



Australian Government

Department of Resources, Energy and Tourism

## **2008 RELEASE OF AUSTRALIAN OFFSHORE PETROLEUM EXPLORATION AREAS**

### **RELEASE AREAS AC08-7 AND AC08-8 NORTHERN CASWELL SUB-BASIN, BROWSE BASIN, WESTERN AUSTRALIA**

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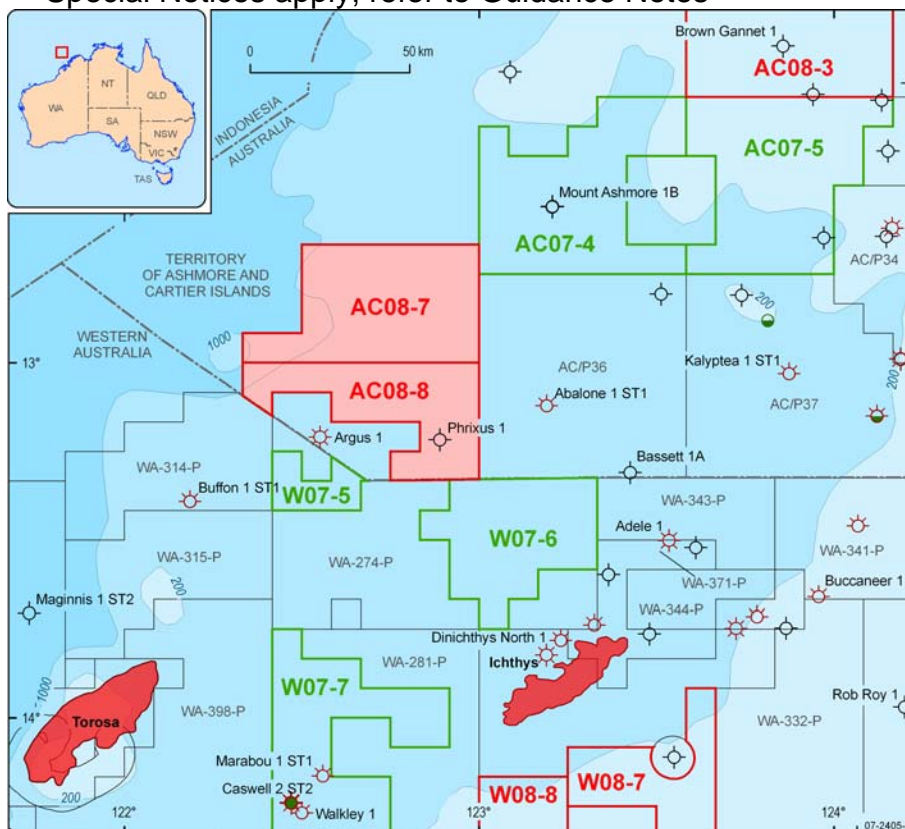


## SUMMARY

### RELEASE AREAS AC08-7 AND AC08-8 NORTHERN CASWELL SUB-BASIN, BROWSE BASIN WESTERN AUSTRALIA

#### BIDS CLOSE - 9 OCTOBER 2008

- Under-explored areas directly adjacent to the Argus gas field, where appraisal drilling is planned
- Partial 3D seismic coverage
- Triassic–Early Jurassic (gas) and Late Jurassic–Early Cretaceous (oil) source rocks
- Demonstrated Jurassic sandstone reservoir in Argus 1
- Water depths between 400 and 1450 m
- Special Notices apply, refer to Guidance Notes



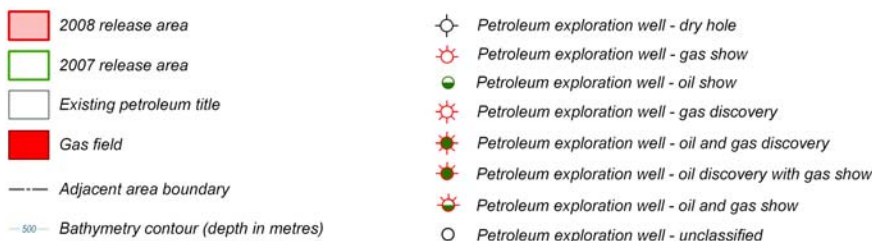
Well symbols supplied by Geoscience Australia (basic data open file) and Encom Petroleum Information Pty Ltd (basic data confidential).

These were generated from open file data as at 31 Jan 2008.

Field outlines supplied by Encom Petroleum Information Pty Ltd. Field outlines in GPInfo are sourced from the operators of the fields only.

Outlines are updated at irregular intervals but with at least one major update per year.

Field outlines for Comea and Ichthys are sourced from IHS Energy, 2006.



## BROWSE BASIN REGIONAL GEOLOGY

The Browse Basin is a northeast trending, Palaeozoic to Cenozoic depocentre situated entirely offshore in the Timor Sea region of Australia's North West Shelf. It covers an area of approximately 140000 km<sup>2</sup> and contains in excess of 15 km of Palaeozoic, Mesozoic and Cenozoic sedimentary section (Struckmeyer et al, 1998). It hosts significant, but as yet undeveloped, reserves of gas and condensate ([Figure 1](#)). Five large gas fields have been discovered in the Browse Basin; Scott Reef (Torosa), Brecknock, Brecknock South (Calliance), Ichthys and Crux, together with a number of other smaller gas discoveries (Adele 1, Argus 1, Caspar 1A, Cornea field, Echuca Shoals 1 and Psepotus 1). Oil discoveries are focussed on the Yampi Shelf (Cornea field, Focus 1, Sparkle 1 and Gwydion 1), although oil was also discovered at Caswell 1 and 2 ST2 in the central Caswell Sub-basin. Oil and gas shows have been encountered in several other wells drilled in the basin.

The Browse Basin belongs to a series of extensional basins that formed part of the Westralian Superbasin underlying the North West Shelf region (Bradshaw et al, 1988; Willis, 1988). Struckmeyer et al (1998) divided the Browse Basin into three major sub-basins; Caswell, Barcoo and Seringapatam ([Figure 2](#)). The basin is flanked to the west by the Scott Plateau and the eastern and southeastern elements of the basin are the Yampi and Leveque shelves (Maung et al, 1994; Struckmeyer et al, 1998). The basin is contiguous with the Rowley Sub-basin of the Roebuck Basin to the southwest, and the Ashmore Platform, Vulcan Sub-basin and Londonderry High structural elements of the Bonaparte Basin to the northeast ([Figure 2](#)).

## BASIN EVOLUTION AND TECTONIC DEVELOPMENT

The Browse Basin is filled with over 15 km of sediments (Palaeozoic-Cenozoic; [Figures 3 and 4](#)) and has experienced a multi-stage structural history with six major phases of basin development (Struckmeyer et al, 1998):

1. Late Carboniferous to Early Permian extension.
2. Late Permian to Triassic thermal subsidence.
3. Late Triassic to Early Jurassic inversion.
4. Early to Middle Jurassic extension.
5. Late Jurassic to Cenozoic thermal subsidence.
6. Middle to Late Miocene inversion.

Since a formal lithostratigraphy still needs to be established for the basin, formation-equivalent names from the Vulcan Sub-basin (Bonaparte Basin) to the north have been adopted by Blevin et al (1998a) and Struckmeyer et al (1998) and are used in this review ([Figure 5](#)).

The basin was initiated as a series of intracratonic extensional half-grabens during the Late Carboniferous to Early Permian (Symonds et al, 1994). Further to the west, this extensional event presumably led to breakup and separation of Sibumasu from northwest Australia in the Early Permian (Metcalf, 1990). The upper-crustal faulting resulted in characteristic half-graben geometry with large-scale normal faults compartmentalising the basin into distinct sub-basins. Structures resulting from the Late Palaeozoic extensional event controlled the

location of subsequent reactivation events and the distribution and nature of the sedimentary fill (Struckmeyer et al, 1998).

The Carboniferous section is dominated by fluvio-deltaic sediments, while the Early Permian sediments (mainly limestones and shales) were deposited in a marine environment. The Late Permian section consists of sandstones that grade upwards into shale and limestone. Marine claystones, siltstones and volcanoclastic sediments (eg, Echuca Shoals 1) deposited during a regional marine transgression are the oldest rocks (Early Triassic) intersected in the Browse Basin. These are overlain by fluvial and marginal to shallow-marine sandstones, limestones and shales of Triassic age.

The Permo-Triassic thermal subsidence (sag) phase was terminated by compressional reactivation in the Late Triassic to Early Jurassic, resulting in partial inversion of Palaeozoic half-grabens and the formation of large scale anticlinal and synclinal features within the hanging walls. This event is marked by a regional unconformity that is correlated with the Fitzroy movement in the Canning and Bonaparte basins (Etheridge and O'Brien, 1994). The arcuate Triassic anticlinal trends in the Caswell Sub-basin ([Figure 2](#)) developed at this time.

The Early to Middle Jurassic extensional phase resulted in widespread small-scale faulting and the collapse of the Triassic anticlines. Extensional faulting was concentrated in the northeastern part of the Caswell Sub-basin ([Figure 2](#); Struckmeyer et al, 1998). The Heywood Graben also formed during this period ([Figure 6a](#)). Syn-rift sediments (Plover Formation) comprise sandstones, mudstones and coals deposited in deltaic and coastal plain settings. Widespread erosion and peneplanation occurred in the Callovian, associated with continental breakup and the initiation of sea-floor spreading in the Argo Abyssal Plain.

From the Late Jurassic to the Cenozoic, accommodation space was controlled by the interplay of thermal subsidence, minor reactivation events and eustasy. Late Jurassic interbedded sandstones and shales onlap and drape the pre-Callovian structures, providing a thin, regional seal across much of the basin. An overall transgressive cycle began in the Early Cretaceous and peaked in the mid-Turonian, with open marine conditions established throughout the basin by the Aptian. Thick marine claystones deposited during this period (Echuca Shoals and Jamieson formations), provide a regional seal and contain potential source rocks, with particularly high total organic carbon (TOC) values recorded at the maximum flooding surfaces of several Early Cretaceous transgressive cycles ([Figure 7](#); Blevin et al, 1998b).

The Turonian–Cenozoic section represents a major progradational (regressive) cycle in which the shelf edge migrated northwestwards to the outer limits of the Scott Reef–Brecknock and Buffon anticlinal trends. The development of submarine canyons on the Yampi Shelf and deposition of turbidite mounds within the central Caswell Sub-basin occurred during the middle to Late Campanian (Benson et al, 2004). Inversion in the Late Miocene occurred as a result of the convergence of the Australia-India and Eurasia plates (Shuster et al, 1998).

## HYDROCARBON RESERVES

The Browse Basin is one of Australia's most prolific offshore basins for hydrocarbons. It has estimated reserves of 13.6 MMbbl (2.2 GL) of oil, 29.4 Tcf (832.0 BCM) of gas, 438.2 MMbbl (69.7 GL) of LPG and 629.0 MMbbl (100.0 GL) of condensate as at January 2006 (Geoscience Australia, 2008).

During late 2006–07 several extension/appraisal wells were drilled; Brecknock 3, Torosa 1, 2 and 3, Prelude 1, 1A, Crux 2 ST1, Dinichthys North 1, Tocatta 1 and Fossetmaker 1. Brecknock 3 was drilled to appraise Early to Middle Jurassic Plover Formation reservoir sandstones encountered in Brecknock 1 and 2. It intersected a 48.5 m gross gas column in the Plover Formation. A second hydrocarbon bearing zone was intersected in the Late Cretaceous with an 8.7 m gross gas column (Woodside, 2006). Details and results of the other extension/appraisal wells are not available at the time of publication. The Torosa and Calliance fields appraisal continued in the second half of 2007 with further 3D seismic acquisition (DoIR, 2007, p. 19). A retention lease was awarded over the Argus accumulation in January 2007, with an appraisal well to be drilled in year three of the current permit term (DPIFM, 2007).

### INITIAL RESERVES – BROWSE BASIN

Field	Liquids MMbbls*	Gas Tcf	Gas Mmboe <sup>1</sup>	Date	Source
Argus	6.80	0.60	102.00	Aug-04	DPIFM
Brecknock	109.44	5.30	901.01	Dec-06	DoIR
Calliance (Brecknock S)	86.80	3.97	674.91	Dec-06	DoIR
Crux	38.90	1.40	238.00	Oct-04	DPIFM
Ichthys Brewster	276.75	6.99	1188.69	Dec-06	DoIR
Ichthys Plover	35.22	2.51	426.25	Dec-06	DoIR
Torosa (Scott Reef)	121.02	11.50	1954.98	Dec-06	DoIR

\*Liquids includes crude oil and condensate, <sup>1</sup> Conversion factor for gas (Tcf to Mmboe) is 0.17x1000.

All reserves are P<sub>50</sub>. All developed field resources from DoIR have been compiled using the remaining reserves plus the cumulative production as of December 2006. All other fields are reserves as of 31st December 2006.

DoIR - Department of Industry and Resources, Western Australia,

[http://www.doir.wa.gov.au/documents/mineralsandpetroleum/PWA\\_Sept\\_2007.pdf](http://www.doir.wa.gov.au/documents/mineralsandpetroleum/PWA_Sept_2007.pdf).

DPIFM - Department of Primary Industry, Fisheries and Mines, Northern Territory.



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**BIDS CLOSE - 9 OCTOBER 2008**

### LOCATION

Release areas AC08-7 and AC08-8 are located in Australia's Territory of Ashmore and Cartier Islands about 450-500 km north-northwest of Derby in the Timor Sea ([Figure 1](#)). Geologically, the areas belong to the northern part of the Caswell Sub-basin of the Browse Basin and are adjacent to current offshore petroleum exploration permits and the Argus gas field.

Release Area AC08-7 comprises 26 full graticular blocks with an area of approximately 2170 km<sup>2</sup>. Water depths range from 450 m in the southeast to 1330 m in the northwest.

Release Area AC08-8 comprises 18 full graticular blocks and 1 part block with an area of approximately 1530 km<sup>2</sup>. Water depths range from 400 m in the southeast to 1450 m in the west.

## GRATICULAR BLOCK LISTINGS AND MAP

### RELEASE AREA AC08-7

#### NORTHERN CASWELL SUB-BASIN, BROWSE BASIN, TERRITORY OF ASHMORE AND CARTIER ISLANDS

##### *Map Sheet SD 51 (Brunswick Bay)*

607	608	609	610	611	612
679	680	681	682	683	684
751	752	753	754	755	756
821	822	823	824	825	826
827	828				

Assessed to contain 26 full blocks

### AREA AC08-8

#### NORTHERN CASWELL SUB-BASIN, BROWSE BASIN, TERRITORY OF ASHMORE AND CARTIER ISLANDS

##### *Map Sheet SD 51 (Brunswick Bay)*

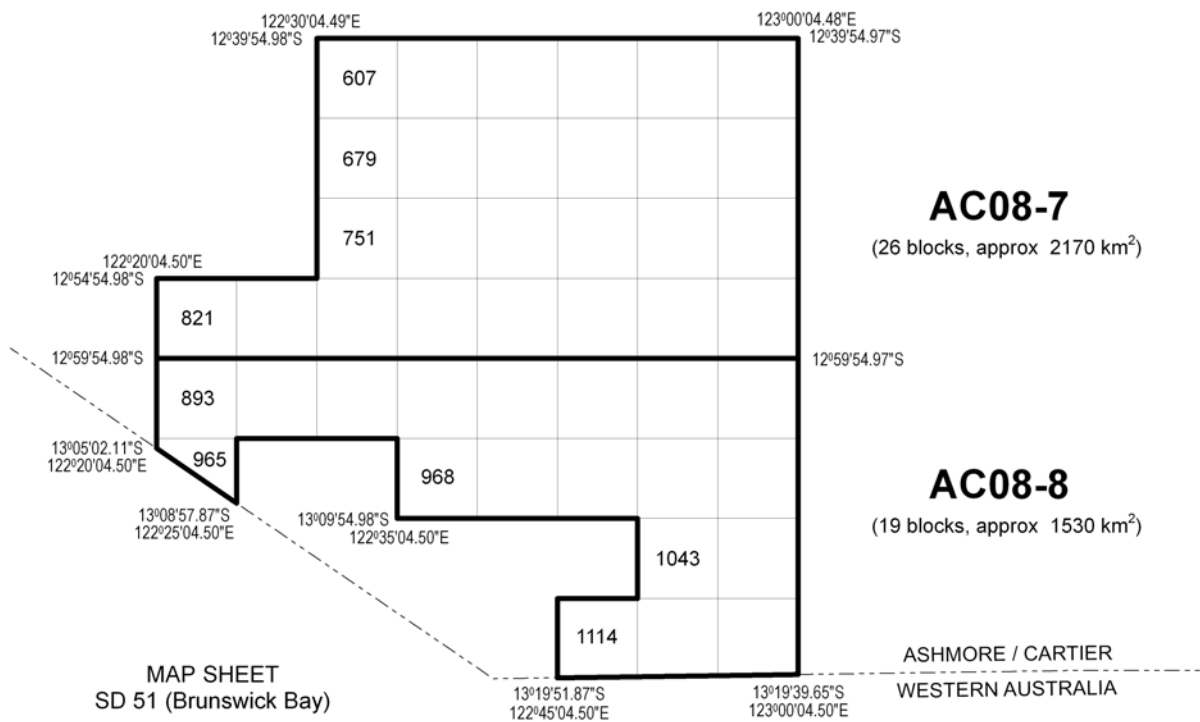
893	894	895	896	897	898
899	900	965 part	968	969	970
971	972	1043	1044	1114	1115
1116					

Assessed to contain 19 blocks (includes 18 full blocks and 1 part block)

# 2008 Release Areas

## Northern Caswell Sub-basin, Browse Basin

### Territory of Ashmore and Cartier Islands



Grid coordinates on this map are presented with reference to the Geocentric Datum of Australia (GDA94). Permit areas are based on the same grid, Australian Geodetic Datum (AGD66), that has defined areas since the Petroleum (Submerged Lands) Act was proclaimed in 1967. However, with the adoption of GDA94, the gridlines are no longer referred to in whole multiples of 5 minutes as they were under AGD66.

## RELEASE AREA GEOLOGY

The Browse Basin is a northeast-trending, Palaeozoic to Cenozoic depocentre that belongs to a series of extensional basins (extending to the northwest) that formed part of the Westralian Superbasin underlying the North West Shelf region (Bradshaw et al, 1988; Willis, 1988). Struckmeyer et al (1998) divided the Browse Basin into three major sub-basins; Caswell, Barcoo and Seringapatam.

The Release areas are located in the Caswell Sub-basin; the northernmost major depocentre of the Browse Basin, containing up to 15 km of Palaeozoic to Cenozoic sediments (Struckmeyer et al, 1998). It is flanked by the Leveque and Yampi shelves to the east and southeast, by the Ashmore Platform, Vulcan Sub-basin and the Londonderry High of the Bonaparte Basin to the north and northeast, and is contiguous with the Barcoo and Seringapatam sub-basins to the southwest and northwest, respectively ([Figure 2](#)). The Release areas are situated in the northern outboard part of the Caswell Sub-basin, directly adjacent to the Seringapatam Sub-basin and the Ashmore Platform.

The Caswell Sub-basin is marked by a series of arcuate Triassic anticlinal trends ([Figure 2](#); Struckmeyer et al, 1998). These anticlinal trends primarily comprise tilted fault blocks that formed through compressional reactivation of Palaeozoic structures in the Late Triassic to Early Jurassic. Historically, one of the most successful exploration plays in the Browse Basin has targeted gas reservoirs in the Early to Middle Jurassic Plover Formation within these fault blocks, where seals are provided by onlapping marine shales of the Cretaceous Echuca Shoals and Jamieson formations (Keall and Smith, 2004). The large gas fields that have been discovered in the outboard part of the Caswell Sub-basin (Torosa, Brecknock, Calliance and Argus) are situated on these Triassic anticlinal trends ([Figure 2](#) and [Figure 3](#)). [Figure 4](#) shows an equivalent anticline in the northwestern part of Release Area AC08-7 (unmapped by Struckmeyer et al, 1988, and consequently not shown in [Figure 2](#)).

## EXPLORATION HISTORY

### BROWSE BASIN EXPLORATION OVERVIEW

Six large gas fields have been discovered in the Browse Basin; Scott Reef (Torosa), Brecknock, Brecknock South (Calliance), Ichthys, Crux and Argus, together with a number of gas accumulations and significant gas shows (Arquebus 1/ST1, Caspar 1A, Echuca Shoals 1 and Psepotus 1). Small oil discoveries were made at Caswell 2 and Cornea 1B; small gas accumulations have been discovered at Stirrup 1 and Macula 1 (Cornea structure), and small oil and gas accumulations have been discovered at Adele 1, Gwydion 1, Cornea South 2 ST1, Focus 1 and Sparkle 1. Oil and gas shows have been found in several other wells in the Browse Basin.

The first well drilled in the Browse Basin was Leveque 1 (1970), which was a stratigraphic test of the sedimentary succession on the Leveque Shelf. This was followed by the discovery of gas at Scott Reef 1 in 1971. Scott Reef 1 intersected a thick sequence of gas-bearing reservoirs within Early–Middle Jurassic (Plover Formation) sandstones and sandy dolostones of Late Triassic–Jurassic age on the southern culmination of a faulted anticline located on the

Scott Reef–Brecknock anticlinal trend. Gas flows of 278,000–515,000 m<sup>3</sup>/day were recorded from drill stem tests (DSTs), and were accompanied by 49–54° API gravity condensate (Willis, 1988). Two appraisal wells (Scott Reef 2A in 1977, and North Scott Reef 1 in 1982) were drilled to further delineate the extent of the field (Bint, 1988). North Scott Reef 1 recorded a maximum gas flow rate of 1,275,000 m<sup>3</sup>/day from a DST (Willis, 1988). No net hydrocarbon pay was assigned to the Scott Reef 2A well.

In 1979, Brecknock 1 tested a broad anticlinal feature 40 km southwest of Scott Reef. The well penetrated 68.3 m of net gas sand in Early to Middle Jurassic sediments, of similar age to the reservoir section at Scott Reef (Bint, 1988).

Other significant discoveries during the early 1980s included Brewster 1A (1980), Caswell 2 ST1 (1983) and Echuca Shoals 1 (1983). Late Jurassic to Early Cretaceous (Berriasian age) gas-bearing sandstones were interpreted in Brewster 1A ST1 from logs. Caswell 2 ST1 encountered numerous minor oil shows and high gas readings within the Late Jurassic and Early Cretaceous sediments, and it recovered oil from a thin Late Cretaceous (Campanian) sandstone. Log interpretation of the Echuca Shoals 1 well indicated gas in two separate reservoirs of Late Jurassic (Tithonian) to Early Cretaceous (Berriasian) age (Willis, 1988).

Between 1984 and 1994 exploration was focussed largely in the northern Caswell Sub-basin (Gryphaea 1 (1987), Asterias 1 (1987), Discorbis 1 (1989) and Kalyptea 1 ST1 (1989), and along the basin margin faults of the Leveque and Yampi shelves (Trochus 1 ST1 (1991), Arquebus 1 ST1 (1991), Sheherazade 1 (1993), Copernicus 1 (1993) and Yampi 2 (1994)). Many of the wells reported minor hydrocarbon shows from Late Jurassic or Early Cretaceous reservoirs (Maung et al, 1994). Definitive evidence of the oil generative potential of the basin was demonstrated by the Gwydion 1 (1995) oil and gas discovery in 1995, and the Cornea 1 oil discovery (1997), both located on the Yampi Shelf.

Gwydion 1 discovered three gas-zones and one oil/gas-zone in Barremian to Albian shallow marine sandstones draped over a prominent basement high (Spry and Ward, 1997). The Cornea 1, 1B and 2 wells encountered a 25 m gas column overlying an 18 m oil column in the base-Albian reservoir sequence (Ingram et al, 2000), and was the first oil discovery in what was previously considered to be a gas-prone basin (Stein et al, 1998). In 1998, Adele 1 discovered oil and gas in Middle Jurassic (Plover Formation) sands, and Psepotus 1 (1998) and Caspar 1A (1998) discovered small gas accumulations within Early Cretaceous sandstones on the Leveque Shelf and Yampi Shelf, respectively.

Drilling in 2000 resulted in the discovery of several major gas accumulations in the Browse Basin, as well as the extension of previous recognised gas provinces. Brecknock South 1, located on the Scott Reef–Brecknock anticlinal trend some 19 km south of Brecknock 1, intersected a 134 m gross gas column in good quality reservoir sandstones of the Middle Jurassic Plover Formation (King, 2001). To the north, on the Buffon anticlinal trend, Argus 1 encountered a gross gas column in excess of 240 m in Oxfordian sandstones and volcanics (Keall and Smith, 2004). Significant gas discoveries were encountered in the

central Caswell Sub-basin in 2000 with the drilling of Titanichthys 1, Gorgonichthys 1 and Dinichthys 1 on the Brewster structure.

Crux 1, drilled in 2000 in the northeastern part of the Browse Basin, encountered a 280 m gross gas column in the Late Triassic to Early Jurassic Nome Formation (Kaoru et al, 2004).

In 2001–2002, exploration for liquids in Early Cretaceous lowstand fans and 'ponded' turbidites within the Caswell Sub-basin was unsuccessful (Carbine 1, Firetail 1 and Marabou 1 ST1). In 2002–2003 Maginnis 1A ST2 tested the hydrocarbon potential of the deep-water Seringapatam Sub-basin, but no hydrocarbons were encountered.

Evaluation of the gas accumulations along the Scott Reef–Brecknock anticlinal trend continued in 2005-2007 with the drilling of the extension/appraisal wells Torosa 1, 2, and 3, Brecknock 2 and 3, and Calliance 1 and 2.

Appraisal drilling in the Ichthys gas field was primarily undertaken in 2003–2004 (Ichthys 1A, Ichthys 2A ST2, and Ichthys Deep 1). In this field, gas is primarily reservoirised within the upper Vulcan Formation (Brewster Member) and within the Plover Formation (Ban and Pitt, 2006). These authors also reported that gas was encountered within Callovian sandstones (named as the Ichthys Formation), and in basal Oxfordian sandstones of the lower Vulcan Formation.

Drilling continued in this region in 2007 with the exploration/appraisal drilling of Prelude 1A, Dinichthys North 1 and Tocatta 1 in the Ichthys Field and Fossetmaker 1 on the Echuca Shoals structure. Drilling results are not available at the time of writing.

Nexus Energy Ltd (2007a) reported that the Fossetmaker 1 appraisal well, drilled on the Echuca Shoals structure 7 km east-northeast of Echuca Shoals 1 and reached a total depth of 3822 mKB in September 2007. Wireline logs indicated the well encountered a 10 m tight gas interval with a low net to gross at a depth just below the 70 m main gas column seen in Echuca Shoals 1 well. Nexus reported that further studies are required to assess the commercial implications of this result for the Echuca Shoals gas accumulation.

The appraisal of the Crux gas field continued in 2006-2007 with acquisition of a 3D seismic survey and the drilling of Crux 2 and Crux 2 ST1 wells. Nexus Energy Ltd (2007b) reported that the Crux 2 well confirmed a gross gas column of 70 m with a net 26 m of good quality sandstones in the Plover Formation. The well did not intersect the required minimum thickness of reservoir facies necessary to support the proposed liquids project gas injection rate and a decision was made to sidetrack the well.

The Crux 2 ST1 sidetrack encountered the same gas reservoirs as in Crux 1. By sidetracking the Crux 2 well to a more optimal location the company plans to utilise the cased large-bore well as the first of six wells required for the potential recycling project.

Shell Development (Australia) Pty Ltd drilled a further six exploration wells (Gigue 1, Bouree 1A, Rigaudon 1, Rondo 1, Trio 1 and Fortissimo 1) in

petroleum exploration permit WA-371-P in 2007. Drilling results are not available at the time of writing.

In June 2007 Woodside Energy Ltd drilled the top hole sections of the Snarf 1 exploration well (Petroleum Exploration Permit WA-275-P) and Torosa 4 appraisal well. It is currently planned that a rig will return to drill the bottom hole section of these wells later in the year (DoIR, 2007).

### **WELL CONTROL**

Only one well, Phrixus 1, has been drilled in the Release Area (AC08-8). A number of wells have been drilled in petroleum exploration permits adjacent to Release areas AC08-7 and AC08-8, including the gas discovery at Argus 1.

### **Buffon 1 (1980)**

Buffon 1 was drilled by Woodside Petroleum Development Pty Ltd to test the hydrocarbon potential of Early to Middle Jurassic and Triassic reservoirs sealed by Cretaceous claystones in a rotated fault block in the outer Caswell Sub-basin. The well reached a total depth of 4787 mRT. Significant gas shows were recorded in a Middle Jurassic volcanic sequence comprising layered volcanic tuffs, altered basal flows and pyroclastic material; a drill stem test over this interval (3737-4246 mRT) flowed 12 bbl/hr formation fluid (salt water) with traces of gas.

### **Mount Ashmore 1B ST1 (1980)**

Mount Ashmore 1B ST1 was drilled by Woodside Petroleum Development Pty Ltd to test the hydrocarbon potential of Early to Middle Jurassic and Triassic reservoirs sealed by Early Cretaceous claystones in a large, faulted domal anticline on the Ashmore Platform. The Plover Formation was absent and the well reached a total depth of 2655 mRT in Triassic sediments. The well confirmed the presence of reservoir, a valid structure and sealing units. No significant shows were observed during drilling and wireline logs indicated that all potential reservoirs are water-bearing.

### **Abalone 1 ST1 (2000)**

Abalone 1 ST1 was drilled by Japex AC Ltd to test the hydrocarbon potential of the Late Cretaceous Puffin Formation and Early Cretaceous Echuca Shoals and upper Vulcan formations. The Abalone Structure is a faulted anticlinal structure with approximately 80 m of relief at the Late Cretaceous level and a faulted domal anticline with approximately 340 m of relief at the Early Cretaceous level. The well, which was drilled as a deviated hole below 3600 m, reached a total depth of 4795 m (4663 m TVDRT). The planned total depth of 4950 m was not reached due to high formation pressure in the upper Echuca Shoals Formation below 4668 m. Therefore, the well did not intersect the lower Echuca Shoals Formation and upper Vulcan Formations as proposed. The well proved a valid structure at the top of the Puffin and Echuca Shoals formations. Sandstone with good reservoir potential was encountered in the Puffin Formation between 3196 and 3209 mRT with an average porosity of approximately 16% and a water saturation of 50%. MDT pretest and sampling identified a 5 m gas column with an 8 m underlying water leg in this interval. Gas indications were encountered in the Gibson, Jamieson and upper Echuca Shoals formations. Fair quality source rocks were encountered in the Jamieson Formation, but the anticipated source rocks in the Echuca Shoals Formation were not reached.

### **Argus 1 (2000)**

Argus 1 was drilled by BHP Petroleum Pty Ltd to test the hydrocarbon potential of Early to Middle Jurassic sandstones of the Plover Formation, in a complex east-west-trending fault block that has undergone several phases of faulting. The well reached a total depth of 4878 mRT, terminating in a volcanic (probably Callovian) sequence comprising basalt or dolerite intrusions or ponded lava flows. The well encountered a gross gas column, minimum 207 m and probably in excess of 240 m, in the Late Jurassic (Oxfordian) Montara Formation and underlying volcanic section. Oil was recovered from the drilling mud and sidewall cores from Paleocene carbonates. Methane forms 93.9% of the Argus 1 MDT sample obtained from the Montara Formation at 4656.2 mRT, which can therefore be considered relatively dry (Keall and Smith, 2004). The proportion of methane, ethane, propane, butane and pentane in the sample suggest that it is a cracked-oil gas of advanced but not very high maturity. This is supported by the stable carbon isotopic compositions of the gas, which also indicate that it was expelled from its source rock at a thermal maturity equivalent to about 1.4-1.5 %VR (Keall and Smith, 2004). The *n*-alkane compositions of the Montara Formation MDT sample are very different to the extracts from the Paleocene section. Aromatic biomarker data suggests that the Late Jurassic hydrocarbons are considerably more mature than the hydrocarbon extracts obtained from the Paleocene. Although both hydrocarbon suites appear to be derived from a land-plant influenced source, it is unlikely that the naturally occurring hydrocarbons in the Paleocene section represent fluids that have leaked upwards from the Montara Formation reservoir; they are more likely to represent a discrete migration system. Keall and Smith (2004) interpreted the deeply buried Triassic and Jurassic sediments as the gas source and the Late Jurassic–Early Cretaceous marine shales as the oil source. The liquids are contained within a network of micro-pores and fractures that developed over the crest of the deeper Argus structure (Keall and Smith, 2004).

### **Phrixus 1 (2001)**

Phrixus 1 was drilled by BHP Petroleum Pty Ltd to test the hydrocarbon potential of Late Cretaceous sandstones of the Puffin Formation in a simple four-way dip-closure, with secondary objectives in Paleocene and Eocene sandstones. The well was drilled to a depth of 3874 mRT, terminating in the Jamieson Formation. No sandstones were intersected in the Puffin Formation and Tertiary sandstones lack top-seal lithologies. Minor hydrocarbon shows were encountered during drilling and fluorescence was observed in two thin carbonate beds within the lower Puffin Formation. Hydrocarbons were successfully extracted from sidewall cores from Cretaceous and basal Paleocene sandstones but porosity is very low and the hydrocarbons are interpreted to be immovable. The well was plugged and abandoned as a dry hole.

**KEY WELLS LISTING – RELEASE AREAS AC08-7 AND AC08-8 Northern Caswell Sub-Basin**

Well	Operator	Total Depth (m)	Year <sup>\$</sup>	Data Avail <sup>*</sup>	Basic Avail	Interp Avail	Source <sup>#</sup>
Abalone 1	Japex AC Ltd	2504	2000	A	-	-	-
Abalone 1 ST1	Japex AC Ltd	4795	2000	A	-	-	-
Argus 1	BHP Petroleum Pty Ltd	4878	2000	A	-	-	-
Bassett 1	Woodside Petroleum Development Pty Ltd	949	1978	A	-	-	-
Bassett 1A	Woodside Petroleum Development Pty Ltd	2706	1978	A	-	-	-
Buffon 1	Woodside Petroleum Development Pty Ltd	2905	1980	A	-	-	-
Buffon 1 ST1	Woodside Petroleum Ltd	4787	1980	A	-	-	-
Mount Ashmore 1	Woodside/Burmah Oil NL	664		A	-	-	-
Mount Ashmore 1A	Woodside/Burmah Oil NL	1058		A	-	-	-
Mount Ashmore 1B	Woodside Petroleum Development Pty Ltd	1680	1980	A	-	-	-
Mount Ashmore 1B ST1	Woodside Petroleum Ltd	2655	1980	A	-	-	-
Phrixus 1	BHP Petroleum Pty Ltd	3874	2001	A	-	-	-
Turbo 1	Japex AC Ltd	3900	2000	A	-	-	-

<sup>\$</sup>Year is based on Rig-released date, <sup>\*</sup> A = All data (Basic and Interpretive) is available, <sup>#</sup> RRD = Rig release date. Data is accurate at 16 January 2008.

## SEISMIC COVERAGE

Release areas AC08-7 and AC08-8 are covered by a broad grid of reconnaissance seismic lines of varying vintage and quality (eg. BR97, line spacing approximately 10 km) and a detailed 2D industry grid (HBR 1998B, line spacing approximately 2 km). The North Browse TQ 3D seismic survey, which was acquired in 1998, covers the majority of Release Area AC08-8 and most of the eastern half of Release Area AC08-7.

### Seismic Surveys – AC08-7

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
Mermaid Cartier	Burmah Oil	4326	1973	Yes	Yes	609	S6730011/29
Tessa-Troubadour	BOCAL, Woodside & Other partner	5572	1975	Yes	Yes	152	S0750001
Scientific Investigation 17SL Marine Seis	Halliburton Geophysical Service	1203	1984	Yes	Yes	574	S6840031
AGSO Marine Survey 119, Browse	Australian Geological Survey Or	4043	1993	Yes	Yes	599	S6930071
AGSO Marine Survey 130, Browse Basin	AGSO	3692	1994	Yes	Yes	741	S6940031
AGSO Marine Survey 175, Browse Basin Regi	Australian Geological Survey Or	5264	1996	Yes	Yes	602	S6960034
Timor Sea Spec Marine Seismic	Digicon	2403	1996	Yes	No	661	not known
Browse 98	Veritas	23892	1998	No	No	2851	S8980012
HBR 1998B	BHP	4299	1999	Yes	Yes	852	S8980016

## Seismic Surveys – AC08-8

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
Mermaid Cartier	Burmah Oil	4326	1973	Yes	Yes	609	S6730011/29
Woodbine-Victoria Project 79A/79B Marine Seismic	Woodside	2558	1979	Yes	No	148	S8780001
Dampier-Broome Marine Seismic: Project 81D	Woodside	2536	1981	Yes	Yes	155	S6810045
Project 82A of 2DW Marine Seismic	Woodside	3349	1981	No	Yes	853	S6810002
Project 82B of 2DW Marine Seismic			1982	Yes	Yes		S6810036
Project 82D of 2DW (Dampier-Broome Marine Seismic)			1982	Yes	Yes		S6810028
Project 82K of Dampier Broome Marine Seismic (2DW)			1982	No	Yes		S8810009
Projects 82E-1 of 2DW Marine Seismic			1982	No	Yes		S6810038
Projects 82E-2 & 82J of 2DW Marine Seismic			1982	No	Yes		S6810035
Projects 82F & 82G 2DW Marine Seismic			1982	Yes	Yes		S6810037
AGSO Marine Survey 119, Browse	Australian Geological Survey Org	4043	1993	Yes	Yes	599	S6930071
AGSO Marine Survey 130, Browse Basin	AGSO	3692	1994	Yes	Yes	741	S6940031
AGSO Marine Survey 175, Browse Basin	Australian Geological Survey Org	5264	1996	Yes	Yes	602	S6960034
Timor Sea Spec Marine Seismic	Digicon	2403	1996	Yes	No	661	not known
Browse 98	Veritas	23892	1998	No	No	2851	S8980012
IFR-98 Seismic Survey	Genting Oil & Gas	2660	1998	Yes	Yes	1500	S6980040
HBR 1998 B Marine Seismic	BHP	4299	1999	Yes	Yes	852	S8980016

Data is accurate as at 17 December 2007.

## HYDROCARBON POTENTIAL

### PETROLEUM SYSTEMS

Geochemical analysis of oils, oil stains, fluid inclusion oils, condensates, gases and source rocks from the Browse Basin have been undertaken by Boreham et al (1997, 2001), Blevin et al (1998a, b), AGSO and Geotech (2000), Edwards et al (2000, 2004, 2006), Edwards and Zumberge (2005) and Volk et al (2005). [Figure 8](#) demonstrates that the stable  $^{13}\text{C}$  isotopic data of gases and oils can be used to discriminate the different sources of hydrocarbons in this basin. These isotopic datasets, together with molecular analyses, provide evidence that at least three hydrocarbon families/petroleum systems are present in the Caswell Sub-basin (Kennard et al, 2004).

1. An outer sub-basin, relatively dry gas-prone system sourced from mixed terrestrial and marine organic matter (Torosa, Brecknock and Calliance fields: condensate/gas ratios of 10–20 bbl/MMscf). The Argus gas accumulation (CGR <10 bbl/MMscf; Keall and Smith, 2004) probably represents a northern extension of this system (Kennard et al, 2004). Edwards et al (2004) proposed that the Early–Middle Jurassic Plover Formation was the most likely source for these gases, whereas a Permo-Triassic source has been modelled by Belopolsky et al (2006). Edwards and Zumberge (2005) suggest a source interval from within the Triassic to Middle Jurassic succession on the basis of bulk isotopic signatures and  $^{13}\text{C}$  isotopic profiles of n-alkanes for condensates from the Torosa (Scott Reef) Field.
2. A central sub-basin, wet gas-prone system, the source(s) of which has yet to be established (Brewster/Ichthys field; condensate/gas ratios of 60 bbl/MMscf). These accumulations could have been charged from either underlying Jurassic (Plover or Vulcan formations) or overlying Early Cretaceous (Echuca Shoals Formation) source rocks, but the lack of an oil leg in these wells tends to suggest that they did not receive a significant charge from the oil-prone Early Cretaceous petroleum system. From the similarity of the  $\delta^{13}\text{C}$  isotopic data of the gas/condensates recovered from the Brewster reservoir in the Ichthys field with those of Bayu and Undan in the northern Bonaparte Basin, a Jurassic source is implied, with the possibility of a contribution from Late Jurassic Vulcan Formation source rocks.
3. An inner sub-basin oil (plus gas)-prone petroleum system sourced from predominantly marine algal and bacterial organic matter within the Early Cretaceous sediments of the Echuca Shoals Formation (Cornea and Gwydion fields, Caswell 2 oil accumulation). Blevin et al (1998a) defined this system as the Westralian (W3) Petroleum System. The Cornea and Gwydion oils and gases are biodegraded to differing extents.

In the Heywood Graben, the Crux gas discovery is interpreted to be sourced from mixed terrestrial and marine organic matter contained within Early–Middle Jurassic source rocks (Edwards et al, 2004). However, the gas is drier than the gases from the Ichthys field (Nippon Oil Exploration, 2001; Kaoru et al, 2004). From biomarker data (George et al, 2000), and the  $\delta^{13}\text{C}$  isotopic evidence

presented in [Figure 8](#), the samples of gas and condensate recovered from Crux 1 represent another hydrocarbon family within the Browse Basin.

### **Source Rocks**

An assessment of the source rock potential of the Browse Basin was undertaken by Boreham et al (1997), and the results summarised by Blevin et al (1998a, b). These studies recognised organic-rich rocks with fair to moderate oil potential at multiple stratigraphic levels within the Permian–Early Cretaceous section, and that some local, thin, high-quality coals and pro-delta shales occur within the Early–Middle Jurassic, fluvio-deltaic Plover Formation ([Figure 7](#)). Blevin et al (1998b) noted that although many potential source units within this succession have liquids potential (HI values of >200 mg hydrocarbons/gTOC), they contain less than 2 % TOC ([Figure 7](#)). At these low-to-moderate TOC levels, any generated oil may remain within the source rock (ie, not be expelled from the source rock) and may be subsequently cracked to gas at higher maturities.

[Figure 6](#) shows generalised distribution maps of Late Jurassic (Vulcan Formation) and Early Cretaceous (Echuca Shoals and Jamieson formations) potential source units in the basin, which are interpreted to have sourced oil shows in the Paleocene section of Argus 1. The Late Jurassic section is generally thin throughout the Browse Basin, with major sediment thickening restricted to the Heywood Graben in the northeast, where restricted marine source facies are likely to be best developed. Localised thickening of Late Jurassic sediments also occurs on the Leveque Shelf ([Figure 6a](#)), but here the section is dominated by deltaic facies with poorer quality terrigenous organic matter. Thick sections of Early Cretaceous sediments occur within both the Caswell and Barcoo sub-basins ([Figure 6b](#), [6c](#) and [6d](#)), and contain mixed marine and terrestrial organic matter with moderate to good source potential. Available pyrolysis data suggests that these sediments have better liquids potential within the Caswell Sub-basin (HI=150–350 mg hydrocarbons/gTOC) than the Barcoo Sub-basin (HI=100–250 mg hydrocarbons/gTOC; Kennard et al, 2004, table 1).

Potential source facies also occur within the thick succession of Early–Middle Jurassic sediments (Plover Formation) that extend throughout the basin and reach a maximum penetrated thickness within the Barcoo Sub-basin (920 m in Barcoo 1). This section is dominated by fluvio-deltaic facies, including pro-delta shales and coastal plain shaly coals that have significant source potential (Blevin et al, 1998a). It is likely that these source facies are also present in the underlying Triassic succession (Keall and Smith, 2004; Edwards and Zumberge, 2005). The hydrocarbons generated from this section are thought to be dominated by gas and are interpreted to have sourced the giant gas fields of the Brecknock-Scott Reef trend.

### **Reservoirs and Seals**

Reservoir facies are best developed within fluvio-deltaic sandstones of the Jurassic Plover and Montara formations, and submarine fans and 'ponded' turbidite mounds of Berriasian, Barremian, Campanian and Maastrichtian age ([Figure 9](#)). Late Jurassic-Early Cretaceous (Vulcan Formation) and Early Cretaceous (Echuca Shoals Formation) claystones provide regional seals throughout much of the basin. Potential intraformational seals occur within the

Early–Middle Jurassic Plover Formation (Blevin et al, 1998a), and Late Cretaceous claystones of the Puffin Formation provide potential seals for Campanian–Maastrichtian ponded turbidites and unconfined fan sediments (Benson et al, 2004).

### ***Timing of Generation and Expulsion***

Hydrocarbon expulsion modelling (Kennard et al, 2004) suggests multiple effective source units for gas expulsion in the basin, whereas effective oil-charge is largely restricted to the Heywood Graben in the northeast, the central and southern Caswell Sub-basin, and possibly the rift section in the deep-water Seringapatam Sub-basin.

Modelling suggests that significant quantities of oil were expelled from Jurassic sediments (Plover and Lower Vulcan formations) in the Heywood Graben during the Cenozoic. These charges are likely to have sourced the thick palaeo-oil columns interpreted at Heywood 1 and Crux 1 on the basis of fluid inclusion analysis (Eadington and Middleton, 2000; Brincat et al, 2004). Lesser quantities of oil are modelled to have been expelled from the Vulcan Formation in the central and southern Caswell Sub-basin. Fluid inclusion analyses from the Browse Basin gas accumulations have shown that the hydrocarbon charge consisted of an early oil charge, filling only the crestal parts of the structures before being displaced or absorbed by gas (Brincat and Kennard, 2004). Only relatively minor gas expulsion, but no oil, is predicted to occur in the Barcoo Sub-basin where source facies are generally leaner (Kennard et al, 2004).

Recent hydrocarbon generation and expulsion studies of Early Cretaceous (Echuca Shoals and Jamieson formations) source rocks using Small Angle Neutron Scattering (SANS) confirm the existence of potential oil and gas-prone source rocks that are sufficiently thermally mature for generation to occur, but which show little or no evidence of expulsion and effective regional charge (Radlinski et al, 2004).

Similarly, fluid inclusion analyses have not provided any evidence for an effective regional oil charge to Cretaceous reservoirs in the Caswell Sub-basin (Brincat and Kennard, 2004; Brincat et al, 2004). However, as the organic-rich sediments within this succession were deposited as thin transgressive sheets in response to fluctuating sea level on a gently inclined ramp margin, detailed understanding of the local expulsion-migration history may require higher resolution (systems tract level) sequence stratigraphic models. Effective oil charge from parts of the Echuca Shoals Formation is confirmed by geochemical analysis of the Cornea, Gwydion and Caswell accumulations, and is postulated as the probable source of the inferred gas accumulation at Marabou 1 ST1 (Benson et al, 2004).

### **PLAY TYPES**

The major play types within the basin include Late Triassic faulted anticlines, Jurassic horsts/tilted fault blocks and associated drape anticlines, Early Cretaceous drape of erosional basement highs on the Yampi and Leveque shelves, as well as Late Cretaceous basin floor fans and ‘ponded’ turbidite stratigraphic traps ([Figure 9](#)). To date, the prominent Late Cenozoic fault-reactivation anticlines along the basinward margin of the Leveque Shelf (eg, Trochus, Lynher, Lombardina and Sheherazade structures) have proved

unsuccessful, with the possible exception of the inferred hydrocarbon column at Arquebus 1 ST1 (Haston and Farrelly, 1993).

A play type of particular significance to the Release areas is the Oxfordian Montara Formation play, which is proven in the Argus gas accumulation. Generally, the post-Callovian section onlaps the Callovian unconformity in wells that have drilled Callovian or Triassic structures (Keall and Smith, 2004). In Argus 1 the hiatus extends from the Oxfordian to the Albian, with development of the Argus structure and deposition of the deltaic Montara Formation post-dating structuring along the Scott Reef–Brecknock anticlinal trend (Keall and Smith, 2004). Potential exists for this play to be exploited in structures in the Release areas that are similar to the Argus structure ([Figure 4](#)).

### **CRITICAL RISKS**

A risk to the presence of hydrocarbon accumulations within the Release areas is the potential absence of Triassic and Jurassic reservoir facies typically associated with Browse Basin plays. For example, target sandstones were not encountered within the Puffin Formation in Phrixus 1. The lack of sandstone was unexpected in light of a relatively thick (500 m) Puffin isopach, however, correlations to offset wells suggest that the lower parts of the Puffin, which are more distal and less sand-prone, are overthickened at the well location compared to the more proximal and sand-rich upper Puffin Formation. Similarly, the Argus prospect targeted sandstones of the Jurassic Plover Formation, but terminated in a Callovian volcanic succession without encountering the Plover Formation. This risk is offset by the presence of reservoir sandstones that are not typically associated with the Browse Basin, such as the Montara Formation sandstones in Argus 1.

A thick Late Jurassic succession is absent from the Browse Basin because major rifting did not occur in the region at that time, and consequently the restricted conditions that favour development of marine source rocks did not develop (Longley et al, 2002; Keall and Smith, 2004). This interval is considered to have the best oil source rock potential on the North West Shelf; therefore the absence of this unit is an additional risk to liquid hydrocarbon accumulations within the Release areas.

## FIGURES

- Figure 1:** Location map of Release areas AC08-7 and AC08-8 in the Browse Basin showing existing petroleum title areas, petroleum accumulations and significant wells.
- Figure 2:** Regional setting of the Browse Basin (after Struckmeyer et al, 1998), also showing the location of seismic lines BBHR 175/10 (Fig. 3) and BBHR 175/11 (Fig. 4).
- Figure 3:** Seismic line BBHR 175/10 through Argus 1 and Release Area AC08-8, northern Caswell Sub-basin. Location of the line is shown in Figure 2. Regional seismic horizons are shown in Figure 5.
- Figure 4:** Seismic line BBHR 175/11 through Release areas AC08-7 and AC08-8. Location of the line is shown in Figure 2. Regional seismic horizons are shown in Figure 5.
- Figure 5:** Tectonostratigraphic summary and hydrocarbon discoveries for the Browse Basin (after Blevin et al, 1998a; Struckmeyer et al, 1998).
- Figure 6:** Generalised distribution map of (a) Tithonian to Callovian, (b) Barremian to Valanginian, (c) Aptian to Barremian, and (d) Turonian to Aptian sediments in the Browse Basin (based on two-way time isopachs maps; after Blevin et al, 1998b). The shelf margin hinge is shown in black and arrows indicate the direction of sediment transport. The 2008 Release areas shown in red.
- Figure 7:** Plots of age (a) present day and initial TOC, and (b) present day and initial S<sub>2</sub> values for the Browse Basin wells drilled prior to 1998 (Blevin et al, 1998b).
- Figure 8:** Carbon isotopic composition for C<sub>7+</sub> *n*-alkanes of gases, condensates and oils recovered from the Browse Basin (after Edwards et al, 2004, 2006).
- Figure 9:** Browse Basin schematic cross-section, showing hydrocarbon play types (Keall and Smith, 2004).

## REFERENCES

AGSO AND GEOTECH., 2000—Characterisation of Natural Gases from West Australian basins. Browse Module. Non-Exclusive Study. Australian Geological Survey Organisation, Canberra and Geotechnical Services Pty Ltd, Perth, Australia.

BAN, S. AND PITT, G., 2006—The Ichthys giant gas-condensate field. 2006 AAPG International Conference and Exhibition, 5–8 November, Perth, Australia, Abstract.

BELOPOLSKY, A.V., WOODFINE, R., STOVER, C., PIGGOT, N., PRICE, S. AND JONES, B., 2006—Reservoir systems of Browse Basin, Northwest Shelf of Australia, in a sequence stratigraphic framework. 2006 AAPG International Conference and Exhibition, 5–8 November, Perth, Australia, Abstract.

BENSON, J.M., BREALEY, S.J., LUXTON, C.W., WALSH, P.F. AND TUPPER, N.P., 2004—Late Cretaceous ponded turbidite systems: a new stratigraphic play fairway in the Browse Basin. *The APPEA Journal*, 44(1), 269–285.

BINT, A.N., 1988—Gas fields of the Browse Basin. In: Purcell, P.G. and Purcell, R.R. (editors), *The North West Shelf, Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium*, Perth, 1988, 413–417.

BLEVIN, J.E., STRUCKMEYER, H.I.M., CATHRO, D.L., TOTTERDELL, J.M., BOREHAM, C.J., ROMINE, K.K., LOUIT, T.S. AND SAYERS, J., 1998a—Tectonostratigraphic framework and petroleum systems of the Browse Basin, North West Shelf. In: Purcell, P.G. and Purcell, R.R. (editors), *The Sedimentary Basins of Western Australia 2: Proceedings of the Petroleum Exploration Society of Australia Symposium*, Perth, 1998, 369–395.

BLEVIN, J.E., BOREHAM, C.J., SUMMONS, R.E., STRUCKMEYER, H.I.M. AND LOUIT, T.S., 1998b—An effective Lower Cretaceous petroleum system on the North West Shelf: evidence from the Browse Basin. In: Purcell, P.G. and Purcell, R.R. (editors), *The Sedimentary Basins of Western Australia 2: Proceedings of the Petroleum Exploration Society of Australia Symposium*, Perth, 1998, 397–420.

BOREHAM, C.J., ROKSANDIC, Z., HOPE, J.M., SUMMONS, R.E., MURRAY, A.P., BLEVIN, J.E. AND STRUCKMEYER, H.I.M., 1997—Browse Basin Organic Geochemistry Study, North West Shelf, Australia. Volume 1, Interpretation Report. AGSO Record 1997/57.

BOREHAM, C.J., HOPE, J.M. AND HARTUNG-KAGI, B., 2001—Understanding source, distribution and preservation of Australian natural gas: a geochemical perspective. *The APPEA Journal*, 41(1), 523–547.

BRADSHAW, M.T., YEATES, A.N., BEYNON, R.M., BRAKEL, A.T., LANGFORD, R.P., TOTTERDELL, J.M. AND YEUNG, M., 1988—Palaeogeographic evolution of the North West Shelf region. In: Purcell, P.G.

and Purcell, R.R. (editors), The North West Shelf, Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 29–54.

BRINGAT, M.P. AND KENNARD, J.M., 2004—Fluid Inclusion Analysis (GOI™) of 12 Wells in the Browse Basin. Destructive Analysis Report, unpublished.

BRINGAT, M.P., LISK, M., KENNARD, J.M., BAILEY, W.R. AND EADINGTON, P.J., 2004—Evaluating the oil potential of the gas-prone Caswell Sub-basin: insights from fluid inclusion studies. In: Ellis, G.K., Baillie, P.W. and Munson, T.J. (editors), Timor Sea Petroleum Geoscience. Proceedings of the Timor Sea Symposium, Darwin, 19–20 June 2003. Northern Territory Geological Survey, Special Publication 1, 437–455.

DoIR, 2007—Department of Industry and Resources, Western Australia – Petroleum in Western Australia, Publication, September 2007, 73 pp.

DPIFM, 2007—Department of Primary Industry, Fisheries and Mines, Northern Territory – Northern Territory Oil and Gas 2006. Northern Territory Government, Publication, April 2007.

EADINGTON, P.J. AND MIDDLETON, H., 2000—History of hydrocarbon charge and pore water migration in the Crux-1 Gas-Condensate Well, Browse Basin, Timor Sea. CSIRO Petroleum Confidential Report No. 00-069 to Nippon Oil Exploration Pty Ltd

EDWARDS, D.S. AND ZUMBERGE, J.E., 2005—The Oils of Western Australia II. Regional Petroleum Geochemistry and Correlation of Crude Oils and Condensates from Western Australia and Papua New Guinea. Geoscience Australia and GeoMark Research Ltd, Canberra and Houston, unpublished.

EDWARDS, D.S., KENNARD, J.M., PRESTON, J.C., SUMMONS, R.E., BOREHAM, C.J. AND ZUMBERGE, J.E., 2000—Bonaparte Basin: geochemical characteristics of hydrocarbon families and petroleum systems, AGSO Research Newsletter, December 2000, 14–19.

EDWARDS, D.S., PRESTON, J.C., KENNARD, J.M., BOREHAM, C.J., VAN AARSSSEN, B.K.J., SUMMONS, R.E. AND ZUMBERGE, J.E., 2004—Geochemical characteristics of hydrocarbons from the Vulcan Sub-basin, western Bonaparte Basin, Australia. In: Ellis, G.K., Baillie, P.W. and Munson, T.J. (editors), Timor Sea Petroleum Geoscience. Proceedings of the Timor Sea Symposium, Darwin, 19–20 June 2003. Northern Territory Geological Survey, Special Publication 1, 169–201.

EDWARDS, D.S., BOREHAM, C.J., ZUMBERGE, J.E., HOPE, J.M., KENNARD, J.M., AND SUMMONS, R.E., 2006—Hydrocarbon families of the Australian North West Shelf: a regional synthesis of the bulk, molecular and isotopic composition of oils and gases. 2006 AAPG International Conference and Exhibition, 5–8 November, Perth, Australia, Abstract.

ETHERIDGE, M.A. AND O'BRIEN, G.W., 1994—Structural and tectonic evolution of the Western Australian margin basin system. PESA Journal, No. 22, 45–63.

GEORGE, S.C., AHMED, M., QUEZADA, R.A. AND EADINGTON, P.J., 2000—Geochemical Composition of Oil Trapped in Fluid Inclusions from Crux-1 Well, AC/P 23, Timor Sea. CSIRO Petroleum Confidential Report No. 00-039 to Nippon Oil Exploration Pty Ltd

GEOSCIENCE AUSTRALIA., 2008. Oil and Gas Resources of Australia 2005, in preparation. Geoscience Australia, Canberra.

HASTON, R.B. AND FARRELLY, J.J., 1993—Regional significance of the Arquebus 1 well, Browse Basin, North West Shelf, Australia. The APEA Journal, 33(1), 28–38.

INGRAM, G.M., EATON, S. AND REGTIEN, J.M.M., 2000—Cornea case study: lessons for the future. The APPEA Journal, 40(1), 56–65.

KAORU, M., KURATA, Y., CHRISTIANSEN, D.J. AND SCOTT, J., 2004—The Crux gas-condensate discovery, northern Browse Basin, Australia. In: Ellis, G.K., Baillie, P.W. and Munson, T.J. (editors), Timor Sea Petroleum Geoscience. Proceedings of the Timor Sea Symposium, Darwin, 19–20 June 2003. Northern Territory Geological Survey, Special Publication 1, 67–79.

KEALL, J. AND SMITH, P., 2004—The Argus discovery, Browse Basin. In: Ellis, G.K., Baillie, P.W. and Munson, T.J. (editors), Timor Sea Petroleum Geoscience. Proceedings of the Timor Sea Symposium, Darwin, 19–20 June 2003. Northern Territory Geological Survey, Special Publication 1, 37–52.

KENNARD, J.M., DEIGHTON, I., RYAN, D., EDWARDS, D.S. AND BOREHAM, C.J., 2004—Subsidence and thermal history modelling: new insights into hydrocarbon expulsion from multiple petroleum systems in the Browse Basin. In: Ellis, G.K., Baillie, P.W. and Munson, T.J. (editors), Timor Sea Petroleum Geoscience. Proceedings of the Timor Sea Symposium, Darwin, 19–20 June 2003. Northern Territory Geological Survey, Special Publication 1, 411–435.

KING, G.M., 2001—2000 exploration review. The APPEA Journal, 40(2), 56–67.

LONGLEY, I.M., BUESSENSCHUETT, C., CLYDSDALE, L., CUBITT, C.J., DAVIS, R.C., JOHNSON, M.K., MARSHALL, N.M., MURRAY, A.P., SOMERVILLE, R., SPRY, T.B. AND THOMPSON, N.B., 2002—The North West Shelf of Australia - a Woodside perspective. In: Keep, M. and Moss, S. (editors), The Sedimentary Basins of Western Australia, Vol. 3, pp. 27-88. Petroleum Exploration Society of Australia, Perth.

MAUNG, T.U., CADMAN, S. AND WEST, B., 1994—A review of the petroleum potential of the Browse Basin. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 1994, 333–346.

METCALFE, I., 1990. Allochthonous terrane processes in Southeast Asia. Philosophical Transactions of the Royal Society, London, A 331, 625–640.

NEXUS ENERGY LTD, 2007a—ASX Announcements, Fossetmaker-1 appraisal well intersects a tight gas column in Exploration Permit WA-377-P, 3 September 2007.

NEXUS ENERGY LTD, 2007b—ASX Announcements, Crux 2 ST1 Progress Report No.16, 20 April 2007.

NIPPON OIL EXPLORATION (VULCAN) PTY LTD, 2001—Crux 1 Final Geological Report, Volume 1, unpublished.

RADLINSKI, A.P., KENNARD, J.M., EDWARDS, D.S., HINDE, A.L. AND DAVENPORT, R., 2004—Hydrocarbon generation and expulsion from Early Cretaceous source rocks in the Browse Basin, North West Shelf, Australia: a Small Angle Neutron Scattering study. *The APPEA Journal*, 44(1), 151–180.

SHUSTER, M.W., EATON, S., WAKEFIELD, L.L. AND KLOOSTERMAN, H.J., 1998—Neogene tectonics, greater Timor Sea, offshore Australia: implications for trap risk. *The APPEA Journal*, 38(1), 351–379.

SPRY, T.B. AND WARD, I., 1997—The Gwydion discovery: a new play fairway in the Browse Basin. *The APPEA Journal*, 37(1), 87–104.

STEIN, A., MYERS, K., LEWIS, C., CRUSE, T. AND WINSTANLEY, S., 1998—Basement control and geoscientific definition of the Cornea discovery, Browse Basin, Western Australia. In: Purcell, P.G. and Purcell, R.R. (editors), *The Sedimentary Basins of Western Australia 2: Proceedings of the Petroleum Exploration Society of Australia Symposium*, Perth, 1998, 421–431.

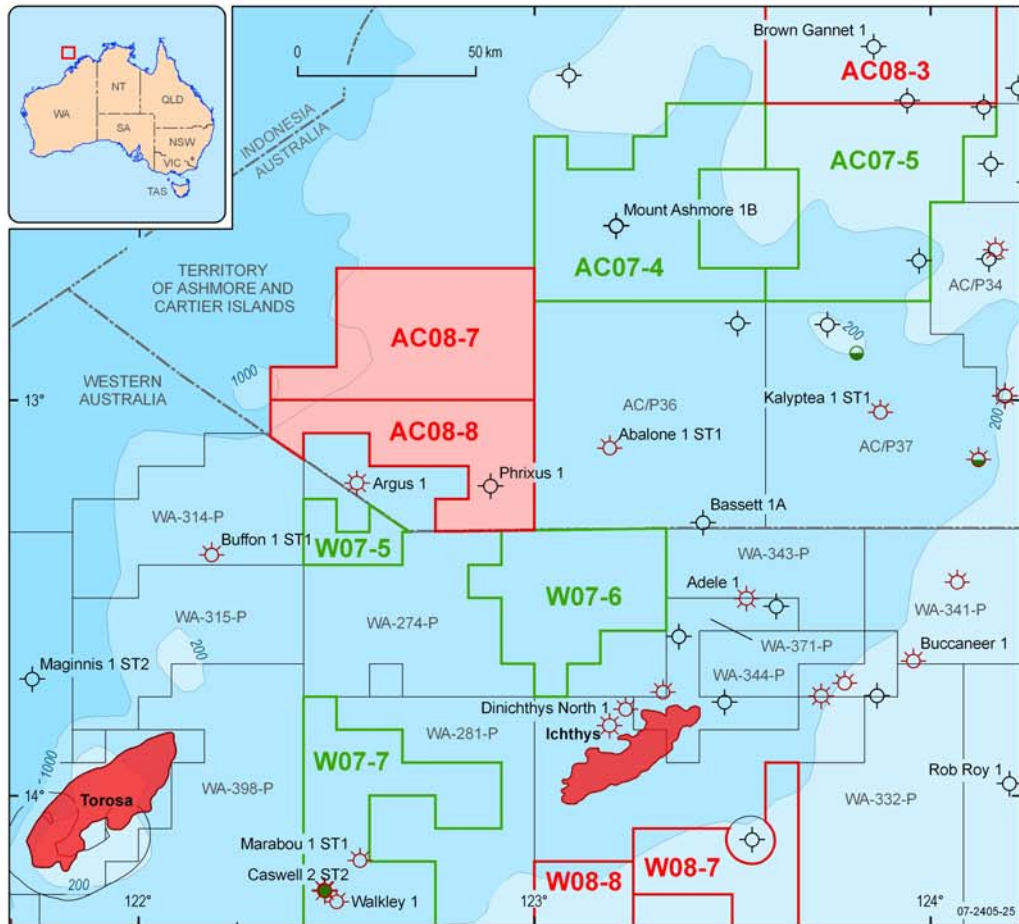
STRUCKMEYER, H.I.M., BLEVIN, J.E., SAYERS, J., TOTTERDELL, J.M., BAXTER, K. AND CATHRO, D.L., 1998—Structural evolution of the Browse Basin, North West Shelf: new concepts from deep-seismic data. In: Purcell, P.G. and Purcell, R.R. (editors), *The Sedimentary Basins of Western Australia 2: Proceedings of the Petroleum Exploration Society of Australia Symposium*, Perth, 1998, 345–367.

SYMONDS, P.A., COLLINS, C.D.N. AND BRADSHAW, J., 1994—Deep structure of the Browse Basin: implications for basin development and petroleum exploration. In: Purcell, P.G. and Purcell, R.R. (editors), *The Sedimentary Basins of Western Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium*, Perth, 1994, 315–331.

VOLK, H., BRINCAT, M.P., GEORGE, S.C., KENNARD, J.M., EDWARDS, D.S., BOREHAM, C.J., AHMED, M. AND LISK, M., 2005—Clues to fill histories of gas fields in the Caswell Sub-basin—evidence from the distribution and geochemistry of palaeo-oils. *The APPEA Journal*, 45(1), 679.

WILLIS, I., 1988—Results of exploration, Browse Basin, North West Shelf, Western Australia. In: Purcell, P.G. and Purcell, R.R. (editors), *The North West Shelf, Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium*, Perth, 1988, 259–272.

WOODSIDE, 2006—Woodside third quarter report for period ended 30 September 2006. ASX Announcement, Thursday, 19 October 2006.



Well symbols supplied by Geoscience Australia (basic data open file) and Encom Petroleum Information Pty Ltd (basic data confidential). These were generated from open file data as at 31 Jan 2008.  
 Field outlines supplied by Encom Petroleum Information Pty Ltd. Field outlines in GPinfo are sourced from the operators of the fields only. Outlines are updated at irregular intervals but with at least one major update per year.  
 Field outlines for Cornea and Ichthys are sourced from IHS Energy, 2006.

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|--|--|
| <span style="display: inline-block; width: 15px; height: 15px; background-color: #f08080; border: 1px solid black; margin-right: 5px;"></span> 2008 release area | Petroleum exploration well - dry hole                    |
| <span style="display: inline-block; width: 15px; height: 15px; border: 2px solid green; margin-right: 5px;"></span> 2007 release area                            | Petroleum exploration well - gas show                    |
| <span style="display: inline-block; width: 15px; height: 15px; border: 1px solid black; margin-right: 5px;"></span> Existing petroleum title                     | Petroleum exploration well - oil show                    |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: red; margin-right: 5px;"></span> Gas field                                      | Petroleum exploration well - gas discovery               |
| <span style="display: inline-block; width: 15px; border-bottom: 1px dashed black; margin-right: 5px;"></span> Adjacent area boundary                             | Petroleum exploration well - oil and gas discovery       |
| <span style="display: inline-block; width: 15px; border-bottom: 1px dashed black; margin-right: 5px;"></span> -500- Bathymetry contour (depth in metres)         | Petroleum exploration well - oil discovery with gas show |
|  | Petroleum exploration well - oil and gas show            |
|  | Petroleum exploration well - unclassified                |

Figure 1. Location map of Release areas AC08-7 and AC08-8 in the Browse Basin showing existing petroleum title areas, petroleum accumulations and significant wells.

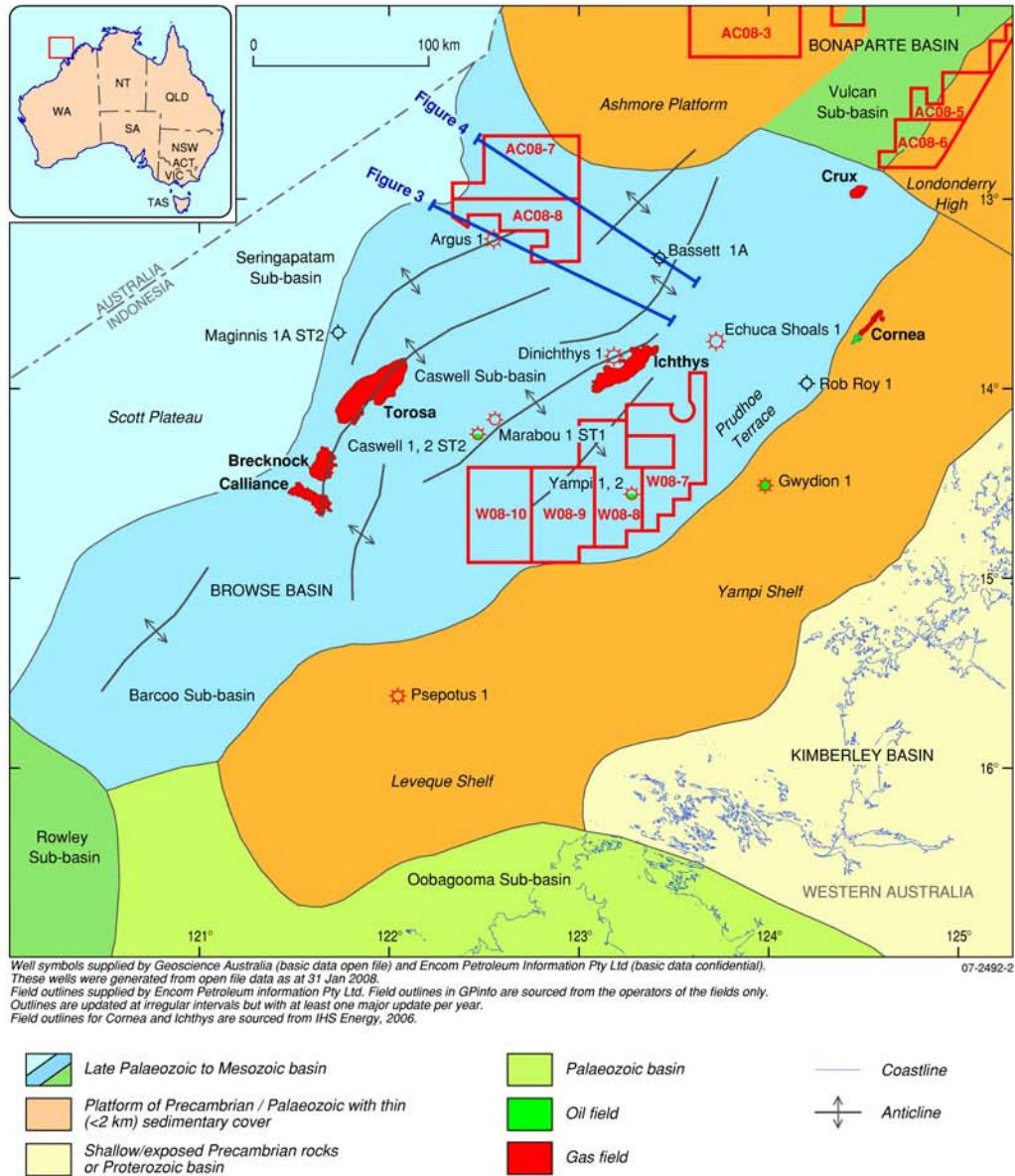


Figure 2. Regional setting of the Browse Basin (after Struckmeyer et al, 1998), also showing the location of seismic lines BBHR 175/10 (Figure 3) and BBHR 175/11 (Figure 4).

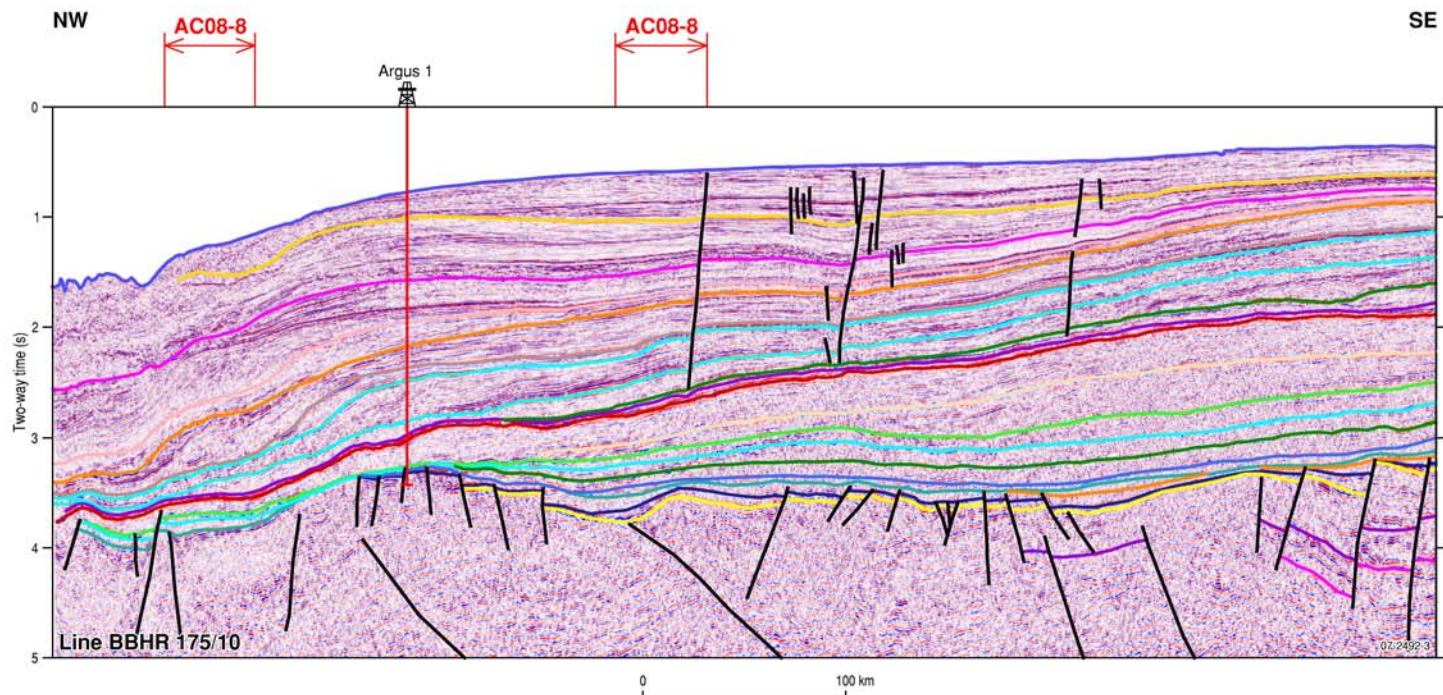


Figure 3. Seismic line BBHR 175/10 through Argus 1 and Release Area AC08-8, northern Caswell Sub-basin. Location of the line is shown in Figure 2. Regional seismic horizons are shown in Figure 5.

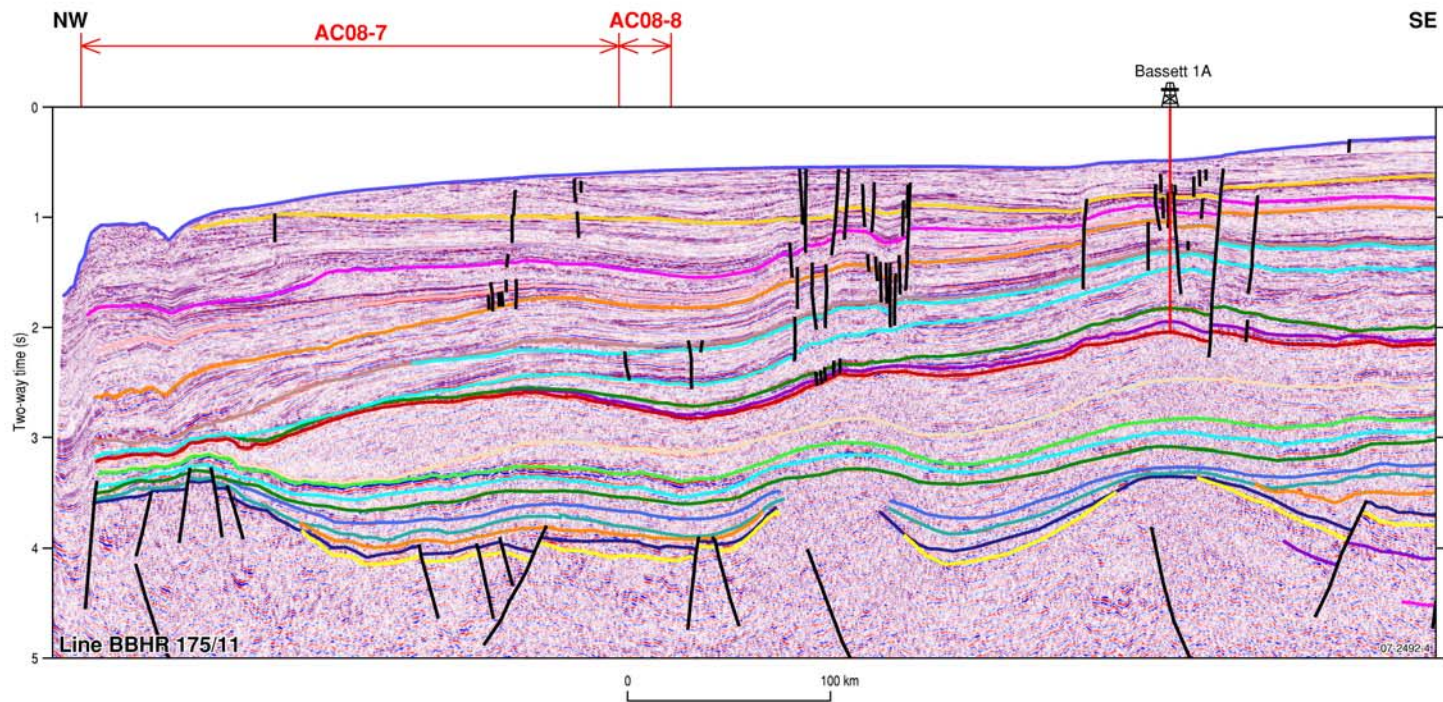


Figure 4. Seismic line BBHR 175/11 through Release areas AC08-7 and AC08-8. Location of the line shown in Figure 2. Regional seismic horizons are shown in Figure 5.

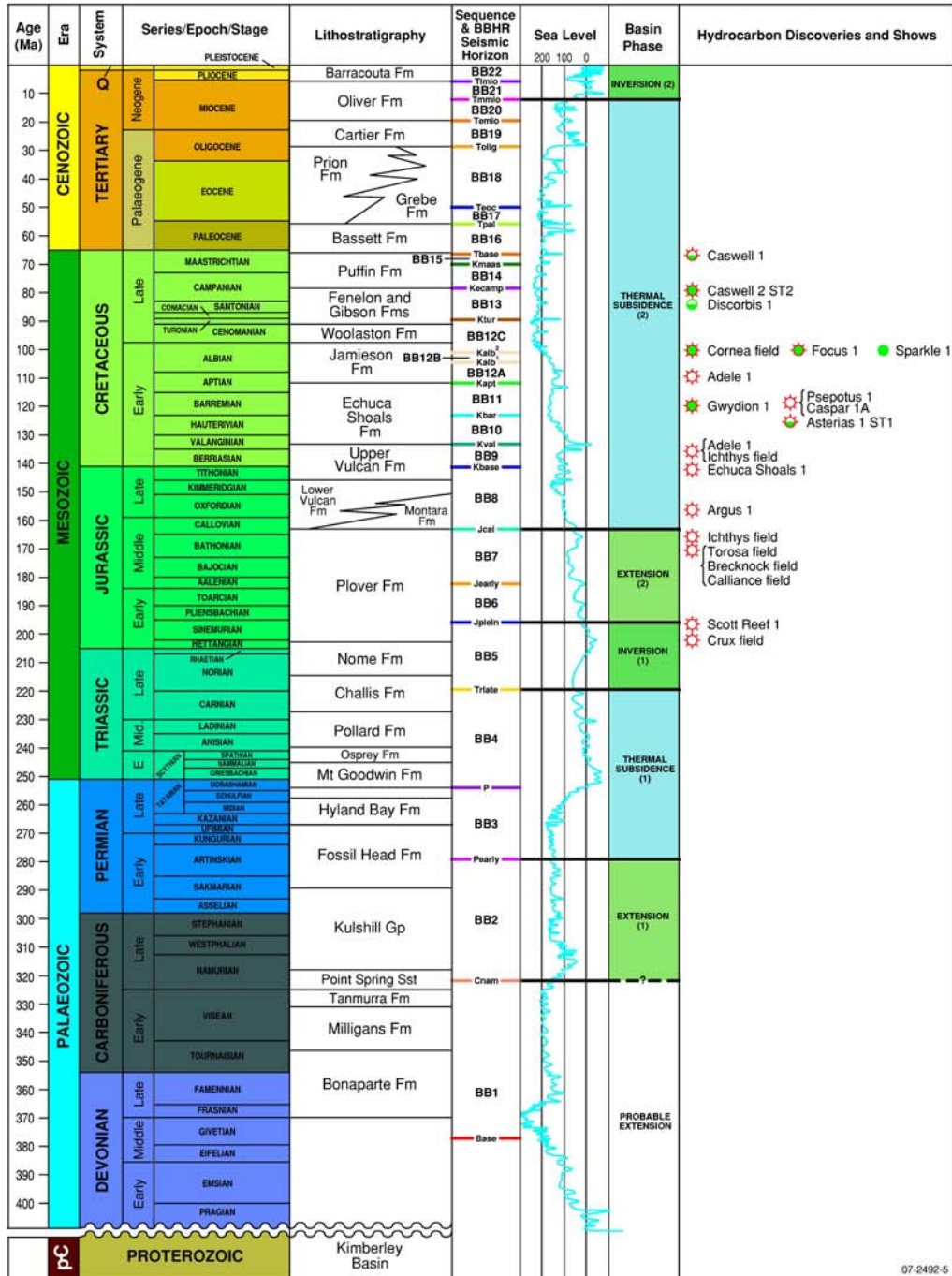


Figure 5. Tectonostratigraphic summary and hydrocarbon discoveries for the Browse Basin (after Blevin et al, 1998a; Struckmeyer et al, 1998).

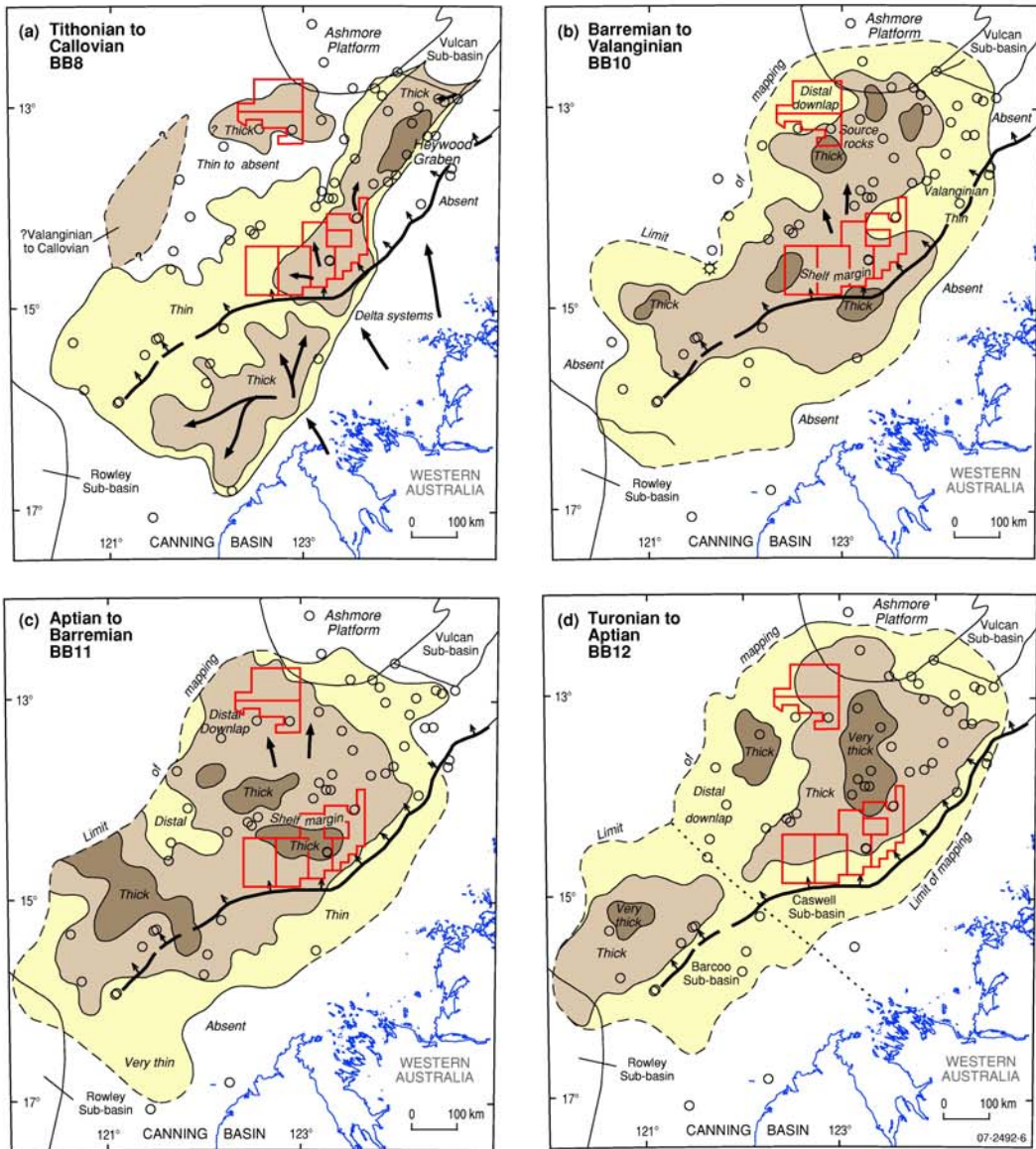


Figure 6. Generalised distribution map of (a) Tithonian to Callovian, (b) Barremian to Valanginian, (c) Aptian to Barremian, and (d) Turonian to Aptian sediments in the Browse Basin (based on two-way time isopachs maps; after Blevin et al, 1998b). The shelf margin hinge is shown in black and arrows indicate the direction of sediment transport. 2008 Release areas shown in red.

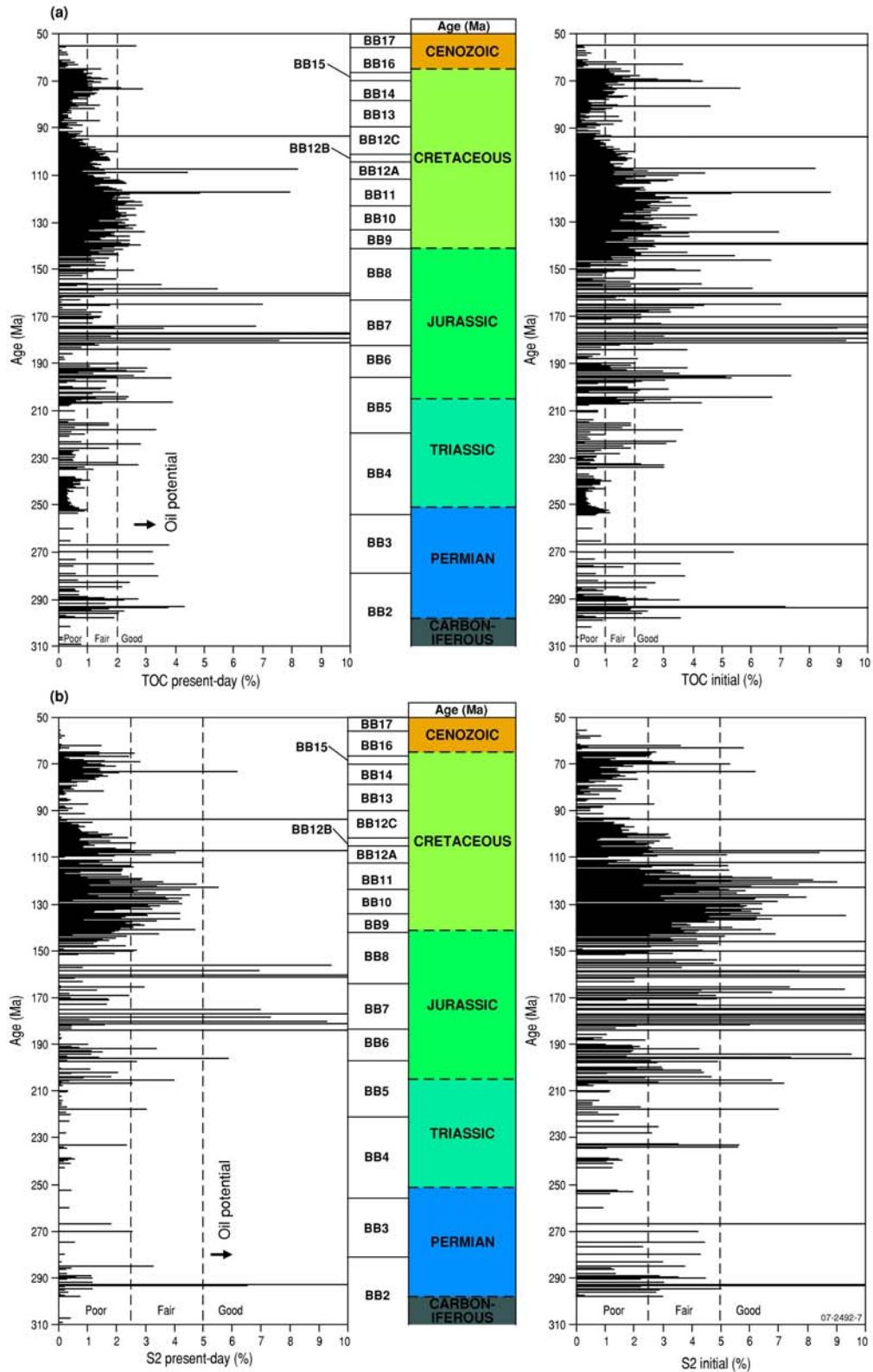


Figure 7. Plots of age (a) present day and initial TOC, and (b) present day and initial S2 values for the Browse Basin wells drilled prior to 1998 (Blevin et al, 1998b).

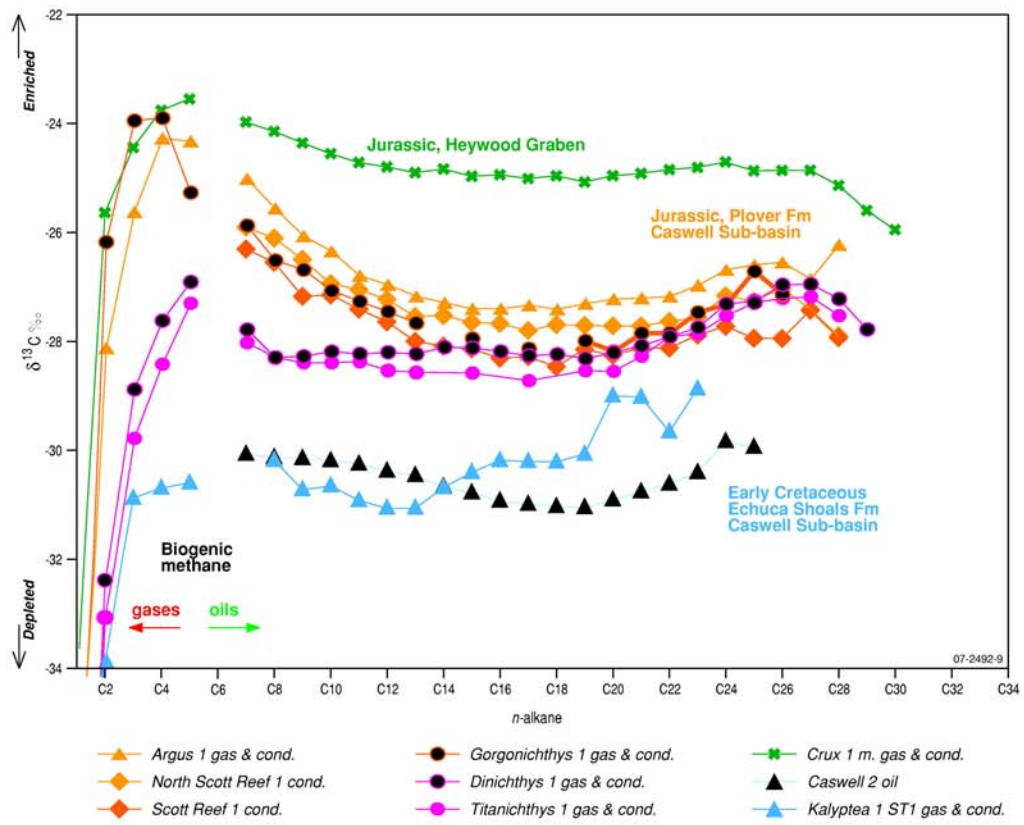


Figure 8. Carbon isotopic composition for  $\text{C}_7+$  n-alkanes of gases, condensates and oils recovered from the Browse Basin (after Edwards et al, 2004, 2006).

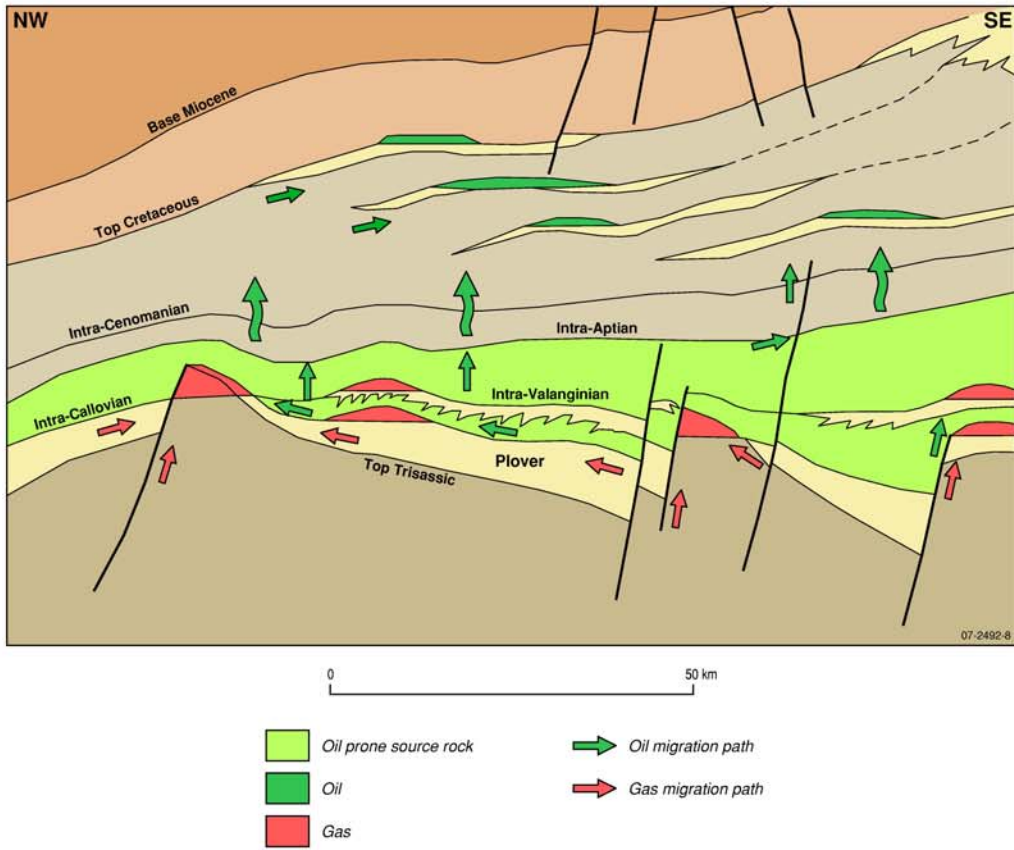


Figure 9. Browse Basin schematic cross-section, showing hydrocarbon play types (Keall and Smith, 2004).