	149	Tessa-Troubador (1976) Haycock-Laminaria (1977) Hermite-Barton (1979) Woodbine-Victoria (1979)	668 km 84 km 162 km 87 km	Caswell No. 1 (1978)
WA-34-P(R2)	1980-1985	Woodside	74	Dampier-Broome (1981) 1982/2DW (1982) Caswell-Echuca (1985)	181 km 563 km 300 km	
WA-34-P(R3)	1987-1992 (surrendered 1989)	BHP	37	BW87 (1988)	587 km	
WA-35-P	1969-1975	Bocal, Woodside, Shell		See WA-32-P		Londonderry No. 1 (1973) Rob Roy No. 1 (1972) Prudhoe No. 1 (1974)
WA-35-P(R1)	1975-1980	Bocal, Woodside, Shell	123	Tessa-Troubadour (1976) Haycock-Laminaria (1977) Hermite-Barton (1979) Woodbine-Victoria (1979)	626 km 707 km 31 km 120 km	
WA-35-P(R2)	1980-1985	Woodside	62	Dampier-Broome (1981) 1982 2DW (1982) Caswell-Echuca (1985)	208 km 961 km 308 km	Brewster No. 1A (1981) Echuca Shoals No. 1 (1984)
WA-35-P(R3)*	1987-1992	Shell	31	BW87 (1988)	474 km	Buccaner No. 1 (1980)
WA-37-P	1969-1975	Bocal, Woodside, Shell	-	See WA-32-P		Heywood No. 1 (1974)

Table 2. Permit status - Browse Basin (cont'd)

PERMIT	PERMIT TERM	OPERATOR	PERMIT SIZE (Graticular blocks)	SEISMIC SURVEYS	LINE KILOMETRES SEISMIC	WELLS
WA-37-P(R1)	1975-1980	Bocal, Woodside, Shell	59	Tessa-Troubadour (1976) Haycock-Laminaria (1977) Hermite Barton (1979) Woodbine-Victoria (1979)	417 km 165 km 34 km 73 km	Buffon No. 1 (1980)
WA-37-P(R2)	1980-1985 (surrendered 1983)	Woodside	30	Dampier-Broome (1981 1982 2DW (1982)	122 km 63 km	
WA-68-P	1977-1983 (expired 1983)	Oxoco Int.	249	Penguin Shoal (1980) North Whimbrel (1981)	250 km 164 km	
WA-104-P	1978-1984 (cancelled 1983)	Oberon Oil	242	Fraser-Inlet (1979) Churchill (1981) Adele Island (1981)	1083 km 850 km 162 km	Adele Island No. 1 (1982)
WA-177-P	1981-1987 (relinquished 1983)	Weaver Oil & Gas	233			
WA-180-P	1982-1988 (surrendered 1987)	Seahawk Oil	61	Calliance Reef (1984) Fantome (1986)	508 km 480 km	
WA-187-P	1982-1988 (surrendered 1983)	Esso	32	BE82A (1983)	2016 km	
WA-188-P	1982-1988 (surrendered 1984)	Esso	71	BE82B (1983)	2040 km	
WA-197-P	1982-1988	Seahawk Oil	31	Calliance Reef (1983) Scobell (1985) Fantome (1985)	509 km 201 km 121 km	Browse Island No. 1 (1986)

Table 2. Permit status - Browse Basin (cont'd)

PERMIT	PERMIT TERM	OPERATOR	PERMIT SIZE (Graticular blocks)	SEISMIC SURVEYS	LINE KILOMETRES SEISMIC	WELLS
WA-200-P	1985-1991 (surrendered 1988)	Marathon	116	Capella (1986)	1502 km	
WA-206-P*	1988-1994	Ampol	77	Olga (1989)	424 km	
WA-207-P*	1989-1994	Bridge	72			Trochus No. 1 (1991)
WA-212-P*	1989-1995	Ampolex	105			

* Current permits

4. <u>REGIONAL GEOPHYSICS</u>

(T.U Maung)

The Browse Basin, an offshore area, in the northwestern part of Australia, was revealed by the Rowley Shoals, Scott Reef and Sahul Bank aeromagnetic survey carried out for Burmah Oil Company (BOC) and its partners in 1963. The survey indicated the presence of sufficient sedimentary thickness to make the area prospective as a petroleum province.

4.1 HISTORY OF SEISMIC EXPLORATION

The first reconnaissance marine seismic survey, that is, the northwest Australia marine seismic survey, was carried out in 1964. This survey confirmed the very general results of the aeromagnetic survey and provided a number of structural leads. It was followed by the following surveys:

1965 - Montebello-Mermaid Shoal marine seismic survey

1966 - Rankin-Troubadour marine seismic survey

1967 - Ashmore Reef shallow water marine seismic survey

1967 - Scott-Cartier marine seismic survey

1968 - Offshore Canning-Seringapatam marine seismic survey.

All these surveys were financially assisted under the Petroleum Search Subsidy Act (PSSA). The 1965 survey was a relatively large semi-reconnaissance marine seismic program conducted to locate structural features that could be detailed for drilling. In the 1966 survey, some of the most promising areas were detailed and an attempt was made to obtain sufficient surounding control for an understanding of the structural features. Each structural feature was further examined with a refraction depth probe and expanded spread velocity profiles. The 1967 Scott-Cartier survey included a detail program over Scott Reef. This was followed by further detailing over this feature during the 1968 Offshore Canning-Seringapatam survey, when a non-dynamite energy source was used.

In addition, BMR conducted extensive combined marine geophysical surveys over the North West Shelf of Australia incorporating gravity, magnetic, sparker reflection and some airgun refraction data in 1968 (Whitworth, 1969). These data provided a very valuable framework for regional studies.

Commencing with the 1964 survey, the techniques employed in successive years are a documentary of the rapid technical evolution of the marine seismic method of exploration. The marine seismic surveys carried out between 1964 and 1967 used explosive energy source and analog recording systems. In 1968, in the case of offshore Canning-Seringapatam seismic survey, a non-explosive energy source, the sleeve gun with the trade name of Aquapulse, was used for the first time in conjunction with the digital recording system. The sampling rate was 4 milliseconds. Also, computer derivation of average velocities from normal moveout scanning for the stacking of seismic data was introduced for the first time.

The use of a non-explosive energy source and digital recording system resulted in cost reduction, making it feasible to deconvolve the data and apply time variant filtering routinely. Experimentation of various sum/stack combinations and shooting densities, using a 48 channel, 2400 metre streamer cable, suggested that a fair quality data can be obtained anywhere in the basin if processed by vertically summing four traces to produce 1200 % coverage.

In the 1969 Legendre-Marie and Adele-Scott seismic surveys, this general technique was continued, except in areas where extra detail was desired. In these areas, the data were processed by vertically summing two traces to produce 2400 % coverage. In these surveys, the Type N Radyst system was replaced by the XR Shoran system for navigation, after adequate comaprison of the results. This enabled 24 hour operation and this navigation system was adopted in the 1970 surveys.

In some areas covered by the 1969 Legendre-Marie seismic survey, the accuracy of the existing navigation systems at that time was doubtful in some instances because of extremely long-range and net-work geometry. Assuming the equipment was in perfect calibration, the theoretical repeatability of the shotpoint positions was approaching 152 metres (500 feet). This navigation shortcoming resulted in bad ties which were often interpreted as navigation errors. Only two lines were suspected of positional errors for this survey.

The velocity analyses, for these seismic surveys, were generated at approximately 16.1 kilometre (10 mile) intervals along the strike lines and at approximately 8.05 kilometre (5 mile) intervals on dip lines. They were then used for regional projections. However, the data quality of these surveys occasionally suffered from insufficient velocity control in situations where the velocity changed rapidly, particularly in areas where more detail was desired.

The 1969 Legendre-Marie and Adele-Scott seismic surveys were wide-ranging programs of reconnaissance nature. Improved velocitiy studies, higher density shooting and stacking provided great improvements in the quality of the data compared to the previous years. These 1969 reconnaissance grids confirmed the presence of a separate basin in the offshore area of the Kimberly Block containing a maximum of over 10 000 metres of Phanerozoic sediments.

In the 1970 Tryal-Evans survey, an attempt was made to improve penetration and record quality by using a combination of two regular and two 'big' Aquapulse guns. This survey included some detail projects in the area and resulted in the drilling of the Lynher No.1 and Leveque No.1 wells and the maturing of the Scott Reef No.1 as a drilling location.

In reviewing the geophysical operations in the area, the most significant factor during this period was the steady decline in the cost of computer time. In 1970 cost reduction permitted all data to be processed by vertically summing two traces to produce 2400 % coverage. In addition, the cost reduction made it possible the deconvolution of the seismic data before and after stacks using continuous computer velocity analysis at every stack point. This process made a significant improvement in data quality, particularly in the deeper sections.

Another improvement in the case of the 1970 seismic survey was that the navigation data were post plotted scale factored on the new Australia Map Grid (AMG), Universal Transverse Mercator Projection. The previous base maps were scale factored and repositioned on the AMG maps from the non-scale factored positions.

The 1971 Trimouille-Dillon seismic survey was recorded using the Maxipulse energy source and a 48 channel, 2400 metres streamer cable with 2 milliseconds sampling rate. The data were processed to produce 4800 % coverage. The data at the shallower horizons were fair to good, but were generally poor at the deeper levels. Some of the filtered time sections from this survey were converted to depth sections by the Western Geophysical Company, using average velocity functions (with Dix correction applied) (Dix, 1955) provided by BOC. These velocity functions were obtained from velocity analyses made on a nearly continous basis. The results of this survey enabled the selection of the Rob Roy No.1 drilling location.

The 1971 Scott Reef Detail seismic survey was carried out to provide further detail control over the Scott Reef structure following the successful completion of the Scott Reef No.1 well.

The 1972 Browse Basin seismic survey was a comprehensive semi-detail and detail program. This survey covered a large area of the Browse Basin where water depths were less than 200 metres and where the 1969 reconnaissance survey had indicated structural features. This survey essentially subdivided the approximately 24 kilometre (15 mile) grid of the 1969 survey to approximately 8 kilometre (5 mile) grid, although greater emphasis was placed on the more prospective areas. In the areas just north of the Leveque Shelf, the 24 kilometre (15 mile) grid was subdivided into a 12 kilometre (7.5 mile) grid. This survey made seismic ties to all available wells in the area (Scott Reef No.1, Rob Roy No. 1, Leveque No.1 and Lynher No.1 wells).

In 1972, the use of 48 channel, 3200 metre cable, 16 tuned airgun array source and the Texas Instruments DFS III recording system yielded considerable improvements in data quality when processed to produce 2400 % coverage. The resolution of primary events was much better than the previous years' data for all levels down to 6 seconds.

In 1972, the North Scott Reef Detail, Prudhoe-Hibernia and Browse Island seismic surveys were also carried out to provide more detail control and to mature some leads into drillable locations.

The available stratigraphic information from wells and the generally good quality seismic data remarkably sped up the evolution of the geologic concepts of the Browse Basin; for example, what used to be known as the Leveque Terrace was changed to the Leveque Shelf. The well data used were both in the basin and in the surrounding areas. The seismic data were considered to be generally good compared to those recorded before 1969 and were obtained with the best existing technology during 1969 to 1972.

The 1973 Mermaid-Cartier seismic survey was of a more reconnaissance nature designed to obtain information in the deeper water portions of the Browse and Canning Basins.

The 1974 Kendrew-Cootamundra seismic survey was designed to mature prospects for drilling and to outline the most prospective areas in the Northwest Shelf Joint Venture consortium's permits prior to relinquishment of some areas.

The 1976 Tessa-Troubadour seismic survey was detailed to semi-detailed in nature, designed to provide more control and to mature prospects for drilling. Excluding the Scott Reef and North Scott Reef areas, this survey resulted in maturing of several prospects into drillable status including the Buffon, Brecknock and Bassett structures. The data were recorded with 48 channel, 3200 metre streamer cable.

In 1977, there was a change in operator from BOC to Woodside. BOC probably left the consortium and Australia at this time. The 1977 Haycock-Laminaria survey was conducted by Geophysical Service Inc. (GSI) for Woodside and was designed to give infill and detail control over widely dispersed leads and prospects. The mapping of the data from this survey led to maturing of the Caswell prospect and drilling of Caswell No.1 well during 1977. This survey also defined the Echuca Shoals structure. The data were recorded with 96 channels using 3200 metres or 2400 metre streamer cables in different areas depending on the water depths.

Further detailing of the leads and prospects was carried out by Woodside between 1978 and 1982, which resulted in maturing of some of the leads and prospects, for example, the Brewster prospect drilled in 1980.

In the 1964 to 1978 surveys, which were mainly carried out by BOC and Woodside as operators, the Browse Basin was included as projects which form parts of an overall evaluation program of the permit areas. After 1978, marine seismic surveys were also carried out by other oil companies such as Oberon Oil, BHP Petroleum, Marathon, Ampol, Weaver Oil and Gas, and Bridge Oil.

In 1985, Geophysical Service Inc (GSI) carried out a 2700 kilometre non-exclusive seismic survey over an area covering the northern and western flanks of the Leveque Shelf. In addition, several key lines of 1979 and 1980 vintage were reprocessed in 1986 by GSI and were made available on a non-exclusive basis. These data were useful for regional evaluation of the areas around the Leveque Shelf. The 1985 GSI non-exclusive data also provided ties between the Lyhner No.1, Leveque No.1, Caswell No.1, Barcoo No.1 and Lombardina No.1 wells.

In 1986, Marathon used wavelet processing technology for its Capella seismic survey and carried out amplitude versus offset and normal incident modeling of the Capella prospect. The company also carried out modeling to generate synthetic common depth point records, including reflection and transmission losses, at Heywood No.1 well location (Marathon, 1986c, 1986d).

In 1988, Bridge Oil carried out a 3D seismic survey, using 2400 metre dual streamer cables, 150 metres apart, in the area surrounding the Lyhner No.1 well. The recording vessel traverses were 225 metres apart, so that the subsurface line spacings were alternately 75 metres and 150 metres (Bridge Oil, 1989b). The 3D seismic data were interpreted by using an interactive seismic interpretation work station.

Major advances in data acquisition, processing and interpretation technology during the past 15 years have resulted in a significant improvement in seismic data quality. Good seismic data quality and better stratigraphic and velocity control have enabled better identification and mapping of deeper horizons than was previously possible, and more accurate mapping of horizons already identified in some parts of the Browse Basin.

In the aquisition phase, the increase in coverage from 24- to 75-fold by the use of more hydrophone channels (96 to 300), longer streamer cables (from 2400 metres up to 3750 metres) and the introduction of larger volume airgun arrays and improvements in the airguns to reduce bubble effects, have achieved higher resolution. The introduction to Australia, in 1983, of digital streamer cables using fibre optic technology for data transmission offered improved signal quality by virtually eliminating the effects of leakage and cross-feed interference between channels (Laster, 1985).

In the processing phase, the introduction of wavelet processing techniques has made a particularly useful contribution to the resolution of the seismic section, and the use of pre-stack migration (dip moveout) was used to good effect for improving fault definition. The advent of 3D seismic survey resulted in time-slice sections and has helped to resolve complex events and correlation problems across fault blocks (Brown, 1986; Denham, 1982; Horvath, 1985; Schultz, 1985).

In seismic interpretation, the development of the interactive seismic interpretation systems has facilitated the rapid construction of accurate structure contour and isopach maps.

The development of new depth conversion methods (Carter, 1989; Cordier, 1985; Denham, 1980; Hubral & Krey, 1980; Hughes, 1985; Marsden, 1989; Sherwood, 1989), improvements in seismic processing techniques, and the additional well control have helped to overcome the time-depth conversion problems in some parts of the the Browse Basin.

4.2 SEISMIC DATA AVALABILITY

Seismic surveys carried out between 1969 and 1989 are listed in Appendix 3 and the seismic coverage of the areas to be released are shown in Plates 23 to 27. The stratigraphic control within the study area of the Browse Basin is provided by 22 wells which are listed in Table 1.

The seismic grid spacing varies across the Browse Basin. The 1964 to 1974 survey data are generally of reconnaissance nature and the seismic lines are oriented in northwest-southeast direction (in the regional dip direction) and northeast-southwest direction (in the regional strike direction). Later surveys lines are of semi-detail and detail coverage and were designed to mature prospects and leads into drillable status.

In the north-western, central-western and north-central parts of the basin around the Buffon, Scott Reef, Barcoo, Central Basin Arch and Inner Basin Arch Trends (Plate 1), the seismic grid spacing varies from 1.5 x 2.5 to 4.0 x 4.0 kilometres and in some areas is as large as 8.0 x 10.0 kilometres. The general seismic grid spacing is fairly sparse in the northeastern, eastern and southeastern parts of the basin on the Prudhue Terrace and Yampi and Leveque Shelves. In these areas the seismic grid spacing varies from 4.0 x 4.0 to 11.5 x 12.0 kilometres and in some areas is as large as 12.0 x 22.0 kilometres.

The seismic line locations for the Gazetted Acreage are shown in Plates 23 to 27; the scale of these maps is 1:100 000. The general seismic grid spacing for these areas are:

- 1.5 X 3.5 to 4.0 X 4.0 kilometres for Area W91-13
- 2.0 X 2.0 to 5.0 X 5.0 kilometres for Area W91-14
- 1.5 X 2.5 to 4.0 X 4.0 kilometres for Area W91-15
- 2.0 X 3.5 to 11.5 X 12.0 kilometres for Area W91-16
- 4.0 X 4.0 to 12.0 X 22.0 kilometres for Area W91-17

The larger grid spacing for Areas W91-15, W91-16 and W91-17 generally lies on the eastern parts of the basin. The eastern parts of Areas W91-15 and W91-16 are located on the Prudhoe Terrace and Yampi Shelf and the eastern part of Area W91-17 is located on the Leveque Shelf.

4.3 SEISMIC DATA QUALITY

All the seismic sections before 1975 were displayed in variable area or a combination of variable area and wiggle trace mode at a vertical scale of 5 inches (12.7 centimetres) per second and later reduced to 2 inches (5.08 centimetres) per second up to 5 seconds. The horizontal scale for the original section was generally 2.7 inches per mile (4.05 centimetres per kilometre), and for the reduced section was generally 1.08 inches per mile (1.70 centimetres per kilometre). The horizontal scale for the reduced sections was found to vary for data of different vintages.

All the seismic sections after 1975 were displayed in variable area mode at a vertical scale of either 5 centimetres per second or 10 centimetres per second. The horizontal scale varies and is generally given as 24 traces per inch, 10 traces per centimetre, 1:50 000 or 1:25 000.

The presence of thick Tertiary carbonates over much of the Browse Basin caused poor transmission of seismic energy. They are present within the shallower sections and thicken towards the northwest. The poor tranmission is due to absorption of the energy by the highly variable velocity and density characteristics of these carbonates. These carbonates and their sub-unit boundaries produce a train of strong multiples with stacking velocities close to the primary events in the deeper target zones. The insufficient separation between the normal move out corrections of the multiple and primary events makes the effective attenuation of the multiples very difficult (Allen & others, 1978; Barter & others, 1982; Willis, 1988).

In 1978, these difficulties were overcome by the use of f-k (frequency-wavenumber) domain multiple attenuation program. This program produced significant improvements in seismic data quality so that deep seismic events could be mapped with more confidence. The attenuation of multiples was also helped by the use of long streamer cables as this produces greater normal move out corrections for the primary events than the multiple events. The migration process further improved the quality of the seismic data, particularly in areas of structural complexity (Allen & others, 1978; Barter & others, 1982; Willis, 1988).

The quality of seismic data from 1963 to 1967 was very poor rendering the data unusable because of the unsuitability of:

. explosive energy source

. analog recording system and

. the coverage of generally 100 %, 200 % and 300 %

The quality of the 1968 seismic data was also rather poor although a non-explosive energy source (Aquapulse) and digital recording system were used for the first time.

The seismic data from 1969 to 1977 were poor to fair in the shallower parts, but were poor to very poor in the deeper target zones. As discussed previously, this was due to poor transmission of seismic energy and interference of multiples caused by the shallow Tertiary carbonates and their sub-units.

The seismic data from 1978 to present were fair to good in the deeper target zones because of the progressive application of the following:

. the poor transmission problems were partially overcome by the use of large volume, normal pressure (about 4750 cubic inch, 1800-2000 psi)) or relatively smaller volume (about 1530 cubic inches), high pressure (4500 to 5000 psi) tuned airgun arrays

- f-k domain multiple attenuation program
- longer streamer cables - 3200 metres or 3750 metres
- introduction of digital streamer cables using fibre optics technology for data transmission in 1983
- closely spaced velocity analysis programs to obtain more accurate stacking velocities
- residual static corrections
- higher coverage - 2400 % to 7500 %
- migration

The seismic data after 1978 were found to be superior to those before 1978. However, the post-1978 data were generally more restricted in areal coverage as the surveys were of semi-detail or detail nature.

There is lateral variation in velocities in some areas of the Browse Basin due to both increase in water depths from east to west and to lithological changes within the Tertiary. These lateral changes made it essential to undertake a careful analysis of seismic velocities in order to produce a reliable time-depth conversion (Faust, 1951, 1953). The operating oil companies produced root mean square (RMS) velocity maps showing the stacking velocities for each seismic horizon, which were tied at intersections. Interval velocities were then computed by correcting erroneous values from these values. RMS velocity functions were calculated by smoothing, with a smoothing radius of 5 kilometres, to produce new interval velocities which were used for the calculation of average velocities. These average velocities were then applied to the reflection times for depth computations.

Time-depth conversion, particularly for the older pre-1978 survey data, was affected by poor velocity analysis and by difficulties in deciding how much of the measured velocity variation was due to lithogical changes and how much was due to noise. Also there was evidence to suggest a bulk shift in measured velocities from one vintage of velocity analysis to another.

4.4 REGIONAL SEISMIC MAPPING

The horizons indentified and used for seismic interpretation in the Browse Basin, according to Barter & others (1982), Elliott (1990), and Willis (1988) are:

Symbol	Seismic Horizon	Relationships
E	Base Miocene (intra Early)	Unconformable
M	Base Eocene disconformity	Disconformable
X	Base Tertiary unconformity	Unconformable
D	Intra Upper Cretaceous (Turonian)	Unconformable disconformable
F	Intra Aptian	Disconformable unconformable
Jc	Upper Jurassic (near top Tithonian)	Unconformable disconformable
Jb	'Breakup' unconformity	Unconformable disconformable
T	Lower Jurassic/Upper Triassic unconformity	Unconformable
O	Top Permian	Unconformable
B	Basement/Precambrian igneous metamorphic rocks	Unconformable

Generalised time structure contour maps were synthesised and compiled from interpretive company data at a scale of 1:500 000 by PRAB for the following seismic horizons:

. Near Jb ('breakup' unconformity) horizon

. Near D horizon (Intra-Upper Cretaceous) and

. Near Base Tertiary unconformity

They are shown in Plates 6, 5 and 4, respectively. The maps were primarily prepared to illustrate the regional structural and fault trends and the regional dips of the potential reservoir rocks which could affect hydrocarbon migration.

4.4.1 Near Jb Horizon ('Breakup' Unconformity)

Generalised time structure contour map of the 'breakup' unconformity horizon (near Jb) is shown in Plate 6. The sedimentary rocks in the Browse Basin are generally recognised to be comprised of two major series: the Permian to Lower-Middle Jurassic sequences and the Late Jurassic to Quarternary sequences. These two major series are separated by a Late Jurassic unconformity, which is recognised as the Jb seismic event (Allen & others, 1978; Barter & others, 1982; Crostella, 1976; Elliot, 1990;

Powell, 1976; Willis, 1988). This unconformity delineates the end of the intra-cratonic rifting phase that occurred along the Northwestern Australian Margin and was dated as Late Jurassic Oxfordian (160 Ma) age by Veevers (1984, 1988).

The Jb horizon is an important mapping horizon because of the presence of the Lower to Middle Jurassic reservoir below it and the overlying Upper Jurassic to Lower Cretaceous marine claystones that act as a seal.

The latest Jurassic to earliest Creteaceous (Upper Tithonian to Lower Neocomian) sandstones, the principal reservoirs of the post-breakup interval, are near the Jc horizon (Allen & others, 1978; Barter & others, 1982; Willis, 1988). The Jc horizon is generally about 400 to 650 metres above the Jb horizon in most of the wells except in Heywood No.1 well, where it is about 1150 metres above Jb horizon. It is, therefore, reasonable to infer that the map of Jb horizon also generally reflects the Jc horizon in the major parts of the basin with less faulting.

Seismic mapping indicates that the Lower to Middle Jurassic sediments are thin or absent in the northwestern (Scott Plateau) and southeastern (Yampi and Leveque Shelves) regions of the basin (Plate 1) (Allen & others, 1978; Elliot, 1990; Powell, 1976).

The mapping also indicates a regional dip from southeast to northwest; the contour value for the Jb horizon is about 700 milliseconds in the southeast around Adele Island No.1 well and increased to about 4100 milliseconds in a structural low area in the northeast (west of the Scott Reef No.1 and No.2A wells). The mapping also delineates many structural and fault trends; the major structural and fault trends are oriented in a northeast-southwest direction and the minor structural and fault trends are oriented in an approximately east-west direction.

The major structural trends are structural closures and noses. They are the Buffon, Scott Reef, Barcoo, Buccaneer Nose (north of Lombardina No.1 well), Central Basin Arch (around Caswell No.1 and No.2 wells) and Inner Basin Arch (around Brewster No.1 well) Trends (Plate 1). A major structural closure, parallel to the Buffon Trend and northwest of the Buffon No.1 well, is observed on this map at water depths of 1020 to 1120 metres. Several major northeast-southwest trending faults are observed around Echuca Shoals No.1, Prudhoe No.1, Buccaneer No.1, and Heywood No.1 wells in the northeastern region and around Yampi No.1 well in the east-central region. These are down-to-the-basin faults along the western edge of the Prudhoe Terrace (Allen & others, 1978). Other northeast-southwest trending faults occur around

Lombardina No.1 and Lynher No.1 wells in the southwestern region.

These major structural and fault trends were probably related to the Late Triassic and Late Jurassic tectonic events. The Late Triassic tectonic event was dated as 230 Ma by Veevers (1988). As some of these structural and fault trends are also observed on the Near D and Near Base of Tertiary horizons, they may also be related to the later structural events that occurred during the Early Cretaceous and Oligocene times.

The east-west oriented minor structural and fault trends are only observed locally in the region east and northeast of the Buffon No.1 well, around the Yampi No.1 well, and in the region just north of the Leveque No.1 well. These structural and fault trends are probably related to local uplifting and tilting which occurred during the Late Jurassic tectonic event. Some of the minor fault trends were probably rejuvenated by later events as some of these faults are observed on the maps of Near D and Near Base Tertiary horizons.

4.4.2 Near D Horizon (Intra-Upper Cretaceous)

A generalised time structure contour map of the Near D horizon is shown in Plate 5. The D horizon is an important horizon due to its relationship with the younger Cretaceous sandstones. These sandstones occur near the F horizon along the basin margins and above the D horizon in parts of the central basin (Bint, 1988; Willis, 1988).

The mapping indicates a regional dip from southeast to northwest; the contour value is about 300 milliseconds in the southeast around Leveque No.1 well and increased to about 3700 milliseconds in a structural low area in the northeast (west of the Scott Reef No.1 and No.2A wells). The mapping also delineates some structural and fault trends oriented in a northeast-southwest direction and some minor fault trends oriented in an approximately east-west direction.

The major structural trends observed as structural closures or noses on this map are the Buffon, Scott Reef, Buccaneer Nose, and Central Basin Arch Trends (Plate 1). The Barcoo structural trend is not well defined on this map and the Inner Basin Arch is observed as a northwest-southeast trending nose north of Brewster No.1A well. The northeast-southwest trending major faults are observed only around Echuca Shoals No.1, Prudhoe No.1, Buccaneer No.1, and Heywood No.1 wells in the northeastern region and around Lombardina No.1 and Lynher No.1 wells in the southwestern region. The major structural and fault trends observed on this map may be formed or reactivated by the stresses associated with the sinking of the outer basin margin and general northwest tilting of the shelf in Early Cretaceous time.

The east-west trending minor faults are observed only locally in the region northeast of the Buffon No.1 well and just north of the Lombardina No.1 well. The faults around the Buffon No.1 well may be related to the Early Cretaceous event. On the other hand, the fault located just north of the Lombardina No.1 well is observed both on this map and the Near Base of Tertiary horizon map and may be formed or rejuvenated by uplifting during the Oligocene time.

4.4.3 Near Base Tertiary Horizon

Generalised time structure contour map of the Near Base Tertiary horizon is shown in Plate 4. The Near Base Tertiary or the X horizon is synthesised and compiled to illustrate the distribution of the Tertiary sedimentary rocks above the Upper Cretaceous sequence.

The mapping indicates a regional dip from southeast to northwest; the contour value is about 500 milliseconds in the southeast around Lynher No.1 well and increased to about 3 500 milliseconds in a structural low area in the northeast (west of the Scott Reef No.1 and No.2A wells). The mapping also delineates fewer structural and fault trends oriented in a northeast-southwest direction than at deeper levels, and one east-west trending minor fault.

The major structural trends observed as structural closures or noses on this map are the Buffon, Scott Reef and Buccaneer Nose. The Central Basin Arch and the Barcoo structural trend are not observed on this map. The Inner Basin Arch is observed as a northwest-southeast trending nose north of Brewster No.1A well as in the case of the D horizon map. The major northeast-southwest trending faults are only observed around Prudhoe No.1, Buccaneer No.1, and Heywood No.1 wells in the northeastern region and around Lombardina No.1 and Lynher No.1 wells in the southwestern region. These major structural and fault trends are observed on the Jb, D and Near Base Tertiary horizons. They may have been reactivitated by uplifting during Oligocene time.

Only one east-west trending minor fault is observed just north of the Lombardina No.1 well on this map and may also be related to the uplift during the Oligocene time.

4.5 REGIONAL SEISMIC CROSS-SECTIONS

Three regional seismic cross-sections, A-A′, B-B′, and C-C′, were interpreted across the Browse Basin to illustrate the major structural features and the regional stratigraphic variations.

The cross-section line A-A' is in general oriented in a west-northwest-east-southeast direction and B-B' is in general oriented in a northwest-southeast direction. These two lines are more or less perpendicular to the major structural trends. The cross-section line C-C' is in general oriented in a northeast-southwest direction and is more or less parallel to the major structural trends. The location of these cross-section lines are shown in Plate 74.

The seismic sections used in the interpretation of these cross-sections are of 1969 to 1974 vintage except for one 1986 (Marathon) seismic section. The well-seismic data used in these cross-sections are shown in Appendix 4.

The most prominent and easily identifiable reflectors on these seismic sections are found to be E, M, D, Jb and B horizons and in some cases also X, F and Jc horizons. The Jb seismic horizon, in some cases, is less prominent and very difficult to interpret, e.g. the northern part of Line 73-1177. The T and O seismic horizons are generally conjectural in the major parts of the three cross-sections as there is less well control for these horizons. The wells that encountered Triassic and Permian sequences and used in the regional cross-sections are:

- Brecknock No.1 - only T horizon
- Echuca Shoals No.1 - both T and O horizons
- Lynher No.1 - both T and O horizons

Other wells that encountered Triassic and Permian and not used in the regional cross-section are:

T horizon only	O horizon only	Both T and O horizons
Barcoo No.1	Prudhoe No.1	Yampi No.1
Scott Reef No.1	Rob Roy No.1	Buccaneer No.1
North Scott Reef No.1		
Mount Ashmore No.1B		
Woodbine No.1		

Other wells located along the northeastern region north of the study area such as Prion No.1 and Puffin No.1, No.2 and No.3 wells also encountered Triassic sequences. The above list provides a general idea of the extent and distribution of the Triassic and Permian sequences and a general guide-line for interpretation of the regional cross-sections.

The T horizon is interpreted and included on the three seismic cross-sections to illustrate the thickness of the Lower to Middle Jurassic sequence and variation in thickness of this sequence across the basin. There are no significant reflection characteristics for this horizon and the interpretation of this horizon on the 1969 to 1974 vintage data is dependent on well control.

The O horizon is interpreted and included on the three seismic cross-sections for completeness and to indicate the approximate levels of this horizon on the three cross-sections. The O horizon is generally observed, to be a very prominent low frequency reflector.

These two horizons are more easily identifiable on the post-1978 seismic sections. They are generally observed as low frequency reflectors and as defining tilted fault blocks below the Jb horizon on these seismic sections.

4.5.1 Cross-section A-A'

The seismic lines, or parts of lines, used on cross-section A-A' are listed in the List of Plates under Plates 10A to 10G.

Except for the section of Line M200-04 (1986) all the other sections have a vertical scale of 2 inches per seconds (5.08 centimetres per second) and generally a horizontal scale of 1.08 inches per mile (1.70 centimetres per kilometres). The horizontal scale varies for data of different vintages. The section of Line M200-04 has a vertical scale of 5.0 centimetres per second and a horizontal scale of 2.0 centimetres per kilometres. The horizontal scales for individual seismic sections are shown on Plates 10A to 10G. The interpreted sections of Lines 74-1372 and 73-1377 are joined together at the intersection point and shown on Plate 10F.

The quality of the M200-04 seismic section is superior to the other lines, particularly at the deeper levels. The interpretation of Basement on Lines M200-04 is considered reliable as it is a very strong reflector broken up by faulting. There are very few or no coherent reflections below it.

The interpretation of T and O horizons, on this cross-section, is controlled by the Echuca Shoals No.1 well. These horizons are also correlated and carried into cross-sections B-B' and C-C' from the intersection points with cross-section A-A'. Similarly, these horizons are correlated and carried over from the Lyhner No.1 well into cross-sections A-A' and B-B' from the the intersection points with cross-section C-C'

The interpretation of T and O horizons is doubtful in the major part of this cross-section except on Line 73-1169 (Plate 10E) where the projection of the Echuca Shoals No.1 well is located. The interpretation of these horizons is also considered to be reliable on Line M200-04 because of the data quality of the seismic section. The T and O horizons cannot be interpreted on Line 73-1155

(Plate 10A), approximately about 24 kilometres northwest of the intersection point of Line 73-1180 (Plate 10B).

The interpretation of the Jb and younger horizons are fairly reliable as these horizons are almost always present in all the wells used for control for interpreting the three seismic cross-sections. The three cross-section lines intersect each other and the seismic horizons can be correlated between cross-sections at the intersection points.

The X horizon is interpreted to onlaps onto the D horizon on Line 73-1180 (Plate 10B), about 27.0 kilometres northeast of Buffon No.1 well as the X horizon is absent in this well. The Jb horizon is interpreted to onlaps onto T horizon on Line 73-1169 (Plate 10E), about 10.0 kilometres southwest of Echuca Shoals No.1 well as this horizon is interpreted to have merged with T horizon in this well. The Jc, Jb, T and O horizons are interpreted to onlap onto basement between 7.0 to 27 kilometres northwest of Londonderry No.1 well as these horizons are absent in that well.

The time intervals between most of the interpreted seismic horizons decrease on Lines 73-1180 and 73-1158 (Plates 10B, 10C) towards the Buffon No.1 well. The time intervals between Jc and Jb, Jb and T seismic horizons also decrease on Line 73-1158 (Plate 10C) from the intersection point of Line 73-1177 (cross-section C-C') towards the intersection point of Line 73-1180 (Plate 10B). Thinning of the stratigraphic units from northwest to southeast is thus indicated on these lines.

The Buffon Trend is observed on Line 73-1155 (Plate 10A) adjacent to the intersection point of Line 73-1180 (Plate 10B). The Inner Basin Arch Trend is observed straddling Lines 73-1158 and 69-321 (Plate 10D). The projection of Brewster No.1A well is located on this trend on Line 69-321 (Plate 10D). The eastern edge of the Prudhoe Terrace is observed on M200-04 (Plate 10G) about 15.0 kilometres from the intersection point of Line 74-1377 (Plates 10F). Yampi Shelf is observed on this cross-section (Plate 10G) and the Londonderry No.1 well is located near its southeastern end.

Several structural highs are observed throughout the cross-section A-A', for example, on Line 73-1155 (Plate 10A) west of Buffon No.1 at water depths of 1020 to 1120 metres. The structural high is also observed on the Jb horizon map.

5.5.2 Cross-section B-B'

The seismic lines, or parts of lines, used on cross-section B-B' are listed in the List of Plates under Plates 11A to 11H.

All the above sections have a vertical scale of 2 inches per second (5.08 centimetres per second) and generally a horizontal scale of 1.08 inches per mile (1.70 centimetres per kilometres) except Line 70-474 (Plate 11G); this line has a horizontal scale of 1.5 inches per mile (3.81 centimetres per kilometre). The horizontal scale varies for data of different vintages. The horizontal scales for individual seismic sections are shown on Plates 11A to 11H. The interpreted sections of Lines 73-1147 and 73-1175 are joined together at the intersection point and shown on Plate 11E.

The Leveque No.1 well penetrated the Basement and only E, D, F, Jc and Jb seismic horizons are present above the Basement in this well. This well was used to assist in interpreting the Basement on all three seismic cross-sections.

The interpretation of Basement on Lines 69-243, 70-474 and 69-303 (Plates 11F, 11G, 11H, respectively) is considered reliable as it is a very strong reflector broken up by faulting. There are few or no coherent reflections below it.

The interpretation of the O horizon is conjectural over much of this cross-section as this horizon is correlated only to the Echuca Shoals No.1 well on cross-section A-A' and to the Lyhner No.1 well on cross-section C-C. The O horizon can be characterised as a very prominent low frequency reflector with numerous diffraction patterns on Line 73-1149 (Plate 11A). The prominent low frequency reflector on Line 73-1149 might be interpreted as the T horizon instead of the O horizon as the T horizon onlaps onto O horizon about 45.0 kilometres northwest of Brecknock No.1 well on this line. There is also no well control in this part of the Browse Basin (water depth is more than 2000 metres) and the interpretation of the O horizon is mainly based on reflection characteristics on this line. The interpretation of the O horizon is doubtful at the south-eastern end of Line 73-1149 (Plate 11A) and on Lines 73-1148, 73-1147 and 69-300 (Plates 11C, 11D, 11E, respectively) between Brecknock No.1 and Lombardina No.1 wells. It onlaps onto basement about 2.0 kilometres southeast of Lombardina No.1 well on line.

The interpretation of the T horizon is considered to be reliable between Brecknock No.1 and Lombardina No.1 wells. It is conjectural northwest of Brecknock No.1 well and southwest of the Lombardina No.1 well on Line 69-243 (Plate 11F). The T horizon is interpreted to onlap onto Basement about 4.5 kilometres southeast of the Lombardina No.1 well on this line.

The interpretation of the Jb and younger horizons is fairly reliable as most of these horizons are present in all the three wells used for control in interpreting this seismic cross-section.

The F horizon is interpreted to onlap onto the Jb horizon about 4.0 kilometres northwest of Brecknock No.1 well as the thickness between F and Jb horizons is found to be only 57 metres in this well (Plate 11C). The Jc horizon is absent in Brecknock No.1 well, and it is interpreted to onlap onto the Jb horizon about 7.0 kilometres southeast of this well and to be absent on Lines 73-1148 and 73-1149 (Plates 11B, 11C) northwest of the well. The time intervals between seismic horizons are interpreted to decrease from the Lombardina No.1 well towards the Brecknock No.1 well, particularly on Line 73-1148 (Plate 11C), indicating that there is thinning of the stratigraphic units from southeast to northwest.

The Seringapatam Trend is seen as a horst structure at the interpreted O horizon on Line 73-1149 (Plate 11A). The water depth over this structural trend is over 2500 metres. In this part of the basin, only E, M, X, D, and O horizons are present. The Jb horizon is interpreted to onlap onto the O horizon about 2.0 kilometres southeast of the Seringapatam Trend.

The Brecknock No.1 well is located on the Scott Reef Trend and the Central Basin Arch is located about 27 kilometres southeast of this well straddling Lines 73-1148 and 73-1147 (Plates 11C, 11D). The Buccaneer Nose is interpreted on Line 69-300 (Plate 11E) about 45.0 kilometres northeast of the Lombardina No.1 well.

The northwestern edge of the Leveque Shelf is interpreted to be located about 20.5 kilometres southeast of Lombardina No.1 well on Line 69-243 (Plate 11F). The major part of Line 69-243 and all of Lines 70-474 and 69-303 (Plates 11F, 11G, 11H, respectively) are interpreted to be located on the Leveque Shelf. The basement is very shallow on these lines and is estimated to be less than 900 metres.

4.5.3 Cross-section C-C′

The seismic lines or parts of lines used on cross-section C-C′ are listed in the List of Plates under Plate 12A to 12H.

All the above sections have a vertical scale of 2 inches per second (5.08 centimetres per second) and generally a horizontal scale of 1.08 inches per mile (1.70 centimetres per kilometre). The horizontal scale varies for data of different vintages. The horizontal scales for individual seismic sections are shown on the on Plates 12A to 12H. The interpreted sections of Lines 73-1147 and 73-1175 are joined together at the intersection point and shown on Plate 12E.

The interpretation of Basement on Line 70-489 (Plate 12A) is considered reliable as it is a very strong reflector broken up by faulting. There are few or no coherent reflections below it. The interpretation of the basement is unreliable on the southern part of Line 69-300 (Plate 12B), south of Lombardina No.1 well, as the reflectors identified as basement are less distinct. The basement and the Permian and Triassic sequences on these lines reflect the extension of the Leveque Shelf as a Palaeozoic nose westwards particularly around Lynher No.1 well.

The interpretation of the O horizon is reliable on Line 70-489 (Plate 12A) and on the southern parts of Line 69-300 (Plate 12B). It is unreliable northeast of Lombardina No.1 well up to the intersection point of Line 73-1147 (Plate 12D). It is observed to be a very prominent low frequency reflector. The interpretation of this horizon is considered reliable on the southern part of Line 73-1177 (Plates 12E, 12F) south of the projection of Caswell No.2 well but unreliable on the northern part of Line 73-1177 (Plates 12G, 12H) north of the well.

The interpretation of the T and younger horizons is considered reliable throughout the cross-section C-C′ except on the northern part of Line 73-1177 (Plates 12G, 12H) north of the projection of Caswell No.2. Only E, M, X and D horizons are thought to be reliable in this part of the cross-section. The remaining horizons are conjectural as the quality of the seismic data deteriorates in the northern part of Line 73-1177 (Plates 12G, 12H). There are no significant variations in the thicknesses of the stragraphic units on this cross-section.

The Buccaneer Nose is interpreted on Line 69-300 (Plate 12C) about 45.0 kilometres northeast of Lombardina No.1 well as in the case of cross-section B-B′. The Central Basin Arch is observed on:

- Line 73-1177 (Plate 12G) at a distance of about 8.0 kilometres south of the intersection point of Line 73-1158 (Plate 12C) of cross-section A-A′
- Line 73-1177 (Plate 12E) at distance of about 10.5 kilometres north of the intersection point of Line 73-1147 (Plate 12D) and
- Line 73-1147 (Plate 12D) midway between Caswell No.2 and Lombardina No.1 wells at at a distance of about 80.0 kilometres from these wells.

Several structural highs are observed on cross-section C-C′.

5. PALAEOGEOGRAPHY

(A.E. Stephenson)

Palaeogeographic reconstructions tend to be highly subjective, and this reconstruction of the Browse Basin is no exception. I have used the 'time slice' approach, whereby 'typical' environments over periods of between 13 and 33 million years have been grouped into a (I hope) plausible overview of the basin. Such a reconstruction will not, by definition, give a 'snapshot' of the basin at any given point in time - which would have been the alternative approach one could take to present palaeogeographic data. I have preferred the time slice approach to the snapshot approach for two main reasons. Firstly, a time slice approach allows seismic data to be incorporated into the palaeogeographic picture - something which is very difficult to do on a basinal scale with inadequate well ties, and often broad palynological/ palaeontological dating of those horizons which can be traced. Secondly, this reconstruction is not designed to give the definitive palaeogeography of any given area at prospect or lead scale - that is the job of petroleum company explorationists. It should always be kept in mind that the reconstructions herein are based on only 23 useable wells in an area of over 100 000 square kilometres - a frontier area by any definition. The interpretations given here can and must change in future, as more wells are drilled and seismic data are acquired and interpreted. As would be expected, maps of the oldest time slices are based on the least well data, with well control for younger slices becoming progressively better.

Ten time slices have been selected in part to cover the significant seismic events (see Chapter 4 - Regional Geophysics), and in part to cover important periods of source and reservoir development within this particular basin. The time scale used is that of Haq & van Eysinga (1987). However, absolute dating in million years is less critical for a time slice approach to palaeogeography than for the alternative snapshot approach, and the general pictures given should be similar for alternative geochronologies. Details of the time slices used are given in Table 3, and the palaeogeographic maps are shown as Figures 4 through 13. They are self explanatory, and I do not include a blow-by-blow description in this section.

The maps are based upon the basic data contained in the completion reports for the wells listed in Table 4, supplemented by interpretive palynological and palaeontological dating from those well reports where available. Data points used, wells, and time slices are cross referenced in Table 4. In addition, seismic interpretations by my colleagues working on this prospectivity study have been incorporated into the maps

Table 3. Palaeogeographic time slices used

Time slice 1: Middle Triassic.
Anisian-Ladinian (230-243 Ma)
[the earliest time with any useful data]

Time slice 2: Late Triassic.
Carnian-Rhaetian (210-230 Ma)
[pre T horizon]

Time slice 3: Early Jurassic.
Hettangian-Toarcian (184-210 Ma)
[post T horizon]

Time slice 4: Early-middle Middle Jurassic.
Aalenian-Bathonian (165-184 Ma)
[pre Jb horizon]

Time slice 5: Late Middle-middle Late Jurassic.
Callovian-Kimmeridgian (145-165 Ma)
[post Jb horizon]

Time slice 6: Late Late Jurassic-early Early Cretaceous.
Portlandian-Neocomian (124-145 Ma)
[near Jc horizon]

Time slice 7: Middle Early-early Late Cretaceous.
Barremian-Cenomanian (91-124 Ma)
[F-D horizons]

Time slice 8: Middle-late Late Cretaceous.
Turonian-Campanian (72-91 Ma)
[post D horizon]

Time slice 9: Latest Cretaceous-earliest Tertiary.
Maastrichtian-Paleocene (55-72 Ma)
[near X horizon]

Time slice 10: Middle-late Paleogene.
Eocene-Oligocene (24-55 Ma)
[near M horizon]

Timescale used: Haq & van Eysinga, 1987.

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where possible. The maps showing Mt Victoria Land to the northwest of the Browse Basin are highly speculative in their detail, but not in generality, as it is certain that such a landmass was present at the times shown. Dating of the final rift at 160 million years is based upon Veevers & others (1991). Structural development within the Browse Basin has also impacted the palaeogeography, in particular the highs shown from Early Jurassic times onwards (see Chapter 2 - Basin Evolution).

In summary, these maps must be regarded as preliminary and subject to change. A more detailed paper on the palaeogeography of the Browse Basin is in preparation, and should be published in early 1992 as a BMR Record, and later that year (hopefully) in a refereed journal.

Table 4. Browse Basin wells - data points for time slices

TIME SLICE NUMBER:	1	2	3	4	5	6	7	8	9	10
Adele Island 1	x	x	x	x	*	x	*	*	*	*
Asterias 1	-	-	-	-	-	*	*	*	*	*
Barcoo 1	-	*	*	*	*	*	*	*	*	*
Bassett 1A	-	-	-	-	-	-	*	*	*	*
Brecknock 1	*	*	*	-	*	*	*	*	*	*
Brewster 1A	-	-	-	*	*	*	*	*	*	*
Buccaneer 1	*	x	x	*	*	*	*	*	*	x
Buffon 1	-	-	*	*	*	x	*	*	*	*
Caswell 1	-	-	-	-	-	*	*	*	*	*
Caswell 2	-	-	-	*	*	*	*	*	*	*
Echuca Shoals 1	*	*	x	x	x	*	*	*	*	*
Heywood 1	-	-	*	*	*	*	*	*	*	*
Kalyptea 1	-	-	-	-	-	*	*	*	*	*
Leveque 1	x	x	x	x	x	*	*	*	*	*
Lombardina 1	-	-	*	*	*	*	*	*	*	*
Londonderry 1	x	x	x	x	x	*	*	*	*	*
Lynher 1	x	*	*	*	*	*	*	*	*	*
North Scott Reef 1	-	*	*	x	x	x	*	*	*	*
Prudhoe 1	x	x	x	x	x	*	*	*	*	*
Rob Roy 1	x	x	*	x	x	*	*	x	*	x
Scott Reef 1	-	*	x	*	x	*	*	*	*	*
Scott Reef 2A	-	-	*	*	*	*	*	*	*	*
Yampi 1	x	*	*	*	*	*	*	*	*	*

* Data point used
x Sediments not deposited/preserved
- Below TD

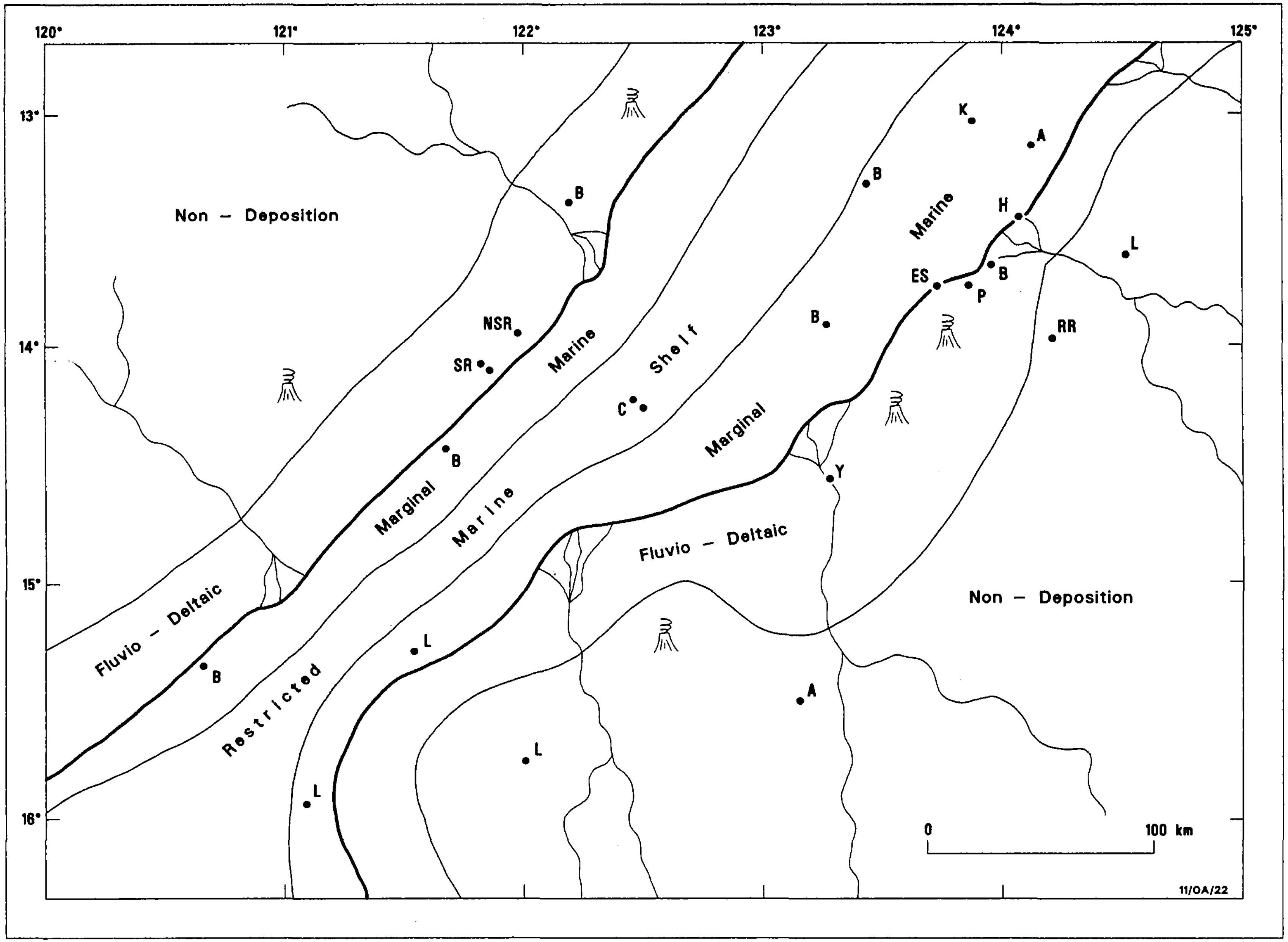


Figure 4. Palaeogeographic time slice 1: Middle Triassic. Anisian-Ladinian (230-243 Ma)

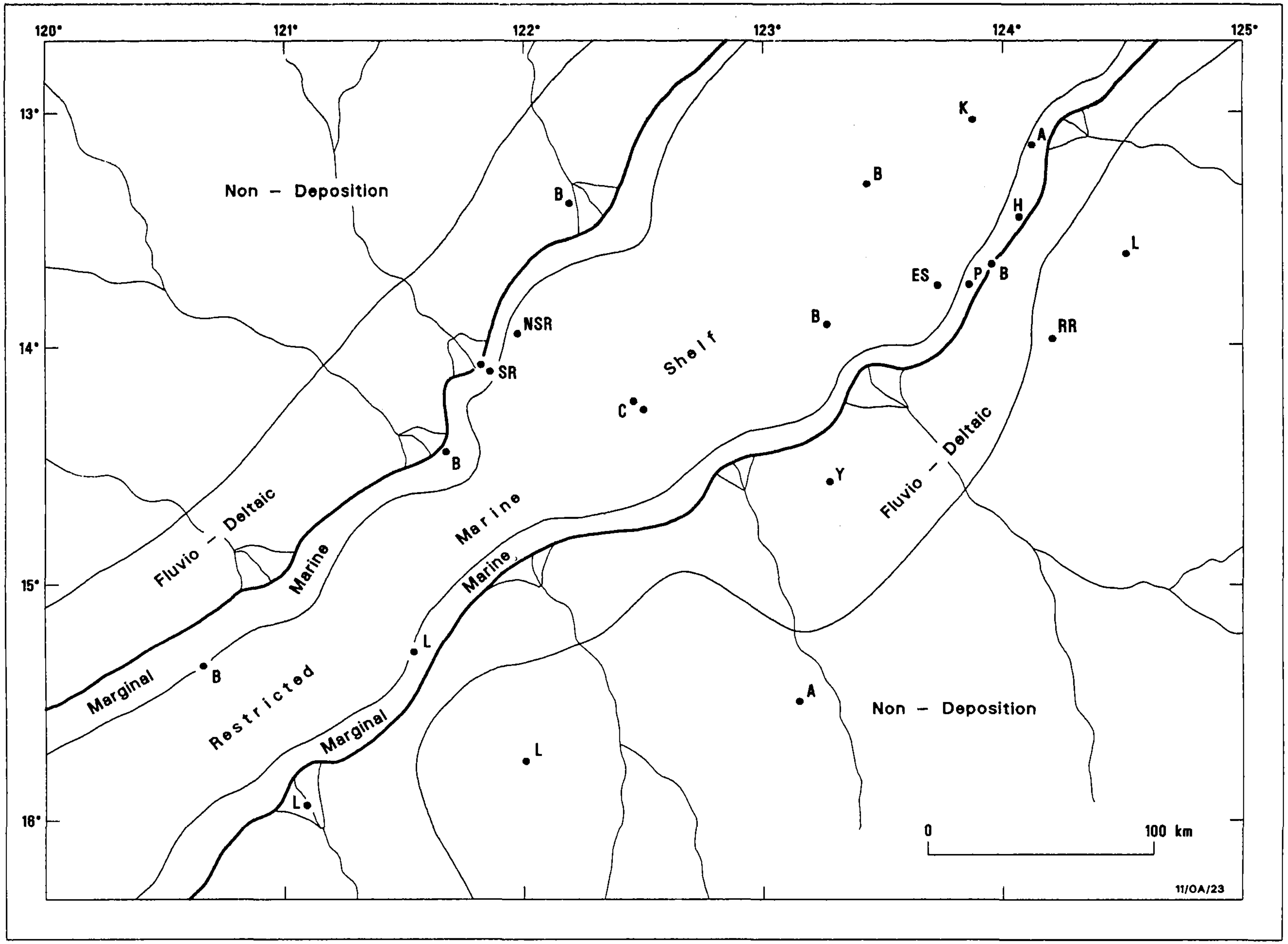


Figure 5. Palaeogeographic time slice 2: Late Triassic. Carnian-Rhaetian (210-230 Ma)

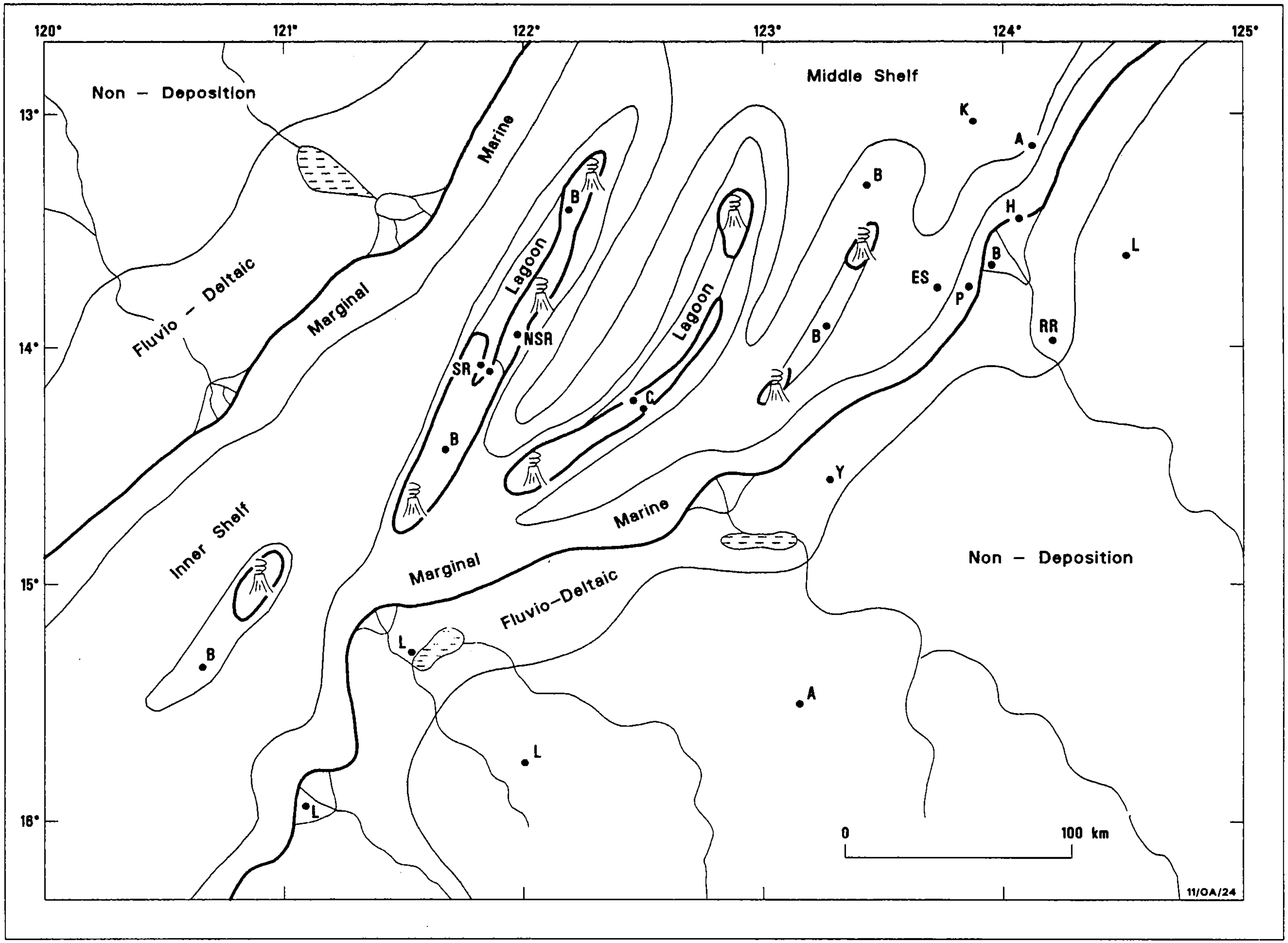


Figure 6. Palaeogeographic time slice 3: Early Jurassic.
Hettangian-Toarcian (184-210 Ma)

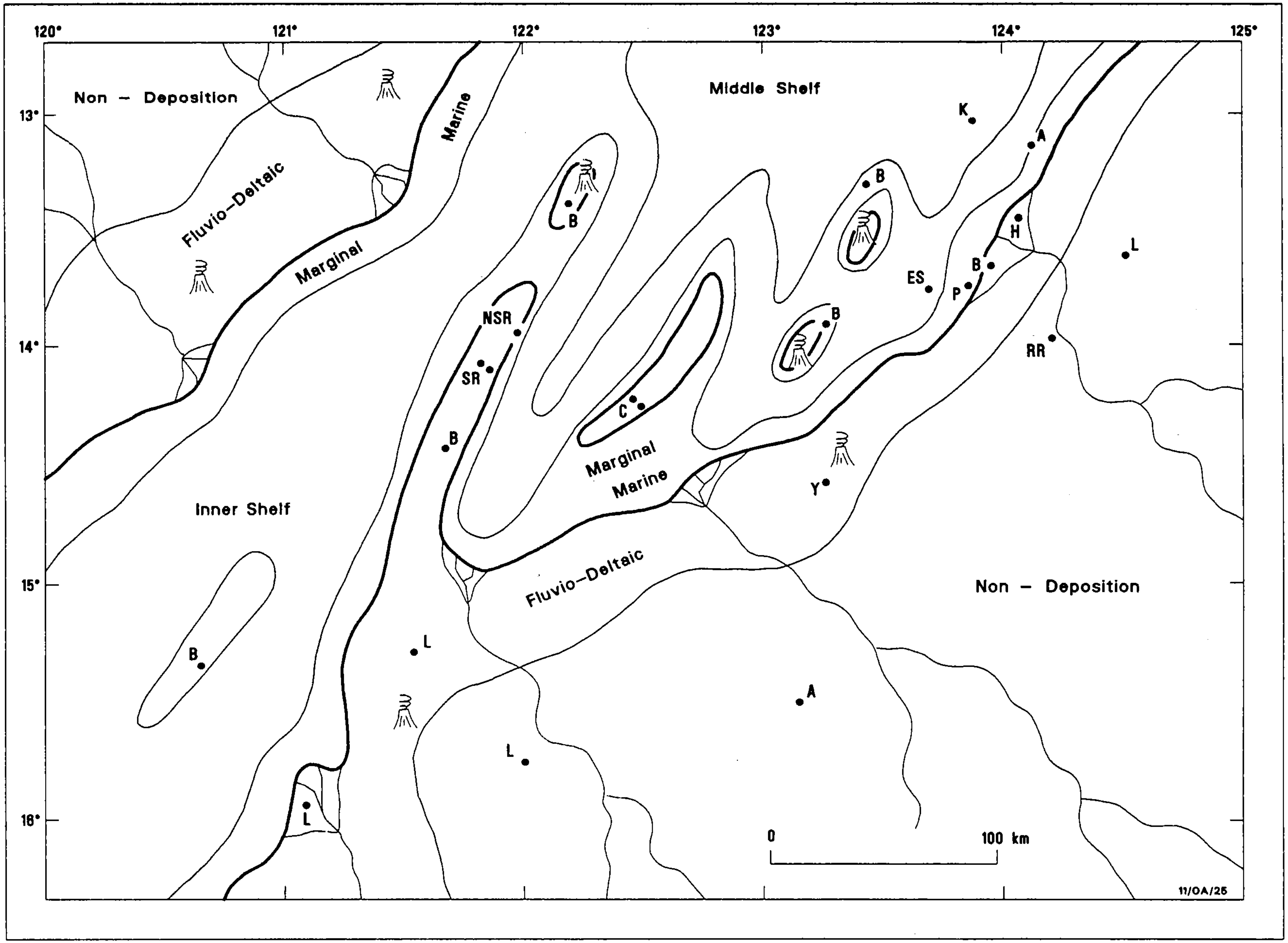


Figure 7. Palaeogeographic time slice 4: Early-middle Middle Jurassic. Aalenian-Bathonian (165-184 Ma)

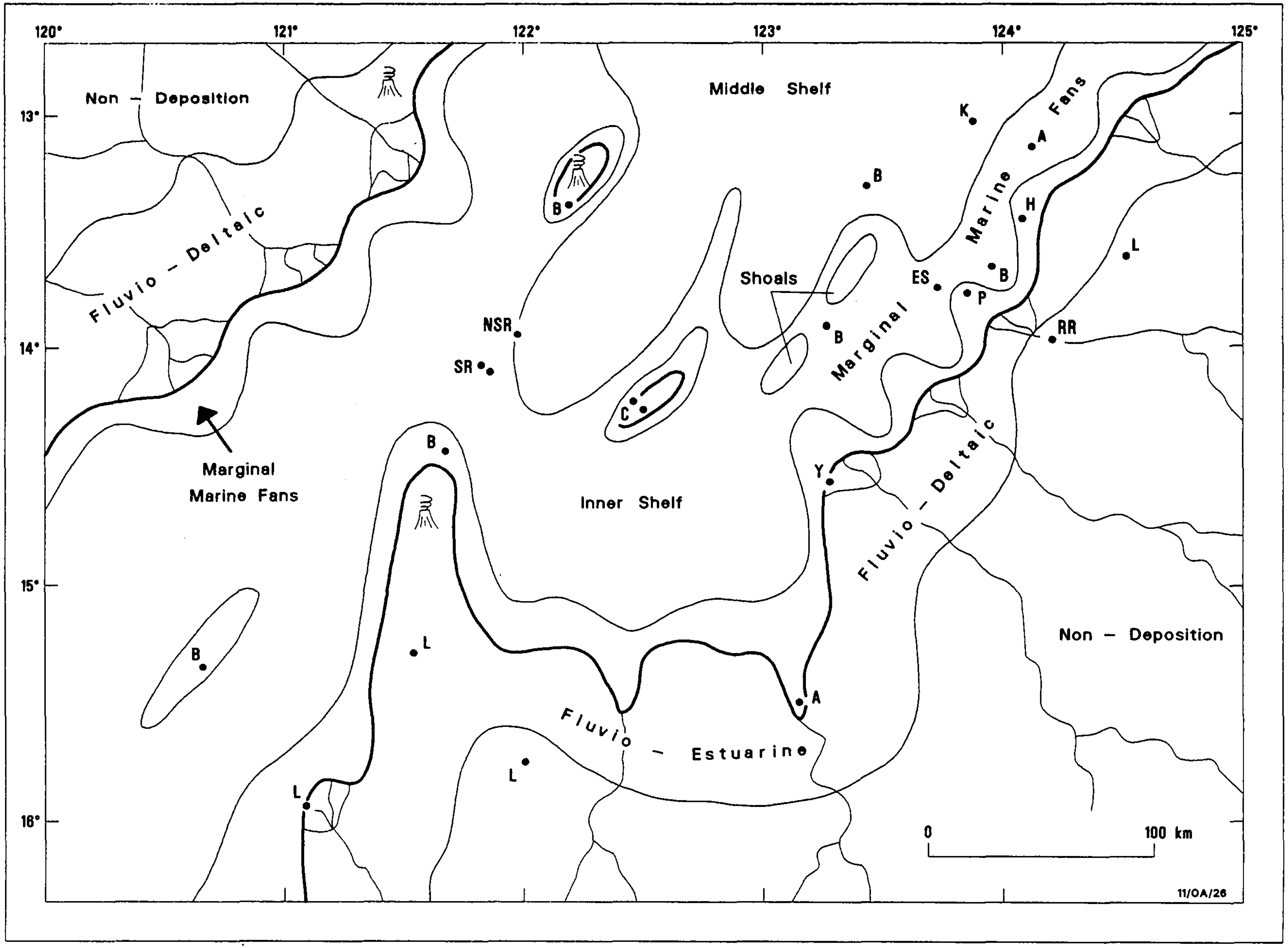


Figure 8. Palaeogeographic time slice 5: Middle-middle Late Jurassic. Callovian-Kimmeridgian (145-165 Ma)

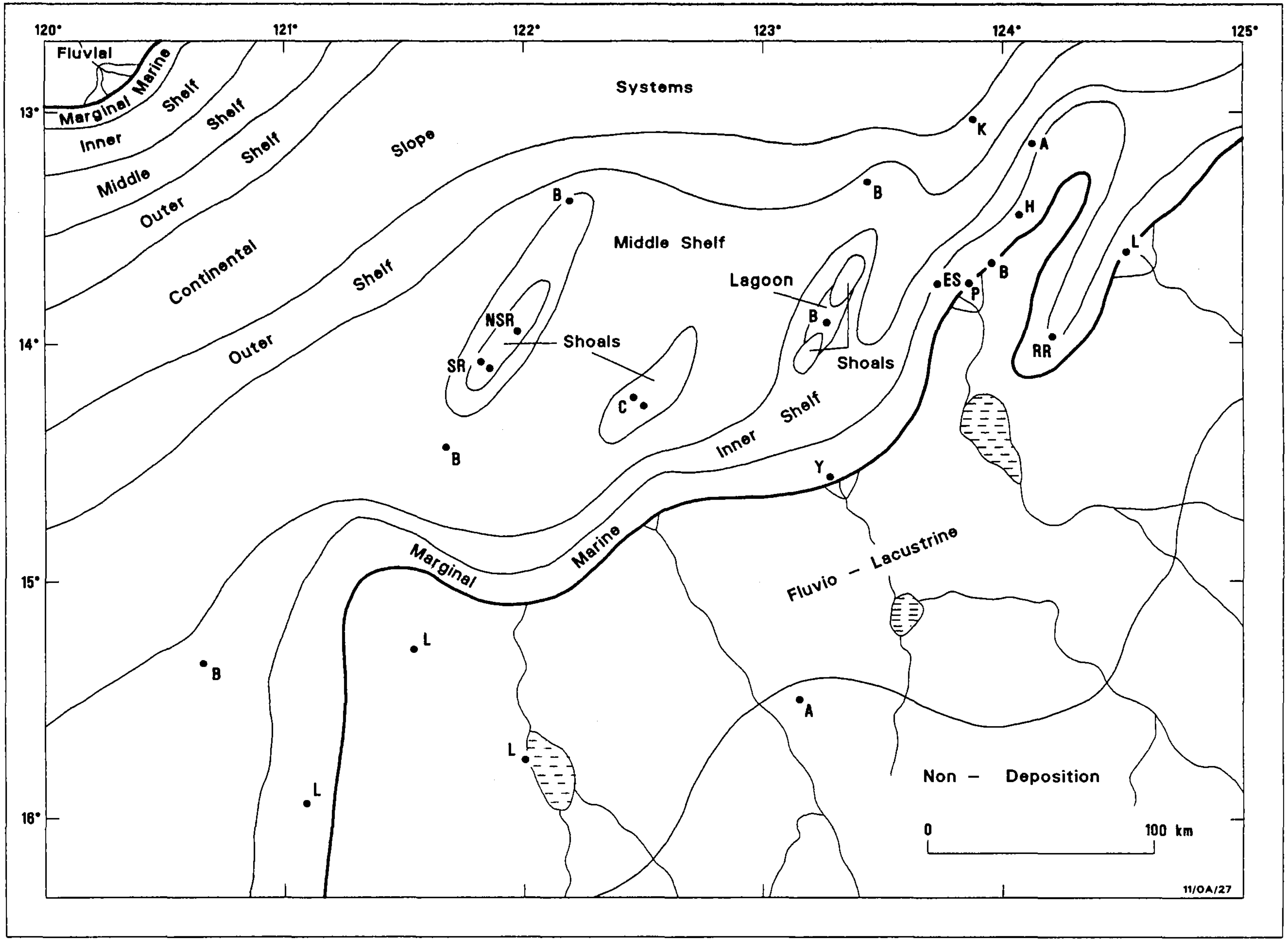


Figure 9. Palaeogeographic time slice 6: late Late Jurassic-early Early Cretaceous. Portlandian-Neocomian (124-145 Ma)

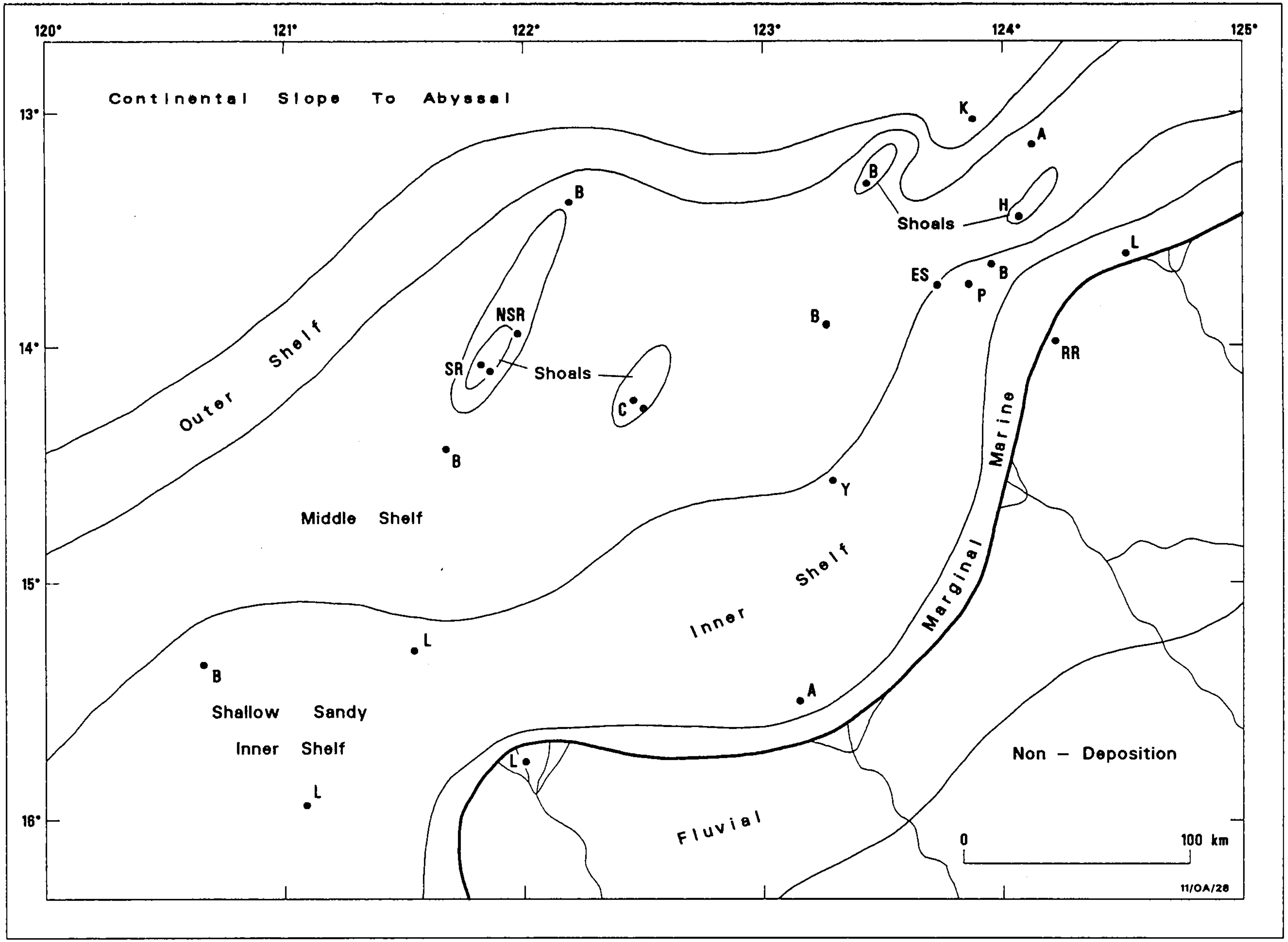


Figure 10. Palaeogeographic time slice 7: middle Early-early Late Cretaceous. Barremian-Cenomanian (91-124 Ma)

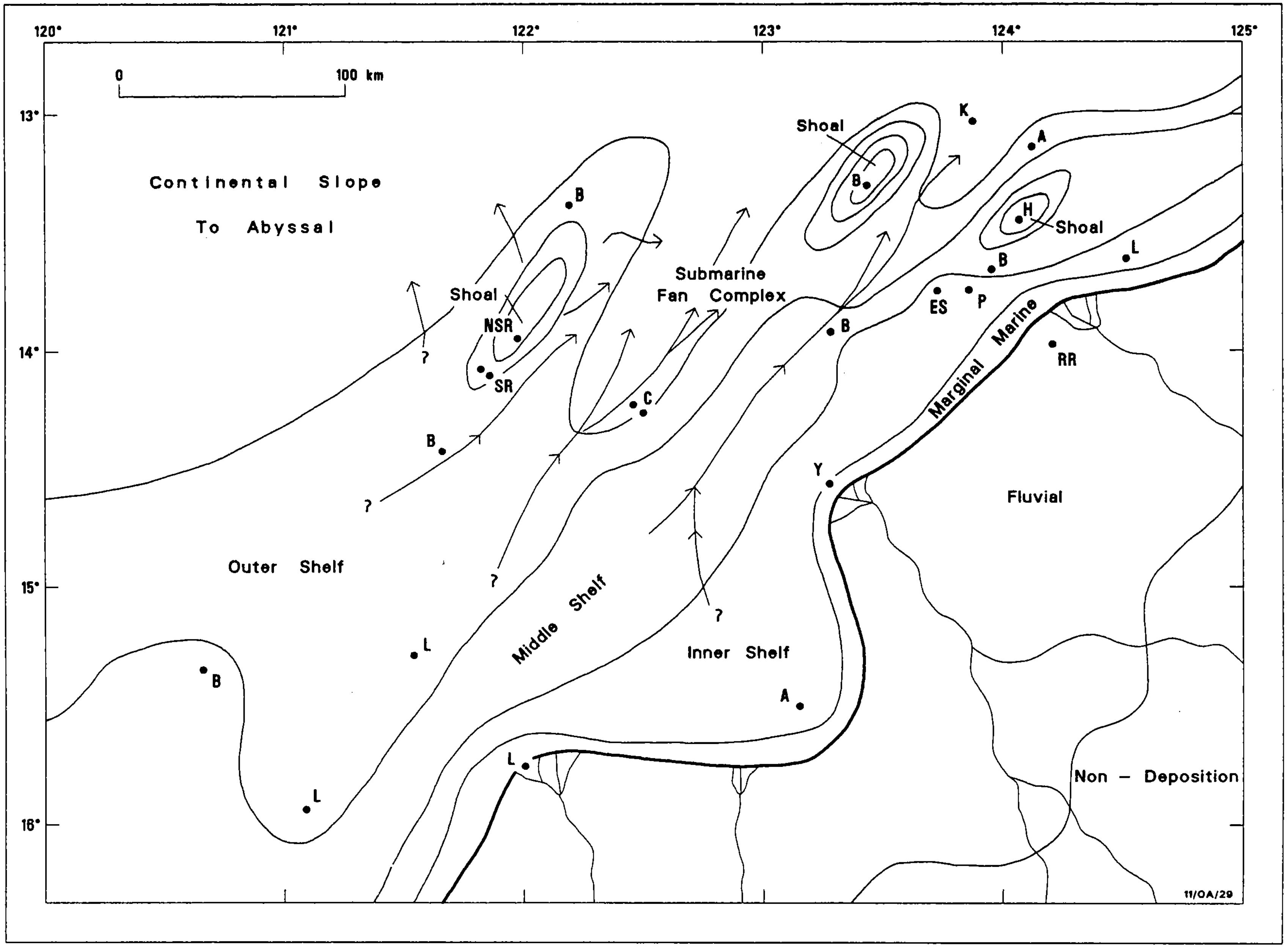


Figure 11. Palaeogeographic time slice 8: Middle-late Late Cretaceous. Turonian-Campanian (72-91 Ma)

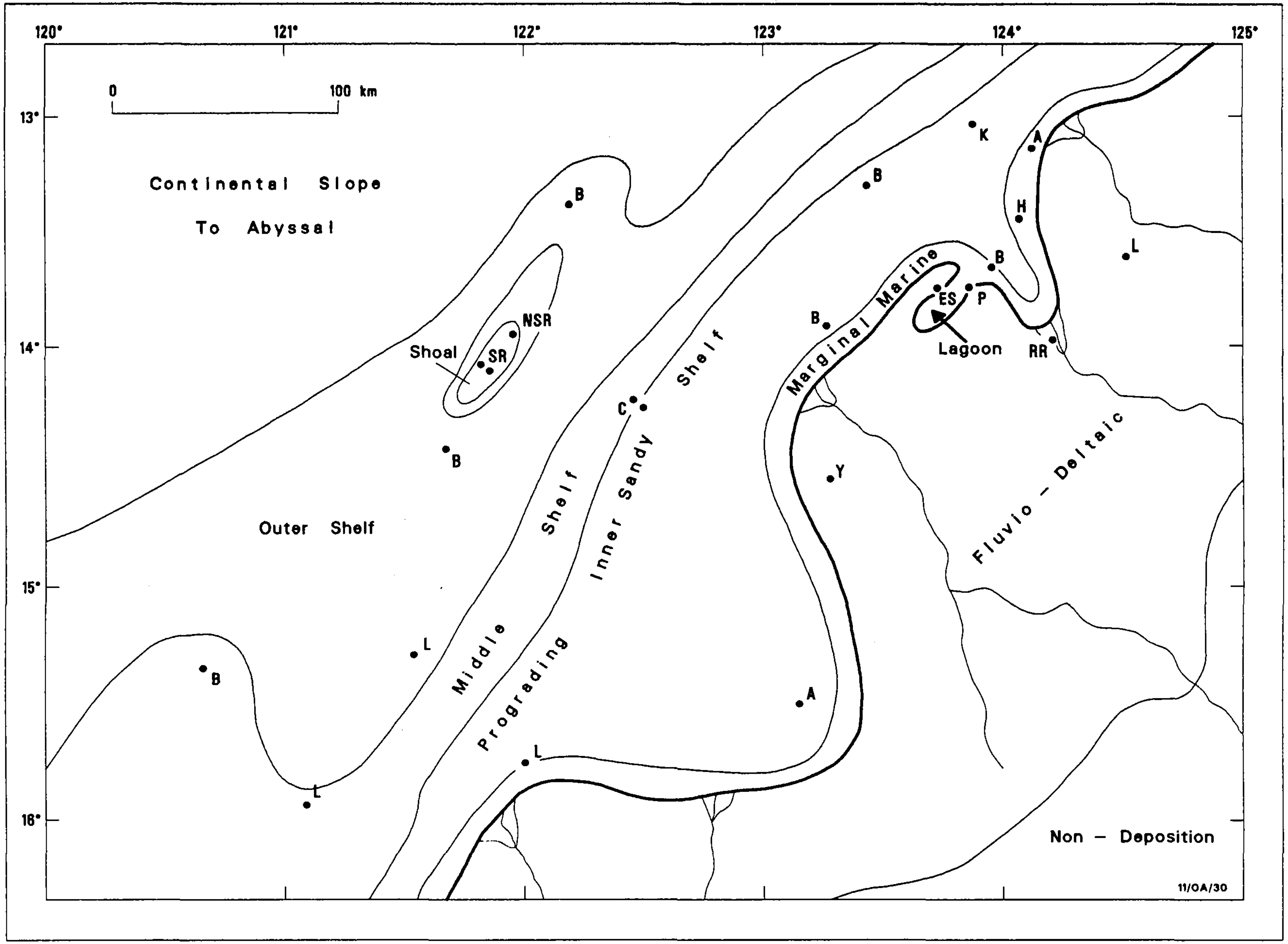


Figure 12. Palaeogeographic time slice 9: latest Cretaceous-earliest Tertiary. Maastrichtian-Paleocene (55-71 Ma)

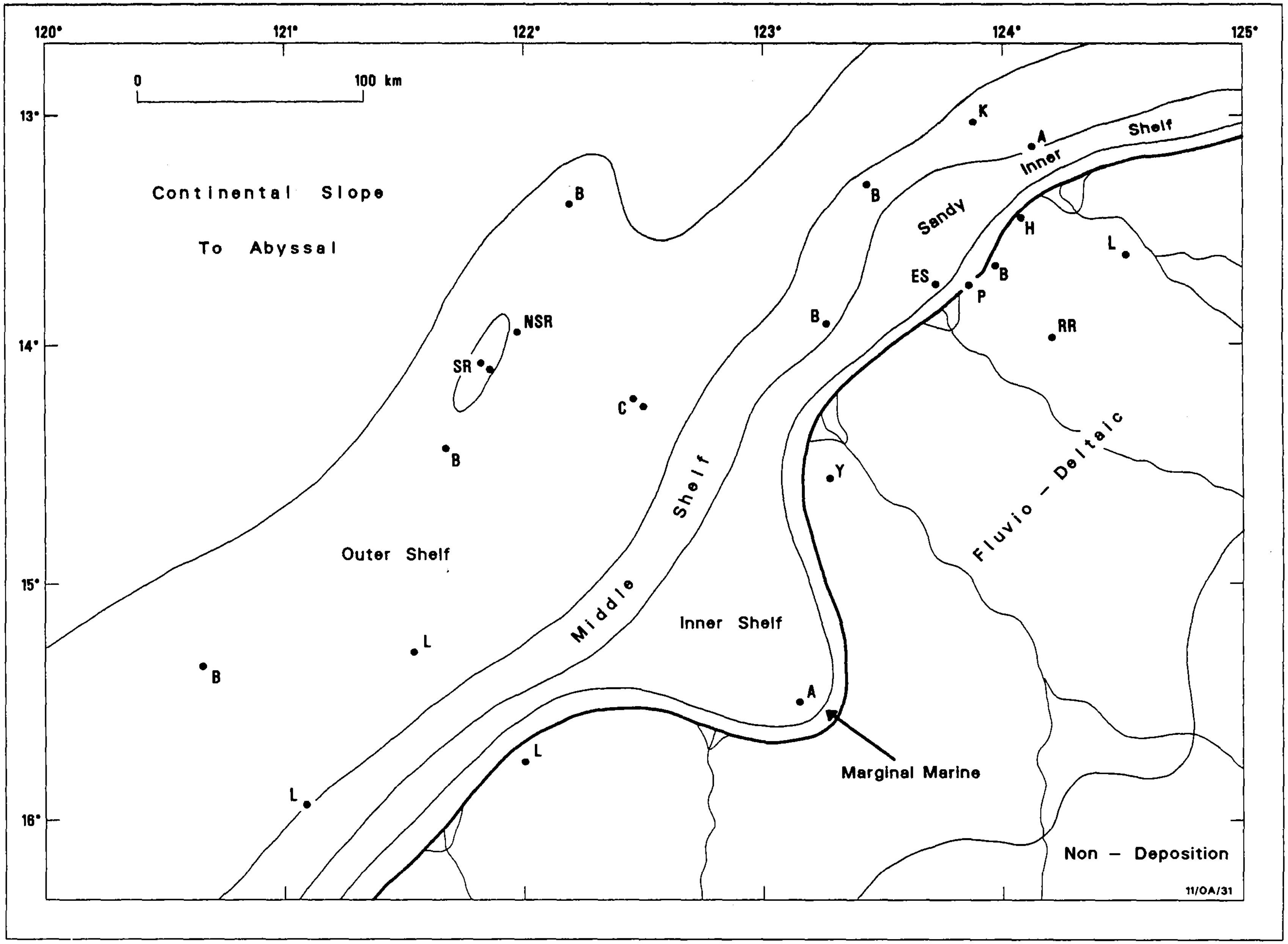


Figure 13. Palaeogeographic time slice 10: Middle-late Paleogene. Eocene-Oligocene (24-55 Ma)

6. STRATIGRAPHY

(V.L. Passmore)

The Browse Basin contains over 11 000 metres of late Palaeozoic and younger clastic, volcanic, and carbonate sediments (Allen & others, 1978; Elliott, 1990) that reflect the rifting and separation associated with the breakup of Gondwana in the Mesozoic. The maximum thickness of this sequence is not known, but Crostella (1976) has suggested there are at least 12 000 metres.

The age of these sediments ranges from possible latest Carboniferous to probable Recent. Their regional relationship are summarised on Figure 14 and are depicted on Plates 78 and 79.

Lithological control was provided by 26 wells in and near the basin (see Appendix 1) shown on Plates 1 and 74. The wells in the basin and their location with respect to the basin structure are shown on Plate 1. The location of stratigraphic section D-D' (Plate 78) and E-E' (Plate 79) are shown on Plate 74. For ease of discussion, the basin is divided into a southern part (encompassing wells between 120^{o} and 123^{o}, and a northern part (covering wells between 123^{o} and 125^{o}).

Regional geological relationships with other North West Shelf basins suggest that an earlier, pre-Permian Palaeozoic sequence of rocks, as old as Cambrian or Ordovician at its base (Passmore, 1980), may underlie the known Browse Basin sequence. The presence and lithology of this sequence is speculative as no wells have drilled deep enough in the central part of the basin to intersect these rocks.

Detailed discussion of the basin's stratigraphy is restricted to the Permian and younger sediments. This chapter discusses the lateral and vertical change in lithology across the basin. It is not the purpose of this chapter to discuss the environmental change. These are presented in Chapter 5.

6.1 PALAEOZOIC

6.1.1 Pre-Permian

Pre-Permian sediments were deposited into an intracratonic trough initiated by the spreading of Paleo-Tethys (Veevers, 1988). The lithology of this sequence is unknown, but it is most likely mainly marine clastics and carbonates, similiar to sediments of the same age in the Canning Basin to the south (Passmore, 1991; Yeates & others, 1984). The region may have been uplifted and sediment eroded in the Carboniferous (Robertson Research, 1986)

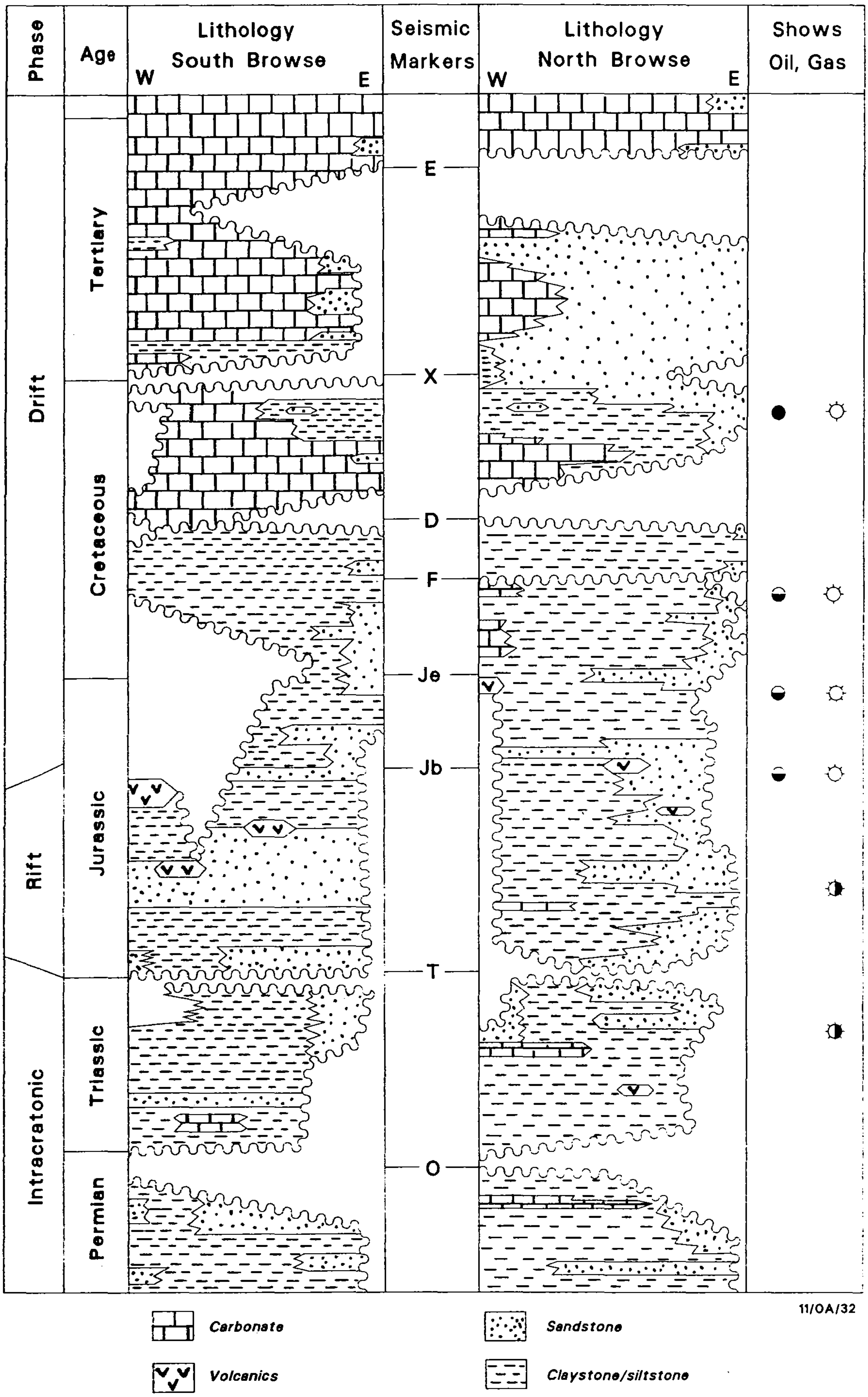


Figure 14. Stratigraphic columns for the Northern and southern Browse Basin.

6.1.2 Permian

The Permian is the most wide-spread of the Palaeozoic seqences in the Browse Basin, onlapping Precambrian metamorphic and igneous basement and filling depressions in the irregular basement surface. The extent of the the Permian sequence is unknown as only wells on the eastern side of the basin reached the Permian, but it is likely that Permian age sediments underlie most of the basin and probably also originally onlapped the Palaeozoic landmass on the west. In the central basin, Permian sediment may unconformably overlie the eroded pre-Permian sequence. The source areas for these sediments were probably the Kimberley Block to the east and the landmass forming the Palaeozoic western margin.

In the northern part of the basin, the Permian is dominantly carbonaceous siltstone and claystone which grades in part into, and is interbedded with fine-grained, well-sorted, argillaceous quartz sandstone and beds of fine to course-grained quartz sandstone. Sand percentage increases eastward and southward onto the Yampi Shelf and sandstone is probably the dominant lithology at its eastern limit. Prudhoe No.1 also recorded minor interbeds of coal, and Rob Roy No.1 had minor amounts of anhydrite. Thin limestone beds are interbedded with some of the claystone in wells as far east as Rob Roy No.1 (Plate 78). Yampi No.1 had no limestone beds but traces of dolomite were recorded over a 30 metre thick interval.

In the southern part of the basin, the Leveque Shelf remained emergent and probably sourced the Permian sediments that onlap the flank of the Shelf. Lynher No.1, the only well to reach the Permian in the south, is composed mainly of poorly sorted, fine to course quartz sandstone. Sand grains are more angular than those in the north and lithic fragments are more common. The sandstone is interbedded with minor amounts of grey or multicolored siltstone.

Only Rob Roy No.1 reached the base of the Permian sequence. The other wells to encounter the Permian all reached total depth while still within the Permian sequence. The Upper Permian has been eroded from wells on the Yampi Shelf and Prudhoe Terrace, but as indicated by Echuca Shoals No.1, the Upper Permian is present in the cental basin, west of the eastern terraces.

6.2 MESOZOIC

6.2.1 Triassic

Triassic clastics unconformably overlie the Permian sequence. This hiatus is due to the tectonic activity and erosion that occured at the end of the Permian. There are no Triassic sediments on the Yampi and Leveque Shelves or the Prudhoe Terrace. In the south, however, the Triassic laps onto the flanks of the Leveque Shelf, extending updip of the Permian limit.

The source areas for the Triassic sequence probably were the same as for the underlying Permian. Allen & others (1978) suggest the Scott Plateau could have been a local source area for parts of the Scott Reef Trend. Wells along the Scott Reef and Barcoo Trends in the southern part of the basin which penetrated to the Triassic indicate that the southern Browse was an area of active deposition, however, none of these wells reached the base of the sequence.

The Triassic lithology in the Browse Basin is dominantly claystone and siltstone or carbonates, in which sandstone is only a minor component. Towards the Leveque Shelf the sandstone content increases and the Triassic sequence becomes dominantly sandstone with interbedded siltstone and rare thin coal beds as in Lynher No.1, suggesting the main source area was the Leveque Shelf. Farther north, Triassic sediments were deposited on the downthrown side of the faults that mark the western edge of the Prudhoe Terrace. The Triassic sequence thickens towards the centre of the central basin, thinning over the arches and trends within it (Plate 78), and extends westward towards the Scott Plateau. In Yampi No.1, the Triassic sequence is a dominantly argillaceous, fine to medium-grained, moderately sorted, quartz sandstone interbedded with silty claystone, but towards the north the sandstone content decreases. Northward from the Yampi well, the sandstone dominant sequence becomes interbedded siltstone, silty sandstone, and calcilutite, and finally interbedded claystone and siltstone near Gryphaea No.1.

Thin interbeds of igneous rock in Lower Triassic sediments in Echuca Shoals No.1 and Upper Triassic sediments in Barcoo No.1 indicate widespread sporatic volcanic activity throughout the Triassic.

Most of the wells that intersected the Triassic reached only Upper and/or Middle Triassic sediments. Echuca Shoals No. 1 was the only well to reach the base of the Triassic, but did not encounter a complete section as the Upper Triassic was missing.

6.2.2 Jurassic

Block faulting in the late Triassic created a highly irregular surface across the basin. The hiatus between the Jurassic and underlying Triassic sequences is variable in the amount of time it represents. This tectonism and accompanying erosion, created an unconformable surface onto which Jurassic or younger sediments were deposited. The eastern and the northern margins of the basin were uplifted and remained emergent throughout most or all of the Jurassic. The whole of the Jurassic is absent at Gryphaea No.1 at the northern end of the basin, and also over much of the Yampi and Leveque Shelves. Many of the wells in the central Browse Basin did not reach the base of the Jurassic and the lateral and vertical extent of the hiatus is uncertain in this part of the basin.

Some of the horst blocks that form the present arches and highs, such as those on which Prudhoe No.1 and Echuca Shoals No.1 were drilled, were emergent for most of the Jurassic. The depressions that flank the highs were filled with interbedded fine to course-grained, quartz sandstone and silty claystone (Plate 78). Minor coal beds are present in the rift fill deposits near the eastern side of the basin. In Buccaneer No.1 well calcilutite is interbedded with the clastic sequence. Sand content decreases towards the centre of the basin. In Lombardina No.1 reddish brown claystone occurs near the base of the Lower Jurassic sediment but changes vertically to grey or black claystone higher in the sequence.

Along the Scott Reef and Buffon Trends, the Lower and Middle Jurassic sequence is dominantly sandstone, particularly the Middle Jurassic deposits. The rifting system influenced sedimentation to the end of the Early Jurassic (Robertson Research, 1986). Local structural disturbances continued into the Middle Jurassic (Forrest & Horstman, 1986) probably syndepositionally with deposition.

Lower to Middle Jurassic sediments were mainly deposited between the outer Prudhoe Terrace and the eastern margin of the Scott Plateau (Allen & others, 1978).

Volcanics are recorded in several wells, suggesting intermittent volcanic activity associated with rifting and pre-breakup in most of the basin. The age of the volcanics varies from well to well but the majority were emplaced in the Middle Jurassic.

Tectonic activity in the late Middle Jurassic rejuvenated movement along some of the basin's structures. This is most evident in the southern part of the basin where the Scott Reef and Buffon Trend well areas were uplifted, and resulted in an hiatus covering most of the Late Jurassic. In the northern part of the basin, an hiatus at the Jb level occurs only locally and several of the wells record no break. These local breaks are not shown on the stratigraphic columns on Figure 14.

Claystone deposition predominated during the Upper Jurassic. A basal Late Jurassic sandstone is recorded in a number of wells in the north and near the end of the Jurassic. Tithonian siliciclastic sandstone covers much of the northern and central parts of the basin, while in the south sandstone deposition is largely confined to the eastern part of the basin.

6.2.3 Cretaceous

The base of the Lower Cretaceous is unconformable on the Jurassic across much of the the southern Browse Basin, and is locally unconformable on Jurassic or older rocks in the central basin. In the east, Neocomian clastics extend beyond Jurassic and Permian limits to onlap Precambrian basement. Major unconformities such as those recognized in wells along the Scott Reef and Buffon Trends and along the eastern side of the northern Browse Basin, or regional basinwide breaks such as that at the D seismic marker which represents a basinwide hiatus at the top of the Cenomanian are depicted on Figure 14. However, no attempt has been made to depict the more local unconformities at the base of the Cretaceous sequence or small disconformities higher in the section.

With the foundering of the western margin, marine conditions became permanently established in the basin in the Cretaceous as is illustrated by the thick wedge of marine Cretaceous claystone and limestone that covered the basin (Plate 79).

A basal sandstone lies at the base of some of the northern wells and claystone at the base of the remainder. A transgressive sea spread a basal layer of sandstone across the eastern end of the basin, depositing Neocomian clastics east of Londonderry No.1 and onlapping the widespread Jurassic clastics on the eastern margin. The sequence in Londonderry No. 1. is mainly quartz sandstone with minor interbedded claystone. It grades westwards to interbedded sandstone and claystone or siltstone and eventually to wholly claystone with minor carbonates in the central basin (Plate 78). As shown on Plates 78 and 79, the Lower Cretaceous sequence (between Jc and D seismic markers) is predominantly thick claystone. The micropalaeontological evidence suggests that these restricted marine conditions continued until the Late Cretaceous (Allen & others, 1978). In the south, the early Lower Cretaceous is thin or absent over the Scott Reef Trend, but claystone covered these highs before the end of the Early Cretaceous (Williams, 1991).

Open marine conditions were established in the Turonian (Allen & others, 1978; Forrest & Horstman, 1986). The basin clastics changed from dominantly siliceous to predominantly calcareous with the establishment of full oceanic circulation. This is most obvious in the southern part of the basin where the Cretaceous changes from a dominantly claystone sequence to a dominantly limestone and/or marl one (Figure 14). Limestones also become more common in the western part of the northern Browse Basin.

During the Campanian, channel sands and possible turbidites sands were deposited in the central basin as channel fill, mounds, and possible fans. These features are not well defined but appear to prograde northward parallel to the highs in this part of the basin. In Bassett No.1A and Caswell No.2 the sandstones are mainly fine to medium-grained, glauconitic, dominantly quartzitic, with minor calcite cement.

Towards the end of the Cretaceous, sandstones on the Yampi Shelf spread westward across the northern part of the Browse Basin.

6.3 CAINOZOIC

6.3.1 Tertiary

A depositional hiatus occurs at the base of the Tertiary in the southern part of the basin, but is found only locally in the north. Only the hiatus along the eastern edge of the basin in the north is depicted on Figure 14. Local hiatus also occurred in other parts of the Paleogene sequence. The Leveque Shelf, at least at the Leveque No.1 well, remained emergent until the Miocene, but the rest of the southern basin was covered by a basal Paleocene claystone that was followed by mainly fine-grained carbonates, either marl or calcilutite. At Buffon No.1 interbedded claystone limestone and marl were deposited at the base of the Tertiary sequence.

With the tilting of the Browse Basin, the depocenter shifted westward from the cental basin. In the south and west, a complex carbonate prograding wedge was formed (Williams, 1991) that was over 3000 metres thick at Scott Reef No.1.

A thick sequence of porous, fine to course-grained, moderately to well sorted sandstone, similar to that deposited near the end of the Cretaceous, also covered most of the northern Browse Basin in the Paleogene. Thin coal beds are interbedded with sandstones on the eastern side of the basin. Towards the north and south, rare carbonate beds are interbedded with the sandstone (Plate 79), but they form a minor component of the Tertiary sediments in this part of the basin until the Miocene, when calcarenite with lesser amounts of marl and calcisiltite and calcilutite covered the basin. Over most of the basin there is a hiatus between the Eocene and the Miocene sediments.

The Neogene is dominantly calcareous. Yampi No.1 intersected a possible Pliocene age section of unconsolidated, fine to course-grained sandstone above Miocene calcarenites and dolomite. The extent of the clastic sequence is unknown as few wells collected samples above the Miocene.

6.3.2 Quaternary

None of the wells collected samples in the unconsolidated Quaternary section. The lithology of this sequence is likely to be calcareous ooze.

6.4 NOMENCLATURE

The Browse Basin has no formally defined stratigraphic nomenclature. Various authors on the basin have used a variety of informal terms. Sediment sequences have usually been referred to by age (Crostella, 1976; Willis, 1988), or grouped under informal headings. Forrest & Horstman (1986) use age and tectonic heading such as prerift and postrift subdivisions, Allen & others (1978) recognized an 'upper' and 'lower' series, and Elliott (1990) has divided the Permian to Recent sediments into eight labeled 'depositional sequences'. BHP applied Bonaparte Basin formation names to the Browse Basin sediments. Lavering & Pain (1991) also applied Bonaparte Basin names but only at the Group level.

A detailed stratigraphic examination of the whole basin is needed and formal nomenclature applied to appropriate units. The change in lithology from north to south and east to west makes it difficult to carry a single lithological name throughout the basin. The author feels it is inappropriate to carry Bonaparte formation names into the Browse Basin as the lithologies and age relationships of Browse Basin rock units do not necessarily correspond fully to Bonaparte Basin rock units.

7. HYDROCARBONS

7.1 HYDROCARBON DISCOVERIES

(S.J. Cadman, S. Miyazaki)

Six hydrocarbon discoveries have been made in the Browse Basin. Of these accumulations three are presently classified as sub-economic (Scott Reef, Brecknock, Brewster) and three are considered uneconomic (Caswell, Echuca Shoals, Heywood) (Lavering & Pain, 1991). The Scott Reef gas/condensate accumulation is the most significant of the discoveries in the basin to date.

The discoveries are discussed individually below. Additional information is in Appendix 1, Reservoir Geology and Hydrocarbon Show Evaluation section, and in Lavering & Pain (1991).

7.1.1 Scott Reef

The Scott Reef gas field was discovered by Scott Reef No.1 in 1971 and appraised by Scott Reef No.2A and North Scott Reef No.1. The field is situated 280 kilometres off the coast of Western Australia in 0 to 600 metres of water, within Exploration Permit WA-33-P (R2) and onshore Exploration Permit W-36-P. The irregular water depths and exploration permit boundaries are due to the reefal buildup on Scott Reef. Exploration Permit WA-33-P was due to expire in 1985, but still subsists, and neither a production licence nor a retention lease has been issued over the field.

The Scott Reef structure (Figure 15), is a faulted anticline, 53 kilometres in length and 19 kilometres in width on the Scott Reef Trend. Both the anticline axis and the faulting trend northeast. The structure is fault bounded to the northwest and dip closed in other directions.

Scott Reef No.1 was drilled on the crest of the southwestern culmination of the structure. The well penetrated a thick carbonate section (>3000 metres) above the Cretaceous and Jurassic claystone seals that overlie the well's Early to Middle Jurassic and Triassic reservoir sands, and intersected gas-bearing reservoir rocks consisting of Lower Jurassic sandstone and Upper Triassic dolostone and sandstone. Three formation interval tests (FITs) and four drillstem tests (DSTs) were carried out in the reservoir sands. Gas and condensate were recovered, with the best recorded DST flow rate of 0.52 x 10 million cubic metres gas per day and 57.9 cubic metres condensate per day. Twenty-four metres of net pay were interpreted to be present in the Early to Middle Jurassic section (Bint, 1988; Willis, 1988).

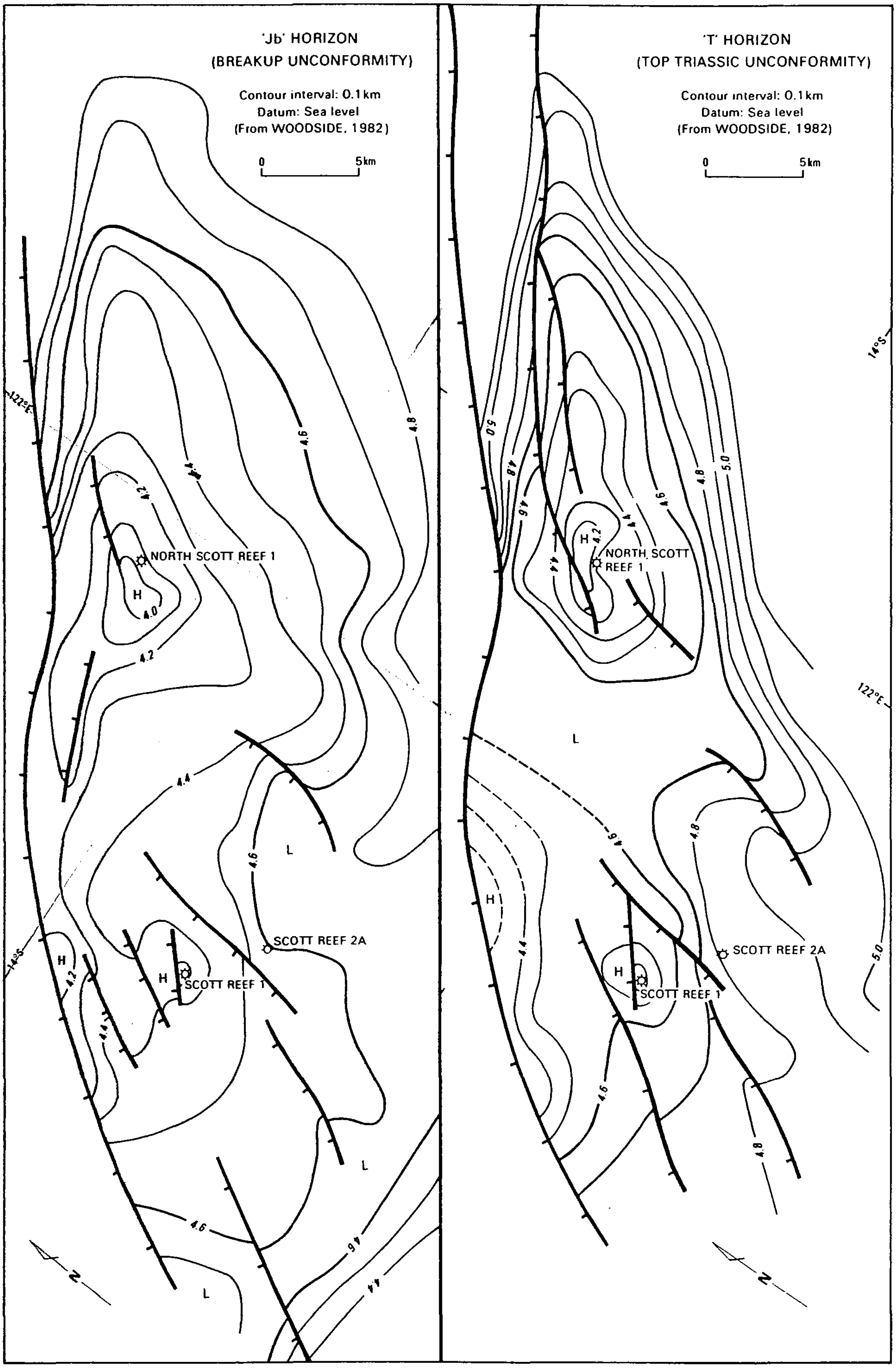


Figure 15. Depth structure maps, Scott Reef gas field.

Scott Reef Nos.2 and 2A were spudded in 1977 (Scott Reef No.2 was abandoned after encountering mechanical problems at 288 metres subsea). Scott Reef No.2A was sited 4.4 kilometres downdip from Scott Reef No.1 and separated from the latter by a fault. Scott Reef No.2A was located on the eastern edge of the culmination, but Jurassic sandstones turned out to be water-bearing. Only a trace to minor amounts of hydrocarbons were recovered from this well. Although no net reservoir is indicated in Scott Reef No.2A, the well is thought to have intersected a gas/water transition zone (Bint, 1988; Willis, 1988).

In 1982, North Scott Reef No.1, located 20 kilometres northeast of Scott Reef No.1 on the northern culmination of the Scott Reef structure, was drilled in water depths of 442 metres. North Scott Reef No.1 was drilled near the crest of the northeastern limb and intersected gas-bearing Lower Jurassic sandstone. None of the Upper Triassic rocks are of reservoir quality in this well. Sixty-six metres of net gas pay were intersected in sandstones of Early Jurassic age. A production test over this interval flowed gas at 1.27 million cubic metres per day and condensate at 79 cubic metres per day (Bint, 1988).

Tight Jurassic volcano-clastics overlie the gas-bearing reservoirs in both Scott Reef No.1 and North Scott Reef No.1. However, pressure data and variation in the thickness of these volcanics suggest that they are neither a cap rock nor reservoirs. Instead, Upper Jurassic and Lower Cretaceous claystones which overlie the volcanics above the Middle Jurassic Jb 'breakup' unconformity, appear to seal the structure.

The left-hand part of Figure 16 displays a cross-section across the field and shows reservoir distribution. Above the field-wide gas-water contact at 4600 metres subsea, the major part of the reservoirs is composed of Lower to Middle Jurassic rocks (area A on Figure 16), between the Jb unconformity and the top Triassic T unconformity. However, none of the three wells intersected a gas-water contact. The Upper Triassic rocks, shown as area C above the gas-water contact, form the remaining reservoirs. However, the Upper Triassic dolostones and sandstones contribute only a minor amount to the total gross rock volume of the field. This is because the Upper Triassic rocks in the vicinity of North Scott Reef No.1 (area D on Figure 16), are not a part of the gas reservoirs. All the reservoirs intersected in Scott Reef No.1 and North Scott Reef No.1, appear to make up a single gas pool.

Wire-line data suggest that the lithology of the Upper Triassic rocks changes laterally across the saddle area between Scott Reef No.1 and North Scott Reef No.1, from sandstone and dolostone into claystone and limestone to the north. Thus, the Upper Triassic rocks, shown as

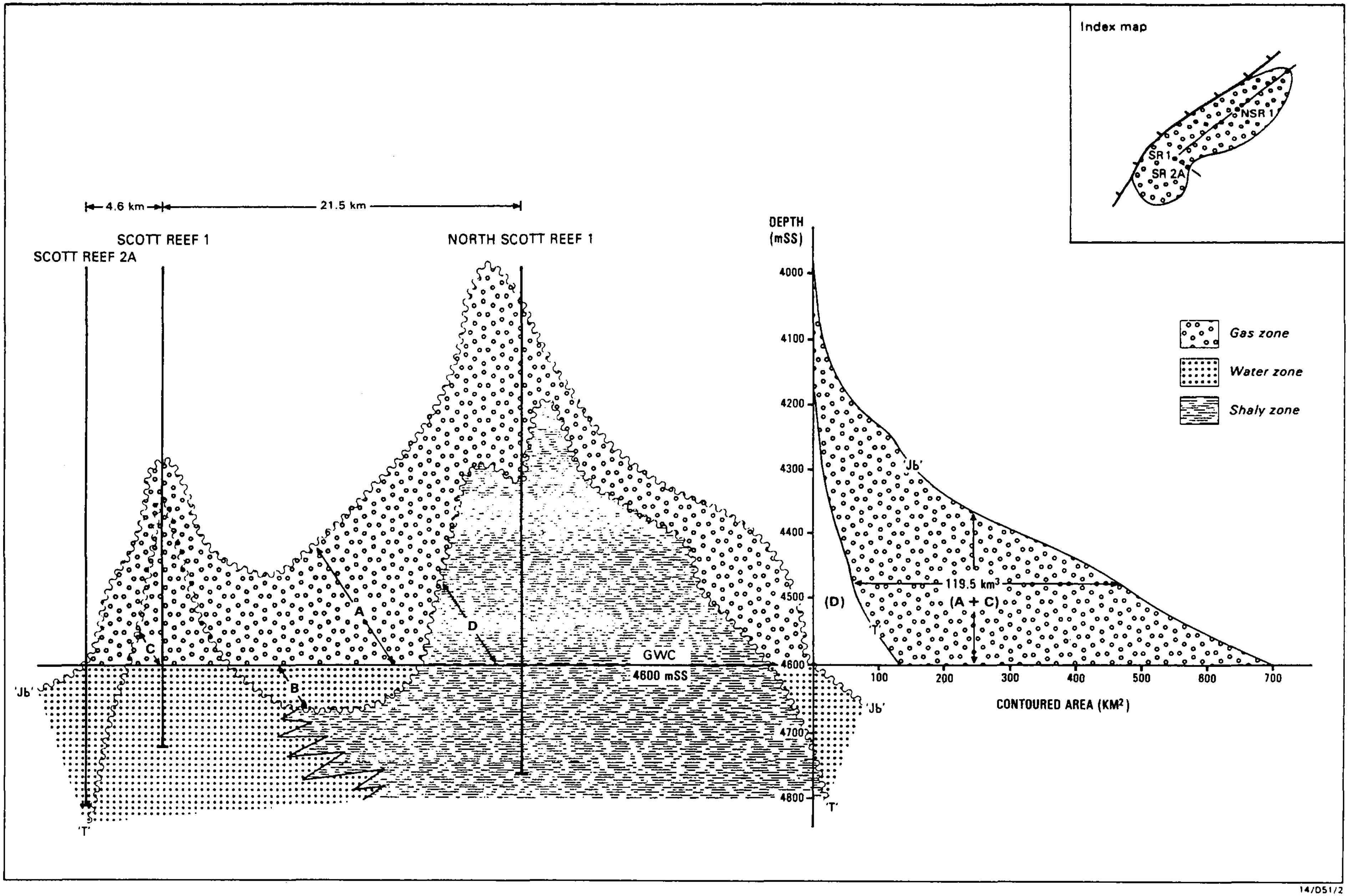


Figure 16. Cross-section across the Scott Reef gas field (left-hand side) and its gross rock volume (right-hand side).

area D, around North Scott Reef No.1 are regarded as non-reservoirs.

On these assumptions, the reservoirs in the entire Scott Reef field have a gross rock volume of 119.5 billion cubic metres (including interbedded non-reservoir rocks), as shown in the right-hand part of Figure 16. The reservoirs have a maximum gross gas column height of 620 metres and a net/gross ratio of 0.13. The Jb horizon has its largest closed area of 694 square kilometres at a depth of 4600 metres subsea. This depth coincides with the field-wide gas-water contact and suggests that the Scott Reef structure is filled to spill point.

According to Woodside (1990), the Scott Reef gas field contains proven plus probable reserves of 13.31 trillion cubic feet of dry gas and 158.5 million barrels of condensate. Gas in the Scott Reef accumulation is relatively lean, with limited quantities of hydrocarbons more complex than pentane. This 'dry gas' appears to include LPG components as well as inert and corrosive gases such as carbon dioxide (which comprises 11 % of the dry gas). A detailed discussion of the field and current reserve estimates are available in Morrison & Miyazaki (1991).

For further discussion on Scott Reef No.1, Scott Reef No.2A and North Scott Reef No.1, refer to Appendix 1.

7.1.2 Brecknock

Brecknock No.1 was drilled 42 kilometres southwest of Scott Reef No.1 in 1979. Located in 543 metres of water on the Scott Reef Trend, it tested a Jurassic/Triassic horst block with overlying drape (anticlinal closure persists through to Lower Tertiary level). As in the Scott Reef wells, Brecknock No.1 penetrated a thick Tertiary carbonate sequence overlying a predominantly claystone Cretaceous section. The Lower to Middle reservoir sandstone underlies a thin volcanic sequence of possible Callovian age. These reservoir sands lie at depths in excess of 3800 metres. Approximately 68 metres of net pay is present in the Jurassic sequence, with porosities ranging from 15 % to 17 %, permeabilities in the order of 220 to 280 millidarcys and water saturations varying from 34 to 66 %. Gas and condensate were recovered from a number of RFTs over the objective interval, and a DST conducted between 3886 metres and 3899 metres recovered 0.20 cubic metres (7.2 cubic feet) of gas and 40 litres of water. Mechanical difficulties prevented production testing of the accumulation (Willis, 1988).

7.1.3 Brewster

Brewster No.1, drilled in the central Browse Basin in 1980, was plugged and abandoned after encountering mechanical difficulties at a depth of 655 metres subsea. Brewster No.1A, spudded ten days later, tested an anticlinal drape over two covergent horst blocks of Early to Middle Jurassic age. Objectives were Jurassic sandstone above and below the 'breakup' unconformity. The well penetrated approximately 1000 metres of Tertiary carbonates and nearly 2000 metres of fine-grained Cretaceous clastics (which provide a seal for the objective section).

The presence of two Late Jurassic gas-bearing sands was inferred from logs (at intervals 3942 to 4172 metres and 4456 to 4675 metres). Gas was seen to be bleeding from a core taken in the upper interval, although no hydrocarbons were recovered from the nine RFTs conducted over this section. Porosities ranged from 4.4 % to 12.7 % and permeabilities from 0.2 millidarcys to 1.6 millidarcys over the cored interval. The lower gas sand was interpreted to be tight, with only 1.6 metres of the net pay exhibiting log porosities greater than 10 %.

7.1.4 Caswell

Caswell No.1 was drilled in 1977 in the central Browse Basin. Drilled to test Early to Middle Jurassic objectives in a drape anticline, it failed to reach its programmed objectives due to mechanical problems. The well reached a total depth of 4097 metres in Neocomian sediments.

Brilliant bluish-white fluorescence in cuttings samples and free oil in the drilling mud was observed in Caswell No.1 while drilling thin sandstones of Albian age between 3606 metres and 3611 metres. No hydrocarbons were recovered from an RFT conducted within this interval but the test indicated permeabilities in the order of 0.1 to 1.0 millidarcys. Log porosities ranged between 7 % and 17 %.

Caswell No.2 was drilled in 1983 in an attempt to evaluate the original Early to Middle Jurassic objectives that Caswell No.1 had failed to penetrate. The well encountered high gas readings, and fluorescence and oil staining in Campanian sandstones between 3264 and 3268 metres. An RFT conducted at 3265 metres recovered 0.8 litres of 47 degree API oil and 0.6 cubic metres of gas. Log porosities of 18.2 % and water saturations of 38 % were recorded over this interval.

The hydrocarbons in the Caswell accumulation are thought to be reservoired in thin overpressured sands not in communication, and of possible turbidity origin (Willis, 1988).

7.1.5 Echuca Shoals

Echuca Shoals No.1 was drilled in 1983 on the downthrown side of the basin margin fault system as a test of a Permo-Triassic fault block with minor Jurassic and Cretaceous drape.

High gas readings with some fluorescence and minor oil staining in cuttings samples were recorded while drilling Lower Cretaceous sandstones of Berriasian to Albian age. Log analysis indicated the presence of two gas-bearing intervals in the Late Jurassic section (at 3314 to 3335.5 metres and 3617 to 3656.6 metres). Log porosities between 12 % and 15 % and water saturations between 19 % and 23 % were calculated for these gas sands. No hydrocarbons were recovered from RFTs conducted in these intervals.

High gas readings were also recorded while drilling Permian sediments between 4281 and 4304 metres, although log porosities calculated for this interval ranged between 2 % and 5 %.

7.1.6 Heywood

Heywood No.1 was drilled on the northeast Browse Basin margin in 1974 on what was interpreted to be a Permo-Triassic horst block. However, it was subsequently concluded that this well did not test a valid structural closure.

Fluorescence in cuttings samples and live oil in the drilling mud were observed while drilling the Late Jurassic section (3405 to 4240 metres). An FIT conducted at 4147.5 metres recovered only water and it was inferred that the hydrocarbon-bearing sands were of low permeability. Log porosities averaged around 10 % over this interval.

7.2 HYDROCARBON CHARACTERISATION

7.2.1 Gas/Condensate

Although there has been a number of encouraging gas shows in the Browse Basin, in only four instances has gas been directly retrieved from subsurface accumulations (Scott Reef, North Scott Reef, Brecknock and Caswell) (Table 1).

The Scott Reef gas comprises 79 % to 95 % methane, 4.4 % to 7.5 % ethane and propane and up to 2 % of heavier hydrocarbons (Table 5). However, 20 kilometres to the north at North Scott Reef, gas collected during a production test comprised 10.8 % carbon dioxide (Bint, 1988).

Table 5. Analyses of natural gases in Browse Basin petroleum accumulations

	Scott Reef 2A	North Scott Reef 1	Breck-nock 1	Breck-nock 1
Methane	95.2	79.42	93.73	93.308
Ethane	3.81	5.22	5.06	5.428
Propane	0.74	2.3	0.95	0.915
i-Butane	0.11	0.44	0.16	0.164
n-Butane	0.07	0.41	0.08	0.129
i-Pentane	0.16	0.18	0.01	0.059
n-Pentane	-	0.12	-	-
Hexane	-	0.16	-	-
Heptanes+	-	0.61	-	-
H_2S	-	-	-	-
CO_2	-	10.83	-	-
Depth	4613 m (m KB)	4041 (m SS)	3890 (m KB)	3847 (m KB)

Analyses in Mole %

Data from Woodside reports

Condensate produced from the Scott Reef accumulation is straw yellow in colour with a gravity of between 48 degrees and 54 degrees API.

Gas analysed from an RFT conducted in a Lower to Middle Jurassic reservoir at Brecknock contained 93 % methane, 5 % ethane and less than 2 % propane, butane and pentane (Table 5).

No data are available on the composition of the 0.6 cubic metres of gas recovered in an RFT at Caswell.

7.2.2 Oil.

Caswell is the only accumulation in the Browse Basin where oil was directly recovered from the subsurface. In this instance, 0.8 litres of 47 degree API oil was recovered from a thin Campanian sandstone at 3265 metres.

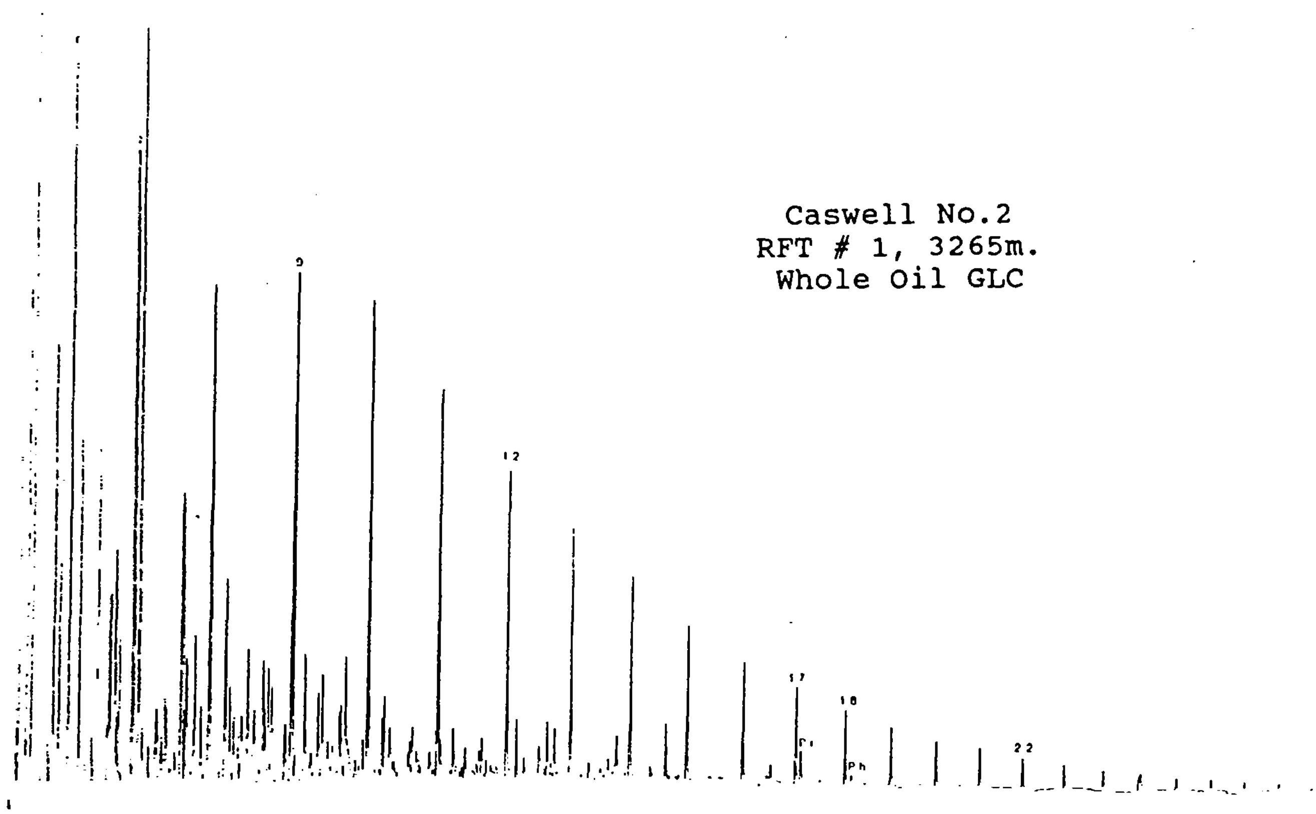
The results of 'whole oil' and C12+ saturate fraction gas/liquid chromatography undertaken on this oil sample are displayed in Figure 17. Selected fragmentograms from a GCMS analysis of the same sample are shown in Figures 18a and 18b. (Woodside Petroleum, 1983).

High concentrations of C27 steranes/diasteranes in comparison to C29 steranes/diasteranes (217 ion) indicate that this oil has probably been sourced from oil-prone rather than gas/condensate-prone organic matter. This interpretation is confirmed by the abundance of low molecular weight n-alkanes and the low concentrations of high molecular weight 'waxy' n-alkanes on the GLC traces (Figure 17).

A high C27 Ts/Tm triterpane ratio (191 ion), relatively high concentrations of C29S steranes to C29R steranes and a high hopane/moretane ratio (191 ion), indicate that the Caswell oil is a mature oil.

The 'skewing' of the GLC traces towards the low molecular weight compounds (Figure 17) is a further indication that this oil is a good quality, light mature crude that has been derived from oil-prone marine source rocks. No evidence of biodegradation or water-washing is apparent.

Although oil was not directly recovered from the Yampi No.1 well, as mentioned previously, residual oil was extracted from a core taken between 3173 and 3178.3 metres. Results of this core analysis are shown in Table 6.



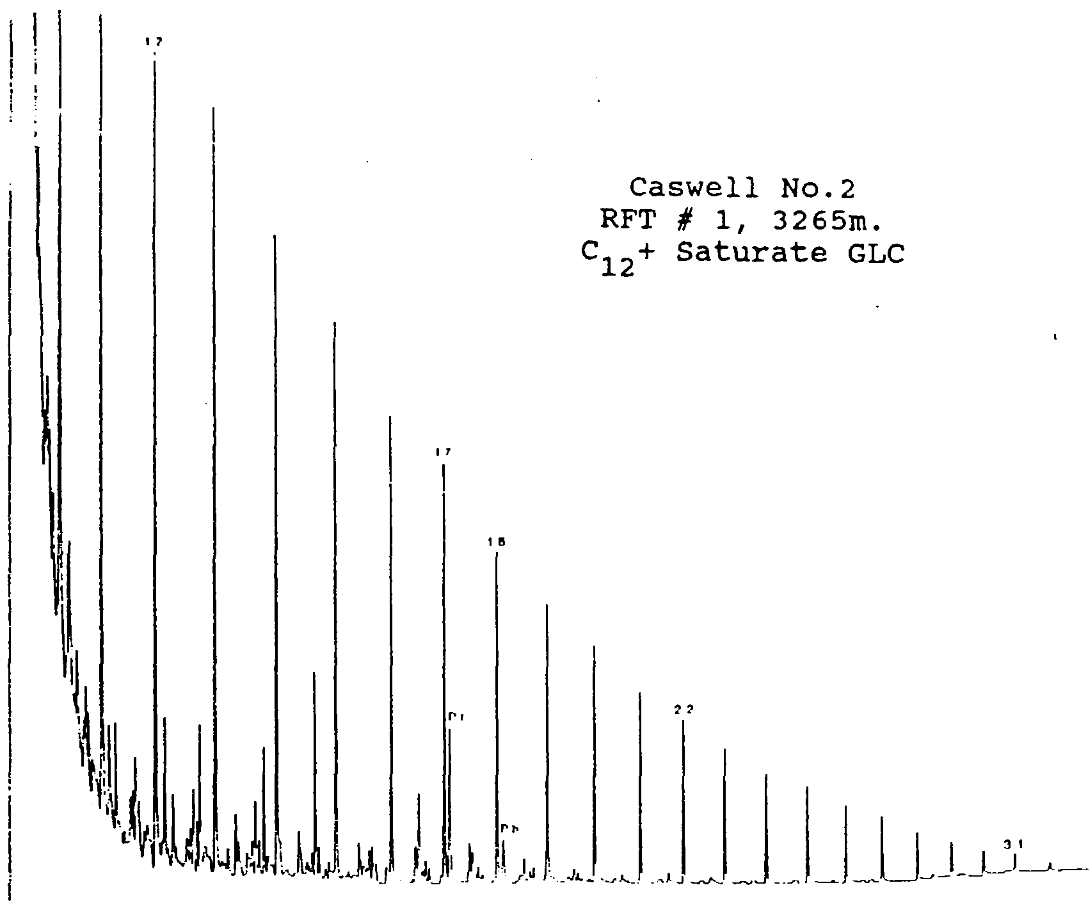
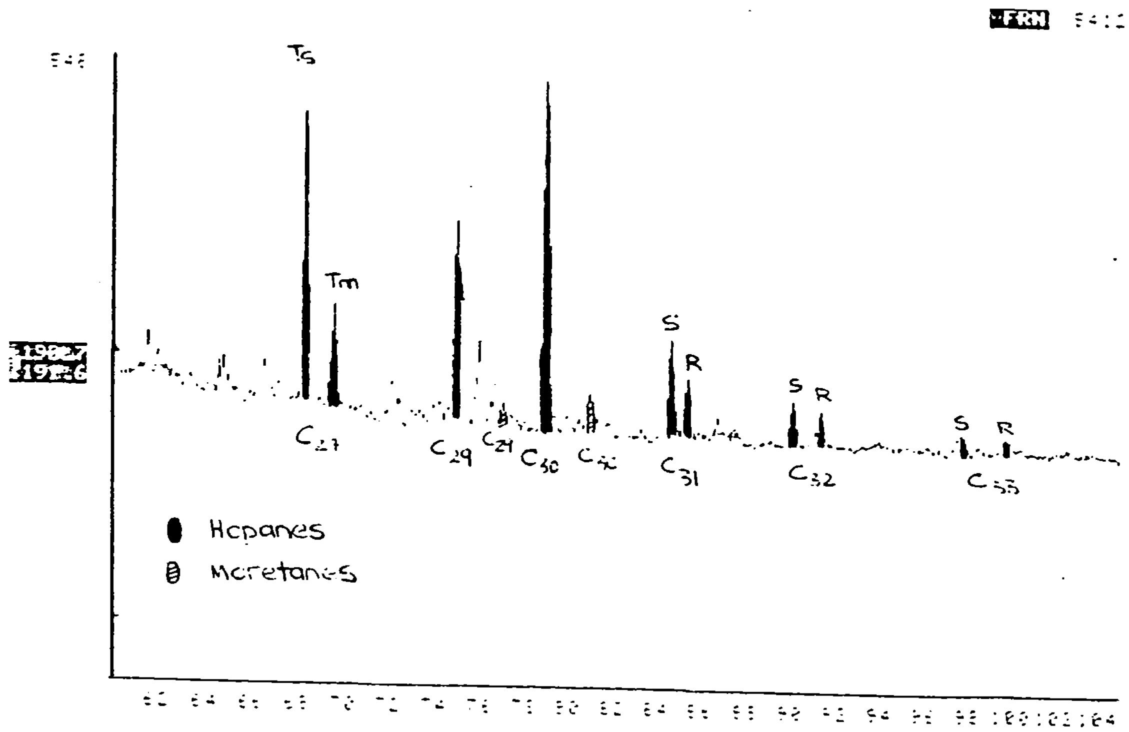


Figure 17. Caswell No.2, whole oil GLC, C12+ saturate GLC.

Caswell No.2
RFT # 1, 3265m
GCMS Selected Saturate Fragmentograms



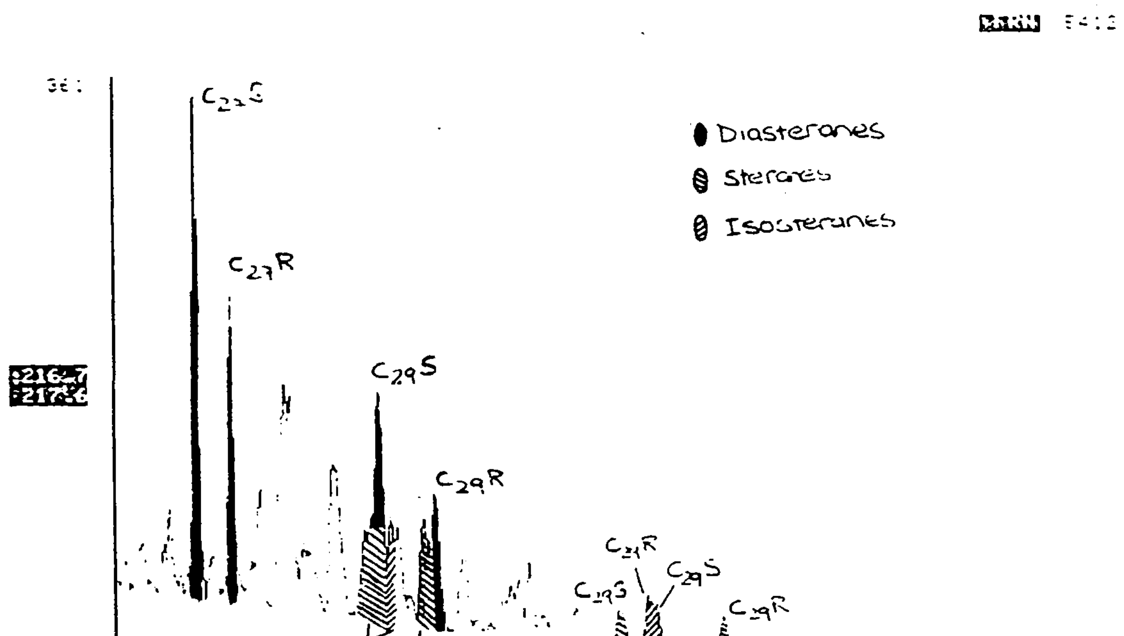


Figure 18a. Caswell No.2, GCMS fragmentograms.

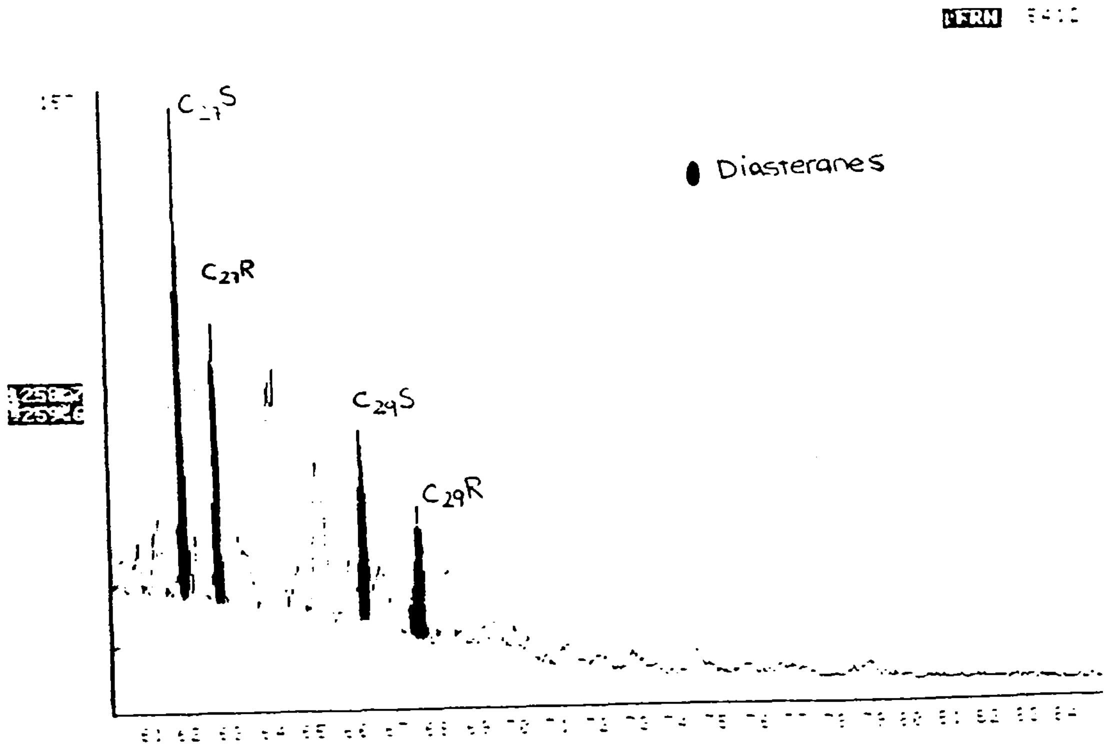


Figure 18b. Caswell No.2, GCMS fragmentograms.

Table 6. Core analysis results - Yampi No.1.

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. YAMPI NO. 1

DATE ANALYSIS COMPLETED SEPTEMBER 1973

Core No.	Sample Depth (metres)		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	Sample "cut" in tetrachlorethylene
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				
1	3174.10	3174.15	As above MIC	6.6	0.1	0.1	2.49	2.69	20.2	1.7	N.D.	Tr	even light yellow	Fair
1	3176.25	3176.30	Slst; carb aren shly	5.8	N.D	22	2.50	2.69	32.4	1.6	N.D.	Fair	dull yellow	Fair

Remarks: -

General File No. 72/2914
Well File No. 73/214

8. HYDROCARBON HABITAT

This chapter examines the source rock, reservoir rock and seal potential of the Browse Basin rocks. The geohistory analysis looks at heatflow, burial history, maturity levels of source rock and timing of hydrocarbon generation.

8.1 SEALS

(S.J. Cadman)

8.1.1 Triassic

Late Triassic sediments have been intersected in Barcoo No.1, Brecknock No.1, Yampi No.1, Lynher No.1, Scott Reef No.1 and North Scott Reef No.1. The Triassic sequence in these wells consists predominantly of interbedded sandstone, siltstone and claystone with minor recrystallised limestone. Any reservoirs developed in the Triassic section will probably be sealed by intraformational claystones.

To date, the only Triassic hydrocarbon discovery in the Browse Basin is the Scott Reef gas/condensate accumulation. At Scott Reef No.1, although Late Triassic gas sands appear to be sealed by a thin claystone/dolomite bed of Triassic age, the reservoir is probably in communication with overlying Jurassic gas sands (Morrison & Miyazaki, 1991). The Late Triassic section at North Scott Reef No.1 is essentially 'tight'.

It is probable that a similar reservoir/seal relationship exists in Triassic reservoirs elsewhere in the basin.

8.1.2 Jurassic

The Early to Middle Jurassic syn-rift sediments consist of interbedded fluvio-deltaic to marine sandstone, siltstone and claystone with minor coal. Intraformational claystones are the most likely seals for hydrocarbon accumulations reservoired within this section.

In many of the Browse Basin wells, a volcanic sequence (consisting of basaltic flows and pyroclastic material) of probable Middle Jurassic age has been encountered. It is possible that these volcanics, thought to be associated with 'breakup', may provide a seal for underlying Middle Jurassic sands. However, in Buffon No.1, gas was encountered in what were interpreted to be fractures within Middle Jurassic volcanics. In this instance, seal is probably provided by overlying Cretaceous claystones.

In the late Middle Jurassic, drift phase sedimentation in the central basin commenced with the deposition of transgressive marine shale and claystone. These claystones and shales eventually onlapped areas of high relief and parts of the Prudhoe Terrace. They probably provide a competent regional seal for both Early to Middle Jurassic and Triassic sands in these areas.

On the eastern basin margin, deltaic to marginal marine sedimentation prevailed through most of the Late Jurassic. Late Jurassic sediments on these shelfal areas typically comprise interbedded sandstone, siltstone and claystone with minor coal. Intraformational claystones are the most likely seals within this sequence. A thick claystone (approximately 100 metres thick) of Tithonian age with good sealing potential was penetrated in Heywood No.1, Yampi No.1 and Echuca Shoals No.1.

In the southern Browse Basin (Lombardina No.1, Leveque No.1, Lynher No.1), Middle to Late Jurassic sediments are sealed by a thick Late Jurassic to Early Cretaceous claystone.

8.1.3 Cretaceous

Regressions in the Early Neocomian and Campanian, together with a transgression in Late Neocomian times, has led to the deposition of interbedded sandstone, siltstone and claystone over much of the eastern margin of the Browse basin during the Cretaceous. On the Prudhoe Terrace and Yampi Shelf, intraformational claystones are the most likely seals within this section. Elsewhere in the basin, marine claystone and marl characterised Cretaceous deposition.

On the eastern basin margin, sandstone deposition is virtually continuous from Late Cretaceous (Maastrichtian) to Eocene times.

8.1.4 Tertiary

Regionally competent seals for most of the Tertiary carbonate section throughout the Browse Basin appear to be absent. This does not preclude the possibility that recrystallised limestones within the Tertiary carbonates may provide local seals. An adequate seal for these sands has yet to be encountered.

8.2 RESERVOIRS

8.2.1 Reservoir Potential Summary

(S. Miyazaki)

Tertiary and Upper Cretaceous rocks in the central basinal areas lack the development of good reservoir rocks. Here, the dominant lithology is calcilutite and marl. Lower Cretaceous sandstones tend to retain good porosity to depths of 3000 metres. Thereafter, reservoir quality deteriorates with depth in a fairly predictable manner (Figure 19).

Jurassic sandstones tend to exhibit good porosity even below 4000 metres, but their permeability is low. Lower Jurassic fluvial sandstones, the main reservoirs in the Scott Reef and Brecknock gas fields, are primary objectives in the basin. However, the vertical and areal distribution of Jurassic sandstones is difficult to predict because Lower to Middle Jurassic volcanics occasionally and irregularly occupy a large proportion of geological structures. These volcanics appear to act as a thief zone, where they are of neither reservoir nor seal quality. However, as in Buffon No.1, gas may be trapped in fractures developed in the volcanics.

Porosities in Triassic reservoirs vary widely, regardless of depth (Figure 19). High porosity may be due to secondary porosity. Dolostones are gas-bearing in Scott Reef No.1. However, dolostones were not intersected in nearby North Scott Reef No.1, nor in the Triassic section of any other wells in the Browse Basin. The distribution of porous sandstones is mainly confined to Upper Triassic rocks deposited in fluvial and deltaic environments. There are not enough data available to speculate on the dolomitisation process or their areal distribution. Limestones are tight and, in many wells, recrystallised.

There is little likelihood that the Permian section contains high quality reservoir rocks. More detailed discussions on reservoir porosity and permeability are contained in the reservoir distribution section below and, for individual wells, in the reservoir geology and hydrocarbon show evaluation section of Appendix 1.

8.2.2 Reservoir Distribution

(S.J. Cadman)

Poor well control throughout the Browse Basin has made prediction of porosity trends difficult. Apart from cores recovered from stratigraphic tests of the eastern basin margin (Leveque No.1, Londonderry No.1, Rob Roy No.1), the only wells in the basin in which direct porosity measurements were made on core material are Yampi No.1, Brewster No.1A, North Scott Reef No.1, Scott Reef No.1 and Scott Reef No.2A.

Silicification seems to have occluded reservoir porosity in a number of wells. In Lombardina No.1, early Jurassic sandstones are extensively cemented with recrystallised silica below 2701 metres, reducing porosity to around 7 %. In nearby Lynher No.1, significant silica cementation commences in Jurassic, Late Triassic and Permian sandstone below 1940 metres.

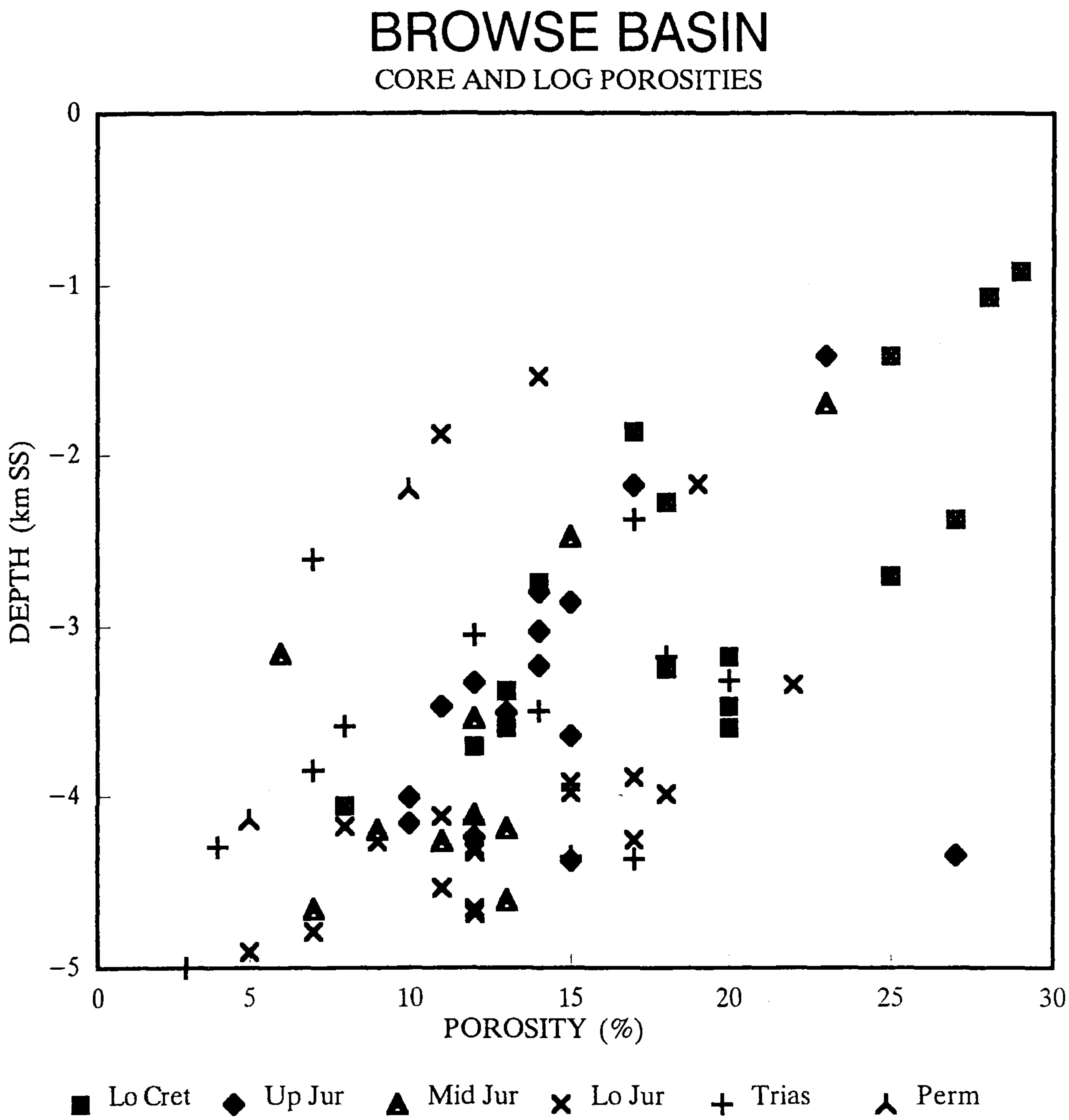


Figure 19. Porosity versus depth trends, Browse Basin.

Further to the north, in Yampi No.1, an increase in silica cement in Neocomian sandstones below 1832 metres was noted. In this well, silicification seems to have affected Early Cretaceous, Jurassic, Triassic and Permian reservoirs. Similarly, in Heywood No.1, silica cement is observed in Early Cretaceous and Jurassic sandstones below 3093 metres.

Basinwards, in Brewster No.1A, a core cut between 4012 metres and 4021.3 metres in a gas sand of Late Jurassic age, gave low porosity measurements (<10 %) due to the presence of authigenic quartz. In this reservoir, hydrocarbon emplacement seems to have post-dated porosity occlusion. For this reason, it is considered unlikely that in Jurassic reservoirs in the deeper, central Browse Basin early hydrocarbon emplacement will have preserved primary porosity.

To the west, on the Scott Reef structural trend, conventional cores taken in Scott Reef No.1, Scott Reef No.2A and North Scott Reef No.1 at depths in excess of 4500 metres show relatively limited silica cementation. Porosities of around 12 % and average permeabilities of nearly 4 millidarcys recorded in these cores are considered excellent for sandstones at this depth.

The source of the silica which has reduced reservoir porosity in many areas of the Browse Basin is uncertain. However, it is likely that Late Jurassic and Early Cretaceous compacting and de-watering shales in the central Browse Basin have expelled significant volumes of silica saturated water. It is conceivable that sand bodies stratigraphically isolated from silica saturated aquifers may retain better porosity versus depth relationships than regionally extensive sands.

8.2.2.1 Permian

A wedge of Permian sediments has been penetrated in a number of wells on the eastern basin margin. Although encountered at relatively shallow depths, porosity preservation in the sandstone, siltstone, claystone and minor limestone of the Permian sequence is poor. Two conventional cores cut in the Permian section encountered in Rob Roy No.1 gave porosities of between 3 % and 12 % with permeabilities of around 0.21 millidarcys. Poorly sorted, well cemented Permian sandstones in Lynher No.1 gave log derived porosities of between 5 % and 10 %.

Basinwards, on the Prudhoe Terrace, Prudhoe No.1 intersected a recrystallised Permian limestone underlain by claystone. Log derived porosities approached zero over the limestone interval.

A Permian sandstone/siltstone/claystone sequence in Yampi No.1 showed extensive silica cementation with minor dolomite cement. Log-derived porosities of less than 9 % were indicated despite high gas reading. An RFT conducted at 4065.5 metres failed to recover formation fluids. Log porosities were poor in Euchuca Shoals No.1 (2-5 %). An RFT taken in the interval failed to recover formation fluids.

8.2.2.2 Triassic

A number of wells on the eastern basin margin and on the Scott Reef structural trend have intersected sediments of Late Triassic age. With the possible exception of wells drilled in the Scott Reef area (porosities of up to 20 % were measured in Late Triassic sandstones around 4380 metres in Scott Reef No.1), silicification of Triassic reservoirs may be a problem throughout much of the Browse Basin.

Direct porosity measurements on Triassic sandstones were made only in Scott Reef No.1. Well control in the Triassic is poor, but log derived measurements indicate that porosities in Triassic sandstones probably do not exceed 10 % over much of the basin. Higher porosities could be expected in areas isolated from the influence of silica saturated aquifers.

8.2.2.3 Jurassic

Direct porosity measurements and log derived porosity values have been used to contour the generalised Jurassic porosity trends in Figure 20. It must be remembered that average porosity values have been used to produce this figure and that porosities in the Early to Middle Jurassic fluvio-deltaic and nearshore marine sandstones vary widely, reflecting a combination of the original depositional fabric and later diagenesis.

Although porosity occlusion of Jurassic reservoirs with authigenic quartz has been noted in a number of wells (Heywood No.1, Yampi No.1, Brewster No.1A, Lombardina No.1, Lynher No.1), it can be seen from Figure 20, that where there is sand development in the Jurassic section, fair to excellent reservoir porosities are indicated over most of Leveque Shelf, Yampi Shelf, Prudhoe Terrace and Scott Reef structural trend. Only in the central basinal areas can porosities of less than 10 % be expected.

In Buffon No.1, log porosities of between 9 % and 20 % together with high gas readings were recorded over a thick volcanic sequence of probable Middle Jurrassic age. As an RFT conducted in this interval indicated tight formation with possible fracture porosity and permeability, these porosity values were not used in Figure 20.

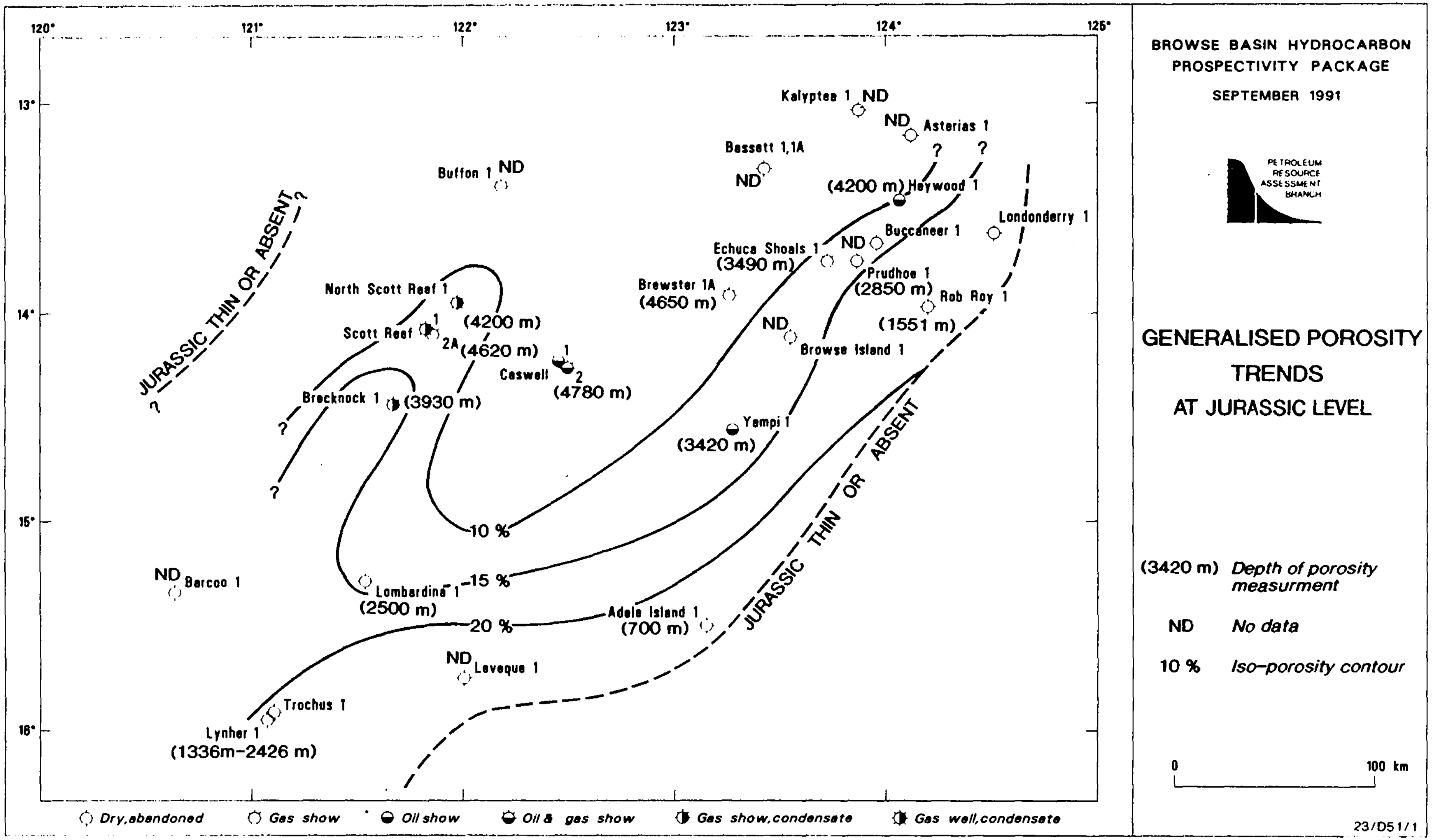


Figure 20. Generalised porosity trends at Jurassic level.

8.2.2.4 Cretaceous

Reservoir porosity in the Cretaceous sand sequences is generally good to excellent over most of the basin (>15 %). Exceptions are the very fine Early Cretaceous sands encountered in Leveque No.1, which, because of their small grain size, gave average log porosities of around 8 %.

Little sand development is evident in the Cretaceous away from the shelfal areas - the Cretaceous section in Buffon No.1, Brecknock No.1 and the Scott Reef wells consists predominantly of claystone, marl and calcilutite. A lack of reservoir potential in the Cretaceous is also evident in Lombardina No.1 and Lynher No.1. Here, the lithology is claystone and minor marl. Occasional thin sandstones are developed in the Cretaceous at Lynher No.1. However, logs indicate porosities of less than 10 % in these units.

Thin Campanian hydrocarbon bearing sandstones in the Caswell area gave porosities of around 18 %.

Silicification does not appear to be a major problem in Cretaceous reservoirs. However, an increase in silica cement was noted in Early Cretaceous sands below 3093 metres in Heywood No.1 and below 1832 metres in Yampi No.1.

8.2.2.5 Tertiary

Except where extensive carbonate recrystallisation has occurred, excellent reservoir porosity is observed (20 to 40 %) in most of the Tertiary carbonate section.

8.3 SOURCE ROCKS

(B.G. West)

The geochemical data included in this study have been synthesised from well completion reports, destructive analysis reports and the Robertson Research (1986) geochemical study of the Northwest Shelf. Pyrolysis data from fifteen of the wells are summarised in Appendix 6.

For convenience, the stratigraphic sequence in the Browse Basin was subdivided into six major units, and the geochemical data grouped into one of these major units. The units, based on the seismic markers of Willis (1988), are:

1. Aptian - Cenomanian (D seismic marker)
2. Neocomian - Aptian (F seismic marker)
3. Late Jurassic - Early Neocomian (Jc seismic marker)
4. Early - Middle Jurassic (Jb seismic marker)
5. Triassic (T seismic marker)
6. Permian (O seismic marker)

Maps showing the generalised distribution of Total Organic Carbon (TOC), kerogen facies and maturity level at each major stratigraphic unit, were constructed from the pyrolysis data, and are presented as Figures 21a through to 26a. Also included, are maturity versus depth plots (Figures 27 to 37) constructed from pyrolysis data and vitrinite reflectance determinations for eleven of the wells.

8.3.1 Aptian - Cenomanian

The Aptian - Cenomanian sequence has been intersected by all of the wells drilled in the basin. Marine conditions probably prevailed over most of the central basin and Prudhoe Terrace during this time, depositing thin, organically rich mudstones and shales in the southern part where the sequence is the thickest.

Geochemical data from wells in the basin (Appendix 6) indicates that thin organically rich shales occur in Yampi No.1 (% TOC 0.88-4.44), Lombardina No.1 (% TOC 1.09-2.47) and Barcoo No.1 (% TOC 1.42-4.47). The hydrogen index (HI) however is very low in Yampi No.1 (less than 100), but in Lombardina No.1 HI values range from 112-237, and in Barcoo, 132-312, indicating possible oil-prone kerogens in the southern part of the basin.

The generalised distribution of TOC, kerogen facies and maturity levels based on the pyrolysis data (Figures 21a, 21b) indicate that a large part of the basin may contain mature source rocks. However, the maturity versus depth plots (Figures 27-37) suggest that only the area around Buffon No.1 in the north, has reached a maturity level sufficient to generate liquid hydrocarbons. This is generally in agreement with the conclusions of Willis (1988).

Although potential source rocks occur througout the basin in the Aptian - Cenomanian, their level of organic richness is greatest in the southern part of the basin, where the sediments are thickest. However, the maturity level is too low to have generated liquid hydrocarbons. Although the level of organic richness is lower elsewhere in the basin, if sufficient thickness of sediment has accumulated in grabens postulated to occur in the northern central part of the basin, it is possible that the level of maturity there has been sufficient to generate liquid hydrocarbons.

8.3.2 Neocomian - Aptian

Most of the wells in the basin have intersected a Neocomian - Aptian sequence of widely varying thickness, with the thickest section occuring in the central and northeast parts of the basin. Marine shelf claystones with interbedded silt, sand and carbonates were deposited

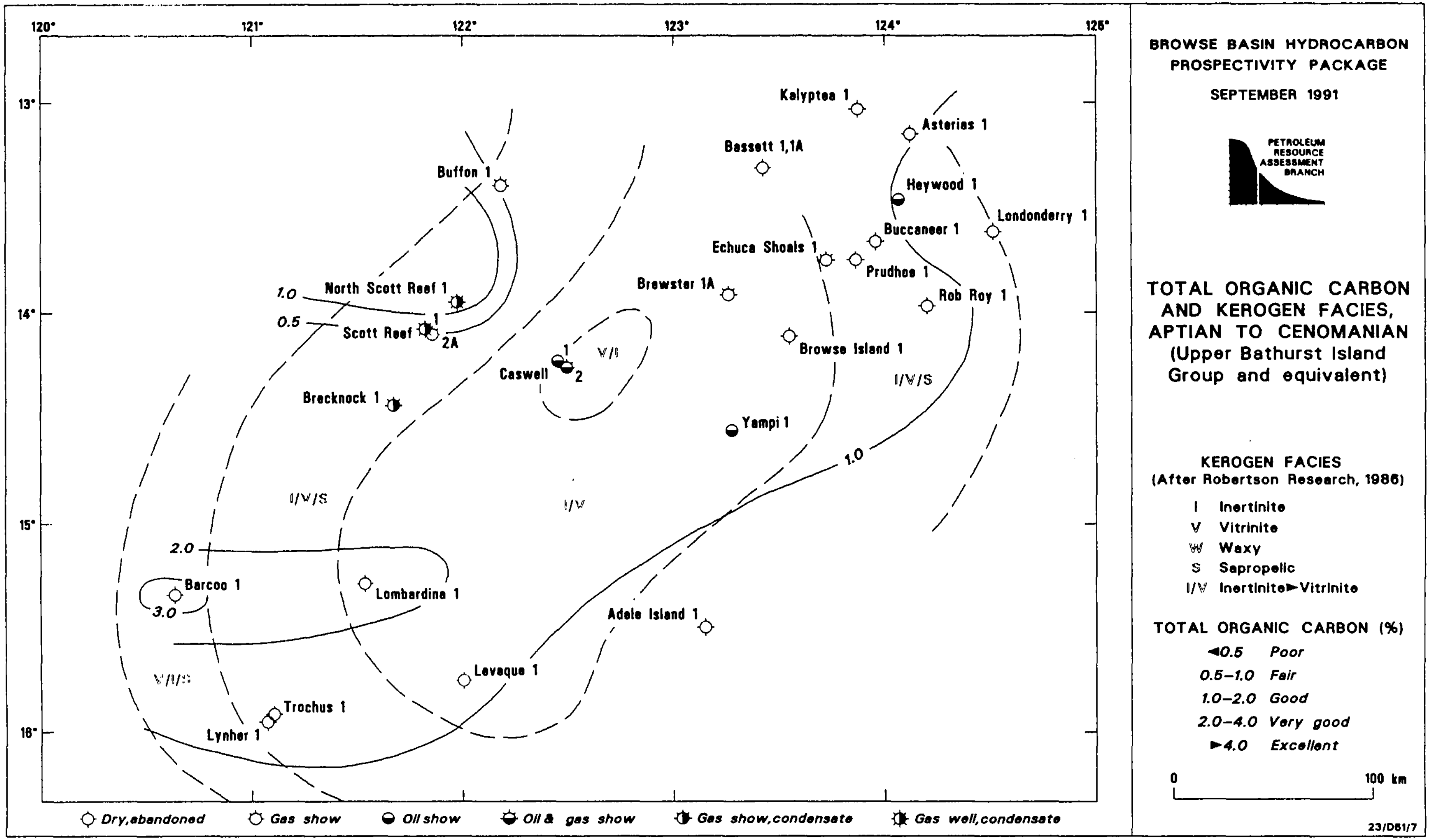


Figure 21a. TOC and kerogen facies, Aptian to Cenomanian.

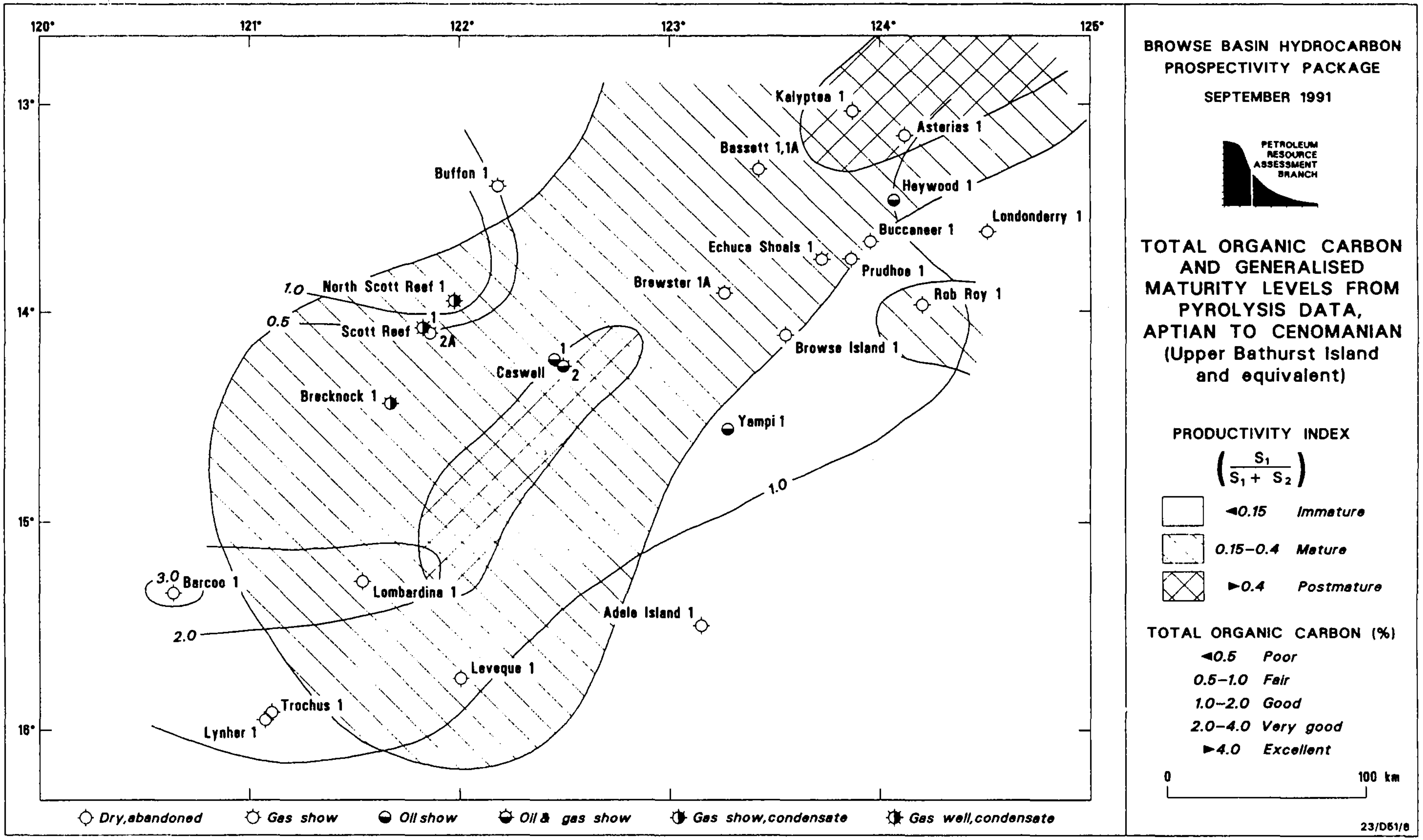


Figure 21b. TOC and generalised maturity from pyrolysis data, Aptian to Cenomanian.

over most of the area. Their absence around Buffon No.1 in the northwest, and Yampi No.1 and Adele Island No.1 in the southeastern shelf area may be due to local uplift.

Geochemical data from wells (Appendix 6) indicates the presence of organically rich shales (% TOC 1.0-1.5) throughout the basin, however the only wells where the HI is significant enough to indicate oil-prone source rocks are Prudhoe No.1 (156-204) and Asterias No.1 (102-160), both in the northeast.

The TOC, kerogen facies and maturity levels plotted from the pyrolysis data (Figures 22a, 22b) indicate the central part of the basin is potentially mature for the generation of liquid hydrocarbons, but the maturity versus depth plots (Figures 27-37) suggest that the central and northern parts of the basin may be marginally overmature, and the southern part mainly immature or marginally mature for oil generation.

A substantial thickness of organically rich sediments suitable for sourcing liquid hydrocarbons occur in the central and northern parts of the basin. Data indicates these rocks are either mature (for example at Prudhoe No.1) or marginally overmature. We believe these data indicate that the Neocomian - Aptian section may have potentially generated significant quantities of liquid hydrocarbons.

8.3.3 Late Jurassic - Early Neocomian

Late Jurassic to Early Neocomian marine transgressive shales and siltstones have been intersected by wells throughout the basin, except in the north (Buffon No.1) and northeast shelf area (Londonderry No.1 and Rob Roy No.1). The section is thickest in the northern central basin where it exceeds 800 metres in Heywood No.1 and 600 metres in Brewster No.1A, and it rapidly thins towards the present basin margin in the east and south.

Although the geochemical data is very limited for most wells except Lynher No.1 (Appendix 6), they indicate a widespread distribution of organically rich shales. TOC values generally range from 0.5 % to 1.9 %, Lynher No.1 being the exception with TOC values ranging from 1.02 % to 19.3 %, and averaging 8.8 %. Most of the wells with high TOC values also have moderate HI values of between 100 and 200, indicating the source has fair to good liquid hydrocarbon potential.

The mapped TOC, kerogen facies and maturity levels (Figures 23a, 23b) indicate moderate source potential and maturity levels throughout the central basin area. The maturity versus depth plots (Figures 27-37) indicate that the central deep area, represented by Caswell No.1, Lombardina No.1 and Brewster No.1A is overmature. However

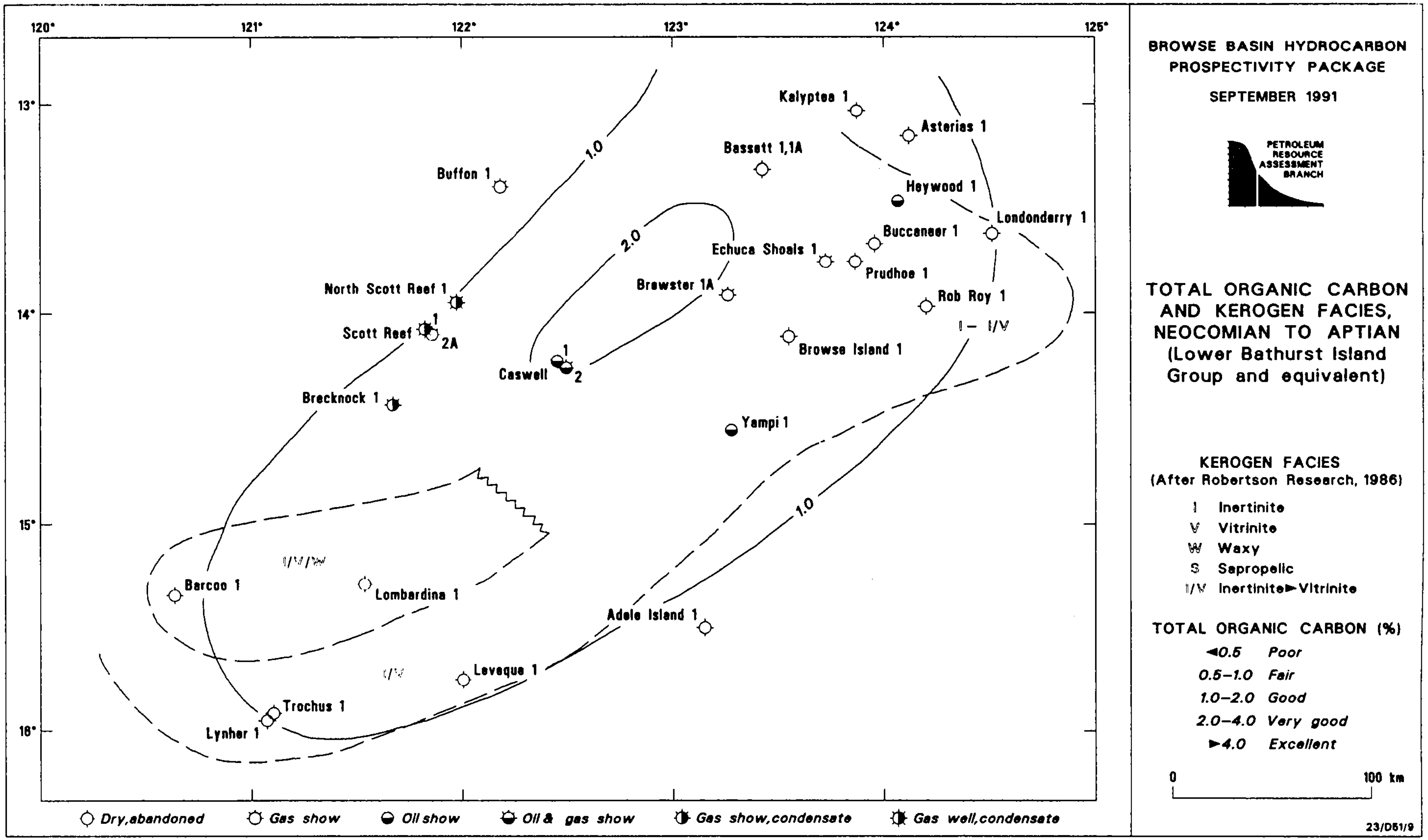


Figure 22a. TOC and kerogen facies, Neocomian to Aptian.

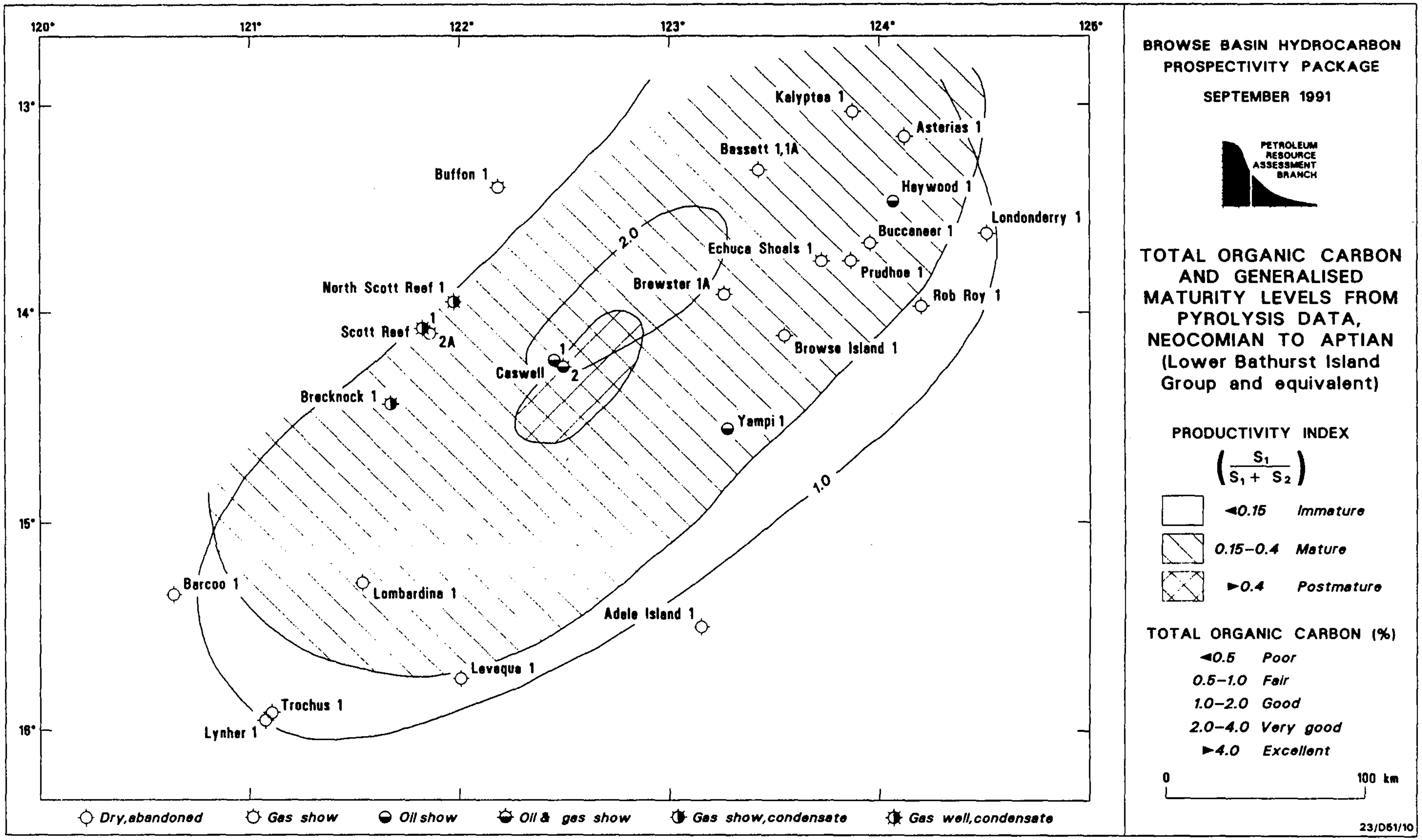


Figure 22b. TOC and generalised maturity from pyrolysis data, Neocomian to Aptian.

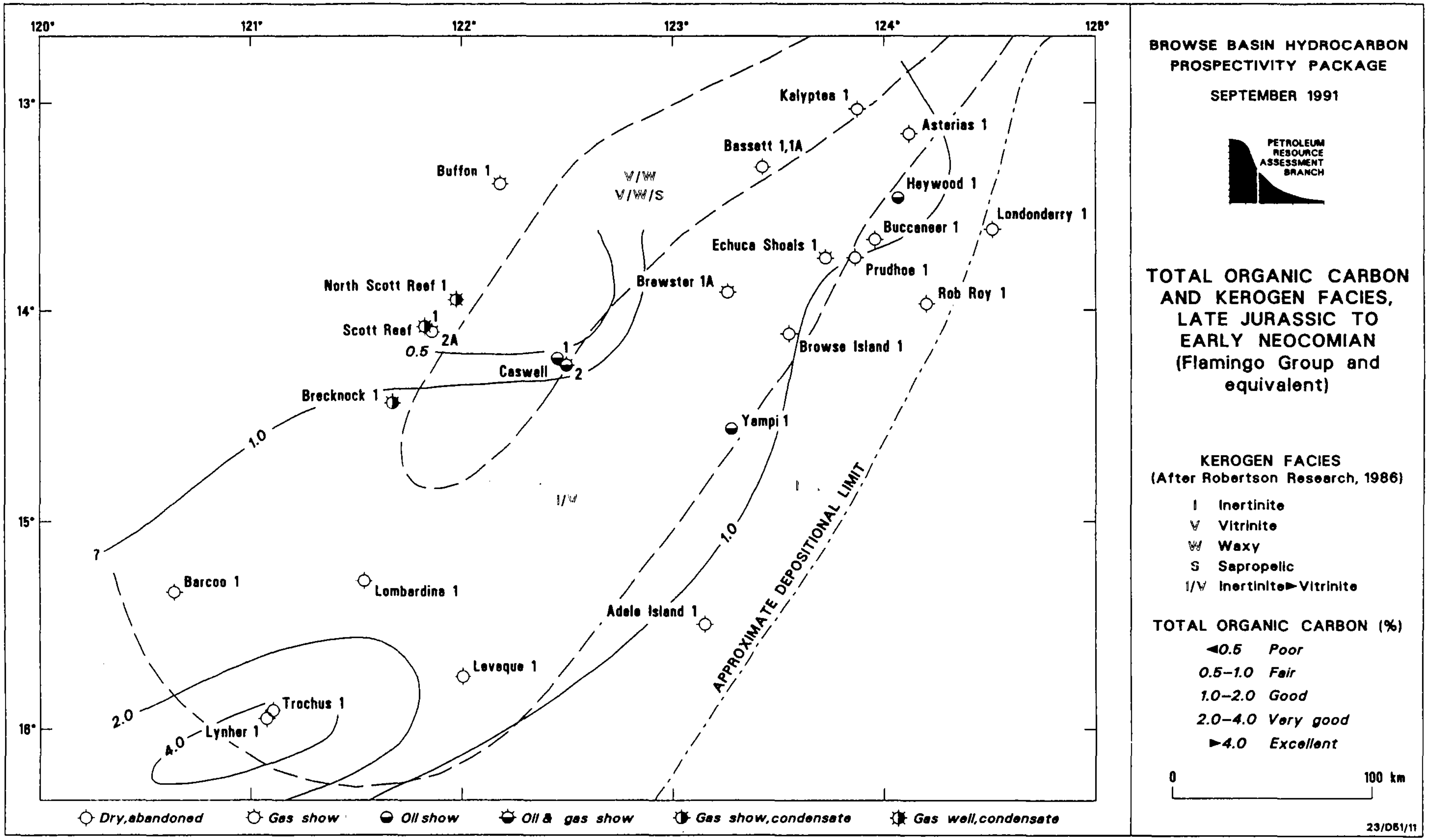


Figure 23a. TOC and kerogen facies, Late Jurassic to Early Neocomian.

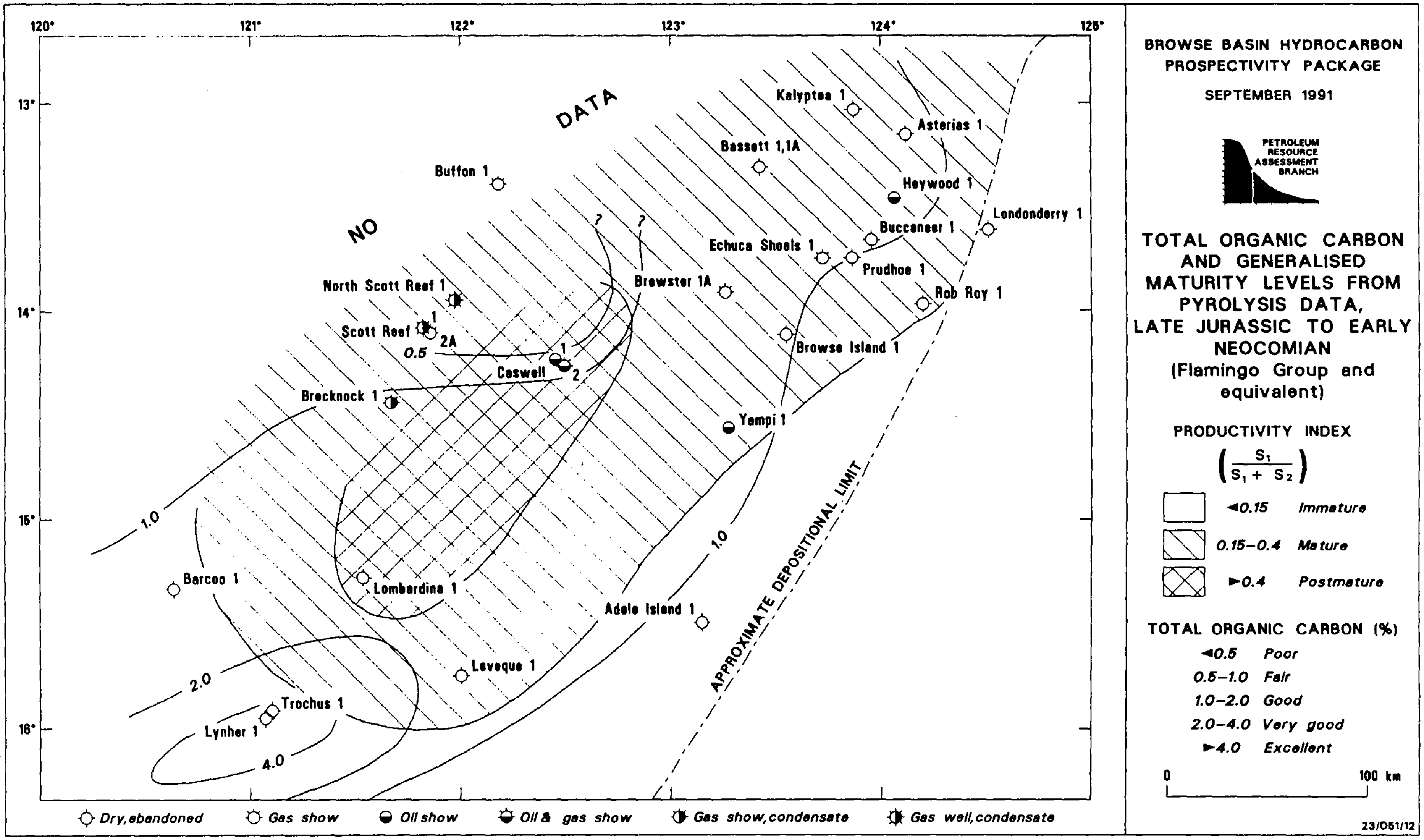


Figure 23b. TOC and generalised maturity from pyrolysis data, Late Jurassic to Early Neocomian.

the southern basin margin area represented by Lynher No.1 and Barcoo No.1, and northeastern basin margin area represented by Prudhoe No.1 and Yampi No.1 are marginally mature for the generation of liquid hydrocarbons.

Late Jurassic to Early Neocomian marine shales are considered to be a major potential source of liquid hydrocarbons in the basin, where their thickness and lateral extent would compensate for lower yield, although insufficient well data have prevented an accurate assessment of their productivity. The distribution of mature source rocks demonstrates they have the capacity to charge possible updip stratigraphic pinchouts along the basin margins, as well as the more conventional structural plays.

8.3.4 Early - Middle Jurassic

The Early to Middle Jurassic (pre-breakup) rocks are very variable in thickness, ranging from thin to absent on the basin margins, to over 1000 metres in the central basin area. Sediments range from fluvial to delta plain in the south and the basin margins, through nearshore and delta front, to prodelta and marine in the central and northern part of the basin (Robertson Research, 1986).

Available geochemical data (Appendix 6) indicates a widespread distribution of source rocks, with TOC values generally ranging from about 1.0 % to greater than 3.0 %. Only one well, Buffon No.1, had TOC values considerably less than 1.0 %. The wells with high TOC values generally also have moderately high HI values, ranging from about 100 to 200, suggesting a possible oil source.

The TOC, kerogen facies and generalised maturity maps (Figures 24a, 24b), and the maturity versus depth plots (Figures 27-37) both indicate that these rocks are likely to be a good oil source, and are likely to be mature throughout the central basin area. Where the sequence is thick, we believe there is potential for substantial quantities of liquid hydrocarbons to have been generated. The areas of best source potential are likely to be in postulated grabens in the central part of the basin, and along the eastern basin margin.

The Early - Middle Jurassic prodelta sediments are likely to be a major source of liquid hydrocarbons in the basin. Their distribution and inferred level of maturity is sufficient to have generated considerable quantities of liquids, which may have migrated laterally to the basin margins, and become trapped in tilted fault blocks marginal to the western edge of the basin, or in stratigraphic pinchouts along the southern and eastern basin margins.

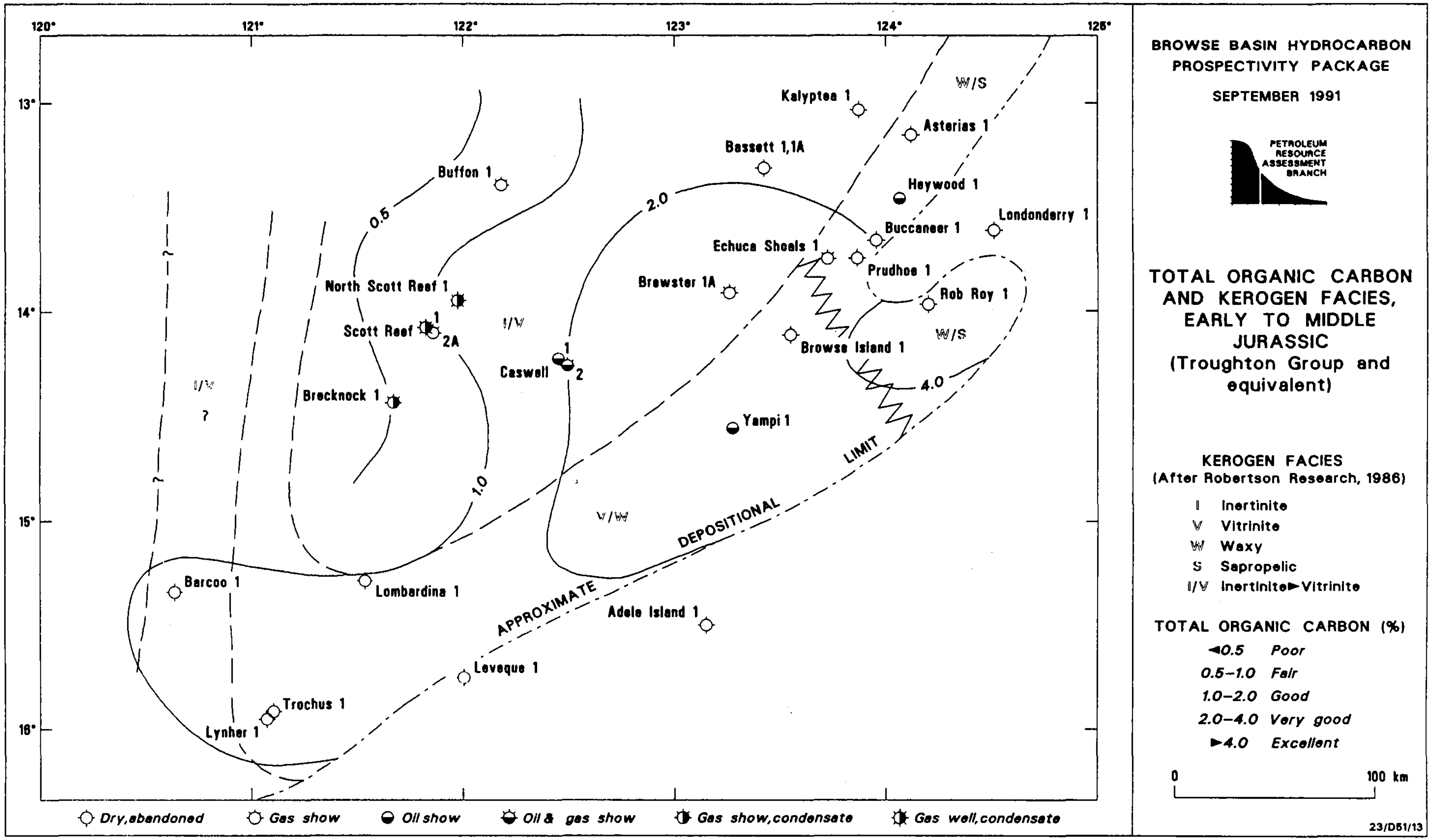


Figure 24a. TOC and kerogen facies, Early to Middle Jurassic.

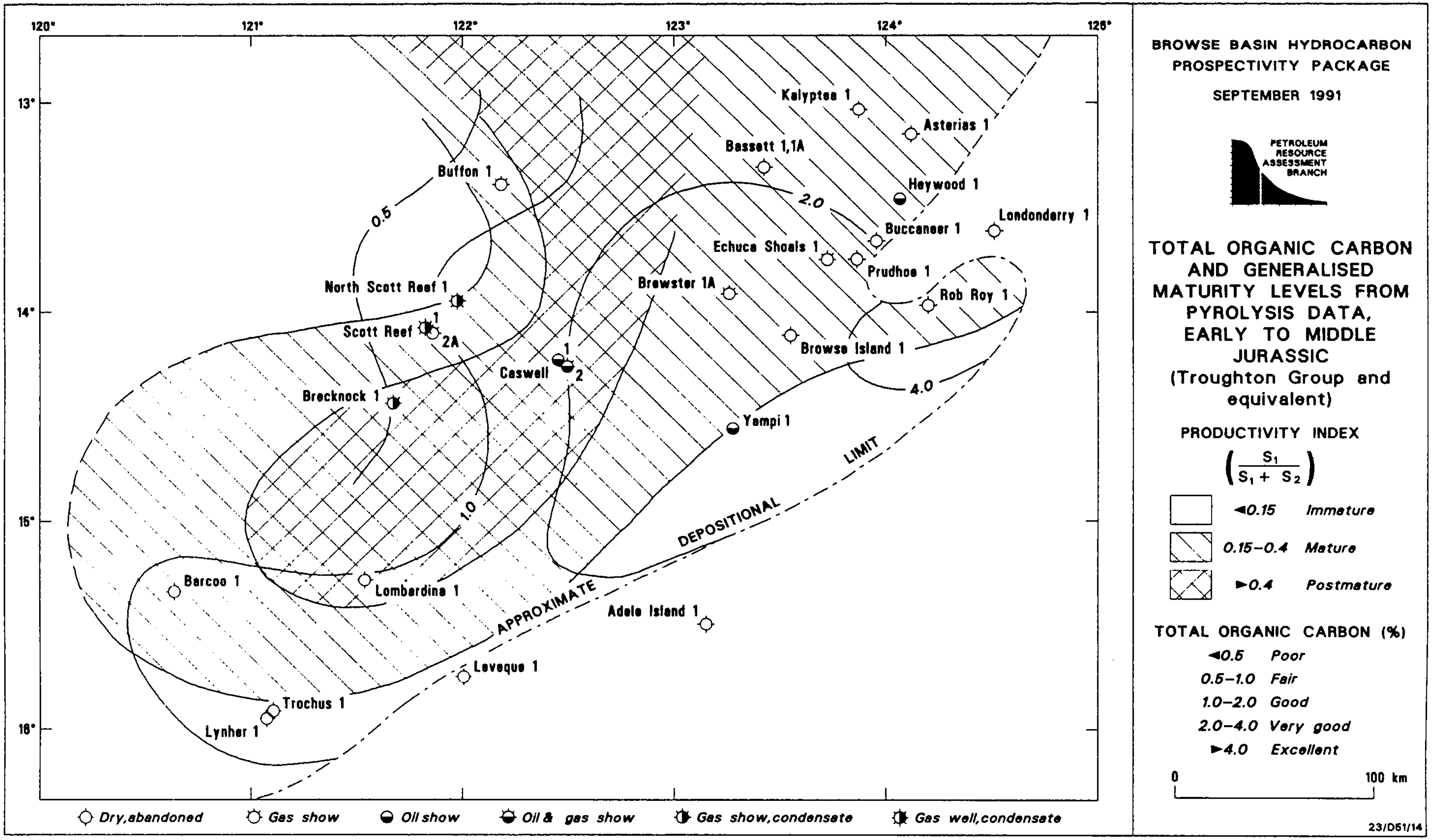


Figure 24b. TOC and generalised maturity from pyrolysis data, Early to Middle Jurassic.

8.3.5 Triassic

Triassic rocks have been encountered in wells basinwards of the basin margins to the east, west and south. Scott Reef No.1 on the western margin of the basin, and Barcoo No.1 in the southern basin deep reached total depth in Triassic rocks of unknown thickness. Elsewhere, Lynher No.1, Yampi No.1 and Echuca Shoals No.1 encountered a relatively thin (maximum 547 metres) sequence of Triassic age rocks.

The Triassic sequence generally comprises marginal marine carbonates and shales at the base, which grade upwards to fluvio-deltaic sands and shales containing thin coaly beds, and organically rich mudstones. The sediments appear to have been largely sourced from the northwest (Robertson Research, 1986).

Geochemical data from wells is sparse (Appendix 6), with only Lynher No.1 showing significant levels of organic matter (% TOC 1.14-1.57). The HI values for Lynher No.1, however, were very low (69-78), and are only significant in Barcoo No.1 (100-243), but in this case the TOC values are relatively low (0.57 % to 0.70 %).

The generalised distribution of TOC, kerogen facies and maturity levels (Figures 25a, 25b) are based on very limited pyrolysis data, and should be treated with caution. When looked at together with the maturity versus depth plots (Figures 31, 33 and 34), the data indicate the Triassic section may only be marginally mature. Generally, the thin organically rich mudstones and coaly beds are unlikely to have provided significant hydrocarbon source potential.

8.3.6 Permian

Permian rocks represent the oldest sedimentary sequence encountered in the Browse Basin, having been penetrated by wells along the northeast and southern shelf areas. Along the eastern basin margin the Permian section is relatively thin, comprising of marine claystones and siliciclastics (Willis, 1988). The nature of the sediments in the central basin and Scott Plateau is unknown, but is likely to be similar to the Canning and Bonaparte Basins.

Geochemical data from wells is sparse (Appendix 6) but they show the Permian rocks to be organically poor to good (% TOC 0.37-2.72), with little or no liquid hydrocarbon source potential except for Rob Roy No.1, which shows HI values of 103-274. The distribution of TOC, kerogen facies and maturity levels (Figures 26a, 26b), and the maturity versus depth plots (Figures 28, 30, 31 and 33) are very subjective because of the lack of data, but they show that any source rocks are likely to be mature along the eastern and southern basin margin, and overmature in

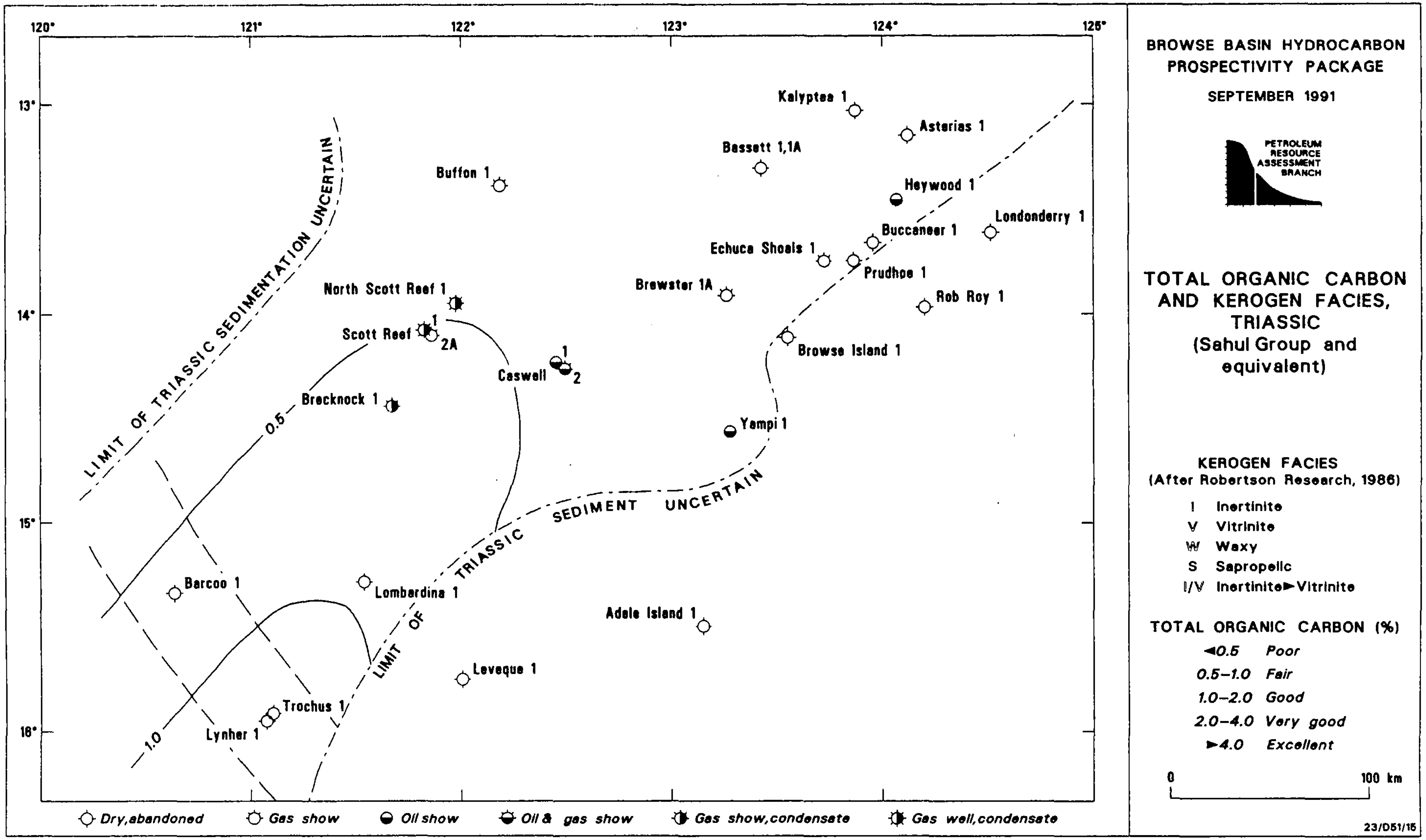


Figure 25a. TOC and kerogen facies, Triassic.

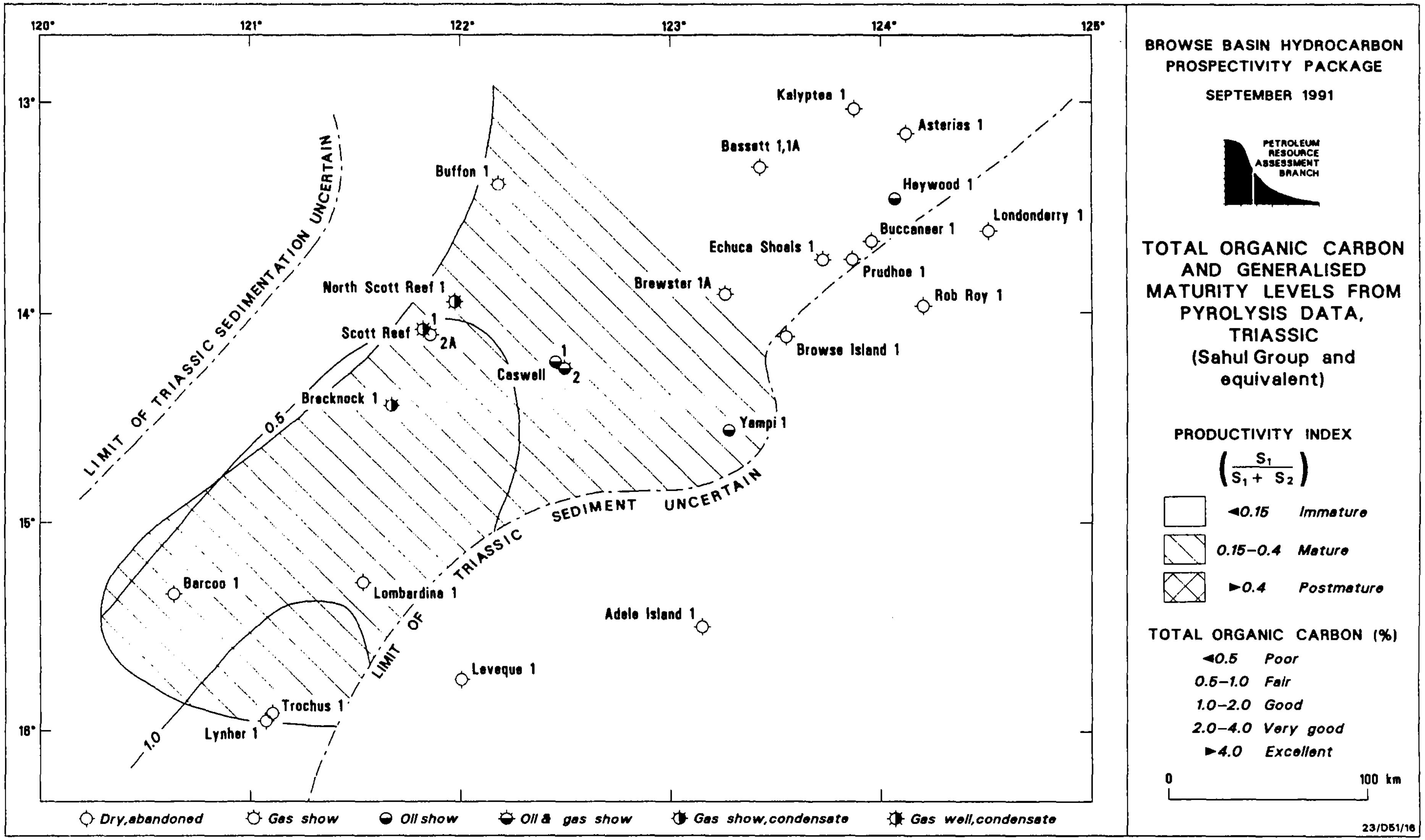


Figure 25b. TOC and generalised maturity from pyrolysis data, Triassic.

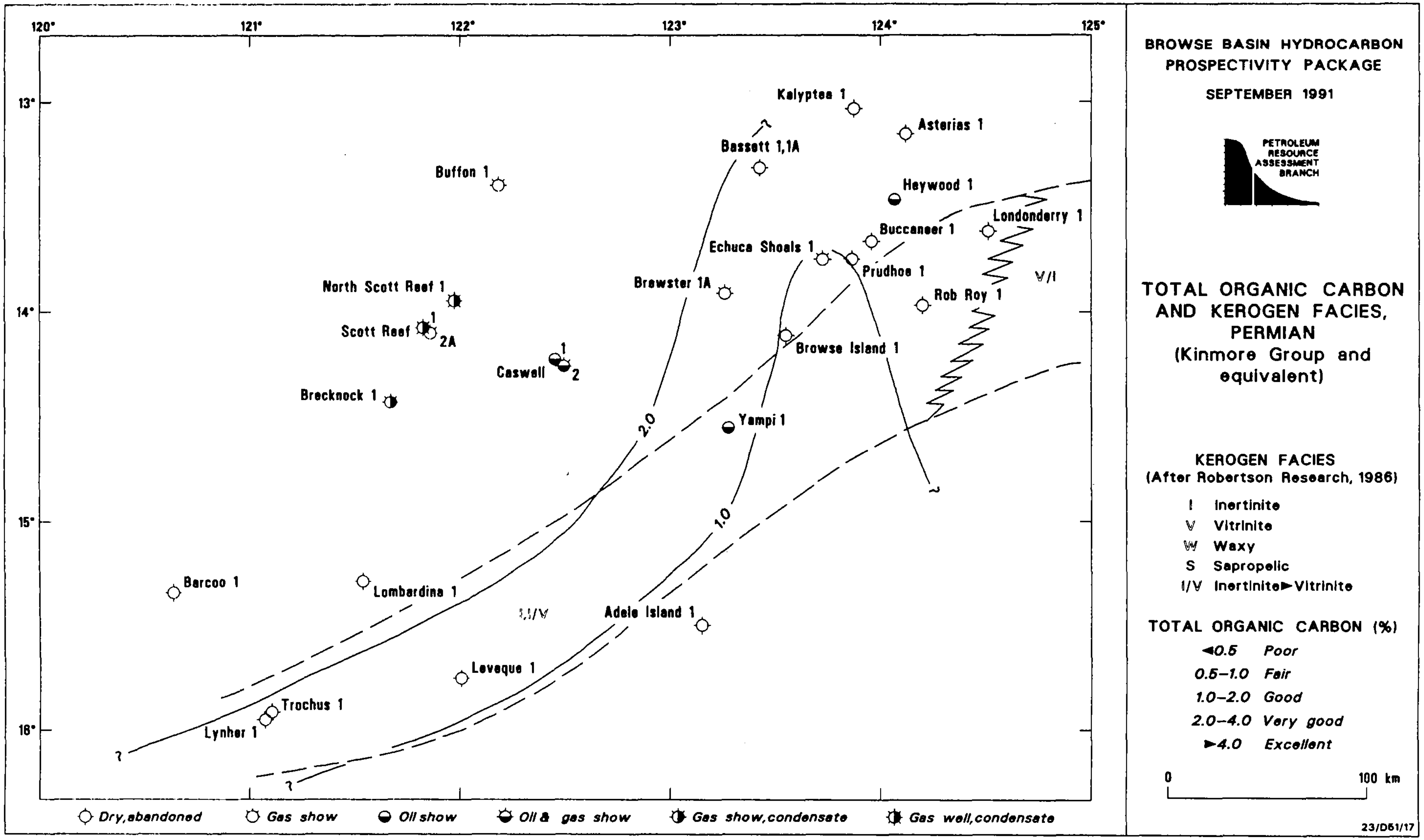


Figure 26a. TOC and kerogen facies, Permian.

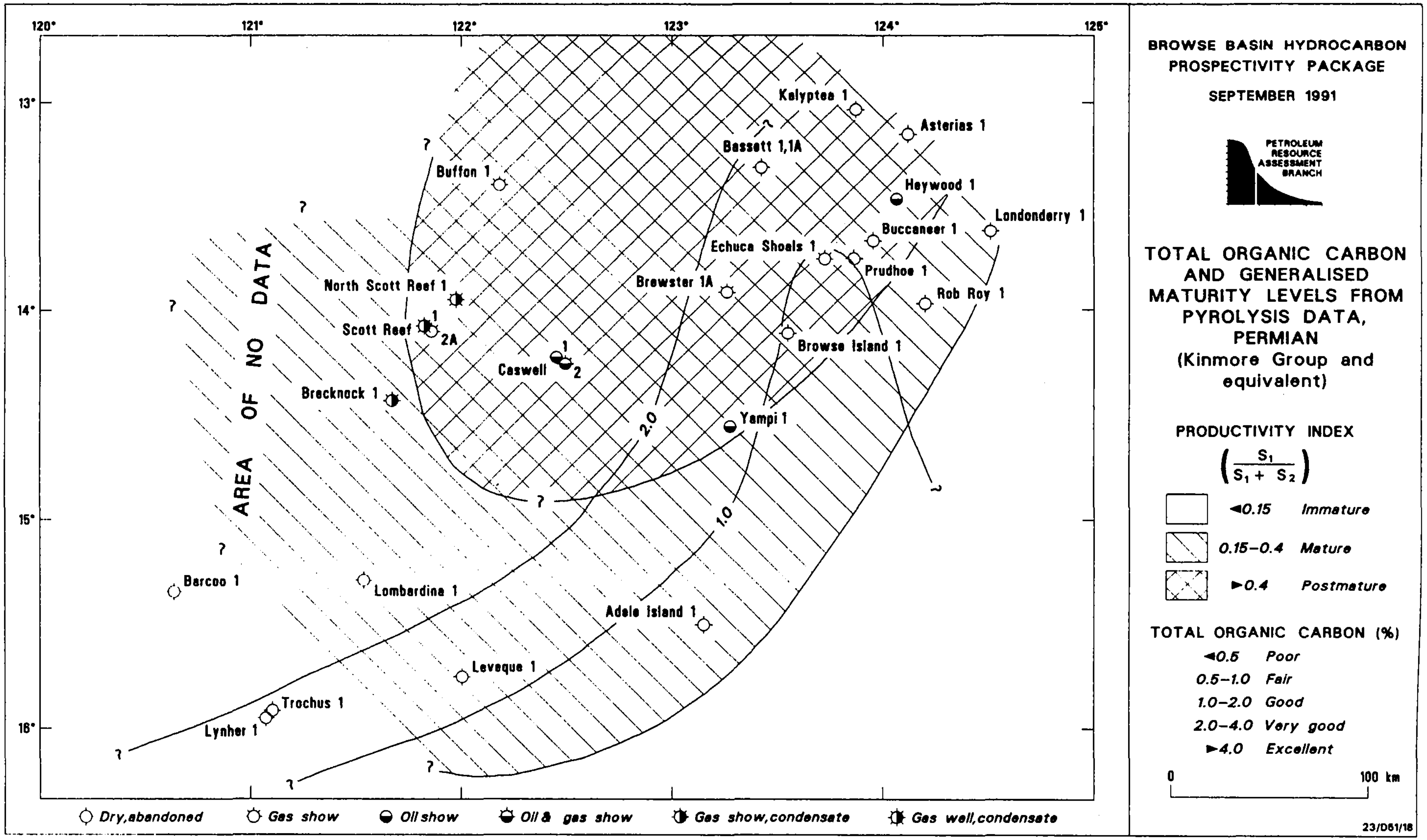


Figure 26b. TOC and generalised maturity from pyrolysis data, Permian.

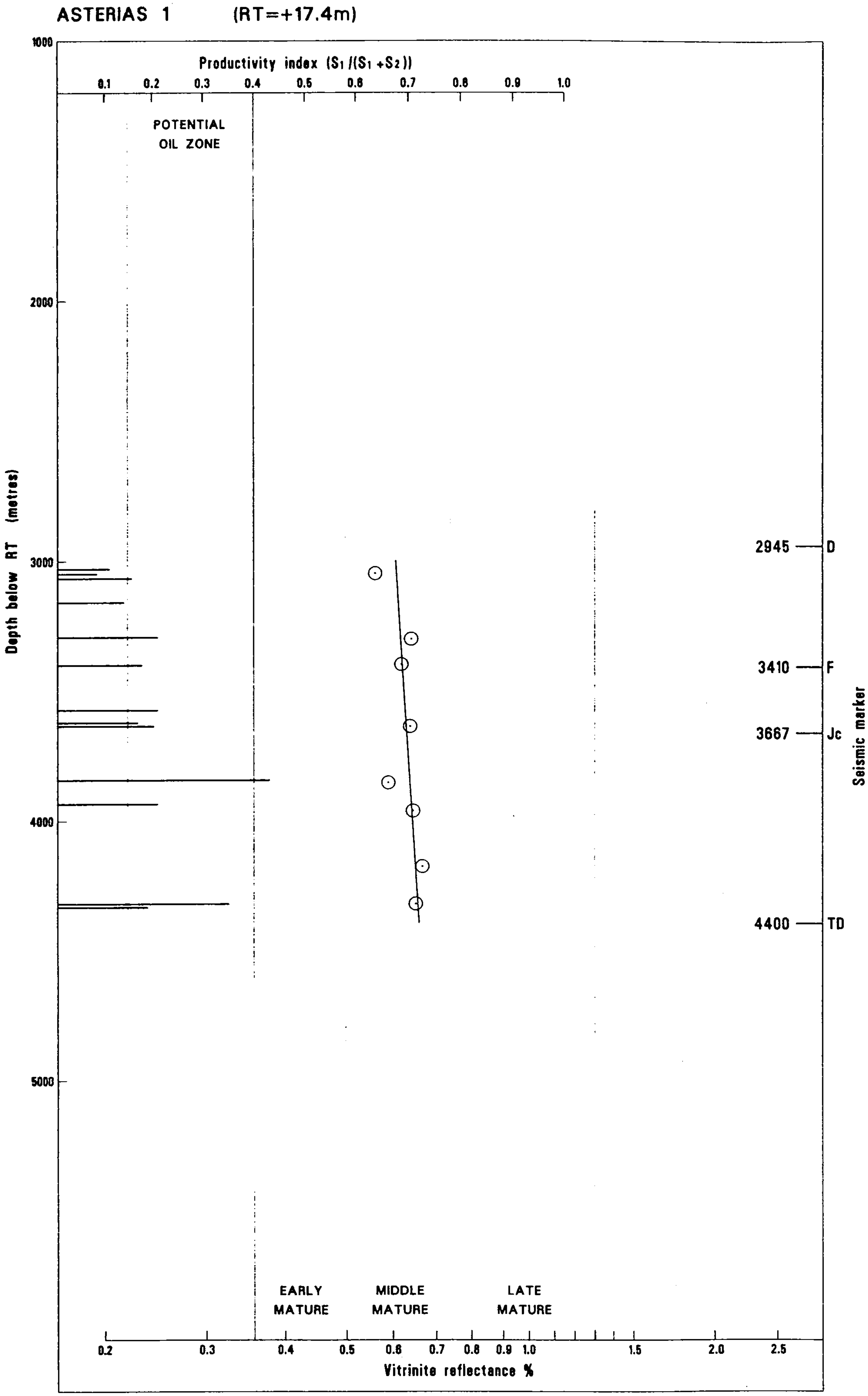


Figure 27. Maturity versus depth, Asterias No.1.

23/D51/19

PRUDHOE 1 (RT=+30m)

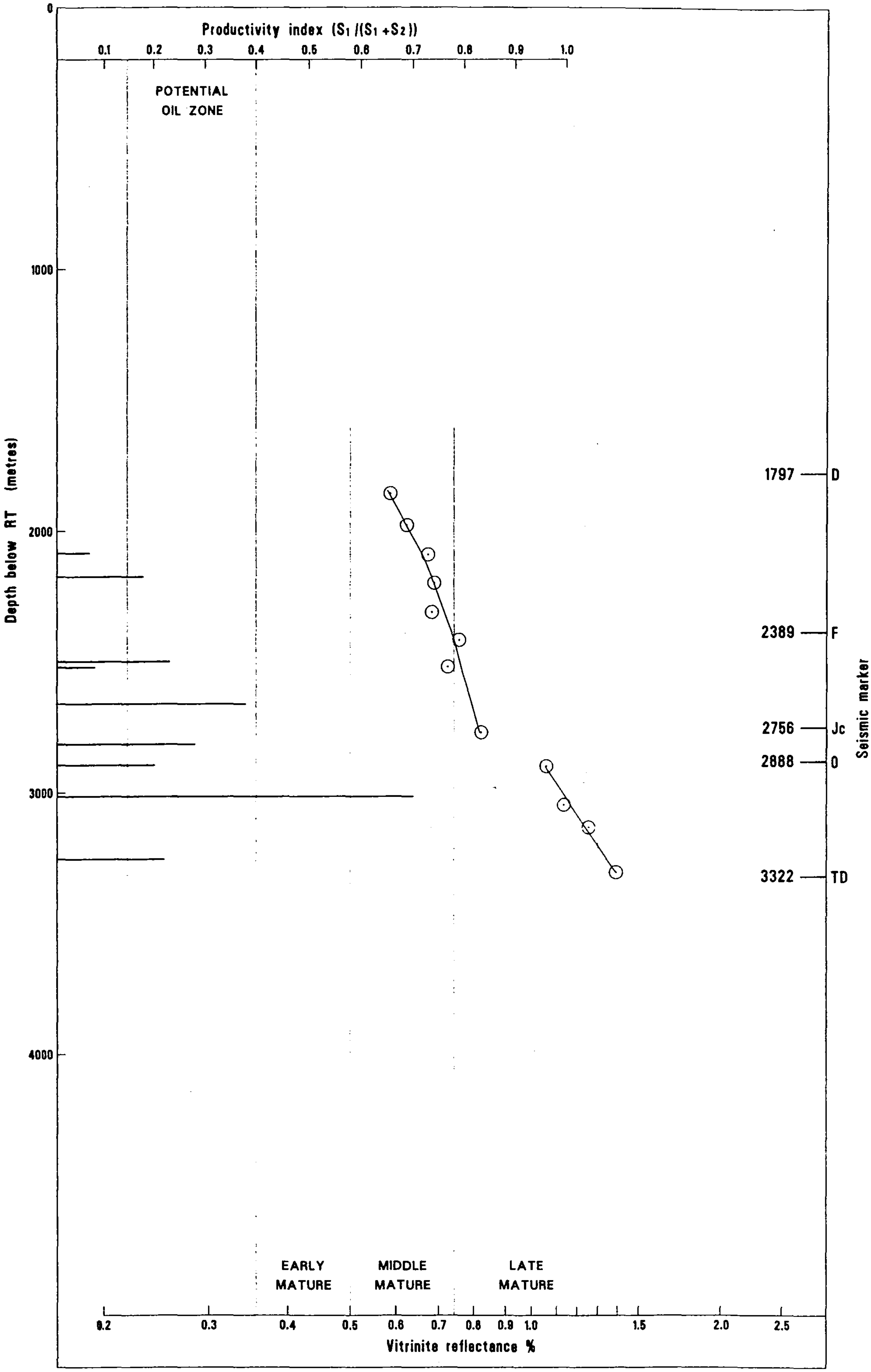


Figure 28. Maturity versus depth, Prudhoe No.1. 23/D51/20

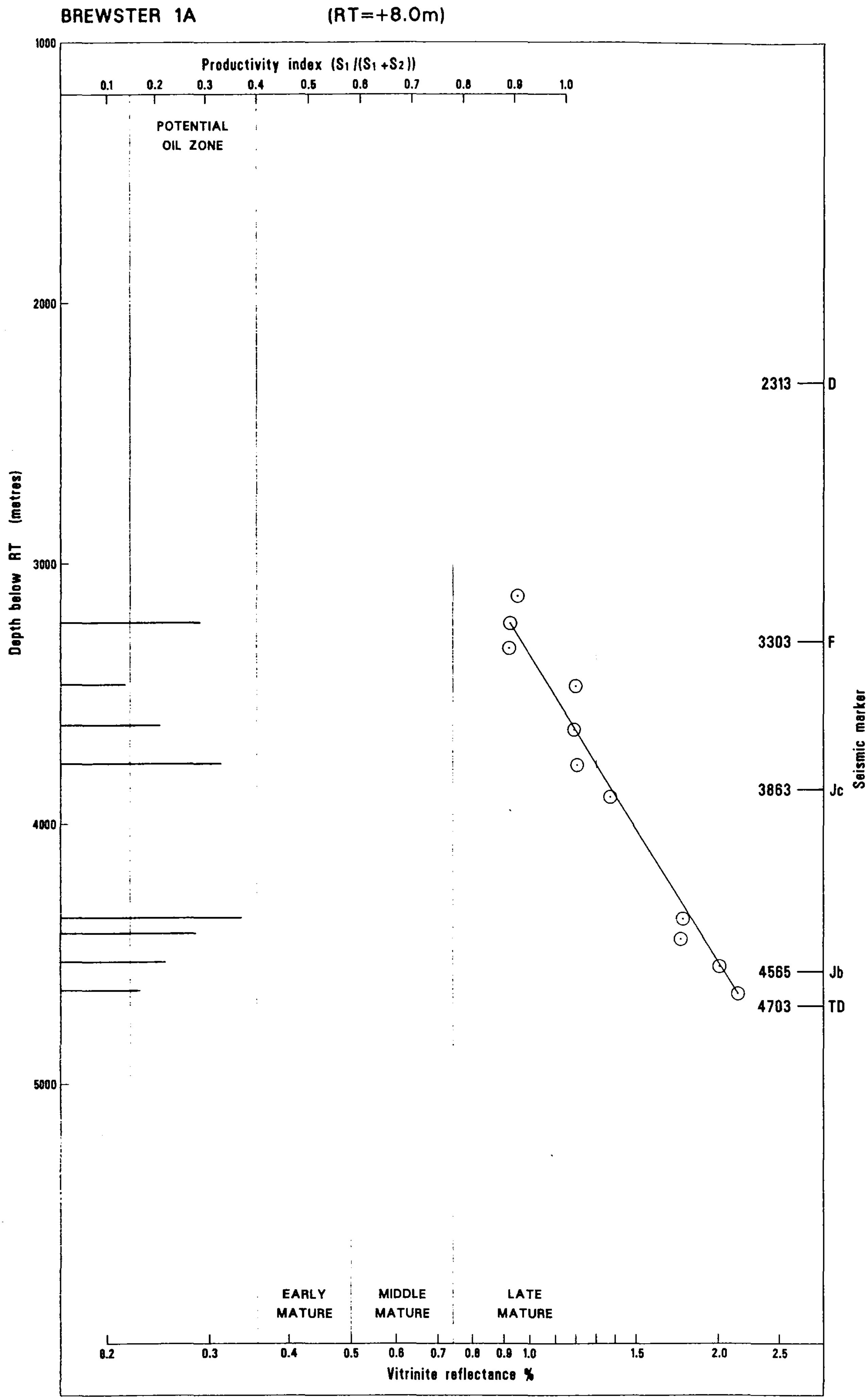


Figure 29. Maturity versus depth, Brewster No.1A. 23/D51/21

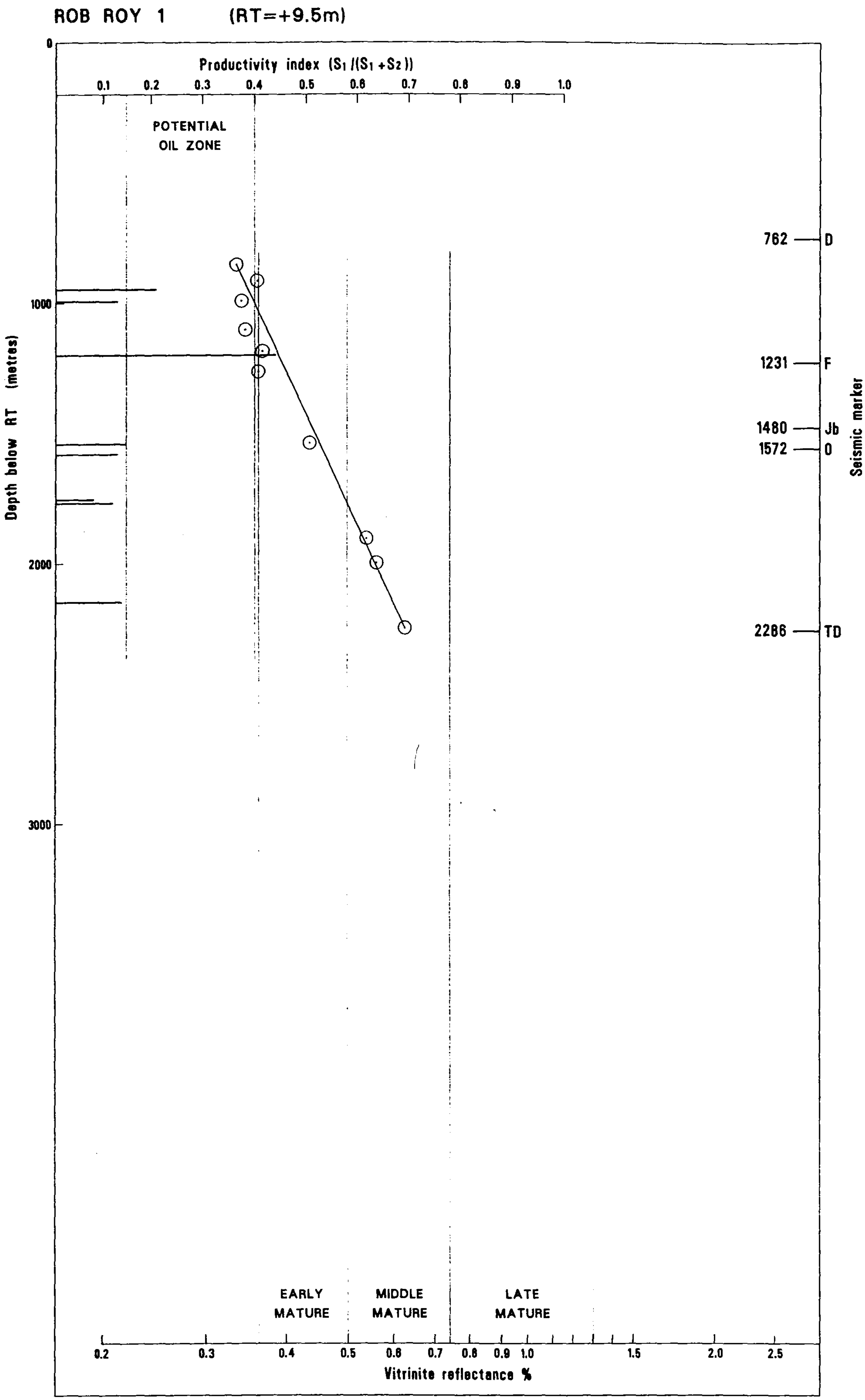


Figure 30. Maturity versus depth, Rob Roy No.1.

23/D61/22

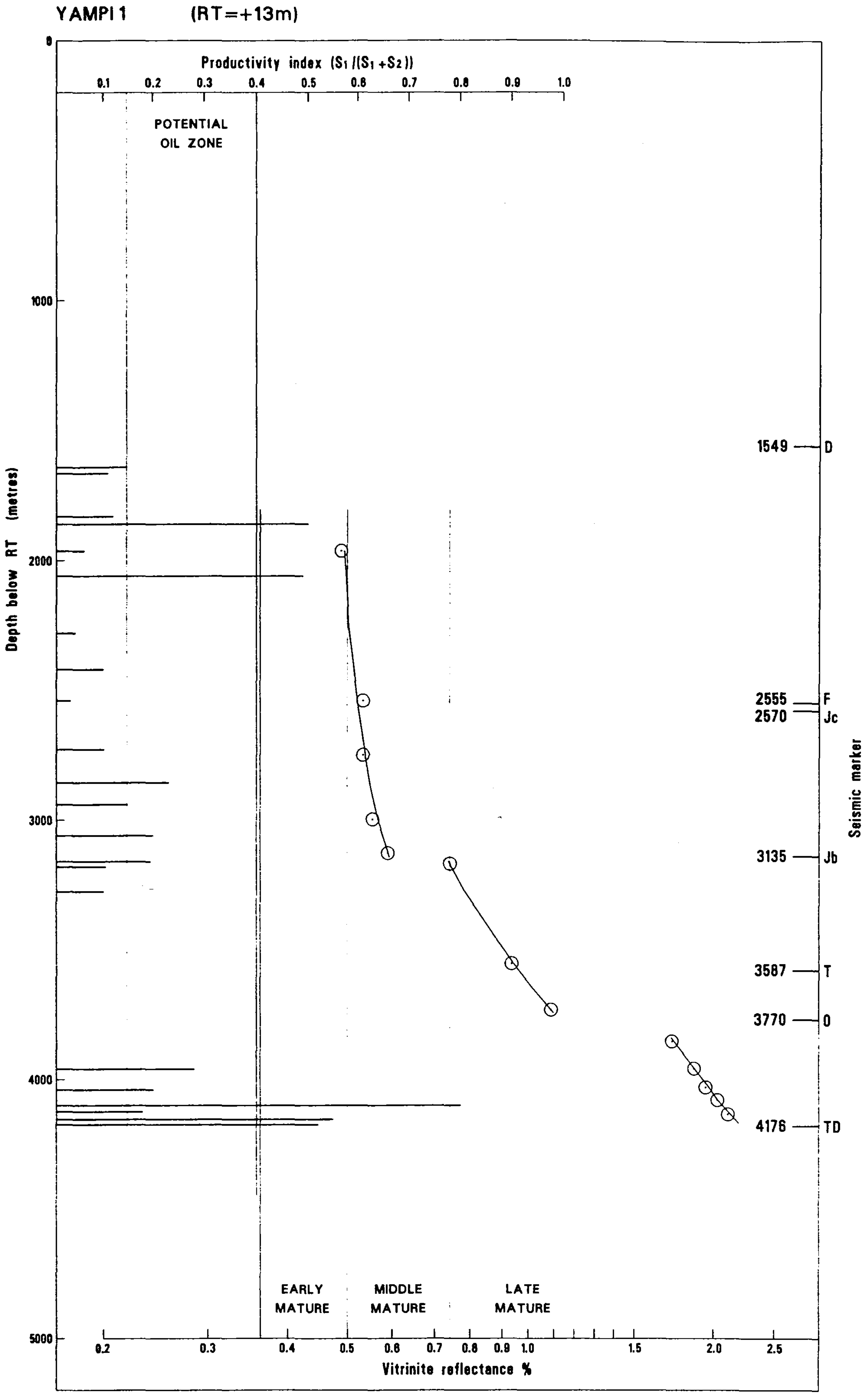


Figure 31. Maturity versus depth, Yampi No.1.

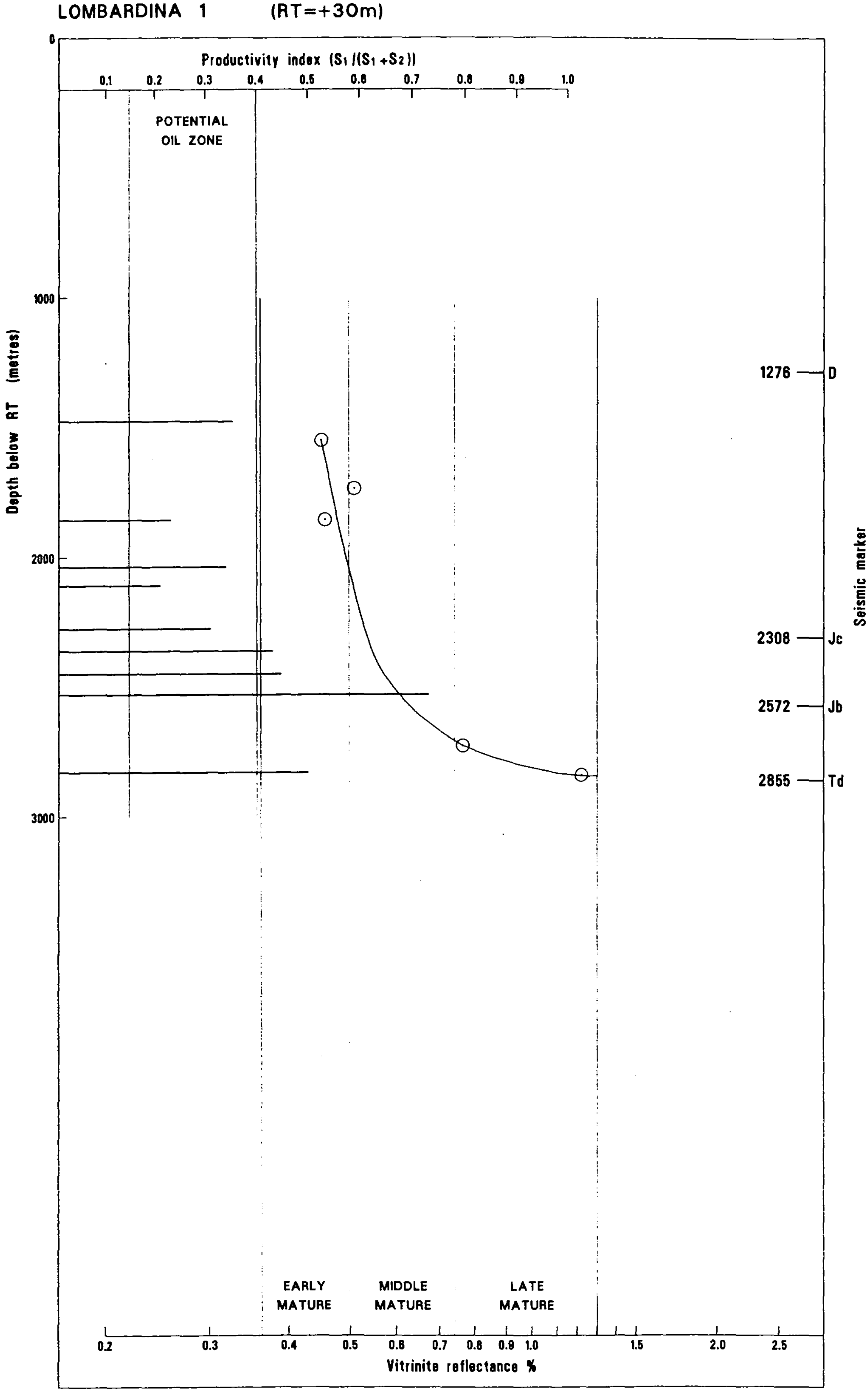


Figure 32. Maturity versus depth, Lombardina No.1. 23/D51/24

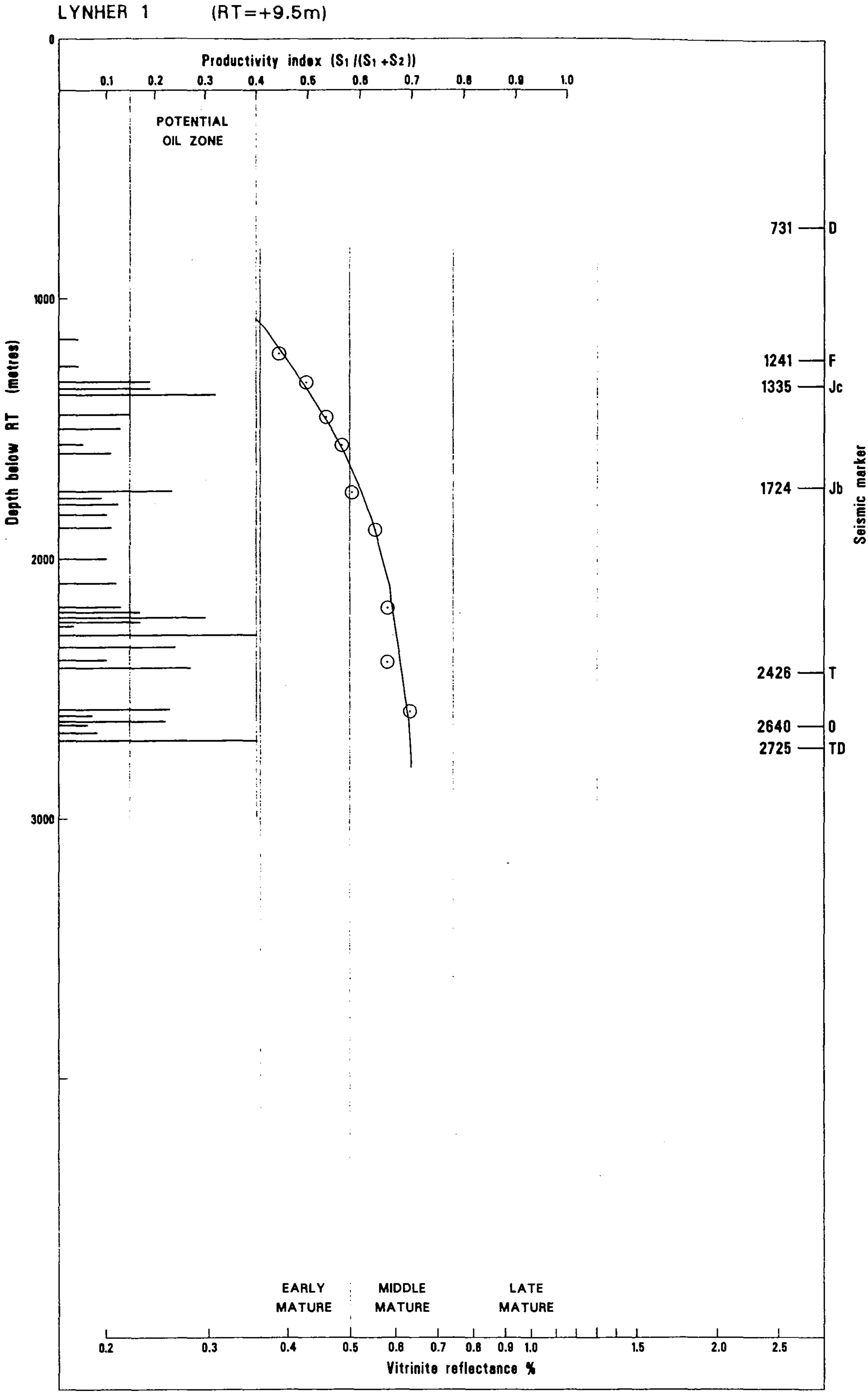


Figure 33. Maturity versus depth, Lynher No.1. 23/D51/26

BARCOO 1 (RT=+11.0m)

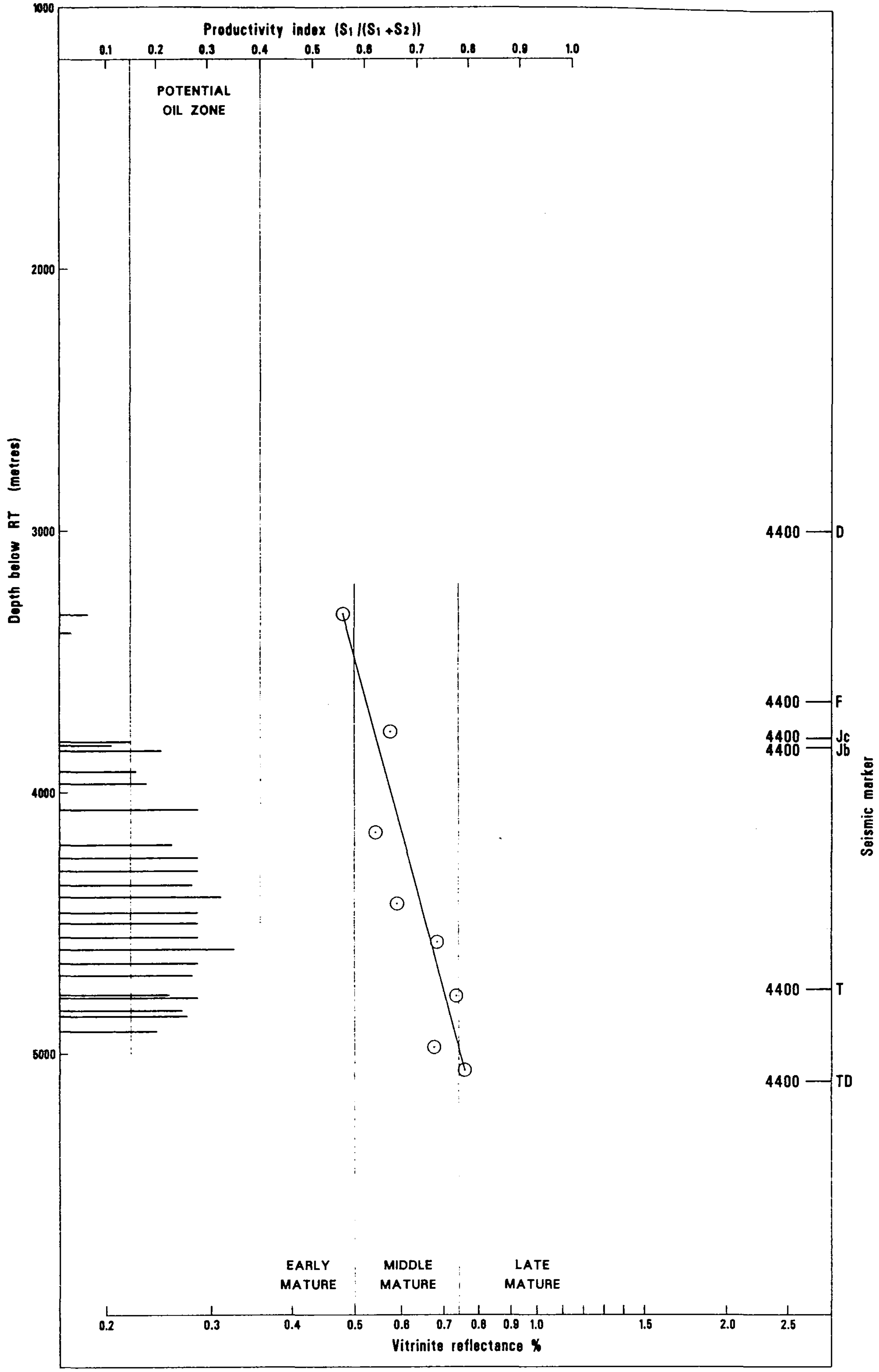


Figure 34. Maturity versus depth, Barcoo No.1.

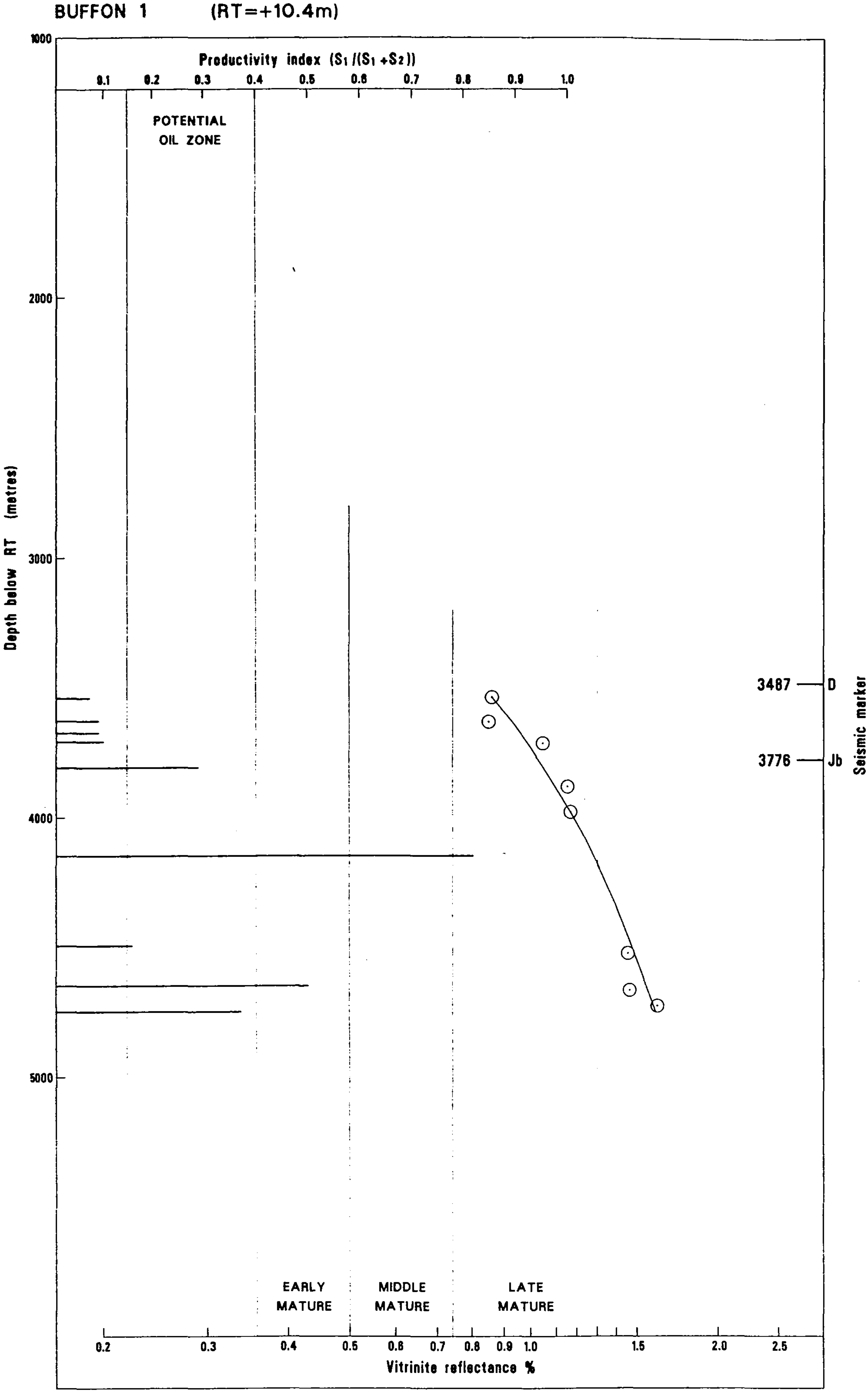


Figure 35. Maturity versus depth, Buffon No.1.

CASWELL 1 (RT=+8.0m)

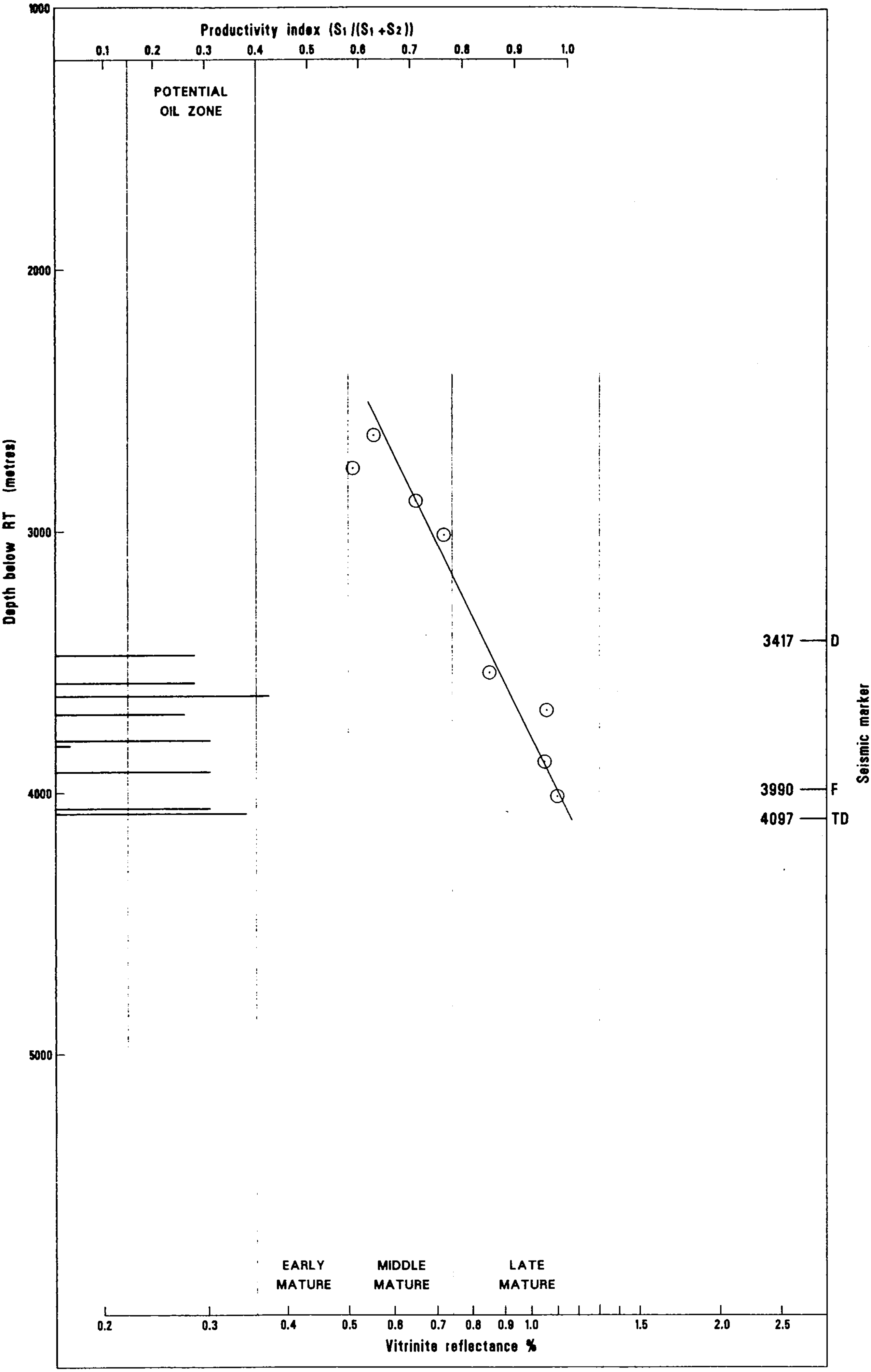


Figure 36. Maturity versus depth, Caswell No.1.

23/D51/28

CASWELL 2 (RT=+17.0m)

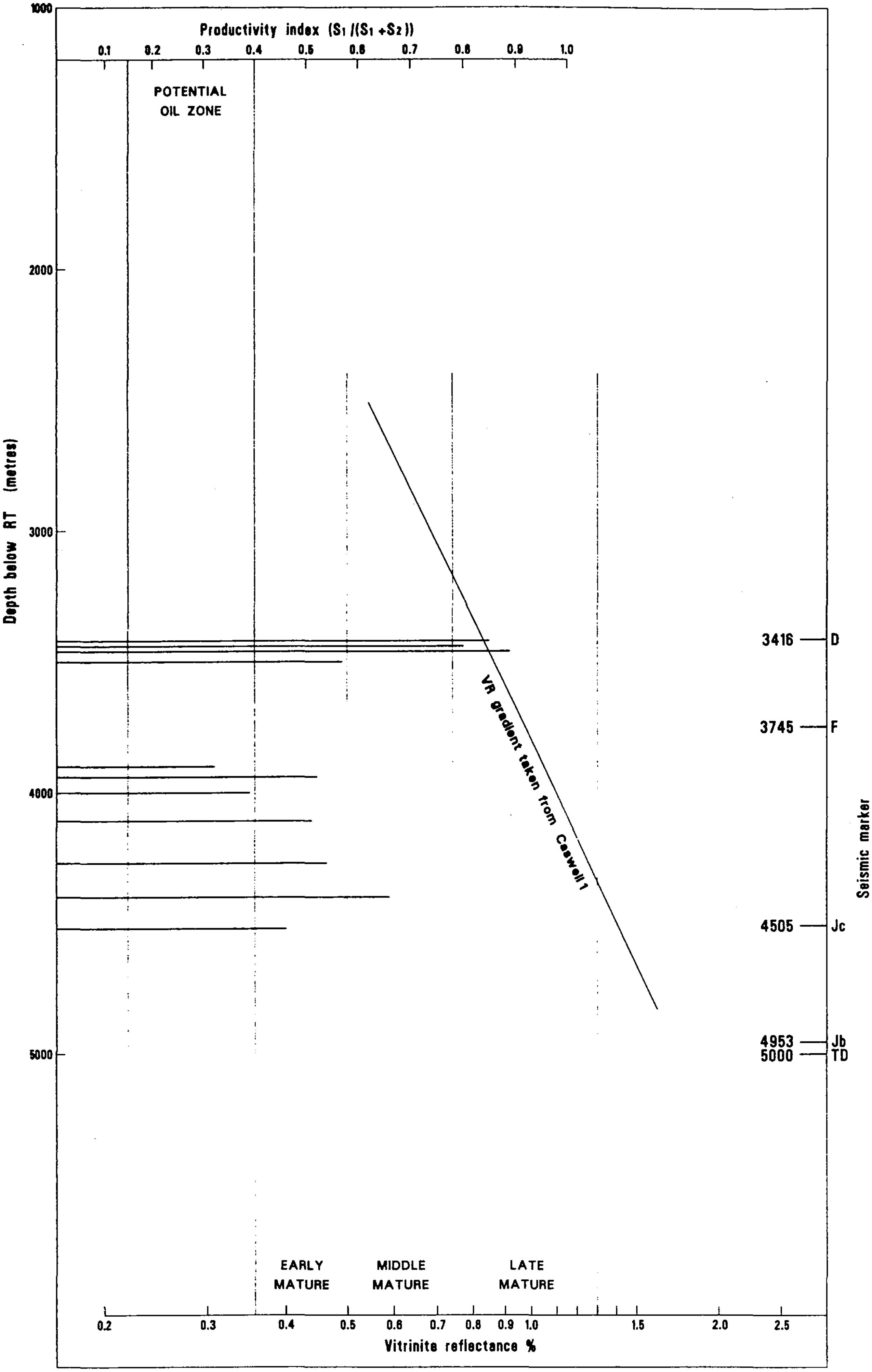


Figure 37. Maturity versus depth, Caswell No.2.

the north. The Permian is not regarded as a significant source of liquid hydrocarbons in the basin.

8.3.7 Summary

The Early to Middle Jurassic (pre-breakup) sequence is sufficiently thick and widespread, and its organic richness and maturity levels are sufficient to have generated liquid hydrocarbons. Although the Late Jurassic to Early Neocomian (post-breakup) sequence has generally lower levels of organic richness, its thickness, lateral extent and maturity level are probably sufficient to have generated liquid hydrocarbons. The pre-breakup and post-breakup Jurassic sequences are regarded as the major source of liquid hydrocarbons.

The Neocomian to Aptian sequence has a substantial thickness of good source rocks, which are generally mature to overmature, and may have potentially generated significant quantities of hydrocarbons. The Aptian to Cenomanian sequence has thick organic rich sediments in the south which are probably immature, but in the deeper part of the basin, they may have reached a sufficient level of maturity to generate hydrocarbons. Early Cretaceous marine shales, and the Neocomian to Aptian sequence in paticular, is regarded as a secondary source of liquid hydrocarbons.

The Triassic and Permian sequences are not considered to have much source potential in the Browse Basin.

8.4 GEOHISTORY ANALYSIS AND MATURATION

(S.J. Cadman)

Data from eight wells in the Browse Basin have been input into the 'BURY, version 5.42' geohistory analysis software package suppled by Paltech Pty Ltd. Burial histories for four wells on the eastern basin margin (Leveque No.1, Yampi No.1, Lynher No.1, Prudhoe No.1) and four wells in the central and western Browse Basin (Caswell No.1, Brewster No.1A, Buffon No.1, Scott Reef No.1) have been modelled. Burial history plots and plots of computed versus observed vitrinite reflectance values are shown in Figures 38 through 53.

8.4.1 Heatflow

For the wells near the eastern basin margin, heatflow values of between 1.2 HFU and 1.6 HFU were used from the Early Cretaceous through to the present day. During the Triassic and Jurassic (rift phase) higher heatflows (1.6 HFU to 1.8 HFU) were input into the models. However, substantially greater heatflow values were required to succesfully model burial history in Prudhoe No.1 (2.2 HFU to 2.5 HFU).

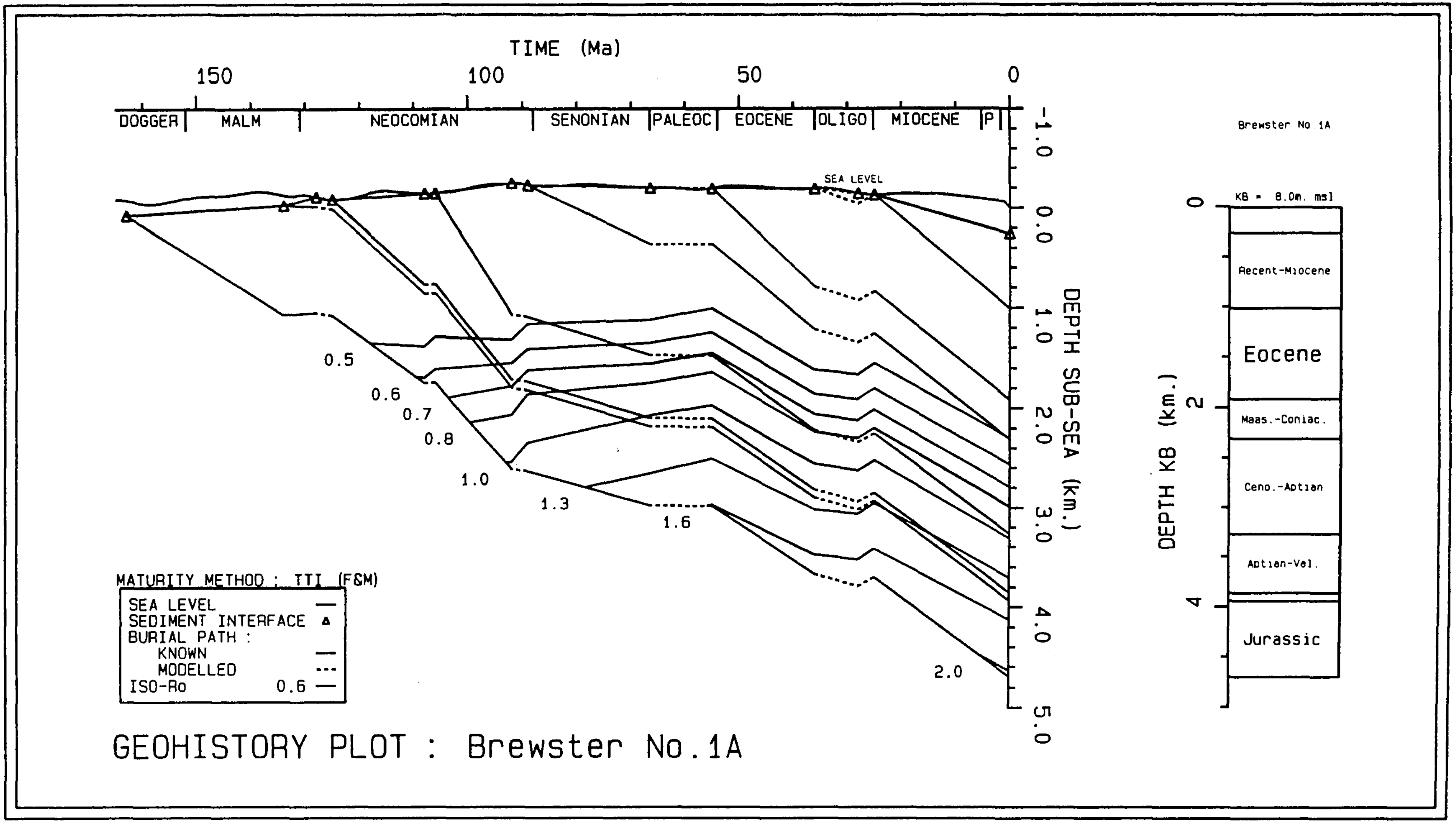


Figure 38. Geohistory plot, Brewster No.1A.

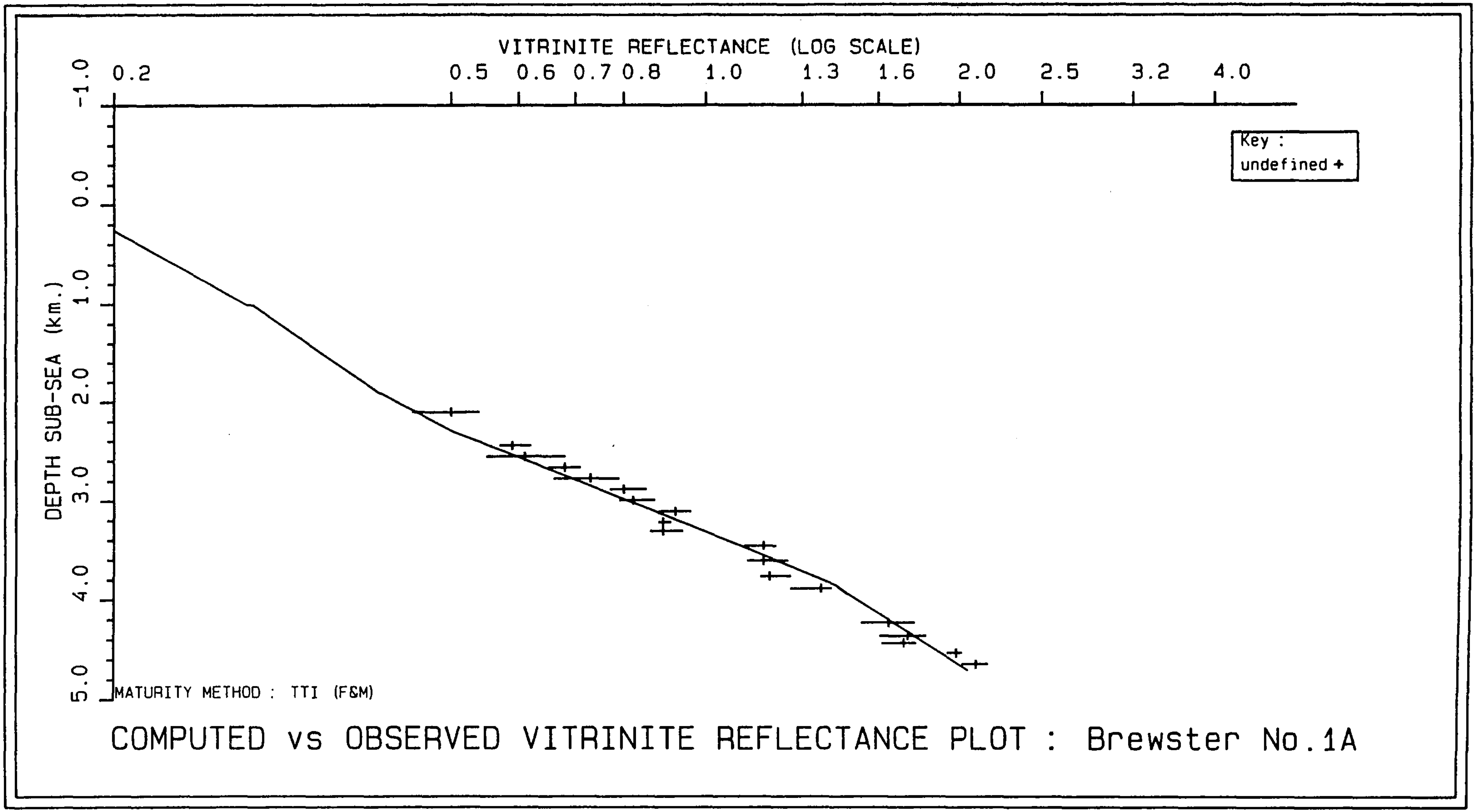


Figure 39. Computed versus observed vitrinite reflectance plot, Brewster No.1A.

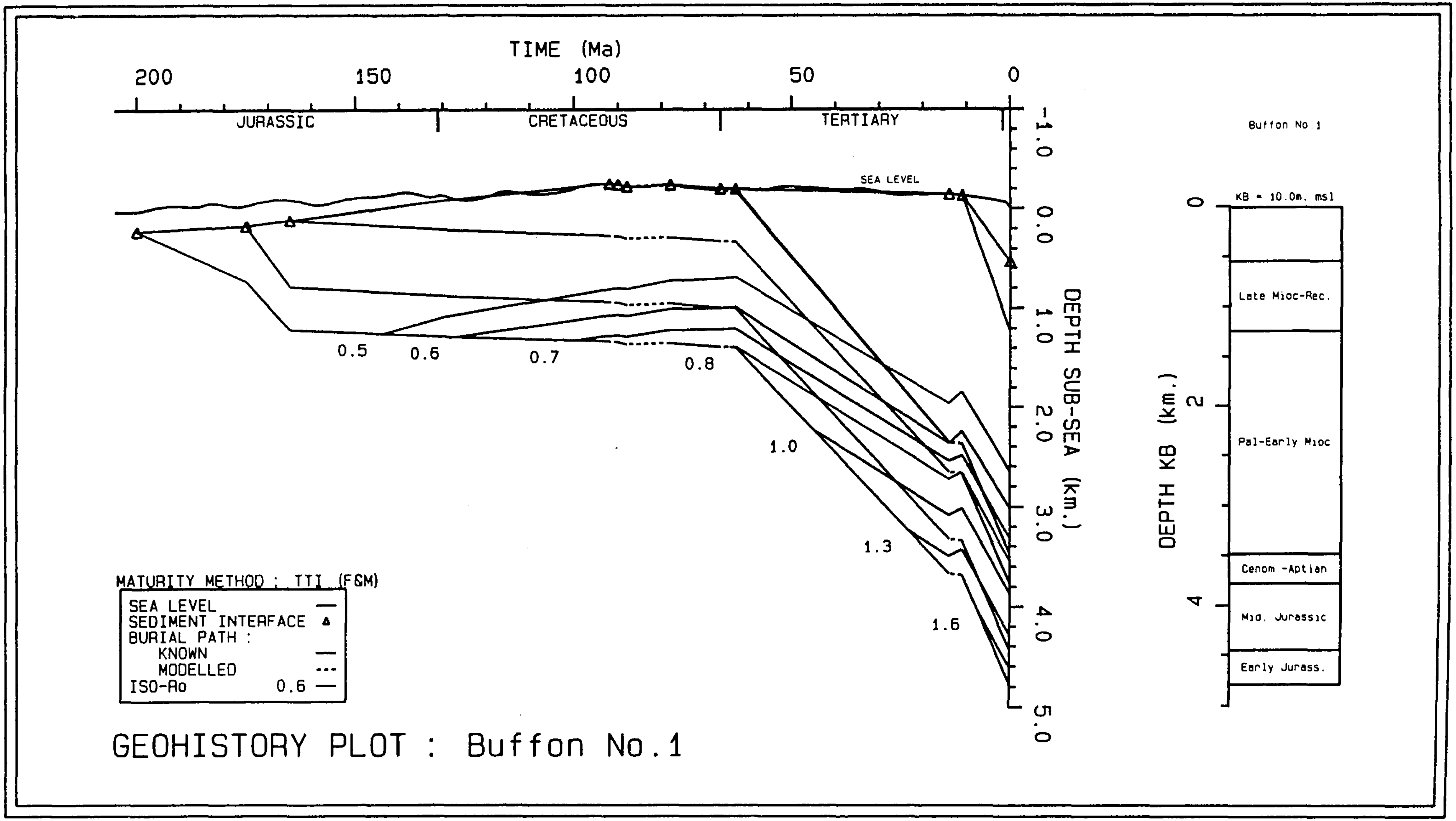


Figure 40. Geohistory plot, Buffon No.1.

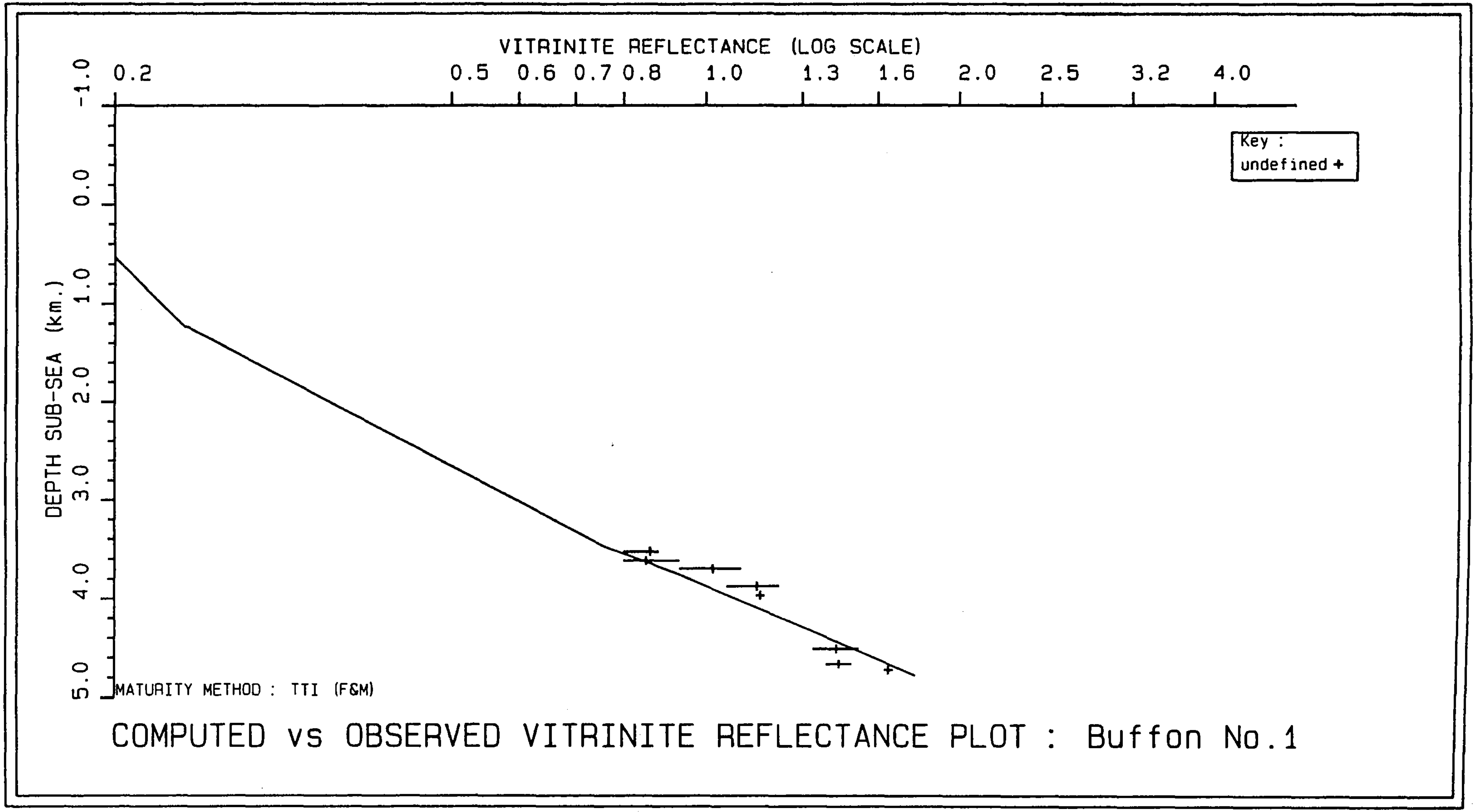


Figure 41. Computed versus observed vitrinite reflectance plot, Buffon No.1.

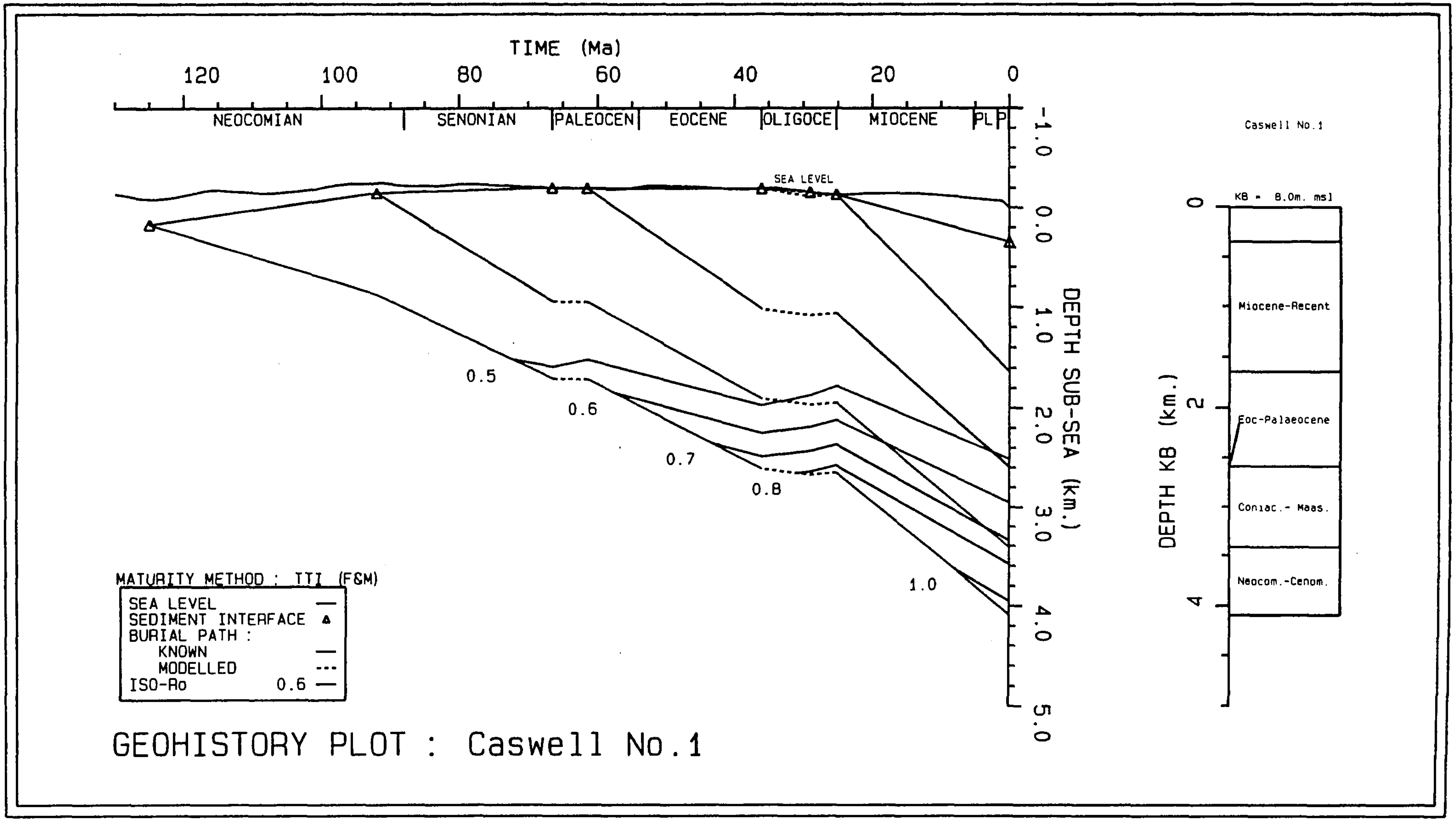


Figure 42. Geohistory plot, Caswell No.1.

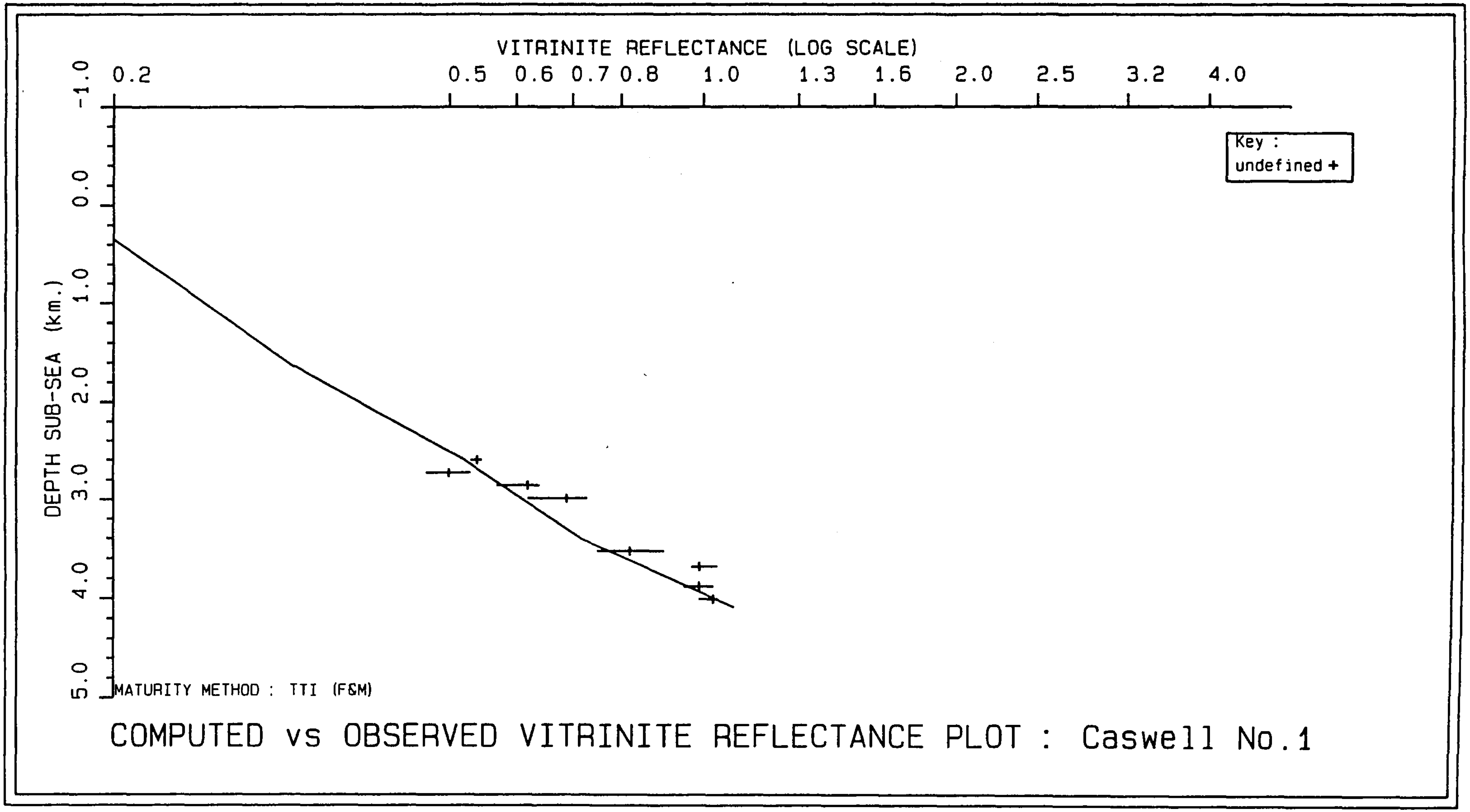


Figure 43. Computed versus observed vitrinite reflectance plot, Caswell No.1.

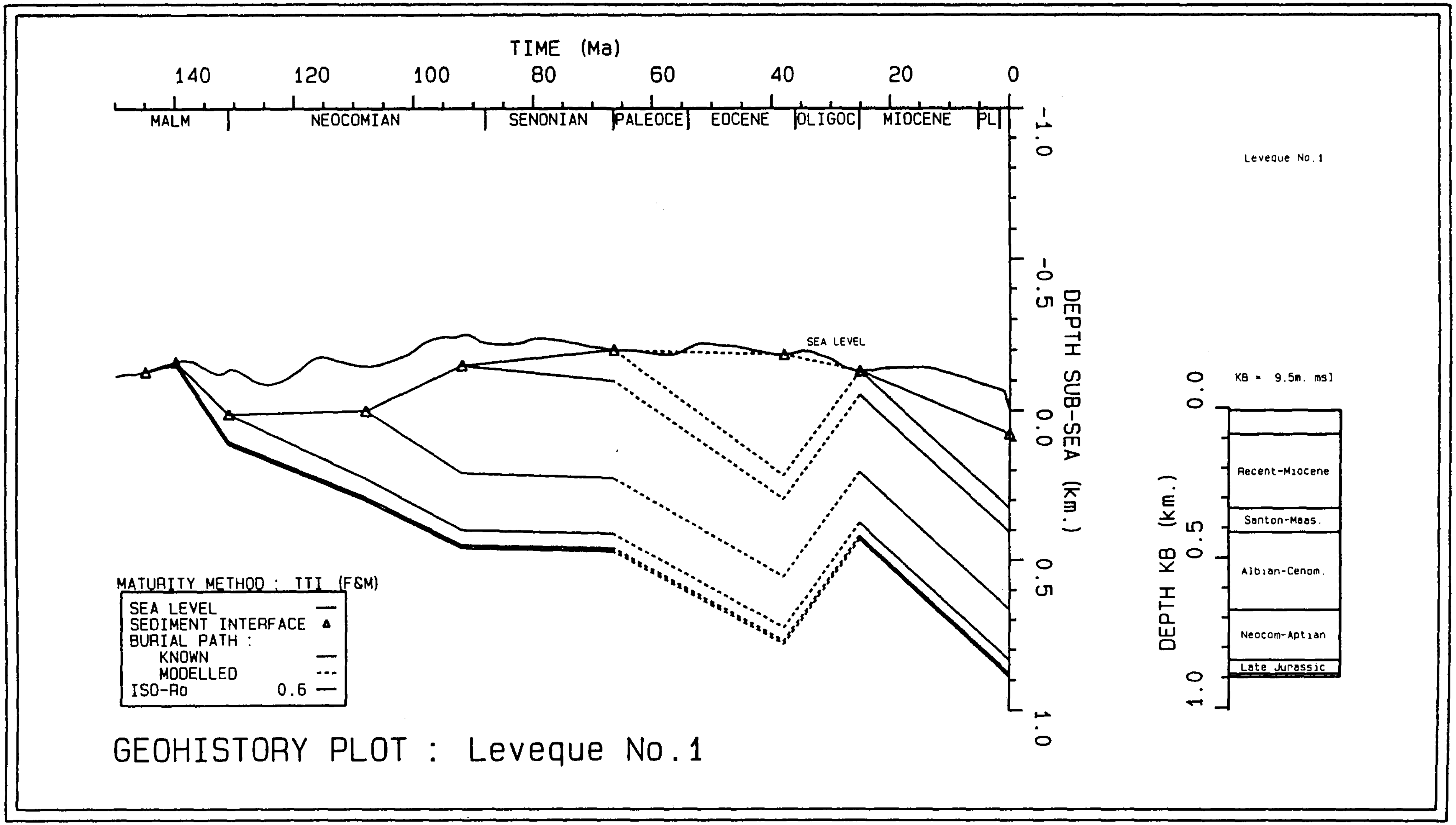


Figure 44. Geohistory plot, Leveque No.1.

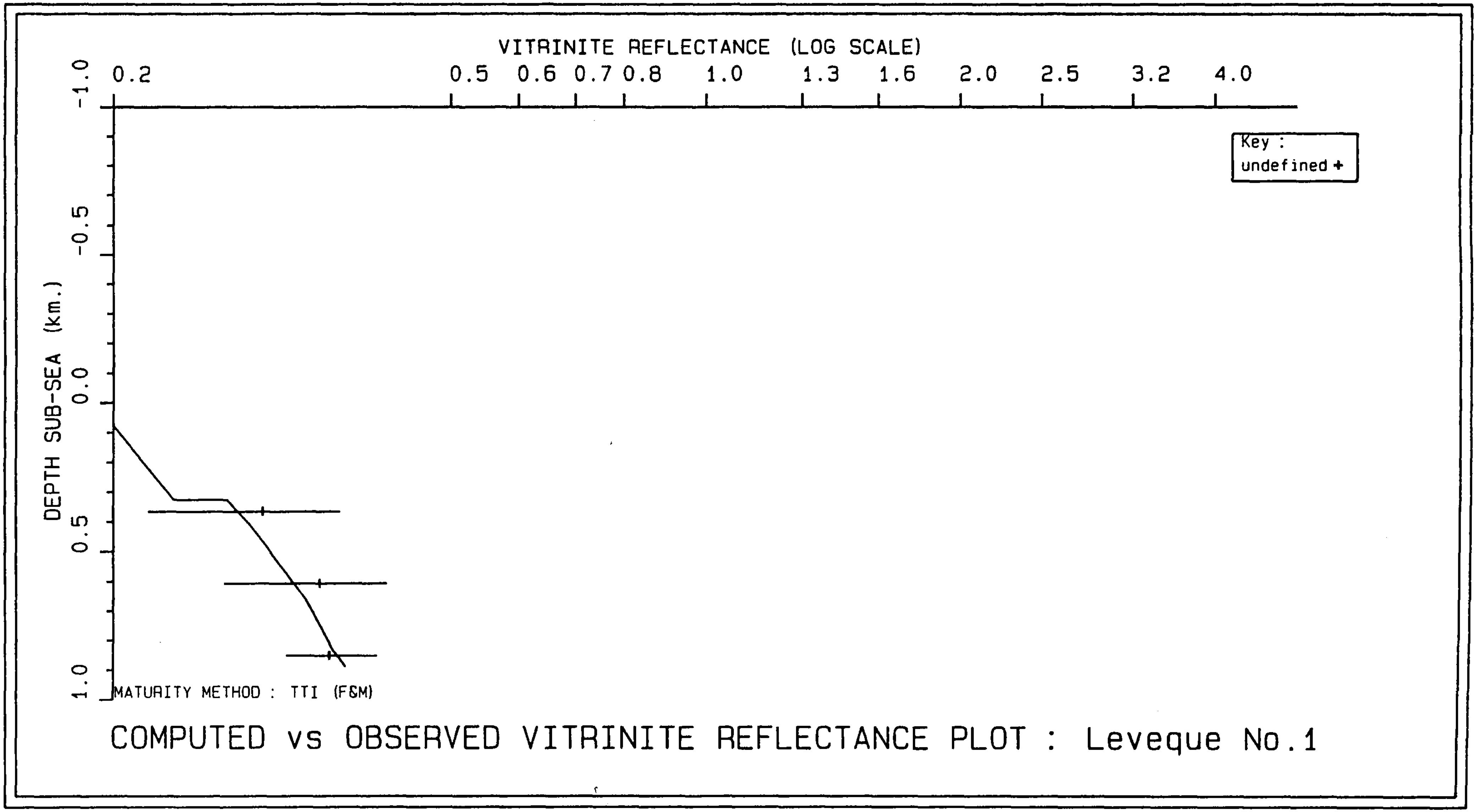


Figure 45. Computed versus observed vitrinite reflectance plot, Leveque No.1.

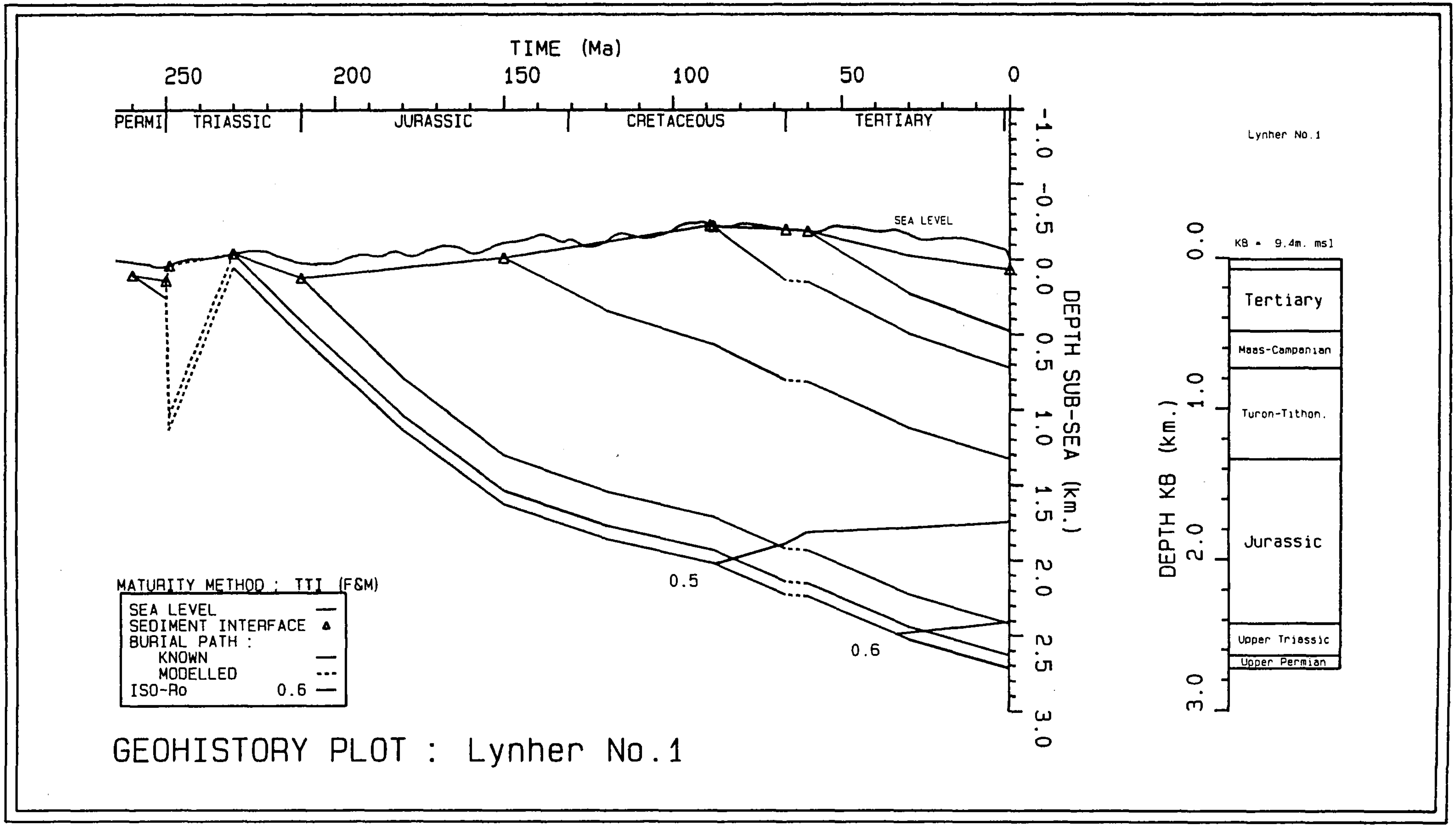


Figure 46. Geohistory plot, Lynher No.1.

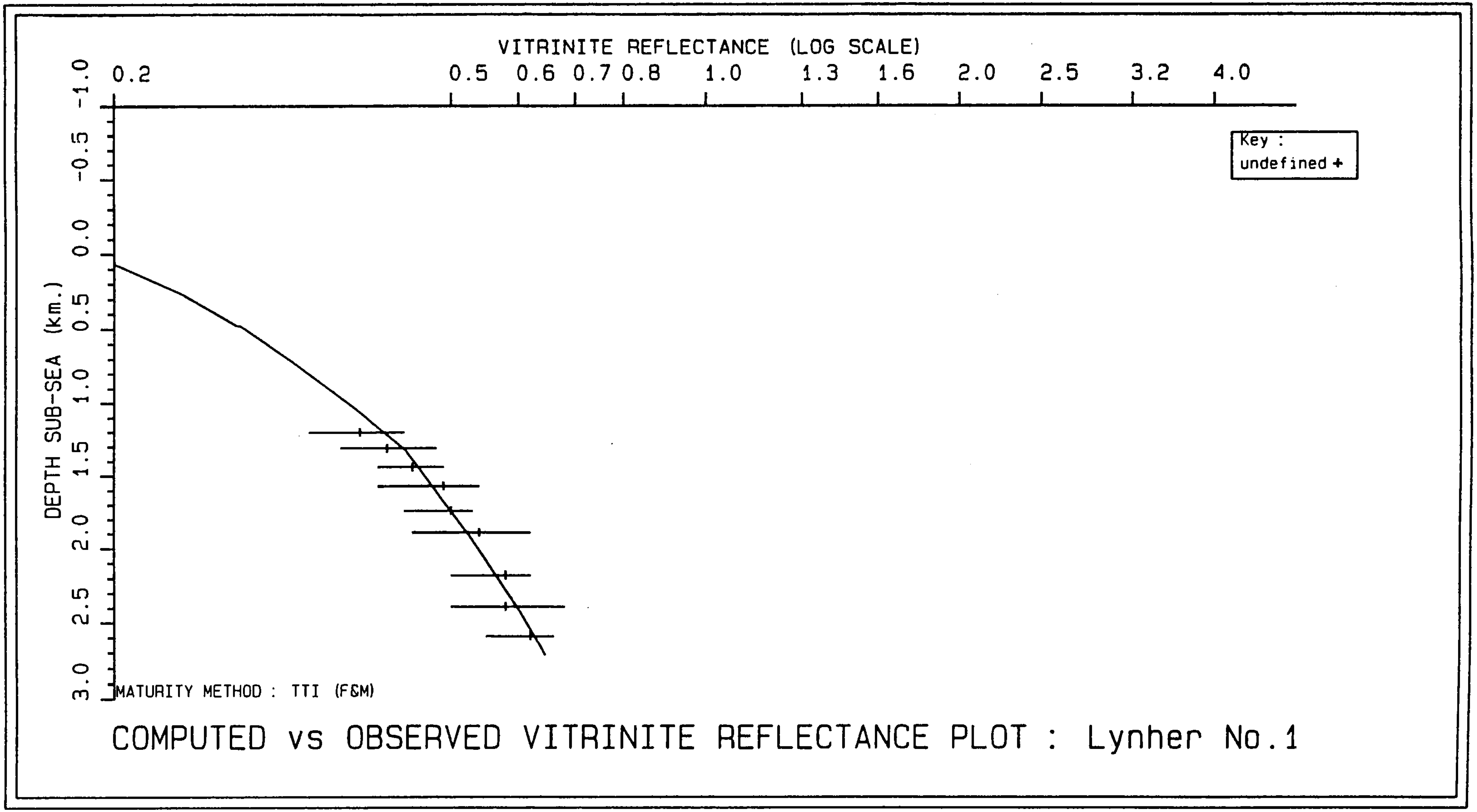


Figure 47. Computed versus observed vitrinite reflectance plot, Lynher No.1.

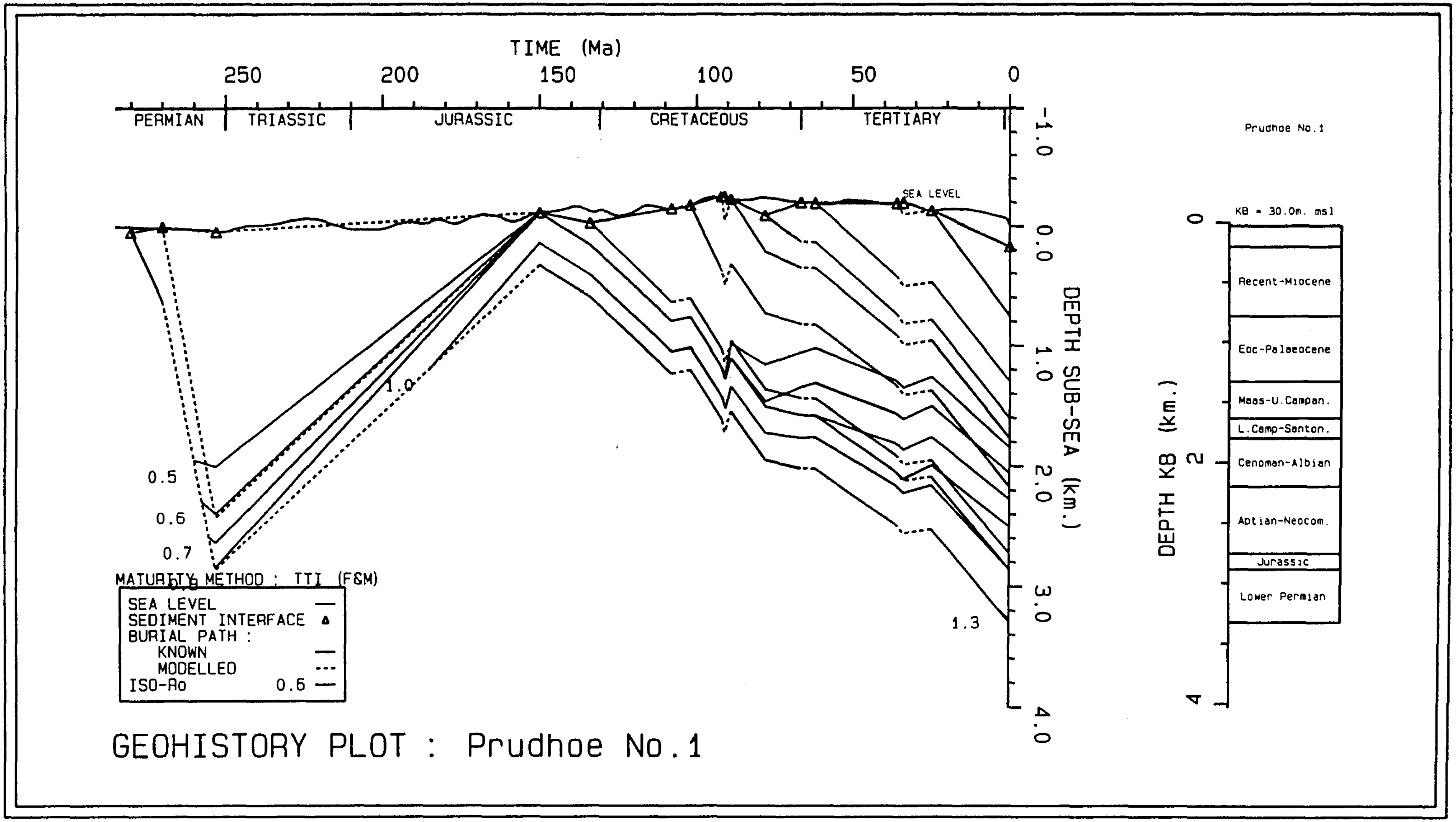


Figure 48. Geohistory plot, Prudhoe No.1.

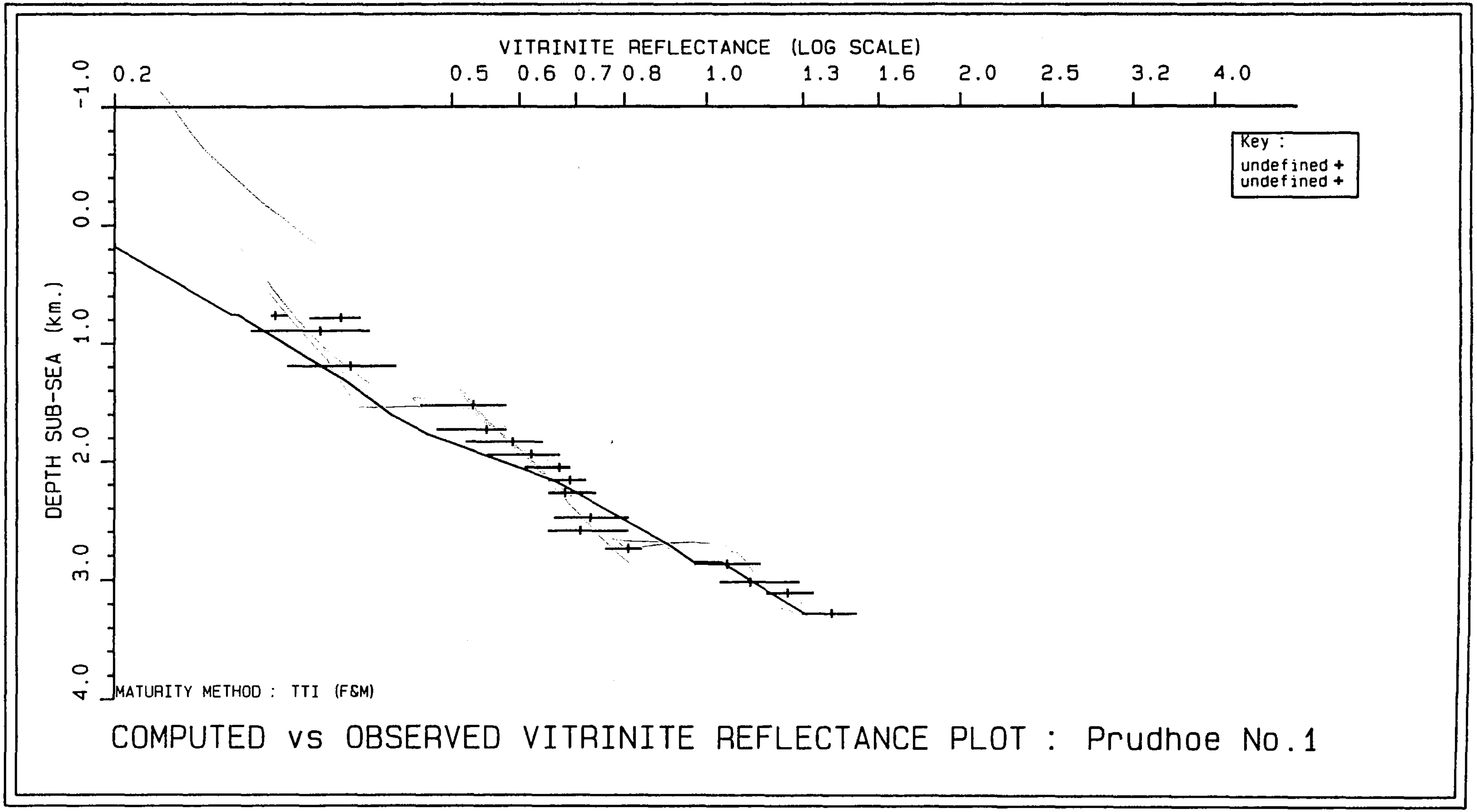


Figure 49. Computed versus observed vitrinite reflectance plot, Prudhoe No.1.

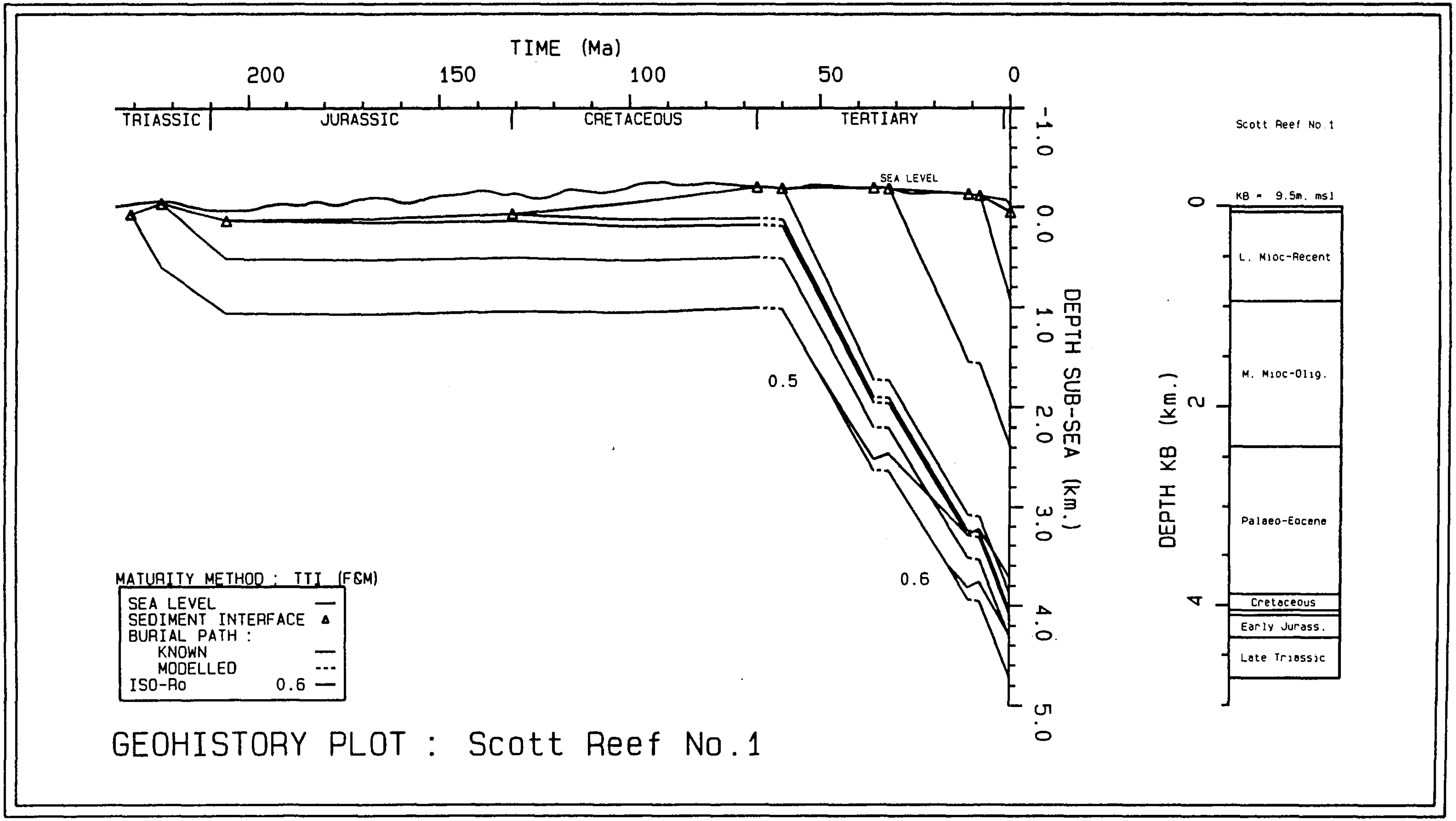


Figure 50. Geohistory plot, Scott Reef No.1.

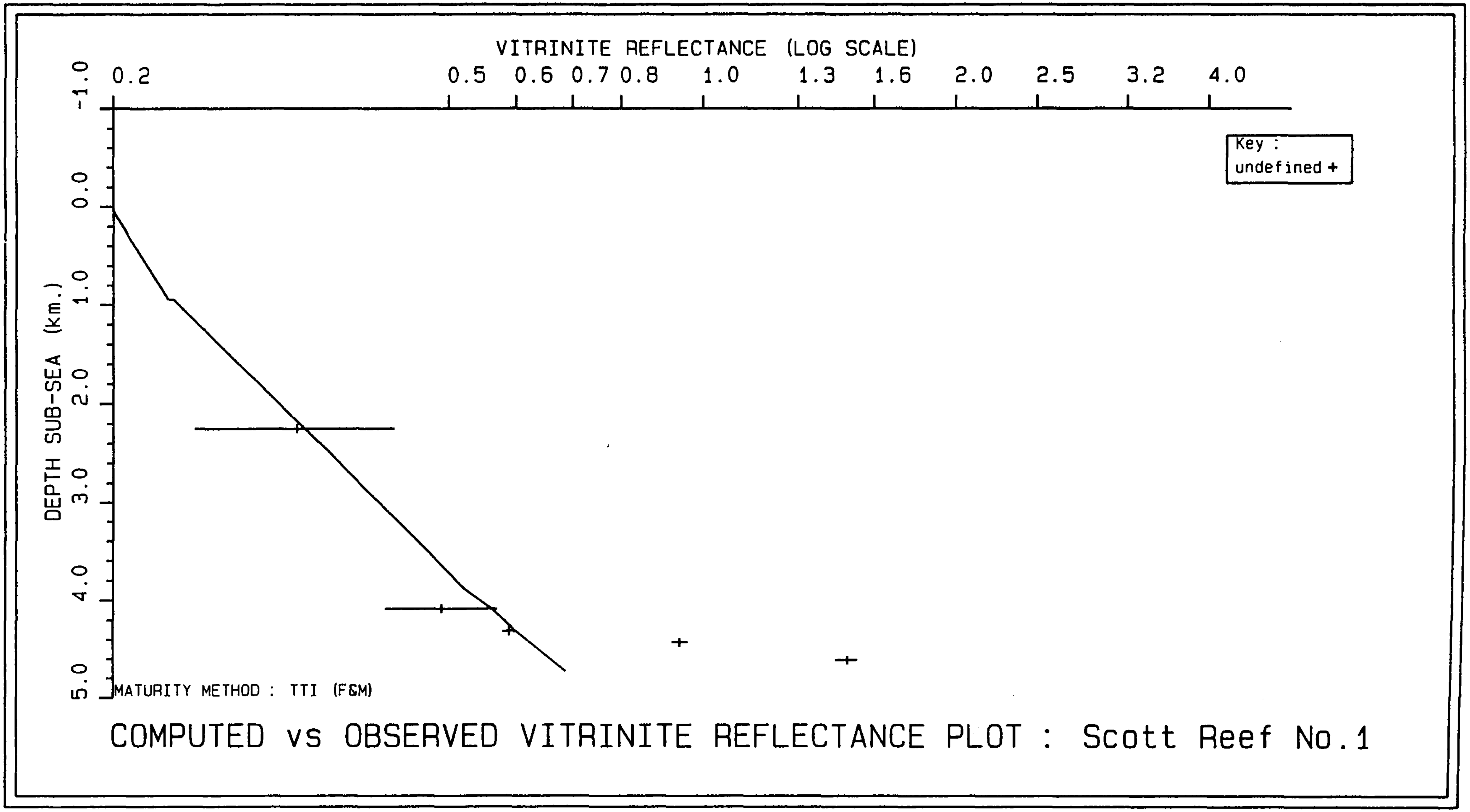


Figure 51. Computed versus observed vitrinite reflectance plot, Scott Reef No.1.

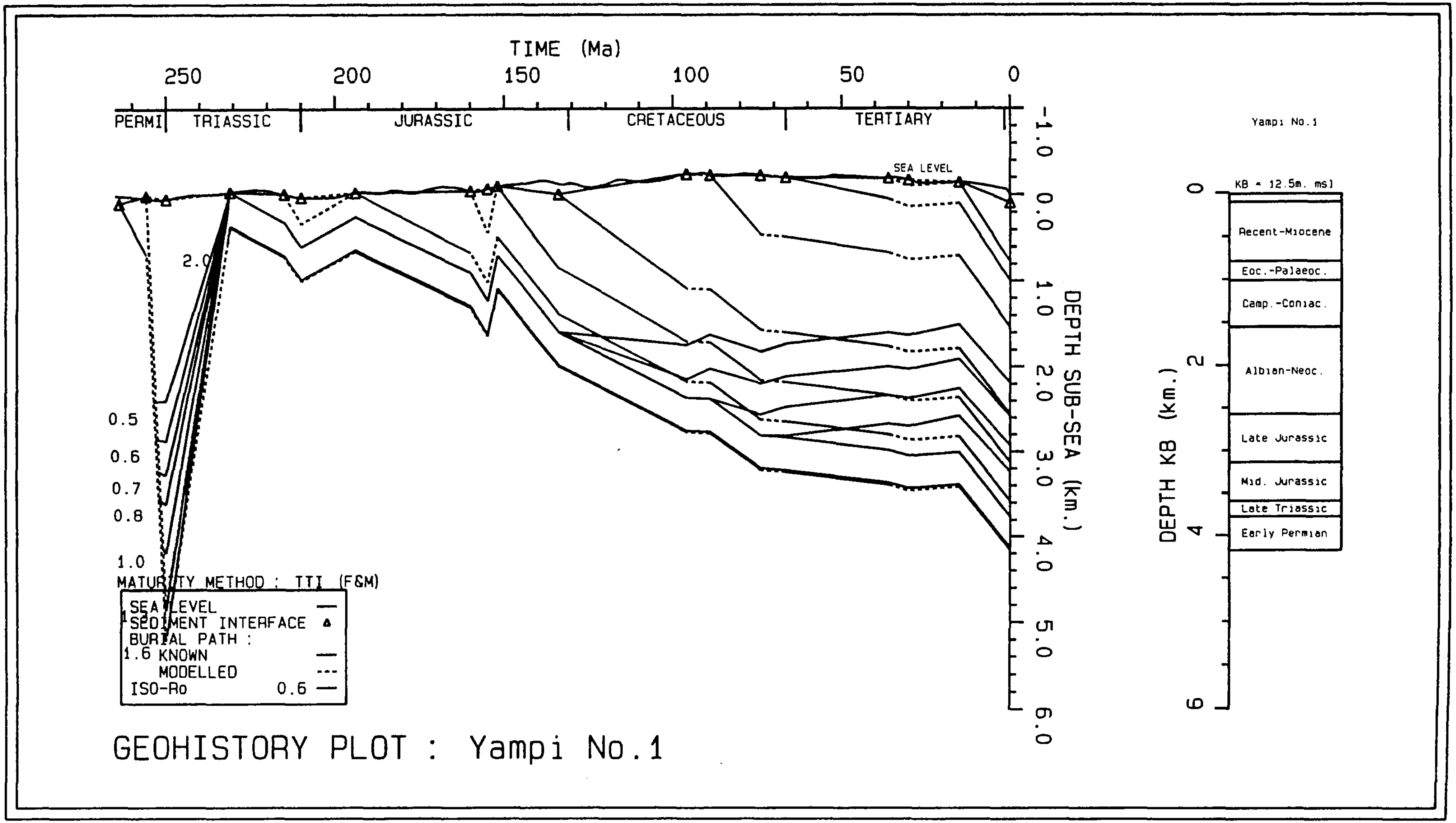


Figure 52. Geohistory plot, Yampi No.1.

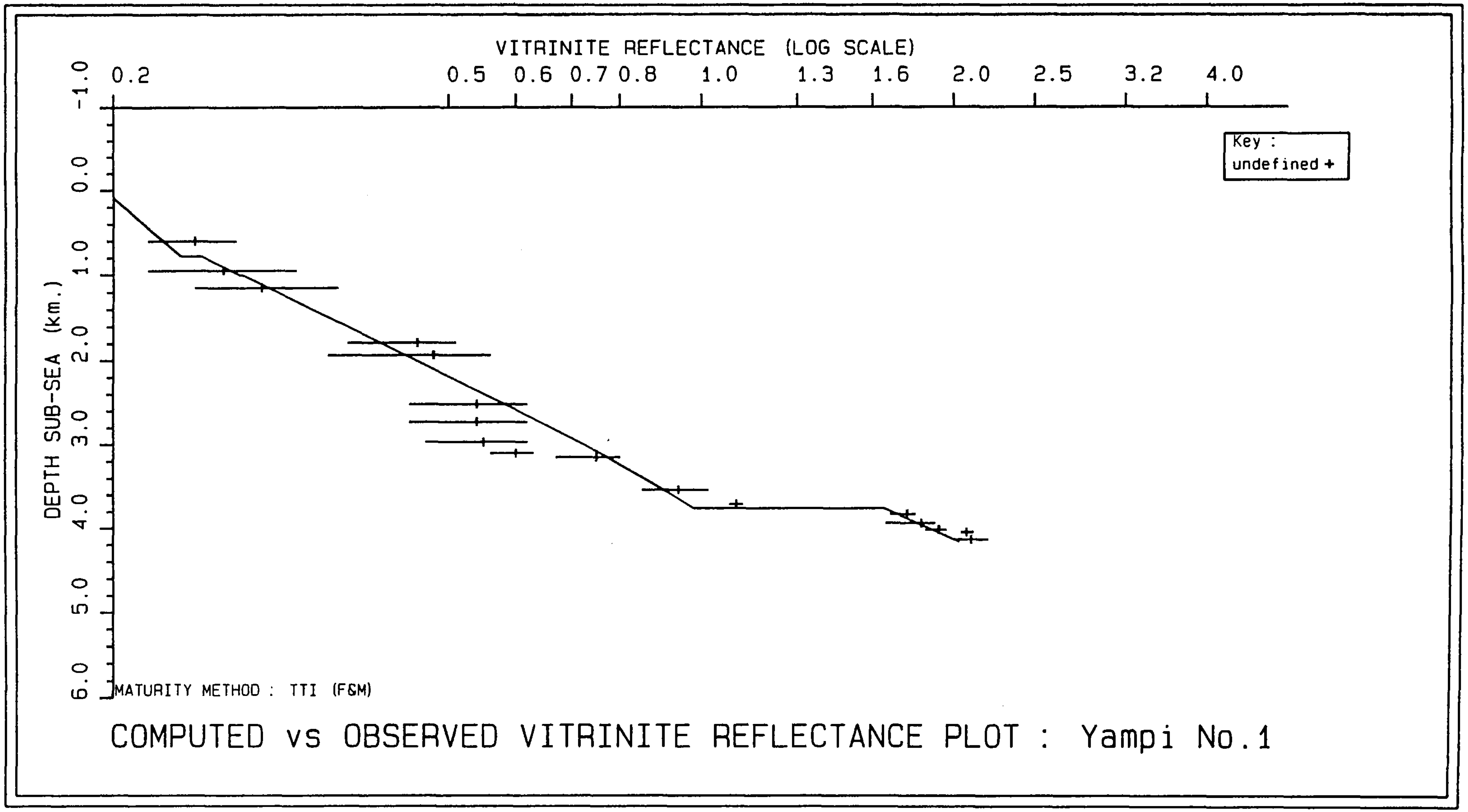


Figure 53. Computed versus observed vitrinite reflectance plot, Yampi No.1.

In the central and western Browse Basin, Cretaceous to present day heatflows of between 1.8 HFU and 2.0 HFU and syn-rift heatflows of up to 2.5 HFU were needed to produce a good match between observed and computed vitrinite reflectance values.

The exception is the Scott Reef No.1 well, where a milder thermal history seems to have prevailed. Heatflows similar to those used in wells on the eastern basin margin were modelled in this instance. A basaltic intrusive of probable Middle Jurassic age encountered below 4000 metres in Scott Reef No.1 made maturation modelling difficult in this well. The presence of these Middle Jurassic volcanics has given rise to anomalously high vitrinite reflectance values in the Early Jurassic interval (Figure 51).

8.4.2 Burial History

The uplift and erosion which occurred over most of the inner shelf in the Oligocene has been modelled in five wells. Between 40 metres and 100 metres of Tertiary section is interpreted to be missing at the Oligocene unconformity in Yampi No.1, Prudhoe No.1, Caswell No.1 and Brewster No.1A. In Leveque No.1, it was necessary to model the erosion of approximately 400m of Oligocene sediments to achieve an acceptable match with observed vitrinite reflectance data. No evidence of an Oligocene unconformity is found in the two wells in the outer Browse Basin (Scott Reef No.1, Buffon No.1). No data are available on the Oligocene erosional event in the Lynher No.1 well.

A number of transgressions and regressions in the Cretaceous have given rise to several unconformities within the Cretaceous section. These have generally been modelled as hiatuses with little or no erosion postulated.

Three of the wells analysed (Prudhoe No.1, Yampi No.1 and Lynher No.1) encountered sediments of Permian age. Burial history modelling indicates that the episode of block faulting and erosion that resulted from tensional movements in the Late Permian has removed a considerable thickness of Permo-Triassic sediments from the eastern basin margin. It was necessary to postulate the erosion of nearly 4000 metres of Middle Permian to Middle Triassic sediments in order to model the observed Permian thermal maturities in Yampi No.1. Higher Permian heatflows may have been partially responsible for these elevated thermal maturities. However, the best match between observed and computed vitrinite reflectance was obtained by invoking a major erosional event in the Late Permian. Lesser amounts of erosion were modelled in Prudhoe No.1 (2400 metres) and Lynher No.1 (1000 metres).

Although these thicknesses may seem excessive, further south, in the offshore Canning Basin, in excess of 2000 metres of Triassic sediments are thought to be present (Middleton, 1990). A Permian section of unknown thickness underlies this sequence, although in the Fitzroy Trough, the presence of more than 2000 metres of Permian section has been inferred (Middleton, 1990). Further to the north on the Ashmore Platform, considerable thicknesses of Triassic sediments are thought to occur.

8.4.3 Timing of Hydrocarbon Generation

Burial history modelling indicates that Lower Cretaceous and Jurassic source intervals in Prudhoe No.1 probably entered the oil window (>0.65-0.7% Ro) approximately 50 million years Before Present (Eocene). In Yampi No.1, the Cretaceous section is immature, although Jurassic sediments may have commenced sourcing hydrocarbons in the Late Cretaceous.

Cretaceous source intervals in the central Browse Basin have probably been generating hydrocarbons from the Eocene to the present day. Burial history modelling of wells in this area (Brewster No.1A, Caswell No.1 and Buffon No.1) shows that Jurassic sediments probably entered the oil window in the Early to Middle Cretaceous.

The Triassic section is absent in Prudhoe No.1. However, in Yampi No.1, modelling indicates that any Triassic source rocks present in the well probably commenced significant hydrocarbon generation in the Middle Cretaceous.

The Permian section is overmature in both Prudhoe No.1 and Yampi No.1. Any source rocks present in the Permian probably entered the oil window as early as Late Triassic times.

8.4.4 Maturation

Present day thermal maturities at four stratigraphic levels are shown in Figures 54, 55, 56 and 57 (Late Triassic, Middle Jurassic, Early Cretaceous and Late Cretaceous). Generalised iso-maturity contours have been based on mean vitrinite reflectance values provided by Robertson Research (1986). Present day geothermal gradients in the Browse Basin are shown on Figure 58.

A number of wells in the Browse Basin have encountered pyroclastic and basaltic volcanics of Middle Jurassic age associated with the Jurassic rifting event. These volcanics have imparted elevated thermal maturities to Jurassic and Triassic sediments in some wells. These heating events are assumed to be of a local nature and their effect has been ignored when contouring the iso-maturity maps.

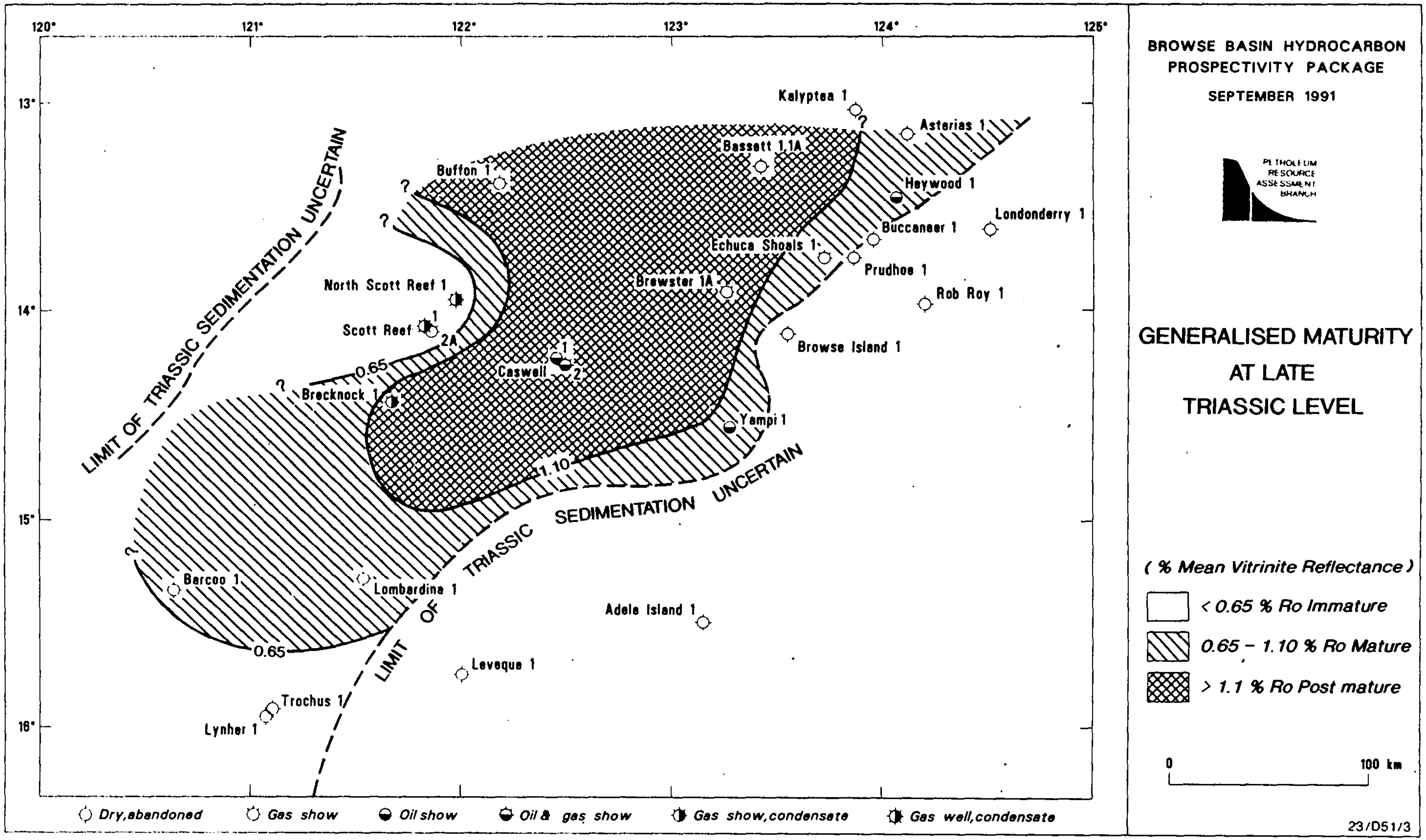


Figure 54. Generalised maturity at Late Triassic.

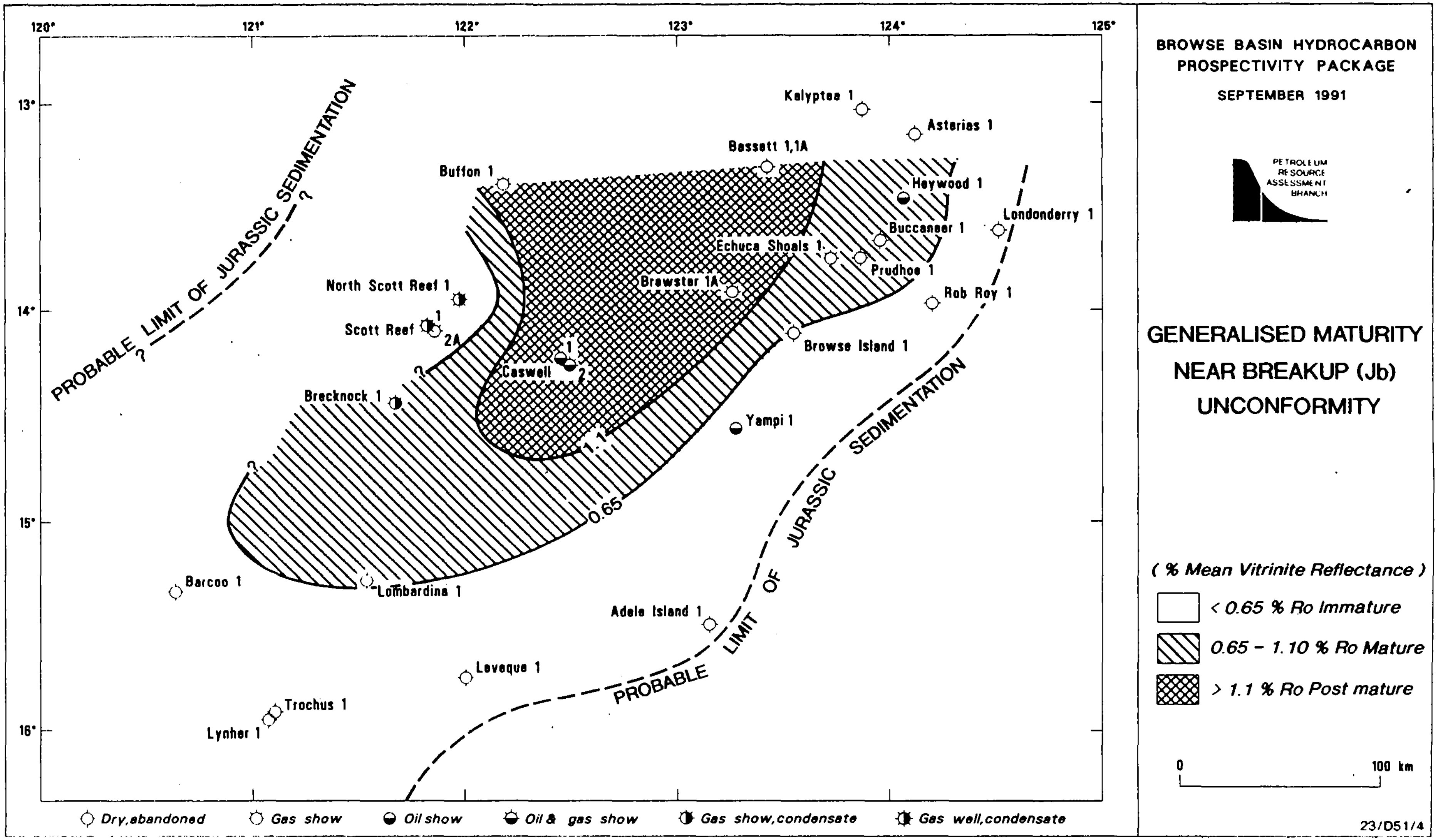


Figure 55. Generalised maturity near 'breakup' unconformity.

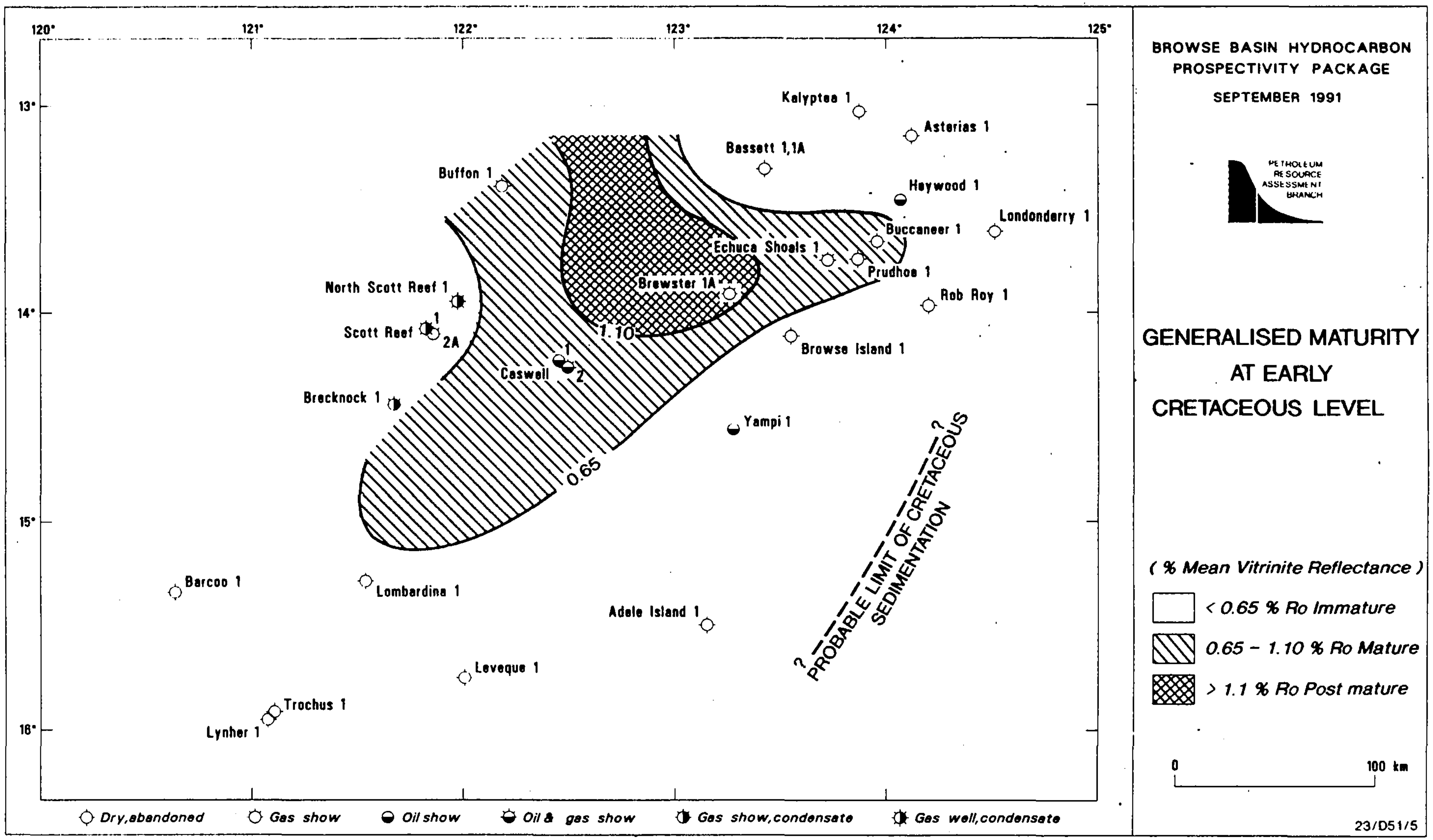


Figure 56. Generalised maturity at Early Cretaceous.

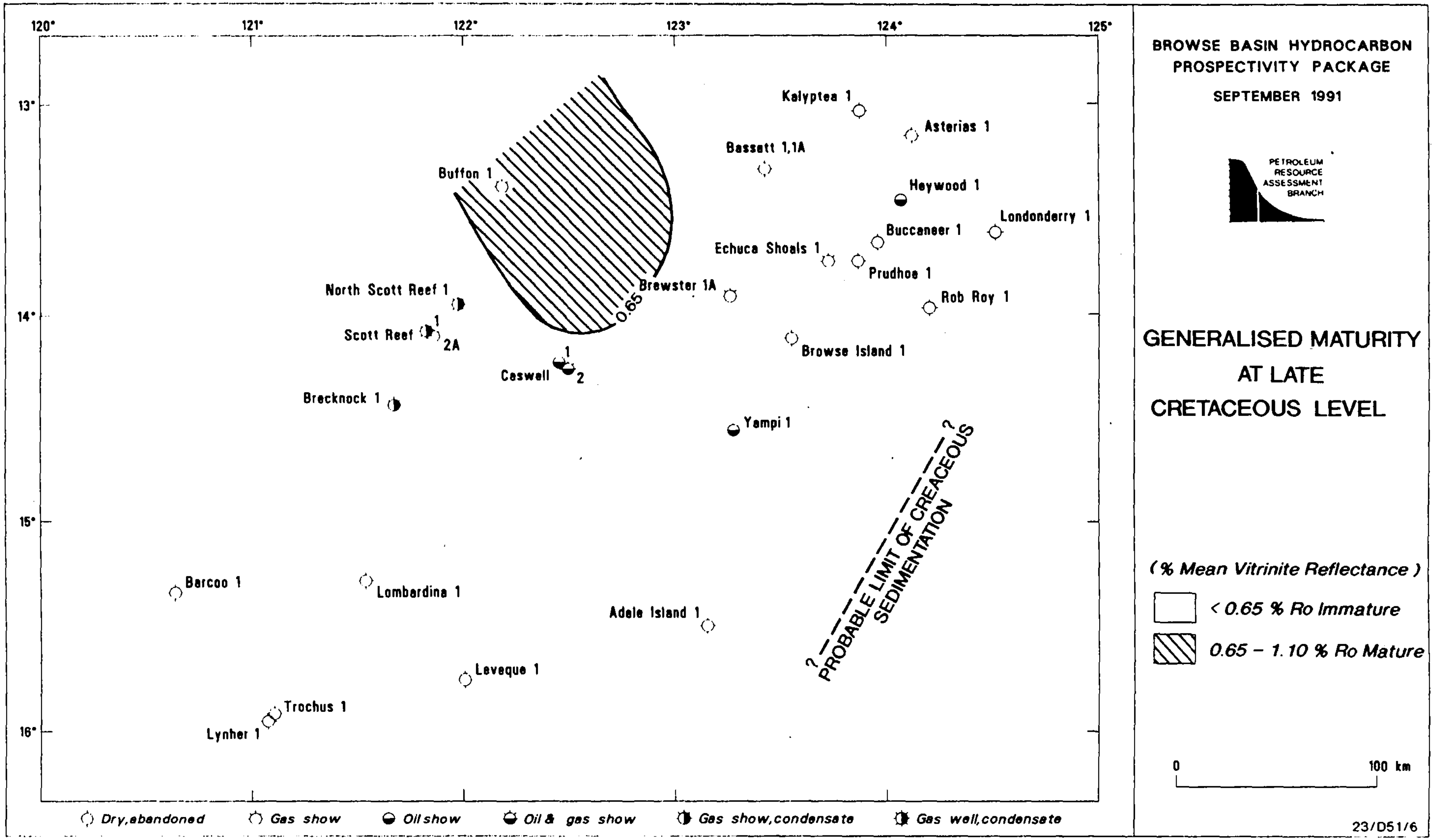


Figure 57. Generalised maturity at Late Cretaceous.

The Triassic is thought to be overmature over most of the central Browse Basin. However, in the southern Browse Basin (Barcoo No.1, Lombardina No.1) and on the basinward margin of the Prudhoe Terrace, Late Triassic sediments may still lie within the oil window (Figure 54).

Jurassic sediments are probably overmature in the deepest of the central basinal areas. Over the remainder of the central Browse Basin and much of the Prudhoe Terrace, most of the Jurassic sequence is probably oil generative. Immature Jurassic sediments are found on the Yampi Shelf and in the southern Browse Basin in the vicinity of Lynher No.1, Barcoo No.1 and Leveque No.1 (Figure 55).

Mature, Early Cretaceous sediments are confined to the central Browse Basin (Figure 56), while Late Cretaceous sediments only attain thermal maturities in excess of 0.65 % Ro in the Buffon No.1 well.

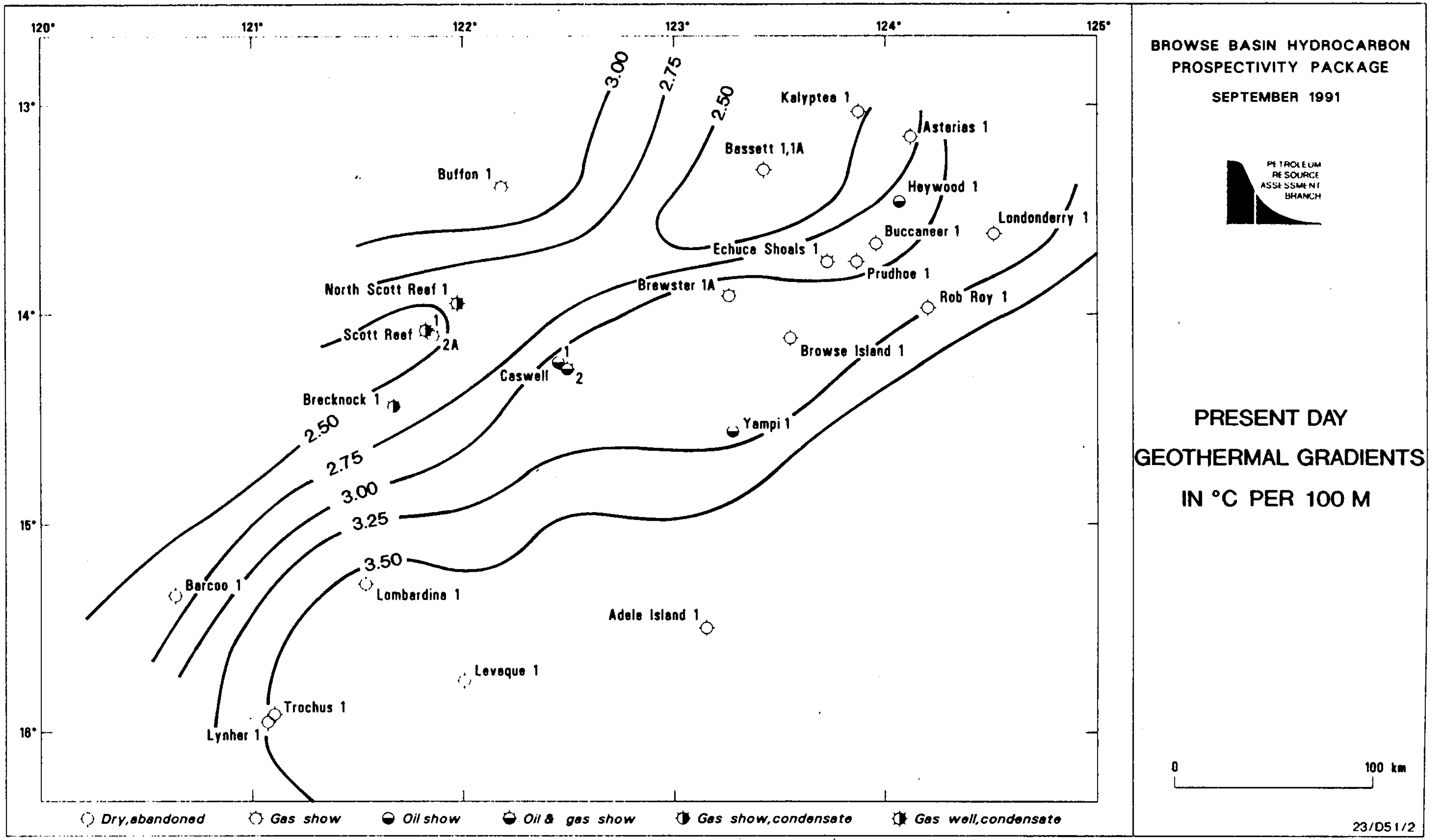


Figure 58. Present day geothermal gradients, Browse Basin.

9. HYDROCARBON PLAYS AND PROSPECTS

9.1 PLAY CONCEPTS AND OVERVIEW

(S.J. Cadman)

The traditional play type tested in the Browse Basin has been the drape anticline - Late Jurassic to Early Cretaceous claystone draped over Triassic to Middle Jurassic horst blocks. To date, eight wells have been drilled as tests of drape anticlines. All have made either hydrocarbon discoveries or encountered significant hydrocarbon shows (Scott Reef No.1 and No.2A, Caswell No.1 and No.2, Brecknock No.1, Buffon No.1, Brewster No.1A and North Scott Reef No.1).

Where erosional and depositional wedgeouts occur on the eastern basin margin, considerable potential for stratigraphic/structural traps exists. These basin margin plays are, as yet, untested.

9.1.1 Permian

In the central Browse Basin, Permian sediments lie too deep to constitute valid exploration objectives. However, sandstone, siltstone, claystone and recrystallsed limestone of Permian age have been penetrated in five wells on the eastern basin margin. Porosity preservation is poor in the Permian, with log derived porosity values rarely exceeding 10 %. Permian reservoir quality appears to have been seriously degraded by the emplacement of silica cement.

Although thin claystones and recrystallised limestones may provide intraformational seals in the Permian section, the overlying Triassic and Lower Jurassic sediments on the eastern basin margin are predominantly sandy. Consequently, adequate seal may be a problem for Permian stratigraphic pinchouts on the eastern flank of the basin.

Good quality Permian source rocks have yet to be intersected in the basin. In addition, burial history modelling indicates that any hydrocarbon sources within the Permian section probably entered the oil window as early as Triassic times, raising the possibility of late gas flushing in Permian reservoirs.

In view of the above, Permian stratigraphic/structural plays on the eastern basin margin could be seen as extremely high risk.

9.1.2 Triassic

In the central Browse Basin, Triassic sediments probably lie at depths in excess of 5000 metres. Silicification of

Triassic reservoirs is likely to be a problem in these areas, although sands of Triassic age intersected on the Scott Reef structural trend (Scott Reef No.1) retained excellent porosities (up to 20 %) at depths of around 4400 metres.

The episode of block faulting that occurred at the end of the Triassic dissected the Triassic sequence into a number of northeast/southwest trending horst blocks. A further episode of block faulting in the Middle Jurassic terminated syn-rift deposition and reactivated much of the Triassic faulting. Subsequent deposition of transgressive marine claystones in the Late Jurassic and Early Cretaceous has given rise to the most important hydrocarbon trap in the Browse Basin to date - the drape anticline.

In these drape anticlines, seal for Triassic reservoirs is likely to be provided by either intraformational claystones or, as in the case of the Scott Reef accumulation, by Late Jurassic and Early Cretaceous claystones above the 'breakup' unconformity. As mentioned previously, historically, the drape anticline has been the most important play type in the Browse Basin and may continue to constitute the primary exploration target in the area for some time to come.

Triassic source rock facies have only been encountered on shelfal areas on the eastern basin margin and on the Scott Reef structural trend. Here, source rock quality is poor to fair, with a predominance of humic, Type III, organic matter. Hydrocarbons generated from Triassic source rocks have probably made a significant contribution to the Scott Reef gas/condensate accumulation. Although Triassic source rocks appear to be gas prone, it is possible that an organically rich, oil-prone Triassic source facies may be developed in the central basinal areas and in local lows. This facies has yet to be intersected (Willis, 1988).

The Triassic section is overmature over most of the central Browse Basin. Consequently, late gas flushing of Triassic reservoirs may be a problem in these areas. In addition, silicification of Triassic reservoirs may have occluded porosity in the deeper parts of the basin. However, towards the eastern basin margin and in the southern Browse Basin, Triassic sediments probably lie within the oil window at the present time. Traps in these areas are ideally located to receive hydrocarbons from mature Triassic source rocks.

The limits of Triassic sedimentation are uncertain. However, rocks of Triassic age have been intersected on the Prudhoe Terrace, the Yampi Shelf and the margins of the Leveque Shelf. The deltaic to marginal marine Triassic facies in these localities are predominantly sandy. Although some potential exists for stratigraphic traps in these basin margin delta fan complexes and for structural traps associated with the basin margin fault system, lack of adequate seal may be a problem in Triassic reservoirs developed along the eastern basin margin. In this area, valid stratigraphic traps would rely on the development of competent intraformational Triassic or Early to Middle Jurassic claystone seals.

9.1.3 Jurassic

Traditionally, Early to Middle Jurassic syn-rift fluvio-deltaic to marine sandstones have been the primary objectives in the Browse Basin. Reservoir porosity in this sequence is fair to good over most of the study area, although quartz overgrowths may occlude porosity in the deeper parts of the basin.

Fair to good quality source rocks have been encountered in the pre-breakup Jurassic sediments. Maturation modelling indicates that Early to Middle Jurassic source rocks are probably oil mature over most of the basin and immature to marginally mature on the eastern basin margin. Although source rocks analysed in this interval, to date, are predominantly gas-prone (vitrinite and inertinite are the most abundant macerals), this does not preclude the possibility that an as yet untested Early to Middle Jurassic oil-prone source rock facies may be present in the basin.

Historically, drape anticlines have been targeted in the search for Early to Middle Jurassic hydrocarbon accumulations. However, collision of the Australian plate with Timor in the Miocene has given rise to compressional reactivation and reversal of down-to-the-basin normal faults on the Lombardina/Lynher structural trend. Lombardina No.1 tested a fault dependent closure which formed both as a result of this compressional event and the northwest tilting of the basin during the Tertiary.

Similarly, elsewhere in the basin, where structure has been influenced by Miocene tectonism, late formed structural traps may be present at Jurassic level. However, burial history modelling indicates that Early to Middle Jurassic source rocks probably entered the oil window in the central Browse Basin as early as Late Cretaceous times. Consequently, structural traps formed in the Late Tertiary may not be ideally placed to receive an adequate hydrocarbon charge.

In the central basin, the Early to Middle Jurassic syn-rift sequence is sealed regionally by Late Jurassic to Early Cretaceous transgressive marine shales overlying the 'breakup' unconformity. In addition, intraformational claystone seals within tilted Triassic/Jurassic horst blocks, may give rise to stacked reservoirs.

Towards the eastern margin of the basin, there is pronounced sand development throughout the entire Jurassic section. Sand development is particularly pronounced in the Tithonian. Where these sands are sealed by Early Cretaceous claystones, they constitute valid exploration objectives. Reservoir porosity is generally fair to excellent in this interval and potential exists for Jurassic stratigraphic pinchouts and fault traps associated with the basin margin fault system. In a number of wells, sandstone deposition is virtually continuous from Late Jurassic to Neocomian times. In these areas, lack of adequate seal for the Jurassic section may be a problem.

Due to poor well and seismic control, the basinward extent of any Jurassic deltaic sequences or submarine fans shed from the adjacent Kimberley Block is uncertain. However, the prospectivity of these basin margin plays is probably enhanced by the fact that they lie updip from closures where late generated gas may be displacing oil and from breached traps which have lost closure due to Late Tertiary tilting.

Migration distances from mature Jurassic source rocks to these basin margin structural/stratigraphic traps on the Prudhoe Terrace and Yampi Shelf are generally from 40 to 100 kilometres. Shorter migration distances can be invoked if these traps are charged by hydrocarbons sourced from the Triassic via fault conduits associated with the basin margin fault system. Traps on the Leveque Shelf are further removed from the Jurassic kitchen area and in these instances, migration distances probably exceed 100 kilometres.

9.1.4 Cretaceous

Rejuvenation of pre-breakup faulting in the Late Jurassic and Early Cretaceous is evident in some areas (Allen & others, 1978). Consequently, there may be some potential for structural traps associated with the basin margin fault system at Neocomian level. Potential Neocomian stratigraphic plays on the eastern basin margin include deltaic complexes and submarine fans. Potential Neocomian stratigraphic plays on the eastern basin margin include deltaic complexes and submarine fans.

The basinward extent of Neocomian sand development is uncertain. However, Neocomian deltaic complexes and submarine fans are probably restricted to the Yampi Shelf and Prudhoe Terrace.

In the central Browse Basin, Early Cretaceous sediments are predominantly claystone and marl. However, thin, hydrocarbon-bearing sandstones of Albian age were intersected in Caswell No.1. These have subsequently been interpreted as turbidite sands. The occurrence of turbidite deposits in the vicinity of the Caswell structure indicates that Early Cretaceous sand development may extend a considerable distance from the eastern basin margin.

Early Cretaceous source rocks presently lie within the oil window in the central Browse Basin and may have sourced the Caswell oil (although there may also have been a significant contribution from the Jurassic section via fault conduits). Similarly, in areas distal to mature Early Cretaceous source rocks (such as the eastern basin margin), hydrocarbons may have migrated from mature Jurassic sources up fault planes associated with the basin margin fault system into stratigraphic and structural traps at Neocomian level.

Claystone of Aptian to Turonian age probably provide competent local seals for Neocomian reservoirs. In addition, intraformational claystones in Early Cretaceous deltaic sequences may form potential seals.

Deltaic complexes, submarine fans and turbidite sequences, fed by sediments shed from the Kimberley Block, may form potential reservoirs on the eastern flank of the basin. Prograding foresets and sand mounding is seen on many seismic sections at Campanian level. The orientation of some of these foresets indicates sediment supply seems to have been predominantly from the southeast.

In the Late Cretaceous, sand development probably extended a considerable distance from the present day basin margin (Brewster No.1A, drilled on the Inner Basin Arch, intersected a 90 metre thick sandstone unit of Maastrichtian to Campanian age) and in the central Browse Basin, the Caswell wells also penetrated a thick (aproximately 200 metres) Maastrichtian/Campanian sandstone and minor claystone sequence. Oil recovered from these Campanian sands in Caswell No.2 has probably been sourced from Early Cretaceous shales which currently lie within the oil window in the central basin.

Wells drilled on the Prudhoe Terrace and Yampi Shelf indicate that in many areas, sand deposition is almost continuous from Late Cretaceous to Eocene times. Thick Maastrichtian claystones, encountered in some wells to the north of the study area, do not appear to be present. The absence of a regional seal and large migration distances to mature Cretaceous source rocks, may downgrade Campanian/ Maastrichtian sand plays on the eastern flank of the basin. However, Late Cretaceous intraformational claystones could provide adequate local seals and the possibilty that Jurassic source rocks have provided a hydrocarbon charge for Late Cretaceous sand plays cannot be discounted. Late Cretaceous sands juxtaposed against older sediments across basin margin faults may also form valid structural traps.

9.1.5 Tertiary

Although mapping at base Tertiary indicates a general lack of structure at this level, the collision of the Australian plate with Timor in the Miocene may have given rise to Tertiary structural closures in the northern Browse Basin. 'Hourglass' structures, resulting from the reactivation of Triassic and Jurassic faulting in the Miocene (akin to those seen in the Vulcan Sub-basin to the north), have been noted on a number of seismic sections in the north of the study area.

Thick, prograding carbonate wedges cover most of the basin. Lithologies are predominantly calcarenite, calcisiltite, calcilutite, recrystallised limestone and minor dolomite. Reservoir porosity is excellent through most of Tertiary section (>20 %) and recrystallised limestones may provide intraformational seals. However, Cretaceous and Jurassic sources would have to be invoked in order to charge these traps and burial history modelling indicates that the timing of hydrocarbon generation probably pre-dates trap formation in many areas. For these reasons, Tertiary carbonate plays are seen as high risk.

9.2 PROSPECTS AND LEADS

(J.C. Conolly, B.G. West and J. Blevin)

The variety of plays recognised in the Browse Basin are depicted on Plates 75 and 76 and show where the main prospects and leads are located within the vacant areas.

Each of the five areas prepared by BMR for Release 2 of 1991 were examined during the study. Maps of the leads at 100 000 scale (Plates 13-17), plus bathymetry maps (Plates 18-22) and seismic line locations maps (Plates 23-27) at the same scale, were compiled for each release area.

9.2.1 Area W91-13, Prospects and Leads

(J.E. Blevin)

9.2.1.1 Bathymetry

Area W91-13 comprises an area of 80 graticular blocks on the outer continental shelf and slope in the central Browse Basin. Seafloor slopes gently from 300 metres in the east to 600 metres at the outer shelf, before dropping steeply to over 1700 metres on the outer slope. There are no prominent shallow bathymetric features in the block such as Scott Reef and North Scott Reef situated to the south and west. Scott Reef and North Scott Reef are Late Tertiary carbonate buildups located over northeasterly-trending Triassic horst blocks. A northerly extension of the Triassic horst system underlying the Scott Reef Trend appears to continue into the northern region of Area W19-13 although there is no modern bathymetric evidence for this trend. Likewise, the structural blocks forming the Buffon Trend in the northwest region of the block do not appear to have prominent modern bathymetric expression.

9.2.1.2 Geology of Area W91-13

The majority of Area W91-13 forms the intervening trough between two major Triassic structural highs, the Scott Reef Trend and the Central Basin Arch. Jurassic and Early Cretaceous sediments thicken along the northeast-trending trough axis. Generally, Late Cretaceous sediments are thin in the trough, although localised thickening occurs along the eastern edge of the block near the Central Basin Arch. A westward-thickening wedge of Tertiary carbonates prograde across the block reaching a maximum thickness of 300 metres in the central basin.

Thick sequences of Jurassic and Early Cretaceous claystones deposited in the trough under semi-restricted marine conditions are expected to be excellent source rocks. Shows at both Caswell No.1 to the east and North Scott Reef No.1 to the west confirm that hydrocarbons have been generated in the area. Drilling has shown that reservoir sands can be expected in the Early to Middle Jurassic sequence (beneath the Jb horizon), and possibly within the Late Jurassic (Jc, post-breakup sands) and Paleocene sequences. Volcanics may be present in the Jurassic section. Leads in Area W91-13 are likely to occur as drapes over isolated horsts structures along the margins of the block and as deeper continuations of established high trends (Scott Reef Trend, Buffon Trend). Continued or reactivated faulting over deep Triassic horsts is common along the eastern margin of the block. The faults commonly have a complex 'hourglass' structure which may provide further traps within the Cretaceous and Early Tertiary sedimentary sequence.

The precise boundaries of Area W91-13 were unavailable during the early preparation of this report and leads were not assessed beyond the preliminary boundaries. A likely change will extend the northern boundary further to the north. Prospective structures are likely to lie in the far northern region of the block as indicated by regional trends of the Jb horizon. However, this area was not included in this assessment.

Differences in the trend and depth of horizon Jb as shown on the generalised structure map near 'breakup' (Jb) unconformity (Plate 6) and the leads map on Jb horizon (Plates 13A, 13B) can be attributed to the vintage of seismic data used in the compilation. Esso Seismic Survey S82A and Woodside Survey 82F and 82G provided the primary database for the assessment of Area W91-13.

9.2.1.3 Lead Descriptions

Lead W91-13-A

Lead W91-13-A occurs in the eastern region of Area W91-13 in water depths of approximately 450 metres. Woodside Seismic Line 82-2545 (Plates 43A, 43B) shows a series of faulted Triassic blocks forming a broad, low arch with a relatively thick overlying sequence of Early to Middle Jurassic sediments (Jb) draping the structures. The proposed Early to Middle Jurassic reservoir interval appears to thin away from the structural high probably due to erosion. Late Jurassic (Jc) sediments are absent from the crest of the structure. The Early to Middle Jurassic sequence is directly overlain by Lower Cretaceous shales which may provide a competent regional seal.

Lead W-19-B

Lead W91-13-B also occurs in the eastern region of Area W91-13 in water depths of 450 to 500 metres. An interpretation of Woodside Seismic Line 82-2554 (Plates 42A, 42B) indicates Triassic horst blocks are draped by Early to Middle Jurassic sediments. Lead W91-14-A (also shown on Plates 42A and 42B) is a similar play situated to the east. An intervening trough is located between the two structural highs and may provide a local hydrocarbon source. Tithonian sands interpreted at Lead W91-14-A (Plates 42A, 42B) may extend eastwards to Lead W91-14-A and onlap the margins of the Triassic structural high. Continued or reactivated faulting extends upwards from the Triassic through to the Miocene to Recent carbonate sequence. Campanian ?turbidite sands interpreted above horizon D may be sourced by hydrocarbons generated in the Lower Cretaceous to Early Jurassic intervals via the fault system. A favourable seal could be eastward prograding Campanian or younger foreset shales.

Lead W91-13-C

Lead W91-13-C occurs in the north-central region of the block in water depths of 450 to 500 metres. An interpretation of Esso Seismic Line S82A-127 (Plate 28A) indicates a Triassic horst block approximately 4.0 kilometres wide draped by an overlying sequence of Early-Middle (Jb) and Late Jurassic (Jc) sediments (Plate 28B). The Triassic structure and overlying sediments lie at depths between 3.0 to 3.5 s TWT.

The Triassic horst structure of Lead W91-13-C appears to be a deeper northerly extension of the Scott Reef Trend, although the structure is slightly offset to the southeast from the established trend. Lead W91-13-C is ideally situated updip from potential source rocks in the central trough. A second, smaller and deeper horst block occurs to the southwest of Lead W91-13-C and is noted on the leads map (Plates 15A, 15B).

Lead W91-13-D

Lead W91-13-D is situated in the far northwest region of the block near Buffon No.1 in water depths of 550 to 600 metres. Buffon No.1 recovered Early to Middle Jurassic volcanics, claystone and sand (beneath the Jb horizon), and recorded a gas show within the volcanics interval. An interpretation of Woodside Seismic Line 82-2528 (Plate 29A) indicates a possible onlap of Late Jurassic (Jc) sediments on the southwestern edge of the Buffon structure (Plate 29B). Potential reservoirs may exist as sands above the breakup unconformity (Jb). In addition, remapping of the Early to Middle Cretaceous sequence draping the Buffon structure (T to Jb interval) may clarify the distribution of volcanics which occurred withing the Buffon No.1 objective section.

Lead W91-13-E

Lead W91-13-E occurs in the central region of the block in water depths of approximately 450 metres. Seismic Line S82A-58 (Plate 30A) shows a series of Triassic horst blocks forming a broad, low arch and an overlying drape of Early to Middle Jurassic sandstones and claystones (Plate 30B). The structure has a northeasterly trend and lies updip from the central axis of the trough between the Scott Reef Trend and the Central Basin Arch. A possible sequence of Paleocene mounds (?sands) are noted at the southern end of Seismic Line S82A-58 (Plate 30B). Faults extending from deep structures (?Triassic) though the section may act as conduits for hydrocarbon migration into local reservoirs. Facies mapping of the mounds and details of fault geometry and movement are necessary to properly evaluate the potential of the Paleocene mounds.

Esso Seismic Line S82A-58 (Plate 30A) also gives a north-to-south regional overview of the geology in Area W91-13. Seismic Line S82A-79 (Plate 31A), a section between Scott Reef No.1 and Caswell No.1, ties to Line S82A-58 and presents an east-west perspective of the geology in the block (Plate 31B). Thickening of the Early to Late Jurassic sequences occurs in the central trough, south of Lead W91-13-E. Above the Jc (Late Jurassic) horizon, thinning and thickening of the units appears to be minimal. The Campanian turbidite sequence recovered at Caswell No.1 (within the X to D interval) does not appear to extend into this region. Local thickening of the X to D interval does occur along the eastern boundary of the basin and is attributed to distal mud mounds associated by turbidite sands.

Lead W91-13-F

Lead W-91-13-F is located on the eastern side of the block in water depths of 400 metres. Woodside Seismic Line 82-2551 (Plate 32A) shows Early to Middle Jurassic (Jb) and Late Jurassic (Jc) sediments (Plate 32B). This lead is similar to Leads W91-13-C and E. Faults extending from deeper (?Triassic) structures through the Miocene carbonate will add structural complexity to simple migration and trapping mechanisms. Mapping of this lead is difficult as the structure is relatively small and is located along the boundary of previous blocks where seismic coverage is marginal.

Lead W91-13-G

Lead W91-13-G is located on the eastern side of the block in approximately 400 metres of water. Faults extending from deeper structures (similar to Lead W91-13-F) have 'hourglass' type geometries which may provide migration paths and traps within the Cretaceous section. Although a specific lead is not noted on the leads map (Plate 13A, 13B), a steep fault on Seismic Section 82-2543 (Plate 33A) is highlighted as a potential trap (Plate 33A)

Lead W91-13-H

Lead W91-13-H lies in the southernmost region of the block in water depths of 600 metres. Triassic horsts with an Early to Middle Jurassic (Jb) and Late Jurassic (Jc) drape are interpreted from Seismic Line S82A-55 (Plates 34A, 34B). The drape shows a moderate thinning and thickening across the horst. Volcanics are probably within the Early to Middle Jurassic sequence as recorded at Brecknock No.1 to the south. Closure of the structure is unclear as it occurs near the end of the seismic line and near a previous block boundary which limited mapping of the structure.

Esso Seismic Line S82A-54 (Plates 35A, 35B) is situated in the central area of the block and denotes the possible presence of post-Jurassic reservoirs. Reservoir sands in Area W91-13 are generally thought to be restricted to pre-breakup and early post-breakup sequences. Seismic Line S82A-54 (Plate 35A) shows a broad Late Cretaceous channel (horizon D) which is infilled by thin overlying Late Cretaceous sediments (horizon X) (Plate 35B). The D to X interval at Caswell No.1 recovered an unanticipated reservoir and oil show in Campanian turbidite sandstones. Turbidite sequences are generally believed to be restricted to areas east of Area W91-14. However, if remapping of the systems indicates an extension into the block, this occurrence may provide a favourable lead.

Seismic Line S82A-54 (Plates 35A, 35B) also contains a series of mounds which overlie horizon M and may be Late

Paleocene in age. Paleocene deltaic sequences mapped outside the block to the east are generally of early Paleocene age and occur between Horizons M and E.

9.2.2 Area W91-14, Prospects and Leads

(J.C. Conolly)

9.2.2.1 Bathymetry

Area W91-14 covers a large area of the continental shelf with water depths ranging from 100 to 400 metres (Plate 19). If the economic appraisal of the area was only dependent upon water depths (all other factors being equal) then the region could be subdivided into three major bathymetric zones: one with water depths of about 120 metres or less representing the inner shallow continental shelf; the second with water depths of 120 to 400 metres, representing a gentle continental shelf surface sloping gradually down from the inner shelf zone; and a third zone of elevated areas, representing isolated Pliocene to Pleistocene reef build-ups.

Only one obvious reef build-up, Browse Island, occurs in the region. Other present day island-atoll complexes such as Scott Reef occur in the general region over paleo-highs. It is still not clear whether Browse Island sits over a basement-elevated horst-block, but this may be the case, and may yet represent a valid prospect.

The inner continental shelf is characterised by elongate channels, oriented mainly in a north-south direction and probably represent low-stand Pleistocene drainage, probably dominated by tidal forces. These Pleistocene tidal-estuaries extend seawards from the present day shoreline to the inner shelf break at about 120 metres. The zone seaward of this area represents a definite slope that varies in steepness along its length, but which tends to flatten out onto the deeper outer continental shelf slope at depths of 210 to 270 metres. Oceanwards from this slope, the outer shelf region is characterised by gentle, broad swells and swales; the broad highs probably represent sediment build-ups.

The present day bathymetry tends to mirror the overall gross structural grain of the underlying Browse Basin. Much can probably be learned from a study of sedimentation patterns that exist today and in the recent past, as it would probably reflect the mechanisms of sediment transport and deposition that controlled the sediment patterns we interpret to have occurred in, say, the Cretaceous. It appears that the Browse Basin shelf has always been a region characterised by many bathymetric highs and intervening deeps. The deeper areas have accumulated more sediment, and represent possible source troughs, whereas the highs more obviously represent structural traps. In the Jurassic, the bathymetric patterns consisted of many individual horst and graben-controlled bathymetric highs and lows. Today, only the largest of these features, such as the Scott Reef trend, still has relief.

9.2.2.2 Prospect and Lead Descriptions

Leads W91-14-A and W91-14-B

Both Leads W91-14-A and W91-14-B lie in the northwest portion of Area W91-14, in water depths of 350 to 400 metres. Woodside Seismic Lines 73-1158 (Plates 41A, 41B) and 77-1862 (Plates 37A, 37B) are used to illustrate these leads. The Lead W91-14-A zone also appears to extend southwestwards towards the edge of the block where Woodside Seismic Line 82-2554 (Plate 42A) may also cross it. This part of Area W91-14 is characterised by deep horst blocks, separated by wider troughs or graben. The Lead W91-14-A and W91-14-B horsts are about 2.5 to 3.5 kilometres wide at the 'breakup' unconformity (Jb) structural level, and the intervening trough is 7 to 9 kilometres wide at the Jb level (Plates 37B, 41B). The next major horst to the northwest of Lead W91-14-A is another 9-10 kilometres away as is the next major block to the southwest of Lead W91-14-B. In all, there could be at least four major horst blocks similar to those at Leads W91-14-A and W91-14-B extending across the northern two-thirds of Area W91-14.

Other major horst blocks underlie the prospects and leads throughout the remainder of the block. The Brewster feature horst block is wider at the Jb level (5 to 6 kilometres) as are some of the other horst features in the southern part of the block, showing some local variation in the width and separation of the major rift-block control.

Leads W91-14-A and W91-14-B are controlled by deep faults that extend from the sides of old Triassic horst blocks upwards through the sediment pile into Tertiary limestones. They tend to have an 'hourglass' structural style with graben features in the Tertiary section sitting over horst features at depth.

This structural style is similar to structures in the Vulcan Sub-basin in the Timor Sea region. The origin of these structures and their development through time has been the subject of much discussion and debate. It is possible, for example, that the horst controlling faults may extend upwards through the sediment section, almost to the present day surface in some instances, and that these faults have moved in different directions through time.

As is the case with many of the known oil fields (Jabiru, Cassini, Skua, Talbot, Challis No.2) in the Vulcan Sub-basin, the major control is faulting; the secondary major factor is the distribution of good reservoirs. Both these factors will be similarly important in the areas of Leads W91-14-A and W91-14-B.

The highest risk in this region will be the occurrence and distribution of good reservoirs. The closest wells are Bassett No.1A, Brewster No.1A, and Caswell No.1 and No.2 wells, all of which are greater than 50 to 60 kilometres from Leads W91-14-A and W91-14-B. Seismic stratigraphy at the known reservoir levels, that is the Tithonian sands at the base Cretaceous (Jc) level, and the Upper Cretaceous (Campanian Sands) at the D level, are difficult to trace using the present old seismic database.

The Tithonian sands may extend as far seawards as Lead W91-14-B, as shown on Seismic Line 73-1158 (Plate 41B), but it is doubtful whether they would extend as far as Lead W91-14-A as suggested on the Seismic Lines 77-1862 and 82-2554 (Plates 37B, 42B, respectively). However, it is expected that Upper Cretaceous to Eocene age sandstones are present above the horst blocks. Oil could be trapped in these sands against faults. The oil would be sourced from either Lower Cretaceous or Jurassic age shales.

The lateral extent and thickness of such shallower Cretaceous-style oil fields would depend on the extent of vertical and lateral seal, as yet unknown because of lack of good seismic and well control. On the positive side, these reservoirs should be well sorted shelf or marine bar sands with excellent good porosity and permeability.

Lead W91-14-C

Lead W91-14-C sits on the edge of the block and extends into the adjacent vacant area to the west. Woodside Seismic Line 82-2538 (Plates 49A, 49B) illustrates Lead W91-14-C, which is a typical horst block feature similar, in most regards, to Leads W91-14-A and W91-14-B, except that here there is likely to be a better reservoir sand development at both the Tithonian (Jc) and Campanian to Paleocene levels.

Lead W91-14-C sits in the central Browse Basin, on strike with the Caswell No.1 and No.2 oil discoveries. As such, it is suitably placed for oil which could accumulate anywhere from the Tithonian sand level to the younger Cretaceous sands.

Woodside Seismic Line 82-2545 (Plate 43A), which runs across the grain of the horst-block trend, is a long line illustrating the general tectonic style found in this part of the block (Plate 43B). It is noted on this line that potential Campanian age turbidite reservoir sands may exist in this region similar to those that have already been drilled in the Caswell No.1 and No.2 wells.

Prospect W91-14-D

Prospect W91-14-D is basically a southwest extension of the Brewster structure. It is illustrated here by Woodside Seismic Lines 82-2558 (Plate 44A) and 82-2563 (Plate 38A) shot in 1982. Prospect W91-14-D is a large closure at the 'breakup' unconformity (Jb) level extending over an area of about 50 square kilometres (Plates 38B, 44B). Closure will also exist at the base Cretaceous (Jc) level so that both Tithonian and mid-Jurassic sandstone reservoirs are possible targets. The occurrence of gas in the Brewster structure at levels beneath the 'breakup' unconformity has helped to downgrade the present economic potential of this structure as seen by past permit holders.

Prospect W91-14-D lies closer to the deeper Browse Basin and hence closer to potential Lower Cretaceous source rocks which should be oil mature, suggesting that oil could be found in Tithonian sands, or in any sand found in a structure at stratigraphically higher levels. Campanian turbidite sands probably exist in this region and are important secondary targets.

Leads W91-14-E and W91-14-F

Leads W91-14-E and W91-14-F lie to the north of the Brewster structure on a separate deep horst feature.

Woodside Seismic Line 82-2569 (Plate 45B) shot in 1982 illustrates Lead W91-14-E, part of which may lie in the Shell permit WA-35-P. Line 82-2569 (Plate 45A) also ties to the Brewster No.1A well. Lead W91-14-E has good potential drape of Tithonian quartz sands over a horst block. Lead W91-14-F lies in a similar setting to Lead W91-14-E.

As for Prospect W91-14-D, there is more hope in finding oil since these leads are located closer to potential Lower Cretaceous source shales.

Prospect W91-14-G

Prospect W91-14-G lies directly south of the Brewster-Prospect W91-14-D horst block on a separate horst. It has been called the Brunswick Prospect by prior permit holder BHP and has been remapped more recently by them in 1987. Seismic Line HBW87-218 (Plate 40A), shot by BHP, is used to illustrate this prospect (Plate 40B).

The prospect has a closure of about 25 square kilometres as mapped by BHP (BHP's general contour shapes are used in this report) at the Jb level. The play in this prospect is at the Jb or deeper levels. Once again, one must hope that oil and **not** gas is present at these levels. Certainly oil would be expected at levels higher than the base Cretaceous unconformity (Jc).

The dark grey shales of lowermost Cretaceous age which were deposited across the base Cretaceous unconformity are the best hope for a matured oil source rock.

Several other highs exist on trend with Prospect W91-14-G.

Prospect W91-14-H

Prospect W91-14-H lies in the southwest corner of the block. It has been called the Camden Prospect by prior permit holder, Woodside. Several vintages of seismic data have been shot over the prospect. The most detailed maps have been made by the Woodside group and the general outline of the prospect has been taken from their early work.

Two lines, Woodside 76-1689 (Plate 39A) and BHP HBW87-206 (Plate 46A), are used to illustrate this prospect. As can be seen from these lines, the main horst block is cut by several faults, some of which extend into and through the base Cretaceous unconformity, and hence could be sealing faults for Tithonian age sand reservoirs draped across the prospect (Plates 39B, 46B).

Secondary targets might exist in Campanian turbidite sands, and in the deep Jurassic sands below the 'breakup' unconformity.

Prospect W91-14-H lies about 40 kilometres due east of the Caswell feature, which already has been shown to have oil shows in Cretaceous sands. It is probably more likely to be oil-prone in this location than Prospects W91-14-D and W91-14-E, and the occurrence of good potential secondary targets in the Campanian makes it one of the best prospects in the block. It lies in about 260 metres of water. It is quite clear that this region needs to be remapped before drilling as each succeeding permit operator has mapped this feature differently. However, a good grid of old data exists that could be used for this purpose before expensive shooting becomes necessary.

Leads W91-14-I, W91-14-J and W91-14-K

Leads W91-14-I and W91-14-J lie in the southeast corner of the block. Seahawk Seismic Line S85-54 (Plate 47A) illustrates these leads. Both leads are small structural closures at the 'breakup' unconformity (Jb) level (Plate 47B). Control in this region comes from the Yampi-No.1 well which has an interesting oil show in Jurassic (Callovian) sandstones. Good reservoir sands are predicted to exist in Callovian (beneath Jb), Tithonian (beneath Jc) and younger (Lower Cretaceous) levels. In addition, Campanian turbidite sands can be inferred from mound-like features on the seismic.

Lead W91-14-K lies about 5 kilometres southwest of Browse Island. Seahawk Seismic Line S83-05 (Plate 36A) illustrates the nature of Lead W91-14-K (Plate 36B) which sits in a similar structural setting to Leads W91-14-I and W91-14-J.

Additional prospects may exist in stratigraphic traps in lower Cretaceous sands. Seahawk Seismic Line S85-52 (Plate 48A) suggests that at least two lower Cretaceous clastic sand wedges built out from the 'Kimberley' shore line (Plate 48B). Oil could be trapped in these wedges, either as simple stratigraphic traps or as combination traps with some of the faults shown as seals.

9.2.3 Area W91-15, Prospects and Leads

(J.C. Conolly)

9.2.3.1 Geology of Area W91-15

The geology of this Area W91-15 is very similar to that described for Area W91-14 except that this block, in its eastern portion, shallows onto the Prudhoe Shelf.

The leads are shown on two general structure contour maps. These maps are drawn at the main unconformity level across the block. East of the Prudhoe Fault trend, the 'breakup' unconformity pinches out and the base Cretaceous unconformity surface Jc has been mapped.

Eleven seismic sections have been used to illustrate the major play types and leads in Area W91-15.

9.2.3.2 Lead Descriptions

Leads W91-15-A, W91-15-B and W91-15-C

Leads W91-15-A, W91-15-B and W91-15-C are illustrated by Seismic Lines M200-10, M200-13 and M200-15 respectively (Plates 50B, 51B, 52B, respectively). These leads are all associated with rollover into the major Prudhoe Fault zone (located approximately 5 kilometres east of the Heywood No.1 well and trending northeasterly along the margin of the Browse Basin). They have been mapped in considerable detail by Marathon as operator of WA-200-P in 1986 and 1987, and the seismic lines (Plates 50A, 51A, 52A) used to illustrate these leads were shot by Marathon in 1986.

Line M200-13 (Plate 51B) is a key seismic line and ties the leads to the Heywood No.1 well. The major targets are Neocomian to Tithonian sands in all three leads. Secondary targets may occur in middle Jurassic sandstones deposited on postulated talus slopes against the downthrown side of the Prudhoe Fault.

Fluorescence and live oil were noted to occur over the middle Jurassic, Callovian interval in Heywood No.1. Minor oil shows also occurred in the Neocomian and Tithonian sands in this well confirming the presence of potential oil source in the area.

Leads W91-15-A, W91-15-B and W91-15-C are considered to be excellent leads. They occur in water depths of about 100 metres and form a string of potential prospects that together could form an economic target.

Lead W91-15-D

Lead W91-15-D is illustrated by Seismic Line M200-27 (Plates 53A, 53B). It is formed by drape of Neocomian to Tithonian sands over the Prudhoe Fault zone block.

Early mapping of this region by Marathon suggests that the Prudhoe Fault bifurcates south of Lead D into two major faults. Lead W91-15-D would lie on the high block east of the westerly fault zone. The most likely potential source rocks would be Upper Jurassic marine shales (as for Leads W91-15-A, W91-15-B and W91-15-C), thought to lie in the oil window on this flank of the Browse Basin.

Lead W91-15-E

Lead W91-15-E lies in 200 metres of water and is illustrated by seismic line 74-1370 (Plates 57A, 57B).

It is controlled by an northeast-southwest fault and drape over a potential high horst block. The major targets would be Tithonian sands at the Jc (base Cretaceous) level and middle Jurassic sands at the Jb ('breakup' unconformity) level.

Potentially good oil source rocks occur in thick Upper Jurassic shales to the north and south of this feature making it an attractive target.

Campanian turbidite sands similar to those drilled in the Bassett No.1A well are also predicted to occur in this location and form a good secondary target.

Lead W91-15-F

Lead W91-15-F lies in 320 metres of water. It is illustrated by Seismic Line 76-1725 (Plates 56A, 56B). Lead W91-15-F is controlled by a major fault which extends from the Permian into the Tertiary sequence. Late Tertiary movement along the fault has created potential traps in Campanian turbidite sands and overlying Paleocene and Eocene sands. Deeper targets are Tithonian sands associated with the base Cretaceous unconformity and middle Jurassic sands associated with the 'breakup' unconformity.

An oil scum was noticed in the blender mud while drilling the Campanian turbidite sands in the nearby Bassett No.1A well. In this part of the deeper Browse Basin, the lower Cretaceous shales may lie within the oil window.

Leads W91-15-G and W91-15-H

Leads W91-15-G and W91-15-H are both areas where Campanian age turbidite sands may form stratigraphic traps.

These sands can be up to 200 metres in thickness (as at Caswell No.1 and No.2, and Basset No.1A) and are generally deposited as mound-like features, out in front of continental slope or outer shelf prograding shales.

Progradation of the sequence above the D horizon is in a northerly direction, along the axis of the deep Browse Basin. Seismic Lines 76-1725 and 74-1369 (Plates 56A, 56B) illustrate Lead W91-15-G and Seismic Lines 79-2276 and 84-2429 (Plates 58A, 58B) illustrate Lead W91-15-H.

Both mound and channel features occur in the lead areas. Detailed seismic will be required to properly delineate targets.

Recoverable reserves from a 200 metres thick turbidite mound with good porosities and permeabilities is potentially high. This, along with shallower drilling depths, makes this play one of the most attractive in the Browse Basin.

Lead W91-15-J

Lead W91-14-J is illustrated by Seismic Line 74-1378 (Plates 60A, 60B). It is a potential structural trap at the 'breakup' unconformity (Jb) and base Cretaceous unconformity (Jc) levels. Reservoirs would be Tithonian age sands beneath the Jc horizon and Middle Jurassic sands beneath the Jb horizon. The region needs more seismic as the 1974 data are generally of poor quality and it is extremely difficult to pick the deeper horizons accurately. Lead W91-15-J is situated close to potential upper Jurassic oil source rocks in deeper parts of the Browse Basin to the north.

Other structural targets should exist in this part of Area W91-15, but new seismic data are required before they can be defined. Large portions of this part of Area W91-15 cannot be accurately mapped with the present seismic data base.

Leads W91-15-I, W91-15-K and W91-15-L

Plate 15B illustrates the general structural geology of the southern half of Area W91-15 at the main unconformity surface (Jb to Jc). It is stressed that the age of the main unconformity surface transgresses time, becoming younger in a landward (eastwards) direction.

The main unconformity surface overlies Jurassic age sediment in the western portion of the block, then Permian (where the Jurassic sequence pinches out), and then basement (where the Permian pinches out) (Plates 55A, 55B).

No large structural closures or leads have been located except those that may be associated with the Rob Roy Fault zone.

One potential structural closure, Lead W91-15-K, has been illustrated by Seismic Line M200-44 (Plates 54A, 54B) across the Rob Roy Fault.

Lead K has potential closure on the upthrown side of the Rob Roy Fault.

The main reservoir targets are predicted to be lower Cretaceous and Jurassic sands, with secondary targets in deeper Permian sediments.

The structure requires migration of oil from Jurassic source rocks to the west.

Similar migration of oil is required to charge the pinchout plays that should occur along the flank of the main Browse Basin.

The most attractive of these plays would occur in Tithonian age quartz sands lying beneath the base Cretaceous unconformity surface (Jc). This zone of potential pinchout plays is illustrated on Seismic Line M200-44 (Plate 54B) as Lead L, and on Seismic Line 74-1393 (Plate 59A) as Lead W91-15-I (Plates 59B).

These plays are considered to be high risk since little is known about bottom and top seals, as well as oil source.

9.2.4 Area W91-16, Prospects and Leads

(J.C. Conolly)

9.2.4.1 Geology of Area W91-16

Area W91-16 lies south of Areas W91-14 and W91-15, and to the east of WA-212-P, operated by Ampol Exploration.

It sits on the updip edge of the Browse Basin. One well, Yampi No.1, drilled by BOC of Australia Ltd in 1973, is the only well drilled in this block.

The Yampi No.1 well had encouraging oil shows in a core cut in Middle Jurassic sandstones beneath the 'breakup' unconformity (Jb). A drilling break with minor mud gas shows also occurred in Aptian sands at 1865 metres. These sands belong to a coarsening-upward sequence of deltaic sands capped by marine shales with log porosities of 17 to 20 %. They are 50 metres thick and would make a good reservoir target.

A younger Paleocene to Campanian deltaic complex of sands, containing coal in its upper part was also intersected in the Yampi No.1 well between 1789 and 1210 metres. These sands can be seen to be prograding in a general northwestwards direction on Seismic Line S83-31 (Plates 62A, 62B). They have log porosities of 23 to 36 % in the Yampi No.1 well.

Three thick (80 to 120 metres) sand zones occur below the base Cretaceous (Jc) unconformity reflector between depths of 2570 and 3050 metres in the Yampi No.1 well. These have a Tithonian age. The two lower zones are coarsening-upwards deltaic sequences and the upper zone may represent a shallow marine facies. All these sands contain zones described as friable quartz sands which should have good porosities and permeabilities. Each sand is capped by a sealing shaly interval. As a group, they represent an excellent series of reservoir targets.

There is little doubt that good reservoirs can be predicted to occur in the western portion of Area W91-16, as shown by the geology on the Yampi No.1 well.

The potential of an oil source has also been shown to exist from the occurrence of residual oil extracted from the core below the 'breakup' unconformity in the Yampi No.1 well. The most obvious source rocks for this oil would be Upper to Middle Jurassic shales which should lie within the oil window in this easterly portion of the Browse Basin. Other potential source rocks could be underlying Triassic or overlying Lower Cretaceous shales.

Seismic shot by Seahawk Oil in 1983 and by Santos in 1985, subsequent to the Woodside Group relinquishment of acreage, forms the base for structural mapping in the Yampi region of Area W91-16.

A generalised structure map based on the work done by both the Seahawk, Santos and Woodside has been used to illustrate the location of potential leads in Area W91-16. This map (Plate 16A, 16B) is contoured at the 'breakup' unconformity surface (Jb) to a point to the east where the Jb reflection pinches out and merges with another major unconformity surface. This surface can be closely correlated to the base Cretaceous unconformity (Jc). It is a major erosional surface east of the Jb pinchout, cutting through older, tilted and folded Triassic and Permian rocks which, in turn, lap onto Precambrian basement further eastwards as shown on Line 74-1411 (Plates 69A, 69B).

The eastern two thirds of Area W91-16 lies in the zone east of the Jb pinchout, and is regarded as less prospective than the western area near the Yampi No.1 well.

The most obvious lower risk play occurs in the western one third of Area W91-16 where structural and stratigraphic leads are located updip from the Yampi oil show. These leads are briefly described in the following section.

9.2.4.2 Lead Descriptions

Lead W91-16-A

Seismic Line S83-32 (Plates 61A, 61B) illustrates Lead W91-16-A, which lies 8 kilometres southwest of and updip of the Yampi No.1 well in water depths of about 80 metres. Lead W91-16-A is a simple fault-controlled structural high with potential structural closure at the 'breakup' unconformity (Jb) and the base Cretaceous unconformity (Jc). Closure may also exist at deeper top Triassic and top Permian levels. Tithonian age sands sealed by overlying Lower Cretaceous shales form the main target at the Jc level, whereas Middle Jurassic sands sealed by Upper Jurassic shales form the target at the Jb level. Depths to these targets will be slightly shallower than those at the Yampi No.1 well, between about 2300 and 3000 metres. The area of closure of this lead at these levels can only be properly defined with more seismic. However, all the leads described here near the Yampi No.1 well are relatively small in size (2 to 6 square kilometres).

The economics of this play will depend largely on finding several of these fields and/or finding more than one pay zone. The drilling depths and shallow depth of water should make drilling and completion costs less expensive than elsewhere in the Browse Basin.

Lead W91-16-B

Lead W91-16-B is illustrated by Seismic Line F85-60 (Plates 65A, 65B) which ties to the Yampi No.1 well. It is located 10 kilometres southeast and updip from the Yampi No.1 well. Closure is predicted to exist at the 'breakup' unconformity (Jb) and below, although some closure may exist at the base Cretaceous level (Jc). The reservoirs and seals will be similar to those at Lead W91-16-A.

Closure is controlled by a major north-south oriented fault which is intersected by the east-west Yampi fault southeast of Lead W91-16-B. Secondary targets may exist in Triassic sands.

Lead W91-16-C

Seismic Line F85-43 (Plate 64A) illustrates Lead W91-16-C (Plate 64B). This lead is a simple structural rollover controlled by deeper faulting in the Triassic-Permian sequence. Structural targets may occur at the base Cretaceous (Jc), 'breakup' unconformity (Jb) and top Triassic levels, with the major targets being the same reservoir sands as intersected by the Yampi No.1 well.

An additional stratigraphic play may be intersected by a well at this location. These would be Campanian-age turbidite sands sealed by an envelope of marine shale. The progradation of these sediments can be traced from the Caswell No.1 and No.2 wells northwards along the axis of the main Browse Basin. Seismic Line F85-43 shows progradation of foresets of this age in a general northeasterly direction with the formation of possible mounded turbidites 'out in front' of this progradation trend. Some of the major faults in the Yampi No.1 well region extend upwards through the Cretaceous section (see Seismic Line F85-60 (Plates 65A, 65B)). These could have acted as a conduit for Upper Jurassic oil to migrate upwards into shallower sands.

Leads W91-16-D, W91-16-F and W91-16-G

Seismic Line F85-61 (Plates 66A, 66B) illustrates Leads W91-16-D, W91-16-F and W91-16-G. Lead W19-16-D is similar in many respects to Lead W91-16-C, and Leads W91-16-F and W91-16-G are associated with the east-west Yampi fault. Lead W91-16-G is similar to Lead W91-16-A and sits on the upthrown side of the Yampi fault, while Lead W91-16-F is formed by rollover on the downthrown side of the Yampi fault.

The major reservoir targets are Tithonian age sands at the base Cretaceous (Jc) level and Middle Jurassic sands at the 'breakup' unconformity level (Jb). A potential Triassic pinchout trap occurs as a secondary target at Lead W91-16-D. Triassic and deeper Permian targets form secondary targets at Leads W91-16-F and W91-16-G. All leads are in relatively shallow water (100 metres) and updip from the Yampi No.1 oil show. Once again, the potential structural closures are relatively small (2 to 6 square kilometres), but to offset this there are several potential pay zones.

Lead W91-16-H

Seismic Line 74-1406 (Plates 68A, 68B) illustrates Lead W91-16-H. Lead W91-16-H is a closure against a fault that occurs close to the pinchout of the 'breakup' unconformity surface (Jb) against older Permian or Precambrian basement to the southeast.

As for the other leads, the major reservoirs should be sands underlying the sealing shales at the Jb and Jc unconformity levels. Lead W91-16-H lies in 93 metres of water and is located 28 kilometres southeast and updip from the Yampi No.1 well.

Lead W91-16-I

Seismic Line 71-672 (Plates 67A, 67B) illustrates Lead W91-16-I. Lead W91-16-I is located about 40 kilometres northwest and updip from the Yampi No.1 well. Closure at Lead W91-16-I is controlled by an easterly dipping fault. The major targets will be reservoirs at the Jb and Jc levels.

Potential pinchout plays occur along the eastern margin of the Browse Basin as described in Area W91-15 to the north, and Area W91-17 to the south. Some of these leads are enhanced by faulting. Others are simple pinchout stratigraphic traps such as those illustrated by Seismic Lines 74-1411 (Plates 69A, 69B), 71-672 (Plates 67A, 67B) and F85-43 (Plates 63A, 63B).

Structural leads also occur at Permian levels at drillable depths along the flank of the Browse Basin in Area W91-16. Little is known about the hydrocarbon potential of the Permian sequence. The Yampi No.1 well intersects a sequence of interbedded sandstones, siltstones and shales, olive gray in colour, which are thought to be overmature for oil. In general, the Permian sequences are gently folded, faulted and tilted. The Permian faults trend northwest-southeast. In some instances, the imprint of these faults can be seen in the overlying sediment (Yampi fault).

Large Permian features remain to be drilled, probably in combination with other targets.

9.2.5 Area W91-17, Prospects and Leads

(B.G. West)

9.2.5.1 Bathymetry

Area W91-17 lies to the south of Area W91-16 and to the southeast of permit WA-212-P, operated by Ampol

Exploration. The block is located entirely on the Leveque Shelf, in water depths of between 50 and 100 metres.

9.2.5.2 Geology of Area W91-17

Seismic data ranges from 1969 vintage to 1985. However, most of the pre-1985 data are of poor quality due in part to the effects on the data of the thick section of Tertiary carbonates. Seismic coverage varies from 4 kilometres x 4 kilometres in the area around Leveque No.1 in the southwest, to more than 20 kilometres x 20 kilometres over more than half of the area. The eastern two thirds of the block is only very sparsely covered with pre-1975 data.

A southwest-northeast trending strike line, and a northwest-southeast trending dip line were constructed to show general regional trends and stratigraphic relationships. The strike line comprises part of Lines 85LM-13, 85LM-26, 85LM-54 and 85LM-32, and the dip line, part of Lines 85LM-51, 74-1434, 74-1397 and 74-1396.

Two wells have been drilled in Area W91-17. Leveque No.1 in the southwestern part of the block reached a total depth of 899.5 metres after intersecting what was interpreted to be Precambrian basement at a depth of 895.8 metres. Adele Island No.1 in the east of the block reached a total depth of just over 700 metres in the Late Jurassic.

The pre-Jurassic sequence appears to wedge out before coming up onto the Leveque Shelf, and the pre-breakup Jurassic sequence (Jb) thins rapidly between basement and the base Cretaceous unconformity (Jc) in a southeasterly direction. Plate 17 is a structure map at the Jb and/or basement level, showing the general direction of thinning and shallowing of the sequence. A number of broad, east-west trending faults cut across the block, and step down to the north. These are believed to be associated with the edge of the Leveque Shelf.

The rapid thinning and shallowing of pre-Cretaceous sediments against inferred basement, and the lack of good seismic data makes the identification of leads very difficult and subjective. However, we believe there may be some potential for pinchout plays, particularly if they are enhanced by faulting. In addition, the source rock data indicate the Jurassic sequence has the potential to source areas updip to the basin margins.

9.2.5.3 Lead Descriptions

Leads W91-17-A, W91-17-B, W91-17-C, W91-17-D, W91-17-E

Seismic Lines 85LM-13 (Plates 70A, 70B) (Leads W91-17-A and W91-17-B), 85LM-26 (Plates 70A, 70B) (Lead W91-17-C), 85LM-32 (Plates 71A, 71B) (Lead W91-17-D) and 74-1397 (Plates 73A, 73B) (Lead W-91-17-E) demonstrate the potential for Jurassic pinchouts, enhanced by updip faulting. Seismic Lines 85LM-51 and 74-1434 (Plates 72A, 72B) are north of the Jb pinchout. The Jurassic sediments are more likely to be fluvio-deltaic or marginal marine sands, with good porsity and permeability. The overlying Cretaceous sediments are likely to be marginal marine silts, with some interbedded shales and carbonates, which may downgrade its seal integrity.

Leads W91-17-1 to 3

Several large (50 to 200 square kilometres) fault controlled, anticlinal features were mapped at the Jb level by the previous permittee, however seismic control is very limited (10 to 20 kilometre grid), and more detailed seismic would be required to better define these structures (Plate 17).

Potential leads in Area W91-17 are more than likely going to be Jurassic pinchouts enhanced by faulting. These features will require detailed seismic mapping to identify valid traps. If such structures occur, there is some potential that they may have trapped liquid hydrocarbons that have migrated updip from the central basin area.

APPENDIX 1

DETAILED SUMMARY OF EXPLORATION WELLS

V. Vuckovic, S. Miyazaki and P. Jung

Information from 26 wells is summarised in this Appendix. Basic drilling data, pore pressure data, reservoir data and potential, and hydrocarbon indications and tests from well completions reports are prepared for each well. A lithological column and pore pressure plot has been prepared for most wells. Composite well logs for each well are included in this package.

1. DRILLING SUMMARIES AND PORE PRESSURE EVALUATION

(V. Vuckovic, P. Jung)

Pore pressures in each well were evaluated by indirect methods based on various parameters measured during drilling and hole surveys ("d" exponent, gas readings, shale densities), and direct methods based on formation pressure measurement during RFT and production testing. Although the evaluation of pore pressures by indirect methods is subjective, it should provide sufficient definition of the pressure regime to allow safe drilling in the area.

Normal pore pressure at depth is usually defined as the hydrostatic pressure exerted by a column of water from that depth to the surface, and is a function of formation water density. Therefore, normal formation pressure can only be maintained if a sufficiently permeable pathway to surface exists.

The normal pressure gradient generally varies between 0.433 psi/feet for fresh water (1.00 specific gravity) and 0.465 psi/feet for salt water (1.07 specific gravity). Pore pressures in excess of these values are considered abnormal.

There are numerous possible causes of over pressured regimes in geological formations. These include hydrocarbon generation, non-equilibrium compaction, fluid migration and diagenetic effects. Sometimes formation pressures higher than hydrostatic are caused by differential effects; that is, low density gas on top of a normally pressured water column is called abnormal pressures. However, it is doubtful whether this is correct, as the system is basically under a hydrostatic regime. The over pressures caused by differential effects are limited. One metre of 0.1 specific gravity gas on top of a normally pressured water column (1.0 specific gravity) would result in over pressure of only 1.28 psi. Over pressures of 2000 to 3000 psi (which are not uncommon in over pressured formations) would require a gas column of 1562 to 2343 metres if it were to be caused by differential effects alone.

Four of the 26 wells studied in the Browse Basin have penetrated over pressured formations.

Abbreviations used in Appendix 1 are:

"	inches
bbl/mmcf	barrels per million cubic feet
C1	methane
C2	ethane
C3	propane
C4	butane
C5	pentane
C.C.L.	casing collar locator
C.M.C.	sodium carboxymethylcellulose
CNL	Schlumberger's neutron porosity log
FDC	Schlumberger's formation density log
FIT	formation interval tester
GOR	gas/oil ratio
K.C.L.	potassium chloride
L.C.M.	lost circulation material
m	metres
mmcf/d	million cubic feet per day
ppm	parts per million
psi	pounds per square inch
psia	pounds per square inch absolute
R.F.T.	repeat formation tester
s.g.	specific gravity
SP log	spontaneous potential log
TD	total depth

1.1a Adele Island No.1

General well data:

Operator - Oberon Oil Pty Ltd
Location - 15°30'39''S ;123°09'20''E
Elevation - Ground 4.0m above sea level.
Kelly bushing 3.0m above ground level.
Date Spudded - 29 / 07 / 1982
Rig Released - 21 / 08 / 1982
Total Depth - 789.5m
Well Status - Plugged and abandoned

Well objective:

Adele Island No.1 was drilled to test a possible closed structure centered on Adele Island. No seismic was recorded over the island due to tides and reefs. The presence of a possible structure was based on the seismic data surrounding the island.

Hole sizes:

17 1/2" - from ground level to 36.5m
12 1/4" - from 36.5m to 301.1m
8 1/2" - from 301.1m to 789.5m

Casing:

13 3/8" - from surface to 36m
9 5/8" - from surface to 299m

Drilling summary:

The well was programmed for a depth of 1066 metres but was plugged and abandoned at 789.5 metres in quartzitic basement. No hole problems were encountered during drilling. The mud used was sea water and gel with occasional caustic. Average mud weight was 1.05 specific gravity.

Formation integrity:

A formation integrity test was not performed.

Pore pressures:

The entire hole section was normally pressured.

1.1b. Ashmore Reef No.1

General well data:

Operator - B.O.C. of Australia Ltd
Location - 12°10'49 07''S ;123°05'10.60''E
Elevation - Sea floor - +38.7m
Kelly bushing - -10.0m
Date Spudded - 16 / 10 / 1967
Rig Released - 02 / 04 / 1968
Total Depth - 3915m
Well Status - Plugged and capped

Well objective:

Stratigraphic test of the sedimentary section on the Sahul Shelf region of the Australian Continental Shelf.

Hole sizes:

36" - 102.7m
26" - 102.7m to 309.4m
17 1/2" - 309.4m to 1112.5m
12 1/4" - 1112.5m to 2491.7m
8 1/2" - 2491.7m to 3915.0m

Casing:

30" - Shoe at 101.2m
20" - Shoe at 300.2m
13 3/8" - Shoe at 1094.0m
9 5/8" - Shoe at 2481 1m

Drilling summary:

The 36" hole was drilled using salt water. Prior to running casing, the hole was filled with low density (1.04 specific gravity) and high viscosity slugs containing L.C.M.

Drilling of 26" hole commenced using low density high viscosity fresh water mud treated with L.C.M. Complete loss of circulation was experienced, despite placement of several cement plugs, and drilling continued blind with sea water to 20" casing setting depth.

In the 17 1/2" hole section, drilling continued using mud with high concentrations of L.C.M., but continuous losses occurred of up to 120 barrels per hour. Sporadic mud losses of up to 150 barrels per hour continued in the 12 1/2" hole section, particularly while tripping. Periodically, the hole required resting for up to six hours, after which losses stopped.

No lost circulation occurred during the drilling of the 8 1/2" hole. An oil emulsion mud was used throughout this section.

Formation integrity:

Not available

Pore pressures:

The formations in Ashmore Reef No.1 are normally pressured.

1.1c Asterias No.1

General well data:

Operator - BHP Petroleum Pty Ltd
Location - 13°09'08.3''S ; 124°07'12.0''E
Elevation - Sea floor - +194.4m
Kelly bushing - -17.6m
Date Spudded - 14 / 06 / 1987
Rig Released - 15 / 09 / 1987
Total Depth - 4402m
Well Status - Plugged and abandoned; oil and gas shows

Well objective:

Early Berriasian sandstone at and beneath the near base Cretaceous disconformity.

Hole sizes:

36" - 248m
26" - 248m to 472m
17 1/2" - 472 to 1607m
12 1/4" - 1350m to 2531m (side track)
8 1/2" - 2531m to 4001m
6" - 4001m to 4402m

Casing:

30" - Shoe at 248m
20" - Shoe at 462m
13 3/8" - Shoe at 1342m
9 5/8" - Shoe at 2521m
7" liner - Shoe at 4001m

Drilling summary:

The hole was drilled to 1086 metres with good returns and no hole problems. From 1086 to 1576 metres, hole sticking became a problem. At 1576 metres, total circulation was lost with the pipe stuck in hole. The drill string was cut and recovered from 1387 metres. A cement plug was set with the top at 1350 metres and 13 3/8" casing was run and cemented at 1342 metres. A sidetracked 12 1/4" hole was drilled to 2217 metres. In this section, losses occurred from 1627 to 1767 metres where 70 to 80 % returns were obtained.

Drilling continued to 4332 metres, where an 8 barrel kick was taken. The mud was weighted to 1.3 specific gravity and the well killed. Drilling proceeded to total depth without further problems.

Formation integrity:

2531m - 1.47 s.g. leak off
4013m - 1.70 s.g. leak off

Pore pressures:

All available pore pressure evaluation parameters and direct RFT pressure measurements indicate a normal pore pressure regime from surface to TD. The gas kick at 4332 metres, which required 1.3 specific gravity mud to be circulated out of the hole, appears to be due to a differential density effect (low density gas or oil on top of a normally pressured water column) rather than abnormally pressured formation.

RFT Summary:	3415m	4966.2psia	1.02s.g.
	3434m	4991.8psia	1.02s.g.
	3458m	5023.5psia	1.02s.g.
	3484m	5059.6psia	1.02s.g.
	3651m	5420.0psia	1.05s.g.
	3716m	5400.0psia	1.02s.g.

1.1d Barcoo No.1

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 15°20'37 00''S ;120°38'12.20''E
Elevation - Sea floor - +720.0m
Kelly bushing - -11.0m
Date Spudded - 14 / 12 / 1979
Rig Released - 12 / 07 / 1980
Total Depth - 5109m
Well Status - Plugged and abandoned; dry hole.

Well objective:

The primary objectives were sandstones of Late Triassic and Early-Middle Jurassic age. A secondary objective consisted of sandstones of possible Late Jurassic age underlying the Jc seismic event.

Hole sizes:

36" - 772m
26" - 772m to 1125m
14 3/4" - 1125 to 2252m opened up to 17 1/2"
17 1/2" - to 2240m
12 1/4" - 2240m to 3156m
8 1/2" - 3156m to 4212m
6" - 4212m to 5109m

Casing:

30" - Shoe at 765m
20" - Shoe at 1111m
13 3/8" - Shoe at 2226m
9 5/8" - Shoe at 3106m
7" liner - Shoe at 4202m

Drilling Summary:

The 36" and 26" holes were drilled with sea water and high viscosity bentonite slugs. No problems were encountered.

The 14 3/4" pilot hole was drilled with gel-sea water mud. Mud density was maintained at 1.08 specific gravity by mud dilution with sea water. Water loss was lowered by addition of C.M.C. at 1937 metres. The under-reamed 17 1/2" hole was treated with L.C.M. below 2076 metres because of circulation losses. While running and cementing 13 3/8" casing, only partial returns were achieved.

In the 12 1/4" hole section, the drilling fluid was converted to a brine polymer system. Mud losses occurred throughout the interval 2242 to 2650 metres. Mud weight was initially 1.2 specific gravity and chlorides were

124 000 ppm. When mud losses occurred, the mud weight was lowered to 1.15 specific gravity and chlorides to 100 000 ppm. L.C.M. pills were spotted with partial success. For maximum inhibition, the chlorides needed to be maintained above 120 000 ppm. Mud weights were increased to 1.18-1.19 specific gravity by addition of salt. With these mud weights, the mud losses continued at rates of up to 120 barrels per hour at 2635 metres where mud returns climbed to 1.21 specific gravity. The mud system was watered down to 1.18 specific gravity and the mud losses stopped from 2693 to 3065 metres. As the drilling continued, the mud weight once again reached 1.21 specific gravity, resulting in losses at 3065 metres of up to 1800 barrels per hour. The mud weight was reduced to 1.18 specific gravity and mica was added to the system, thus halting further losses. During a wiper trip at 3358 metres, the pipe become stuck. A free point indicator and C.C.L. logs indicated free pipe at 3219 metres. The pipe was backed off to 3216 metres and the hole sidetracked after 9 5/8" casing was set at 3106 metres.

In the 8 1/2" sidetracked hole section, lime and Premix were added to the mud system to improve the yield. Gel strengths and density were increased to 1.29 specific gravity to prevent caving. Loss of circulation occurred from 3892 to 4011 metres with 1.31 specific gravity mud in the hole. L.C.M. pills were spotted and the mud weight reduced to 1.27 specific gravity, giving partial returns. Mud losses continued periodically to 4212 metres, while a mud weight of 1.25 specific gravity was maintained. While checking a drilling break at 4020 metres, the pipe became stuck at 3997 metres, but was successfully recovered.

In the 6" hole section, the mud weight was reduced to 1.20 specific gravity by the addition of resinex. From 5054 metres, the mud weight was gradually increased to 1.29 specific gravity. Penetration rates in the 6" hole section were slow, but trouble free.

Formation integrity:

2226m - 1.4 s.g. leak off
3106m - 1.76 s.g. leak off
4202m - 1.39 s.g. leak off

Pore pressures:

The formations in Barcoo No.1 appear to be normally pressured. Five RFT tests performed between 3861 and 4114 metres gave a pressure gradient of 1.3737 psi per metre. One formation water sample was taken at 3861 metres. The formation pressure at this depth was 5482 psig or 1.0 specific gravity equivalent mud density. Formation pressures recorded at other depths were not available.

BARCOO 1

KB 11m

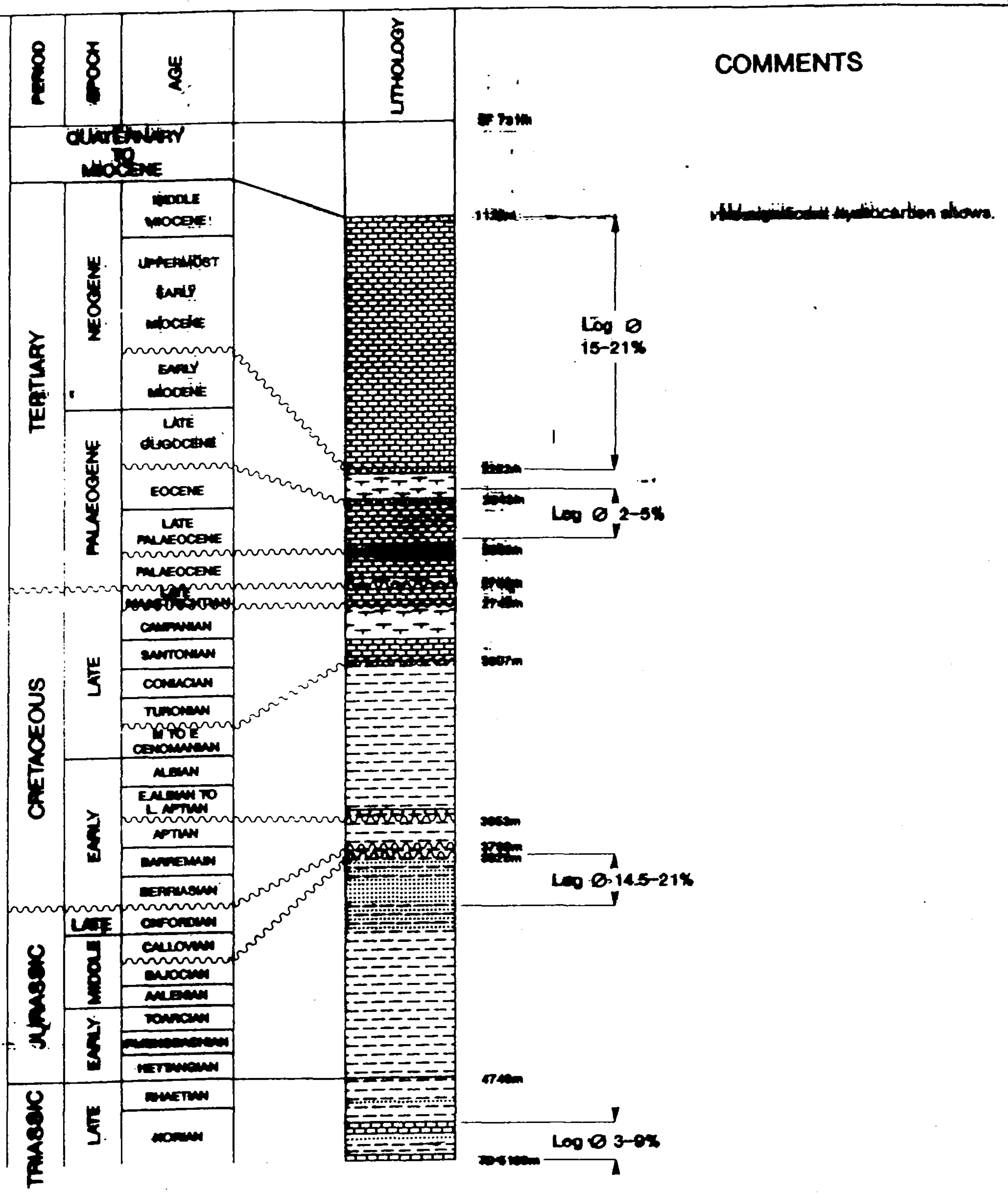
WD 720m

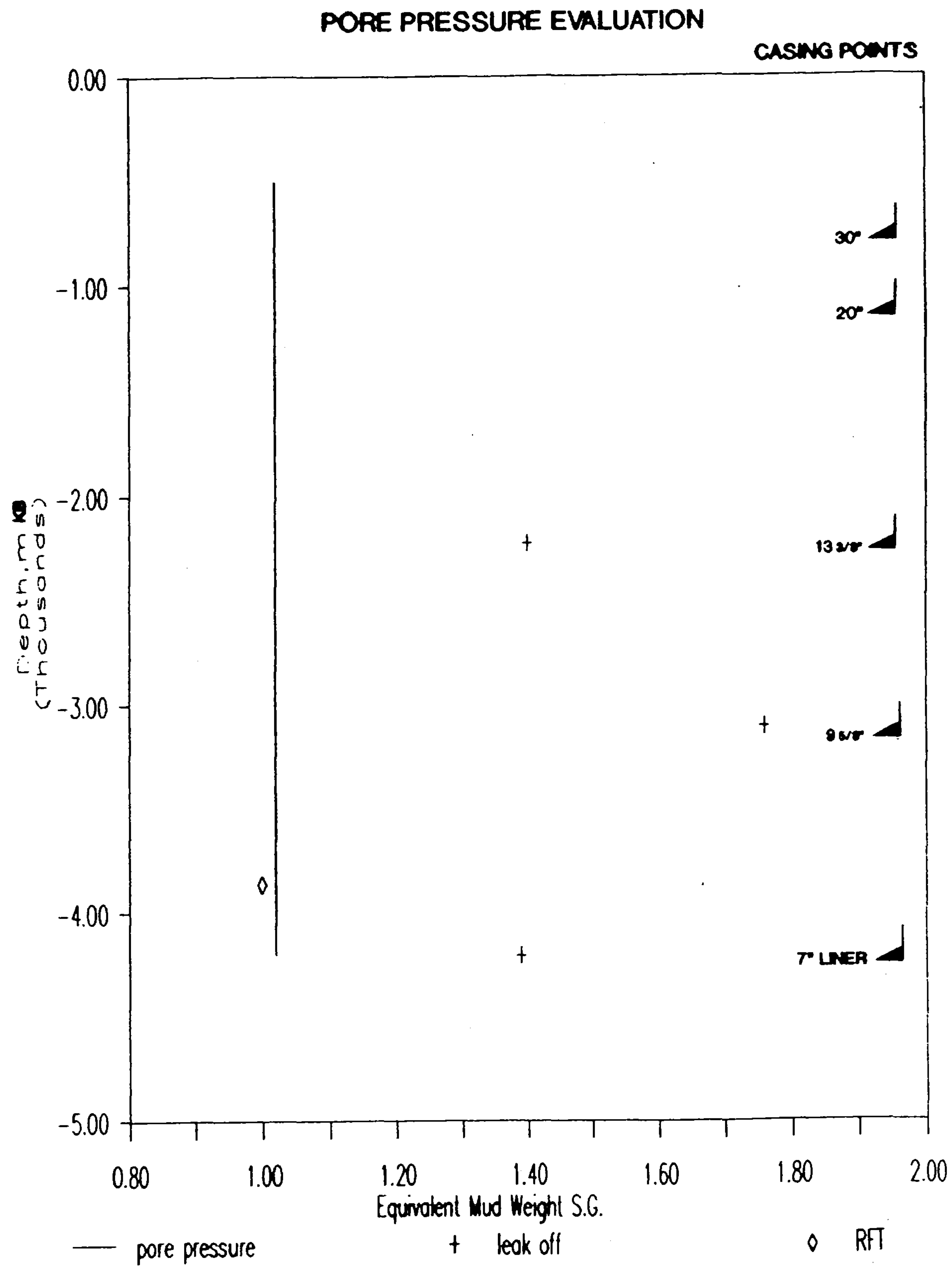
TD 5109m

STRUCTURE: Large, northeast-trending anticline.

OBJECTIVES: Early to Middle Jurassic sandstones.

COMMENTS: Predicted intra-Neocomian seismic marker proved to be 'Jb' breakup unconformity. Limited closure at 'Jb' level.





1.1e Bassett No.1A

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 13°18'41 70''S ;123°25'30.80''E
Elevation - Sea floor - +372.0m
Kelly bushing - -8.0m
Date Spudded - 19 / 06 / 1978
Rig Released - 28 / 07 / 1978
Total Depth - 2706m
Well Status - Plugged and abandoned; dry hole

Well objective:

To test the hydrocarbon potential of Maastrichtian/ Campanian sands on a large, faulted anticline in the central Browse Basin. Secondary objectives were Lower Tertiary sands.

Hole sizes:

36" - 416.0m
26" - 416.0m to 717.0m
17 1/2" - 717.0m to 1394.0m
12 1/4" - 1394.0m to 2050.0m
8 1/2" - 2050.0m to 2706.0m

Casing:

30" - Shoe at 406.0m
20" - Shoe at 701.0m
13 3/8" - Shoe at 1381.0m
9 5/8" - Shoe at 2038 0m

Drilling summary:

Bassett No.1 well was abandoned at depth of 943 metres because of mechanical difficulties. Bassett No.1A was spudded some 36.5 metres to the east of the Bassett No.1 location.

The 36" and 26" hole sections in Bassett No.1A were drilled with sea water and high viscosity bentonite slugs at connections without hole problems.

Drilling of the 17 1/2" hole started with sea water treated with prehydrated bentonite, but at 821 metres, complete loss of circulation necessitated a change back to sea water. The hole was flushed with high viscosity mud slugs at connections. Drilling continued with difficulties in the entire 17 1/2" hole section due to lost circulation in high porosity sandstone and carbonate formations. Losses were partially controlled by the setting of cement plugs.

The 12 1/4" hole section was drilled with a non-dispersed low solids sea water/polymer mud system. The mud density was kept below 1.07 specific gravity because of a low leak off value below the 13 3/8" casing shoe. The hole was drilled without difficulty to the 9 5/8" casing setting point.

The 8 1/2" hole was drilled to 2536 metres with a similar mud system to that used in the 12 1/4" hole, at which point the mud density was raised to 1.15 specific gravity due to tight hole conditions. This mud density was maintained to total depth. However, before a successful logging run could be made, the mud density had to be increased to 1.30 specific gravity.

Formation integrity:

1381.0m - 1.1 s.g. leak off
2038.0m - 1.42 s.g. leak off

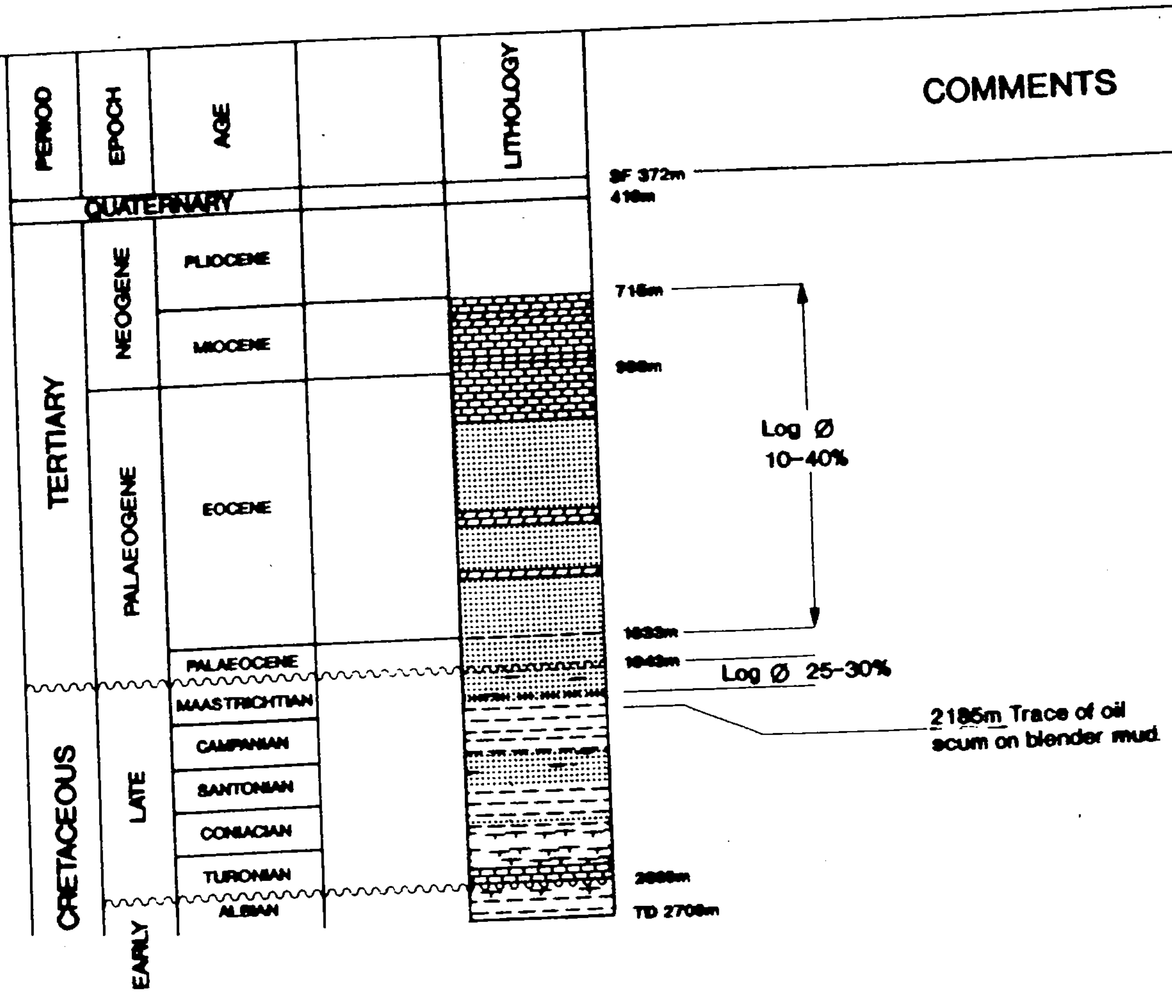
Pore pressures:

Formations in Bassett No.1 well appear to be normally pressured.

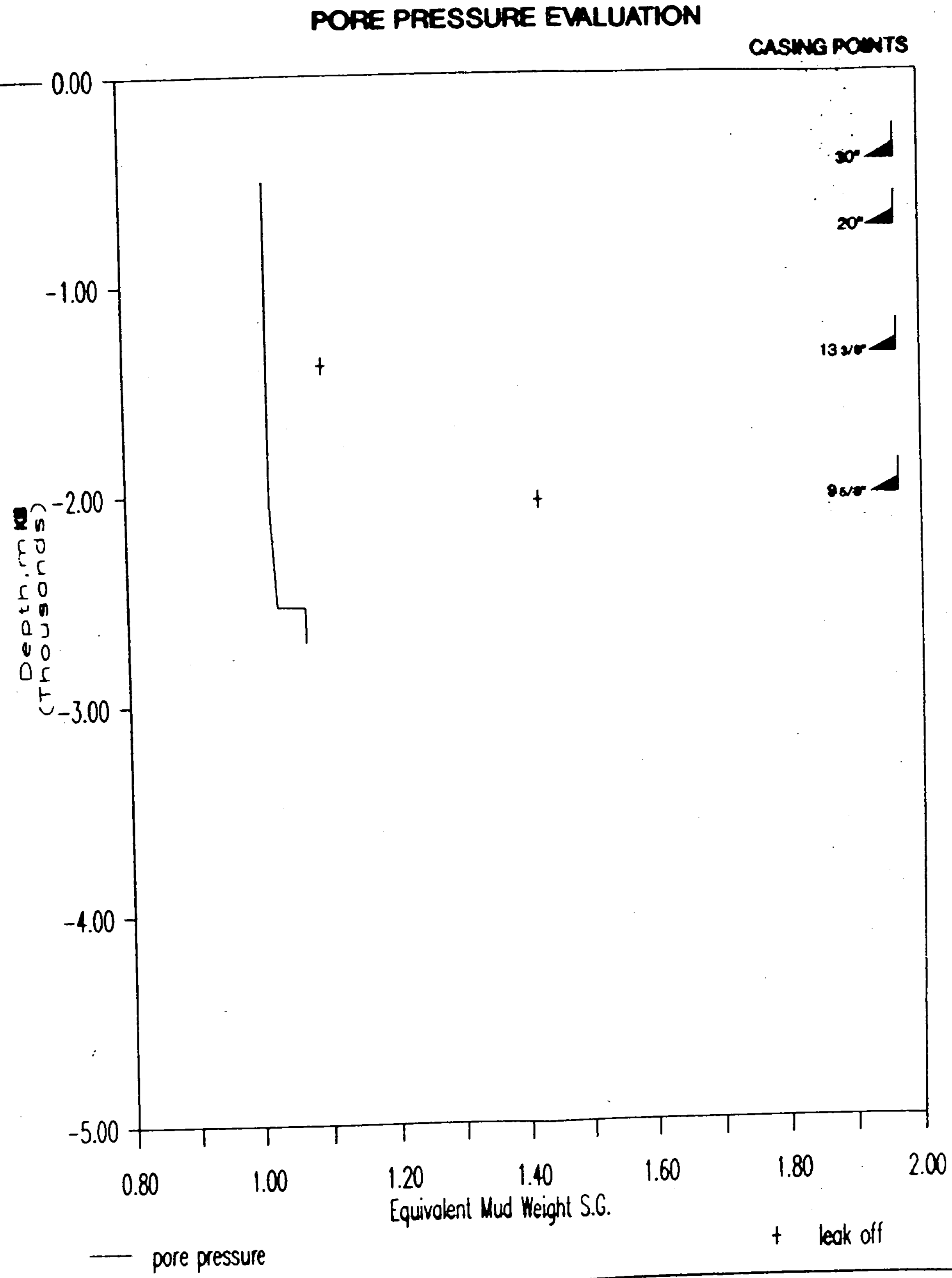
BASSETT 1A

KB 8.0m
WD 372m
TD 2706m

STRUCTURE: Faulted drape anticline.
OBJECTIVES: Maastrichtian/Campanian Sands.
COMMENTS: Basset 1 abandoned at 943m due to mechanical problems.



PORE PRESSURE EVALUATION



1.1f Brecknock No.1

General well data:

Operator - Woodside Offshore Petroleum Pty Ltd
Location - 14°26'13 07''S ;121°40'21.00''E
Elevation - Sea floor - +543.0m
Kelly bushing - -11.0m
Date Spudded - 31 / 07 / 1979
Rig Released - 12 / 12 / 1979
Total Depth - 4300m
Well Status - Plugged and abandoned; capable of gas production.

Well objective:

To test the Middle-Lower Jurassic and Triassic sandstones of the pre-breakup sequence, as encountered in the Scott Reef wells located to the north.

Hole sizes:

36" - 590m
26" - 590m to 930m
14 3/4" under-reamed to 17 1/2" - 930 to 2100m
12 1/4" - 2100m to 3687m
8 1/2" - 3687m to 4300m

Casing:

30" - Shoe at 590m
20" - Shoe at 911m
13 3/8" - Shoe at 2083m
9 5/8" - Shoe at 3631m
7" liner - Shoe at 4251m

Drilling summary:

The 36" and 26" holes were drilled with sea water and high viscosity bentonite slugs. The 14 3/4" and 17 1/2" holes were drilled with a light polymer mud of 1.03 specific gravity to 1075 metres, at which point severe mud losses occurred. Drilling continued with sea water and high viscosity L.C.M. to 2100 metres. When under-reaming the 14 3/4" hole, it was found that the hole was washed out and that only the interval 2062 to 2100 metres needed to be under-reamed.

In the 12 1/4" hole section, the mud system was displaced with a low solids polymer mud and drilling progressed without problems to 3687 metres in a predominantly limestone formation. Minor mud losses were experienced after a drilling break at 3000 metres and were treated with L.C.M. pills.

In the 8 1/2" hole section, the mud system was saturated with salt and the mud weight raised to 1.24 specific gravity. A series of drilling breaks necessitated constantly increasing the mud weight to a final figure of 1.35 specific gravity. Gas sands were penetrated in the interval 3840 to 3907 metres.

Formation integrity:

2083m - 1.19s.g. leak off

Pore pressures:

The formations in Brecknock No.1 are normally pressured to approximately 4120 metres. Below this depth, RFT pressure measurements indicate a sharp increase in pore pressure. This may be due to a thin bed of impermeable limestone at 4120 metres.

RFT summary:	4151.5m	7086.7psia	1.20s.g.
	4151.0m	7062.4psia	1.19s.g
	4125.0m	7059.3psia	1.20s.g.
	4093.0m	5974.2psia	1.02s.g.
	3973.5m	5797.0psia	1.02s.g.
	3963.0m	5781.0psia	1.02s.g.
	3949.5m	5762.7psia	1.02s.g.
	3915.0m	5715.9psia	1.02s.g.
	3893.5m	5697.6psia	1.02s.g.
	3886.0m	5695.8psia	1.03s.g.
	3879.0m	5694.5psia	1.03s.g.
	3855.0m	5688.2psia	1.04s.g.
	3845.5m	5683.4psia	1.04s.g.
	3835.5m	5677.2psia	1.04s.g.
	3873.0m	5690.5psia	1.03s.g.
	3862.0m	5686.1psia	1.03s.g.
	3855.0m	5685.2psia	1.04s.g.
	3867.0m	5688.6psia	1.03s.g.
	3836.0m	5676.0psia	1.04s.g.
	3879.0m	5692.4psia	1.03s.g.

Depths are relative to Mean Indian Springs Low Water (11 metres below rotary table).

Formation testing:

A production test was performed in the water saturated interval below the gas zone. The water bearing sand was perforated from 3971 to 3967 metres with 2 1/8" enerjets. The well flowed water at an average rate of 1.1 barrels per minute with traces of gas. The productivity index was calculated at 26.5 barrels per day psi. The production test in the gas zone was aborted because of mechanical difficulties.

BRECKNOCK 1

KB 11.0m

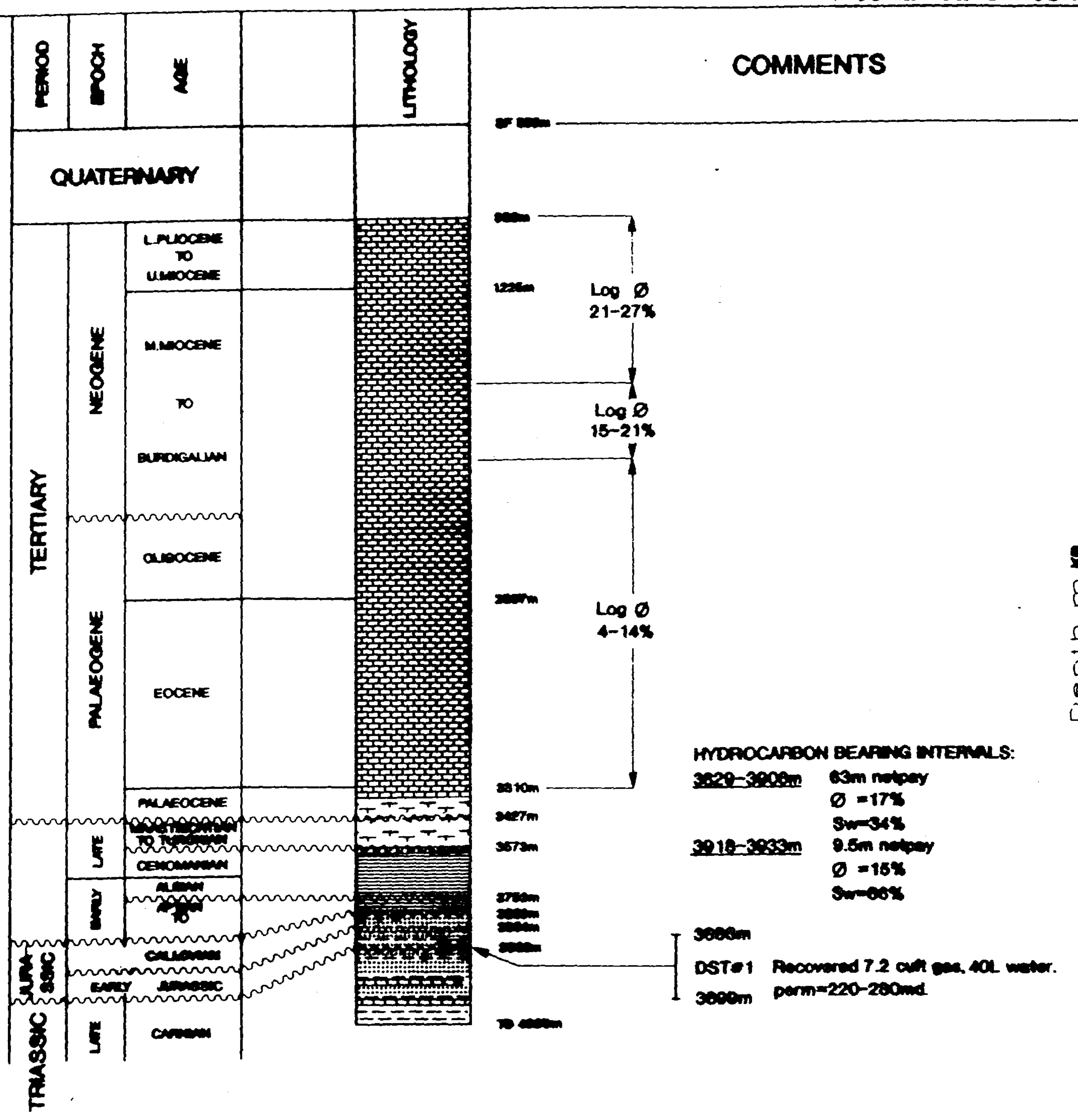
WD 543m

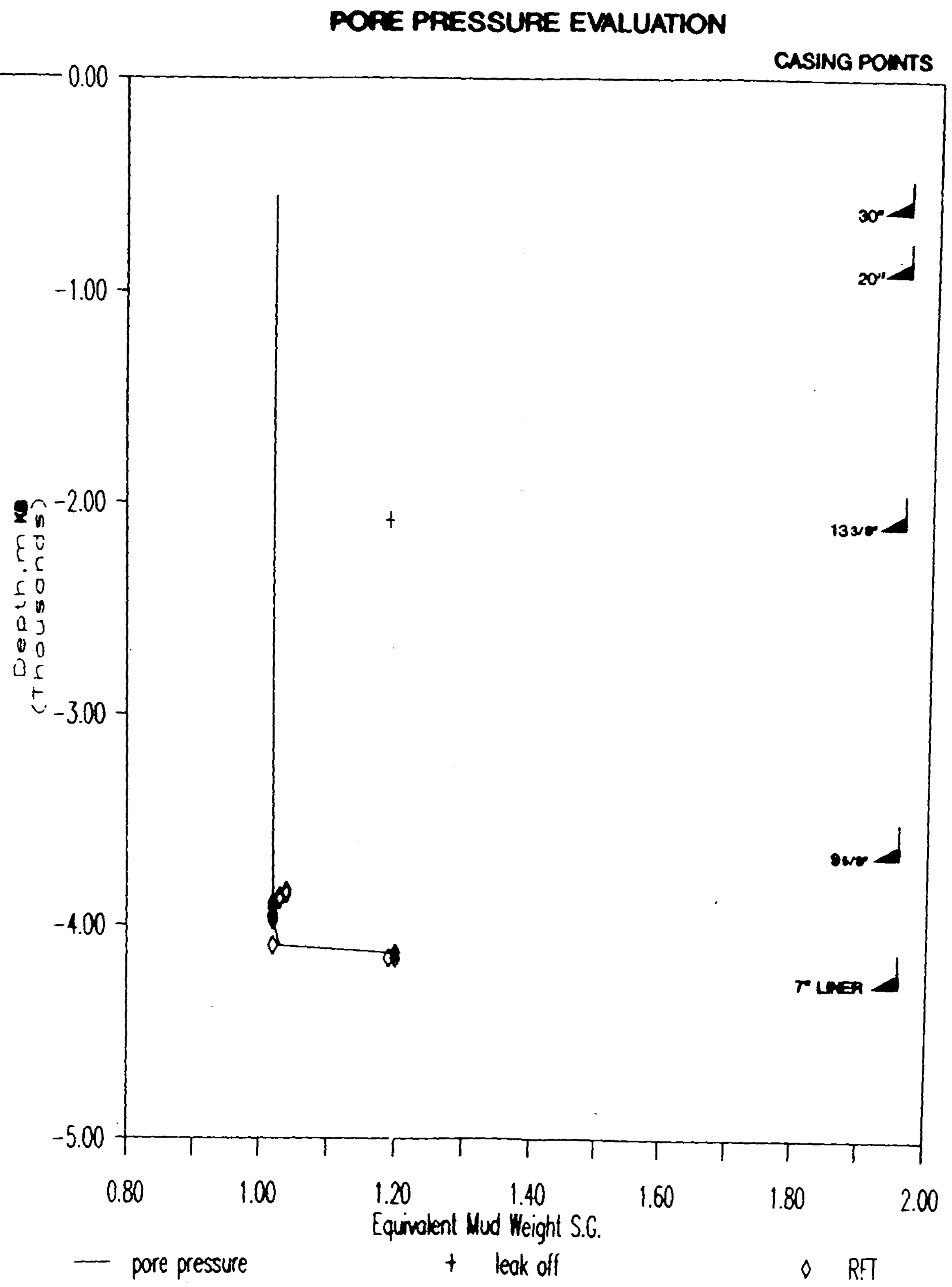
TD 4300m

STRUCTURE: Drape anticline.

OBJECTIVES: Lower to Middle Jurassic sandstones.

COMMENTS: Subeconomic and undeveloped gas/condensate discovery. Mechanical difficultes prevented production testing.





1.1g Brewster No.1A

General well data:

Operator - Woodside Offshore Petroleum Pty Ltd
Location - 13°54'49 34''S ;123°15'28.54''E
Elevation - Sea floor - +256.0m
Kelly bushing - -8.0m
Date Spudded - 23 / 05 / 1980
Rig Released - 19 / 12 / 1980
Total Depth - 4703m
Well Status - Suspended

Well objective:

To test a northeast-trending, low relief, anticlinal feature formed by the drape of post-breakup sediments over two convergent horsts of Middle-Late Jurassic age.

Hole sizes:

36" - 305m
26" - 305m to 636m
17 1/2" - 636 to 2420m
12 1/4" - 2420m to 3673m
8 1/2" - 3673m to 4220m
6" - 4220m to 4703m

Casing:

30" - Shoe at 299m
20" - Shoe at 624m
13 3/8" - Shoe at 2366m
9 5/8" - Shoe at 3658m
7" liner - Shoe at 4220m

Drilling summary:

The 36" and 26" holes were drilled with sea water and slugs of bentonite mud. The 17 1/2" hole was drilled with sea water Q-mix mud. Lost circulation occurred in the zone 2004 to 2420 metres. Mud density was maintained at 1.08 specific gravity.

The 12 1/4" hole was drilled with a brine polymer mud system. Mud weight was raised to 1.6 specific gravity to overcome shale problems. The same mud system was used in the 8 1/2" hole section. Severe circulation losses occurred in the interval 3895 to 4142 metres (mainly sandstone formation). To a lesser extent, losses occurred at 4252 metres and 4433 metres. At 4464 metres, the string became differentially stuck and had to be backed off. The attempts to recover the fish were unsuccessful and the hole had to be sidetracked from 3855 metres. Losses occurred in the sidetracked hole in the zone 4075 to 4121 metres and were treated with L.C.M. pills and by gradually decreasing the mud weight from 1.68 to 1.39 specific gravity.

The 6" hole section was drilled with a brine polymer system of low density. The density was gradually raised to 1.46 specific gravity due to high gas readings, but was complicated by intermittent circulation losses. Losses occurred at 4538 and 4563 metres in a sandstone/siltstone formation and were successfully treated with L.C.M. pills.

Formation integrity:

3658m - 1.88s.g. leak off
4225m - 1.56s.g. limit test

Pore pressures:

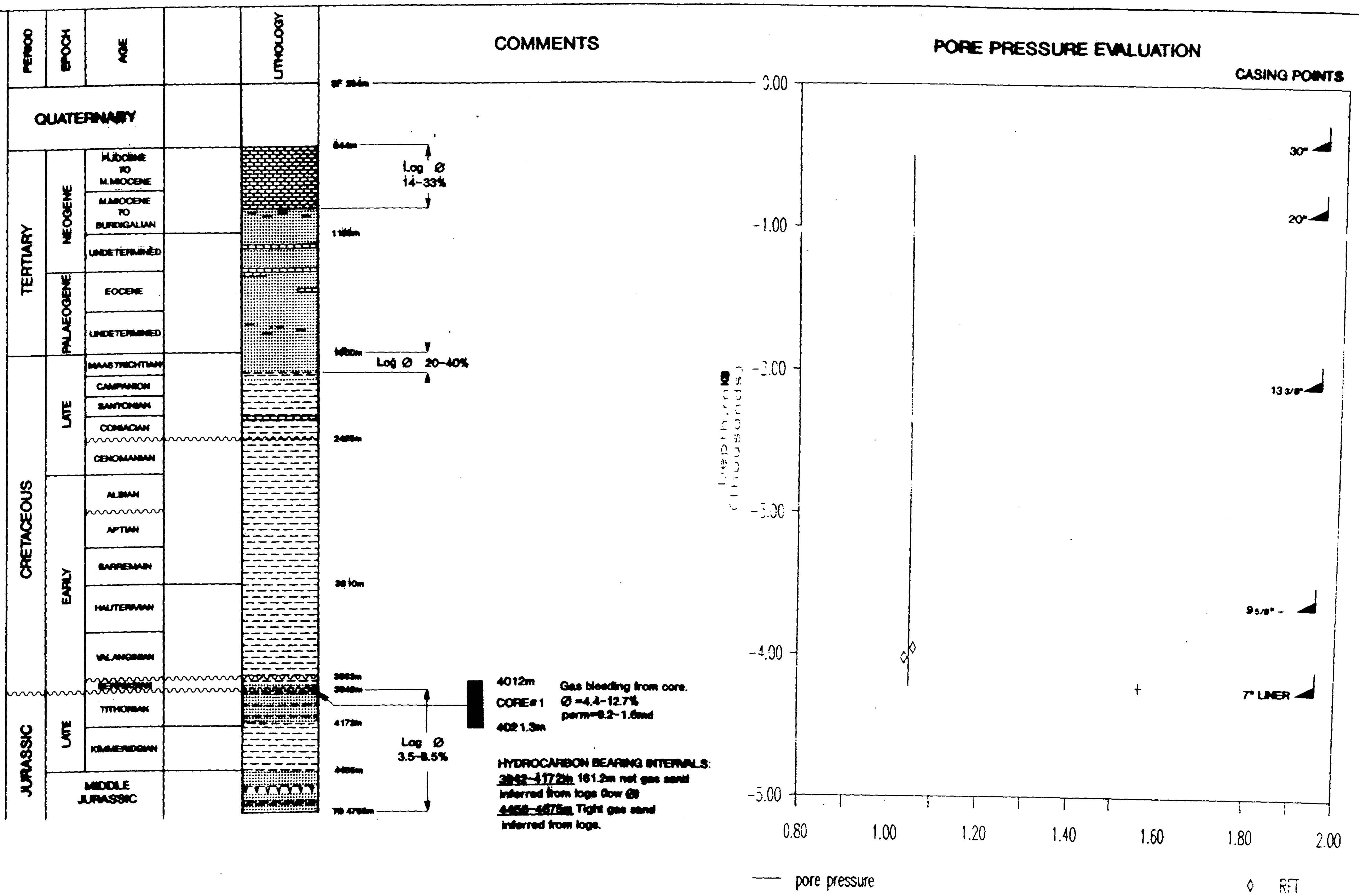
The formations in Brewster No.1A appear to be normally pressured.

RFT summary:	4023.0m	5959.0psi	1.04s.g.
	3955.0m	5940.0psi	1.06s.g.

BREWSTER 1A

KB 8.0m
WD 256m
TD 4703m

STRUCTURE: Drape anticline.
OBJECTIVES: Middle to Late Jurassic sandstones.
COMMENTS: Gas discovery inferred from logs. Tight reservoir.



1.1h Browse Island No.1

General well data:

Operator - Santos Ltd
Location - 14°06'45.2''S ;123°32'57.1''E
Elevation - Ground 2.9m above sea level
Rotary table 4.4m above sea level
Date Spudded - 15 / 05 / 1986
Rig Released - 27 / 05 / 1986
Total Depth - 405.5m
Well Status - Plugged and abandoned

Well Objective:

This shallow well was drilled to determine the thickness and interval velocity of the surface reef associated with Browse Island.

Hole sizes:

10 5/8" - Surface to 28.5m
6" - 28.5m to 405.5m

Casing:

12" conductor - Surface to 3.0m
8 5/8" - Surface to 18.7m

Drilling Summary:

The well was drilled with a 1.3 specific gravity salt water/gel/polymer mud system from surface to TD. Significant lost circulation and hole caving occurred from surface to 28.5 metres requiring spotting of four cement plugs.

Formation integrity:

Formation integrity tests were not performed.

Pore pressures:

As could be expected at such shallow depths, normal pore pressures were experienced throughout the entire hole section.

1.1i Buffon No.1

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 13°23'37.93''S ;122°10'59 62''E
Elevation - Sea floor - +533.0m
Rotary table - -10.36m
Date Spudded - 04 / 01 / 1980
Rig Released - 03 / 08 / 1980
Total Depth - 4787m
Well Status - Plugged and abandoned

Well objective:

Lower to Middle Jurassic and Triassic sandstones, sealed by Cretaceus claystones. The well was drilled to test a large anticlinal feature in the northern part of the Browse Basin, interpreted to be a high-relief fault block.

Hole sizes:

26" - 846m
17 1/2" - 846m to 1840m
12 1/4" - 1840m to 2905m
8 1/2" - 2727m to 3657m
6" - 3657m to 4787m

Casing:

30" - Jetted to 572m
20" - Shoe at 830m
13 3/8" - Shoe at 1827m
9 5/8" - Shoe at 2727m
7" liner - Shoe at 3642m
4 1/2" slotted liner - Shoe at 4192m

Drilling summary:

The well was drilled to 1840 metres (13 3/8" casing setting point) using 1.07 to 1.09 specific gravity sea water/gel mud with no problems. Drilling continued in the 12 1/4" hole to 2905 metres, with serious lost circulation and hole problems. Because of low leak off pressure below the 13 3/8" casing shoe (1.15 specific gravity), mud density had to be kept very low. Circulation was first lost at 2395 metres with 1.11 specific gravity mud in the hole. Circulation was regained by reducing mud weight to 1.08 specific gravity and by using L.C.M. pills. At 2538 metres, circulation was lost completely and was not fully regained. Cement plugs were frequently set and sea water and viscous slugs were used in an attempt to plug the lost circulation. At 2647 metres, the well flowed salt water, and a cement plug had to be set to control the flow. At 2674 metres, the formation changed from limestone to shale. The shale proved sensitive to sea water. Low hydrostatic pressure resulted in insufficient clean up and caving. By 2925 metres, tight hole had become a problem and during a check trip the pipe was stuck at 2905 metres. The assembly was backed off to 2858 metres and a cement plug set to allow a kick off. Hole problems prevented dressing off the plug, and a 9 5/8" casing had to be run and the hole side tracked.

Drilling proceeded to 3657 metres with severe lost circulation problems. At this depth, a 7" liner was run and cemented. Drilling continued in the 6" hole with a mud weight of 1.18 to 1.20 specific gravity. At 3780 metres, a drilling break showed a change in formation from shale to volcanics. At 4270 metres, the mud weight was raised to 1.27 specific gravity because of increasing gas readings. A core barrel was run at this depth and after the core barrel was pulled out of the hole, a flow up the drill string was observed. The drill string was stripped in the hole to 1648 metres and 1.93 specific gravity mud was used to kill the well.

Drilling continued to 4296 metres where logs were run. The hole was then deepened to 4500 metres, where more logs were run and RFT testing was performed. Drilling proceeded to TD where a full suite of logs were run. The well was then plugged back to 4248 metres and a 4 1/2" slotted liner was set with the shoe at 4192 metres. The liner was slotted from 3737 metres to 4156 metres.

The test string was run in the hole and a drill stem test performed. The well flowed 12 barrels per hour of formation fluid (salt water) with traces of gas. The test is considered inconclusive because, although the 6" liner was slotted between 3737 and 4156 metres, the entire interval below the 7" liner shoe was open to flow.

Formation integrity:

1840m - 1.15 s.g. leak off
2727m - 1.36 s.g. leak off
3659m - 1.56 s.g. no leak off

Pore pressures:

The well was normally pressured from surface to 3780 metres. At this depth, formation changed from claystone to volcanics. At 4270 metres, the well kicked with 1.27 specific gravity mud in hole. 1.52 specific gravity mud was used to control and drill the section from 4270 metres to TD. The production test over the entire section below the 7" liner shoe produced water and gas. From the final pressure build up measurement, formation pore pressure in the volcanic formation below 3780 metres is 1.48 specific gravity. This is considered to be over pressured.

BUFFON 1

KB 10.36m

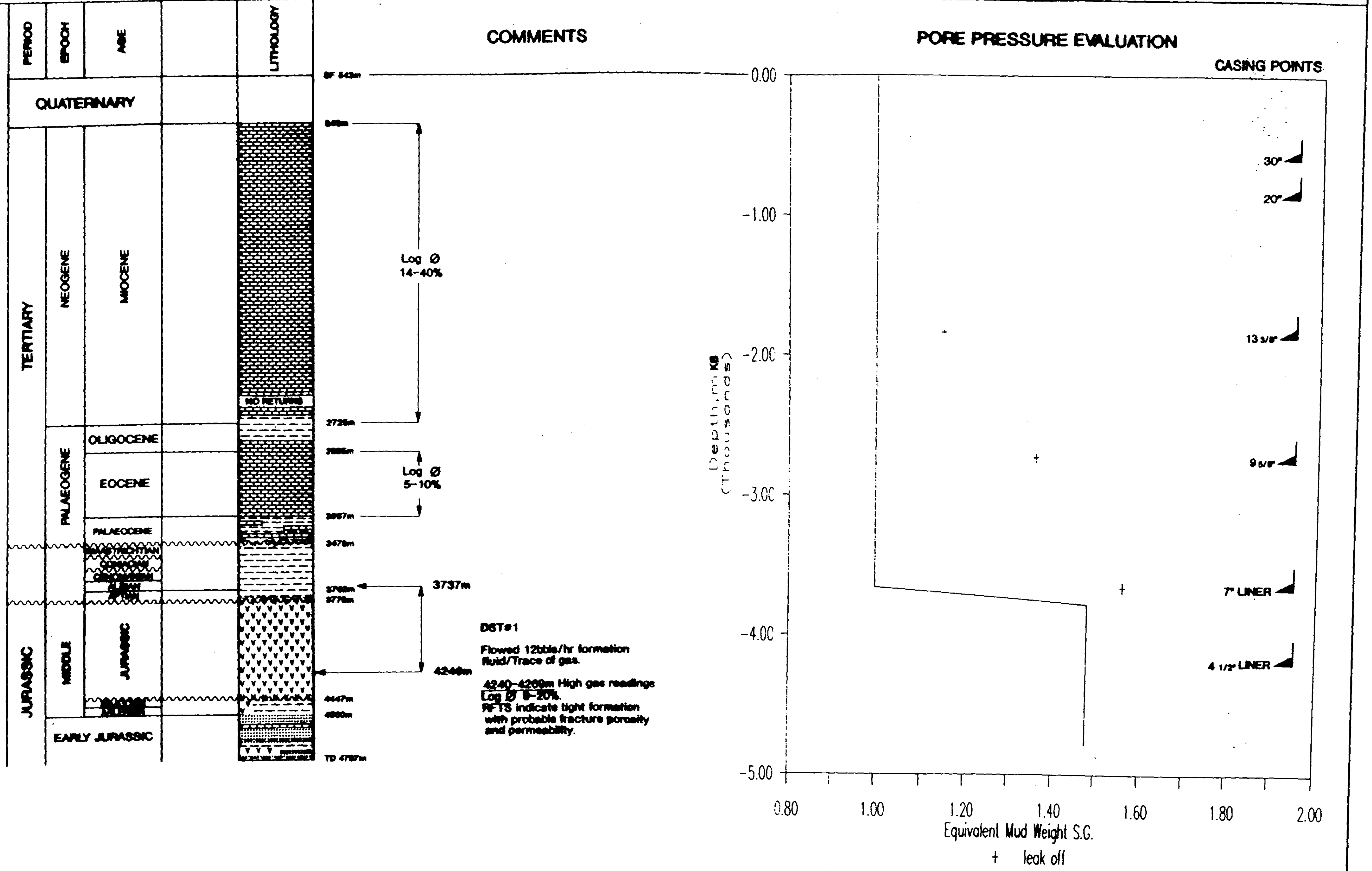
WD 533.0m

TD 4787m

STRUCTURE: High relief Triassic/Lower to Middle Jurassic drape anticline, north of Scott Reef.

OBJECTIVES: Early to Middle Jurassic and Triassic sandstones.

COMMENTS: Gas shows in thick Middle Jurassic volcanic section.



1.1j Caswell No.1

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 14°14'28.7''S ;122°28'3.0''E
Elevation - Sea floor - +345.4m
Kelly bushing - -8.0m
Date Spudded - 16 / 08 / 1977
Rig Released - 13 / 01 / 1978
Total Depth - 4097m
Well Status - Plugged and abandoned; dry hole

Well objective:

To test a northeast-southwest trending antiform feature situated near the northern extremity of the Central Basin Arch. The structure consists of a horst block of pre-breakup sediments overlain by post-breakup deposits.

Hole sizes:

36" - 394m
26" - 394m to 675m
17 1/2" - 675 to 1825m
12 1/4" - 1825m to 3348m
8 1/2" - 3348m to 3607m
6" - 3607m to 4097m

Casing:

30" - Shoe at 388.7m
20" - Shoe at 659.7m
13 3/8" - Shoe at 1807m
9 5/8" - Shoe at 3328m
7" liner - Shoe at 3515m

Drilling summary:

36" and 26" holes were drilled with sea water and high viscosity gel slugs to 675 metres with no hole problems. In the 17 1/2" hole, sea water bentonite mud was used to 1662 metres, when a complete loss of circulation occurred. In order to maintain circulation, aerated sea water was used while drilling to 1775 metres. This proved to be unsuccessful and sea water was used to deepen the 17 1/2" hole to 1825 metres.

After the 13 3/8" casing was set, a 12 1/4" hole was drilled to 3348 metres with brine polymer mud treated with C.M.C. This section was drilled with many difficulties. The hole condition progressively deteriorated and extensive reaming and washing was required through the claystone section between 2700 and 3230 metres in order to keep the hole open. Slight mud losses occurred while drilling from 2494 to 2562 metres with 1.18 specific gravity mud density. Mica was added to the mud and losses ceased. At 3085 metres, complete loss of circulation occurred with 1.29 specific gravity mud in the hole. The point of lost circulation was assumed to be just below the 13 3/8" casing seat. Circulation was re-established with the addition of lost circulation materials to the mud and by setting two cement plugs at 1817 and 1900 metres. In order to isolate the zones of lost circulation and troublesome shales, the 9 5/8" casing was set at 3328 metres.

After drilling out the 9 5/8" casing shoe using 1.34 specific gravity mud, complete loss of circulation occurred at 3348 metres. Full circulation was re-established after a cement plug was set in the open hole and inside the 9 5/8" casing. After the cement was drilled out, the formation was tested to 1.5 specific gravity. While drilling the 8 1/2" hole at 3564 metres, slight mud losses occurred but ceased when mica was added to the mud. A drilling break at 3607 metres resulted in a well kick of approximately 200 barrels of oil. The killing operation was difficult due to intermittent mud losses when the mud density was increased to 1.51 specific gravity. Four cement plugs were set to seal off the open hole back to the 9 5/8" casing shoe. The cement was drilled out to 3521 metres where a 7" liner was run and cemented at 3515 metres. The 6" hole was then drilled to TD, with the mud density gradually increasing to 1.68 specific gravity.

Formation integrity:

1825m - 1.29 s.g. leak off
3348m - 1.50 s.g. limit test

Pore pressures:

The formations in Caswell No.1 are normally pressured from surface to approximately 3400 metres. From 3400 metres to TD formations are overpressured.

RFT summary:	3608.0m	7850 psig	1.53 s.g.
	3608.5m	7907 psig	1.54 s.g.
	3610.2m	7840 psig	1.53 s.g.
	3610.5m	7841 psig	1.53 s g.
	3658.7m	7950 psig	1.53 s.g.
	3659.2m	8180 psig	1.57 s.g.
	3705.8m	8300 psig	1.58 s.g.

CASWELL 1

KB 8.0m

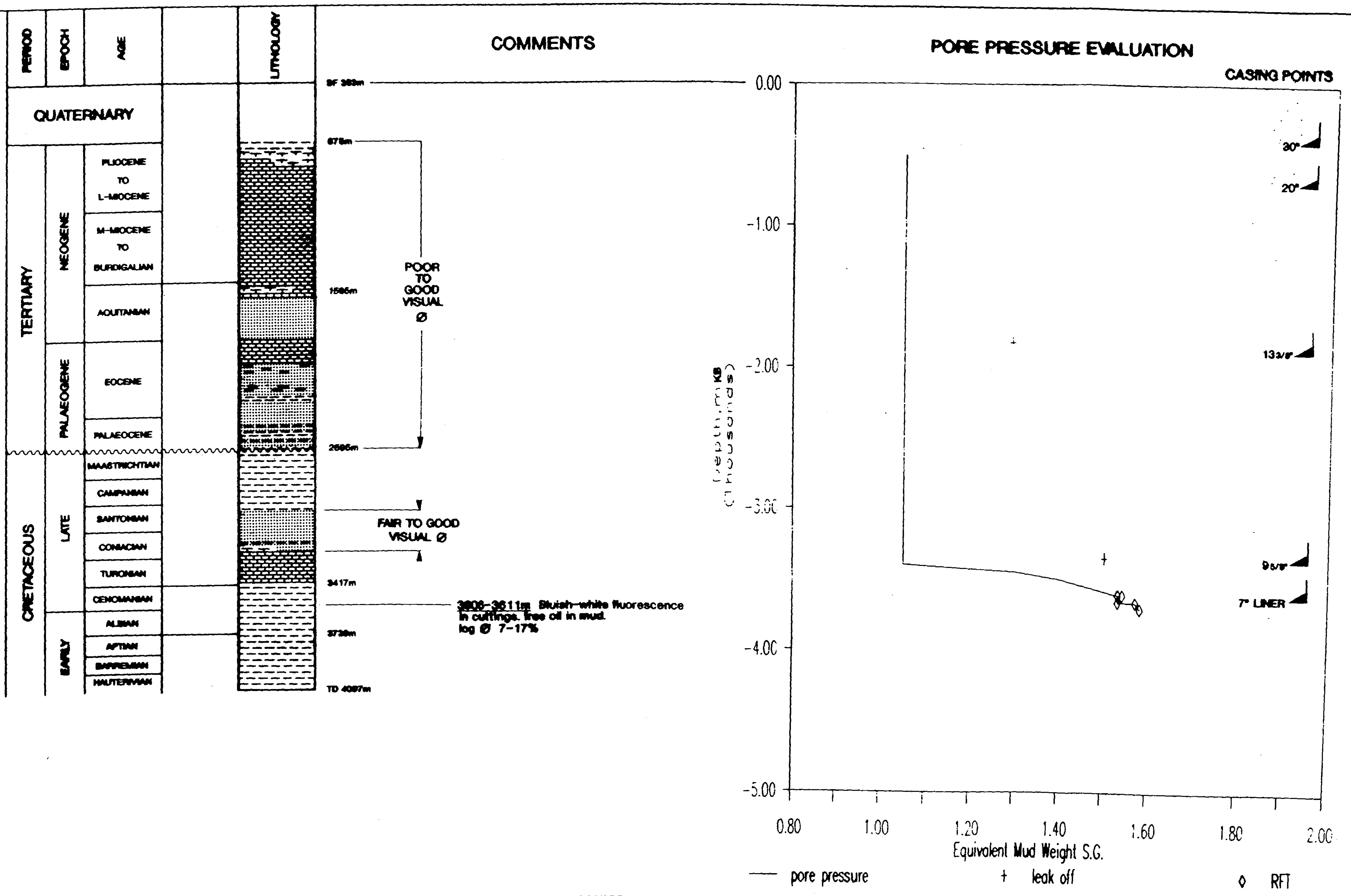
WD 345.4m

TD 4097m

STRUCTURE: NE/SW Trending drape anticline located in the Central Browse Basin.

OBJECTIVES: Lower to Middle Jurassic sandstones

COMMENTS: Failed to penetrate Jurassic section due to mechanical problem. Oil show in Albian sandstone.



1.1k Caswell No.2

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 14°14'33.10''S ;122°28'10.28''E
Elevation - Sea floor - +344.0m
Kelly bushing - -17.0m
Date Spudded - 01 / 04 / 1983
Rig Released - 06 / 11 / 1983
Total Depth - 5000m
Well Status - Plugged and abandoned; oil and gas show

Well objective:

The well was designed to test Upper Jurassic sands and pre-breakup Middle-Lower Jurassic sands on a large north-trending drape anticline.

Hole sizes:

36" - 407m
26" - 407m to 691m
17 1/2" - 691 to 2647m
12 1/4" - 2647m to 3500m
8 1/2" - 3500m to 4554m
6" - 4244m to 5000m

Casing:

30" - Shoe at 398.0m
20" - Shoe at 675.0m
13 3/8" - Shoe at 2632.0m
9 5/8" - Shoe at 3483.0m
7" liner - Shoe at 4549.0m

Drilling summary:

The 36" and 26" sections were drilled using sea water and high viscosity slugs with returns to the sea bed. In the 17 1/2" hole, the mud was changed to a fresh water high viscosity C.M.C. system. The mud weight in this section was kept below 1.07 specific gravity. Partial mud losses were experienced below 1671 metres and were treated with L.C.M.

The 12 1/4" hole was drilled using a freshwater potassium chloride polymer mud. The mud weight was gradually increased to 1.3 specific gravity at a depth of 3396 metres. A trip at this depth resulted in the backed off string and a total of 1939 metres of drill pipe lost in the hole. The entire string could not be recovered and the hole had to be sidetracked from a depth of 2700 metres. The sidetracked hole was drilled to a depth of 3500 metres where a suite of logs and 9 5/8" casing were run. In this section, lost circulation was encountered below 3306 metres and was treated with L.C.M. and Flo-check.

The 8 1/2" hole was drilled to 4554 metres using K.C.L/ Polymer mud. The mud weight in this section was increased to 1.69 specific gravity due to gas below 3907 metres. Because of lost circulation below 4482 metres and high gas readings, a 7" liner was run with the shoe at 4549 metres.

A number of hole problems existed in the 6" section. At 4900 metres, a diamond bit became stuck. The string was pulled free leaving the turbine assembly in the hole. The turbine could not be retreived and the well was sidetracked. Due to the hard abrasive nature of the silty sandstone, bit life was short and resulted in junk being left in the hole. Lost circulation was encountered below 4680 metres and was treated with L.C.M. The mud weight was maintained at 1.32 specific gravity to a total depth of 5000 metres.

Formation integrity:

675m - 1.29 s g. leak off
2632m - 1.38 s.g. leak off
3483m - 1.80 s.g. leak off
4549m - 1.66 s.g. leak off

Pore pressures:

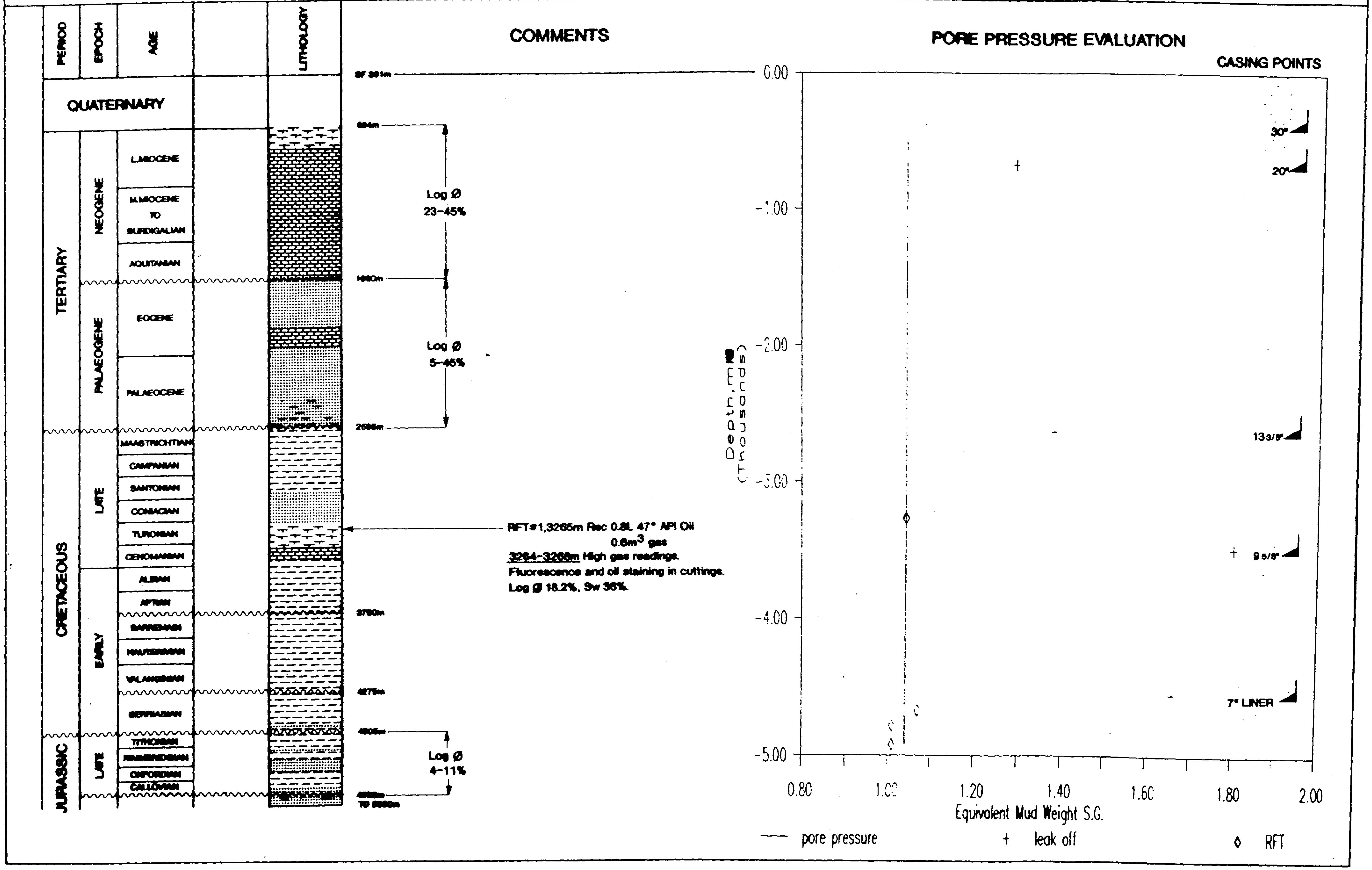
In contrast to Caswell No.1, the formations in Caswell No.2 are normally pressured from surface to TD.

RFT Summary:	3265.5m	4822.06psig	1.04s.g.
	3266.5m	4823.10psig	1.04s.g.
	3267.5m	4824.07psig	1.04s.g.
	3269.0m	4825.01psig	1.04s.g.
	3265.5m	4820.91psig	1.04s.g.
	4671.0m	7127.00psig	1.07s.g
	4783.5m	6882.00psig	1.01s.g
	4920.5m	7062.00psig	1.01s.g.

CASWELL 2

KB 17.0m
WD 344m
TD 5000m

STRUCTURE: NE/SW Trending drape anticline in Central Browse Basin.
OBJECTIVES: Lower to Middle Jurassic sandstones.
COMMENTS: Oil and gas show in Late Cretaceous.
No significant hydrocarbon shows in Jurassic.



1.11 Echuca Shoals No.1

General well data:

Operator - Woodside Offshore Petroleum Pty Ltd
Location - 13°45'01.232''S ;123°43'25.022''E
Elevation - Sea floor - +194.0m
Kelly bushing - -17.0m
Date Spudded - 08 / 11 / 1983
Rig Released - 29 / 02 / 1984
Total Depth - 4365m
Well Status - Plugged and abandoned; untested gas shows

Well objective:

The prospect consisted of a large Permo-Triassic block with minor Jurassic and Lower Cretaceus drape closure. The shallower targets were Lower Neocomian-Tithonian and Middle Jurassic sandstones above the horst block. The deeper objectives were sandstones within the fault block.

Hole sizes:

36" - 244.0m
26" - 244.0m to 530.0m
17 1/2" - 530.0m to 2113.0m
12 1/4" - 2113.0m to 3605.0m
8 1/2" - 3605.0m to 4294.0m
6" - 4294.0m - 4365.0m

Casing:

30" - Shoe at 234.0m
20" - Shoe at 519.0m
13 3/8" - Shoe at 2088.0m
9 5/8" - Shoe at 3586 0m
7" liner - Shoe at 4185m

Drilling summary:

The 36" and 26" holes were drilled with sea water and high viscosity slugs. In the 17 1/2" hole, the mud system was gradually changed to a sea water/polymer/gel system. Maximum mud density in this hole section was 1.08 specific gravity.

In the 12 1/4" hole section, the mud system was converted to a 10 % K.C.L./polymer mud. The mud density was maintained between 1.22 and 1.25 specific gravity. Mud losses of 60 barrels per hour were experienced at 2828 metres but were successfully cured with L.C.M. Drilling continued trouble-free to 3605 metres, at which point 9 5/8" casing was set.

Drilling continued in a 8 1/2" hole using the same mud system. Initial mud density was 1.13 specific gravity.

The final mud density was 1.54 specific gravity. At 4281 metres, the mud weight was raised to 1.2 specific gravity as a result of increased gas readings. At 4294 metres the well flowed and was circulated with 1.35 specific gravity mud, then closed and observed. Casing pressure increased to a greater pressure than the leak off pressure at the casing shoe. A pill of 2.38 specific gravity mud was spotted in the open hole section. The string was pulled out of the hole and a cement plug set with the top at 3556 metres through open ended drill pipe. The cement plug was milled out at 3714 metres and the string run to bottom, circulating out the 2.38 specific gravity mud while maintaining 1.52 specific gravity mud in the hole. At 4288 metres, the well flowed again and was shut in. 1.8 specific gravity mud was spotted in the open hole from 4288 metres. The mill was pulled out and an open ended drill string was run to bottom in stages. A 100-sacks cement plug was then placed on bottom and a 137 barrels pill of 2.06 specific gravity mud placed above it. The plug was then drilled out to 4195 metres, the hole logged and the 7" liner set at 4185 metres.

The 6" hole section was drilled with 10 % K.C.L./polymer mud to TD. Initial mud density was 1.62 specific gravity and final density was 1.68 specific gravity.

Formation integrity:

536m - 1.25 s.g. leak off
2119m - 1.50 s.g. leak off
3596m - 1.53 s.g. leak off
3611m - 1.43 s.g. leak off
3680m - 1.53 s.g. leak off
4185m - 1.91 s.g. limit test

Pore pressures:

The formations in Echuca Shoals No.1 are normally pressured from surface to 4281 metres. At this depth to 4304 metres, high gas readings were recorded and the well flowed with 1.52 specific gravity mud in the hole. The formations below 4281 metres are considered to be over pressured.

RFT summary:

3318.0m	4933.39psi	1.05s.g.
3325.2m	4936.00psi	1.05s.g.
3328.0m	4937.89psi	1.04s.g.
3334.0m	4952.23psi	1.04s.g.
3369.7m	4998.51psi	1.04s.g.
3384.0m	5007.07psi	1.04s.g.
3406.0m	5037.82psi	1.04s.g.
3465.5m	5121.51psi	1.04s.g.
3588.0m	6298.07psi	1.23s.g.
3590.5m	6102.12psi	1.19s.g.
3592.8m	6056.00psi	1.19s.g.
3619.6m	5513.26psi	1.07s.g.

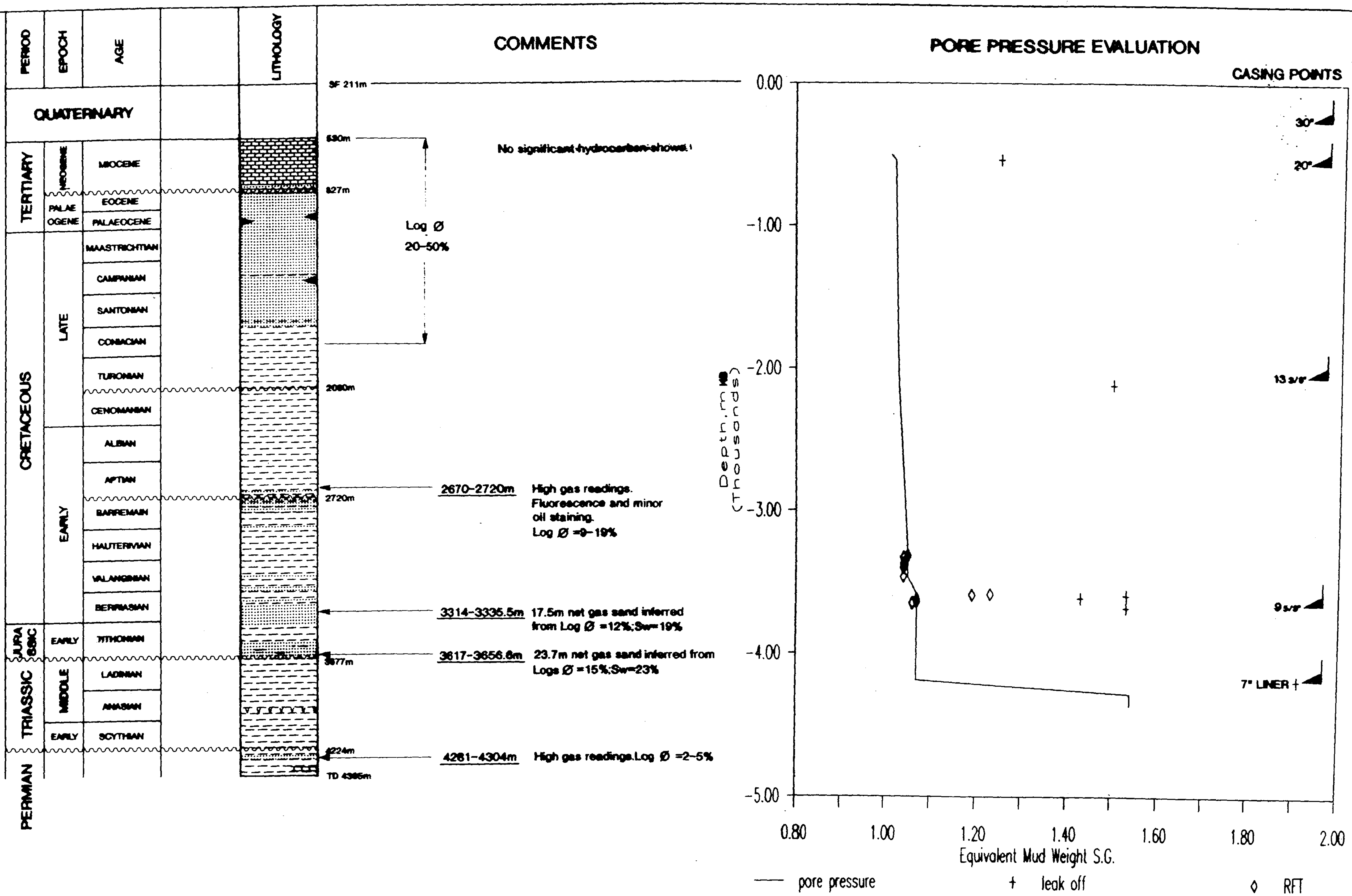
3624.6m	5541.40psi	1.07s.g.
3638.2m	5516.31psi	1.07s.g.
3642.0m	5519.93psi	1.07s.g.
3647.1m	5521.82psi	1.06s.g.
3652.1m	5523.85psi	1.06s.g.

RFT depths are relative to sea level.

ECHUCA SHOALS-1

KB 17.0m
WD 194m
TD 4365m

STRUCTURE: Permo-Triassic fault block with minor Jurassic and Cretaceous drape.
OBJECTIVES: Early Cretaceous, Jurassic and Triassic sandstones.
COMMENTS: Two gas bearing intervals in the Upper Jurassic section inferred from logs.



1.1m Gryphaea No.1

General well data:

Operator - BHP Petroleum
Location - 12°48'38 33''S ;123°44'21.64''E
Elevation - Sea floor - +199.0m
Kelly bushing - -17.0m
Date Spudded - 17 / 09 / 1987
Rig Released - 24 / 11 / 1987
Total Depth - 3950m
Well Status - Plugged and abandoned

Well objective:

To test a faulted closure on a major tilted fault block trend which forms the northern boundary of the Browse Basin. The primary ojectives were Late Triassic sandstones. Secondary objectives were Aptian calcarenites.

Hole sizes:

36" - 256m
26" - 256.0m to 465.0m
20" - 465.0m to 1304.0m
17 1/2" - 1304.0m to 1980.0m
12 1/4" - sidetracked 1731.0m to 2644.0m
8 1/2" - 2644.0m to 3950.0m

Casing:

30" - Shoe at 253.0m
20" - Shoe at 460.0m
16" - Shoe at 1292.0m, 16" casing hanger hung off in a 20" casing landing sub at 329m.
13 3/8" - Shoe at 1726.0m
9 5/8" - Shoe at 2650.0m

Drilling summary:

The 36" and 26" hole sections were drilled with sea water and high viscous pills. Good returns were experienced while drilling and cementing.

The 20" hole section was drilled with 17 1/2" bit to 490 metres and a 20" under-reamer with a 17 1/2" bit was then used to drill/under-ream to 1304 metres. Sea water and 40 barrel high viscous pills were used for drilling (every kelly). Full returns were maintained to 918 metres, when 10 % losses occurred, which were treated back to 5 % with L.C.M. pills. These 5 % losses were present until TD was reached.

The 17 1/2" hole was drilled with a 17 1/2" under-reamer/ 12 1/4" bit combination to 1980 metres. Slight losses were experienced after the 16" casing shoe was drilled out and gradually increased to 20 % by 1794 metres despite L.C.M. treatment. Total losses were experienced while drilling at 1974 metres and drilling proceeded blind to 1980 metres, where tight hole resulted in stuck pipe. The pipe could not be freed and the drill string was cut at 1756 metres.

The 13 3/8" casing was then set at 2634 metres and the hole sidetracked with a 12 1/4" bit. Drilling of the sidetracked hole proceeded to the 9 5/8" casing setting point, with mud losses averaging between 20 and 50 barrels per hour, despite L.C.M. treatment. No returns were obtained during the 9 5/8" casing cementation.

The 8 1/2" hole section was drilled with little trouble using 5 to 6 % K.C.L. mud. Total returns were maintained throughout this section. From about 3700 metres, small quantities of splinter cuttings were noted and the mud density was increased from 1.1 to 1.17 specific gravity. Tight hole was experienced from 3850 metres, but increased mud density was able to control this problem.

Formation integrity:

2650m - 1.43 s.g. The formation was fractured.

Pore pressures:

The formations in Gryphaea No.1 are normally pressured.

1.1n Heywood No.1

General well data:

Operator - B.O.C. of Australia Ltd
Location - 13°27'46 66''S ;124°04'00.21''E
Elevation - Sea floor - +35.0m
Kelly bushing - -10.0m
Date Spudded - 07 / 04 / 1974
Rig Released - 14 / 07 / 1974
Total Depth - 4572m
Well Status - Plugged and abandoned; dry hole.

Well objective:

The well was located on a Permo-Triassic/Middle Jurassic horst block towards the northeast margin of the Browse Basin.

Hole sizes:

36" - 74m
26" - 74m to 377m
17 1/2" - 377 to 1515m
12 1/4" - 1515m to 3354m
8 1/2" - 3354m to 4572m

Casing:

30" - Shoe at 69m
20" - Shoe at 367m
13 3/8" - Shoe at 1506m
9 5/8" - Shoe at 3346m

Drilling summary:

The 36" and 26" holes were drilled with sea water and slugs of gel mud. The 17 1/2" hole was drilled with a 1.05 specific gravity lightly dispersed sea water/gel mud system.

The 12 1/4" hole was drilled using a brine/polymer mud system with a high chloride concentration. In this section, the mud density was increased to 1.37 specific gravity to control swelling claystones.

Drilling of the 8 1/2" hole section commenced with a 1.16 specific gravity slightly dispersed, controlled salinity (60 000 ppm) mud system and completed with chlorides reduced to 25 000 ppm to help reduce mud density to 1.13 specific gravity. At 4572 metres, the drill pipe twisted off. The subsequent fishing operation was unsuccessful and the well was plugged and abandoned.

Formation integrity:

Not available

Pore pressures:

The formations in Heywood No.1 appear to be normally pressured from surface to TD. The 12 1/4" hole section was drilled with an increased mud weight of 1.37 specific gravity because of swelling claystones. However, there was no indication of overpressuring in this section from logs and other available drilling parameters.

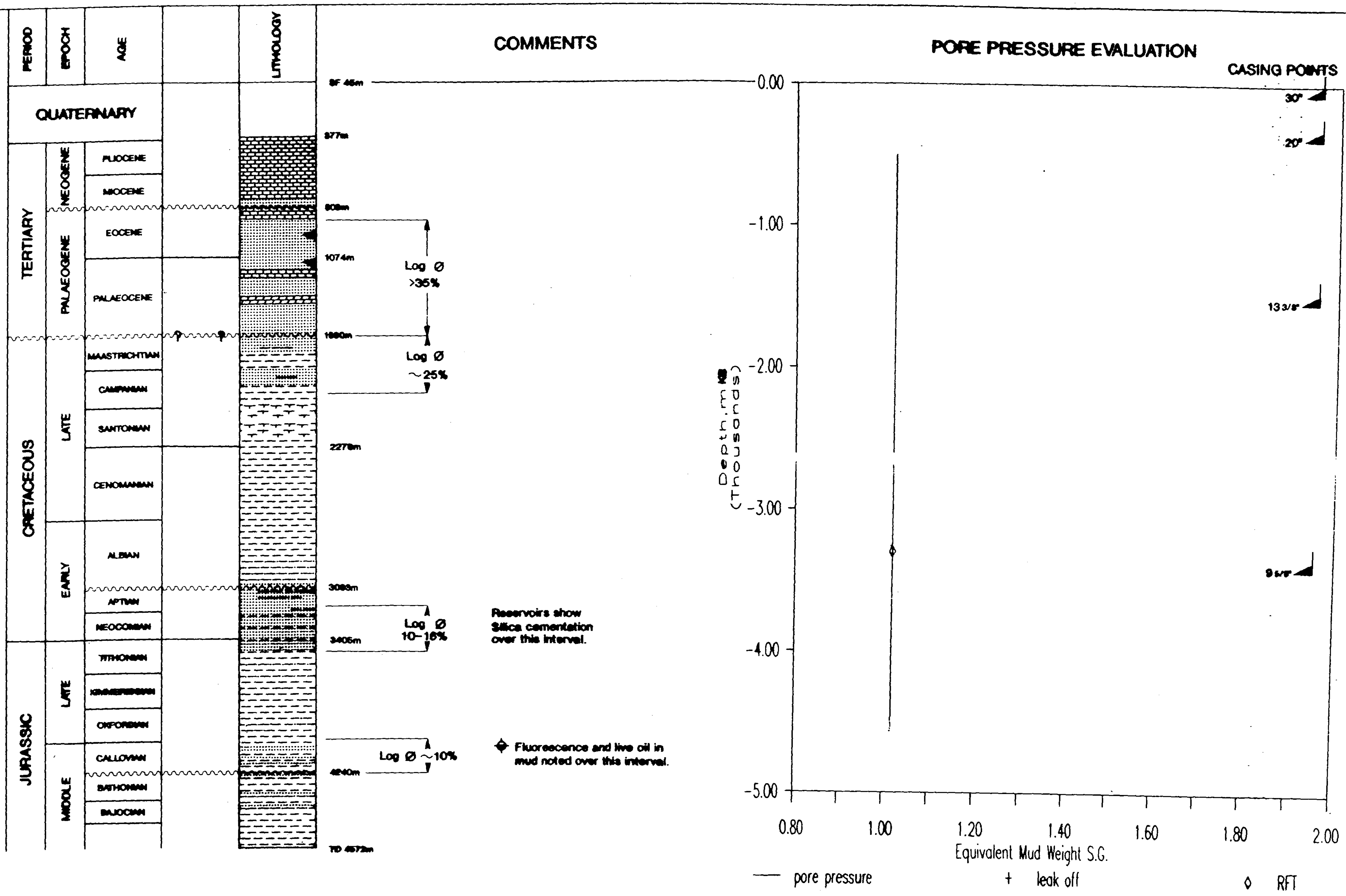
FIT Summary:	4147.5m	48psi	Tight
	3299.0m	4790psi	1.02s.g.

Recovered 15 000 cubic centimetres of water

HEYWOOD 1

KB 10m
WD 35m
TD 4572m

STRUCTURE: Permo-Triassic horst block on northeast basin margin.
OBJECTIVES: Triassic
COMMENTS: No structural closure.



1.1o Leveque No.1

General well data:

Operator - B.O.C. of Australia Ltd
Location - 15°45'11 924''S ;122°00'17.665''E
Elevation - Sea floor - +77.7m
Kelly bushing - -9.4m
Date Spudded - 22 / 08 / 1970
Rig Released - 06 / 09 / 1970
Total Depth - 899.5m
Well Status - Plugged and abandoned

Well objective:

The well was drilled as a stratigraphic test of the Browse Basin margin. It was located on the basinward flank of a large paleo-topographic high on the Leveque Shelf.

Hole sizes:

26" - pilot hole to 124.9m opened to 36"
17 1/2" - 124.9m to 484.6m
12 1/4" - 484.6m to 896.4m
8 7/16" - 896.4m to 899.5m

Casing:

20" - Shoe at 120.4m
13 3/8" - Shoe at 455.7m

Drilling summary:

The 26" hole was drilled to 124.9 metres and opened to 36" using sea water and slugs of gel mud. The 20" casing was run utilizing a 30" suspension joint attached to the top of the 20" casing joint.

The 17 1/2" hole was drilled to 187 metres using seawater Q-mix/C.M.C. mud, where lost returns necessitated changing the system back to sea water and slugs of gel mud. Drilling continued with partial returns to the 13 3/8" casing setting depth.

The 12 1/4" hole was drilled to 882 metres, at which depth cavernous formations were encountered down to 888 metres, with mud losses of up to 200 barrels per hour, which required cementation. The mud system in this hole section was sea water, with Q-mix, Dextrid low solids and low pH. At 896 metres, the drilling rate decreased and core was cut to 899.5 metres, which confirmed the presence of igneous basement.

The mud density throughout the entire hole section was kept between 1.09 and 1.10 specific gravity.

Formation integrity:

Not available

Pore pressures:

The formations in Leveque No.1 are normally pressured.

LEVEQUE 1

KB 9.4m

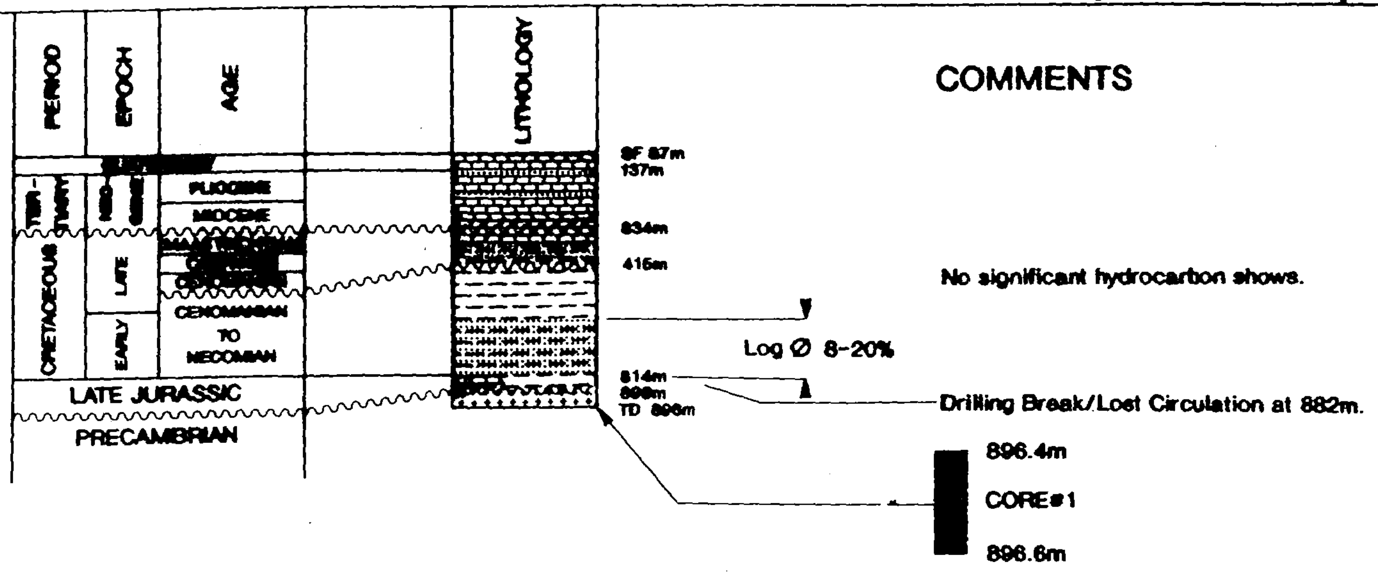
WD 78m

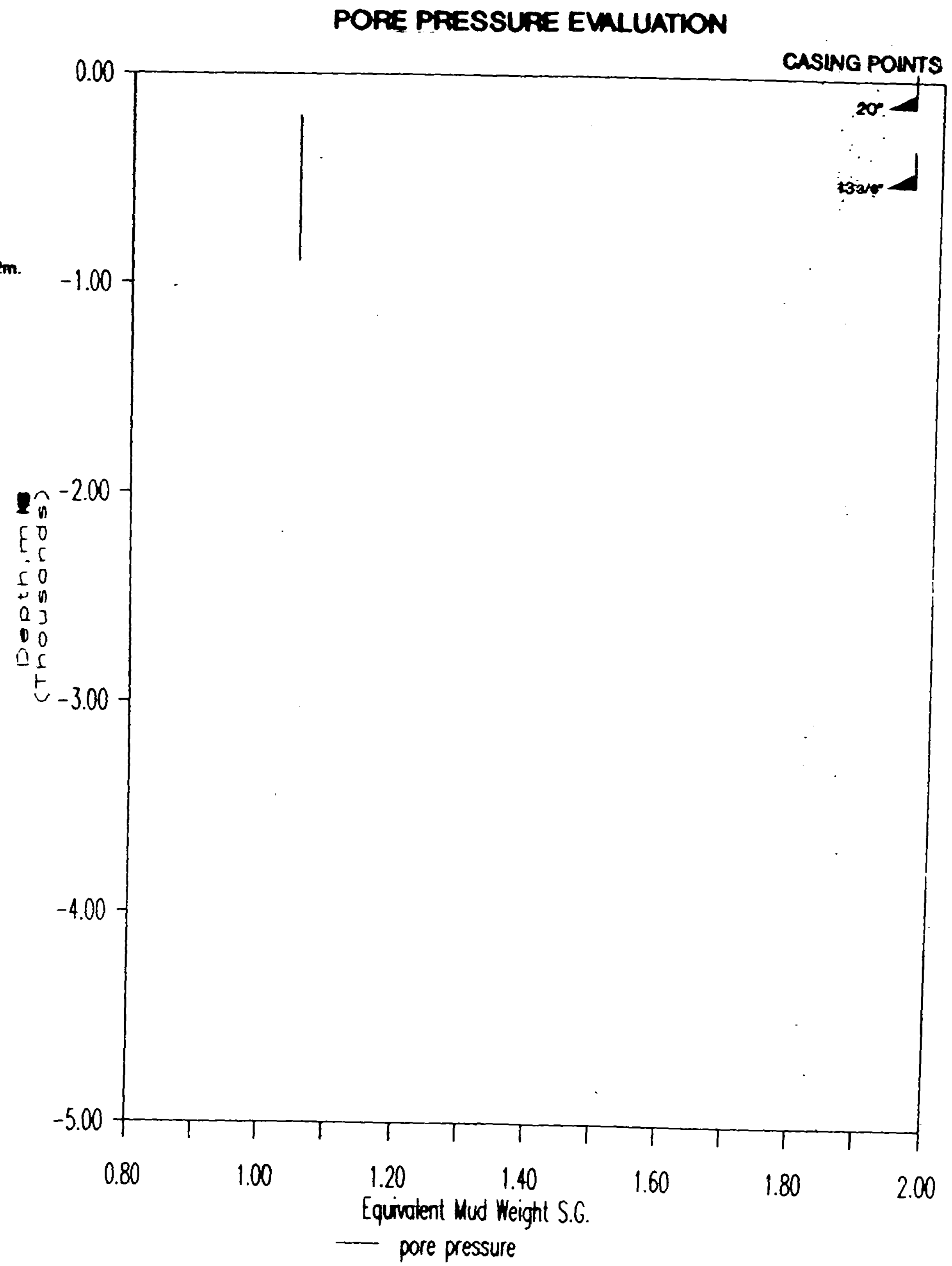
TD 899.5m

STRUCTURE: Stratigraphic test of the eastern basin margin.

OBJECTIVES: None

COMMENTS: Located on the flank of a large palaeo-topographic high on the Leveque Shelf.





1.1p Lombardina No.1

General well data:

Operator - B.O.C. of Australia Ltd
Location - 15°17'20 19''S ;121°32'14.29''E
Elevation - Sea floor - +175.0m
Kelly bushing - -30.0m
Date Spudded - 15 / 05 / 1974
Rig Released - 21 / 07 / 1974
Total Depth - 2855m
Well Status - Plugged and abandoned.

Well objective:

To test the hydrocarbon potential of a faulted anticlinal feature on the Leveque Shelf.

Hole sizes:

36" - 233.0m
26" - 233.0m to 530.0m
18 5/8" - 530.0m to 1500.0m
12 1/4" - 1500.0m to 1960.0m
8 1/2" - 1960.0m to 2855.0m

Casing:

30" - Shoe at 228.0m
20" - Shoe at 519.0m
13 3/8" - Shoe at 1494.0m
9 5/8" - Shoe at 1938 0m

Drilling summary:

The 36" and 26" holes were drilled using sea water and high viscosity gel slugs. The 12 1/4" pilot hole was drilled to 1500 metres using a sea water/gel mud system lightly treated with C.M.C. and Q-mix. After logs were run, the hole was under-reamed to 18 5/8". Minor lost circulation problems were encountered both during drilling of the pilot hole and under-reaming. Mud weight was gradually increased to 1.21 specific gravity in this hole section because of caving problems in claystone formations.

Drilling continued with a 12 1/4" bit using a controlled salinity Dextrid/Dispac mud system. At 1960 metres, it was necessary to run 9 5/8" casing with the shoe at 1938 metres, due to problems with the 13 3/8" casing seal assembly. Mud weights were increased up to 1.5 specific gravity in this hole section.

Drilling continued in the 8 1/2" hole to TD. In this section, lost circulation occurred over intervals 2513 to 2537 metres and 2550 to 2569 metres. Mud density was kept at 1.5 specific gravity to approximately 2500 metres. Below this depth, mud density was decreased to 1.36 specific gravity.

Formation integrity:

Not available

Pore pressures:

The formations in Lombardina No.1 well are considered to be normally pressured. Although up to 1.5 specific gravity mud weights were used for drilling below 1300 metres (to control caving problems), there was no evidence of overpressuring from the various parameters (such as "d" exponent, gas readings and shale densities) measured during drilling and hole surveys.

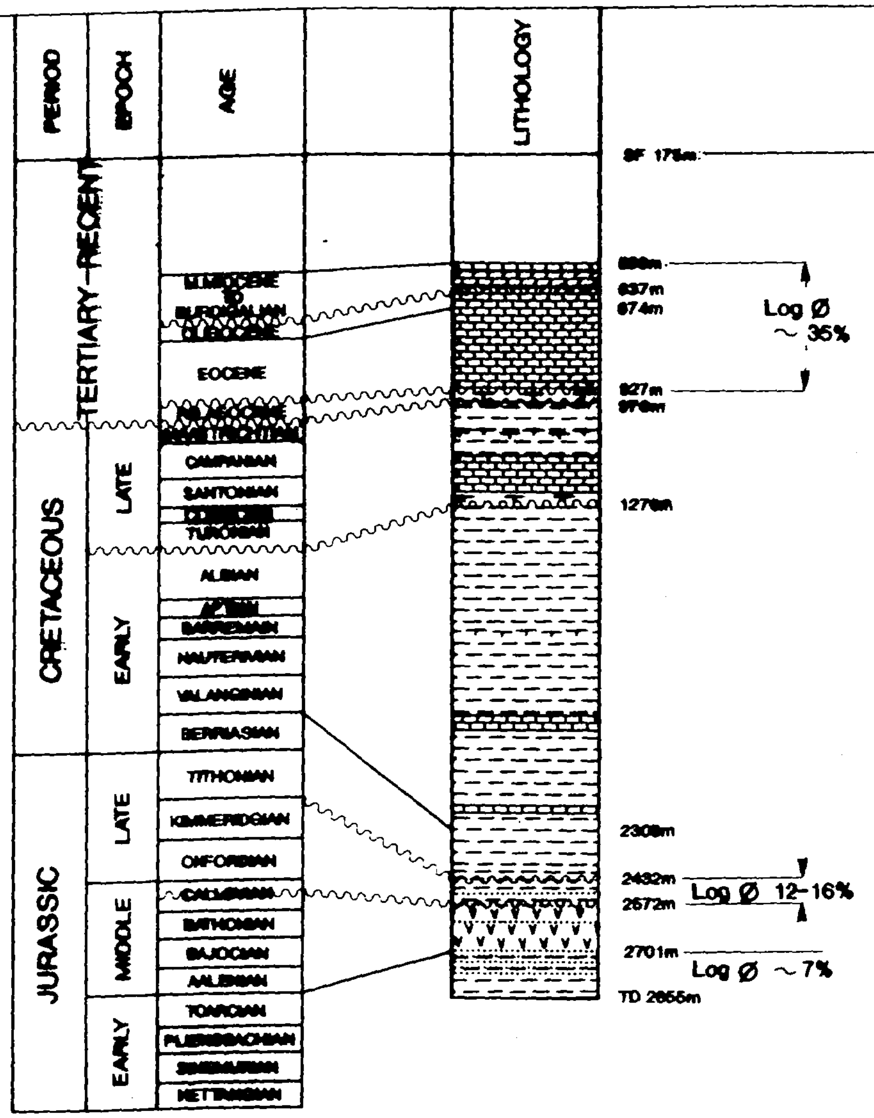
LOMBARDINA 1

KB 30m
WD 175m
TD 2855m

STRUCTURE: Young faulted anticlinal feature on the margin of the Leveque Shelf.

OBJECTIVES: Jurassic sandstones.

COMMENTS: Structure formed by NW tilting of the basin in the Tertiary.

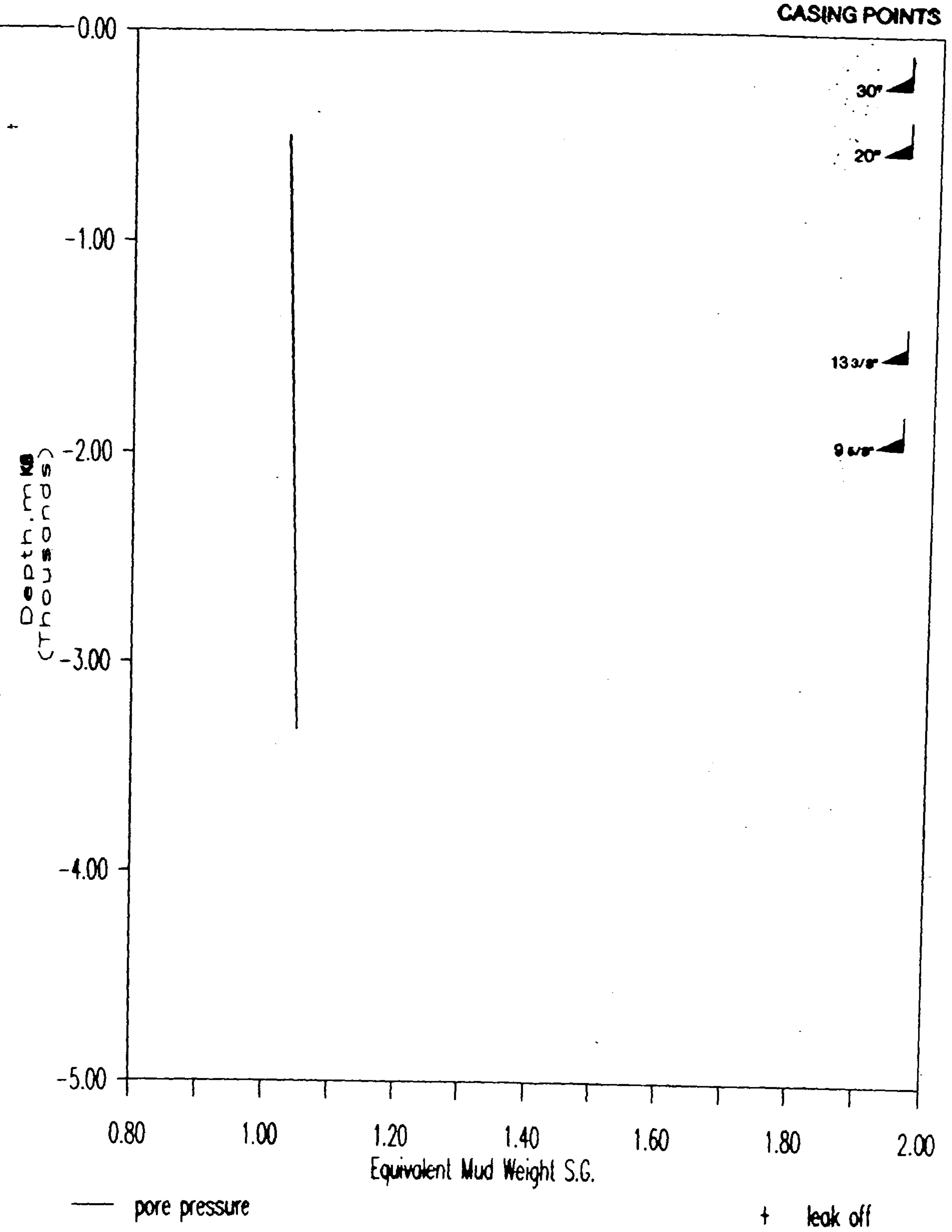


COMMENTS

No significant hydrocarbon shows.

Extensive silica cementation.

PORE PRESSURE EVALUATION



1.1q Londonderry No.1-

General well data:

Operator - BOCAL Australia Ltd
Location - 13°36'53.17''S ;124°30'42.59''E
Elevation - Sea floor +90m
Rotary table -13m
Date Spudded - 28 / 09 / 1973
Rig Released - 08 / 10 / 1973
Total Depth - 1145m
Well Status - Plugged and abandoned

Well objective:

The well was drilled on the southern flank of the Londonderry Arch as a stratigraphic test of the eastern margin of the Browse Basin.

Hole sizes:

36" - 134m
17 1/2" - 415m
12 1/4" - 1143m
8 7/16" - 1145m

Casing:

30" - Shoe at 127m
13 3/8" - Shoe at 410m

Drilling summary:

The 36" and 17 1/2" holes were drilled with sea water and slugs of gel mud. 12 1/4" hole was drilled with a semi-dispersed sea water Q-Mix system with C.M.C. added for filtration control. Mud density was between 1.04 and 1.08 specific gravity. The 17 1/2" hole caved badly. Lost circulation was experienced from 512 to 723 metres.

Formation integrity:

A formation integrity test was not performed.

Pore pressures:

The hole was normally pressured from surface to TD.

LONDONDERRY 1

KB 13.0m

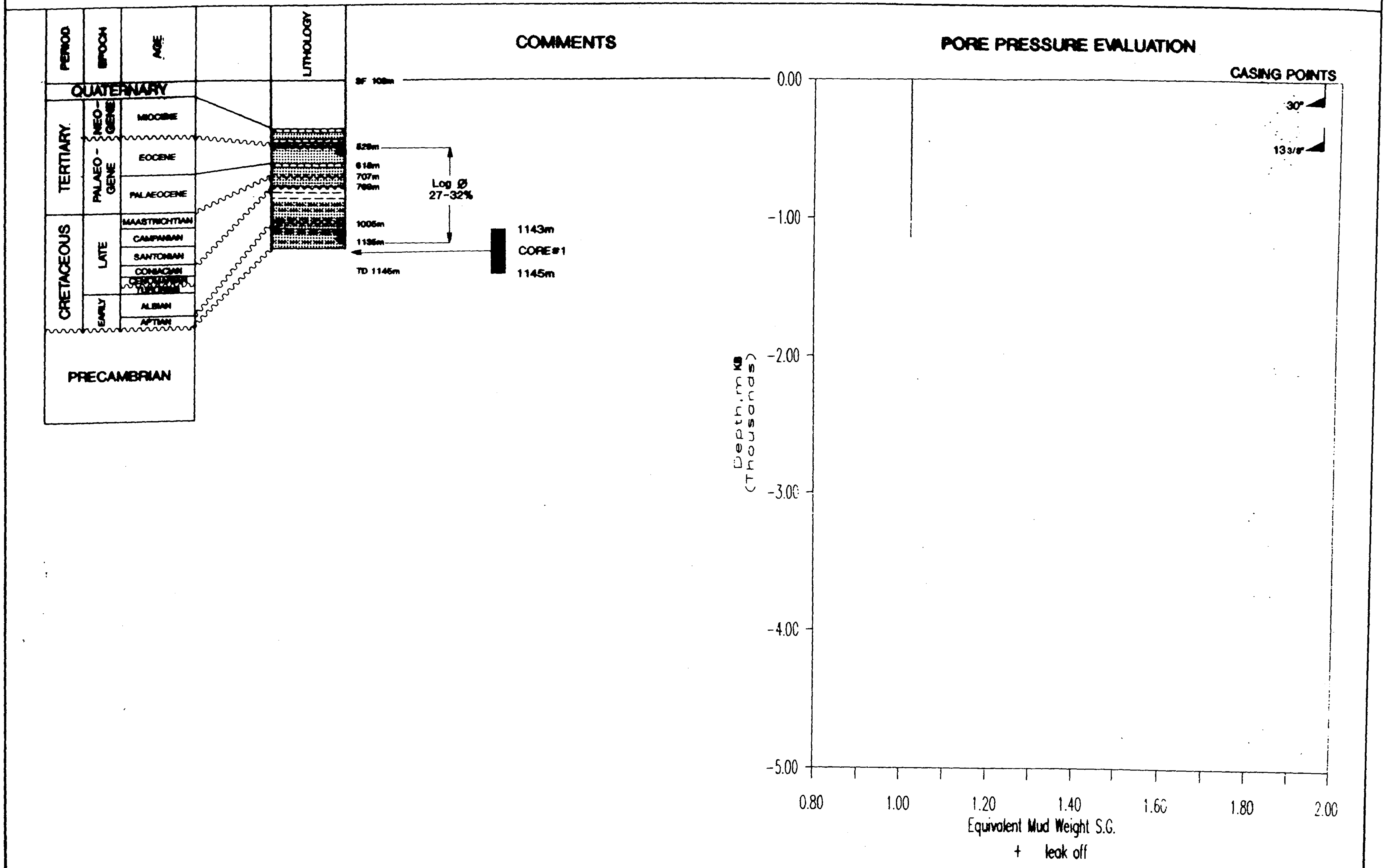
WD 90m

TD 1145m

STRUCTURE: None

OBJECTIVES: Lower Cretaceous

COMMENTS: Drilled as a stratigraphic test of the Eastern Browse Basin Margin.



1.1r Lynher No.1

General well data:

Operator - B.O.C. Of Australia Ltd
Location - 15°56'24.360''S ;121°04'59.036''E
Elevation - Sea floor - +67.4m
Kelly bushing - -9.5m
Date Spudded - 25 / 12 / 1970
Rig Released - 16 / 02 / 1971
Total Depth - 2724.9m
Well Status - Plugged and abandoned.

Well objective:

To test an elongated anticlinal structure located near the outer margin of the Leveque Shelf.

Hole sizes:

26" - to 292.6m
17 1/2" - 292.6m to 1127.8m
12 1/4" - 1127.8m to 2724.9m

Casing:

20" - Shoe at 282.2m
13 3/8" - Shoe at 1114.3m

Drilling summary:

The 17 1/2" hole was drilled to 292.6 metres and then opened to 26" diameter using sea water and slugs of gel mud. The 17 1/2" hole section was drilled to 986 metres using sea water and slugs of gel mud. From this depth, the system was gradually converted to a sea water/Q-mix mud.

Drilling continued in the 12 1/4" hole using a low solids dextrid mud. Bore hole conditions gradually deteriorated, necessitating frequent reaming. At 2724.9 metres, while pulling out of the hole, the drill string, consisting of 39 stands of drill pipe, was accidentally dropped down the hole. As all fishing attempts failed, the hole was plugged and abandoned at this depth.

Formation integrity:

Not available

Pore pressures:

The formations in Lynher No.1 well are normally pressured.

LYNHER 1

KB 9.5m

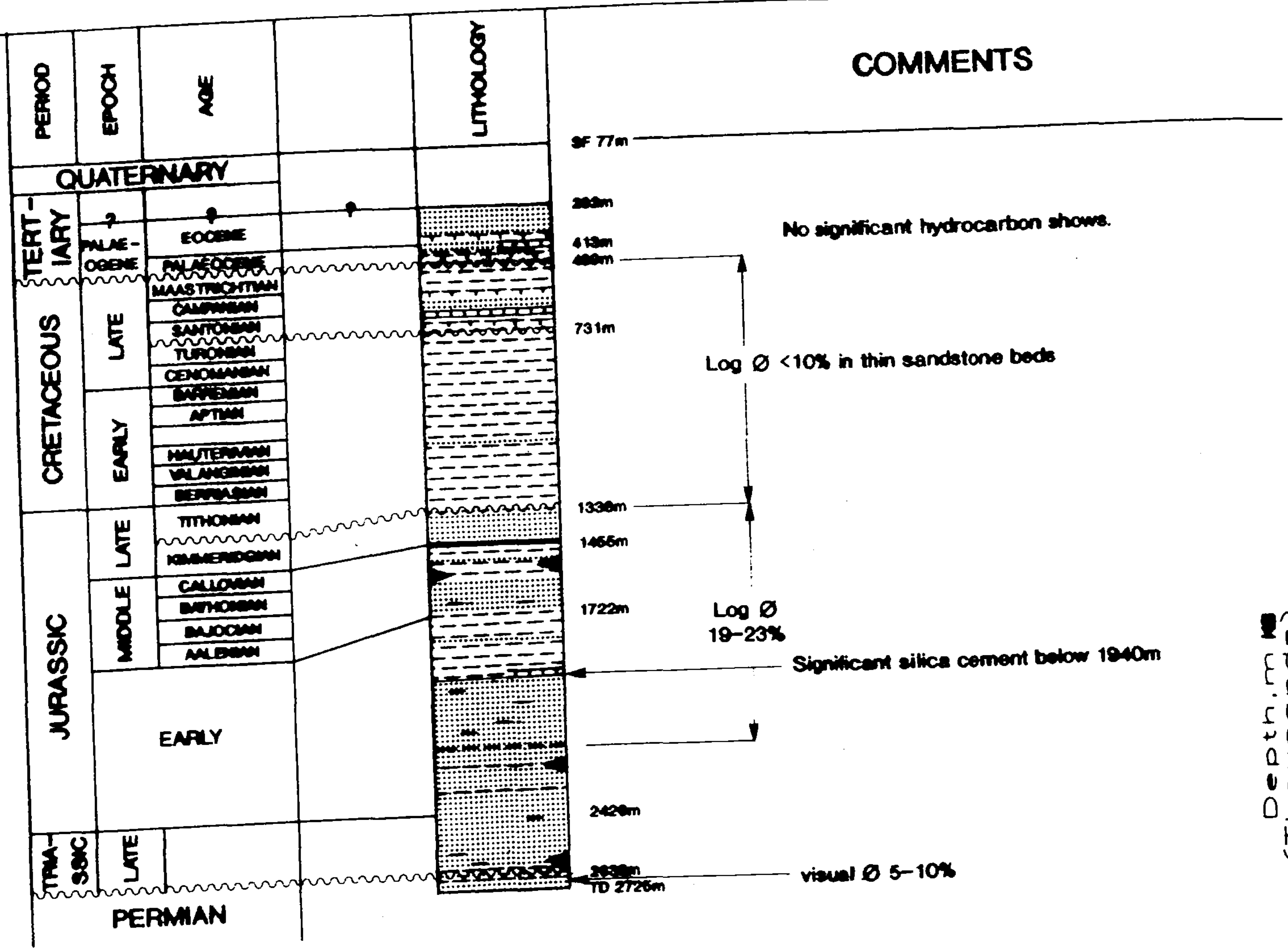
WD 67.4m

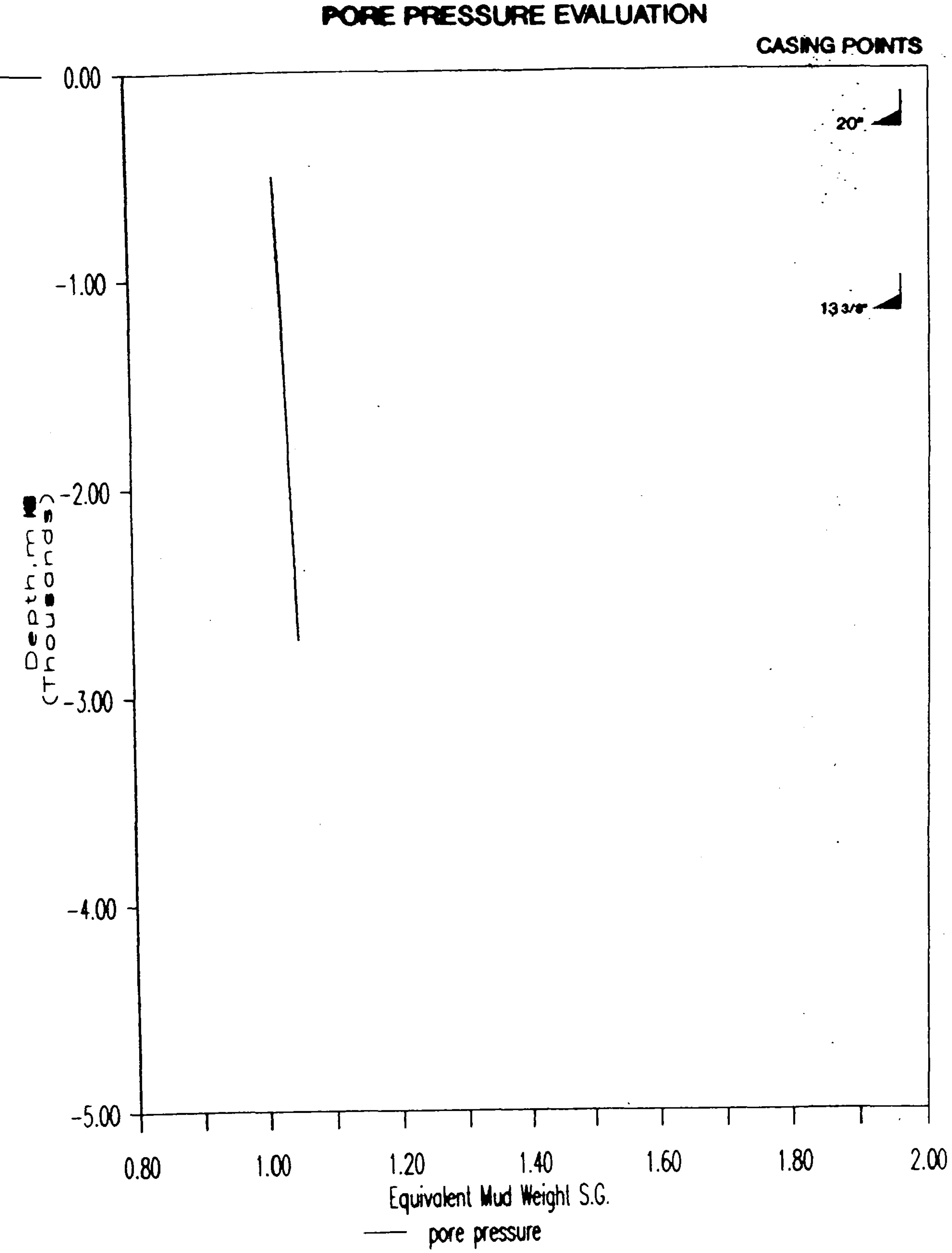
TD 2725m

STRUCTURE Elongated anticlinal structure on the margin of the Leveque Shelf.

OBJECTIVES: Late Cretaceous sands.

COMMENTS: Structure considered to be a very young feature.





1.1s Mount Ashmore No.1B

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 12°33'36 29''S ;123°12'22.12''E
Elevation - Sea floor - +623.0m
Kelly bushing - -11.0m
Date Spudded - 26 / 07 / 1980
Rig Released - 26 / 10 / 1980
Total Depth - 2655m
Well Status - Plugged and abandoned

Well objective:

The well was drilled to test sandstones of Early to Middle Jurassic-Triassic age within a large, dome-shaped structure.

Hole sizes:

36" - 685.0m
26" - 685.0m to 1035.0m
17 1/2" - 1035.0m to 1243.0m
14 3/4" - 1243.0m to 1680.0m
12 1/4" - 1680.0m to 1970.0m
8 1/2" - 1970.0m to 2655.0m

Casing:

30" - Shoe at 683.0m
20" - Shoe at 1018.0m
13 3/8" - Shoe at 1255.0m
9 5/8" - Shoe at 1955 0m

Drilling summary:

Mount Ashmore No.1 and No.1A wells were abandoned at depths of 664 metres and 1058 metres respectively, due to mechanical difficulties, and the rig moved to the Mount Ashmore 1B location.

The 36" and 26" holes were drilled with sea water and high viscosity bentonite pills on connections. The 14 3/4" hole was drilled to 1154 metres with a prehydrated bentonite/ sea water/C.M.C. mud system, at which depth mud losses began to occur. Drilling continued to 1493 metres with the addition of L.C.M. pills, at which depth circulation was totally lost. Cement plugs were set across the loss zones and the hole was deepened to 1680 metres. The hole was under-reamed to 17 1/2" to a depth of 1608 metres, at which point the drill string twisted off. Attempts to recover the fish were unsuccessful and the 13 3/8" casing was cemented at 1225 metres before the hole was sidetracked with a 12 1/4" bit.

The 12 1/4" sidetracked hole was drilled to 1970 metres with sea water polymer mud. The mud weight was maintained at 1.17 specific gravity. Partial losses were experienced over the interval 1911 to 1945 metres.

The 8 1/2" hole was drilled to TD without hole problems. The mud weight in this section was maintained between 1.16 and 1.18 specific gravity.

Formation integrity:

1255m - 1.11 s.g. leak off
1980m - 1.49 s.g. leak off

Pore pressures:

The formations in Mount Ashmore No.1B are normally pressured.

1.1t North Scott Reef No.1

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 13°56'54.43''S ;121°58'31.55''E
Elevation - Sea floor - +442.4m
Kelly bushing - -8.0m
Date Spudded - 06 / 02 / 1982
Rig Released - 18 / 06 / 1982
Total Depth - 4771m
Well Status - Plugged and abandoned; gas discovery

Well objective:

Tilted Triassic fault block in an eroded arch, onlapped by Lower to Middle Jurassic sediments. The objectives were Upper Jurassic sandstones and carbonates as penetrated by the Ashmore Reef No.1 and Mount Ashmore No.1B to the northeast, and the Scott Reef No.1 and Brecknock No.1 to the southwest.

Hole sizes:

36" - 495m
26" - 495m to 800m
17 1/2" - 800 to 2348m
12 1/4" - 2348m to 3894m
8 1/2" - 3894m to 4771m

Casing:

30" - Shoe at 488.0m
20" - Shoe at 786.0m
13 3/8" - Shoe at 2333.0m
9 5/8" - Shoe at 3880.0m
7" liner - Shoe at 4391.0m

Drilling summary:

The 36" and 26" holes were drilled with sea water and high viscosity slugs. The 17 1/2" hole was drilled at a controlled drill rate to 2348 metres, using a sea water polymer mud with periodic high viscosity slugs. The 12 1/4" hole was drilled to 3894 metres using a sea water/ gel mud. The mud density throughout the 17 1/2" and 12 1/4" sections was maintained at 1.08 specific gravity. The 8 1/2" hole section was drilled with a dispersed sea water resinex mud system. The well was drilled to TD and production tested without hole problems. The mechanical problems which occurred during drilling, such as washouts, fishing for backed off string and milling on junk, were successfully resolved.

Formation integrity:

2348m - 1.25 s.g. leak off
3894m - 1.69 s.g. leak off

Pore pressures:

The formations in North Scott Reef No.1 are normally pressured from surface to TD.

RFT Summary:

4114.5m	6515.9psig	1.11s.g.
4117.5m	6516.9psig	1.11s.g.
4180.5m	6538.9psig	1.10s.g.
4224.0m	6555.9psig	1.09s.g.
4242.0m	6557.9psig	1.09s.g.
4259.0m	6563.9psig	1.09s.g.
4281.5m	6573.9psig	1.08s.g.
4293.0m	6761.9psig	1.11s.g.

Production testing:

A production test was carried out over the interval 4223 to 4283 metres in a 7" liner and through a combined 3 1/2" and 5" test string. The well was flowed as follows:

Period (hours)	Oil Rate (bopd)	Gas rate (mmscfd)	GOR (cu ft/bbl)	Choke (64 ths)	Tubing (psi)
3.65	293	26.32	62.82	32	4250
5.75	484	45.04	64.99	48	3375
9.08	385	34.92	63.26	40	3940

NORTH SCOTT REEF 1

KB 8.0m

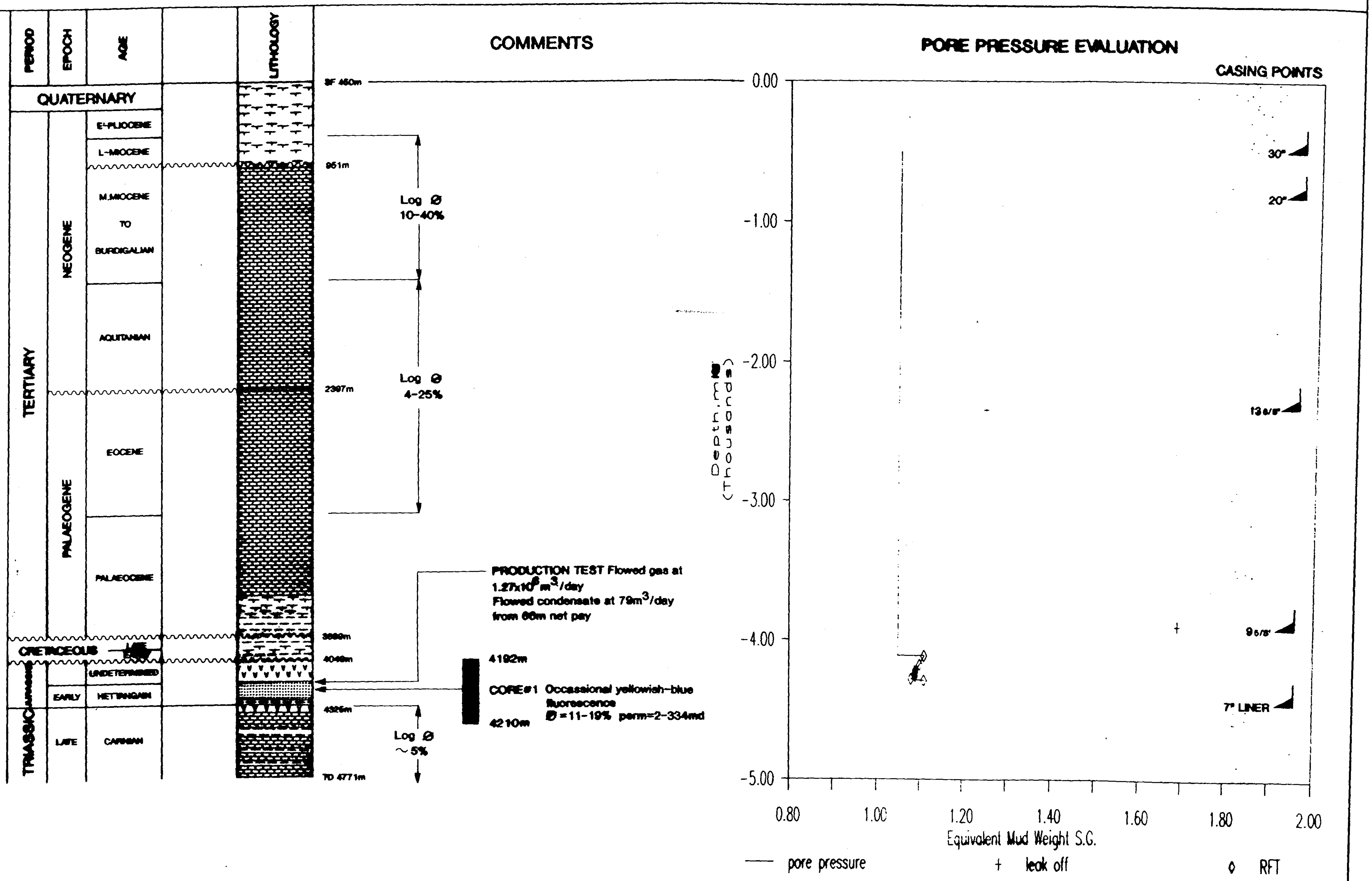
WD 442.4m

TD 4771m

STRUCTURE: Block faulted Lower to Middle Jurassic/Triassic sediments draped by Upper Jurassic and younger sediments,on the Scott Reef structural trend.

OBJECTIVES: Late Triassic/Early Jurassic sandstones.

COMMENTS: Subeconomic and undeveloped gas/condensate discovery.



1.1u Prudhoe No.1

General well data:

Operator - B.O.C. of Australia Ltd
Location - 13°44'55 75''S ;123°51'51.13''E
Elevation - Sea floor - +175.0m
Kelly bushing - -30.0m
Date Spudded - 13 / 09 / 1974
Rig Released - 12 / 11 / 1974
Total Depth - 3322 metres
Well Status - Plugged and abandoned

Well objective:

Prudhoe No.1 well was located on a fault bounded structure towards the northeast margin of the Browse Basin.

Hole sizes:

36" - 235m
26" - 235.0m to 512.0m
17 1/2" - 512.0m to 1328.0m
12 1/4" - 1328.0m to 3322.0m

Casing:

30" - Shoe at 228.0m
20" - Shoe at 505.0m
13 3/8" - Shoe at 1314.0m

Drilling summary:

The 36" and 26" hole sections were drilled using sea water with high viscosity gel slugs. The 17 1/2" hole was drilled to 892 metres, where the drill string was backed off at the stabilizer, leaving a fish consisting of two collars and a bit in the hole. Attempts to recover the fish were unsuccessful and the hole was sidetracked from 751 metres. Several L.C.M. plugs were pumped while attempting to set cement plugs for sidetracking because of fluid loss.

In the sidetracked 17 1/2" hole, persistent mud losses occurred from 892 metres, which had to be controlled with the addition of L.C.M. plugs. Sea water and a prehydrated gel mud system, lightly treated with C.M.C. for fluid loss control, was used for drilling in this hole section. Mud weight in this hole section was kept between 1.03 and 1.08 specific gravity.

Drilling of the 12 1/4" hole commenced using a saturated salt/polymer system. During drilling of this hole section, the mud weight was increased from 1.03 specific gravity to a maximum of 1.34 specific gravity to control shales.

Formation integrity:

Not available

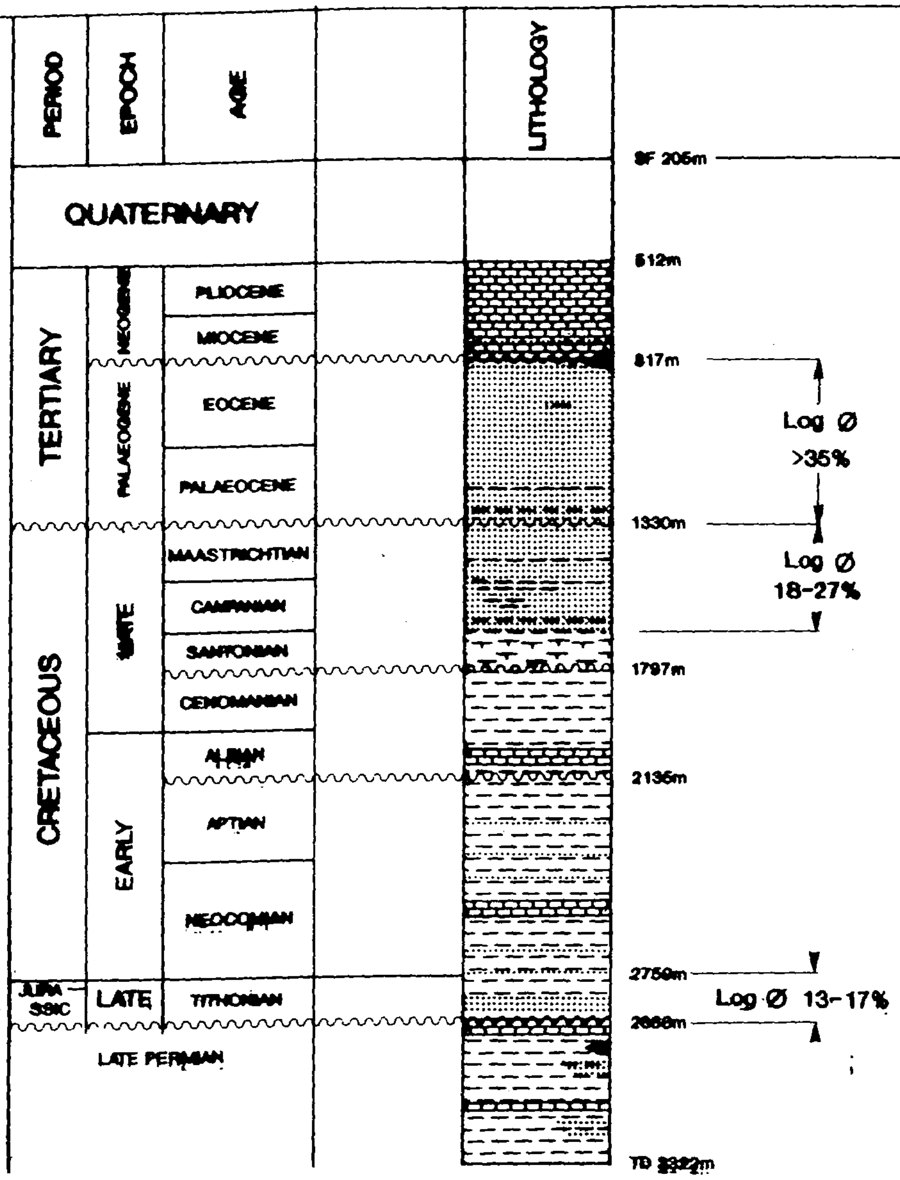
Pore pressures:

The formations in Prudhoe No.1 appear to be normally pressured.

PRUDHOE 1

KB 30m
WD 175m
TD 3322m

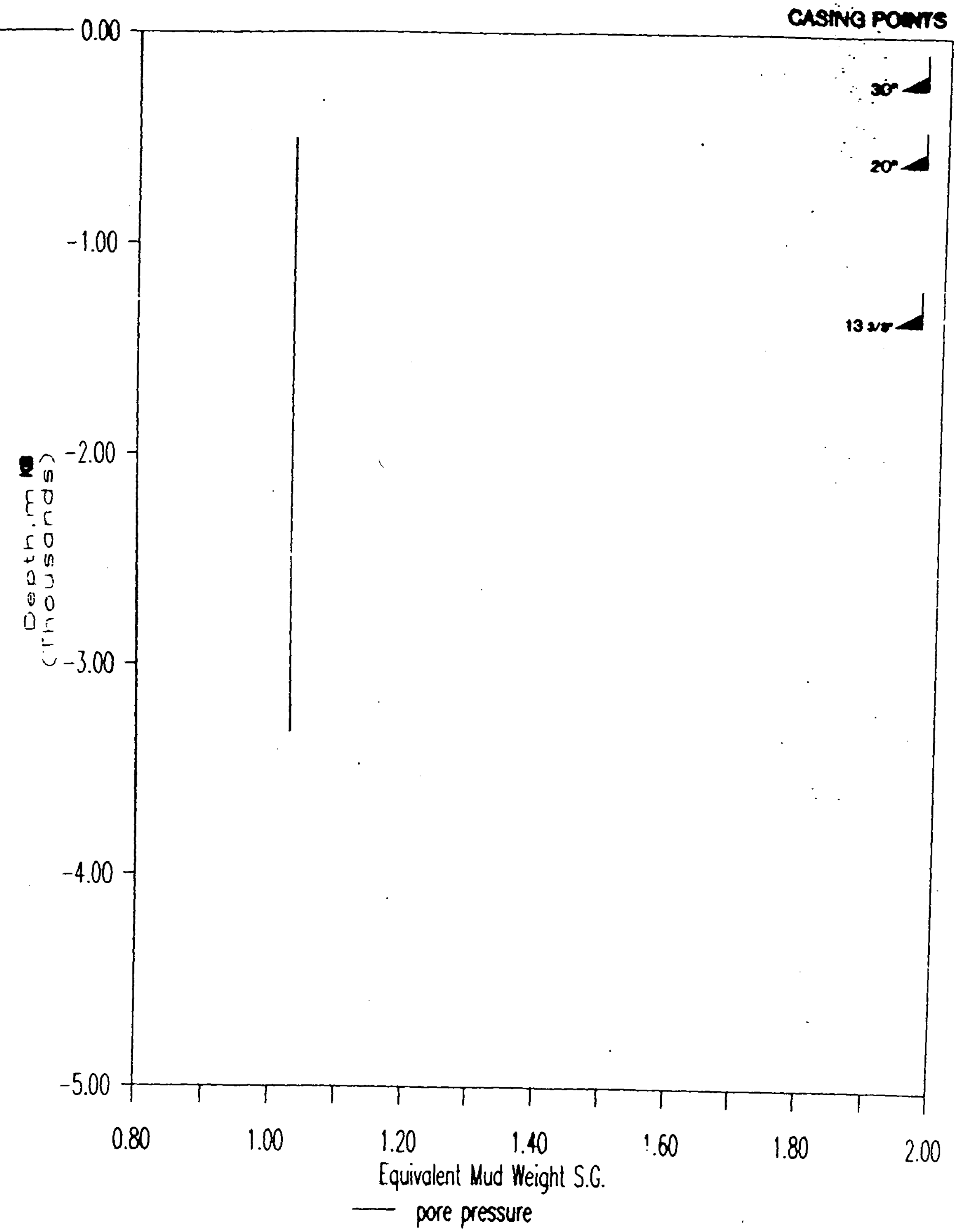
STRUCTURE: Tilted fault block on northeast basin margin.
OBJECTIVES: Early to Middle Jurassic.
COMMENTS: No structural closure at Jurassic Level.



COMMENTS

No significant hydrocarbon shows.

PORE PRESSURE EVALUATION



1.1v Rob Roy No.1

General well data:

Operator - B.O.C. Of Australia Ltd
Location - 13°58'15.60''S ;124°11'57.10''E
Elevation - Sea floor - +111.5m
Kelly bushing - -9.5m
Date Spudded - 27 / 01 / 1972
Rig Released - 28 / 02 / 1972
Total Depth - 2286m
Well Status - Plugged and abandoned

Well objective:

To investigate an anomalous dip zone apparent on seismic sections (interpreted as a possible carbonate buildup) on the western flank of the Rob Roy Graben. No carbonate buildup was penetrated and the anomalous dip zone was found to be the pre-Jurassic erosion surface.

Hole sizes:

36" - 148.4m
26" - 148.4m to 420.6m
17 1/2" - 420.6m to 1292.3m
12 1/4" - 1292.3m to 2286.0m

Casing:

30" - Shoe at 135.6m
20" - Shoe at 405.1m
13 3/8" - Shoe at 1280.2m

Drilling summary:

The 36" and 26" hole sections were drilled with sea water and slugs of gel mud. The 17 1/2" hole was drilled with sea water and gel slugs to 672 metres, where the system was converted to a low solids, sea water, prehydrated gel, Dextrid mud. The 12 1/4" hole was drilled with a low solids polymer mud. Mud density was kept between 1.05 and 1.09 specific gravity throughout the entire hole section. There were no hole problems reported.

Formation integrity:

Not available

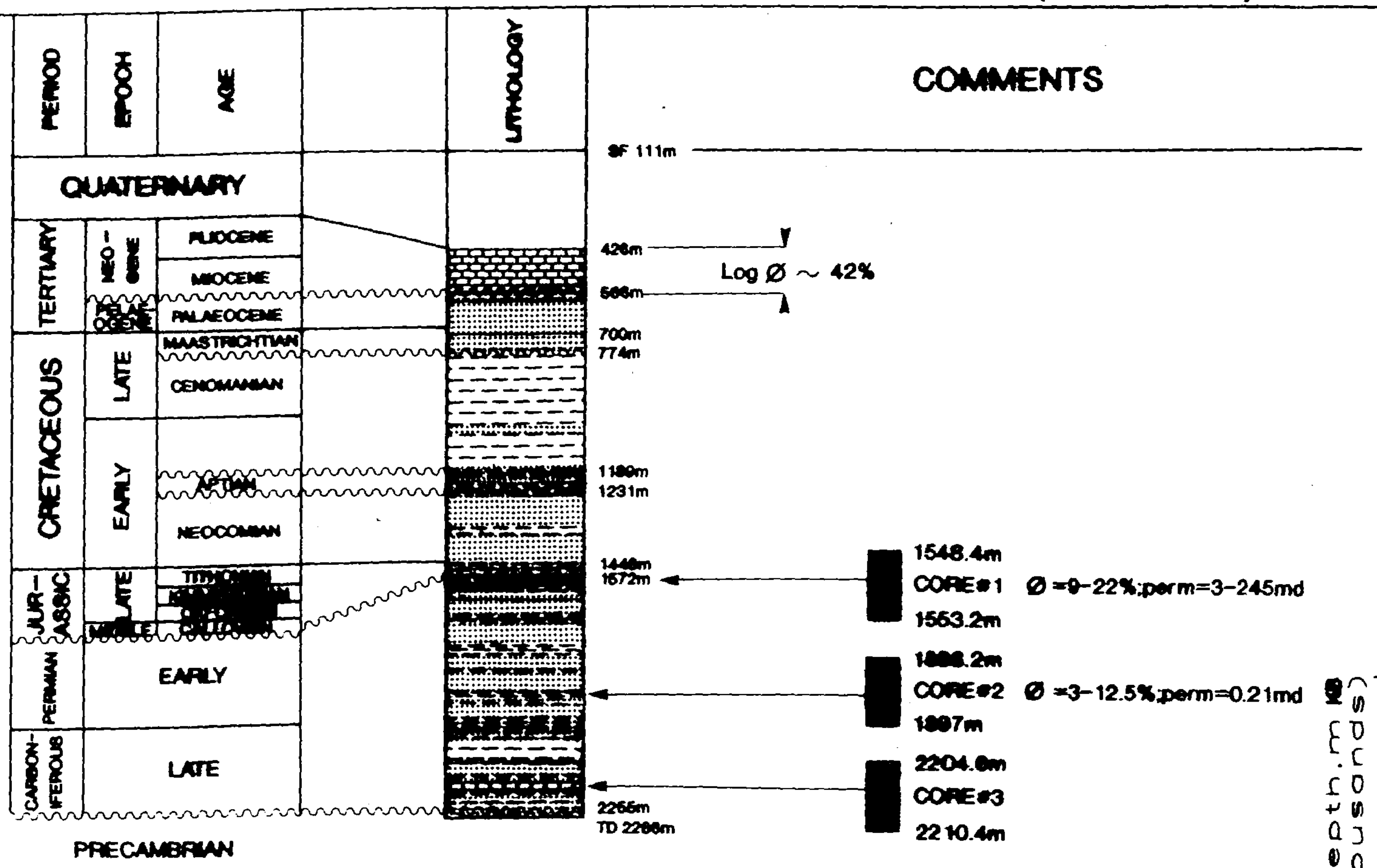
Pore pressures:

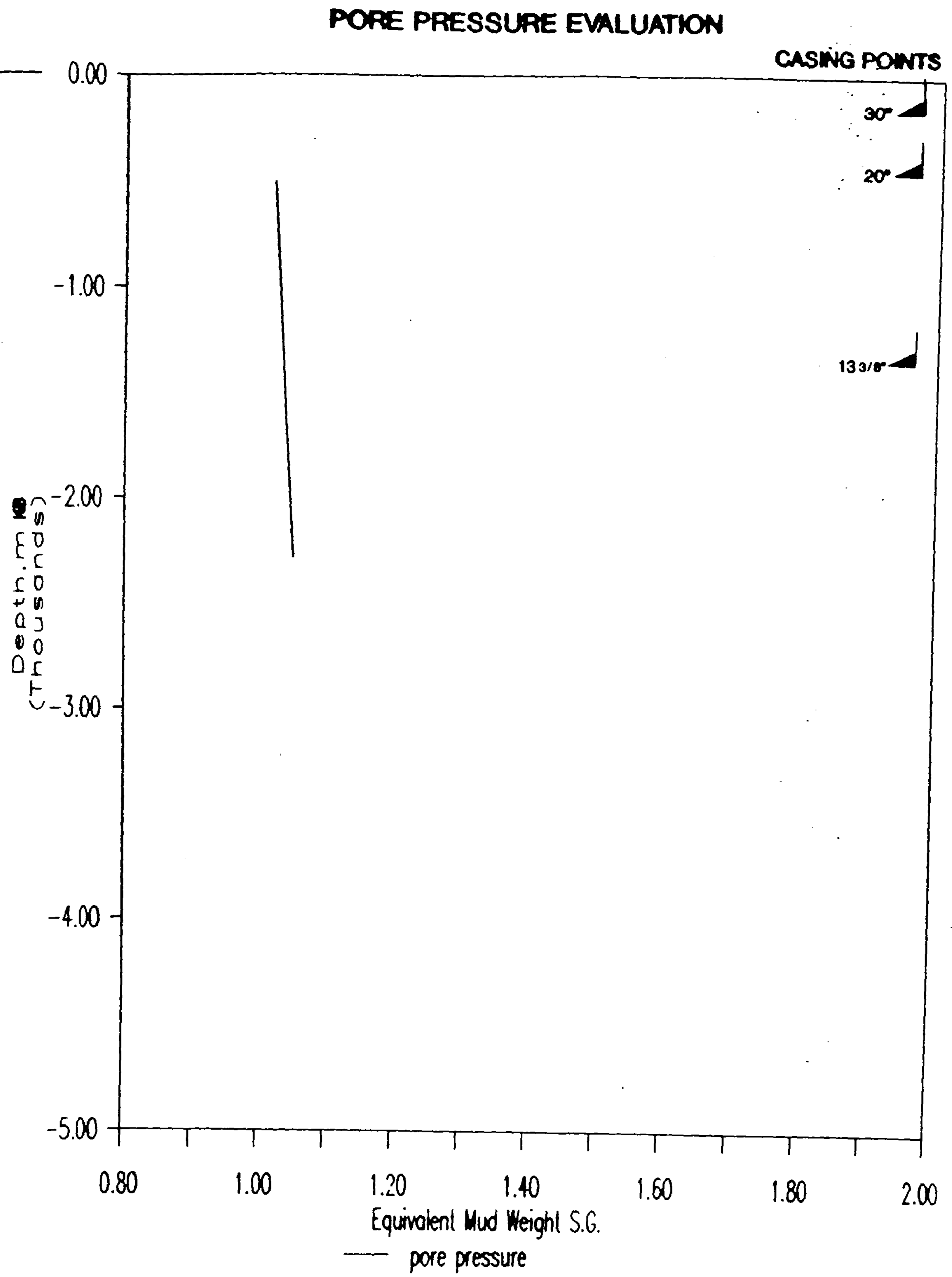
The formations in Rob Roy No.1 are normally pressured.

ROB ROY 1

KB 9.5m
WD 111.5m
TD 2286m

STRUCTURE: Drilled to test postulated carbonate build up.
OBJECTIVES: Jurassic reef.
COMMENTS: Dip reversal apparent on seismic data proved to be pre-Jurassic erosion surface.





1.1w Scott Reef No.1

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 14°04'33.99''S ;121°49'28.76''E
Elevation - Sea floor - +49.6m
Kelly bushing - -9.5m
Date Spudded - 18 / 02 / 1971
Rig Released - 09 / 06 / 1971
Total Depth - 4730.5m
Well Status - Temporarily abandoned; gas well

Well objective:

To investigate the hydrocarbon potential of the Scott Reef anticlinal structural trend extending from Scott Reef to Seringapatam Reef.

Hole sizes:

36" - 88.4m
26" - 88.4m to 326.1m
17 1/2" - 326.1m to 1783.1m
12 1/4" - 1783.1m to 3395.5m
8 1/2" - 3395.5m to 4423.0m
6" - 4423.0m to 4730.5m

Casing:

30" - Shoe at 83.5m
20" - Shoe at 316.1m
13 3/8" - Shoe at 1770.9m
9 5/8" - Shoe at 3382.4m
7" liner - Shoe at 4411.7m

Drilling summary:

The 36" and 26" holes were drilled using sea water and slugs of gel mud. The same mud system was used in the 17 1/2" hole to 624 metres, where a complete loss of circulation occurred. The mud system was changed to aerated sea water to the 13 3/8" casing setting point.

Drilling was continued in the 12 1/4" hole using a Dextrid low solids mud system. The 8 1/2" hole was drilled with a Dextrid/XC polymer mud system, However, increased mud weight (1.2 specific gravity) was required to control tight shales below 4069 metres. The intervals 4076 to 4200 metres and 4230 to 4377 metres were drilled with a turbo drill and diamond bit at greatly increased penetration rates. The 6" hole was drilled to TD reverting back to a Dextrid mud system. After a production test was performed, the well was plugged and abandoned.

Formation integrity:

1783m - 1.27 s.g. limit test
3400m - 1.27 s.g. limit test

Pore pressures:

The formations in Scott Reef No.1 are normally pressured from surface to TD.

FIT summary:

4299.8m Final shut in pressure 6600psi (1.08 s.g.)
Recovery: 242.3 cu.ft. gas
40 c.c. condensate, 43.33 API gravity
636 c.c. water
50 c.c mud

Production testing:

Four cased hole production tests were performed. The 7" liner was perforated with 2 7/8" Ceramic Unijet guns. The test string consisted of 2 7/8" tubing, 5" tubing and a Halliburton RTTS packer.

Test No.1

Perforated intervals: 4340.4m - 4346.4m
4718.0m - 4354.1m
4361.7m - 4367.8m

Pressure recorders: Top at 4328.2m; Bottom at 4335.5m

Pressure readings:	Top gauge	Bottom gauge	Recovery
Initial hydrostatic	7416 5psi	7445.0psi	
First initial flow		5497.1psi	Cushion to surface
First final flow		6031.7psi	Gas to surface
First shut in		6591.7psi	Dry gas to surface
Second initial flow mmcf/d;3/8"		5924.9psi	8 mmcf/d; 3/8" choke
Second final flow		5817.9psi	11 mmcf/d; 1/2 choke
Second shut in		6591.7psi	

Test No.2

Perforated intervals: 4340.4m - 4346.4m
4718.0m - 4354.1m
4361.7m - 4367.8m
4380.0m - 4383.0m

Pressure recorders: Top at 4328.2m; Bottom at 4335.5m

Pressure readings:	Top gauge	Bottom gauge	Recovery
Initial hydrostatic		7365.0psi	
First initial flow		5337.0psi	Cushion to surface
First final flow		6058.0psi	Gas to surface
First shut in		6565.0psi	
Second initial flow		5952.0psi	16 7 mmcf/d; 1" choke
Second final flow		5817.9psi	9.5 mmcf/d; 3/8" choke
Second shut in		6591.7psi	

Test No.3

Perforated intervals: 4380.0m - 4386.1m

Pressure recorders: Top at 4369.3m; Bottom at 4376.6m

Pressure readings:	Top gauge	Bottom gauge	Recovery
Initial hydrostatic		7450.3psi	
First initial flow		3442.6psi	
First final flow		3509.2psi	
First shut in		6578.3psi	
Second initial flow		2777.1psi	Cushion to surface
Second final flow		3789.2psi	Gas to surface
Second shut in		6498.3psi	9.8 mmcf/d; 1" choke GOR 20 bbl/ mmcf

Test No.4

Perforated intervals: 4299.2m - 4305.3m

Pressure recorders: Top not run; Bottom at 4292.8m

Pressure readings:	Top gauge	Bottom gauge	Recovery
Initial hydrostatic		7365.0psi	
First initial flow		6271.7psi	
First final flow		6239.7psi	
First shut in		6575.7psi	
Second initial flow		6271.7psi	Cushion to surface

Test No. 4 (continued)

Second final flow	6431.7psi	Gas to surface 18.28 mmcf/d; 1" choke GOR 20 bbl/ mmcf
Second shut in	6575.7psi	

SCOTT REEF 1

KB 9.5m

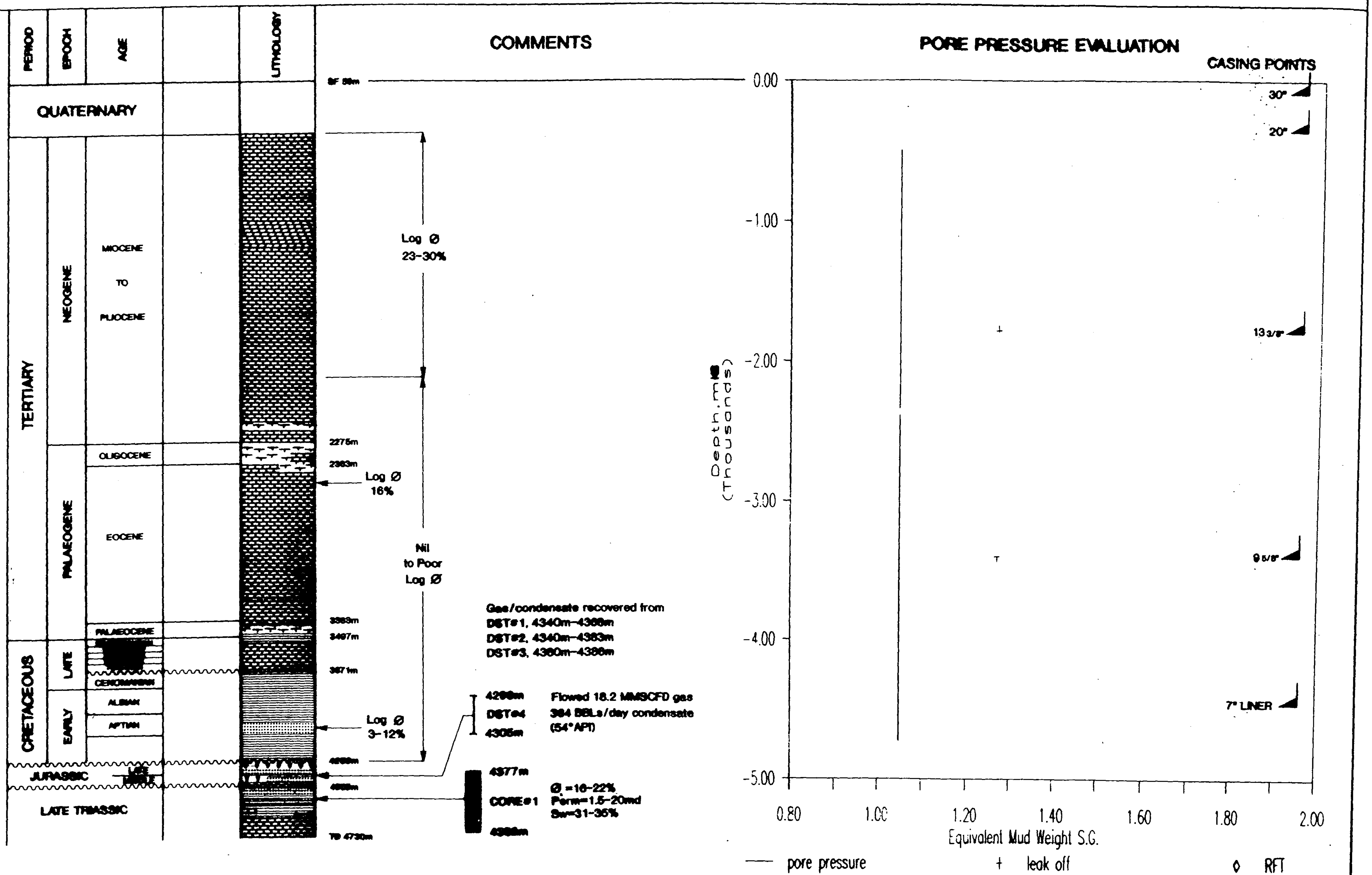
WD 49.6m

TD 4730.5m

STRUCTURE: Drilled on culmination of Scott Reef structural trend.

OBJECTIVES: Tertiary and Mesozoic

COMMENTS: Subeconomic and undeveloped gas/condensate discovery.



1.1x Scott Reef No.2A

General well data:

Operator - Woodside Petroleum Development Pty Ltd
Location - 14°06'05.67''S ;121°51'28.09''E
Elevation - Sea floor - +56.4m
Kelly bushing - -8.0m
Date Spudded - 27 / 04 / 1977
Rig Released - 09 / 08 / 1977
Total Depth - 4820m
Well Status - Plugged and abandoned; hydrocarbon shows

Well objective:

The well was drilled to test the eastern flank of the Scott Reef high. The Scott Reef structure lies on the Scott Reef Trend in the western Browse Basin.

Hole sizes:

36" - 98m
26" - 98m to 377m
17 1/2" - 377 to 1774m
12 1/4" - 1774m to 3615m
8 1/2" - 3615m to 4659m
6" - 4659m to 4820m

Casing:

30" - Shoe at 87.5m
20" - Shoe at 363.8m
13 3/8" - Shoe at 1759.0m
9 5/8" - Shoe at 3588.0m
7" liner - Shoe at 4628.0m

Drilling summary:

The 36" and 26" holes were drilled with sea water and high viscosity gel slugs. The 17 1/2" hole was drilled with aerated sea water. Repeated lost returns were experienced between 1535 and 1676 metres.

The 12 1/4" hole was drilled with a lightly dispersed sea water system. At 2873 metres, circulation was lost while drilling with 1.07 specific gravity density mud. In the 8 1/2" hole section, the mud weight was gradually increased to 1.49 specific gravity as the 7" liner setting depth was approached. Bad hole conditions in this section required several clean out trips to keep the hole clean. In the 6" hole section, the mud weight was reduced to 1.30 specific gravity.

Formation integrity:

1759m - 1.10 s.g. leak off

Pore pressures:

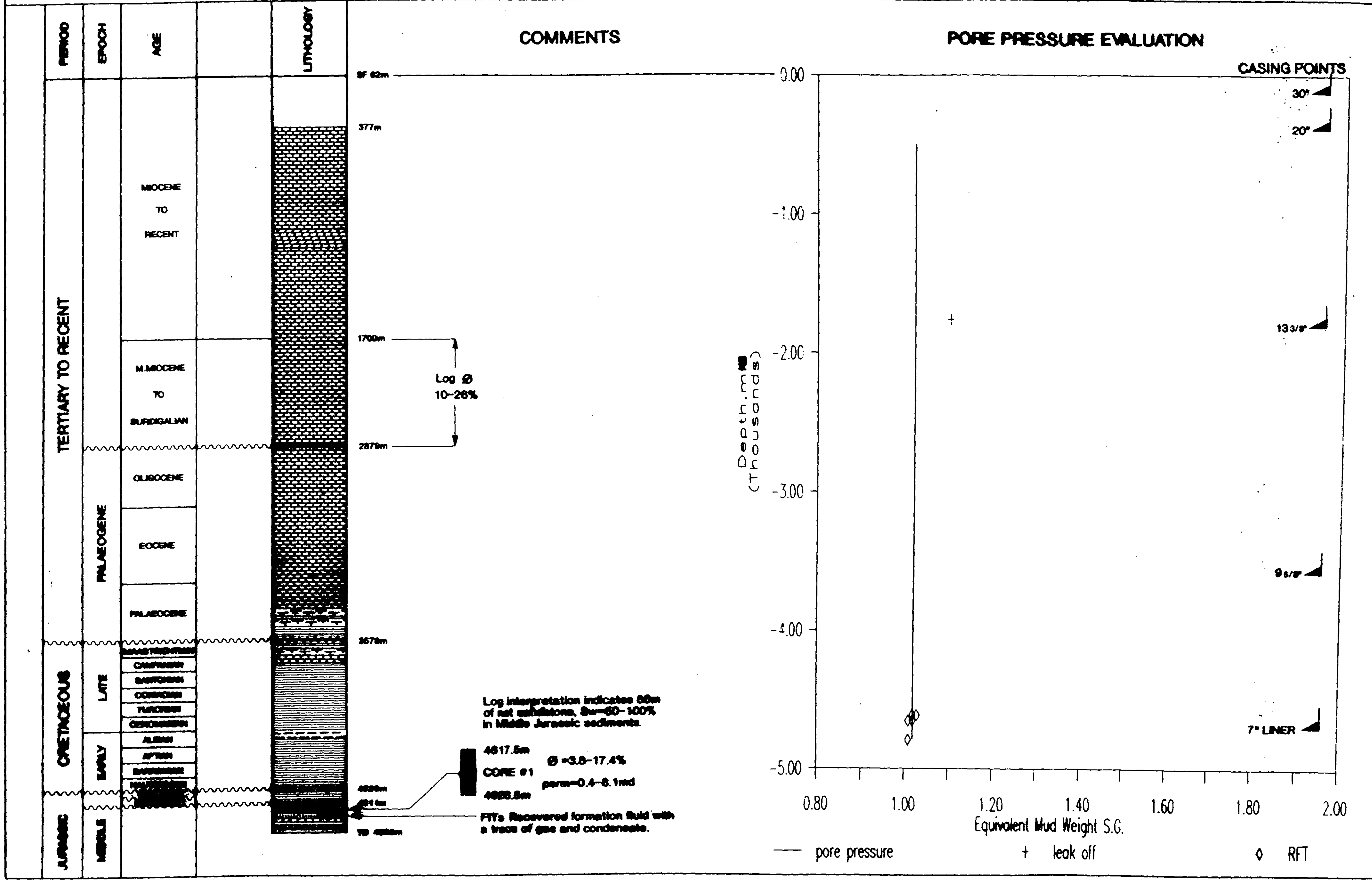
The hole appears to be normally pressured from surface to TD.

FIT Summary:	4613.8m	6689.2psig	1.02s.g.
	4613.8m	6682.5psig	1.02s.g.
	4616.8m	6768.4psig	1.03s.g.
	4616.8m	6755.1psig	1.03s.g.
	4792.0m	6884.4psig	1.01s.g.
	4792.0m	6886.5psig	1.01s.g.
	4655.0m	6705.9psig	1.01s.g
	4655.0m	6772.1psig	1.02s.g.

SCOTT REEF 2A

KB 8.0m
WD 56.4m
TD 4820m

STRUCTURE: Drilled to test eastern extent of Scott Reef gas/condensate discovery.
OBJECTIVES: Jurassic/Late Triassic
COMMENTS: Interpreted to have intersected a gas/water transition zone in Middle Jurassic sediments.



1.1y Woodbine No.1

General well data:

Operator - Woodside Offshore Development Pty Ltd
Location - 12°38'42 74''S ;124°08'49.46''E
Elevation - Sea floor - +189.0m
Kelly bushing - -8.0m
Date Spudded - 06 / 03 / 1979
Rig Released - 19 / 05 / 1979
Total Depth - 3502m
Well Status - Plugged and abandoned; dry well

Well Objective:

The well was drilled to test the Maastrichtian-Campanian sandstones encountered in the Puffin wells some 33 kilometres to the north.

Hole sizes:

36" - 240m
26" - 240m to 515m
17 1/2" - 515 to 1174m
12 1/4" - 1174m to 1847m
8 1/2" - 1847m to 3300m
6" - 3300m to 3502m

Casing:

30" - Shoe at 231m
20" - Shoe at 495m
13 3/8" - Shoe at 1163m
9 5/8" - Shoe at 1832m
7" liner - Shoe at 3291m

Drilling summary:

The 36" and 26" holes were drilled with sea water and high viscosity bentonite plugs. Q-mix was added to the sea water after the 20" casing shoe was drilled out. The 17 1/2" hole was drilled to 917 metres, where a complete loss of circulation occurred. Drilling continued to 951 metres with no returns. Mica mud pills were pumped and two cement plugs were set in an attempt to seal off the formation. After the cement had been drilled out, mud losses continued to 1174 metres, despite L.C.M. being continuously added to the mud.

The 12 1/4" hole was drilled to 1755 metres, where mud circulation was suddenly lost. Circulation was regained and the hole was drilled to 1770 metres, where circulation was lost again. At this point the drill string become stuck. Attempts to free the pipe were unsuccessful and the hole had to be sidetracked from 1299 metres. The sidetracked hole was drilled to 1847 metres, with L.C.M. added continuously to control mud losses.

Drilling continued in the 8 1/2" hole to 330 metres, with L.C.M. being added to control mud losses. The mud weight was increased gradually from 1.07 to 1.24 specific gravity to control tight hole and condition the hole for logging. The 6" hole was drilled to 3502 metres with the mud weight reduced to 1.12 specific gravity. A final suite of electric logs was run and the side wall cores were taken. The hole was then plugged and abandoned.

Formation integrity:

1179m - 1.28 s.g. leak off
1853m - 1.19 s.g. leak off

Pore pressures:

The formations in Woodbine No.1 are normally pressured. Pressure gradient regression of some 120 psi is apparent in the depth range 2805 to 3105 metres.

RFT summary:	1941.4m	2875psig	1.04s.g.
	2341.4m	3474psig	1.05s.g.
	2560.4m	3803psig	1.05s.g.
	2599.4m	3860psig	1.05s.g.
	2651.4m	3936psig	1.05s.g.
	2751.4m	4082psig	1.05s.g.
	3177.4m	4603psig	1.02s.g.
	3177.4m	4614psig	1.02s.g.
	3276.0m	4733psig	1.02s.g.

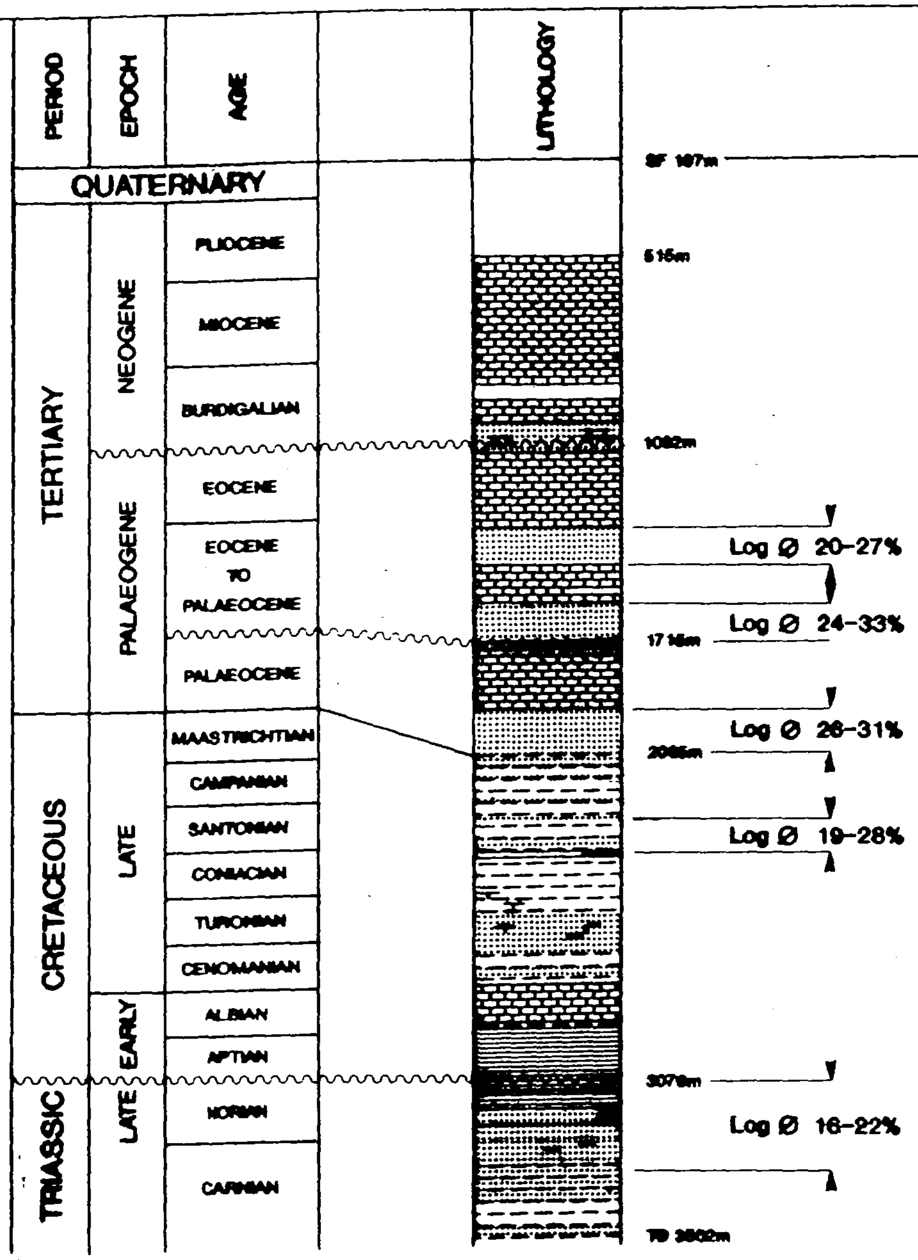
WOODBINE 1

KB 8.0m
WD 189m
TD 3502m

STRUCTURE: Triassic/Jurassic horst block with Cretaceous and Tertiary drape.

OBJECTIVES: Maastrichtian and Campanian sandstones.

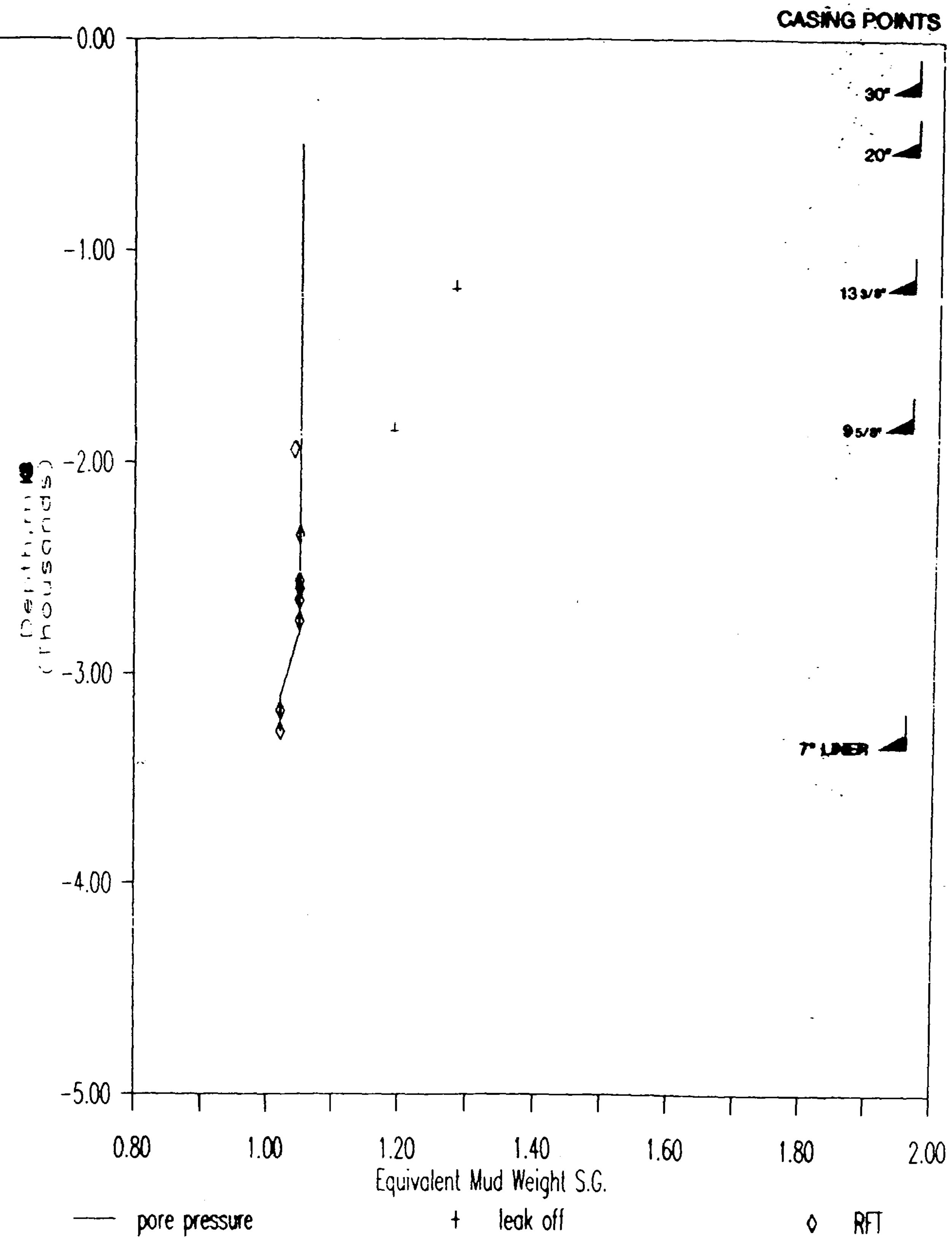
COMMENTS: Jurassic section proved to be absent.



COMMENTS

No significant hydrocarbon shows.

PORE PRESSURE EVALUATION



1.1z Yampi No.1

General well data:

Operator - B.O.C. of Australia Ltd
Location - 14°33'32.00''S ;123°16'33.88''E
Elevation - Sea floor - +91.0m
Kelly bushing - -13.0m
Date Spudded - 03 / 06 / 1973
Rig Released - 27 / 09 / 1973
Total Depth - 4176m
Well Status - Plugged and abandoned

Well objective:

To test the hydrocarbon potential of a well-defined Permo-Triassic fault controlled anticline.

Hole sizes:

36" - 135.0m
26" - 135.0m to 408.0m
17 1/2" - 408.0m to 1530.0m
12 1/4" - 1530.0m to 3048.0m
8 1/2" - 3048.0m to 4176.0m

Casing:

30" - Shoe at 123.0m
20" - Shoe at 399.0m
13 3/8" - Shoe at 1520.0m
9 5/8" - Shoe at 3035 0m

Drilling summary:

The 36" and 26" hole sections were drilled with sea water and slugs of gel mud. In the 17 1/2" hole section, drilling commenced with a sea water gel and was gradually built up to a dispersed 1.08 specific gravity mud system before logging.

The 12 1/4" hole section was drilled with a non-dispersed polymer mud system built to a density of 1.44 specific gravity to overcome tight hole conditions in the shales below 2230 metres.

The 8 1/2" hole section was drilled with a low solids, sea water, prehydrated gel, Dextrid mud system. The mud density was kept at 1.36 specific gravity to overcome hole problems in the volcanic section.

Formation integrity:

Not available

Pore pressures:

Formations in Yampi No.1 are normaly pressured.

FIT summary:	3265m	4771.82psi	1.03s.g.
	3265m	4797.92psi	1.04s.g.
	3175m	6076.45psi	1.35s.g. hydrostatic
	3175m	6053.68psi	1.35s.g. hydrostatic

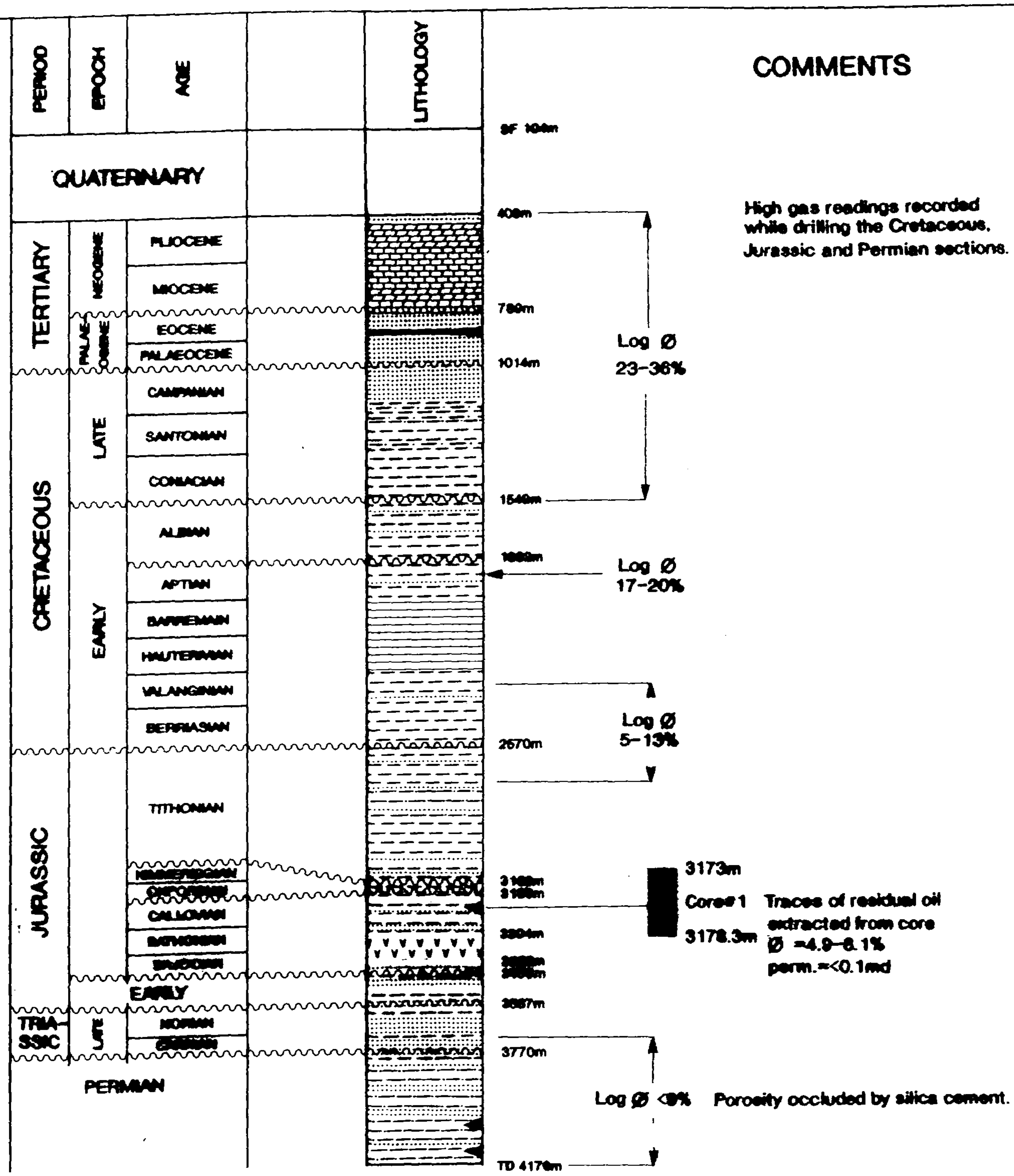
YAMPI 1

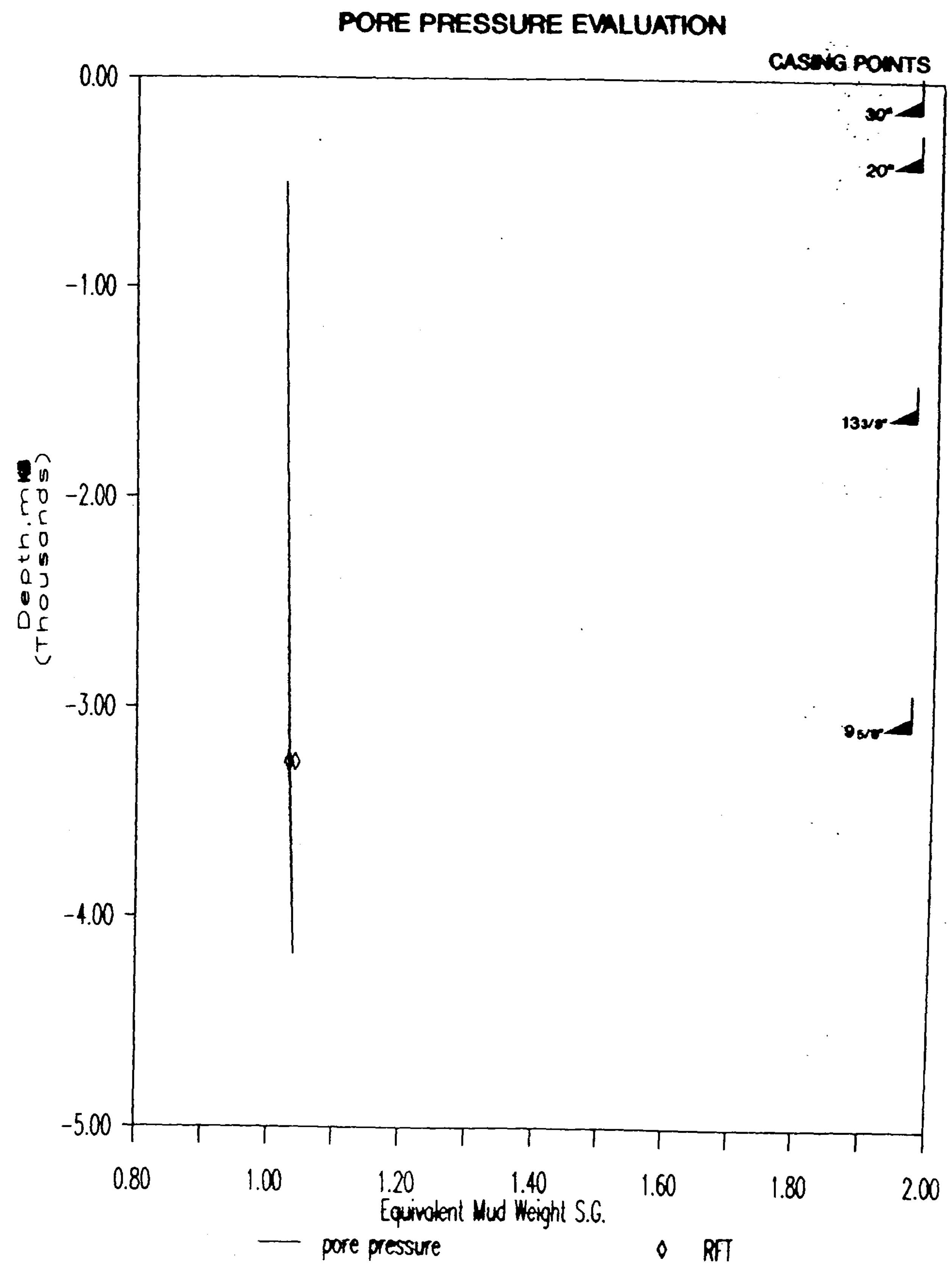
KB 13.0m
WD 91m
TD 4176m

STRUCTURE: Easterly trending fault-controlled Permo-Triassic anticline.

OBJECTIVES: Triassic

COMMENTS: Subsequently found not to have tested a valid structure.





2. RESERVOIR GEOLOGY AND HYDROCARBON SHOW EVALUATION

(S. Miyazaki)

This chapter deals with the evaluation of reservoir rocks and the analysis of hydrocarbon indications observed in each of the wells drilled in the Browse Basin. Reservoir quality has been quantitatively appraised by means of wire-line log evaluation and by the analysis of RFT (repeat formation tester), FIT (formation interval test), DST (drill-stem test), production test and conventional core data. All depths are measured from rotary table or kelly bushing.

2.1a Adele Island No.1

Adele Island No.1 was drilled on the northern tip of Adele Island by Brunswick Oil in 1982 and terminated at 789.5 metres in Proterozoic basement. The rotary table elevation was 2.9 metres above ground level (4 metres above sea level).

The Cretaceous and Jurassic section between 160 and 785 metres consists of sandstone, siltstone, mudstone, dolostone and lignite, and rests on Proterozoic quartzite. The sandstones have good porosity and permeability. However, no hydrocarbon shows were recorded in this well.

2.1b Ashmore Reef No.1

Ashmore Reef No.1 was drilled as a stratigraphic well by BOC in 1967/68 and terminated in Triassic clastics at 3915 metres. The rotary table elevation was 10.1 metres above sea level. This was the first well drilled on the North West Shelf of Australia.

Well-head gas readings were insignificant throughout the entire section and peaked in an interval from 2485 to 2491 metres within Upper Jurassic altered amygdaloidal basalt. Hydrocarbon gases appear to have been trapped in fractures in the volcanics. No hydrocarbon shows were recorded in a total of 121 sidewall core samples. However, nitrogen gas was detected throughout almost the entire well, including the Miocene limestone interval where no hydrocarbon gases were recorded.

A total of 27 conventional cores were cut in this well, and the analytical results are shown on the following Table. Good porosity and permeability are preserved in the uppermost Triassic sandstones.

An FIT was run at 2813 metres in Upper Triassic sandstones, which are overlain unconformably by Jurassic

Ashmore Reef-1 core analysis

Core No	Interval (mRT)	Recovery (m)	Age	Lithology	Porosity (%)	Permeability (md)
1	343 - 351	0.2	Miocene	limestones		
2	697 - 704	4.4	Miocene	limestones	21 - 35	19 - 1134
3	798 - 806	4.0	Miocene	calcilutites	19 - 24	1 - 5
4	884 - 892	6.7	Miocene	calcilutites	14 - 21	0.2 - 2
5	979 - 988	0				
6	989 - 997	0				
7	1104 - 1111	4.9	Oligocene	claystones		
8	1230 - 1238	7.9	Eocene/ Paleocene	calcarenites	18 - 30	20 - 312
9	1384 - 1392	7.8	Eocene/ Paleocene	calcilutites	6 - 14	0.0 - 0.3
10	1530 - 1535	4.6	Eocene/ Paleocene	calcilutites	15 - 21	0.3 - 1.8
11	1687 - 1693	4.3	Eocene/ Paleocene	calcilutites	11 - 21	1 - 11
12	1836 - 1842	6.1	Eocene/ Paleocene	limestones	4 - 19	0.0 - 0.7
13	1987 - 1991	3.0	Eocene/ Paleocene	limestones		
14	2051 - 2057	5.5	Paleocene/ Late Cretaceous	calcilutites, claystones, marl		
15	2210 - 2215	4.1	Paleocene/ Late Cretaceous	marl, calcilutites		
16	2309 - 2313	4.6	Paleocene/ Late Cretaceous	limestones	5 - 9	0.0 - 0.1
17	2443 - 2445	1.2	Late Jurassic	claystones		
18	2524 - 2527	2.7	Jurassic	basalt		
19	2693 - 2696	2.3	Jurassic	basalt		

Ashmore Reef-1 core analysis (continued)

Core No	Interval (mRT)	Recovery (m)	Age	Lithology	Porosity (%)	Permeability (md)
20	2833 - 2840	6.7	Late Triassic	claystones, sandstones, siltstones	7 - 19	2 - 956
21	2969 - 2973	4.3	Late Triassic	calcilutites, mudstones, sandstones	8 - 12	0.1 - 33
22	3063 - 3067	4.6	Late Triassic	sandstones, claystones	10 - 17	5 - 31
		Hydrocarbon shows: The sandstones exhibited solvent fluorescence with rings. (BOC interpreted it as being a result of diesel oil contamination.)				
23	3223 - 3226	2.4	Late Triassic	sandstones	0 - 6	0.0 - 0.4
24	3360 - 3363	3.4	Late Triassic	claystones, limestones		
25	3571 - 3573	2.4	Late Triassic	claystones		
26	3676 - 3679	3.0	Late Triassic	claystones, limestones		
27	3787 - 3790	3.0	Late Triassic	limestones, claystones		

volcanics. The two sample chambers were filled with water.

2.1c Asterias No.1

Asterias No.1 was drilled by BHP in 1987 and reached a total depth of 4402 metres in Tithonian sandstones. The kelly bushing elevation was 17.6 metres above sea level.

Ditch cuttings showed weak intermittent fluorescence from 3310 metres to total depth. Sandstone cuttings from 4324 to 4330 metres displayed spotted, dull fluorescence and streaming cuts with residual rings.

Aptian and Barremian sandstones from 3413 to 3499 metres have a net thickness of 67 metres and an average log porosity of 20 %. RFT pressure drawdown data from this interval indicate that the sandstones have a permeability of 10 millidarcys. Sidewall cores taken from this interval showed minor fluorescence and instantaneous cuts. However, the entire interval appears to be water-wet. The sandstone interval is overlain by 450 metres of Lower Cretaceous claystone.

Valanginian and Berriasian sandstones from 3647 to 3729 metres have a net thickness of 47 metres and an average porosity of 12 %. None of 12 sidewall core samples recovered from this interval exhibited hydrocarbon shows. RFT pressure data indicates that these sandstones tend to be tight and have permeabilities of less than 0.5 millidarcys. There appears to be no moveable hydrocarbons in this interval. This sandstone is overlain by 150 metres of Lower Cretaceous claystone.

Two RFT fluid-sampling tests were carried out for this interval. The first, at 3651.1 metres, recovered 6.2 litres of filtrate in a 10.4-litre sample chamber. The second, at 3716.0 metres, recovered 3.0 litres of filtrate in a 3.8-litre chamber.

Well-head gas reading reached a peak of 17 %, including 0.2 % of butane (C4), at 4332 metres in Tithonian sandstone between 4321 and the total depth of 4402 metres. Coincident with the high gas readings, a gas kick took place at 4332 metres. This forced the drillers to increase the mud weight from 1.13 to 1.30 grams per cubic centimetre to control the well. A number of sidewall core samples from the Tithonian sandstone interval displayed similar hydrocarbon shows to those recorded in the cuttings.

The bottom-hole Tithonian sandstones have a net thickness of 34 metres and an average log porosity of 15 %. Within this interval, a zone between 4373 and 4379 metres has a porosity of 27 %. However, microscopic examination of fragments of ditch cuttings taken from 4376 to 4379 metres, showed that the sample consists of very fine-grained, quartzose sandstones of low porosity. Much of the primary porosity has been filled with quartz overgrowths. This sandstone interval is overlain by 550 metres of Upper Jurassic and Lower Cretaceous claystone and siltstone.

The determination of formation water salinity is difficult in these Tithonian sandstones. This is because there are no water-wet clean sandstones and the SP log did not cover the sandstone zone between 4373 and 4379 metres. If the formation water has a salinity similar to that of sea water, then this sandstone zone has a water saturation of 40 %.

Hydrocarbons extracted from a sidewall core sample at 4325 metres, showed faint fluorescence, cuts and residual rings. A gas chromatographic analysis revealed that the sample contains a number of heavy-range hydrocarbons indicative of oil.

No RFT was carried out in the 6-inch hole below the 7-inch liner shoe at 4001 metres. A post-drill top Tithonian sandstones map indicates that the well was drilled on a saddle between two faulted-anticlines with three and two square kilometres of closure, respectively. These structures may actually form a single faulted-anticline within a compartmented fault block (closure of 12 square kilometres). Thus, the Tithonian sandstones in this area may hold further potential.

2.1d Barcoo No.1

Barcoo No.1 was drilled by Woodside in 1979/80 and reached a total depth of 5109 metres in Triassic recrystallised limestones. The rotary table elevation was 11 metres above sea level. The well is the deepest well in the Browse Basin.

Well-head gas readings were minimal during drilling, the highest readings being 22 ppm of ethane (C2) at 3585 metres in Lower Cretaceous claystones. No fluorescence was observed in ditch cuttings. Of 277 sidewall core samples recovered from the well, no samples above 3275 metres or below 4219 metres showed fluorescence. Among a total of 96 samples recovered from between 3284.5 to 4184 metres in the Cretaceous and Jurassic sections, 54 samples gave fluorescence (mainly solvent fluorescence).

Porous rocks are absent in both the Cretaceous section between 2702 and 3796 metres and the Middle to Upper Jurassic section between 3796 and 3829 metres.

The Lower Jurassic section between 3829 and 4748 metres includes two sandstone zones. The first, between 3829 and 4028 metres has a net thickness of 105 metres and a porosity of 18 %. The second, between 4105 and 4130 metres, has a net thickness of 14 metres and a porosity of 11 %. Both units are water-wet.

A total of five RFTs, run in the Lower Jurassic sandstones, established a water gradient line. One of the five tests was a fluid-sampling test at 3961 metres, and its two chambers, 22.7 and 3.8 litres, recovered 21.5 and 3.5 litres of water, respectively.

The Triassic section between 4748 metres and the total depth of 5109 metres consists of claystone, tight recrystallised limestone and siltstone, with minor interbeds of sandstone and volcanics. Limestones between 5003 and 5020 metres have a porosity of 3 %.

2.1e Bassett No.1A

Bassett No.1A was drilled by Woodside in 1978 and reached a total depth of 2706 metres in Lower Cretaceous claystone. The rotary table elevation was 8 metres above sea level.

Well-head gas readings were minimal while drilling, and no hydrocarbon shows were recorded either in ditch cuttings or in a total of 74 sidewall core samples. No formation tests were carried out in this well.

Campanian sandstones, in the interval 2198 to 2307 metres, have a net thickness of 82 metres and an average log porosity of 18 %. The entire section is water-wet. Microscopic examination showed the sandstones are fine-grained, sub-angular, quartzose and well-sorted, with a calcite matrix. These sandstones are overlain by 125 metres of Maastrichtian claystone.

Below these Campanian sandstones, there are Cretaceous non-reservoir rocks down to a total depth of 2706 metres. The well bottomed in Albian claystone.

2.1f Brecknock No.1

Brecknock No.1 was drilled by Woodside in 1979 and terminated at 4300 metres in Ladinian silty claystone. The rotary table elevation was 11 metres above sea level. A gas and condensate pool was discovered by RFT fluid-sampling in Lower Jurassic sandstone.

Gas readings were moderately high, from 3822 to 4018 metres within the Jurassic and Triassic sections. No pentane (C5) gases were detected at the well-head. Weak fluorescence, recorded in a sample between 3983 and 3986 metres, is the only hydrocarbon indication recognized in ditch cuttings from this well. A total of 18 sidewall core samples from 3800 to 3927 metres (within the Jurassic section), displayed various degrees of cut fluorescence.

Lower Jurassic sandstones, from 3829 to 3907 metres, have a combined net gas column of 63 metres, an average log porosity of 17 %, and a water saturation of 34 %. The upper sandstones, above 3863 metres (interbedded with siltstone and claystone), are inferior in reservoir quality to the lower sandstones, which consists of massive, clean sandstones. Callovian sandstones and tuffaceous volcanics unconformably overlie the Lower Jurassic sandstones and are, in turn, overlain by Cretaceous claystone. A total of seven RFT fluid-sampling tests were carried out in the Lower Jurassic sandstones. The presence of a gas and condensate pool was inferred on the following Table.

Brecknock-1 RFT fluid-sampling results

RFT No	Depth (mRT)	Chamber (litres)	Condensate (litres)	(°API)	Gas (m^3)	Filtrate (litres)
3/26	3847	12.5	0.1		3.68	7.2
6/29	3847	27.3	0.1		2.55	7
7/30	3866.5	27.3	0.5	48	3.03	3
2/25	3878	27.3	0.2	47	4.25	5
1/15	3890	27.3	0.25	45	3.03	11
		4.55	0.05		0.65	0.7
4/27	3890	12.5	(not	opened)		
5/28	3890	27.3	0.25	46.2	2.35	12

A total of 24 valid RFT pressure tests between 3855.5 and 4151.5 metres established an inconclusive gas-water contact at 3920 metres (3909 metres subsea) with a gas gradient of 0.367 psi per metre (2.53 KPa per metre) and a water gradient of 1.473 psi per metre (10.15 KPa per metre). After a 5-inch production string had been run, a planned production test on the gas zone had to be cancelled owing to mechanical troubles caused by an unexpected movement of the drill-ship.

Lower Jurassic sandstones also occur between 3918 and 3933 metres. Resistivity log data suggest the presence of a gas-water contact at 3930 metres (3919 metres subsea). These silty and fining-upward sandstones have a net thickness of 13 metres (including a net gas column of 10 metres above the resistivity-derived gas-water contact), an average porosity of 15 % and a water saturation of 66 %. No RFT fluid samples were taken, and only one RFT pressure survey was seated in this interval.

Between these two Lower Jurassic sandstones is an 11 metre thick claystone. The RFT and log data suggest that these claystones form a hydraulic barrier between the two sandstone units.

The other Lower Jurassic sandstones, intersected between 3959 and 3995 metres are overlain by 26 metres of siltstone and calcarenite. The sandstones have a net thickness of 24 metres and a porosity of 15 % (but are water-wet). A cased-hole DST was run between 3967 and 3971 metres in this interval to obtain clean water samples prior to the planned, but subsequently cancelled, production test on the gas zone. During a 6-hour flow test on a 2-inch choke (with an eventual 1-inch restriction of flow), water was produced at an average rate of 1590 barrels per day with traces of gas.

The water had a resistivity of 0.357 ohm by metres at 29 degrees centigrade and total dissolved-solids of 16 300 milligrams per litre at 180 degrees centigrade. The DST pressure data indicate permeabilities of 220 to 284 millidarcys. Totals of 0.20 cubic metres (7.2 cubic feet) of gas and 40 litres of water were recovered in the test string chamber.

The underlying Carnian section has four sandstone intervals (4044 to 4054 metres, 4094 to 4110 metres, 4123 to 4133 metres, and 4161 to 4166 metres), with a total net thickness of 30 metres and an average porosity of 12 %. The Carnian sandstones are water-wet. Their porosity is lower than that of the Jurassic sandstones, and porosity progressively decreases with depth over the Lower Jurassic and Upper Triassic sections below 3829 metres.

The Brecknock structure is a Triassic/Jurassic horst block, with Cretaceous claystone unconformably draped over the block. After the cancellation of the planned production test in the Lower Jurassic sandstones, the well was plugged and abandoned.

According to Woodside (1990), the Brecknock gas field contains proven plus probable reserves of 5.40 trillion cubic feet of dry gas (which includes LPG an component and inert and corrosive gases) and 54.1 million barrels of condensate. Brecknock No.1 was located 42 kilometres southwest of Scott Reef No.1 and No.2A and 250 kilometres offshore. The field lies in water depths of 500 to 750 metres within Exploration Permit WA-33-P (R2). Brecknock is in the same exploration permit as the Scott Reef gas field, but 42 kilometres southwest of Scott Reef.

2.1g Brewster No.1A

Brewster No.1A was drilled by Woodside in 1980 and bottomed in Jurassic siltstones at 4703 metres. The rotary table elevation was 8 metres above sea level. Woodside has interpreted that two gas pools exist in the Jurassic section, although no hydrocarbons were recovered. No flow tests were carried out, but the well has been suspended.

Well-head gas readings were moderately low, from 2420 metres to the bottom of the original hole at 4464 metres, partly because heavy drilling mud (1.41 to 1.68 grams per cubit centimetres) was used over this section. Gas readings peaked at 4185 metres in Tithonian sandstones and included 84 ppm of C4. Ditch cuttings (mainly claystone), occasionally gave fluorescence and cuts. Of the 60 sidewall core samples taken from the original hole between 2430 and 3902 metres within the Cretaceous section, 43 claystone and 2 marl samples gave hydrocarbon shows.

Lower Cretaceous siltstone, between 3250 and 3350 metres gave log porosities of 12 % and are water-wet.

After unsuccessful fishing operations, the well was sidetracked at 3864 metres. Well-head gas readings had been moderate until the sidetrack reached a depth of 4335 metres in Upper Jurassic claystone, where more than 20 000 ppm of C4 (but no C5) were recorded. High gas readings continued to the total depth of 4703 metres and peaked with 1100 ppm of C4 and 95 ppm of C5 at 4640 metres in Middle Jurassic sandstone.

Various hydrocarbon shows were intermittently observed in ditch cuttings from 3864 to 4090 metres within the Lower Cretaceous and Upper Jurassic sections in the sidetrack. However, no shows were recorded from ditch cuttings taken from around 4335 metres where a surge in gas readings took place. Weak solvent fluorescence was observed in Jurassic claystone and sandstone between 4460 and 4565 metres, above Jurassic volcanics. None of the 23 sidewall core samples taken from the sidetrack gave any hydrocarbon indications.

A conventional core was cut from 4012 to 4023 metres with a recovery of 8.31 metres. The core comprises massive Tithonian sandstone with a few interbeds of silty claystone. The sandstones are grey, fine-grained, poorly sorted and sub-angular to sub-round. The core showed solvent fluorescence and cuts, but no sample fluorescence.

Gas bleeding was observed between 4012.0 and 4012.8 metres and between 4014.2 and 4020.3 metres.
A total of 27 plugs from the core gave porosities between 4.4 and 16.1 % (with an average of 10 %) and permeabilities between 0.2 and 8.2 millidarcys (with a geometric average of 2 millidarcys). These data indicate that the formation is tight.

The Tithonian sandstones, including the interval cored, from 3940 to 4173 metres in the sidetrack, have a net thickness of 161 metres and an average porosity of 10 %. A zone between 4019 and 4074 metres within the sandstones has a water saturation of 46 %. The other zones have water saturations between 64 and 89 %. The sandstones are overlain by 350 metres of Cretaceous claystone and sandstone.

Of the nine RFTs carried out in the Tithonian sandstones in the original hole, six found the formation too tight to give pressure data, and the other three gave permeabilities of 0.1, 0.7 and 1.5 millidarcys. The three valid tests were also fluid-sampling tests. One of the tests at 3955 metres was unable to recover fluids due to mechanical troubles. The second test, at 3993 metres recovered 0.3 litres of filtrate in a 3.8-litre sample chamber. The third, at 4023 metres recovered 3.5 litres of filtrate in a 10.4-litre chamber. All the nine RFTs indicate the sandstones are tight. Plugging by materials used to control lost-circulation could have occurred. However, the core data also showed the tight nature of the sandstone. No RFT was run in the Tithonian sandstones in the sidetrack.

The Tithonian sandstones between 4252 and 4254 metres, in the sidetrack, that are overlain by 80 metres of claystone have a porosity of 12 %, but are water-bearing. All three RFT attempts in the sandstones were unsuccessful.

Jurassic sandstones in an interval between 4540 metres and the total depth of 4703 metres have a net thickness of 78 metres, porosities of less than 10 % (with an average of 5 %) and water saturations ranging from 20 to 100 % (with an average of 53 %). The thickness of each sandstone unit is about 5 metres. In this interval, those sandstones between 4605 and 4675 metres that are interbedded with, or overlain by, volcanics, have an average porosity of 7 %, water saturations of less than 50 % and a combined net thickness of 24 metres. However, if shale effect is considered, the effective porosity could be as low as 5 %. RFT operations were impossible in these Jurassic sandstones because of sticky conditions in the 6-inch hole. The sandstones are overlain by 100 metres of Upper Jurassic claystone.

In summary, the Tithonian sandstones between 4019 and 4074 metres and Jurassic sandstones between 4605 and 4675 metres have water saturations less than 50 %. However, the former proved to be tight, and the latter has extremely low porosities and also appears to be tight. No hydrocarbons were recovered from these sandstones, and no flow tests were carried out in the well. Because of an extrapolated bottom-hole temperature of 154 degrees centigrade and the nature of the hydrocarbon shows in this well, the contents of any hydrocarbon pools are likely to be gas and condensate.

Woodside concluded that Brewster No.1A is a discovery well, and the well was suspended.

2.1h Browse Island No.1

Browse Island No.1 was drilled as a shallow stratigraphic well on Browse Island by Santos in 1986 and terminated at 405.5 metres in Pliocene limestones. The kelly bushing elevation was 4.4 metres above ground level (2.9 metres above sea level).

The well was drilled to determine the thickness and interval velocity of the surface reef. No hydrocarbon shows were recorded, and no potential reservoir rocks were intersected in this well.

2.1i Buffon No.1

Buffon No.1 was drilled by Woodside in 1980 and terminated at 4498 metres in Lower Jurassic sandstones. The rotary table elevation of the well was 10 metres above sea level.

Well-head gas readings, including C4, were fairly high between 2715 and 2920 metres in Miocene and Eocene claystone and calcilutite in the original hole. In a sidetrack, the Tertiary and Cretaceous sections displayed only minimal amounts of well-head gas. Volcanics, dominating the upper Jurassic section between 3776 and 4447 metres showed fairly high gas readings, and an interval between 3779 and 4140 metres recorded small amounts of C5 hydrocarbons.

Miocene calcarenite ditch cuttings from 2360 metres showed weak fluorescence and cuts. Ditch cuttings of Jurassic volcanics from 4210 to 4270 metres exhibited no fluorescence but weak cuts. These hydrocarbon indications resulted in the cutting of a conventional core. Similar shows continued intermittently to the bottom of the Jurassic volcanics at 4447 metres.

The well did not intersect any sandstone zones either in the Tertiary and Cretaceous sections or in the Jurassic volcanics.

A core was cut from 4270 to 4278 metres in the Jurassic volcanics (with a recovery of 100 %). The core consists of agglomerates, volcanic breccias, basalts and andesites. Core photographs show the development of fractures at boundaries between these rock units. A total of four plugs taken from the core have an average porosity of 11 %, a bulk density of 2.42 grams per cubic centimetre and a grain density of 2.77 grams per cubic centimetre. No permeability measurements appear to have been carried out, and the description of hydrocarbon shows are not available for this core.

Quantitative wire-line log evaluation for the Jurassic volcanics is difficult owing to the fact that log responses are quite different from those in sedimentary rocks.

Gamma-ray readings range from 10 to more than 220 API units in the volcanic section, and the interval cored exhibits an average of 140 API gamma-ray units.

For example, volcanics at 4240 metres have low gamma-ray units of 28 API, a CNL porosity of 12 %, a very high FDC density of 2.85 grams per cubic centimetre and a high Microlaterolog resistivity of 40 ohm by metres. On the other hand, other volcanics at 4320 metres have extraordinarily high gamma-ray units of more than 220 API, a CNL porosity of 11 %, a moderate FDC density of 2.53 grams per cubic centimetre and a moderate Microlaterolog resistivity of 3 ohm by metres. Interestingly, the former plot outside the dolomite line on Schlumberger's CNL-FDC chart, and the latter plot on the limestone line. Although the lithological implication is not clear, it appears that each type of volcanics displays a distinctive log response and that gamma-ray, FDC and Microlaterolog data may be particularly useful for the classification of volcanic lithologies.

Of the 24 RFT pressure tests carried out in the Jurassic volcanics, only two gave valid pressure data, and a total of 18 found the formations to be tight. A DST was run over the interval 3737 to 4246 metres in the bottom part of the Cretaceous claystone and the upper part of the Jurassic volcanics. A slotted 4.5-inch liner was set down to 4192 metres and, thus, the DST was a combination of cased-hole and open-hole tests. The well was flowed for a period of 13 hours with a calculated water flow rate of 12 barrels an hour, along with a gas rate of 2 cubic feet a barrel of water. The gas recovered contained 76 % methane.

These RFT and DST results indicate that gas appears to be trapped in fractures between various volcanic rock types and not in inter-granular pore spaces. The 671 metre thick Jurassic volcanic section appears to be tight and has no commercial potential for gas in the Buffon structure.

Below the volcanics are Lower Jurassic sandstone, claystone, oolitic limestone and further volcanics. The sandstones dominating the interval 4532 to 4671 metres have an average porosity of 12 % and a water saturation of 80 %. RFT pressure data from 4653 metres indicate the formation to be tight.

This well encountered a series of drilling problems, and no ditch cuttings were returned to surface from a number of intervals. In addition, no open-hole wire-logs could be run over an 800 metre interval in the Miocene section.

2.1j Caswell No.1

Caswell No.1 was drilled by Woodside in 1977 and terminated at a total depth of 4097 metres (driller's depth) or 4090.2 metres (logger's depth) in Lower Cretaceous claystone. The rotary table elevation was 8.0 metres above sea level.

Well-head gas readings were minimal in the interval 3000 to 3225 metres which includes Campanian sandstones. Resistivity tools were unable to be run deeper than 2750 metres, and no sidewall core samples were taken from this interval, because of poor hole conditions. Eventually casing was set down to 3328 metres and a 7-inch liner was set down to 3507.5 metres (logger's depth) or 3515 metres (driller's depth).

A 4-fold drilling break took place at 3606 metres. Albian sandstones constitute 100 % of the ditch cutting samples from 3606 to 3611 metres and have very good visual porosity. Well-head gas reading exhibited a peak in this zone, and C4 and C5 hydrocarbons were detected on a chromatograph. This zone has an average log porosity of 13 % and water saturations between 44 and 100 %. This zone is overlain by 200 metres of Cenomanian and Albian claystone.

A number of sidewall core bullets were fired in this zone, but only four were recovered. However, none of the four samples contained sandstones. A sample from 3606 metres contained mud-cake only. Claystone and siltstone, recovered from 3608 metres showed fluorescence and streaming cuts. Limestone and claystone, from 3608.4 metres, showed fluorescence, streaming cuts and minor oil staining. An oil sample (probably extracted from this sidewall core sample) has an API gravity of 46 degrees. The fourth sample, from 3611 metres, contained small fragments of claystone without any hydrocarbon indications.

A total of 24 RFT pressure tests were attempted between 3598 and 3732 metres. Of these, 16 indicated the formations are tight, and seven yielded valid formation pressures. These tests confirmed over-pressuring in the

Cretaceous claystone but gave little information on the occurrence of hydrocarbons.
Well-head gas readings were moderately high from 3950 metres to the total depth of 4097 metres. However, claystone is the predominant lithology over this Lower Cretaceous interval.

Although the Jurassic was the original objective, drilling had to be terminated at 4097 metres in Neocomian claystone because of drilling difficulties.

2.1k Caswell No.2

Caswell No.2 was drilled by Woodside in 1983 and reached a total depth of 5000 metres in Middle Jurassic sandstone. The rotary table elevation was 17.0 metres above sea level. The well, drilled 260 metres southeast of Caswell No.1, was designed to test Jurassic sandstones in a drape anticline. Oil was discovered in Campanian sandstone at 3265.5 metres by means of an RFT fluid sampling test.

Upper Cretaceous, clean sandstones between 3009 and 3215 metres have a net thickness of 170 metres and an average log porosity of 20 % (but are water-wet). No significant hydrocarbon shows were recorded from this interval. These sandstones are overlain by 400 metres of Maastrichtian claystone and marl.

Moderately high well-head gas readings were recorded from Campanian silty sandstone from 3264.7 to 3268.7 metres, in both the original well and the first sidetrack. These sandstones showed fluorescence, instantaneous streaming cuts and oil-staining in cuttings samples. Two sidewall core samples from this zone showed fluorescence and cuts but no oil-staining. These sandstones have a net thickness of 4 metres, a log porosity of 18 % and a water saturation of 38 %. They are overlain by 50 metres of Campanian marl.

An RFT fluid sample, taken from 3265.5 metres in the first sidetrack, recovered 0.8 litres of oil with an API gravity of 47 degrees, 21.2 cubic feet of gas and 9.5 litres of filtrate in a 10.4-litre chamber. However, log calculations suggest that the thin Campanian sandstones are of no commercial significance because of their thickness and high water saturation. The well was drilled in 344 metres of water and 240 kilometres offshore.

High gas readings continued from 3970 metres to a total depth of 5000 metres. Ditch cuttings and sidewall cores occasionally showed weak fluorescence and cuts. The highest (non-trip) readings were recorded over 4 metres of Lower Cretaceous siltstone between 4070 and 4074 metres The total gas contained high amounts of C4 and C5.

The Upper Jurassic sandstones between 4506 and 4554 metres have a net thickness of 17 metres and an average log porosity of 11 % (but are water-wet). These sandstones are overlain by 1090 metres of Jurassic and Cretaceous claystone and siltstone.

Below this interval, sandstone porosity deteriorates progressively with depth. The Middle to Upper Jurassic sandstones tend to be tight in intervals between 4660 and 4793 metres and between 4885 metres and the total depth of 5000 metres. Two RFT samples were taken in the Jurassic sandstones in the second sidetrack from 4783.5 and 4920.5 metres, but contained filtrates only. Here, porosities range from 4 to 6 %.

Despite the oil recovery from Campanian sandstones, no flow test was attempted, and the well was plugged and abandoned.

2.11 Echuca Shoals No.1

Echuca Shoals No.1 was drilled by Woodside in 1983/84 and bottomed in Permian limestone at 4365 metres. The rotary table elevation was 17 metres above sea level. Although neither an RFT fluid-sampling nor a DST was attempted in this well, wire-line data, including RFT pressure data, indicate the presence of two gas pools in Upper Jurassic sandstones. Woodside regards Echuca Shoals No.1 as a gas discovery well.

Aptian sandstone, siltstone and claystone between 2672 and 2720 metres yielded high well-head gas readings, including 1290 ppm of C4 and 466 ppm of C5. Only one sidewall core sample (at 2720 metres) out of four taken from this interval, gave fluorescence and a cut. However, weak cuts were observed in sidewall core samples taken from the overlying Lower Cretaceous claystone.

After a 5-fold drilling break at 2730 metres the highest well-head gas readings were recorded from 2730 to 2740 metres in Aptian to Barremian claystone, sandstone and siltstone. Here, 1664 ppm of C4 and 466 ppm of C5 hydrocarbons were observed. The ditch cuttings exhibited weak fluorescence and cuts. However, the two sidewall core samples from this interval showed no hydrocarbon indications.

Barremian sandstones between 2876 and 2884 metres gave high gas readings, including 913 ppm of C4 and 180 ppm of C5. No sidewall cores were taken from this interval.

A total of 39 sidewall core samples (most of them claystone or siltstone) were taken between 2884 and 3329 metres below the Barremian sandstones and above the top Jurassic (Jc) seismic marker. Of these samples, 30 showed various kinds of hydrocarbon indications.

Lower Cretaceous sandstones in an interval between 2672 and 2767 metres have porosities ranging from 9 % to 19 %, but are water-wet. The sandstones are overlain by 790 metres of Cretaceous claystone.

Upper Jurassic sandstones between 3382 and 3485 metres yielded moderate to high gas readings, including 180 ppm of C4 and 80 ppm of C5, and exhibited fluorescence and cuts.

Cut fluorescence was observed in all the seven sidewall core samples taken from Tithonian claystone between 3485 and 3603 metres. Ditch cuttings of the claystones also showed fluorescence and cuts.

RFT pressure data suggest the presence of a gas-water contact at 3356 metres (3339 metres subsea) in Upper Jurassic sandstones between 3331.0 and 3352.5 metres. The contact is not well defined on resistivity logs, because the formations around the gas-water contact tend to be shaly. The sandstones have a net sand thickness of 17.5 metres, a net gas column of 17 metres, a log porosity of 12 % and a water saturation of 19 %. However, this interval yielded only moderate well-head gas readings. The sandstones are overlain by 380 metres of Cretaceous siltstone and claystone.

Other Upper Jurassic sandstone between 3382.5 and 3485.5 metres have a net sand thickness of 81 metres and a porosity of 11 %, and are water-bearing. These sandstones appear to be in hydraulic communication with the gas-bearing sandstones.

Tithonian sandstones from 3603 to 3677 metres yielded moderate gas readings, and ditch cuttings from this interval gave fluorescence and cuts. The two sidewall core bullets recovered from the sandstone were empty.

RFT pressure and wire-line log data suggest that the entire Tithonian sandstone between 3634.0 and 3673.5 metres are gas-bearing and have a net gas column of 23.7 metres. The sandstones have a porosity of 15 % and a water saturation of 23 %, although, while drilling these gas-bearing sandstones, only moderate amounts of well-head gas were observed. This interval is overlain by 150 metres of Upper Jurassic siltstone and claystone, and unconformably underlain by Triassic sediments.

Well-head gas readings were minimal to moderate in the Triassic and Permian sections between 3677 metres and the total depth of 4365 metres. Ditch cuttings from these sections showed no fluorescence. Three claystone and siltstone sidewall cores taken in the Triassic section gave cuts. However, no hydrocarbon shows were observed in a total of 37 sidewall core samples taken below 3720 metres.

The Triassic section from 3677 to 4224 metres consists of claystone with siltstone and volcanics. The section has no reservoir potential.

A gas kick took place at 4294 metres. The well was shut-in, and a 7-inch liner was set down to 4190 metres (logger's depth) or 4185 metres (driller's depth). Eventually, the mud weight was raised from 1.20 to 1.68 grams per cubic centimetre to control the well.

The Upper Permian section between 4224 metres and the total depth of 4365 metres comprises sandstone, siltstone and limestone. The sandstone between 4286 and 4318 metres have porosities of less than 5 %. However, there is some evidence of fracturing, which may be responsible for the gas kick at 4294 metres. The bottom-hole silty limestone below 4318 metres have no effective porosity.

In summary, numerous hydrocarbon shows were observed in Cretaceous and Jurassic rocks. However, wire-line data identified only two Jurassic gas-bearing sandstones, where hydrocarbon indications had been relatively minor while drilling. The characteristics of the hydrocarbon shows suggest that the gas is wet. The Jurassic reservoirs form an anticlinal closure draped over a horst block of Permian and Triassic sediments. The top reservoir is overlain by Jurassic and Cretaceous siltstone and claystone, and the deeper reservoir by Jurassic claystone.

No attempt was made to recover or flow fluids from the Jurassic gas reservoirs by means of RFT, FIT or DST. The well was plugged and abandoned.

2.1m Gryphaea No.1

Gryphaea No.1 was drilled by BHP in 1987 and terminated at 3940.5 metres (logger's depth) or 3950 metres (driller's depth) in Middle Triassic siltstone. The kelly bushing elevation was 17.4 metres above sea level.

Well-head gas readings were low to moderate over the entire section, with the highest peak of 2.5 % (including 0.33 % of C4) at 2592 metres, in Maastrichtian silty sandstone. Ditch cuttings from 2588 to 2592 metres showed faint fluorescence and cuts. Lower Cretaceous sandstones between 3618 and 3630 metres, also showed bright fluorescence. Three sandstone sidewall core samples from 3625.5 metres, 3634.5 metres and 3635.5 metres, exhibited fluorescence, cuts and residual rings. Middle Triassic sandstones from 3810 to 3815 metres, showed dull fluorescence.

The Cretaceous section between 2249 and 3636 metres, contains approximately 250 metres of sandstone, with porosities ranging from 10 to 30 %. The entire interval is water-wet. Underlying the Cretaceous section is the

Middle Triassic, which lacks reservoir potential. None of the sediments in this section has porosities over 10 %.

Wire-line logs were not run between 1304 and 1724 metres in the Tertiary section because of tight hole. No formation tests were run in this well.

2.1n Heywood No.1

Heywood No.1 was drilled by BOC in 1974, and bottomed in Lower Jurassic sandstone at a total depth of 4572 metres. The kelly bushing elevation was 10.0 metres above sea level.

Well-head gas readings had been minimal until the top Lower Cretaceous sandstones between 3284 and 3310 metres gave moderate gas readings. However, ditch cuttings and sidewall core samples taken from this interval did not show any hydrocarbon indications. Moderately high gas readings continued from 4068 metres to the total depth of 4572 metres in the Jurassic section. Claystones between 4104 and 4106 metres exhibited the highest gas readings, including 3490 ppm of C4. Jurassic claystone, from 4068 to 4076 metres and from 4104 to 4108 metres, showed oil-staining and gave bluish white fluorescence with instantaneous streaming cuts. The deeper interval, below 4138 metres in the Jurassic section, consists predominantly of sandstones and, at some depths, claystone. The sandstone occasionally exhibited weak fluorescence and solvent fluorescence. Traces of oil were intermittently observed in the drilling mud in the Jurassic section. Of the 61 sidewall core samples taken in the Jurassic section, 40 gave hydrocarbon shows.

Lower Cretaceous sandstones in an interval between 3284 and 3405 metres, and Tithonian sandstones in the interval between 3445 and 3557 metres, gave log porosities ranging from 10 to 16 %. These sandstones are predominantly water-bearing with occasional low residual hydrocarbon saturations. Lower to Middle Jurassic sandstones in an interval from 4138 metres to the bottom of the logged interval at 4210 metres, have porosities of less than 10 %. BOC interpreted log data for some thin interbeds between 4149 and 4193 metres and concluded that they were salt layers. All the sidewall cores taken from these interbeds were empty, however, and there is no other supporting evidence for this interpretation. The Jurassic sandstones are overlain by 580 metres of Jurassic claystone.

Two FITs were run in this well. FIT No.2, a cased-hole test at 3299 metres in Lower Cretaceous sandstone, recovered 15 litres of water and 1.1 cubic feet of gas in a 22.2-litre chamber. The gas appears to be fire-charge gas, and this test indicates that the formation is water-bearing. FIT No.1 at 4147.5 metres in Jurassic sandstones, found the formation tight and recovered 0.1 litres of mud and 0.1 cubic feet of gas in a 22.2-litre chamber. It is noteworthy that FIT No.1 was run at a depth where no hydrocarbon shows had been recorded. The Jurassic section is not necessarily as tight and non-producible as this test indicates.

The drill string twisted off while drilling at 4572 metres (the subsequent total depth), and the fish has been left in the hole. As a result, no wire-line tools could be lowered below 4240 metres. This well did not fully evaluate the potential of the Jurassic sandstones in the Heywood structure.

2.1o Leveque No.1

Leveque No.1 was drilled by BOC in 1970 and terminated at 899 metres in Proterozoic igneous basement. The rotary table elevation was 9.1 metres above sea level.

Well-head gas readings were generally minimal in this well, and no significant hydrocarbon shows were recorded while drilling. None of the 54 sidewall core samples exhibited any hydrocarbon shows. A drilling break, along with lost circulation, was encountered from 882 to 888 metres within, or immediately above, Upper Jurassic basal conglomerates. Inter-pebble fractures in the conglomerate appear to have caused this drilling-break.

An interval between 675 and 814 metres within the Lower Cretaceous section contains a total of 54 metres of shaly sandstone, which have an average porosity of 16 %.

An FIT was run at 802.8 metres in Lower Cretaceous or Upper Jurassic silty sandstone, and a 22.2-litre-chamber recovered 4 litres of mud and 0.1 cubic feet of gas.

Pressure did not build up during the test, which indicates that the formation is tight or was plugged.

A bottom-hole core was cut from 896 metres to the total depth of 899 metres but only the inner core barrel with 0.1 metres of core was recovered. The core sample consists of Proterozoic gabbro with no hydrocarbon indications. The Proterozoic-Upper Jurassic boundary lies somewhere between 890 and 896 metres.

2.1p Lombardina No.1

Lombardina No.1 was drilled by BOC in 1974 and terminated in Lower Jurassic claystone at 2855 metres The rotary table elevation was 30 metres above sea level.

Well-head gas readings were minimal, and no fluorescence was recorded while drilling. Many of the sidewall core samples taken between 2045 and 2570 metres from the Middle and Upper Jurassic and Lower Cretaceous sections, exhibited weak cuts. Of these, claystone sidewall core samples from 2522.5, 2551 and 2570 metres also showed instantaneous cuts. However, claystone predominates in the Lower Cretaceous to Middle Jurassic sections.

An FIT No.1C was run at 2511.5 metres within a sandstone zone between 2509 and 2519 metres. The Middle Jurassic sandstone at 2511.5 metres has a log porosity of 15 % and a water saturation of 70 %. The test recovered 0.1 cubic feet of gas and 0.112 litres of water in a 22.2-litre chamber. The result indicates that the reservoir is tight or dry. No other formation tests were carried out in this well.

2.1q Londonderry No.1

Londonderry No.1 was drilled by BOC in 1973 and reached a total depth of 1145 metres in Proterozoic basement. The rotary table elevation was 13 metres above sea level.

Well-head gas readings were minimal throughout the well, and the highest readings (366 ppm of propane (C3)) occurred in claystone at 1105 metres. No hydrocarbon indications were observed in this well.

Lower Cretaceous sandstones between 890 and 943 metres and between 1037 and 1086 metres have porosities of 27 to 30 %, and are water-wet.

Below Neocomian sediments lie Proterozoic volcanics between 1135 metres and the total depth of 1145 metres.

A bottom-hole core was cut from 1143 to 1144.7 metres, with a recovery of one metre of Proterozoic volcanics (rhyodacite). A core plug from 1143.25 metres has a porosity of 1.1 % and a permeability of less than 0.1 millidarcys.

2.1r Lynher No.1

Lynher No.1 was drilled by BOC in 1970 to 1971 and terminated at 2725 metres in Upper Permian sandstone. The rotary table elevation was 9.1 metres above sea level.

Well-head gas readings were minimal throughout the well. A total of 62 sidewall core samples did not show any hydrocarbon indications.

A conventional core was cut from 1246 to 1251 metres with a recovery of 3.7 metres in Lower Cretaceous claystone. The core exhibited no hydrocarbon indications. Two claystone plugs taken from the core have porosities of 25 and 32 % and permeabilities of less than 0.1 millidarcys.

Sandstone predominates from 1347 to 1449 metres in the Upper Jurassic section from 1590 to 1724 metres in the Middle Jurassic section and from 1991 to 2198 metres in the Lower Jurassic section. The Upper and Middle Jurassic sandstones have an average porosity of 23 %. The Lower Jurassic sandstones have a porosity of 19 %. All these sandstones are water-wet.

Wire-line logs were not run between 2198 metres and the subsequent total depth of 2725 metres in the lower part of the Lower Jurassic section and the Triassic and Permian sections because of hung sidewall core tools. The section containing the unlogged interval consists mainly of sandstone along with siltstone and coal. A planned bottom-hole core was cancelled owing to the fish in the hole.

2.1s Mount Ashmore No.1B

Mount Ashmore No.1B was drilled by Woodside in 1980 and bottomed in Upper Triassic calcilutite at 2655 metres. The rotary table elevation was 11.0 metres above sea level.

The entire section yielded minimal levels of well-head gas. The Upper Jurassic sandstones from 2033 to 2110 metres, and the Upper Triassic sandstones from 2255 to 2355 metres, gave weak solvent fluorescence and cuts. Of the 157 sidewall core samples, only two showed faint solvent fluorescence: one in Lower Cretaceous claystone at 1954 metres and the other in Upper Jurassic claystone. No other hydrocarbon indications were recorded in this well.

An interval between 2024 and 2410 metres within the Upper Jurassic and Upper Triassic sections contains a total of 71 metres of sandstone with an average porosity of 17 %. Between 2410 metres and the total depth of 2655 metres, the lower part of the Upper Triassic section consists of calcilutite, sandstone and claystone. The sandstones have porosities of less than 10 %.

No formation tests were carried out in this well.

2.1t North Scott Reef No.1

North Scott Reef No.1 was drilled 21.5 kilometres northeast of Scott Reef No.1 and No.2A by Woodside in 1982 and reached a total depth of 4771 metres in Triassic recrystallised limestone. The rotary table elevation was 8 metres above sea level. Gas, condensate and water, flowed during a production test over Lower Jurassic sandstones.

Moderately high well-head gas readings were recorded from 2125 to 2450 metres within Eocene to Miocene calcilutite. Readings peaked at 760 ppm of C4 and 232 ppm of C5.

Moderately high gas readings of 152 ppm of C4 and 44 ppm of C5 were observed from 4163 to 4308 metres in Hettangian sandstones.

Weak fluorescence and cuts were observed in ditch cuttings of Eocene calcilutite at 3587 metresand in Triassic limestone at 4451 metres. None of the 115 sidewall core samples taken in the Tertiary and Cretaceous sections above 4049 metres showed any hydrocarbon indications. Of the 18 sidewall core samples taken from the Jurassic section between 4049 and 4325 metres, 12 gave solvent fluorescence and cuts. Four out of 16 samples taken from the Triassic section below 4325 metres showed solvent fluorescence and cuts.

Porous sandstones were intersected only in the Jurassic section, and no potential reservoirs were encountered in the Tertiary, Cretaceous or Triassic sections in this well.

The Jurassic section between 4049 and 4325 metres comprises volcanics, four sandstone units, claystone and recrystallised limestone. At the top of the section are 63 metres of volcano-clastics underlain by the top sandstone unit. Between 4112 and 4120 metres, the sandstone unit contains a net gas column of 8 metres, a porosity of 12 % and a water saturation of 35 % (with a negligible amount of clay). This sandstone unit is underlain by 43 metres of claystone and volcano-clastics.

The second Jurassic sandstone unit, between 4163 to 4215 metres, is calcareous and interbedded with claystone. This unit has a gross gas column of 39.5 metres, a clay content of 55 %, an effective porosity of 6 % and a water saturation of 58 %. This log porosity is much lower than the core porosity described below, partly because the log-derived gross gas column includes very shaly sandstone zones. However, the high clay content suggests that there is no log-derived net gas column in this unit.

In this second sandstone unit, a conventional core was cut from 4192 to 4210 metres with a recovery of 17.89 metres. The core comprises sandstone along with thin interbeds of claystone. The sandstones are grey, fine-grained, moderately sorted, sub-angular, calcite cemented, calcareous, silty, and occasionally bioturbated and burrowed. The sandstones contain shell fragments. The core exhibited occasional solvent cuts. A total of 79 plugs taken from the core have porosities of 7.8 to 23.9 % (with an average of 13 %). Of these, 60 horizontal plugs have permeabilities of between 0.8 and 334 millidarcys (with an average of 8 millidarcys), and 19 vertical plugs have permeabilities of between 0.8 and 28 millidarcys (with an average of 4 millidarcys).

Below this second sandstone unit are 7 metres of recrystallised limestone underlain by the third Jurassic (Hettangian) sandstone unit. This massive, clean sandstone, from 4222 to 4284 metres, has a net gas column of 62 metres, a porosity of 12 % and a water saturation of 17 % with a negligible amount of clay.

Two RFT fluid sampling tests were carried out in this unit. One, with a 10.4-litre chamber at 4225.5 metres (an invalid test owing to a hydraulic failure), recovered 9.5 litres of water and filtrate as well as 1.2 cubic feet of gas. The second RFT, equipped with a 10.4-litre chamber at 4241.2 metres, recovered 60 cubic feet of gas, 0.25 litres of condensate and 2 litres of water.

Later, a production test was run over the third sandstone unit between 4222 and 4284 metres. The test was conducted in a 7-inch liner through 3.5-inch tubing and 5-inch casing with a perforation interval from 4223 to 4283 metres. During a total flow time of 21 hours, gas flowed at 35 million cubic feet per day, condensate at 384 barrels per day, and water at 164 barrels per day through a 0.5 to 0.75-inch choke. These figures give an average condensate yield of 11 barrels per million cubic feet. The stock tank condensate has an API gravity of 50 degrees. The relatively high water production confirms the high water saturation of the reservoirs. The 9-hour pressure buildup curve gave a permeability of 115 millidarcys and an absolute open flow potential of 185 million cubic feet per day. This permeability value is much higher than those derived from both core analysis and RFT pressure analysis. The reservoirs have an extrapolated formation pressure of 6560 psia and a temperature of 138 degrees centigrade at 4210 metres.

Re-combined reservoir gas (separator gas plus re-combined separator liquid) consists of 79.4 (molecular) % of methane, 5.2 % of ethane, 2.3 % of propane, 0.9 % of butane, 1.1 % of pentane, 10.8 % of carbon dioxide, 0.3 % of nitrogen and a trace of hydrogen sulphide. The raw gas has a sales gas (methane plus ethane) yield of 0.846 standard cubic feet per standard cubic feet and an LPG yield of 22 barrels per million cubic feet.

Below the third sandstone unit are 7 metres of claystones and siltstones underlain by the fourth, and deepest, Jurassic (Hettangian) sandstone unit (between 4291 and 4299.5 metres). The sandstones have a net gas column of 8.5 metres, a porosity of 9 % and a water saturation of 54 % with a negligible amount of clay.

This unit is underlain by 26 metres of Lower Jurassic (Hettangian) claystone, recrystallised limestone and volcanics.

A total of 25 RFT pressure surveys (plus two RFT fluid-sampling tests) were carried out over the four Jurassic sandstone units. Of these, seven valid seats indicated that the formations have an average permeability of 18 millidarcys and that all four sandstone units are part of a single gas pool. In addition, these gas reservoirs appear to be in communication with those in Scott Reef No.1. Thus6, all the gas reservoirs in the Lower Jurassic and Upper Triassic sections intersected in Scott Reef No.1 and in the Lower Jurassic section in North Scott Reef No.1, form a single gas pool.

The Upper Triassic (Carnian) section between 4325 metres and the total depth of 4771 metres comprises interbeds of recrystallised limestone and claystone. Unlike Scott Reef No.1, no porous sandstones and dolostones were intersected in the Upper Triassic section in North Scott Reef No.1.

After the successful production test, this well was plugged and abandoned.

2.1u Prudhoe No.1

Prudhoe No.1 was drilled by BOC in 1974 and terminated at 3322 metres in Lower Permian claystone. The rotary table elevation was 30 metres above sea level.

Well-head gas readings were minimal throughout the well. A minor gas-kick took place at 2853 to 2854 metres in Upper Jurassic sandstones, but it caused no drilling problems. Claystone ditch cuttings from 2525 to 2550 metres in the Lower Cretaceous section gave weak solvent fluorescence. Claystone and sandstone ditch cuttings from 2865 to 2885 metres in the Upper Jurassic section gave a trace of fluorescence and solvent fluorescence. Claystone ditch cuttings, from 3080 to 3090 metres in the Lower Permian section, also exhibited solvent fluorescence. However, none of the sidewall core samples showed any hydrocarbon indications.

The top 1330 to 1448 metres of the Upper Cretaceous section consist of clean and porous sandstone, overlain by 514 metres of Tertiary sandstone. The lower part of the Upper Cretaceous section and the Lower Cretaceous section are dominated by claystone with occasional sandstone and limestone.

The Tithonian section between 2756 and 2888 metres consists mainly of sandstone with minor claystone and siltstone. These sandstones have an average porosity of 15 %, but are water-wet. Underlying Tithonian sediments is the Lower Permian section in which sandstones tend to have porosities of less than 10 %.

No formation tests were carried out in this well.

2.1v Rob Roy No.1

Rob Roy No.1 was drilled as a stratigraphic well by BOC in 1972 and terminated in Proterozoic, recrystalized quartzite at 2286 metres. The rotary table elevation was 9.4 metres above sea level.

Well-head gas readings were minimal, and no hydrocarbon shows were recorded in ditch cuttings. None of the 108 sidewall core samples displayed hydrocarbon shows.

Three conventional cores were cut. The first was cut from 1548 to 1553 metres in the Lower Jurassic section, and a 4.3 metre core was recovered. The top 0.3 metres consist of siltstone, which is dark grey, well sorted, clayey and contain small amounts of coal. The rest of the core consists of sandstone, which is medium to coarse grained, round to sub-angular, partly silty and contains minor coal. This sandstone has core porosities ranging from 9 to 18 % (with an average of 14 %) and air permeabilities of 2.5 to 246 millidarcys (with an average of 20 millidarcys). The core did not exhibit any hydrocarbon indications.

The second core was cut from 1888 to 1897 metres in the Lower Permian section with a recovery of 100 %. The top 1.5 metres consist of claystone, which is dark grey and silty and becomes pyritic with depth. The rest of the core consists of sandstone, which is quartzose, fine grained, sub-angular and well sorted. The sandstones also contain siltstone laminations and anhydrite veins. This sandstone has porosities of 6 to 13 % (with an average of 11 %), and an average permeability of 0.2 millidarcys. The core exhibited no shows.

The third core was cut from 2205 to 2210 metres in the Lower Permian or Upper Carboniferous section with a recovery of 100 %. The entire core consists of silty claystone with occasional sandstone bands with no hydrocarbon indications. A fine-grained sandstone plug, taken at 2209 metres, has a porosity of 9.7 % and a permeability of 106 millidarcys.

A number of sandstone units are present in the Lower Permian section below 1572 metres, but the sandstone porosities tend to be low.

2.1w Scott Reef No.1

Scott Reef No.1 was drilled by BOC in 1971 and bottomed in Triassic claystone at 4730 metres. The rotary table elevation was 9.4 metres above sea level. A gas pool was discovered in Lower Jurassic sandstone and Upper Triassic dolostones and sandstone.

Well-head gas readings were minimal over the entire section of the well, but methane (C1) levels were relatively high in an interval between 4293 and 4423 metres within the Lower Jurassic and Upper Triassic sections. Neither C3 nor C4 was recorded in gas readings in this well, and no hydrocarbon indications were observed in any of the ditch cuttings or in any of 60 sidewall core samples taken in the well.

Neocomian shaly sandstone, from 4029 to 4077 metres, has porosities of 3 to 12 %, and are water-wet.

Below 183 metres of Neocomian claystone is the Upper Jurassic section. From 4260 to 4293 metres this consists of claystone and calcilutite and basal volcanics.

The Lower Jurassic section between 4293 and 4356 metres comprises sandstone and claystone. This section is unconformably underlain by the Triassic. The upper part (between 4356 and 4527 metres) of the Upper Triassic section consists of claystone, dolostone and sandstone. These Lower Jurassic sandstones and Upper Triassic dolostones and sandstones form a single gas reservoir in the Scott Reef field.

The lower part (between 4527 metres and the total depth of 4730 metres) of the Upper Triassic section comprises claystone and recrystallised limestone.

A conventional core was cut from 4378 to 4382 metres in the top of the Upper Triassic section with a recovery of 100 %. The core comprises sandstone interbedded with siltstone and dolostone. The sandstones are light grey, fine-grained, sub-angular, well sorted, silty and dolomitic. The sandstones contain numerous shell fragments, display cross-beddings, have poor inter-granular porosity and good vuggy porosity. The leaching of shells could have caused the vuggy porosity. The dolostones have a sucrosic texture, but there is very little petrographical information available. No hydrocarbon indications were observed in the core. However, a few core plugs exhibited fluorescence.

A total of seven sandstone plugs taken from the core have porosities of between 10.5 and 22.4 % (with an average of 17 %), permeabilities of nil to 19.9 millidarcys (with an average of 1 millidarcy) and a vertical to horizontal permeability ratio of approximately 0.4. A total of three dolostone plugs have porosities of 9.8, 12.4 and 13.7 %, an average horizontal permeability of 2 millidarcys and an average vertical permeability of 0.4 millidarcys. These data show that the sandstones and dolostones have good porosity for sediments at these depths, but low permeability. Some vuggy porosity appears not to be interconnected.

BMR carried out a mercury capillary pressure test on three silty sandstone and three sandy dolostone plugs taken from the core. The sandstones have medium residual water saturations and medium to high threshold pressures. The dolostones have medium residual water saturations and medium to low threshold pressures. Capillary inbibition curves show that the latter have better hydrocarbon recovery characteristics than the former. The sandstones and dolostones have a wide range of pore-size distribution.

The Lower Jurassic section between 4293 and 4356 metres has two sandstone reservoirs and a combined net gas column of 26.9 metres. These sandstones have a clay content of 7 %, an effective porosity of 12 % and a water saturation of 37 %. The Upper Triassic section contains four reservoirs between 4356 and 4385 metres and a combined net gas column of 15.8 metres. A dolostone zone, between 4362 to 4370 metres, has a net thickness of 7.6 metres. The combined Upper Triassic gas column has a clay content of 6 %, an effective porosity of 15 % and a water saturation of 52 %.

Three FITs were attempted in the Jurassic and Triassic gas pools. The first test, at 4300 metres in the Jurassic sandstones, was unsuccessful. The second test at the same depth, recovered 242.3 cubic feet of gas, 0.636 litres of condensate, 0.04 litres of water and 0.05 litres of mud in a 22-litre sample chamber. The pressure data for this test gave a permeability of 1.4 millidarcys. The condensate has an API gravity of 43.3 degrees. The third test, at 4381 metres in the Triassic, was invalid due to seal failure, but recovered 1.1 cubic feet of gas and 20 litres of mud in a 22-litre chamber.

A total of four cased-hole DSTs over a 7-inch liner were carried out in an interval from 4299 to 4386 metres in the Lower Jurassic and Upper Triassic pool. DST-1 had three perforated zones: 4340 to 4346 metres over Jurassic sandstones, 4351 to 4354 metres over Triassic dolostones and 4362 to 4368 metres again over the dolostones. During this six hour test, gas flowed at a rate of 8 million cubic feet per day through 3/8-inch bottom-hole and surface chokes and 11 milion cubic feet per day through a 1/2-inch surface choke. The test also produced small amounts of condensate and water. The test gave a formation permeability of 15 millidarcys.

DST-2 had four perforated zones, three of which are identical to those in DST-1. The fourth, between 4380 and 4383 metres, corresponds approximately to the cored interval. During this 5-hour test, gas flowed at 16.7 million cubic feet per day through a 1-inch choke and 9.5 million cubic feet per day through a 3/8-inch choke, with unspecified amounts of condensate and water. This test also gave a permeability of 15 millidarcys.

DST-3 had one perforated zone from 4380 to 4386 metres over Triassic sandstones. During the 10-hour test, gas flowed at 9.8 million cubic feet per day through a 1-inch choke, accompanied by condensate at a rate of 20 barrels per million cubic feet for the last two hours. A gas sample taken from the separator contained 77.99 (molecular) % of methane, 5.79 % of ethane and 7.56 % of carbon dioxide. A condensate sample taken from the separator had an API gravity of 54 degrees. The test also produced an unspecified amount of water. The formation has a calculated permeability of 25 millidarcys.

DST-4 had one perforated zone from 4299 to 4305 metres over sandstones in the near-top Lower Jurassic section. During this 8-hour test, gas flowed at 18.2 million cubic feet per day, along with condensate at 20 barrels per million cubic feet, and a small amount of water (through a 1-inch choke). This test indicated a permeability of 98 millidarcys.

After these successful DSTs, no production tests were carried out, and the well has been suspended.

2.1x Scott Reef No.2a

Scott Reef No.2A, an appraisal well, was drilled in 1977 by Woodside 4.5 kilometres southeast of Scott Reef No.1. It reached a total depth of 4820 metres in Lower Jurassic claystones. The rotary table elevation was 8 metres above sea level. The well intersected a gas/water transition zone in Lower Jurassic reservoir sands.

Moderately high gas readings, including 100 ppm of C4, were recorded between 4614 and 4660 metres in the Jurassic section. No hydrocarbon indications were observed in ditch cuttings taken from this well or in any of 111 sidewall core samples.

The Lower to Middle Jurassic section between 4611 and 4711 metres consists of sandstone and claystone interbedded with siltstone and basalt. The sandstone has a combined net thickness of 40 metres and a log porosity of 12 %. 4618 metres (logger's depth) or 4628 metres (driller's depth) prior to running wire-line logs, log data are not reliable in the 30 metre interval immediately above the casing shoe. In addition, the cementing job may have caused some adverse effects in subsequent wire-line logs over the interval immediately below the casing shoe.

A conventional core was cut from 4617.5 to 4626.5 metres in the Lower to Middle Jurassic section with a recovery of 7.5 metres. The core comprises claystone, which appear to be cavings from 4617.5 to 4618.08 metres, sandstone from 4618.08 to 4623.58 metres and interbeds of siltstone, claystone and sandstone from 4623.58 to 4625 metres. The sandstone between 4618.08 and 4623.58 metres is white, medium-grained, sub-angular, well sorted and quartzose. No hydrocarbon indications were recorded in this core. A total of 21 plugs, taken mainly from the sandstone intervals and partly from the siltstones in the core, have porosities of 3.8 to 17.4 % (with an average of 13 % for the sandstone intervals) and permeabilities of 0.1 to 16 millidarcys (with an average of 4 millidarcys for the sandstone intervals).

Five FITs were run in the Lower to Middle Jurassic sandstones. FIT No.5A, a cased-hole test at 4612 metres (4604 metres subsea), recovered 22.6 litres of mud in a 22.6-litre sample chamber. Cased-hole FIT No.1, with a 22.6-litre chamber at 4613.8 metres recovered 20.4 litres of water, 0.02 litres of sand and 2.2 cubic feet of gas with traces of condensate. This gas appears to be solution gas dissolved in the formation water. (The solution gas/water ratio for saturated water in these reservoirs is about 0.16 cubic feet/litre at standard conditions.)

A cased-hole FIT No.2 (also equipped with a 22.6-litre chamber) at 4616.8 metres, recovered 13.15 litres of water, traces of gas, mud and sand. However, some gas had leaked off before the chamber was opened. Open-hole FIT No.4 at 4654 metres was a misrun. Open-hole FIT No.6, with two 0.6-litre chambers at 4655 metres recovered 0.65 litres of water, a small quantity of gas and traces of mud and condensate. Although the results of these tests are not conclusive, they suggest that the well was drilled into the gas/water transition zone of the Jurassic gas reservoir intersected in Scott Reef No.1., and also suggest that the gas-water contact lies updip and in close proximity to Scott Reef No.2A.

The Lower Jurassic section, between 4711 metres and the total depth of 4820 metres, comprises interbeds of oolitic limestone, sandstone and claystone. The limestones have porosities of less than 5 % and the sandstones have a porosity of 7 %. Open-hole FIT No.3A, run in sandstones at 4792 metres, recovered 7.2 litres of water and traces of mud and sand in a 9.5-litre chamber.
No flow tests were carried out in this well, and the well was plugged and abandoned.

2.1y Woodbine No.1

Woodbine No.1 was drilled by Woodside in 1979 and bottomed in Upper Triassic claystone at 3502 metres. The rotary table elevation was 8 metres above sea level.

Cut fluorescence was occasionally observed in ditch cuttings from 2130 to 2365 metres within the Maastrichtian section. Claystone cuttings from 2190 and 2250 metres also showed traces of fluorescence. Fair amounts of well-head gas were observed from 3050 to 3290 metres within the Lower Cretaceous and Upper Triassic sections. Of the 110 sidewall cores, two sandstone samples from 3187.5 and 3273 metres within the Upper Triassic section exhibited both fluorescence and cuts.

The Upper Cretaceous section contains seven sandstone units between 2325 and 2759 metres with a total gross thickness of 172 metres, a net thickness of 155 metres and a weighted average porosity of 26 %. All of these units are water-wet. Clean sandstones dominate in a sandstone and claystone interval from 2509 to 2759 metres within the Upper Cretaceous section.

The Triassic section, from 3076 to the total depth of 3499 metres, consists of alternating sandstones, claystones and siltstones, and has a sand/shale ratio of 4:6. These sandstones have porosities of 13 to 22 %. Well developed sandstones, in an interval between 3160 and 3364 metres, have a net thickness of 134 metres and an average porosity of 20 %. However, the entire Triassic section is water-wet.

Of the nine RFT surveys carried out in the well, one is a fluid-sampling test in Triassic sandstones at 3172.4 metres. A 22.7-litre chamber recovered 22.7 litres of water with less than one cubic foot of gas, and the second chamber of 3.8 litres recovered 3.8 litres of water.

2.1z Yampi No.1

Yampi No.1 was drilled by BOC in 1973 and reached a total depth of 4186 metres (logger's depth) or 4176 metres (driller's depth) in Lower Permian claystone. The rotary table elevation was 12.5 metres above sea level.

Moderately high gas readings were observed from 2875 to 3340 metres in the Jurassic section and peaked at 3160 to 3295 metres in Middle Jurassic sandstone. An interval between 3025 to 3050 metres in Upper Jurassic sandstones gave weak fluorescence and cuts. Middle Jurassic sandstones between 3167 and 3304 metres, which overlie 86 metres of Jurassic volcanics, showed fluorescence and streaming cuts.

In the Lower Permian section below 3770 metres, moderately high well-head gas readings continued from 3915 to total depth. Sandstone ditch cuttings from 3992 to 4006 metres showed weak fluorescence and cuts.

Of the 244 sidewall core samples recovered, 39 gave various degrees of hydrocarbon indications. Many of the samples that exhibited hydrocarbon indications were taken from the intervals where both high gas readings and shows in ditch cuttings were recorded.

Following high gas readings and a 5-fold drilling break in Middle Jurassic sandstones, a conventional core was cut from 3173.0 to 3178.3 metres with a recovery of 4.2 metres of Middle Jurassic sandstone and a small amount of claystone. The sandstones are grey, silty and clayey, very fine, moderately sorted, sub-angular to sub-round and cemented with silicious materials with no visible porosity. The sandstones exhibit frequent cross-bedding and remnant burrows. See Appendix 2 for a photograph of the Yampi No. 1 core. The sandstones showed both fluorescence and solvent fluorescence, whereas the claystones gave fluorescence and instantaneous streaming solvent fluorescence. Neither the sandstones nor the claystones exhibited cuts. These sandstones are overlain by 110 metres of Jurassic siltstone.

A total of 11 core plugs taken from this core have porosities ranging between 0.8 and 11.2 % (with an average of 6 %), and permeabilities of 0.0 to 22 millidarcys (with an average of 0.1 millidarcys). The highest residual oil saturation of 14.3 %, along with a residual water saturation of 69.7 %, was recorded in highly silty sandstones at 3174.84 metres. Here, porosity is 5.6 % and permeability is less than 0.1 millidarcys. These core data preclude the presence of moveable oil in the sandstones.

Aptian sandstone between 1832 and 1897 metres has a porosity of 17 %, and Upper Jurassic sandstones between 2570 and 2829 metres and between 2948 and 3057 metres have porosities of 14 %. Sandstones in the Middle to Lower Jurassic interval between 3135 and 3587 metres have a log porosity of 12 %, which is much higher than the core porosities. Triassic and Permian sandstones below 3587 metres have porosities of less than 10 %. Porosity decreases progressively with depth. Wire-line data indicate that all the sandstones, including those from which residual oil was extracted, are water-wet.

Four FITs, each equipped with a 22.2-litre sample chamber, were attempted in this well. FIT No.1 was run at 3175 metres in the Middle Jurassic sandstones where a core had been cut. This test, invalid because of seal failure, recovered 22.2 litres of mud. FIT No.3, at 3265 metres over the same Middle Jurassic sandstones, recovered only 6.5 litres of filtrate. FIT No.4, at 3560 metres in Lower Jurassic sandstones, was unsuccessful, and the tool was left in the hole. FIT No.2 was run at 4066 metres in Lower Permian sandstones and recovered 2.5 litres of mud. This is an invalid test because a seal was lost during the test.

Although good oil shows were recognized in Middle Jurassic sandstones, the reservoir rocks are tight and appear to contain no moveable oil.

APPENDIX 2

CORE PHOTOGRAPH: YAMPI NO.1, CORE 1

E. Resiak & J. Staunton

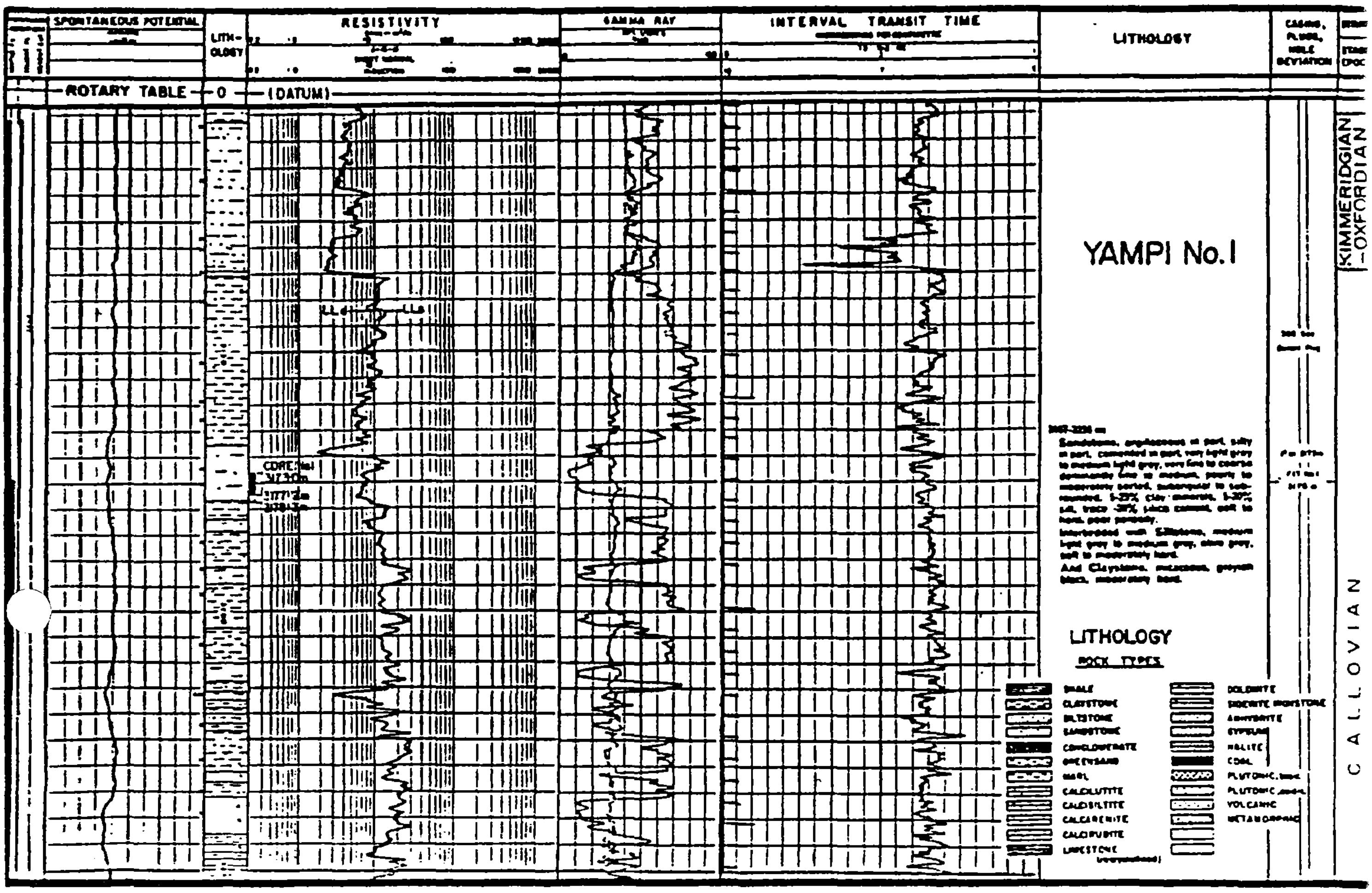
BMR GEOLOGY AND GEOPHYSICS AUSTRALIA

Core Photograph: Yampi No.1. Core 1

BMR GEOLOGY AND GEOPHYSICS AUSTRALIA

APPENDIX 2.

Composite log.: Yampi No.1. Core 1



APPENDIX 3

LIST OF MARINE SEISMIC SURVEYS IN THE BROWSE BASIN

T.U Maung

APPENDIX 3

List of marine seismic surveys in the Browse Basin

SURVEY NAME	OPERATOR	YEAR	CONTRACTOR	ENERGY SOURCE	NO. OF KM SURVEYED	CDP COVERAGE (%)	REFERENCE BMR
Northwest Australia	BOC	1964	Western Geophysical	Dynamite	3459	100	PSSA 64/4329
Montebello-Mermaid	BOC	1965	Western Geophysical	Dynamite	6125	200	PSSA 65/11015
Rankin-Troubadour	BOC	1966	Western Geophysical	Dynamite	2808		PSSA 66/11104
Ashmore Reef Shallow water	BOC	1967	Western Geophysical	Dynamite	-	300	PSSA 67/11144
Scott-Cartier	BOC	1967	Western Geophysical	Dynamite	1642	300	PSSA 67/11173
Offshore Canning-Seringapatam	BOC	1968	Western Geophysical	Dynamite	2802	1200 (48 ch)	PSSA 68/3027
Legendre-Marie	BOC	1969	Western Geophysical	Aquapulse	912	1200 (48 ch)	PSSA 69/3005
Adele-Scott	BOC	1969	Western Geophysical	Aquapulse	841	1200 and 2400 (48 ch)	PSSA 69/3038
Tryal-Evans (Projects 70E, 70F, 70G, 70K)	BOC	1970	Western Geophysical	Aquapulse	1719	2400 (48 ch)	PSSA 70/245
Trimouille-Dillon (Projects 71F, 71G, 71H)	BOC	1971	Western Geophysical	Maxipluse	2028	2400 (48 ch)	PSSA 70/976
Scott Reef Detail	BOC	1971	Western Geophysical	Maxipulse	722	2400 (48 ch)	PSSA 71/481

List of marine seismic surveys in the Browse Basin (continued)

SURVEY NAME	OPERATOR	YEAR	CONTRACTOR	ENERGY SOURCE	NO. OF KM SURVEYED	CDP COVERAGE (%)	REFERENCE BMR
Sahul-Ashmore	BOC	1971	Western Geophysical	Maxipulse	617	2400 (48 ch)	PSSA 71/667
Browse Basin (Project 72C)	BOC	1972	GSI	Airguns	2356	4800	PSSA 72/791
Browse Island (Project 72M)	BOC	1972	Western Geophysical	Aquapulse	147	2400	PSLA 72/2
Baleine	Amax	1972	Western Geophysical	Maxipulse	990	2400 (48 ch)	PSLA 72/25
Mermaid-Cartier	BOC	1973	Western Geophysical	Maxipulse	4861-7	2400 (48 ch)	PSLA 73/204
Kendrew-Cootamundra (Projects 74J, 74K, 74L)	BOC	1974	GSI, Western Geophysical	Airgun, Maxipulse	3151	1200 (48 ch)	PSLA 74/31
Tessa-Troubadour (76F, 76G, 76J)	BOC	1976	GSI	Airgun	2409	4800 (48 ch)	PSLA 75/11
Haycock-Laminaria (Projects 77N, 77P, 77Q)	Woodside	1977	GSI	Airgun	809	4800 (96 ch)	PSLA 77/1
Hermite-Barton (Projects 78F, 78H, 78I, 78J, 78K)	Woodside	1978	GSI	Airgun	2909	4800 (96 ch)	PSLA 78/2
Fraser Inlet	Woodside/ Brunswick	1978	Western Geophysical	Airgun	1082	4800 (96 ch)	PSLA 78/19

List of marine seismic surveys in the Browse Basin (continued)

SURVEY NAME	OPERATOR	YEAR	CONTRACTOR	ENERGY SOURCE	NO. OF KM SURVEYED	CDP COVERAGE (%)	REFERENCE BMR
Woodbine-Victoria (Project northern area)	Woodside	1979	GSI	Airgun	1109.875	4800 (96 ch)	PSLA 79/1 PSLA 78/23
Churchill	Brunswick/ Weaver	1980	Western Geophysical	Airgun	800	4800 (96 ch)	PSLA 80/7
Leveque Shelf Margin (Phase 1)	Weaver	1980	GSI	Airgun	1054	4800 (96 ch)	PSLA 80/34
Eclipse Shoals	Conex	1981	GSI	Airgun	521	4800 (96 ch)	PSLA 81/29
Dampier-Broome	Woodside	1981	GSI	Airgun	2021.42	4800 (96 ch)	PSLA 80/52 PSLA 80/54
Browse	Weaver-Esso	1982	GSI	Airgun	4056.3	4800 (192 ch)	PSLA 82/15 PLSA 82/16
2DW	Woodside	1982	Western Geophysical	Airgun	2715	6000 (120 ch)	PSLA 81/65
Leveque Shelf Margin (Phase 11)	Weavaer	1982	Western Geophysical	Airgun	942.5	4800 (96 ch)	PSLA 81/62
BE 82A and BE 82B	ESSO	1982	GSI	Airgun	2016(A) 2041(B)	4800 (192 ch)	PSLA 82/15 PSLA 82/16
Calliance Reef	Seahawk Oil	1983	GSI	Airgun	1015.92	4800 (192 ch)	PSLA 82/55
Lewis-Brecknock	Woodside	1983	GSI	Airgun	373	6000 (120 ch)	PSLA 83/09
Caswell-Echuca	Woodside	1984	Western Geophysical	Airgun	608	6000 (240 ch)	PSLA 84/15
Scobell	SANTOS and Seahawk Oil	1985	GSI	Airgun	200.5	6000 (120 ch)	PSLA 84/25
Fontome	SANTOS and Seahawk Oil	1985	GSI	Airgun	802.08	6000 (120 ch)	PSLA 85/16

List of marine seismic surveys in the Browse Basin (continued)

SURVEY NAME	OPERATOR	YEAR	CONTRACTOR	ENERGY SOURCE	NO. OF KM SURVEYED	CDP COVERAGE (%)	REFERENCE BMR
Leveque Margin (non-exclusive)	GSI	1985	GSI	Airgun	2700	4800 (192 ch)	PSLA 86/31
Whimbrel	Ampol	1986	GSI	Airgun	2481	4800 (192 ch)	PSLA 85/53
ISL 86-85LM	GSI	1985/6	GSi	Airgun	2717	6000 (240 ch)	PSLA 86/26
Capella	Marathon	1986	Western Geophysical	Airgun	1501.84	6000 (240 ch)	PLSA 85/51
BW87	BHP	1987	GSI	Airgun	474	10 000 (300 ch)	PSLA 87/18 PSLA 87/19
Olga	Ampol	1988	GSI	Airgun	378.3	7500 (300 ch)	PSLA 88/29
2D Lynher	Bridge Oil	1988	GSI	Airgun	210.525	7500 (300 ch)	PSLA 88/28
3D Lynher	Bridge Oil	1988	GSI	Airgun	1015.05	4800 (192 ch)	PSLA 88/28
Enneidra	Ampol	1989	GSI	Airgun	2610	7500 (300 ch)	PSLA 89/24
Roxanne	WMC	1989	Western Geophysical	Airgun	450	4800 (240 ch)	PSLA 89/29
Loretta	Ampol	1989	GSI	Airgun	340	7500 (300 ch)	PSLA 89/44

APPENDIX 4

WELL SEISMIC DATA

T.U Maung

APPENDIX 4A

Well seismic data used in regional cross-section A-A'

Well name and location	Seismic markers											Depth and two-way time	Remarks
	E	M	X	D	F	J_c	J_b	T	O	B	TD		
Buffon No. 1 SP 119 Line 73-1180	2663 2.156	3257 2.441	3470 2.557	3477 2.561	3919? 2.730?	Not present -	3764 2.761	Not pene-trated	Not pene-trated	Not pene-trated	4777 3.087	Depth mSS TWT sec	Depth of F doubtful. X is only 7 m deeper than M so that TWT for X is doubtful
Brewster No.1 SP 850 Line 69-332	1010 0.978	1411 1.236	1707 1.440	2305 1.825	3295 2.559	3934 2.948	4557 3.238	Not pene-trated	Not pene-trated	Not pene-trated	4695 3.302	Depth mSS TWT.sec	-
Echuca Shoals No. 1 SP 41 Line 76-1715	 0.799	823 1.014	1110 1.129	1300? 1.651	2043 2.076	2700? 2.472	3312 2.619	3660 2.619	3660 2.847	4200? -	-4348 2.910	Depth mSS TWT sec	Depths of X, F and O doubtful. Jb and T are at same depth
Heywood No. 1 SP 70 Line 74-1337	798 0.610	1197 0.915	1580 1.050	2268 1.440	3083 1.860	3395 2.340	4230 2.745	Not pene-trated	Not pene-trated	Not pene-trated	4562 2.902	Depth mSS TWT sec	-
Londonderry No. 1 SP 1920 Line M200-04	516 0.490	605 0.560	694 0.600	756 0.690	992? 0.884	Not pene-trated	Not pene-trated	Not pene-trated	Not pene-trated	1122 0.980	1132 1.000	Depth mSS TWT sec	Depths for seismic markers are estimated

Well seismic data used in regional cross-section B-B'

Well name and location	Seismic markers											Depth and two-way time	Remarks
	E	M	X	D	F	J_c	J_b	T	O	B	TD		
Brecknock No. 1 SP 41.2 Line 73-1148	2157 1.740	3300 2.380	3416? 2.387	3562 2.530	3741? 2.535	Not present	3798 2.680	3984 2.830	Not pene-trated	Not pene-trated	4289 2.985	Depth mSS TWT sec	Depths of X and F are doubtful
Lombardina No. 1 SP 42 Line 71-658	607 0.620	897 0.800	946 0.840	1208 1.080	1697 1.450	2278 1.800	2671 2.040	Not pene-trated	Not pene-trated	Not pene-trated	2825 2.140	Depth mSS TWT sec	Depths for seismic markers are estimated
Leveque No. 1 SP 116 Line 70-479	325 0.380	Not present	Not present	406 0.540	708 0.700	835 0.770	879 0.865	Not pene-trated	Not pene-trated	886 1.020	899 1.020	Depth mSS TWT sec	Depths for seismic markers are estimated

Well seismic data used in regional cross-section C-C'

Well name and location	Seismic markers											Depth and two-way time	Remarks
	E	M	X	D	F	J_c	J_b	T	O	B	TD		
Caswell No. 2 SP 31 Line 76-1678	1643 1.480	2062 1.600	2578 1.920	3399 2.320	3728 2.570	4488 2.980	4936 3.200	Not pene- trated	Not pene- trated	Not pene- trated	4983 3.223	Depth mSS TWT sec	-
Lombardina No. 1 SP 42 Line 71-658	607 0.620	897 0.800	946 0.840	1208 1.080	1697 1.450	2278 1.800	2671 1.040	Not pene- trated	Not pene- trated	Not pene- trated	2825 2.140	Depth mSS TWT sec	Depths for seismic markers are estimated
Lynher No. 1 SP 71 Line 70-489	171 0.350	350 0.420	Not present	721 0.720	1004 0.800	1326 0.900	1714 1.100	2417 1.600	2630 1.835	Not pene- trated	2715 1.929	Depth mSS TWT sec	-

APPENDIX 5

AIRBORNE LASER FLUOROSENSOR (ALF) SURVEY
BROWSE BASIN

S.J. Cadman

In July 1989, BP Exploration undertook an Airborne Laser Fluorosensor survey of the Browse Basin. Basic data from this survey are now on open file (BP Exploration Co. Ltd, 1989).

A total of 2185 line kilometres of production were recorded in six sorties, with an average daily production of 437 line kilometres.

A map at a scale of 1:200 000 shows the location of the survey and the Total Fluorescence recorded along the flight line (Plate 2).

Principles of the Technique

A number of authors have shown that gas bubble plumes and sea-bed features associated with offshore petroleum seepages commonly occur in many petroleum provinces. Oil is brought to the sea surface from a trap by gas, driven by buoyancy, rising through the rock matrix to the sea bed and thence through the water column. Bubbles rise at rates which commonly exceed the velocities of ocean currents. Consequently, their emergence at the surface is seldom further away from the seep vents than a distance equivalent to the water depth. Dilution, especially in rough water, causes such slicks to disappear quite rapidly.

A rapid reconnaissance system for detecting seeped petroleum in the marine environment by its characteristic fluorescence can be created by installing a fluorosensor in an aircraft. Fluorescence induced in oil films and near-surface oily emulsions by an excimer laser source of fixed wavelength (308 nm) is collected, recorded and synchronised with navigational and environmental data.

The signal returns from the excimer laser source comprise three components :

(i) **Backscatter** is the unchanged laser light that is reflected directly from the sea surface (308 nm).
(ii) **Raman signal** arises from the sea water and is a measure of the clarity of the water column. It has a characteristic peak around 345 nm.
(iii) **Fluorescence** arising from an oil film. This spectra may peak anywhere between 330 and 580 nm.

The total fluorescence map (Plate 2) represents a continuous recording of the above three spectra.

Interpretative data from this survey are not yet available in the public domain. Consequently, maps showing fluorescence anomalies in the survey area have not been included in this study.

APPENDIX 6

GEOCHEMICAL DATA FROM BROWSE BASIN WELLS

B.G. West

Key:

TOC: Total organic carbon in sample
S1: Volatile hydrocarbons (mg hydrocarbons/g rock)
S2: HC generating potential (mg S2 hydrocarbons/g rock)
S3: Organic carbon dioxide (mg CO2/g rock)
TMAX: Temperature at which S2 signal is a maximum (degrees celsius)
PI: Production Index [S1/(S1+S2)]
HI: Hydrogen Index (mg hydrocarbons/g organic carbon)
OI: Oxygen Index (mg CO2/g organic carbon)

Geochemical data compiled from well completion reports and destructive analysis reports.

Seismic markers after Willis (1988)

APTIAN - CENOMANIAN (D seismic marker)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Leveque-1	655-667	1.10	0.18	0.39	0.53	415	0.32	35	48
Lynher-1	1072.9	0.97	0.01	0.17	0.40	420	0.08	18	1
	1155.2	1.62	0.03	0.54	0.32	421	0.04	33	2
Scott Reef-1	3761.3	0.98	0.16	0.67	0.22	422	0.19	68	22
Rob Roy-1	936-951	1.09	0.06	0.23	1.18	419	0.21	21	108
	985-1000	1.11	0.08	0.56	0.78	423	0.13	50	70
	1200.9	1.12	1.17	1.50	0.70	411	0.44	134	63
Yampi-1	1615	0.88	0.03	0.19	0.27	411	0.15	21	4
	1705	1.36	0.06	0.46	0.26	412	0.11	34	4
	1810	1.27	0.04	0.34	0.22	413	0.12	27	4
	1850	1.05	0.69	0.70	0.26	413	0.50	67	66
	1920-1950	4.40	0.00	1.76	3.56	426	0.00	40	81
	1960	0.98	0.02	0.25	0.18	419	0.06	26	2
	2020-2050	1.52	0.00	1.00	0.90	423	0.00	66	59
	2045	1.02	0.68	0.69	0.27	398	0.49	68	66
	2250-2280	1.87	0.04	1.40	0.60	428	0.03	75	32
	2400-2420	1.95	0.18	1.60	0.80	429	0.10	82	41
	2520-2550	2.31	0.07	1.89	0.55	436	0.03	82	24
Heywood-1	2280-2285	0.81	0.07	0.45	0.53	417	0.13	56	65
	2930 2935	0.67	0.35	1.60	0.37	429	0.18	132	31
Lombardina-1	1470-1485	1.09	1.28	2.37	1.42	-	0.35	217	130
	1845-1855	2.09	1.49	4.95	1.61	432	0.23	237	77
	2030	1.55	0.90	1.74	0.39	432	0.34	112	58
	2085-2095	2.83	1.44	5.43	2.12	431	0.21	192	75
	2265-2275	2.47	1.24	2.79	2.05	434	0.31	113	83

APTIAN - CENOMANIAN (D seismic marker) (continued)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Prudhoe-1	2080-2090	1.27	0.13	1.70	1.14	429	0.07	135	90
	2150-2190	1.15	0.23	1.05	1.36	431	0.18	91	118
Caswell-1	3450-3600	0.73	0.10	0.27	1.60	-	0.28	37	219
	3610-3795	0.70	0.17	0.49	1.16	439	0.26	70	166
	3620-3635	1.37	1.64	2.14	2.27	430	0.43	156	166
	3685-3700	1.55	4.64	4.03	2.22	-	0.54	260	143
	3800-4060	1.52	0.69	1.52	1.26	442	0.31	113	94
	3815-3830	2.28	1.06	1.30	2.03	440	0.03	57	89
Barcoo-1	3290-3340	1.42	0.11	1.87	0.21	432	0.06	132	15
	3370-3400	4.74	0.34	14.79	0.33	432	0.02	312	7
Buffon-1	3530-3545	1.58	0.08	1.14	1.90	428	0.07	72	120
	3620-3635	1.71	0.08	0.80	1.15	429	0.09	47	67
	3675-3690	1.03	0.12	1.17	1.33	431	0.09	114	129
	3700-3900	0.52	0.04	0.11	0.71	-	0.29	21	137
	3705-3720	1.45	0.09	0.81	1.31	431	0.10	56	90
Brewster-1A	3220-3230	1.14	0.79	1.95	1.83	443	0.29	171	161
North Scott Reef-1	4047	0.27	0.01	0.05	0.58	296	0.17	18	214
Caswell-2	3419.5	0.59	0.11	0.02	0.28	274	0.85	3	47
	3428.0	0.34	0.08	0.01	0.22	274	0.89	2	64
	3438.0	0.25	0.04	0.01	0.25	252	0.80	4	100
	3460.0	0.41	0.08	0.01	0.23	223	0.89	2	56
	3495.0	0.78	0.08	0.06	0.19	337	0.57	7	24
Asterias-1	3026-3029	0.78	0.06	0.49	2.25	423	0.11	62	288
	3047	0.73	0.05	0.58	0.59	430	0.08	79	80
	3068-3071	0.97	0.14	0.76	2.73	424	0.16	78	281
	3077-3080	1.08	0.22	1.34	2.23	428	0.14	124	206
	3086-3089	0.96	0.09	0.65	3.09	428	0.12	67	321
	3128-3131	0.98	0.17	0.97	2.18	431	0.15	98	222
	3146-3149	0.96	0.16	1.01	3.88	429	0.14	105	404
	3158-3161	1.00	0.16	1.03	2.73	431	0.13	103	273
	3218-3222	0.80	0.10	0.36	3.17	421	0.22	45	396
	3257-3260	0.77	0.15	0.57	3.24	426	0.21	74	420
	3287-3290	0.91	0.19	0.96	3.70	427	0.17	105	406
	3296-3299	1.24	0.38	1.47	2.89	432	0.21	118	233
	3407-3410	0.94	0.21	0.96	1.65	426	0.18	102	175

NEOCOMIAN - APTIAN (F seismic marker)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Leveque-1	771.2	1.56	0.39	2.42	0.95	419	0.14	155	61
Lynher-1	1246	1.39	0.00	0.10	0.44	431	0.00	7	32
	1254.3	1.39	0.03	0.80	0.20	420	0.04	57	2
	1311-1326	1.77	0.09	1.51	0.57	429	0.06	86	33
	1326-1335	1.11	0.23	0.95	3.17	426	0.19	85	285
Scott Reef-1	4114.9	1.11	0.10	0.34	0.54	-	0.23	31	49
Rob Roy-1	1229-1244	1.43	0.05	0.72	1.00	428	0.07	50	70
	1265-1280	1.59	0.08	0.52	0.83	418	0.12	33	52
Prudhoe-1	2450-2550	1.59	0.73	2.51	2.20	432	0.23	158	138
	2510-2520	1.24	0.17	1.94	1.65	433	0.08	156	133
	2650-2660	1.58	1.83	3.23	0.56	425	0.36	204	35
Caswell-1	3800-4060	1.52	0.69	1.52	1.26	442	0.31	113	94
	4075-4090	2.59	1.65	2.72	1.40	442	0.38	105	54
Brewster-1A	3460-3470	1.51	0.37	2.30	3.76	437	0.14	152	249
	3610-3620	1.92	0.44	1.65	2.36	433	0.21	86	123
	3760-3770	2.37	0.31	0.62	1.54	452	0.33	26	65
Caswell-2	3893.0	1.41	0.32	0.68	0.38	429	0.32	48	26
	3941.0	1.31	0.28	0.26	0.45	430	0.52	19	34
	4000.0	1.96	0.45	0.70	0.49	424	0.39	35	25
	4021.8	2.14	0.58	0.72	0.59	424	0.45	33	27
	4039.9	1.47	0.31	0.25	0.72	411	0.55	17	48
	4050.1	1.06	0.28	0.21	0.55	418	0.57	19	51
	4060.0	1.32	0.33	0.20	0.42	418	0.62	15	31
	4078.0	1.51	0.55	0.55	0.46	422	0.50	36	30
	4097.0	1.63	0.89	0.71	0.44	428	0.56	43	26
	4113.0	1.43	0.32	0.39	0.59	443	0.45	27	41
	4119.9	1.91	0.95	1.15	0.64	433	0.45	60	33
	4193.0	1.27	0.32	0.42	0.82	444	0.43	33	64
	4220.0	1.53	0.38	0.37	0.57	413	0.51	24	37
	4229.0	1.49	0.39	0.53	0.59	539	0.42	35	39
	4240.0	2.07	0.55	0.49	0.53	427	0.53	23	25
	4250.0	1.35	0.21	0.11	0.47	449	0.66	8	34
	4259.0	1.80	0.41	0.33	0.51	414	0.55	18	28
	4270.0	0.93	0.32	0.43	3.90	536	0.43	46	419
	4280.0	2.29	0.71	0.44	0.45	415	0.62	19	19
	4290.0	1.86	0.44	0.23	0.53	417	0.66	12	28
	4300.0	1.86	0.56	0.47	0.46	412	0.54	25	24
	4310.0	1.88	0.78	0.66	0.44	432	0.54	35	23
	4320.0	1.67	0.26	0.23	0.50	434	0.53	13	29
	4330.0	1.42	0.30	0.15	0.43	350	0.67	10	30
	4354.0	1.54	0.25	0.19	0.54	396	0.57	12	35
	4390.1	0.65	0.20	0.07	0.35	274	0.74	10	53

NEOCOMIAN - APTIAN (F seismic marker) (continued)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Caswell-2	4443.1	1.45	0.35	0.23	0.58	374	0.60	15	40
(continued)	4454.2	0.60	0.18	0.14	0.45	352	0.56	23	75
	4466.1	0.71	0.13	0.03	0.52	342	0.81	4	73
	4480.1	0.51	0.13	0.07	0.50	274	0.65	13	98
	4490.0	0.64	0.10	0.08	0.38	296	0.56	12	59
	4504.0	0.45	0.07	0.04	0.55	274	0.64	8	122
Asterias-1	3578-3581	0.97	0.27	0.99	3.54	430	0.21	102	364
	3626-3629	1.25	0.41	1.96	4.47	434	0.17	156	357
	3638-3641	1.90	0.75	3.04	2.88	435	0.20	160	151

LATE JURASSIC - EARLY NEOCOMIAN (Jc seismic marker)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Leveque-1	844.3	1.88	0.22	1.90	0.71	419	0.10	101	38
	877.8	1.90	0.40	3.44	0.95	422	0.29	181	50
Lynher-1	1326-1341	2.57	0.01	1.59	0.80	424	0.00	62	31
	1335-1344	1.02	0.19	0.79	2.41	424	0.19	77	236
	1359-1369	2.09	0.46	0.97	1.94	416	0.32	46	92
	1448-1460	5.43	0.83	6.95	1.41	425	0.11	128	26
	1454-1463	5.15	1.33	7.48	2.67	430	0.15	145	51
	1460-1470	6.72	1.33	10.95	1.14	429	0.11	163	17
	1463-1472	10.40	2.09	15.11	2.24	430	0.12	145	21
	1472-1481	11.40	3.45	20.86	2.58	431	0.14	182	22
	1481-1490	7.68	2.23	14.39	1.92	431	0.13	187	25
	1503-1512	4.54	0.77	5.95	2.24	430	0.11	131	49
	1509-1524	2.49	0.18	3.18	0.92	431	0.07	122	43
	1512-1521	13.10	1.62	24.37	2.74	431	0.06	186	20
	1521-1530	10.10	1.18	16.04	2.31	430	0.07	158	22
	1530-1539	19.30	2.44	36.02	4.18	428	0.06	186	21
	1539.4	15.12	0.72	21.62	6.99	434	0.03	143	5
	1539-1548	16.70	1.94	28.22	3.22	431	0.06	168	19
	1540-1555	3.03	0.18	4.73	0.72	425	0.06	126	33
	1548-1558	13.60	1.40	19.52	2.75	431	0.07	143	20
	1555-1570	1.79	0.00	7.30	0.72	427	0.00	408	40
	1558-1567	11.80	1.16	17.81	2.60	430	0.06	150	22
	1567-1576	16.60	1.65	28.79	2.71	430	0.05	173	16
	1570-1585	2.52	0.15	2.34	0.88	431	0.06	93	35
	1576-1585	19.10	2.11	17.93	4.24	430	0.11	93	22
Yampi-1	2720-2750	2.11	0.22	2.11	0.51	424	0.10	100	24
	2850	1.01	0.18	0.60	0.27	423	0.23	59	17
	2940	1.03	0.11	0.60	0.29	425	0.15	59	11
	3040-3070	1.52	0.30	1.20	1.50	421	0.20	79	99

LATE JURASSIC - EARLY NEOCOMIAN (Jc seismic marker) (continued)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Heywood-1	4159-4175	1.21	0.37	1.32	0.40	433	0.22	197	60
Lombardina-1	2310-2390	1.61	2.22	2.98	1.28	436	0.43	185	80
	2355	1.25	1.17	1.41	0.32	433	0.45	113	93
	2400-2480	1.43	1.64	2.05	1.18	438	0.45	143	83
Prudhoe-1	2780-2850	0.51	0.22	0.57	1.90	432	0.28	112	373
	2880-2890	0.40	0.82	3.27	0.50	433	0.20	818	125
Barcoo-1	3800-3810	0.95	0.16	0.82	2.42	429	0.16	86	254
	3820-3830	1.38	0.20	1.43	2.68	432	0.12	103	194
Brewster-1A	4355-4370	1.23	1.37	2.31	1.43	-	0.37	188	116
	4420-4435	1.51	0.24	0.57	2.23	454	0.28	38	148
	4525-4540	1.46	0.10	0.35	2.61	489	0.22	24	179
Caswell-2	4517.3	0.63	0.14	0.12	0.42	301	0.54	19	66
	4522.1	0.27	0.09	0.15	0.46	367	0.38	55	170
Asterias-1	3848-3851	1.37	3.52	4.73	5.68	411	0.43	345	414
	3926-3929	0.84	0.45	1.73	4.12	429	0.21	205	490
	3947-3950	0.84	0.48	1.66	3.52	431	0.22	197	419
	4317.6	0.92	0.67	1.78	1.76	439	0.27	193	191
	4320.0	0.92	0.49	0.93	0.36	429	0.35	101	39
	4331.5	0.88	0.46	1.90	0.31	440	0.19	215	35

EARLY - MIDDLE JURASSIC (Jb seismic marker)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Lynher-1	1731-1740	0.79	0.21	0.67	2.51	428	0.24	84	317
	1768-1784	1.62	0.15	1.65	2.50	433	0.09	103	87
	1771-1780	1.47	0.23	1.48	4.30	435	0.13	100	292
	1828.8	1.76	0.09	1.89	0.24	432	0.04	107	5
	1829-1845	3.02	0.18	3.38	1.93	431	0.05	112	64
	1838-1847	1.90	0.30	2.72	4.03	433	0.10	143	212
	1856.2	1.57	0.08	1.11	0.00	430	0.07	71	5
	1860-1875	1.55	0.13	1.87	1.53	438	0.07	122	102
	1865-1875	1.85	0.32	2.77	3.15	434	0.10	149	170
	1875-1890	2.29	0.00	0.71	1.81	430	0.00	31	79
	1890-1905	2.01	0.09	1.51	1.13	433	0.06	75	56
	1893-1902	1.49	0.31	1.66	3.00	432	0.16	111	201
	1911-1920	1.15	0.23	1.37	2.60	432	0.14	119	226
	1923.3	1.16	0.03	0.48	0.00	425	0.06	41	3

EARLY - MIDDLE JURASSIC (Jb seismic marker) (continued)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Lynher-1	1942-1951	2.66	0.35	3.14	2.01	434	0.10	118	75
(continued)	1960-1969	1.66	0.32	1.54	2.01	433	0.17	92	121
	1982-1997	2.01	0.16	2.66	0.87	434	0.07	104	50
	1984-1993	2.95	0.53	3.83	2.04	435	0.10	129	69
	2085-2094	2.56	0.70	4.93	1.75	433	0.12	192	68
	2176-2185	2.68	0.57	2.56	2.48	436	0.18	95	92
	2180-2195	1.60	0.10	1.02	0.90	434	0.08	64	56
	2198-2207	2.30	0.44	2.18	2.13	437	0.17	94	92
	2210-2226	1.57	0.47	1.10	0.71	431	0.30	70	45
	2216-2222	1.49	0.20	1.12	1.60	434	0.15	75	107
	2240-2246	1.83	0.34	1.62	1.87	434	0.17	88	102
	2241-2256	1.98	0.08	1.94	0.83	434	0.03	98	42
	2287-2302	1.91	1.40	2.10	0.99	432	0.40	110	52
	2289-2295	1.08	0.20	0.73	1.65	428	0.22	67	157
	2359-2368	1.63	0.46	1.43	2.01	431	0.24	87	123
	2377-2387	2.42	0.30	2.67	1.42	433	0.10	110	58
	2383.5	2.39	0.08	1.79	0.51	429	0.04	75	3
	2393-2409	1.34	0.09	1.23	0.76	431	0.07	92	57
	2417-2423	1.43	0.55	1.38	0.88	429	0.28	96	61
Scott Reef-1	4325.2	0.86	0.07	0.37	0.83	408	0.16	43	97
Rob Roy-1	1537-1546	4.90	2.60	14.50	0.83	419	0.15	296	17
Yampi-1	3160	1.34	0.19	0.79	0.11	432	0.19	59	14
	3160-3190	2.38	0.27	2.40	0.55	420	0.10	101	23
	3173	3.21	0.71	6.29	0.29	425	0.10	196	9
	3250-3280	3.64	0.53	4.91	0.80	423	0.10	135	22
Heywood-1	4245-4250	1.54	0.24	2.56	2.05	428	0.09	166	133
Lombardina-1	2400-2480	1.43	1.64	2.05	1.18	438	0.45	143	83
	2495-2545	0.81	1.71	0.65	1.20	436	0.73	80	148
	2825	0.55	0.20	0.19	0.28	429	0.51	34	36
Barcoo-1	3830-3840	1.43	0.58	1.92	2.65	432	0.23	134	185
	3840-3850	1.74	0.53	2.22	2.94	433	0.19	127	168
	3870-3880	0.99	0.16	0.94	5.95	432	0.15	94	601
	3880-3930	1.15	0.09	0.51	0.32	430	0.15	44	28
	3910-3920	1.20	0.19	0.85	3.08	433	0.18	70	256
	3950-3960	1.18	0.18	0.75	2.35	432	0.19	63	199
	3960-3970	2.02	0.35	1.90	2.13	434	0.16	94	105
	4030-4040	1.11	0.78	2.13	2.37	431	0.27	191	213
	4040-4050	1.06	0.55	1.29	2.25	431	0.30	121	212
	4050-4060	0.95	0.40	1.04	2.27	428	0.28	109	238
	4060-4070	1.25	0.55	1.30	2.62	431	0.30	103	209
	4070-4075	1.01	0.53	1.39	1.50	429	0.28	137	148
	4080-4095	1.00	0.48	1.29	1.68	436	0.27	129	168
	4200-4210	1.19	0.65	2.22	4.61	436	0.23	186	387

EARLY - MIDDLE JURASSIC (Jb seismic marker) (continued)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Barcoo-1	4220-4230	1.09	0.45	1.55	6.65	433	0.22	142	610
(continued)	4230-4240	1.17	1.26	3.43	3.87	436	0.27	293	330
	4240-4250	1.13	0.87	2.32	3.31	436	0.27	205	292
	4250-4255	1.14	0.81	2.05	4.68	433	0.28	179	410
	4260-4270	1.09	1.33	2.50	4.06	430	0.35	229	372
	4290-4300	0.84	0.47	1.21	4.04	430	0.28	144	480
	4320-4330	0.85	0.32	0.87	5.38	427	0.27	102	632
	4360-4370	0.98	0.37	1.03	4.42	428	0.26	105	451
	4390-4400	1.33	1.70	3.44	4.24	423	0.33	258	318
	4400-4410	1.06	0.50	1.50	4.06	428	0.25	141	383
	4410-4420	1.11	0.56	1.31	3.61	428	0.30	118	325
	4420-4430	1.15	0.46	1.14	3.75	427	0.30	99	326
	4430-4440	1.17	0.41	1.10	4.35	427	0.27	94	371
	4440-4450	1.43	0.83	2.09	4.11	425	0.28	146	287
	4450-4460	1.11	0.35	0.89	4.43	428	0.28	80	399
	4460-4470	1.07	0.30	0.71	4.16	426	0.30	66	388
	4470-4480	1.15	0.32	0.80	4.63	426	0.29	69	402
	4480-4490	1.30	0.38	0.98	4.49	427	0.28	75	345
	4490-4500	1.38	0.43	1.11	4.28	429	0.28	80	310
	4500-4510	1.20	0.33	1.13	3.50	433	0.23	94	291
	4510-4520	1.05	0.32	1.00	3.54	432	0.24	95	337
	4520-4530	1.21	0.36	1.12	3.68	430	0.24	92	304
	4530-4540	1.21	0.46	1.23	3.07	431	0.27	101	253
	4540-4550	1.15	0.41	0.93	2.63	431	0.31	80	228
	4550-4560	1.24	0.46	1.29	3.22	432	0.26	104	259
	4560-4570	1.12	0.31	0.71	3.27	429	0.30	63	291
	4580-4590	0.94	0.30	0.57	2.50	431	0.34	60	265
	4600-4610	1.08	1.50	2.84	2.82	420	0.35	262	262
	4620-4630	0.76	0.32	1.07	3.33	426	0.23	140	438
	4650-4660	0.80	0.30	0.77	4.04	428	0.28	96	505
	4680-4690	0.58	0.25	0.64	3.00	427	0.28	110	517
	4710-4720	0.52	0.23	0.63	3.10	427	0.27	121	596
	4740-4750	0.63	0.26	0.88	3.54	429	0.23	139	561
Buffon-1	3700-3900	0.52	0.04	0.11	0.71	-	0.29	21	137
	4100-4200	0.31	0.23	0.05	0.43	-	0.82	16	139
	4300-4400	0.12	0.00	0.02	0.23	-	0.00	17	192
	4485-4500	1.98	0.12	0.57	1.09	427	0.16	29	55
	4600-4700	0.19	0.01	0.01	0.29	-	0.50	5	153
	4700-4785	0.47	0.03	0.05	0.43	-	0.37	11	91
Brewster-1A	4635-4650	2.44	0.26	1.29	0.90	481	0.17	53	37
North Scott Reef-1	4295-4310	1.27	0.04	0.39	1.51	439	0.09	30	117

TRIASSIC (T seismic marker)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Lynher-1	2576-2582	1.14	0.27	0.90	1.51	424	0.23	78	132
	2591-2607	1.46	0.08	1.08	0.42	430	0.07	74	29
	2616-2627	1.57	0.30	1.09	1.18	428	0.22	69	75
	2622-2637	1.33	0.06	1.01	0.55	430	0.06	76	41
Scott Reef-1	4584.2	0.66	0.12	0.47	0.67	-	0.20	71	102
Barcoo-1	4740-4750	0.63	0.26	0.88	3.54	429	0.23	139	561
	4780-4790	0.70	0.65	1.70	2.06	417	0.28	242	294
	4830-4840	0.60	0.14	0.42	2.45	432	0.25	70	408
	4850-4860	0.67	0.24	0.67	2.88	423	0.26	100	429
	4910-4920	0.57	0.16	0.64	2.87	429	0.20	112	503
North Scott	4353.0	0.21	0.03	0.04	0.25	278	0.43	19	119
Reef-1	4415-4430	0.27	0.01	0.05	0.45	398	0.23	15	178
	4450.6	0.38	0.03	0.09	0.38	363	0.25	23	100
	4499.5	0.42	0.04	0.11	0.36	405	0.27	26	85
	4547.0	0.33	0.02	0.04	0.35	291	0.33	12	106
	4685-4700	0.42	0.02	0.11	0.34	405	0.12	25	78
	4700-4715	0.44	0.03	0.19	0.41	445	0.12	39	89
	4715-4730	0.34	0.02	0.17	0.30	445	0.09	46	84
	4730-4745	0.75	0.03	0.32	0.77	446	0.07	41	101
	4743.0	0.35	0.03	0.08	0.34	339	0.27	22	97
	4745-4760	0.66	0.03	0.27	0.57	441	0.08	39	86

PERMIAN - EARLY TRIASSIC (O seismic marker)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Lynher-1	2668-2683	2.00	0.10	1.10	0.70	431	0.08	55	35
	2683-2698	2.72	3.49	2.31	0.30	432	0.60	85	11
	2685.3	0.85	0.02	0.17	0.00	419	0.09	20	2
	2688-2694	1.15	0.28	0.93	1.34	425	0.23	80	116
Rob Roy-1	1570-1585	5.19	4.80	12.92	1.45	420	0.27	249	28
	1578.9	4.29	1.51	10.06	1.89	415	0.13	234	44
	1744-1759	1.83	0.43	5.01	0.90	428	0.08	274	49
	1758.7	0.87	0.16	1.16	0.33	417	0.12	133	38
	2148.9	0.37	0.06	0.38	0.10	425	0.14	103	27

PERMIAN - EARLY TRIASSIC (O seismic marker) (continued)

Well	Depth(m)	TOC%	S1	S2	S3	TMAX	PI	HI	OI
Yampi-1	3940-3955	1.44	0.21	0.55	0.88	483	0.28	38	61
	4025-4040	1.31	0.10	0.35	0.60	485	0.20	27	45
	4090	0.71	0.03	0.01	0.04	385	0.80	1	4
	4115-4130	2.20	0.13	0.86	1.65	431	0.13	39	75
	4130-4145	1.46	0.11	0.50	0.42	482	0.18	34	29
	4140	0.92	0.09	0.07	0.04	322	0.55	8	9
	4145-4160	1.01	0.62	0.57	0.66	-	0.52	56	65
	4160-4175	1.00	0.78	0.73	0.62	-	0.52	73	62
Prudhoe-1	3015-3020	0.98	2.52	1.10	0.40	417	0.70	112	41
	3250-3255	1.75	0.28	0.97	0.60	417	0.22	55	34

Geochemical data were also extracted from the following destructive analysis reports which are not listed as part of the Selected Bibliography. These reports are available separately from BMR.

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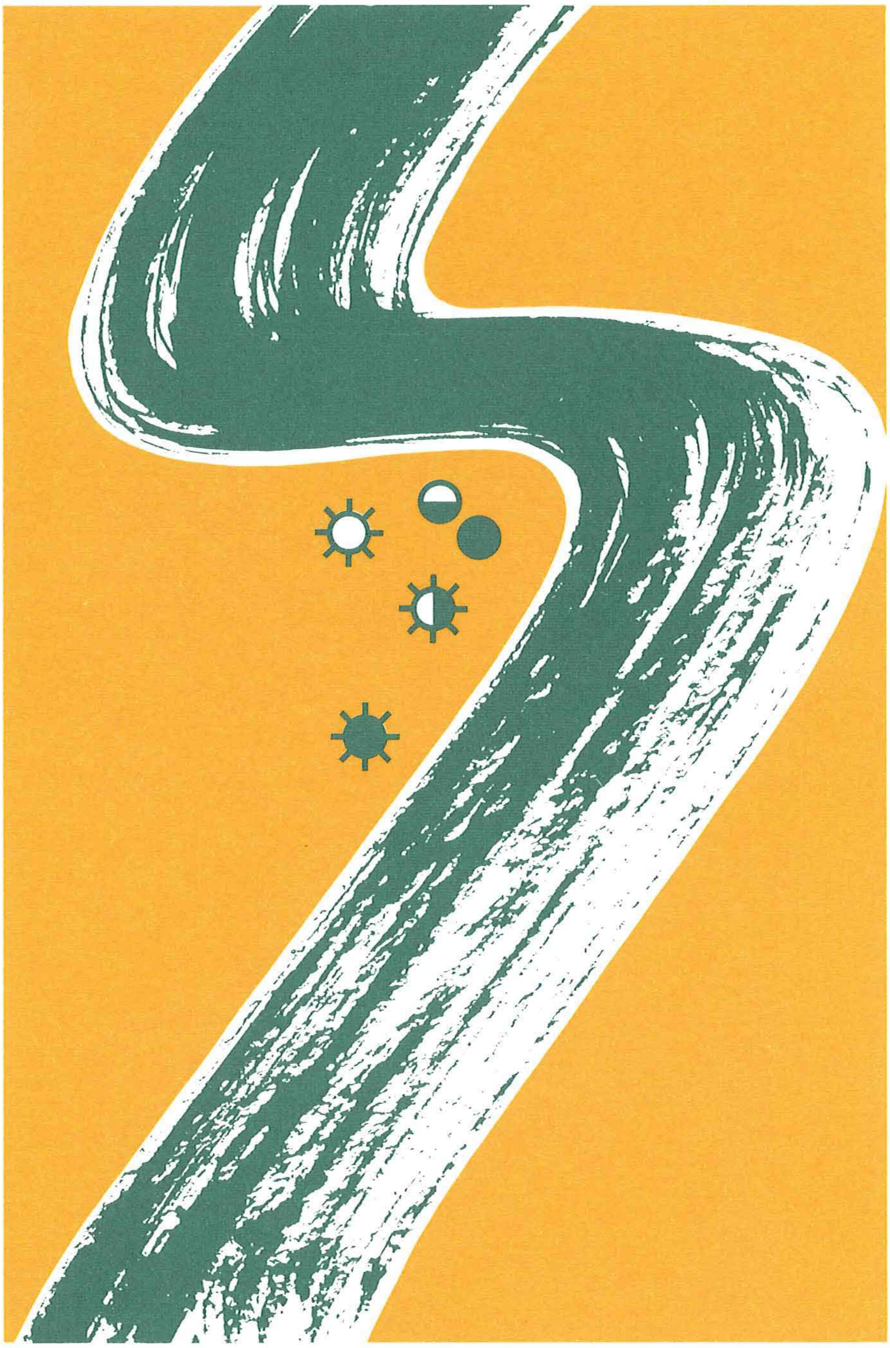
Report 7

Australian Petroleum Accumulations

Browse Basin



I. H. Lavering and L. Pain

Bureau of Mineral Resources, Geology and Geophysics

Department of Primary Industries and Energy
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Australian Petroleum Accumulations Report 7

Browse Basin

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Petroleum Resource Assessment Branch

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FOREWORD

This is the seventh in a series of reports prepared by the Bureau of Mineral Resources, Geology & Geophysics (BMR) presenting data on Australia's identified petroleum resources. Each report describes the petroleum accumulations found in a particular sedimentary basin, and presents information on basin setting, stratigraphy, structure, traps, reservoir and source rocks, petroleum characteristics, reserves, development and production. The six published reports in this series cover the Amadeus, Bass, Gippsland, Adavale, Bonaparte and Otway Basins. Reports on the Canning, Surat-Bowen, Carnarvon, Perth, Eromanga, and Cooper Basins are scheduled for future publication.

Paul E. Williamson
Assistant Director
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ABSTRACT

As at 30 June 1991 the Browse Basin, located along the North West Shelf of the Australian mainland, was known to contain a total of three subeconomic and three uneconomic accumulations of petroleum all of which remain undeveloped. All have been discovered during intermittent periods of exploration drilling which has taken place since the late 1960's.

The Scott Reef, Brecknock and Brewster accumulations contain a very large volume of gas reserves which are currently uneconomic to develop because of the logistics of developing gas reserves in deep water at a significant distance to landfall (300 km).

INTRODUCTION

This report summarises technical information on the petroleum and non-petroleum accumulations found in the Browse Basin up to 30 June 1991. The report contains a brief overview of the geology of the Browse Basin and describes the location and significance of all known petroleum accumulations.

The nature of the Browse Basin sequence, and the petroleum accumulations found to date, indicate that additional petroleum resources are likely to be discovered. The known petroleum accumulations are a major potential resource and highlight the potential of the basin to satisfy some of the nation's energy and industrial resource requirements in the next century.

BASIN SUMMARY

Basin setting

The Browse Basin lies offshore of the northwest margin of the Australian mainland in water depths from 20 metres to more than 2000 metres. The basin contains sediments of Permian to Quaternary age whose maximum thickness is 12 kilometres (Fig. 1).

The eastern margin of the basin comprises the Yampi Shelf, which consists of an eastward-thinning sequence of Mesozoic and younger sediments less than 2 kilometres thick. The southern part of the basin comprises the Leveque Shelf - an offshore extension of the Kimberley Block, overlain by Mesozoic and younger sediments which increase in thickness towards the centre of the basin. The Leveque Shelf separates the Browse Basin proper from the adjacent Fitzroy Graben and Rowley Sub-basin of the Canning Basin (Crostella, 1976).

The Browse Basin extends westwards from the Yampi Shelf into a fault-related structure, the Prudhoe Terrace, which contains several large, basinward normal-fault systems. The central part of the basin contains thick Permian and younger sediments. On the northwest and western margins of the basin, the sedimentary fill thins around a major basement high feature, the Seringapatam Rise. To the west of this feature, the Scott Plateau comprises the oceanward margin of the basin (Stagg, 1978).

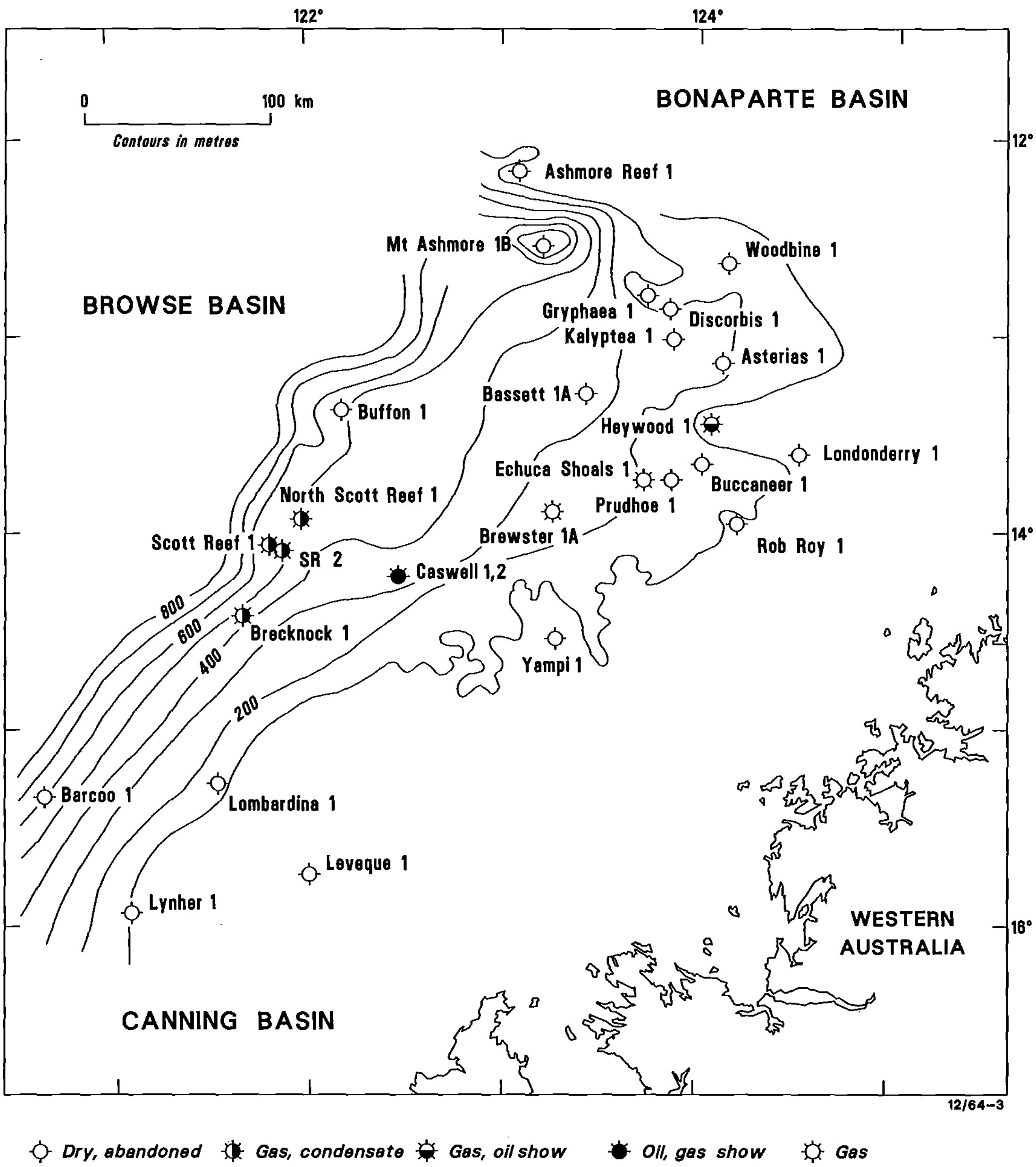

Figure 1. Location map of petroleum exploration wells drilled and accumulations discovered in the Browse Basin.

The northern basin boundary coincides with a bathymetric change evident on the southern parts of the Ashmore Block, the Vulcan Sub-basin and the Londonderry Arch (Williams & others, 1973). This break in slope is due to Late Cretaceous and Tertiary subsidence of the Browse Basin relative to adjacent structural elements of the Bonaparte Basin.

In total, the Browse Basin occupies an area of approximately 185 000 square kilometres, comprised mainly of the outer Scott Plateau (80 000 square kilometres), the central Browse Basin and adjacent terraces (80 000 square kilometres) and the Yampi Shelf (25 000 square kilometres) (Crostella, 1976; Stagg, 1978). The drilling density is 0.2 wells/1000 km^2.

Basin development and stratigraphy

The Browse Basin was initiated as an intracratonic basin in the Late Carboniferous-Early Permian, during an episode of extensional fault movement prior to the main Mesozoic break-up of Gondwana. Upper Carboniferous deltaic and shallow marine sediments are present on the Prudhoe Terrace and Yampi Shelf (Rob Roy 1 well), and seismic data indicate that older Palaeozoic sediments are present beneath the central Browse Basin and Scott Plateau (Allen & others, 1978; Bradshaw & others, 1988; Stagg, 1978).

The Permian sequence in the Browse Basin (Fig. 2) is likely to be similar to that in the Carnarvon, Canning and Bonaparte Basins - predominantly clastic with glacial or glacio-marine facies at the base, overlain by shallow marine, deltaic, and terrestrial sandstone and shale sequences (Lavering, 1985). The Late Permian Mount Goodwin Formation along the eastern basin margin is thin and comprises marine claystone and siliciclastics. It wedges out toward the east, as indicated by seismic and well data (Willis, 1988).

The Triassic Sahul Group unconformably overlies the Permian on the eastern side of the basin. As elsewhere on the North West Shelf, a thick sequence of marine claystone of Scythian to Anisian age is also present. A fluvio-deltaic sequence of Carnian and Norian age developed along the eastern margin of the Browse Basin. A regressive sequence of the same age in the northern part of the basin comprises a basal sequence of shelf carbonate and shale which grades upwards into deltaic sandstone and shale. The western part of the basin contains Late Landinian marine-shelf claystone and limestone, overlain by deltaic clastics and dolomite.

Toward the end of the Triassic, major block-faulting occurred prior to continental break-up (Bint 1988). The Lower and Middle Jurassic Troughton Group overlies a major unconformity surface on top of faulted Triassic and older sequences. The Lower and Middle Jurassic Plover Formation was deposited as a rift-fill sequence of fluvio-deltaic to marginal-marine sandstone, shale, claystone and carbonate in areas of active subsidence.

Subsequent arching and erosion in the Middle Jurassic (Callovian) removed the Plover Formation and older units from elevated regions such as the Ashmore Block and Londonderry High (Fig. 3).

Block-faulting and volcanism in the late Middle Jurassic terminated rift-fill deposition. This was succeeded, in the central and eastern parts of the basin, by the Late Jurassic Flamingo Group and Ashmore Group which comprise deltaic and fluvial sandstones. To the west, the sandstones grade into marine shale and volcanics which overlie part of the Ashmore Block (Fig. 3). The Late Jurassic sequence onlaps a major unconformity surface throughout the basin which is particularly evident over major basement highs (Mory, 1988).

In the northeastern part of the basin part of the Flamingo Group sequence, defined by Mory (1988), is present in an extension of the Malita Graben as the 1500 metre-thick Swan Formation. Flamingo Group sedimentation commenced during the Oxfordian (Late Jurassic) in subsiding depocentres, transgressing over 'highs' and shelf areas, such as the Londonderry High and related features during the Tithonian (latest Jurassic) (Mory, 1988).

An unconformity of Valanginian age truncates the Flamingo Group, separating its lower and middle parts from an upper unit, the Sandpiper Sandstone. This sequence passes into marine shelf shale in the central and western parts of the basin. Fluvial sandstone comprises part of the Sandpiper Sandstone sequence on the Ashmore Block (Mory, 1988).

Cretaceous open marine conditions were well established from the Valangian to Aptian, as evidenced by the deposition of greensand and radiolarian, glauconitic and calcareous claystone which comprises the basal part of the Bathurst Island Group. These lithofacies were deposited

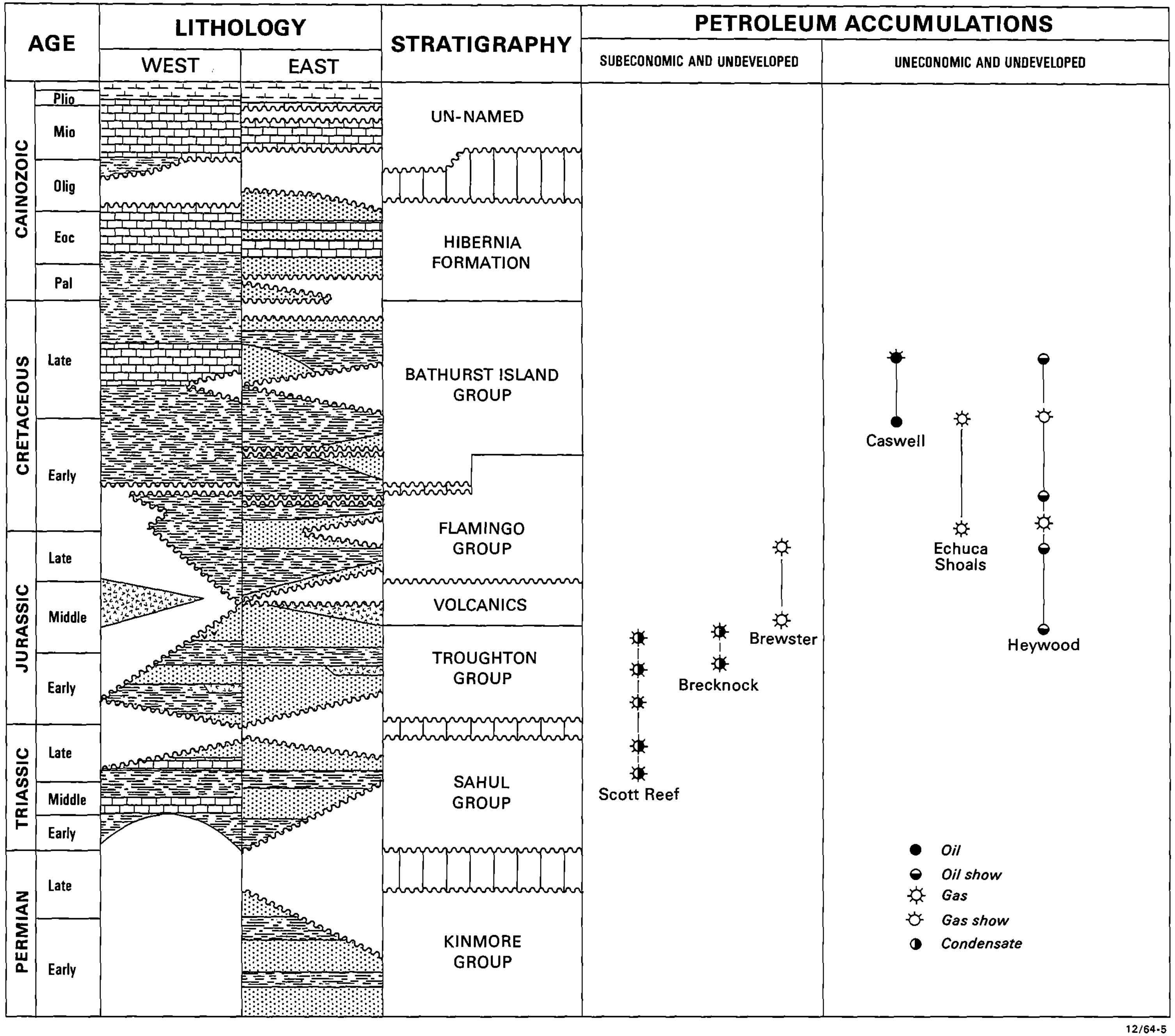

Figure 2 Stratigraphic units of the Browse Basin and occurrence of petroleum accumulations

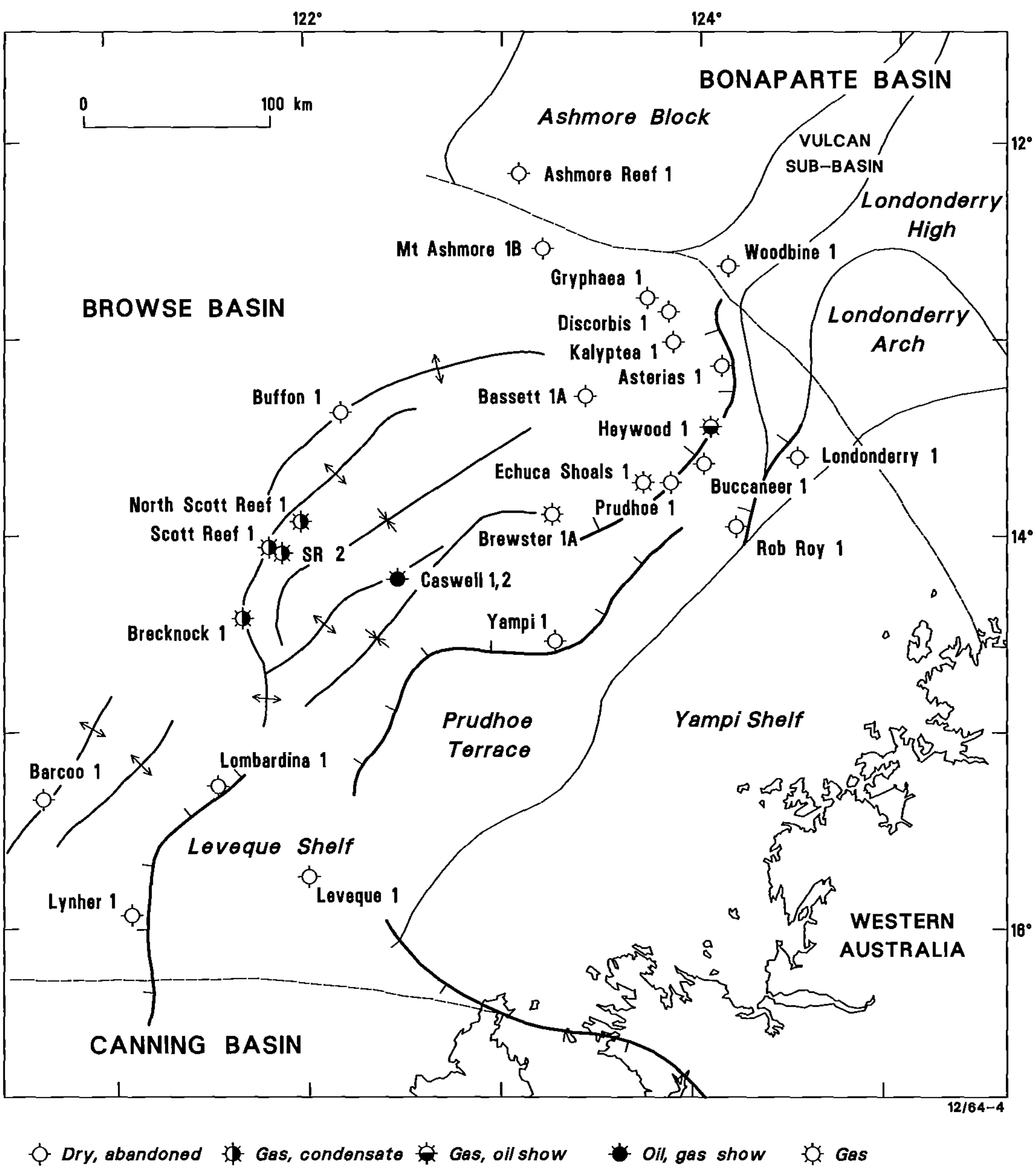

Figure 3. Structural elements of the Browse Basin and location of wells drilled.

on an extensive marine shelf with low clastic sediment supply. The western margin of the Ashmore Block was emergent during this period.

Widespread deposition of marine siltstones and claystones of the Bathurst Island Group occurred during the Albian (Early Cretaceous) to Maastrichtian (Late Cretaceous). Concurrently, a calcareous marine shelf formed on the outer basin margin as the level of clastic input declined, but in the central basin and northwards into the Vulcan Sub-basin up to 2000 metres of fine clastic sediments were deposited (Mory, 1988). During the Campanian to Maastrichtian a series of lenticular sandstone bodies were deposited northwards from the Yampi Shelf into the Vulcan Sub-basin and on the Ashmore Block. Mory (1988) considers these sandstones to be possibly subtidal, but in the Puffin wells they may be slope-deposited turbidites.

By the Early Cainozoic the basin had developed into a carbonate shelf on the outer margin with interbedded sandstone units shorewards in the central and eastern parts of the basin. The Cainozoic sequence ranges in thickness from 200 metres in the east to over 1000 metres in the Scott Reef 1 well to the west.

In the Oligocene, uplift and consequent erosion occurred over much of the eastern part of the shelf and continued carbonate sedimentation was restricted to the outer part of the shelf area. During the Late Cainozoic subsidence on the outer shelf increased and resulted in deposition of thick prograding wedges of carbonate. The outer limits of the Late Miocene shelf are currently in water depths of up to 1000 metres, except in the vicinity of large reef complexes such as Scott Reef where reef growth has kept pace with the rate of subsidence (Willis, 1988).

Petroleum exploration

Twenty four petroleum exploration wells have been drilled in the Browse Basin and adjacent parts of the Bonaparte Basin (Lavering & Ozimic, 1988; 1989) commencing with Ashmore Reef 1 well in 1967 (Appendix 1). This well did not intersect any hydrocarbon-bearing sequences but did confirm that a thick sedimentary sequence was present which ranged from Tertiary to Triassic in age. The well had apparently intersected a faulted anticline which lacked adequate seal (Willis, 1988).

The Leveque 1 and Lynher 1 wells were drilled in 1970 on and near the margin of the Leveque Shelf. Both wells failed to encounter significant indications of hydrocarbons. The Leveque 1 well, on the southern part of the shelf (total depth of 889 metres), intersected a thin Mesozoic sequence overlying Precambrian basement. Post-drilling results indicate that no structural closure was present at the well location. The Lynher 1 well tested a faulted anticline near the margin of the shelf. Over 2700 metres of Tertiary, Cretaceous and Permian sediments were intersected by the well but no major hydrocarbon indications were recorded. Willis (1988) suggested that this was due to thermal immaturity of the sequence and recent development of the structure.

In 1971 the largest geological prospect identified to date in the basin, the Scott Reef structure, was tested by drilling of the Scott Reef 1 well which intersected the southern crest of a faulted anticline in Jurassic and Triassic sequences at a depth of over 4500 metres. Subsequently acquired data suggest that the structure actually comprises several faulted reservoirs, sealed by overlying Late Jurassic and Early Cretaceous marine claystone. The well intersected gas/condensate-bearing reservoirs in both Jurassic and Triassic sequences.

Between 1971 and 1978 a total of nine new-field wildcat wells were drilled (Appendix 1) but only two minor petroleum accumulations were discovered - Heywood in 1974 and Caswell in 1977. In 1979, the Brecknock 1 well intersected gas-bearing reservoirs of Middle and Early Jurassic age in an anticline located southwest of Scott Reef on the same structural trend. Two additional wells, Barcoo 1 in 1979 and Buffon 1 in 1980, failed to discover significant hydrocarbon accumulations.

In 1980 the Brewster 1 well intersected gas-bearing reservoirs of Late to Middle Jurassic age in the northeastern part of the basin (Figs. 1 to 3). The North Scott Reef 1 and Caswell 2 wells were drilled in 1982 and 1983, before the Echuca Shoals 1 well intersected gas shows in Cretaceous and Jurassic sequences. In early 1990 the Buccaneer 1 well intersected the Late Jurassic to Early Cretaceous sequence in a fault-closed trap adjacent to a major basinal fault system. The well was plugged and abandoned as a dry hole.

The three major petroleum accumulations discovered to date in the Browse Basin have been identified by only eight wildcat wells which have penetrated valid traps at the base Cretaceous level (Bathurst Island Group) (Willis, 1988). The overall drilling density for the Browse Basin is 0.2 wells/1000 km^2, compared with 3.1 wells/1000 km^2 for Gippsland (new field wildcats only).

According to Willis (1988), many potential traps remain to be tested, particularly in the central main part of the basin where water depths range from 200 to 500 metres. Hydrocarbons may be trapped in this part of the basin but the chances of early commercial development are considered to be remote (Willis, 1988). Factors critical to the lack of development to date include the depth of water, distance from landfall and the gas-prone nature of accumulations discovered.

Petroleum accumulations

The term 'petroleum accumulation' as used in this report refers to an oil or gas pool or a group of oil and/or gas pools known by a single name.

The most significant petroleum accumulations discovered to date are the Scott Reef, Brecknock and Brewster gas/condensate accumulations. All are reservoired in the Triassic and Jurassic, or Jurassic sequences (Fig. 2). The remaining noteworthy accumulations, Caswell, Echuca Shoals and Heywood, lack the size and economic potential of the first group but do demonstrate the potential of the Mesozoic sequence to source and reservoir petroleum accumulations.

Subeconomic and undeveloped accumulations

Accumulation	**Discovery well**	**Year drilled**
Scott Reef (gas/condensate)	Scott Reef 1	1971
Brecknock (gas/condensate)	Brecknock 1	1979
Brewster (gas)	Brewster 1	1980

While these accumulations are undeveloped they represent a major part of Australia's subeconomic demonstrated sales gas, liquefied petroleum gas (LPG) and condensate resources (BMR, 1989).

Scott Reef

The Scott Reef (Fig. 4) accumulation comprises gas and condensate reservoired at a depth of over 4500 metres (KB), in Triassic and Lower and Middle Jurassic reservoir units (Troughton and Sahul Groups). A net vertical thickness of 24 metres of gas-bearing reservoir is evident in Scott Reef 1 well and 66 metres in North Scott Reef 1 well (Willis, 1988; Bint, 1988). Although no net reservoir is indicated in Scott Reef 2 well (Bint, 1988) the well did intersect an extended gas/water transition zone (Willis, 1988). Condensate comprises a minor part of the Scott Reef accumulation as the gas is relatively lean and contains a limited quantity of hydrocarbons more complex than pentane. Some carbon dioxide is evident in North Scott Reef 1 well (Woodside, 1982).

Brecknock

The Brecknock accumulation is 40 kilometres south-southwest of Scott Reef (Fig. 1) in water up to 543 metres deep. It consists of a gas/condensate accumulation present in Middle Jurassic reservoirs (Troughton Group). The reservoirs are at a depth of 3800 metres and the reservoir interval exhibits porosities of approximately 17 percent (Willis, 1988). A net gas thickness of approximately 68 metres is evident in the well (Willis, 1988). Repeat formation tests of the gas-bearing reservoir recovered samples of gas and condensate but production testing of the accumulation was prevented by mechanical difficulties (Willis, 1988).

Brewster

The Brewster accumulation is present in the central part of the basin 150 kilometres east-northeast of Scott Reef. The accumulation comprises two gas-bearing intervals, one in the Flamingo Group (3942-4172 metres (KB)) and another in the Troughton Group (4456-4703 metres (KB)). Wireline log data indicate that up to 160 metres of net gas-bearing reservoir is present in the upper sequence where porosities range from 7 percent to 12 percent. Up to 90 metres of net gas-bearing reservoir is present in the lower sequence with porosities of less than 12 percent and reduced permeability readings (Willis, 1988).

The remaining accumulations in the basin comprise those which contain small, discrete and measurable quantities of hydrocarbons, and they are significant only as an indication of petroleum occurrence rather than resource potential.

Uneconomic and undeveloped accumulations

Accumulation	Discovery well	Year drilled
Caswell (oil)	Caswell 1	1977
Echuca Shoals (gas)	Echuca Shoals 1	1983
Heywood (oil & gas shows)	Heywood 1	1974

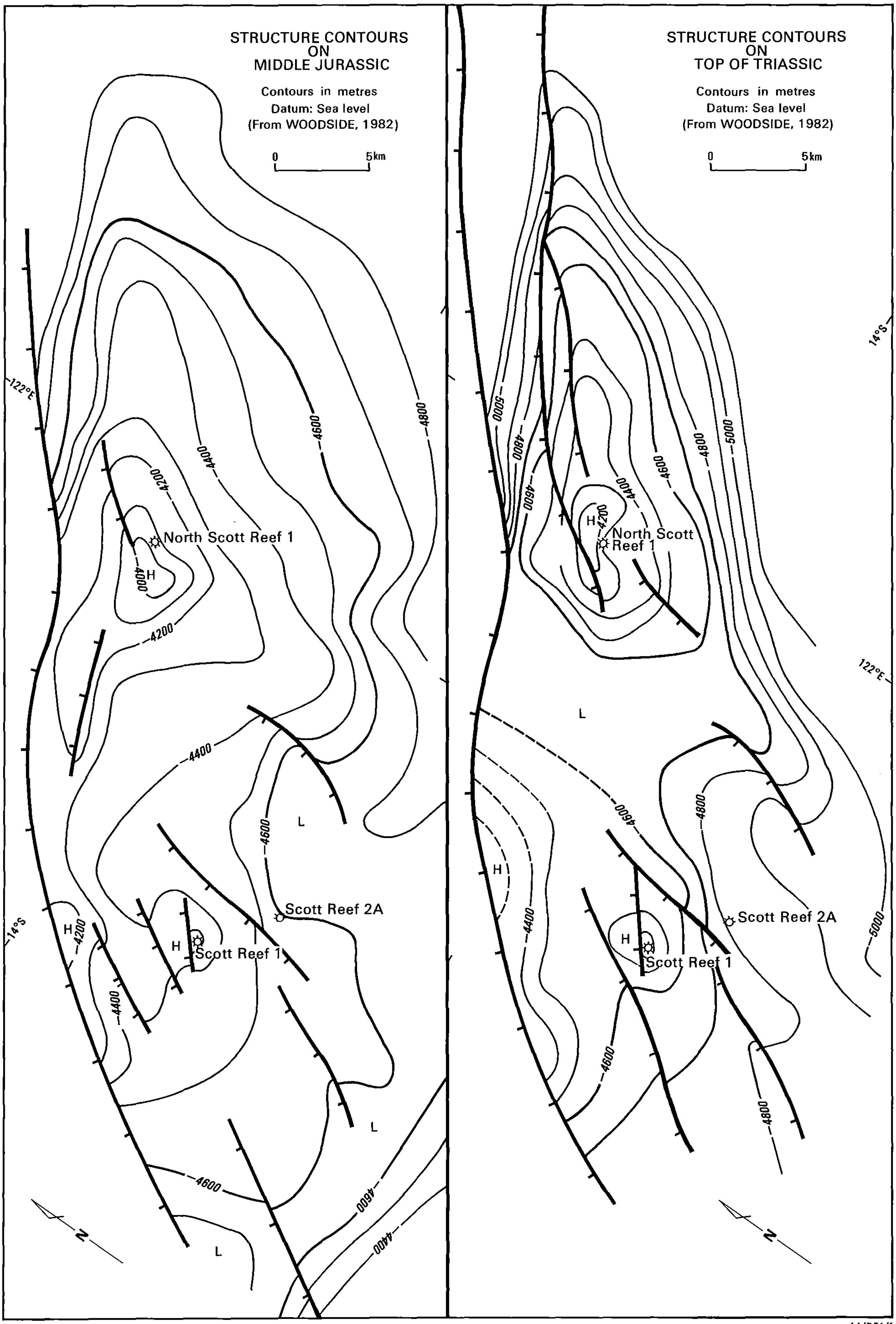

Figure 4. Outline of Scott Reef accumulation

The traps and petroleum-bearing units in which all these accumulations occur are shown in Plate 1. Detailed technical data on each accumulation are given in the 'Petroleum accumulation summaries' section of this report. The stratigraphic position and geographic locations of each accumulation are shown in Figures 1, 2 and 3.

Structure and petroleum traps

The Browse Basin (Fig. 3) began to develop during the Permian, initially as an area of subsidence into which Permo-Triassic sediments was deposited. Immediately north of the Browse Basin is the Ashmore Platform, an uplifted Permo-Triassic terrain. Normal block-faulting in the Late Triassic was possibly responsible for the formation of the Ashmore Block and other major tectonic elements within the Bonaparte and Browse Basins (Lavering & Ozimic, 1989).

The major structural elements in the basin (Fig. 3) include major anticlinal and synclinal features. Anticlinal features are elongate, with Late Jurassic and younger units drape-folded over extensively block-faulted Lower to Middle Jurassic and Triassic sequences. Synclinal features are areas in which considerable thicknesses of Tertiary, Cretaceous and Late Jurassic sequences are preserved. The locations of a number of these features are shown in Figure 3.

Willis (1988) classified structures in the basin as being early-, intermediate- and late-formed traps, according to the amount of structural tilt in block-faulted sequences underlying each feature. The degree of tilting is dependent on the timing of block faulting affecting the Triassic or Early to Middle Jurassic sequences which underlie potential traps in the Late Jurassic and Cretaceous sequences.

Structures formed in the Tertiary and Late Cretaceous tend to exhibit a symmetry, as all sequences have similar heights of vertical closure in the case of anticlinal features, e.g. Mt Ashmore 1 well (Fig. 17, Willis, 1988). In addition, Late Tertiary and recent faults generally penetrate to the sea floor, although rejuvenation of older fault systems may also do this (Wormald, 1988).

The major potential petroleum traps are likely to be in the central part of the basin where Early and Middle Jurassic fault, faulted-anticline and possible stratigraphic traps may be present (Willis, 1988). Structures in this area are optimally sited with respect to mature source rocks. While potential petroleum-bearing structures may be present in

Cretaceous and younger sequences, they are likely to have a higher risk with respect to required maturity and source potential.

Willis (1988) suggests that the majority of potential traps developed by the Late Cretaceous. The presence of many complex tensional fault patterns related to Tertiary to Recent tilting of the outer basin margin represents a real risk of seal failure and leakage.

Reservoir sequences

The major petroleum accumulation in the basin, Scott Reef, comprises gas/condensate reservoired in Upper Triassic and Lower to Middle Jurassic sequences. The reservoirs are sandy dolomite (Sahul Group - Upper Triassic) and sandstone (Troughton and Sahul Groups), sealed vertically by overlying Upper Jurassic marine claystone (Troughton Group).

The Triassic sequence, in particular the Sahul Group, is considered to have some reservoir potential but because of depth of burial, over 5000 metres, reservoir quality may be poor over much of the basin (Willis, 1988). Where the sequence is present at relatively shallow depths along the eastern flank of the basin, a lack of overlying vertical seal between the Triassic and Lower-Middle Jurassic is likely to limit prospectivity of the sequence. Porosities in both the Triassic and younger reservoirs in Scott Reef range from 12 to 16 percent (Crostella, 1976).

The Early to Middle Jurassic sandstone units (Troughton Group) are either fluvio-deltaic or nearshore marine in origin and have widely-ranging porosities. Low porosities are due to a combination of original depositional fabric and subsequent diagenesis (Willis, 1988). The major reservoirs in Scott Reef (including North Scott Reef 1 well), Brecknock and Brewster, are all sealed by Upper Jurassic or Lower Cretaceous transgressive marine claystone (Bathurst Island or Flamingo Groups).

Upper Jurassic and Lower Cretaceous marine sequences contain regressive sandstone units, some of which are gas-bearing in the Brewster 1 well. Younger Cretaceous sandstone units in Bassett 1 and Caswell 1 wells could have potential as reservoir units.

Late Cretaceous and Tertiary sandstone units in the central and eastern parts of the basin lack seal potential but have good porosities and permeabilities.

Porosity and permeability data are available from nine of the 23 wells drilled in the basin (Figs. 5 & 6). These data are taken from an Australia-wide BMR database of porosity-permeability readings (PORPERM) published in 1990. The data show that the porosity of all sequences (including potential reservoirs) rarely exceeds 25 percent (Fig. 5). Indeed, below depths of approximately 2000 metres subsea, porosity readings average 15 percent, decreasing to 10 percent below 4000 metres (Fig. 5).

Few of the samples analysed have permeabilities exceeding 100 millidarcys (Figure 6). Most samples from depths greater than 2000 metres have permeabilities of less than 10 millidarcys.

Depositional environments of reservoirs

The wireline log character and lithology of the major petroleum-bearing units of the Scott Reef and Brecknock accumulations are shown in Figures 7 and 8. In addition to lithology and the contents of the major petroleum-bearing units, the figures also show the interpreted sedimentary environments in which each sequence was deposited.

Regional studies (eg. Allen & others, 1978) suggest that the Triassic (Sahul Group) gas-bearing sequence intersected by the Scott Reef 1 well was deposited under marine-shelf to paralic conditions. The presence of recrystallised limestone, dolomite and clastic sediments containing bryozoa, brachiopods and crinoid remains confirms this.

Two major depositional settings are envisaged for the Jurassic sequence (mainly Troughton Group) in the Scott Reef area according to Allen & others (1978): marine in the lower part of the sequence (Scott Reef 1, 2A and North Scott Reef 1 wells) to non-marine in the upper part.

In the North Scott Reef 1 well the lower part of Troughton Group comprises a marine-shelf sequence of poorly-sorted sandstone, limestone and siltstone. From the lithology and wireline log data, we interpret a major delta complex prograding over the marine-shelf sediments. This sand-rich deltaic system forms the major Jurassic petroleum-bearing reservoir. The sporadic occurrence of major deltaic sand bodies is probably due to periodic relocation ('switching') of the delta system(s). Marine-shelf conditions resumed as deltaic progradation switched.

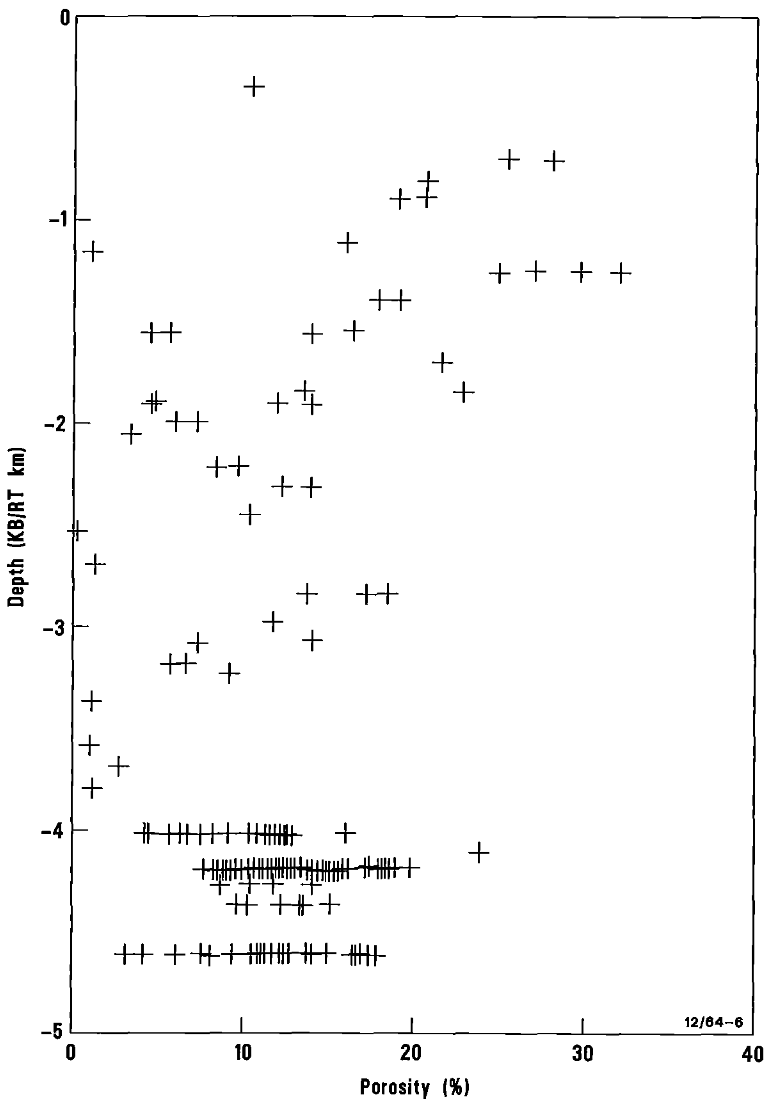

Figure 5. Cross-plot of porosity readings versus depth of burial for core samples collected from Browse Basin wells.

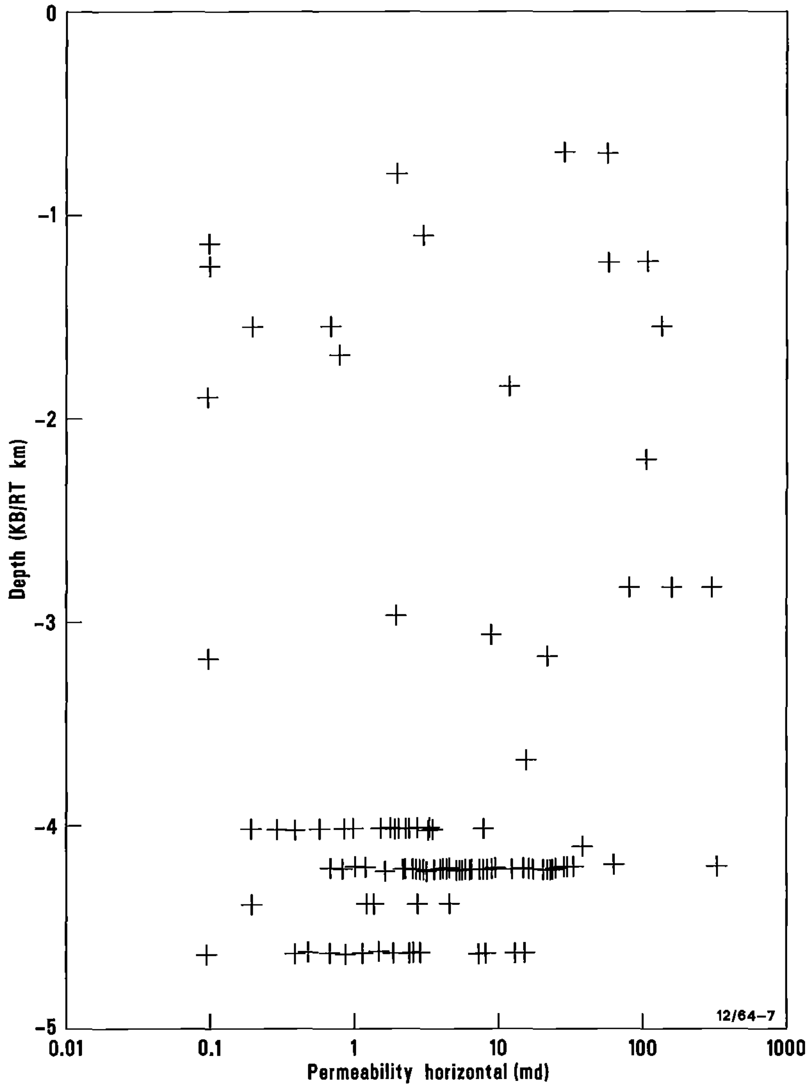

Figure 6. Cross-plot of permeability readings versus depth of burial for core samples collected from Browse Basin wells.

Locally, in the area immediately around the North Scott Reef 1 well, renewed progradation in the Middle Jurassic took the form of a deltaic-alluvial fan complex derived from local volcanic source material. A major coarsening-upwards sequence is evident on the gamma-ray log in this well (Fig. 7). Basin-wide subsidence in the Late Jurassic to Early Cretaceous resulted in a return to marine-shelf conditions (Flamingo Group) and continued subsidence resulted in increased water depth until the end of the Cretaceous (Bathurst Island Group).

The Jurassic sequence intersected by the Brecknock 1 well has some features similar to the Troughton Group in the North Scott Reef 1 well. In Brecknock 1, a deltaic sequence in the lower part of the Troughton Group comprises two delta lobes separated by a thin marine-shelf sequence. The succeeding lobe is part of a major sand-rich delta system similar to that in the North Scott Reef 1 well.

The alluvial fan and delta system in the Troughton Group in the North Scott Reef 1 well does not extend to Brecknock 1 well where marine-shelf conditions prevailed from the Late Jurassic and into the Early Cretaceous (Fig. 8). Part of the Flamingo Group at Brecknock 1 was also deposited in marine-shelf conditions but changed from combined clastic and carbonate deposition to carbonate-dominated deposition (Bathurst Island Group) during the Cretaceous

<u>Source rocks and maturity</u>

Petroleum source rocks in the Browse Basin occur mainly in Early to Middle Jurassic marine and fluvio-deltaic sediments which were deposited during rifting, and Cretaceous epicontinental marine sediments - specifically the Troughton, Flamingo and Bathurst Island Groups.

According to Willis (1988), the total organic carbon (TOC) contents of over 200 samples collected throughout the basin are generally low in most shaly sequences (less than 4 percent). Much of the organic matter consists of vitrinite and inertinite. The richest source rocks are Late Jurassic to Early Cretaceous in age, and are confined to the main basinal depocentres - areas not adequately tested by existing wells. Additional source potential is likely to be in the TOC-rich parts of the Troughton, Flamingo and Bathurst Island Groups which, where sampled, had an average of 1.5 to 2 percent total organic carbon (Willis, 1988).

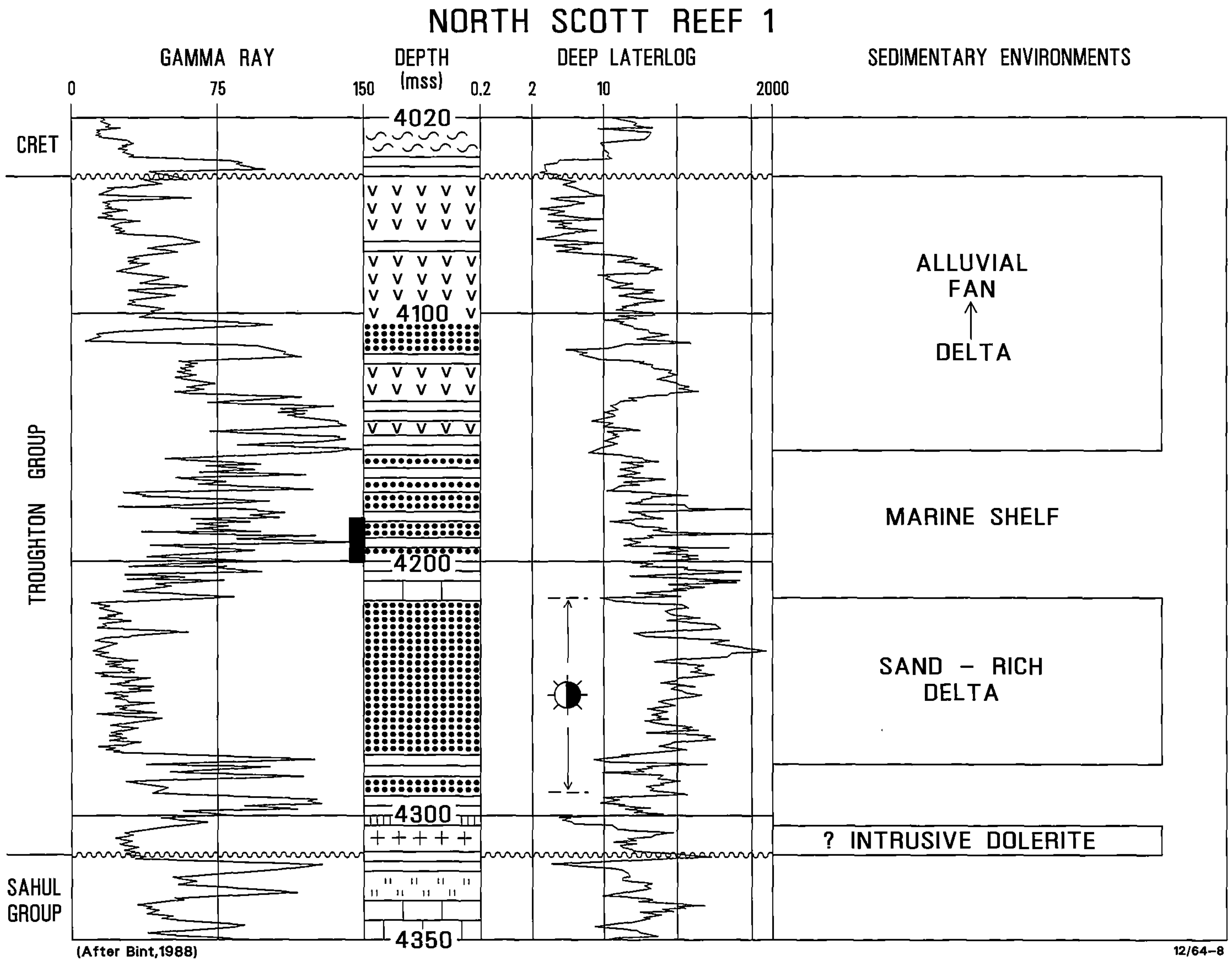

Figure 7. Wireline log character and sedimentary environments of the Triassic, Jurassic and Cretaceous sediments intersected by North Scott Reef 1.

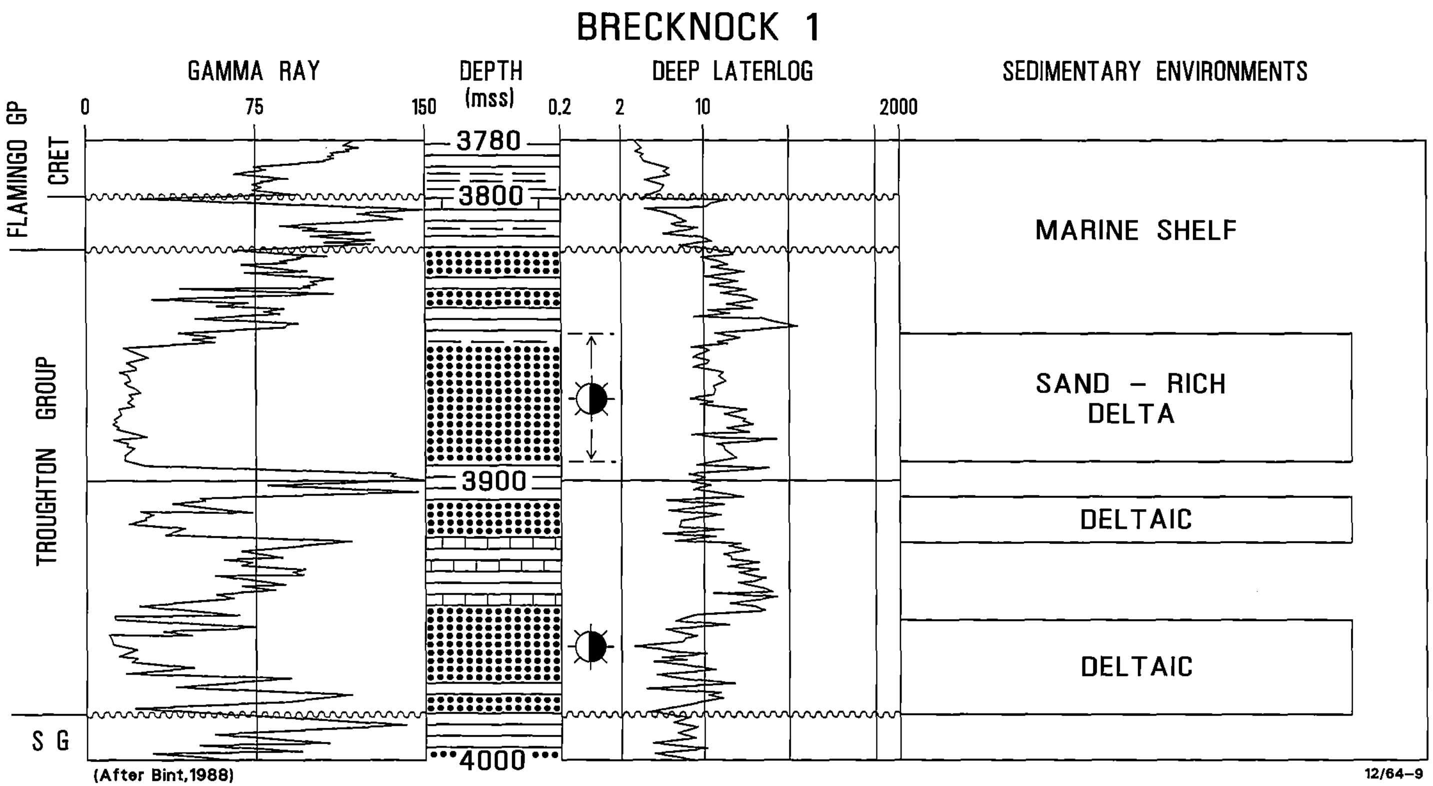

Figure 8. Wireline log character and sedimentary environments of the Triassic, Jurassic and Cretaceous sediments intersected by Brecknock 1

Present geothermal gradients in the basin range from $2^{o}C$ to $3.5^{o}C$ per 100 metres and data presented by Willis (1988) suggest that the youngest part of the Bathurst Island Group is now oil-mature in the central and northwestern parts of the basin. The older Early Cretaceous part of the same group is mature over a wider area, and the Troughton and Flamingo Groups are apparently now oil-mature over much of the basin. The post-Early Cretaceous timing of hydrocarbon migration indicates that all petroleum generation from the post-Triassic sequence is likely to have occurred since the Early Cretaceous seal was deposited and is still taking place (Willis, 1988). Thus maturation risk is low, making exploration success more dependent on the quality of sealing units and fault-seals.

Petroleum types

The Scott Reef accumulation has the largest gas reserves of any single accumulation currently known in Australia in water depths of less than 200 m. Condensate has also been produced from the accumulation during testing with flows of around 55 to 77 M^3 a day. The condensate is straw yellow in colour and has a specific gravity of 49^{o} to 54^{o} API.

The Scott Reef gas contains between 79 to 95 percent of methane, 4.4 to 7.5 percent of ethane and propane, and up to 2 percent of heavier hydrocarbons (Table 1). Up to 10.8 percent of the gas in samples collected from North Scott Reef 1 well consists of carbon dioxide (Woodside, 1982; Bint, 1988).

The Brecknock accumulation when analysed was found to contain 93 percent methane, 5 percent ethane and less than 2 percent propane, butane and pentane with no measurable quantities of heavier hydrocarbons (Table 1).

Table 1. Analyses of natural gases in Browse Basin petroleum accumulations (in Mole %)

	Scott Reef 2A	North Scott Reef 1	Brecknock 1	Brecknock 1
Methane	95.2	79.42	93.73	93.308
Ethane	3.81	5.22	5.06	5.428
Propane	0.74	2.3	0.95	0.915
i-Butane	0.11	0.44	0.16	0.164
n-Butane	0.07	0.41	0.08	0.129
i-Pentane	0.16	0.18	0.01	0.059
n-Pentane	-	0.12	-	-
Hexane	-	0.16	-	-
Heptanes+	-	0.61	-	-
H_2S	-	-	-	-
CO_2	-	10.83	-	-
depth:	4613 m (m KB)	4041 (m SS)	3890 (m KB)	3847 (m KB)

Data from Woodside (1977b, 1979a, 1979b & 1982).

Petroleum reserves and development potential

BMR (1989) estimates that the Browse Basin contains non-commercial reserves of condensate (31.80 million kilolitres), LPG (23.3 million kilolitres) and sales gas (489 billion cubic metres) - all of which are in the Scott Reef, Brecknock and Brewster accumulations. No reserves are currently identified for other accumulations in the basin.

Development of the known accumulations has been hindered by the relative remoteness of the region from land (300 km) and considerable water depths (0-500m), unlike much of the Carnarvon Basin. When development of the known accumulations takes place in future, it is likely that purpose-designed floating facilities or deep-water structures will be used, with pipeline connection to processing facilities on the nearest landfall. Market prices for gas, LPG or condensate will determine the timing of future development of Scott Reef, or other accumulations.

PETROLEUM ACCUMULATIONS SUMMARIES

PETROLEUM ACCUMULATIONS SUMMARY SHEET

ACCUMULATION: **Scott Reef**

COMPILATION DATE: 21/05/90

OPERATOR: B.O.C.Australia Limited

TYPE: Gas/condensate

COMMERCIAL STATUS: Subeconomic and undeveloped

LOCATION: Approximately 289 km from the mainland on Scott Reef Atoll, W.A; water depth varies from 0-500 metres.
STATE: Western Australia

PETROLEUM TITLE(S): WA-33-P

FIRST DISCOVERY WELL: Scott Reef 1 (B.O.C.Aust, 1971)
- latitude: 14°04'33" - longitude: 121°49'28"
- discovery: gas/condensate
- total depth: 4730.0 m
- date total depth reached: May 1971

NUMBER OF WELLS DRILLED:
- exploration & appraisal: 3
- development: Nil

STRUCTURE: Faulted anticline: northeast-southwest trending
- areal closure: 900 sq. km
- vertical closure: 559 m

SUBDIVISION OF PETROLEUM ACCUMULATION:
- number of traps: 2
- number of petroleum-bearing units: 5

NUMBER AND TYPE OF PRODUCING ZONES:
- gas: Nil
- gas/condensate: Nil
- gas/oil: Nil
- oil: Nil

DRIVE MECHANISM: Not available

PRODUCTION COMMENCED: Nil

PRODUCTION INFRASTRUCTURE: Nil

TRAP

TRAP 1: Troughton Group

DISCOVERY WELL(S): Scott Reef 1

CONTENTS: Gas/condensate

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Plover Fm

PETROLEUM CONTENTS: Gas/condensate

PRODUCTION STATUS: Undeveloped

FORMATION: Troughton Group (Plover Fm)

AGE: Mid - Jurassic

LITHOLOGY: Sandstone: interbedded siltstone; minor pyrite; claystone and dolomite

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4299.2 m - 4305.3 m B.R.T.

POROSITY: Up to 19%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 2: Plover Fm

PETROLEUM CONTENTS: Gas/condensate

PRODUCTION STATUS: Undeveloped

FORMATION: Troughton Group (Plover Fm)

AGE: Mid - Jurassic

LITHOLOGY: Sandstone: interbedded siltstone; minor pyrite; claystone and dolomite

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4340.0 m - 4346.4 m B.R.T.

POROSITY: Up to 17%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 3: Malita Fm

PETROLEUM CONTENTS: Gas/condensate

PRODUCTION STATUS: Undeveloped

FORMATION: Troughton Group (Malita Fm)

AGE: Early - Middle Jurassic

LITHOLOGY: Sandstone: interbedded siltstone; minor pyrite; claystone; and dolomite

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4351.3 m - 4354.0 m B.R.T.

POROSITY: Up to 17%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

TRAP

TRAP 2: Sahul Group

DISCOVERY WELL(S): Scott Reef 1

CONTENTS: Gas/condensate

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Sahul Gp.

PETROLEUM CONTENTS: Gas/condensate

PRODUCTION STATUS: Undeveloped

FORMATION: Sahul Group

AGE: Late Triassic

LITHOLOGY: Sandstone: silty; claystone; and dolomite

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4361.6 m - 4367.7 m B.R.T.

POROSITY: Up to 17%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 2: Sahul Gp.

PETROLEUM CONTENTS: Gas/condensate

PRODUCTION STATUS: Undeveloped

FORMATION: Sahul Group

AGE: Late Triassic

LITHOLOGY: Sandstone: silty; claystone; and dolomite

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4379.7 m - 4387.8 m B.R.T.

POROSITY: Up to 17%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM ACCUMULATIONS SUMMARY SHEET

ACCUMULATION: **Brecknock**

COMPILATION DATE: 21/05/90

OPERATOR: Woodside Petroleum Development Pty.Ltd.

TYPE: Gas/condensate

COMMERCIAL STATUS: Subeconomic and undeveloped

LOCATION: Approximately 40 km southwest of Scott Reef accumulation, W.A; water depth ranges from 500-750 metres.

STATE: Western Australia

PETROLEUM TITLE(S): WA-33-P

FIRST DISCOVERY WELL: Brecknock 1 (Woodside, 1980)
- latitude: $14^{o}26'13"$ - longitude: $121^{o}40'21"$
- discovery: gas/condensate
- total depth: 4300.0 m
- date total depth reached: November 1979

NUMBER OF WELLS DRILLED:
- exploration & appraisal: 1
- development: Nil

STRUCTURE: Faulted anticline:
- areal closure: 331 sq. km
- vertical closure: Not available

SUBDIVISION OF PETROLEUM ACCUMULATION:
- number of traps: 1
- number of petroleum-bearing units: 2

NUMBER AND TYPE OF PRODUCING ZONES:
- gas: Nil
- gas/condensate: Nil
- gas/oil: Nil
- oil: Nil

DRIVE MECHANISM: Not available

PRODUCTION COMMENCED: Nil

PRODUCTION INFRASTRUCTURE: Nil

TRAP

TRAP 1: Troughton Group

DISCOVERY WELL(S): Brecknock 1

CONTENTS: Gas/condensate

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Plover Fm

PETROLEUM CONTENTS: Gas/condensate

PRODUCTION STATUS: Undeveloped

FORMATION: Troughton Group (Plover Fm)

AGE: Mid - Jurassic

LITHOLOGY: Sandstone: siltstone; and claystone

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3841.5 m B.R.T.

POROSITY: Up to 11%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 2: Plover Fm

PETROLEUM CONTENTS: Gas/condensate

PRODUCTION STATUS: Undeveloped

FORMATION: Troughton Group (Plover Fm)

AGE: Mid - Jurassic

LITHOLOGY: Sandstone: siltstone; and claystone 3918 - 3933

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3852.0 m - 3890.0 m B.R.T. (3955 - 3940)

POROSITY: Up to 20%

PERMEABILITY: Not available WCR: Water-saturated

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM ACCUMULATIONS SUMMARY SHEET

ACCUMULATION: **Brewster**

COMPILATION DATE: 21/05/90

OPERATOR: Woodside Petroleum Development Pty.Ltd.

TYPE: Gas

COMMERCIAL STATUS: Subeconomic and undeveloped

LOCATION: Approximately 150 km east-northeast of Scott Reef, W.A; water depth 250m.

STATE: Western Australia

PETROLEUM TITLE(S): WA-35-P

FIRST DISCOVERY WELL: Brewster 1A (Woodside, 1981)
- latitude: 13°54'49" - longitude: 123°15'28"
- discovery: gas
- total depth: 4703.0 m
- date total depth reached: December 1980

NUMBER OF WELLS DRILLED:
- exploration & appraisal: 1
- development: Nil

STRUCTURE: Anticline: northeast trending; low relief anticlinal feature
- areal closure: 141 sq. km
- vertical closure: Not available

SUBDIVISION OF PETROLEUM ACCUMULATION:
- number of traps: 2
- number of petroleum-bearing units: 2

NUMBER AND TYPE OF PRODUCING ZONES:
- gas: Nil
- gas/condensate: Nil
- gas/oil: Nil
- oil: Nil

DRIVE MECHANISM: Not available

PRODUCTION COMMENCED: Nil

PRODUCTION INFRASTRUCTURE: Nil

TRAP

TRAP 1: Flamingo Group

DISCOVERY WELL(S): Brewster 1A

CONTENTS: Gas

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Flamingo Gp.

PETROLEUM CONTENTS: Gas

PRODUCTION STATUS: Undeveloped

FORMATION: Flamingo Group

AGE: Late Jurassic

LITHOLOGY: Sandstone: claystone; and siltstone

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3942.0 m - 4172.0 m B.R.T.

POROSITY: 7 to 12%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

TRAP

TRAP 2: Troughton Group

DISCOVERY WELL(S): Brewster 1A

CONTENTS: Gas

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Plover Fm

PETROLEUM CONTENTS: Gas

PRODUCTION STATUS: Undeveloped

FORMATION: Troughton Group (Plover Fm)

AGE: Mid-Jurassic

LITHOLOGY: Sandstone: claystone; and siltstone

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4456.0 m - 4675.0 m B.R.T.

POROSITY: Less than 12%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM ACCUMULATIONS SUMMARY SHEET

ACCUMULATION: **Caswell**

COMPILATION DATE: 21/05/90

OPERATOR: Woodside Petroleum Pty.Ltd.

TYPE: Oil and gas

COMMERCIAL STATUS: Uneconomic and undeveloped

LOCATION: Approximately 410 km north of Broome, W.A; water depth 345m.

STATE: Western Australia

PETROLEUM TITLE(S): WA-34-P

FIRST DISCOVERY WELL: Caswell 1 (Woodside, 1978)
- latitude: 14°14'28" - longitude: 122°28'03"
- discovery: oil
- total depth: 4097.0 m
- date total depth reached: January 1978

SECOND DISCOVERY WELL: Caswell 2 (Woodside, 1984)
- latitude: 14°14'33" - longitude: 122°28'10"
- discovery: oil and gas
- total depth: 5000.0 m
- date total depth reached: October 1983

NUMBER OF WELLS DRILLED:
- exploration & appraisal: 2
- development: Nil

STRUCTURE: Anticline: northeast-southwest trending
- areal closure: 119 sq. km
- vertical closure: Not available

SUBDIVISION OF PETROLEUM ACCUMULATION:
- number of traps: 1
- number of petroleum-bearing units: 2

NUMBER AND TYPE OF PRODUCING ZONES:
- gas: Nil
- gas/condensate: Nil
- gas/oil: Nil
- oil: Nil

DRIVE MECHANISM: Not available

PRODUCTION COMMENCED: Nil

PRODUCTION INFRASTRUCTURE: Nil

TRAP

TRAP 1: Bathurst Island Group

DISCOVERY WELL(S): Caswell 1 and Caswell 2

CONTENTS: Oil and gas

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Bathurst Is.Gp

PETROLEUM CONTENTS: Oil with a show of gas

PRODUCTION STATUS: Undeveloped

FORMATION: Bathurst Island Group

AGE: Early - Mid Cretaceous

LITHOLOGY: Sandstone: silty; interbedded; with marl and micrite

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3264.7 m B.R.T. (No.2)

POROSITY: Up to 20%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 2: Bathurst Is.Gp

PETROLEUM CONTENTS: Oil

PRODUCTION STATUS: Undeveloped

FORMATION: Bathurst Island Group

AGE: Early Cretaceous

LITHOLOGY: Claystone: with minor sandstone and siltstone

TRAPPING MECHANISM: Stratigraphic

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3607.0 m - 3611.0 m B.R.T.

POROSITY: Up to 17%

PERMEABILITY: Up to 1.0 md

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM ACCUMULATIONS SUMMARY SHEET

ACCUMULATION: **Echuca Shoals**

COMPILATION DATE: 21/05/90

OPERATOR: Woodside Offshore Petroleum Pty.Ltd.

TYPE: Gas

COMMERCIAL STATUS: Uneconomic and undeveloped

LOCATION: Near to the north eastern margin ofthe Browse Basin, W.A; water depth 194m.

STATE: Western Australia

PETROLEUM TITLE(S): WA-35-P

FIRST DISCOVERY WELL: Echuca Shoals 1 (Woodside, 1984)
- latitude: 13°45'01" - longitude: 123°43'25"
- discovery: gas
- total depth: 4365.0 m
- date total depth reached: February 1984

NUMBER OF WELLS DRILLED:
- exploration & appraisal: 1
- development: Nil

STRUCTURE: Faulted anticline: southwest-northeast trending
- areal closure: Not available
- vertical closure: Not available

SUBDIVISION OF PETROLEUM ACCUMULATION:
- number of traps: 2
- number of petroleum-bearing units: 3

NUMBER AND TYPE OF PRODUCING ZONES:
- gas: Nil
- gas/condensate: Nil
- gas/oil: Nil
- oil: Nil

DRIVE MECHANISM: Not available

PRODUCTION COMMENCED: Nil

PRODUCTION INFRASTRUCTURE: Nil

TRAP

TRAP 1: Bathurst Island Group

DISCOVERY WELL(S): Echuca Shoals 1

CONTENTS: Gas

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Bathurst Is.Gp

PETROLEUM CONTENTS: Gas show

PRODUCTION STATUS: Undeveloped

FORMATION: Lower Bathurst Island Group

AGE: Early Cretaceous

LITHOLOGY: Sandstone: with minor interbedded siltstone; and claystone

TRAPPING MECHANISM: Structural and possibly stratigraphic

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3331.0 m - 3352.5 m B.R.T.

POROSITY: Average of 12%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

TRAP

TRAP 2: Flamingo Group

DISCOVERY WELL(S): Echuca Shoals 1

CONTENTS: Gas

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Flamingo Gp.

PETROLEUM CONTENTS: Gas

PRODUCTION STATUS: Undeveloped

FORMATION: Flamingo Group

AGE: Late Jurassic (Tithonian)

LITHOLOGY: Claystone: minor interbedded siltstone grading to sandstone

TRAPPING MECHANISM: Structural/stratigraphic

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3382.5 m - 3486.5 m B.R.T.

POROSITY: Average of 15%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 2: Flamingo Gp.

PETROLEUM CONTENTS: Gas

PRODUCTION STATUS: Undeveloped

FORMATION: Flamingo Group

AGE: Late Jurassic (Tithonian)

LITHOLOGY: Sandstone: and interbedded siltstone

TRAPPING MECHANISM: Structural/stratigraphic

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3634.0 m - 3673.5 m B.R.T.

POROSITY: Average of 15%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM ACCUMULATIONS SUMMARY SHEET

ACCUMULATION: **Heywood**

COMPILATION DATE: 21/05/90

OPERATOR: B.O.C.of Australia Limited

TYPE: Oil and gas show

COMMERCIAL STATUS: Uneconomic and undeveloped

LOCATION: Northeast margin of the Browse Basin, W.A. water depth 35m.

STATE: Western Australia

PETROLEUM TITLE(S): WA-37-P

FIRST DISCOVERY WELL: Heywood 1 (B.O.C.Australia, 1974)
- latitude: 13°27'45" - longitude: 124°04'00"
- discovery: oil and gas
- total depth: 4572.0 m
- date total depth reached: June 1974

NUMBER OF WELLS DRILLED:
- exploration & appraisal: 1
- development: Nil

STRUCTURE: Fault
- areal closure: 248 sq. km
- vertical closure: Not available

SUBDIVISION OF PETROLEUM ACCUMULATION:
- number of traps: 3
- number of petroleum-bearing units: 6

NUMBER AND TYPE OF PRODUCING ZONES:
- gas: Nil - gas/condensate: Nil
- gas/oil: Nil - oil: Nil

DRIVE MECHANISM: Not available

PRODUCTION COMMENCED: Nil

PRODUCTION INFRASTRUCTURE: Nil

TRAP

TRAP 1: Bathurst Island Group

DISCOVERY WELL(S): Heywood 1

CONTENTS: Oil and gas

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Bathurst Is.Gp

PETROLEUM CONTENTS: Oil show

PRODUCTION STATUS: Undeveloped

FORMATION: Bathurst Island Group

AGE: Early - Mid Cretaceous

LITHOLOGY: Sandstone: claystone; with thin interbeds of greensand

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3148.0 m B.R.T.

POROSITY: Not available

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 2: Bathurst Is.Gp

PETROLEUM CONTENTS: Gas show

PRODUCTION STATUS: Undeveloped

FORMATION: Bathurst Island Formation

AGE: Early - Mid Cretaceous

LITHOLOGY: Sandstone: siltstone; claystone with thin bands of greensand

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3299.0 m B.R.T.

POROSITY: Up to 16%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

TRAP

TRAP 2: Flamingo Group

DISCOVERY WELL(S): Heywood 1

CONTENTS: Oil and gas

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Upper Flamingo Gp.

PETROLEUM CONTENTS: Oil show

PRODUCTION STATUS: Undeveloped

FORMATION: Flamingo Group

AGE: Late Jurassic - Early Cretaceous

LITHOLOGY: Sandstone: claystone; with minor siltstone

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 3422.0 m B.R.T.

POROSITY: Up to 16%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 2: Middle Flamingo Gp.

PETROLEUM CONTENTS: Gas

PRODUCTION STATUS: Undeveloped

FORMATION: Flamingo Group

AGE: Late Jurassic - Early Cretaceous

LITHOLOGY: Sandstone: claystone; with minor siltstone

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4065.0 m B.R.T.

POROSITY: up to 10%

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

PETROLEUM-BEARING UNIT 3: Lower Flamingo Gp.

PETROLEUM CONTENTS: Oil Show

PRODUCTION STATUS: Undeveloped

FORMATION: Flamingo Group

AGE: Late Jurassic

LITHOLOGY: Sandstone: claystone; with minor siltstone

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4147.0 m B.R.T.

POROSITY: Not available

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

TRAP

TRAP 3: Troughton Group

DISCOVERY WELL(S): Heywood 1

CONTENTS: Oil

PETROLEUM-BEARING UNIT(S)

PETROLEUM-BEARING UNIT 1: Plover Fm

PETROLEUM CONTENTS: Oil show

PRODUCTION STATUS: Undeveloped

FORMATION: Troughton Group (Plover Fm)

AGE: Middle Jurassic

LITHOLOGY: Sandstone: siltstone; claystone; and minor coal

TRAPPING MECHANISM: Structural

DEPTH TO TOP OF PETROLEUM-BEARING UNIT: 4320.0 m B.R.T.

POROSITY: Not available

PERMEABILITY: Not available

TEMPERATURE GRADIENT: Not available

RESERVOIR PRESSURE: Not available

APPENDIX 1

BROWSE BASIN - SUMMARY OF DRILLING RESULTS

Well	Spud date	Water depth (m)	Level reached Age	Level reached Depth subsea (m)	Hydrocarbon indicators	Remarks
Leveque 1	1970	77	Precambrian	889	None	No structural closure
Lynher 1	1970	58	Permian	2715	None	Very strong relief. Thermally immature
Scott Reef 1	1971	50	Triassic	4720	M. Jurassic/ Triassic section gas-bearing	Gas discovery
Rob Roy 1	1972	102	Precambrian	2276	None	Stratigraphic test
Yampi 1	1973	91	Permian	4163	High gas readings, fluorescence, traces of residual oil	No structural closure
Londonderry 1	1973	90	Precambrian	1132	None	Stratigraphic test
Heywood 1	1974	35	L. Jurassic	4562	High gas readings, intermittent fluorescence	Sited on seismic velocity anomaly
Lombardina 1	1974	175	E. Jurassic	2825	Fluorescence indications of residual hydrocarbons	Young feature. Failure of fault seal
Prudhoe 1	1974	175	Permian	3292	None	No structural closure
Scott Reef 2, 2A	1977	55	E. Jurassic	4812	M. Jurassic section in gas transition zone	-
Caswell 1	1977	345	E. Cret.	4089	Flowed oil from fractured shale	Did not reach objective due to technical problems

/continued

			Level reached			
Well	Spud date	Water depth (m)	Age	Depth subsea (m)	Hydrocarbon indicators	Remarks
Bassett 1, 1A	1978	364	L. Cret.	2698	None	Relies on fault seal. Thermally immature
Woodbine 1	1979	189	L. Triassic	3502	None	No structural closure
Brecknock 1	1979	543	L. Triassic	4289	Objective section gas-bearing	Gas discovery
Barcoo 1	1979	720	L. Triassic	5098	None	No structural closure
Buffon 1	1980	533	E. Jurassic	4777	High gas readings from objective section	Objective section proved to be volcanics
Brewster 1, 1A	1980	250	M. Jurassic	4695	Objective section gas-bearing	Indicated gas discovery
North Scott Reef 1	1982	422	L. Triassic	4762	L. Jurassic/ Triassic section gas-bearing	Gas discovery
Caswell 2	1983	344	M. Jurassic	4983	Upper Cret. sand oil-bearing	Step-out well
Echuca Shoals 1	1983	194	Jurassic Perm.-Trias.	4000	Jurassic units gas-bearing	Gas discovery
Gryphaea 1	1987	200	M. Triassic	3950	Hydrocarbon shows in Maastrichtian, Valanginian & Triassic	Poor reservoir development
Asterias 1	1987	194	L. Jurassic	4400	Shows in Jurassic	Lack of good seal
Discorbis 1	1989	202	Jurassic	4196	Shows in Cretaceous & & Jurassic	Timing of migration unknown
Kalyptea 1	1989	214	Cretaceous	4575	Minor hydrocarbon traces.	

Modified from Willis (1988).

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