Australian Government
Department of Resources, Energy and Tourism

Release Areas W09-1, W09-2, W09-3, W09-4 and W09-5, Southern Browse Basin, Western Australia

Location

Release Areas W09-1, W09-2, W09-3, W09-4 and W09-5 overlie the Barcoo Sub-basin and adjacent portions of the Leveque Shelf and Scott Plateau in the southern part of the Browse Basin, a proven gas province on Australia's North West Shelf. The Release Areas are located 125-350 km off the northwest coast of Western Australia. The areas lie adjacent to current offshore petroleum exploration permits WA-306-P, WA-378-P, WA-397-P and WA-423-P, and occur in 40-1950 metres water depth (**Figure 1**).

Release Area W09-1 comprises 53 full graticular blocks (approximately 4375 km^2).

Release Area W09-2 comprises 30 full graticular blocks (approximately 2475 km^2).

Release Area W09-3 comprises 32 full graticular blocks (approximately 2635 km^2).

Release Area W09-4 comprises 39 full graticular blocks (approximately 3210 km^2).

Release Area W09-5 comprises 49 full graticular blocks (approximately 4040 km^2).

Release Area Geology

Local Tectonic Setting

The Barcoo Sub-basin is one of the major depocentres of the Browse Basin (**Figure 2**) and is approximately 200 km long (northeast-southwest) by 130 km wide (northwest-southeast) and contains up to approximately 12 km of Paleozoic to Cenozoic sedimentary strata (Struckmeyer et al, 1998).

The northern depocentre of the Browse Basin, the Caswell Sub-basin, is separated from the Barcoo Sub-basin by a major north to north-northeast trending structural zone, the Buffon-Scott Reef-Brecknock Anticlinal Trend, and is contiguous with the Roebuck Basin to the southwest (**Figure 2**; Struckmeyer et al, 1998).

The Leveque Shelf, an area of shallow basement which is typically highly eroded with a rugose palaeotopographic relief, borders the Barcoo Sub-basin to the southeast (**Figure 2**; Struckmeyer et al, 1998). The boundary between the Barcoo Sub-basin and the Leveque Shelf is defined as the'hingepoint' from more or less flat lying basement to gently basinward-dipping basement, which is marked by steep, basinward dipping normal faults in some locations (**Figure 2**; Struckmeyer et al, 1998).

The deepwater depocentre (approximately 1500-3000 m water depth) of the Scott Sub-basin, which underlies the Scott Plateau, borders the Barcoo Sub-basin to the northwest. An arcuate Triassic structural high associated with the Barcoo fault trend marks the boundary between the Barcoo and Scott sub-basins (**Figure 2**; Struckmeyer et al, 1998).

Structural and stratigraphic evolution of the sub-basin

Struckmeyer et al (1998) defined six major tectonic phases of basin development for the Browse Basin (as described in the Regional Geology of the Browse Basin document):

- Mississippian to Cisuralian extension.
- Cisuralian to Triassic thermal subsidence.
- Late Triassic to Early Jurassic inversion.
- Early to Middle Jurassic extension.
- Late Jurassic to Cenozoic thermal subsidence.
- Middle Miocene to recent inversion.

The initial phase of Palaeozoic rifting significantly influenced the development and infill of the Barcoo Sub-basin, with major displacement on the Barcoo Fault probably controlling sedimentation in the Barcoo Sub-basin throughout this rift phase (Struckmeyer et al, 1998). The half-graben configuration of the Browse Basin during Mississippian to Cisuralian extension resulted in the compartmentalisation of the basin into the Barcoo and Caswell sub-basins (Symonds et al, 1994; Struckmeyer et al, 1998; Blevin et al, 1998a). The north to northeast trend may indicate that the compartmentalisation of the basin was influenced by the presence of older, Proterozoic lineaments (O'Brien et al, 1996; Struckmeyer et al, 1998).

In the Early Jurassic, relaxation of north-south aligned compressional stresses that had affected northern Australia was accompanied by, or closely followed, the onset of an extensional phase which affected areas extending south from the Caswell Sub-basin to the Carnarvon Basin (Blevin et al, 1998a). In the Barcoo Sub-basin, the Late Triassic anticline associated with the Barcoo Fault collapsed and extensional faults on the western margin of the Leveque Shelf were active.

The compartmentalisation of the Browse Basin persisted into the Mesozoic, indicated by a thicker Early to Middle Jurassic succession and a thinner, overlying wedge of Late Jurassic to Cenozoic sediment in the Barcoo Sub-basin, as compared to the Caswell Sub-basin, where the Early to Middle Jurassic succession thickens only within restricted synclinal areas formed during the Late Triassic to Middle Jurassic inversion event (Blevin et al, 1998a; Struckmeyer et al, 1998).

In the Barcoo Sub-basin, collision induced stresses associated with the convergence of the Australian and Eurasian plates in the Middle to Late Miocene resulted in the reactivation of Paleozoic faults along the Leveque Shelf margin and caused the formation of northeast-trending anticlines. Deformation appears to have continued to the present-day in the southern part of the sub-basin (Struckmeyer et al, 1998).

Stratigraphy

The Browse Basin stratigraphy presented in this report is based upon the work of Blevin et al (1997). Formation boundaries and unconformity bounded sequences defined by them have been recalibrated to the timescale of Gradstein et al (2004) (**Figure 3**). Representative seismic sections across the Release Areas in the Barcoo Sub-basin and Leveque Shelf are shown in **Figure 4** and **Figure 5**.

Sediments within the deeper parts of the Barcoo Sub-basin have not been penetrated, thus the age of the oldest strata (and the onset of rifting) remains speculative. Mississippian to Cisuralian rocks deposited during the initial phase of rifting have been intersected in wells on the Yampi Shelf and in the Caswell Sub-basin, but Permian strata have not been intersected in the Barcoo Sub-basin or on the adjacent Leveque Shelf (Blevin et al, 1998a). In the wider Browse Basin, the Carboniferous succession is generally fluvio-deltaic in nature, while the Cisuralian is marine (primarily limestones and shales) (Blevin et al, 1998a). These strata are defined herein as undifferentiated Weaber, Kulshill and Kinmore Group equivalents (**Figure 3**).

The initial phase of thermal subsidence is characterised by a Late Cisuralian to Lopingian succession indicative of a transgressive cycle (transgressive sandstones overlain by limestone), and the oldest Triassic rocks comprise transgressive sandstones overlain by olive-grey to black claystones (highstand) with interbeds of siltstones and volcaniclastic sediments (undifferentiated Kinmore Group equivalents; **Figure 3**; Blevin et al, 1998a). Overlying the deeper water strata is a shallow marine sequence consisting of basal limestones that grade upward to interbedded siltstones and shales (Osprey, Pollard and Challis formations; **Figure 3**; Blevin et al, 1998a).

The onset of Late Triassic inversion is marked by the formation of a northeast-trending, folded topography across the basin, with syn-inversion deposition occurring in the synclines and erosion affecting the crests of the anticlines (Blevin et al, 1998a; Struckmeyer et al, 1998). Flooding of the central and outer basin during the Late Triassic to Early Jurassic resulted in the deposition of onlapping, shallow marine limestones, shelfal sands and siltstones (Nome Formation; **Figure 3**; Blevin et al, 1998a).

The Early to Middle Jurassic was dominated by fluvio-deltaic systems which extended across most of the basin, and deposited stacked sequences of channel sands and/or coarsening upward prograding deltaic sands, interbedded with finer-grained beds of prodelta to delta plain siltstone and shale (Plover Formation; **Figure 3**). Barcoo 1 intersected the most complete section of Late Triassic to Callovian rocks, which suggests that the outer Barcoo Sub-basin was the locus of subsidence during this time (Blevin et al, 1998a). The reorientation of drainage divides along tectonic boundaries in the Late Jurassic, resulted in the redirection of sand-prone fluvial sediments away from the Barcoo Sub-basin (Blevin et al, 1998a).

During the Early to Late Jurassic, the Browse Basin was situated on the margin of a major volcanic province and extrusive and intrusive rocks have been intersected in many wells across the basin (Blevin et al, 1998a).

Sedimentation occurred under a regime of thermal subsidence from the Late Jurassic until the end of the Cretaceous. Late Jurassic fluvio-deltaic sediments of the Montara Formation (**Figure 3**) are relatively thin (<100 m) across most of the basin, with local thickening across the Leveque Shelf (Blevin et al, 1998a). Prograding, deltaic facies with highstand shales (Lower Vulcan Formation; **Figure 3**) were deposited across much of the basin. Base Cretaceous to Aptian strata comprise a lowstand package (Upper Vulcan Formation; **Figure 3**), including slope fans (Brewster Member), overlain by transgressive and highstand depositional packages (Echuca Shoals Formation; **Figure 3**; Blevin et al, 1998a). The Aptian to Turonian was characterised by conditions of rapid flooding and prolonged highstand, during which thick successions of siltstone and shale were deposited (Lower and Upper Jamieson and lower Woolaston Formations; **Figure 3**). Possible distal turbidite facies (?ramp slope fan) are interpreted on well logs (Barcoo 1) in the Barcoo Sub-basin (Blevin et al, 1998a). The Turonian to early Campanian succession is characterised by fine-grained pelagic sediments, primarily calcareous claystone, calcareous shale, marl and calcilutite (upper Woolaston, Gibson and Fenelon formations; **Figure 3**). Deltaic progradation into the basin during the late Campanian to Maastrichtian was periodically interrupted by lowstands, with associated deposition of lowstand fans (Puffin Formation; **Figure 3**; Blevin et al, 1998a).

Exploration History

The first well drilled in the Browse Basin was Leveque 1, which was drilled in 1970 as a stratigraphic test of the sedimentary succession on the Leveque Shelf. In the early 1970s, Lynher 1 and Lombardina 1 were drilled to test major Late Miocene reactivation structures on the down-thrown side of a regional down-to-basin fault near the margin of the Leveque Shelf and Barcoo Sub-basin. Barcoo 1 was drilled in 1979/1980 to test Late Triassic and Early-Middle Jurassic sandstones within a large northeast-trending anticline over the Barcoo fault trend, a play that had been proven in the gas discoveries at Scott Reef 1 and Brecknock 1. A subsequent hiatus in exploration in the Barcoo Sub-basin ended in the early 1990s with re-testing of reactivation structures along the boundary with the Leveque Shelf (Trochus 1 ST1 (**Figure 4**), Arquebus 1 ST1 (**Figure 5**) and Sheherazade 1). In 1998, hydrocarbons were discovered on the Leveque shelf at Psepotus 1. Warrabkook 1 was drilled as the first test of the Scott Plateau and underlying Scott Sub-basin outboard of the Barcoo Sub-basin, but full results of the well are still confidential.

Well Control

One well has been drilled in Release area W09-1 (Barcoo 1), two wells in Release Area W09-3 (Lynher 1, South Galapagos 1), one well in Release Area W09-4 (Trochus 1 ST1) and three wells in Release Area W09-5 (Lombardina 1, Arquebus 1 ST1, Sheherazade 1). There are three wells (Leveque 1, Psepotus 1 and Carbine 1) in the adjacent petroleum exploration permit to the west (WA-423-P), and Warrabkook 1 is located directly to the north of Release Area W09-1.

Three giant gas fields are situated within Triassic to Jurassic strata on the culmination of a faulted anticline along the outer margin of the Caswell Sub-basin. Similar structural features are located along the outer margin of the Barcoo Sub-basin.

Leveque 1 (1970)

Leveque 1 was drilled by Burmah Oil Company of Australia Ltd (BOC) as a stratigraphic test of the sedimentary section on the Leveque Shelf (approximately 30 km east of Release Area W09-5). It was drilled 160 km from the nearest existing well (Lacepede 1A in the Offshore Canning Basin), and therefore provided valuable information in a previously untested part of the continental shelf. The well intersected 882 m of Cenozoic and Cretaceous sediments overlying a thin, Late Jurassic basal conglomerate, and was terminated at 899.5 mRT in Proterozoic igneous basement. Early Cretaceous reservoir sands with an average porosity of 16% were intersected, but no significant hydrocarbon shows were recorded in the well. A Formation Interval Test (FIT) run at 802.8 mRT in Early Cretaceous silty sandstone recovered 4 l of mud and 0.1 cf of gas from the 22.2 l chamber, and pressure data indicate that the formation was tight.

Lynher 1 (1970/71)

Lynher 1 was drilled by BOC on the boundary between Release areas W09-3 and W09-4 to test the potential of an elongate, Late Miocene, reactivated anticline on the downthrown side of a regional down-to-basin fault at the southern margin of the Leveque Shelf and Barcoo Sub-basin (Trochus 1 ST1 was subsequently drilled on the same structure in 1991). The structure has 3-way dip closure against the basin margin fault. The well intersected Cenozoic, Cretaceous, Jurassic and Triassic sediments, and was terminated in ?Early Triassic sediments at 2725 mRT. Potential sandstone reservoirs were intersected within the Late, Middle and Early Jurassic sections with average porosity of 19-23%, but no significant hydrocarbon shows were recorded. Wire-line logs were not able to be run below 2198 mRT in the lower part of the Early Jurassic and Triassic section (consisting mainly of sandstone with siltstone and coal).

Scott Reef 1 (1971), Scott Reef 2A (1977), North Scott Reef 1 (1982)

Scott Reef 1 was drilled by BOC to test the arcuate Triassic structural high associated with the Buffon-Scott Reef-Brecknock Anticlinal Trend that marks the outer margin of the Caswell Sub-basin (a similar Triassic structural high is associated with the Barcoo fault trend on the outer margin of the Barcoo Sub-basin). Scott Reef 1, drilled in 50 m of water, reached a total depth of 4740 mRT. It encountered a gas/condensate column within fluvio-deltaic sands of the Early-Middle Jurassic Plover Formation, and sandy dolostones of the Late Triassic Nome Formation. Gas flows of 278000-515000 m^3/day were recorded from drill stem tests (DSTs), and were accompanied by 49-54° API gravity condensate (Willis, 1988).

Scott Reef 2A (1977) was drilled by Woodside Petroleum Development Pty Ltd (Woodside) as a step-out appraisal well 4.3 km southeast of Scott Reef 1. It reached a total depth of 4820 mRT. The well only encountered hydrocarbon shows in moderate quality reservoirs (average porosity 12%) with a water-up-to (WUT) at 4644 mSS. No net hydrocarbon pay is assigned to the well.

North Scott Reef 1 (1982) was drilled by Woodside to test the northern extent of the gas/condensate field discovered in Scott Reef 1. The well was drilled in 442 m of water and reached a total depth of 4771 mRT. It encountered a 250 m gross gas column with a gas-down-to (GDT) at 4291 mSS within Early Jurassic sandstones. A DST recorded a maximum gas flow rate of 1275000 m^3/day (Willis, 1988).

Lombardina 1 (1974)

Lombardina 1 was drilled by BOC to test a major Late Miocene reactivation structure on the down-thrown side of a regional down-to-basin fault near the margin of the Leveque Shelf and Barcoo Sub-basin. Arquebus 1 ST1 and Sheherazade 1 were subsequently drilled on the same structure in 1991 and 1993, respectively. Lombardina 1 penetrated an Early Jurassic-Cenozoic section, including about 120 m of Middle Jurassic basic volcanics, and was terminated at a total depth of 2855 mRT.

Ditch gas readings were low throughout drilling, but many of the sidewall cores within the depth range 2045-2570 m (Early Cretaceous-Middle Jurassic) exhibited fluorescence with weak cut, and claystone sidewall cores from 2522.5, 2551 and 2570 mRT showed instantaneous cut. Log evaluation over the depth range 2432.5-2577 mRT showed zones of up to 30% hydrocarbon saturation; regarded as residual hydrocarbons. An FIT was run at 2511.5 mRT within a sandstone zone, with a log porosity of 15% and 70% water saturation, recovered 0.1 cf gas and 0.112 L of water in a 22.2 l chamber. Results indicate that the reservoir is either tight or dry. No other formation tests were carried out in the well.

Haston and Farrelly (1993) considered that Lombardina 1 was positioned in a structurally complex transfer zone between two fault segments of the Lombardina wrench anticline structure, and was probably not a definitive test of the structure's prospectivity. They noted that the Jurassic sandstones had poor overall porosity (5-9%), with much of the primary pore space being occupied by diagenetic minerals, together with mineral filled fractures, and that evidence of cataclastic deformation was present throughout the well.

Brecknock 1 (1979)

Brecknock 1 was drilled by Woodside Offshore Petroleum Pty. Ltd to test a broad, elongate anticline formed by drape of Early to Middle Jurassic sediments over an eroded Triassic high (a continuation of the Buffon-Scott Reef-Brecknock Anticlinal Trend) approximately 43 km south-southwest of Scott Reef 1. The well encountered a 77 m gross gas/condensate column (petrophysical interpretation indicated a net gas pay of 68 m; Willis, 1988) in fair quality (average porosity 15%) Early-Middle Jurassic sands of the Plover Formation. Gas and 45° API condensate were recovered from RFT samples. A DST tested the water zone and flowed at 2016 bwpd.

Barcoo 1 (1979/1980)

Barcoo 1 was drilled by Woodside in the central Barcoo Sub-basin, within Release Area W09-1, to test Late Triassic and Early-Middle Jurassic sandstones within a large northeast-trending anticline along the Barcoo fault trend. Possible sandstones of Late Jurassic age were a secondary objective. The well penetrated a thick Cenozoic, Cretaceous and Jurassic section, and reached a total depth of 5109 mRT in Late Triassic recrystallised limestone. To date, Barcoo 1 is the deepest well drilled in the Browse Basin.

Original seismic interpretation of the Barcoo structure suggested that both vertical and horizontal closures progressively increased with depth, and progressive thinning of Jurassic strata over the structure was attributed to differential compaction on the flanks of the underlying fault block. Drilling showed that the targeted Callovian unconformity was approximately 600 m shallower than expected, and consequently closure at this level was only small.

Ditch gas readings were generally low. Of the 96 side-wall cores (SWCs) recovered between 3284.5 and 4184 mRT in the Early Cretaceous-Early Jurassic section, fluorescence (mainly cut fluorescence) was recorded in 54 of them. The Early-Middle Jurassic section (Plover Formation) contains two sandstone zones: the upper zone from 3830-4028 mRT has a net thickness of 105 m and 18% porosity; and the lower zone from 4105-4130 mRT has a net thickness of 14 m and 11% porosity. Both units are water-wet. Fluid inclusion analysis of the upper sandstone over the interval 3830-3990 mRT indicates uniformly low GOI^{TM} values <0.1% (Brincat and Kennard, 2004), and that the level of oil saturation has always been low.

Trochus 1 ST1 (1991)

Trochus 1 was drilled within Release Area W09-4 by Shell Development (Australia) Pty. Ltd as an updip test of the same structure tested by Lynher 1. The primary objective was Middle-Late Jurassic (Callovian-Oxfordian) sandstones (Lower Vulcan Formation) sealed by Early Cretaceous claystone (Echuca Shoals Formation) in a four-way dip closure on the Lynher-Lombardina anticlinal reactivated fault trend bordering the Leveque Shelf. Secondary objectives were Middle Jurassic sands (Plover Formation) sealed by intra-formational shales. Trochus 1 was terminated at 1122 mRT due to mechanical problems, and Trochus 1 ST1 was side-tracked at 909 mRT and terminated at a total depth of 1622 mRT. The well penetrated a Cenozoic-Jurassic section similar to that intersected in Lynher 1, and was terminated in Middle Jurassic sandstone (Plover Formation).

The Oxfordian-Callovian sandstones (1210-1317 mRT) have excellent reservoir potential (92% net/gross, 24% average porosity), and the Early-Middle Jurassic sandstones have good reservoir potential (1317-1466 mRT - 38% net/gross, 21% porosity; 1466-1622 mRT - 74% net/gross, 24% porosity). Gas readings were minimal throughout Trochus 1, and increased in Trochus 1 ST1 at 1317 mRT when coaly Early-Middle Jurassic sediments were intersected. Minor fluorescence was recorded from sandstone cuttings within this coaly Jurassic section. Hydrocarbon odour was recorded from two side-wall cores within this section (1502 and 1561 mRT), but geochemical analysis suggests that solvent-extracted hydrocarbons from these side-wall core samples are due to drilling contaminant. Fluid inclusion analysis of Oxfordian-Callovian and Early-Middle Jurassic sandstones in the interval 1182-1563 mRT indicates uniformly low GOI^{TM} values <0.1%, and that the level of oil saturation has always been low (Eadington, 2003).

Failure of this play has been attributed to either lack of mature source rocks within the drainage area, poor relative migration/trap timing, or fault leakage (Blevin et al, 1997). Subsequent fluid inclusion data (Eadington, 2003) confirm lack of oil charge to the Trochus structure.

Arquebus 1 ST1 (1991)

Arquebus 1 ST1 was drilled within Release Area W09-5 by Amoco Australia Petroleum Company as a further test of Early-Middle Jurassic sandstones within the greater Lombardina structure. This structure is a large 3-way dip closure against the basin bounding fault, with a small four-way closure adjacent to the Arquebus 1 ST1 well. Possible hydrocarbon indicators, resolved as'flat spots', had been previously recognised in the Early Jurassic section on migrated seismic data. A secondary objective was Late Jurassic sandstones. Arquebus 1 was terminated at 1770 mKB due to mechanical drilling problems, and Arquebus 1 ST1 was sidetracked from 1492 mKB and terminated at a total depth of 3256 mKB. The well penetrated a comparable section to that intersected in Lombardina 1, plus a thicker section of Early Jurassic strata. The overall porosity of the Late Jurassic sandstones (2429 to 2524 mKB) is relatively poor, ranging from 6-12%, whereas the reservoir quality of the Middle Jurassic sandstones (2524-2735 mKB) is good with an average porosity of 14%.

Ditch gas readings were moderate in the Early Cretaceous claystone section (<1492 to 2429 mKB), and increased in the sandstone-dominated Late Jurassic section with a gas peak at 2488 mKB (total gas=1%, C1=11,200 ppm, C2=800 ppm, C3=270 ppm, iC4=30 ppm, nC4=70 ppm, C5=40 ppm). Gas readings became subdued in the Middle and upper Early Jurassic section (2524 to 2755 mKB). Cuttings from 2461 to 2524 mKB gave weak natural and cut fluorescence, and weak cut fluorescence continued in the interval 2524-2564 mKB, which roughly corresponds to a carbonaceous interval. Gas readings and fluorescence were insignificant in the lower part (2755-3256 mKB) of the Early Jurassic section. No hydrocarbon shows were observed while drilling the section corresponding to the observed seismic flat-spots which are correlated with lithological changes identified in cuttings and wireline logs. Several SWCs taken from the Jurassic sections showed weak fluorescence.

Of the 50 SWCs analysed for fluid saturation, one (2656 mKB Middle Jurassic) has a residual oil saturation of 16.7%, with a porosity of 25.7%. All other samples have no residual oil saturation. The operator considered that either diesel or the "EZ Spot" spotting fluid may be the cause of fluorescence, and an oil characterisation analysis indicates that gas chromatographs of solvent extracts from side-wall cores (2538, 2540 & 2620 mKB) are similar to that for the diesel sample (Amoco, 1992). A total of 5 RFT fluid sampling tests were carried out in Late and Middle Jurassic sandstones. Filtrate was recovered from 2495, 2501 (two tests, with sniffs of gas), 2517.5 and 2535.5 mKB. Packer seal failure may have been the cause of some of these test outcomes.

Haston and Farrelly (1993) present a detailed interpretation of wireline log and RFT pressure data for the Arquebus 1 well. RFT pressure data indicate that the depth range 2550-3093 mKB is governed by a single water-bearing aquifer system, but these tests are ambiguous for the overlying, inferred hydrocarbon-bearing section, where two interpretations are possible. The first interpretation suggests a 38 m gas column (2492-2530 mKB), with a gas-water-contact (GWC) at 2530 mKB. However, this GWC conflicts with that indicated from the wireline logs at 2545 m. The second interpretation suggests a 51 m gross hydrocarbon column, comprising a 45 m oil leg (2500-2545 mKB) below a 6 m gas cap. However, in this interpretation an intraformational seal must be invoked to explain measured pressure differences at 2495 and 2500 mKB, although no evidence for this seal is indicated on the wireline logs. Log data indicate that a thin sand at 2440 mKB may also be gas-charged, possibly suggesting an ultimate gross hydrocarbon column as large as 105 m (2440-2545 mKB).

Haston and Farrelly (1993) conclude that significant fluid invasion and formation damage occurred during drilling, and thus only mud filtrate was recovered from the 5 RFTs. They suggest that the extremely low clay content and uniform pore throat size of the reservoir sands, combined with the very slow drilling rate and prolonged overbalanced mud weight, jointly resulted in nearly complete flushing of the formation fluids and associated formation damage.

The presence of an inferred oil column at Arquebus 1 has not been supported by subsequent fluid inclusion analysis (Lisk, 1996). Sandstones in the depth range 2503-2638 mKB (within the inferred oil column and underlying water-wet zone) have very low GOI™ values (0-0.08%) consistent with saturation by either water or gaseous hydrocarbons. However, the variable fluorescence colours of the observed oil inclusions suggest migration of oil derived from source rocks at different levels of maturity (Lisk, 1996).

In conclusion, the exact nature and significance of the hydrocarbon shows within Arquebus 1 remain enigmatic.

Sheherazade 1 (1993)

Sheherazade 1 was drilled within Release Area W09-5 by Amoco Australian Petroleum Company, 22 km southwest of Arquebus 1 on the southern portion of the greater Lombardina structure, and is the third well to test this structure (following Lombardina 1 in 1974 and Arquebus 1 in 1991). The Sheherazade prospect also has three-way dip closure against the basin-bounding fault, but is removed from structural complexities associated with compressional en-echelon faulting encountered at the Lombardina 1 location. The primary objective was the Late Jurassic sandstone that contained potential oil shows in Arquebus 1; an Early Jurassic sandstone was a secondary objective. The well terminated at 2544 mKB in Early Jurassic sandstones, and in contrast to Lombardina 1 and Arquebus 1, volcanics were not intersected.

Ditch gas readings increased slowly but steadily in Early Cretaceous claystones from 1371 mKB, with a peak gas at 2307 mKB (total gas=0.25%, C1=1900 ppm, C2=190 ppm, C3=40 ppm & C4=20 ppm). Gas readings stabilised in the sand-dominated Jurassic section (2307-2544 mKB), with several gas peaks. However, C4 readings were significantly lower than those in the Early Cretaceous claystones. Weak fluorescence was observed in some SWCs from Early Cretaceous claystone and Jurassic sandstone. Traces of oil stains were reported from Jurassic sandstone SWCs at 2370 and 2418 mRT. Wireline log interpretation (Amoco, 1993) indicated good reservoir quality (19-22% porosity) but only minor gas saturation (<20%) throughout the Jurassic sandstone section (2307-2544 mKB).

Based on the premise that the inferred hydrocarbon column in Arquebus 1 demonstrated that relative migration/trap timing was not a risk for this Late Tertiary structure, Blevin et al (1997), attributed failure of the Sheherazade 1 well to lack of updip lateral seal and/or reactivation and breach by Pliocene faults.

Psepotus 1 (1998)

Psepotus 1 was drilled by Woodside Offshore Petroleum Pty. Ltd approximately 15 km north-northeast of Leveque 1 on the Leveque Shelf, to the east of Release Area W09-5. The primary target was Early Cretaceous sandstones (early Barremian; *M. australis* zone) in a subtle drape anticline above a basement high. Late Jurassic sands that were predicted to onlap the basement formed a secondary target. A seismic amplitude anomaly is present over the anticline with an area exceeding mapped closure, thereby suggesting a stratigraphic component to the trap. Psepotus 1 intersected a Tertiary-Cretaceous section (seafloor to 1058 mRT), and a thin Late Jurassic section (1058-1080 mRT) overlying ?Pre-Cambrian quartzite basement. The well was terminated at 1118 mRT.

The well intersected a 10 m gross gas column in the target *M. australis* sandstone (Asterias Member of Echuca Shoals Formation), and the gas/water contact at 846.5 mRT indicates that the structure is full to spill point and that an effective top seal is present. The *M. australis* sandstone has an average log porosity of 35%, and the average gas saturation was estimated to be at least 60%. A modular dynamic test (MDT) at 837 mRT recovered 0.35 CF gas, and 65 mL muddy filtrate. Fluid inclusion analysis of the *M. australis* sandstones over the depth range 840-852 mRT had very low GOI™ values (0-0.1%; CSIRO Petroleum Report No. 98-004 in Woodside Petroleum, 1998) and provides no evidence of significant oil migration or accumulation. The predicted Late Jurassic reservoir sands were not present in the well, but fractured basement metasediments with a measured porosity of 16-30% were identified as a potential future reservoir play.

Brecknock South 1 (2000)

Brecknock South 1 was drilled by Woodside Energy Ltd, approximately 19 km south-southwest of Brecknock 1, to test Early-Middle Jurassic Plover Formation sandstones in a prospect with four-way dip closure below the Callovian unconformity. The well was sited on the crest to ensure penetration of the maximum gas column and intersection of the main reservoir interval within structural closure in an area free of structural uncertainty and with a good acoustic impedance response. Brecknock South 1 reached a total depth of 4008 mRT, and intersected a 134 m gross gas/condensate column in good quality reservoir of the Plover Formation as predicted. The GWC was encountered at 3944.4 mRT. The well was plugged and abandoned as a gas/condensate discovery.

Carbine 1 (2001)

Carbine 1 was drilled by Santos Ltd on the southern inner margin of the Caswell Sub-basin to test a Late Cretaceous (Campanian) ponded lowstand turbidite stratigraphic play (Benson et al, 2004). The Carbine prospect has no structural closure, and hence reliable updip lateral and top seals were required to create a viable stratigraphic trap. Local reactivation of extensional Jurassic faults was expected to provide vertical conduits for charge from underlying Early Cretaceous source rocks. The well was also designed to test a seismic amplitude anomaly within the Aptian-Valanginian Echuca Shoals Formation.

The well was terminated at a total depth of 1561 mRT within siltstones of the Echuca Shoals Formation. A full suite of wireline logs could not be run in the target horizons due to hole conditions, and only logged whilst drilling (LWD) gamma ray and resistivity logs were acquired from 1063 to 1561 mRT.

Carbine 1 penetrated a 77 m thick section of high quality sandstone reservoir (Puffin Sandstone), overlain by 150 m of marl (Borde Marl) with good seal potential, but no hydrocarbon shows were recorded. Failure of the well is attributed to lack of hydrocarbon charge, but up-dip seal integrity was also not confirmed.

South Galapagos 1 (2004)

South Galapagos 1, was drilled in Release Area W09-3, by Antrim Energy Inc. to test Late and Early-Middle Jurassic sands (Lower Vulcan and Plover formations, respectively) within a four-way dip closure (Magellan Petroleum Australia , 2002). The well was plugged and abandoned at a total depth of 3636 mRT after failing to encounter any significant hydrocarbon shows (PetroleumNews.net, 2004). Full results of the well are still confidential.

Warrabkook 1 (2007/08)

Warrabkook 1 was drilled by BHP Billiton Petroleum Pty. Ltd as the first test on the Scott Plateau and underlying Scott Sub-basin, in approximately 1517 m of water. The well was terminated at a total depth of 3510 mRT and was plugged and abandoned as a dry hole (DoIR, 2008). Full results of the well are still confidential.

Snarf 1 (2007/08)

Snarf 1 was drilled by Woodside Energy Ltd on the outer margin of the Caswell Sub-basin, outboard of the Buffon-Scott Reef-Brecknock Anticlinal Trend about 13 km from the Brecknock gas field, in approximately 1433 m of water. The well terminated at a total depth of 3776 mRT and was plugged and abandoned as a dry hole (DoIR, 2008). Full results of the well are still confidential.

Calliance/Brecknock/Torosa Field Development

Evaluation of the gas accumulations along the Buffon-Scott Reef-Brecknock Anticlinal Trend continued in 2005-2008 with the drilling of the extension/appraisal wells Brecknock 2 and 3, Calliance 1 and 2, and Torosa 1, 2, 3, 4 and 6.

Brecknock 2 (2005) appraisal well discovered gas over an interval of about 151 m and flowed on test at a maximum rate of 44 MMcf/d (PetroleumNews.net, 2005).

Brecknock 3 (2006) 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, 2006b).

Calliance 1 (2005), drilled in 574 m of water, reached a total depth of 4177 m and intersected a gross gas-bearing interval of 172 m in the Plover Formation. The main reservoir interval was production tested and flowed at a maximum rate of 41 MMscf/d (Woodside, 2006a).

Calliance 2 (2007) was drilled in 501 m of water to appraise the central portion of the Calliance field. The well encountered gas bearing reservoir as expected but no testing was undertaken. The well was plugged and abandoned (Woodside, 2007b).

Torosa 3 (2006) was drilled approximately 4 km north of North Scott Reef 1 well in 481 m of water. The objective was to appraise a separate terrace fault block to the northwest of the main structure. The well encountered the Plover Formation objective with reservoir quality poorer than expected, but within the predicted uncertainty range. No testing was undertaken. The well was plugged and abandoned (Woodside, 2007a).

Torosa 1 (2006) was drilled in 476 m of water to appraise the northeast flank of the Torosa field, approximately 13 km northeast of North Scott Reef 1 well. The well encountered the Plover Formation objective which was gas-bearing. The top of the Plover Formation was structurally higher than expected, but within the predicted uncertainty range. No testing was undertaken. The well was plugged and abandoned (Woodside, 2007a).

Torosa 2 (2007) was drilled in 466 m of water to appraise the eastern flank of the Torosa field. It encountered the Plover Formation objective as predicted. No testing was undertaken. The well was plugged and abandoned (Woodside, 2007b).

Full results of these wells are not available at the time of writing.

Table 1: Key wells listing

Well	Operator	Year	Total Depth	Hydrocarbons
Arquebus 1	Amoco Australia Petroleum Company	1991	1770 mKB	no tests
Arquebus 1 ST1	Amoco Australia Petroleum Company	1991	3256 mKB	minor gas

Barcoo 1 (Woodside)	Woodside Petroleum Development Pty Ltd	1980	3358 mRT	no tests
Barcoo 1 ST1	Woodside Petroleum Development Pty Ltd	1980	3217 mRT	no tests
Barcoo 1 ST2	Woodside Petroleum Development Pty Ltd	1980	5109 mRT	no tests
Brecknock 1	Woodside Petroleum Development Pty Ltd	1979	4300 mRT	Gas
Brecknock 2	Woodside Energy Ltd	2005	3872 mRT	Gas
Brecknock 3	Woodside Energy Ltd	2006	3948 mRT	no public data
Brecknock South 1	Woodside Energy Ltd	2000	4008 mRT	Gas
Calliance 1	Woodside Energy Ltd	2005	4178 mRT	Gas
Calliance 2	Woodside Petroleum Ltd	2007	4188 mRT	no public data
Calliance 3	Woodside Petroleum Ltd	2008	4262 mRT	no public data
Carbine 1	Santos Limited	2001	1561 mRT	no tests
Leveque 1	B.O.C. of Australia Ltd	1970	899 mRT	minor gas
Lombardina 1	B.O.C. of Australia Ltd.	1974	2855 mRT	minor oil

Lynher 1	B.O.C. of Australia Limited	1971	2725 mRT	no tests
North Scott Reef 1	Woodside Offshore Petroleum Pty. Ltd.	1982	4771 mRT	Gas
Psepotus 1	Woodside Offshore Petroleum Pty. Ltd.	1998	1118 mRT	Gas
Scott Reef 1	B.O.C. of Australia Limited	1971	4730 mRT	Gas
Scott Reef 2	Woodside Petroleum Development Pty. Ltd.	1977	296 mRT	no tests
Scott Reef 2A	Woodside Petroleum Development Pty. Ltd.	1977	4820 mRT	minor gas
Sheherazade 1	Amoco Australia Petroleum Company	1993	2544 mRT	minor gas
Snarf 1	Woodside Energy Ltd	2008	3748 mRT	no public data
South Galapagos 1	Antrim Energy Australia Pty Limited	2004	3636 mRT	no public data
Torosa 1	Woodside Energy Ltd	2006	4685 mRT	no public data
Torosa 2	Woodside Energy Ltd	2007	4811 mRT	no public data
Torosa 3	Woodside Energy Ltd	2006	4667 mRT	no public data

Torosa 4	Woodside Energy Ltd	2007	4500 mRT	Gas
Torosa 5	Woodside Energy Ltd	2009	4770 mRT	no public data
Torosa 6	Woodside Energy Ltd	2008	4754 mRT	no public data
Trochus 1	Shell Development (Australia) Pty Ltd	1991	1122 mDF	no tests
Trochus 1 ST1	Shell Development (Australia) Pty Ltd	1991	1622 mDF	no tests
Warrabkook 1	BHP Billiton Petroleum (North West Shelf) Pty Ltd	2008	3492 mRT	no public data

Rig Release Year shown. Shaded areas highlight those wells for which complete data sets are not yet available. Data accurate as at 31 March 2009

Seismic Coverage

Release areas W09-1, W09-2, W09-3, W09-4 and W09-5 are covered by broad grids of reconnaissance seismic lines (eg. Outer Browse OB98, line spacing approximately 12 km; Browse 98, line spacing approximately 5 km) and more detailed 2D grids (HBR2000A, line spacing approximately 2.5 km). The Lynher 3D seismic survey, which was acquired in 1988/1989, is located in the eastern part of Release Area W09-3 and the southern part of Release Area W09-4. A number of regional speculative seismic lines were recently (2008/2009) acquired across the Release areas as part of PGS's'New Dawn' program.

A full listing of the seismic is available in the ______________________________

Hydrocarbon Potential

Petroleum Systems

Magoon and Dow (1991) defined a petroleum system as a mature source rock and all its generated hydrocarbon accumulations. A survey of organic-rich rocks (ORRs) (TOC>2.0%) in the Browse Basin by Blevin et al (1997) and summarised by Blevin et al (1998b), indicated that there may be more than 20 potential source intervals ranging in age from Permo-Carboniferous to Early Cretaceous (**Figure 6**). The ORRs were grouped by Blevin et al (1997, 1998b) into:

> Early Cretaceous petroleum systems and play families;

> Late Jurassic petroleum systems and play families;

> Early to Middle Jurassic petroleum systems and play families;

> Permo-Carboniferous to Late Triassic petroleum systems and play families.

One or both of the Jurassic petroleum systems sourced the giant gas fields in the Caswell Sub-basin, while the oil fields on the Yampi Shelf were sourced from the Early Cretaceous petroleum system (Boreham et al, 1997, 2001; Blevin et al, 1998a, b; Edwards et al, 2000, 2004; Kennard et al, 2004).

In the Barcoo Sub-basin the key petroleum systems are the Early to Middle Jurassic and Permo-Carboniferous to Late Triassic systems, as the Late Jurassic succession is relatively thin and marginally mature, and the Early Cretaceous succession is immature to marginally mature (Blevin et al, 1998a; Kennard et al, 2004).

Source Rocks

Thick sections of Late Jurassic and Early Cretaceous sediments occur within both the Caswell and Barcoo sub-basins (**Figure 7**), and contain mixed marine and terrestrial organic matter with moderate to good source potential. A significant thickness of mostly Barremian age shale was deposited in a topographic low between Barcoo 1 and South Brecknock 1. However, the effectiveness of this'pod' to source structures in the Barcoo Sub-basin is dependent on maturity. Geochemical maturity indicators show that the oil window lies at a depth of 3800 m in Barcoo 1, and that the Lower Cretaceous succession is immature for oil (Blevin et al, 1997, 1998a).

Thick accumulations of Early to Middle Jurassic (pre-Callovian) organic rich sediments are preserved in the western and northeastern Barcoo Sub-basin (**Figure 8**; Blevin et al, 1997). Early Jurassic marine facies in the sub-basin are predicted to have the greatest source potential of the Early to Middle Jurassic sequence in the Browse Basin, particularly at third and fourth order sequence boundaries where reconnaissance samples show TOC values exceed 2% (Blevin et al, 1998b).

Permo-Carboniferous to Late Triassic source intervals are not well documented, as this succession is poorly constrained by well data. Initial source rock richness shows that most of the intervals sampled from this succession have only poor to fair source potential (**Figure 6**), although these samples clearly do not reflect the source potential for facies within the deeper half-graben (Blevin et al, 1998b). For example, Late Triassic highstand shales preserved at Barcoo 1 thicken toward the east into the central Barcoo Sub-basin, and are expected to contain viable source facies (**Figure 9**; Blevin et al, 1998b).

Expulsion and Migration

Recent hydrocarbon expulsion modelling suggests the Late Jurassic to Cretaceous succession in the Barcoo Sub-basin is immature to marginally mature, with only minor gas expulsion from the central part of the sub-basin (Kennard et al, 2004).

Source rocks in the Early to Middle Jurassic Plover Formation in the Barcoo Sub-basin are mature for oil and wet gas generation. Petroleum systems modelling suggests that these source intervals expelled gas in the northern and eastern parts of the sub-basin in the Cenozoic (Kennard et al, 2004).

The Carboniferous to Triassic succession is considered to be overmature in the depocentres of the Browse Basin due to the thickness of sediment deposited during Permo-Triassic extension and early post-rift basin phases (Blevin et al, 1997). However, hydrocarbon generation could be occurring where source facies of this age are not as deeply buried. For example, petroleum systems modelling suggests the Late Triassic succession intersected in Lomardina 1 is currently in the oil window (Blevin et al, 1997).

Post-Eocene migration of hydrocarbons was primarily towards the Late Triassic anticlinal highs and fault blocks in the western Barcoo Sub-basin, and fault traps, late stage anticlines and onlap plays in the eastern part of the sub-basin and on the Leveque Shelf (Blevin et al, 1997).

Reservoirs

Late Triassic and Early to Middle Jurassic fluvio-deltaic sequences provide the main reservoirs for outboard structural and stratigraphic traps. Potential reservoirs for onlap plays on the eastern margin range from Early Jurassic to Late Cretaceous age (Blevin et al, 1997).

Seals

Early Cretaceous (Echuca Shoals Formation) and Late Jurassic (Vulcan Formation) highstand shales provide regional seals for the Barcoo Sub-basin. The Late Triassic highstand shales in the central Barcoo Sub-basin are expected to contain seal facies for a potential Permo-Carboniferous petroleum system (Blevin et al, 1998b). Potential intraformational shale seals occur within the Early-Middle Jurassic Plover Formation, but are poorly documented (Blevin et al, 1998b).

Play Types

Potential play types in the Barcoo Sub-basin are shown by'play number' on **Figure 10** (Blevin et al, 1997; 1998b) and include the following:

> Play 1, Carboniferous to Permian extensional fault-related plays;

> Play 2, Late Triassic tilted fault blocks and associated anticlines;

> Play 3, Early Cretaceous onlaps, erosional truncation seal and associated traps;

> Play 4, Miocene fault reactivation plays.

Late Triassic faulted anticlines, which host the giant gas fields along the outer margin of the Caswell Sub-basin, have been tested unsuccessfully at Barcoo 1, where the tested structure lacked closure.

A gas accumulation was intersected in Early Cretaceous drape of erosional basement highs on the Leveque Shelf at Psepotus 1, but it is unclear whether the gas was sourced from the Barcoo Sub-basin to the northwest of the well, or from the Caswell Sub-basin to the north.

The prominent Late Tertiary fault-reactivation anticlines along the margin between the Barcoo Sub-basin and the Leveque Shelf (e.g., 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).

Critical Risks

A key risk for oil prospectivity in the Barcoo Sub-basin is the absence of source rock of suitable maturity. The Late Jurassic succession is considered to have the best oil source potential on the North West Shelf, but this 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). The oil accumulations that have been discovered in the Browse Basin are sourced from the Early Cretaceous Echuca Shoals Formation in the Caswell Sub-basin, but this succession is immature to marginally mature in the Barcoo Sub-basin.

Evidence of gas at Arquebus 1 ST1, and the gas accumulation at Psepotus 1, suggest that source, maturity and relative migration/trap timing are not critical risks for gas prospectivity in the Barcoo Sub-basin and the adjacent Leveque Shelf. Key risks for the large fault-reactivation anticlines along the boundary between the Barcoo Sub-basin and Leveque Shelf are the lack of updip lateral seal and/or reactivation and breach by Pliocene faults (Blevin et al, 1997).

Figures

Figure 1:	Location map of Release areas W09-1, W09-2, W09-3, W09-4 and W09-5 in the Browse Basin showing existing petroleum title areas, petroleum accumulations and significant wells.
Figure 2:	Regional geological setting of the Browse Basin (after Struckmeyer et al, 1998), showing the location of seismic lines BBHR 175/01 and BBHR 175/03.
Figure 3:	Tectonostratigraphic summary and hydrocarbon discoveries for the Browse Basin. Formation boundaries and unconformity bounded sequences defined in Blevin et al (1997) matched to the timescale of Gradstein et al (2004).
Figure 4:	Seismic line BBHR 175/01 through Trochus 1 ST1 and across Release areas W09-2, W09-3, W09-4 and W09-05 over the central Barcoo Sub-basin and Leveque Shelf. Location of the line is shown in Figure 3.
Figure 5:	Seismic line BBHR 175/03 through Arquebus 1 ST1 and across Release Area W09-05 over the central Barcoo Sub-basin and Leveque Shelf. Location of the line is shown in Figure 3.
Figure 6:	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, 1998a).

Figure 7:	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 isopach maps; after Blevin et al, 1998a). The shelf margin hinge is shown in black and arrows indicate the direction of sediment transport. The 2009 Release Areas are shown in red.
Figure 8:	Map of play elements for Jurassic Petroleum Systems and Play Families in the Browse Basin from Blevin et al (1997).
Figure 9:	Map of play elements for Carboniferous to Late Triassic Petroleum Systems and Play Families in the Browse Basin from Blevin et al (1997).
Figure 10:	Schematic stratal geometry for the Barcoo Sub-basin and Leveque Shelf near seismic line BBHR 175/03, annotated with potential plays in the Release Areas ('play numbers' described in the text) (modified from Blevin et al, 1997).

References

AMOCO, 1992-Arquebus 1, 1 ST1 Well Completion Report. Amoco Australia Petroleum Company, unpublished.

AMOCO, 1993-Sheherazade 1 Well Completion Report. Amoco Australia Petroleum Company, unpublished.

BENSON, J.M., BREALEY, S.J., LUXTON, C.W., WALSHE, 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.

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

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

BLEVIN, J.E., STRUCKMEYER, H.I.M., BOREHAM, C.J., CATHRO, D.L., SAYERS, J. & TOTTERDELL, J.M., 1997-Browse Basin high resolution study, interpretation report, North West Shelf, Australia. AGSO Record 1997/38.

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.

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.

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

DoIR, 2008-Department of Industry and Resources, Western Australia - Petroleum in Western Australia, Publication, September 2008, 60 pp.

EADINGTON, P.J., 2003-GOI measurements to determine potential for palaeo-oil zone in the Trochus 1 ST1 exploration well, Browse Basin. Unpublished CSIRO Petroleum Report 03-029.

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 AARSSEN, 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. (eds), Timor Sea Petroleum Geoscience. Proceedings of the Timor Sea Symposium, Darwin, 19-20 June 2003. Northern Territory Geological Survey, Special Publication 1, 169-201.

GRADSTEIN, F.M., OGG, J.G., SMITH, A.G., AGTERBERG, F.P., BLEEKER, W., COOPER, R.A., DAVYDOV, V., GIBBARD, P., HINNOV, L., HOUSE, M.R., LOURENS, L., LUTERBACHER, H-P., MCARTHUR, J., MELCHIN, M.J., ROBB, L.J., SHERGOLD, J., VILLENEUVE, M., WARDLAW, B.R., ALI, J., BRINKHUIS, H., HILGEN, F.J., HOOKER, J., HOWARTH, R.J., KNOLL, A.H., LASKAR, J., MONECHI, S., POWELL, J., PLUMB, K.A., RAFFI, I., RÖHL, U., SANFILIPPO, A., SCHMITZ, B., SHACKELTON, N.J., SHIELDS, G.A., STRAUSS, H., VAN DAM, J., VEIZER, J., VAN KOLFSCHOTEN, Th. AND WILSON, D., 2004-A Geologic Time Scale 2004. Cambridge University Press, 589 p.

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

KEALL, J. AND SMITH, P., 2004-The Argus discovery, Browse Basin. In: Ellis, G.K., Baillie, P.W. and Munson, T.J. (eds), 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. (eds), Timor Sea Petroleum Geoscience. Proceedings of the Timor Sea Symposium, Darwin, 19-20 June 2003. Northern Territory Geological Survey, Special Publication 1, 411-435.

LISK, M., 1996-Hydrocarbon charge history of Middle Jurassic sandstones from Arquebus 1 Browse Basin. Unpublished APCRC Report No. 221.

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. (eds), The Sedimentary Basins of Western Australia, Vol. 3, pp. 27-88. Petroleum Exploration Society of Australia , Perth.

MAGELLAN PETROLEUM AUSTRALIA , 2002-Farmin opportunities, North West Shelf. 2002 Western Australian Basins Symposium III Deal Day, Perth, Western Australia.

PESA, NSW Branch, unpublished.

MAGOON, L.B. AND DOW, W.G., 1991-The petroleum system. In: Magoon, L.B. and Dow, W.G. (Eds.), The petroleum system - from source to trap. AAPG Memoir 60, 24.

O'BRIEN, G.W., HIGGINS, R., SYMONDS, P., QUAIFE, P., COLWELL, J. AND BLEVIN, J.E., 1996-Basement control on the development of extensional systems in Australia's Timor Sea: an example of hybrid hard-linked/soft-linked faulting? The APPEA Journal, 36(1), 161-201.

PetroleumNews.net, 29 October 2004-[Web page] South Galapagos comes up a dry duck, **www.petroleumnews.net/storyview.asp?storyid=30967** (last accessed 21 January 2009).

PetroleumNews.net, 25 October 2005-[Web page] Surging prices to drive Pluto and Browse LNG, **www.petroleumnews.net/storyview.asp?storyid=48494** (last accessed 21 January 2009).

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. (eds), 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. (eds), The Sedimentary Basins of Western Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 1994, 315-331.

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

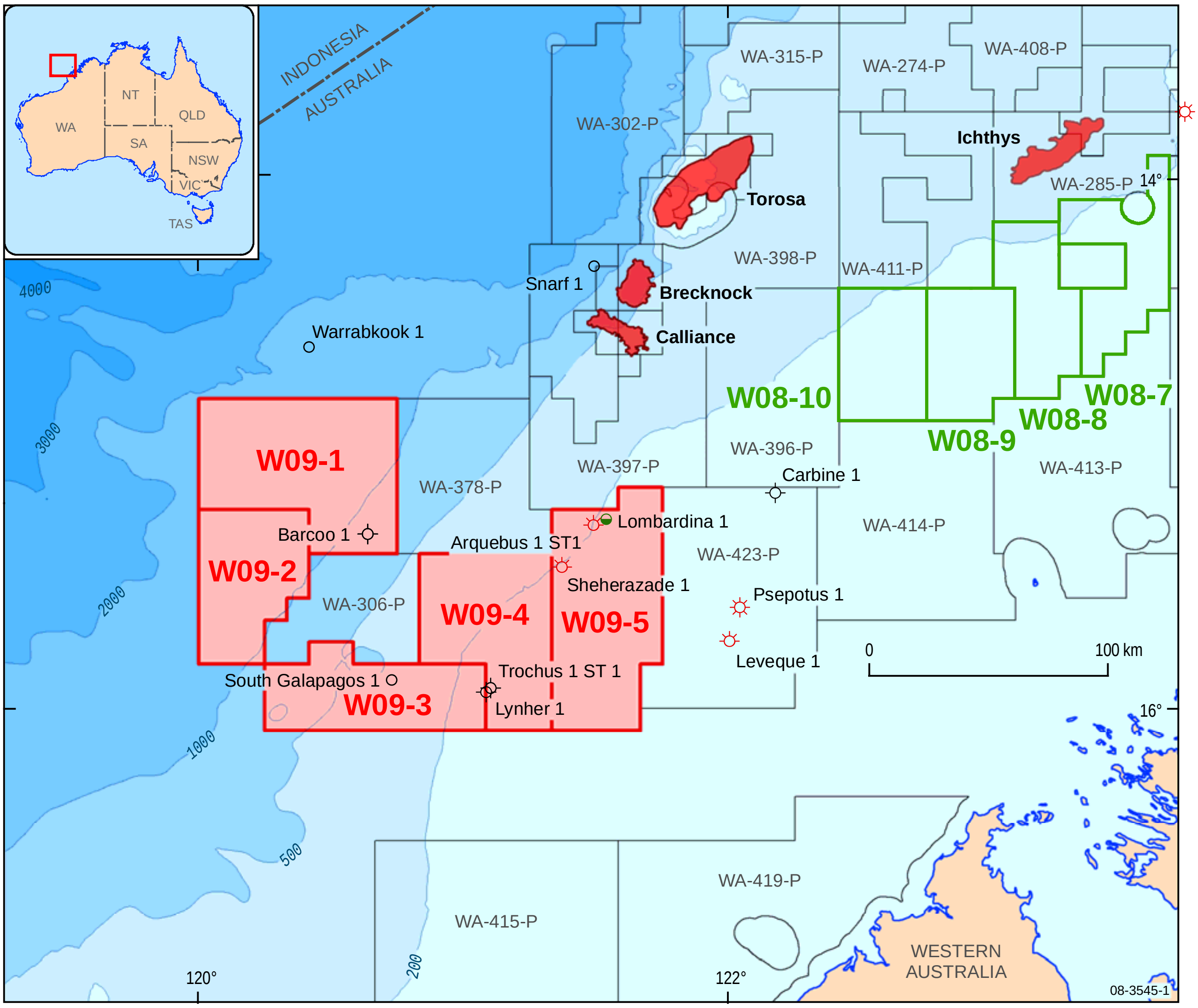
WOODSIDE PETROLEUM, 1998-Psepotus-1 Well Completion Report, unpublished.

WOODSIDE, 19 January 2006a-[Web page] ASX Announcement - Fourth quarter report for period ended 31 December 2005, **www.woodside.com.au/NR/rdonlyres/FDB3053C-0264-4386-8040-0D2D6983D1BC/0/FourthQuarterReportforperiodended31December05.pdf** (last accessed 21 January 2009).

WOODSIDE, 19 October 2006b-[Web page] ASX Announcement - Third quarter report for period ended 30 September 2006, **www.woodside.com.au/NR/rdonlyres/00823202-60E7-421B-8F3C-C1854F0E994B/0/Thirdquarterreportforperiodended30September2006.pdf** (last accessed 21 January 2009).

WOODSIDE, 18 January 2007a-[Web page] ASX Announcement - Fourth quarter report for period ended 31 December 2006, **www.woodside.com.au/NR/rdonlyres/7B180CA8-432F-4596-9C7A-18713C35AE09/0/FourthQuarterReportforperiodended31Dec0618Januray2006.pdf** (last accessed 21 January 2009).

WOODSIDE, 18 April 2007b-[Web page] ASX Announcement - First quarter report for period ended 31 March 2007, **www.woodside.com.au/NR/rdonlyres/721F540D-9DE6-4B1E-9612-4117521C7FE2/0/FirstQuarterReportfortheperiodended31Mar07.pdf** (last accessed 21 January 2009).



Where well symbol information is sourced from publicly available "open file" data, it has been provided by Geoscience Australia from Well Completion Reports. These symbols were generated from open file data as at 31 March 2009. Where well symbol information is not publicly available from titleholders' data, the information has been extracted from other public sources. Field outlines are provided by GPinfo, an Encom Petroleum Information Pty Ltd product. Field outlines in GPinfo are sourced, where possible, from the operators of the fields only. Outlines are updated at irregular intervals but with at least one major update per year.

Field outline for Ichthys is sourced from IHS Energy, 2006.

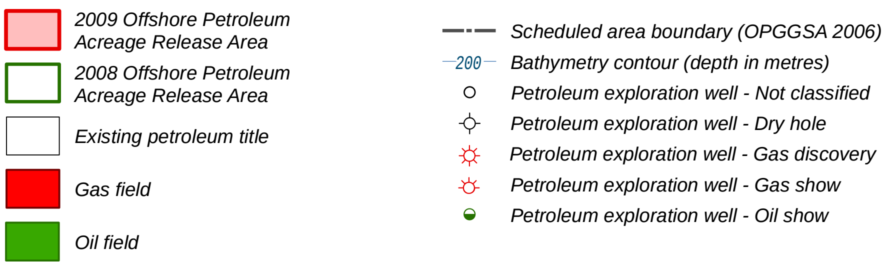
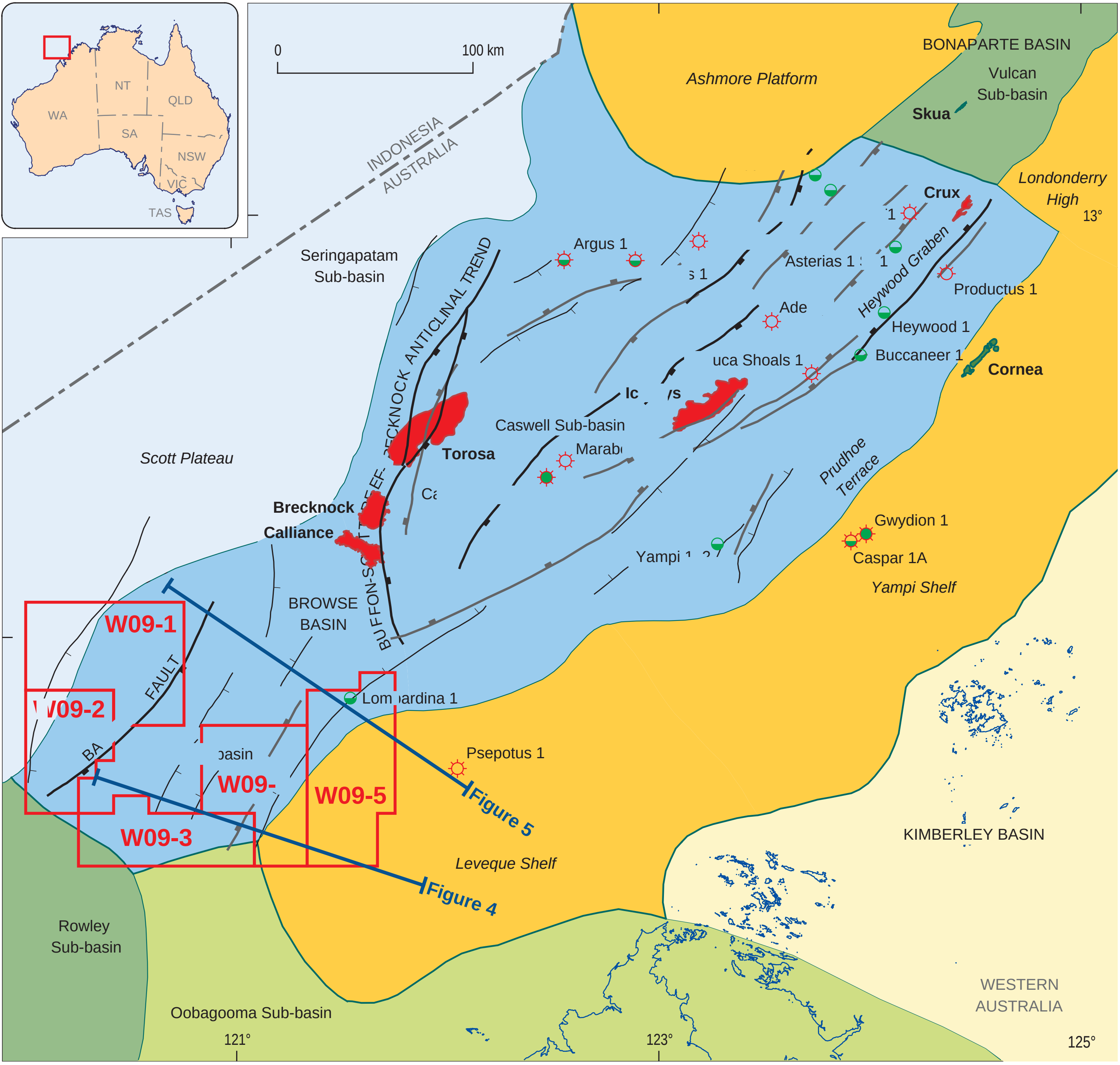


Figure 1. Location map of Release Areas W09-1, W09-2, W09-3, W09-4 and W09-5 in the Browse Basin showing existing petroleum title areas, petroleum accumulations and significant wells.



Where well symbol information is sourced from publicly available "open file" data, it has been provided by Geoscience Australia from Well Completion Reports. These symbols were generated from open file data as at 31 March 2009. Where well symbol information is not publicly available from titleholder's data, the information has been extracted from other public sources. Field outlines are provided by GPinfo, an Encom Petroleum Information Pty Ltd product. Field outlines in GPinfo are sourced, where possible, 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 Ichthys and Cornea are sourced from IHS Energy, 2006.

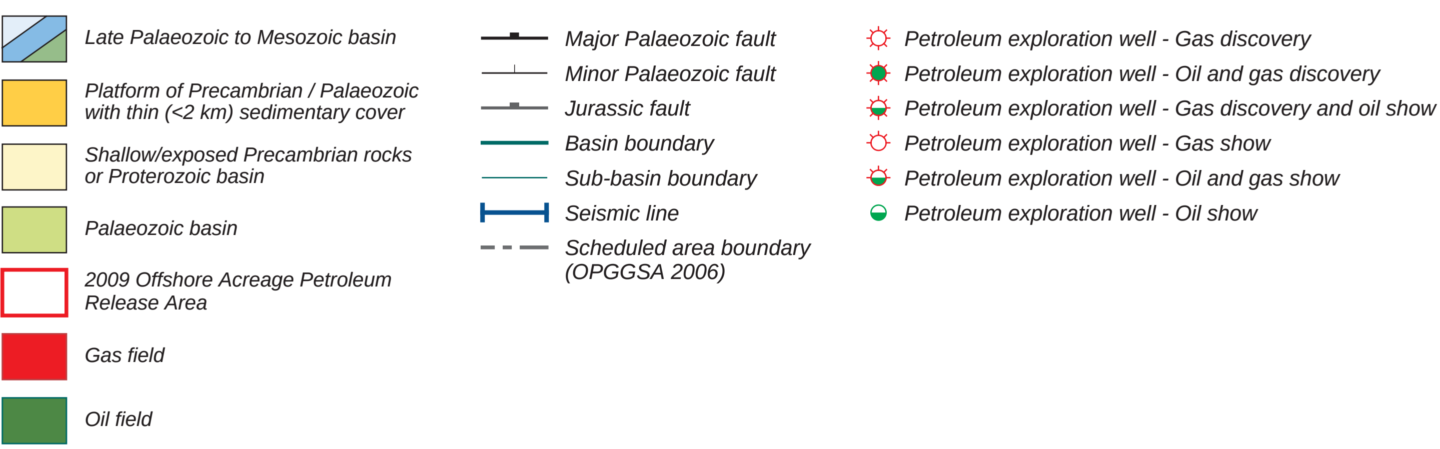


Figure 2. Regional geological setting of the Browse Basin (after Struckmeyer et al, 1998), showing key discoveries and the location of seismic lines BBHR 175/01 (Figure 4) and BBHR 175/03 (Figure 5).

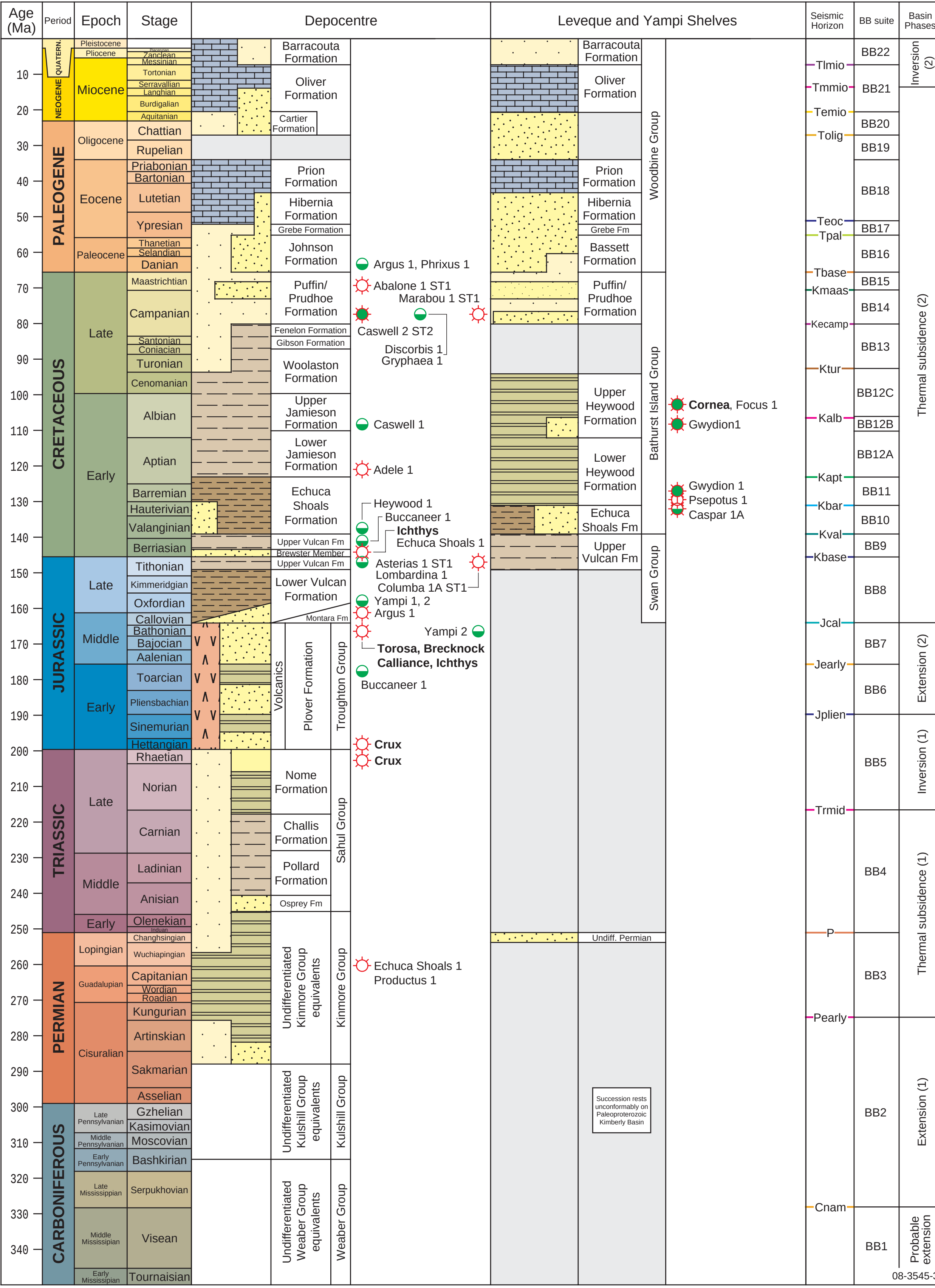


Figure 3. Tectonostratigraphic summary and hydrocarbon discoveries for the Browse Basin. Formation boundaries and unconformity bounded sequences defined in Blevin et al. (1997) matched to the timescale of Gradstein et al. (2004).

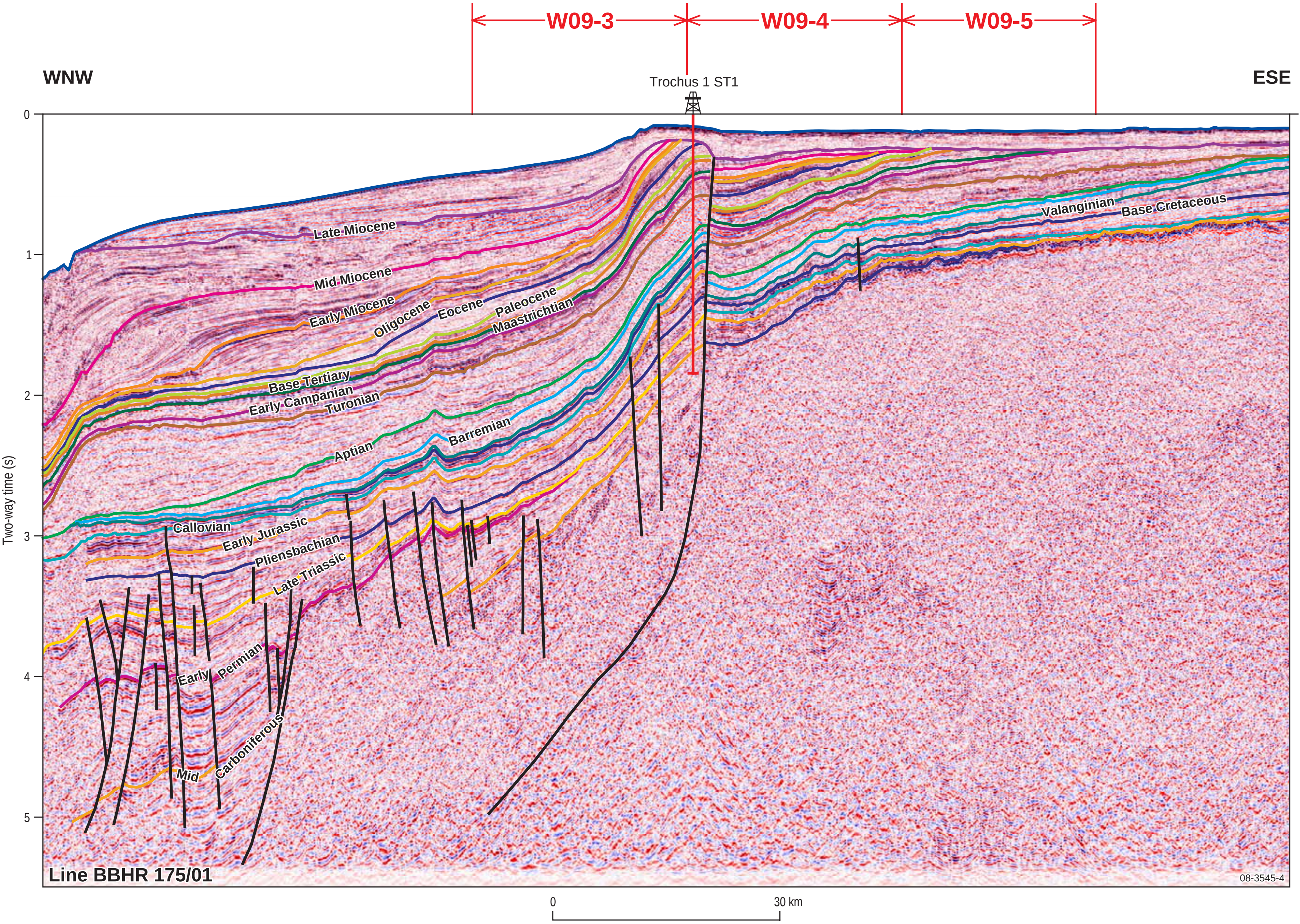


Figure 4. Seismic line BBHR 175/01 through Trochus 1 ST1 and across Release Areas W09-3, W09-4 and W09-05 over the central Barcoo Sub-basin and Leveque Shelf. Location of the line is shown in Figure 2 . Regional seismic horizons are shown in Figure 3.

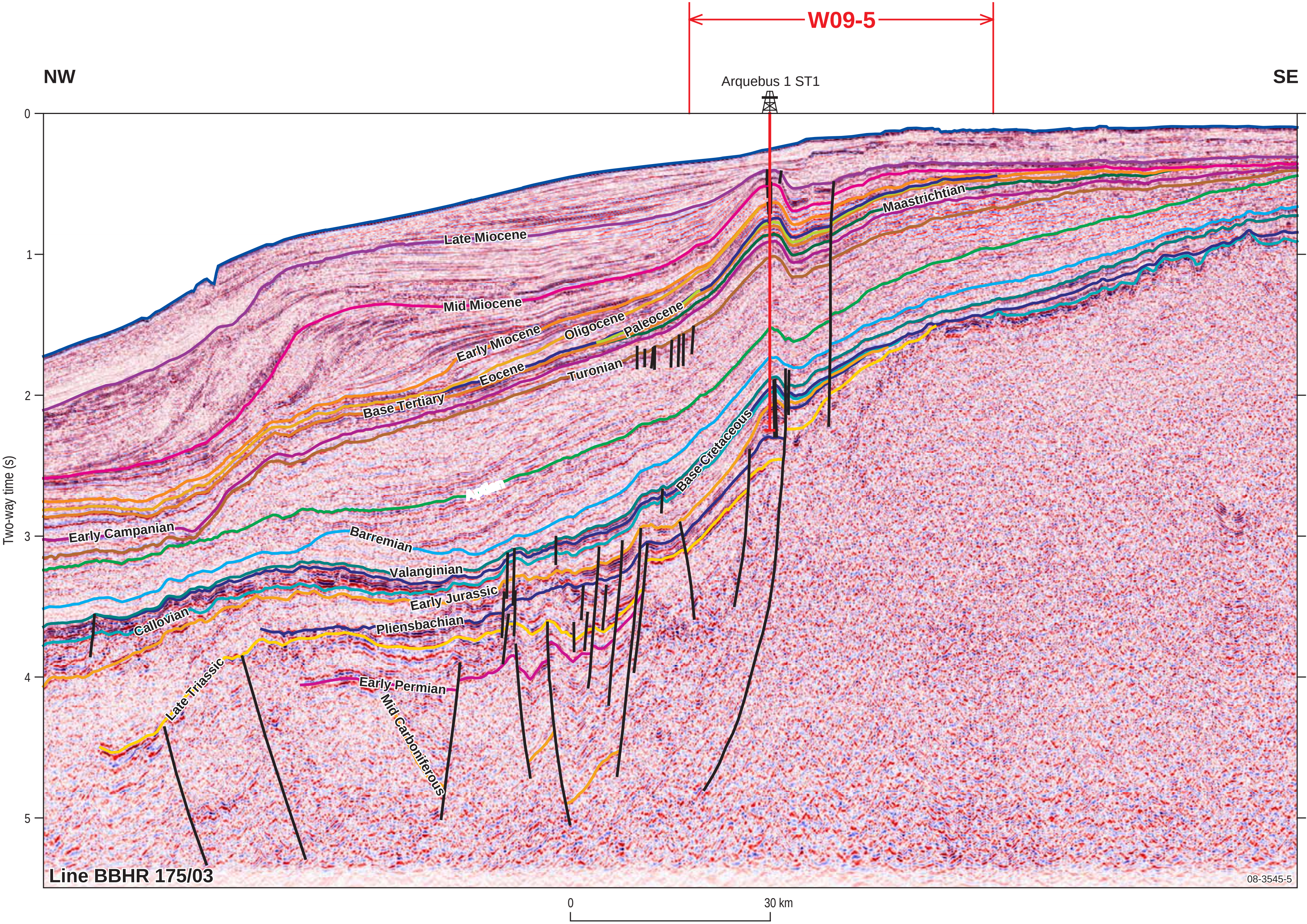


Figure 5. Seismic line BBHR 175/03 through Arquebus 1 ST1 and across Release Area W09-05 over the central Barcoo Sub-basin and Leveque Shelf. Location of the line is shown in Figure 2. Regional seismic horizons are shown in Figure 3.

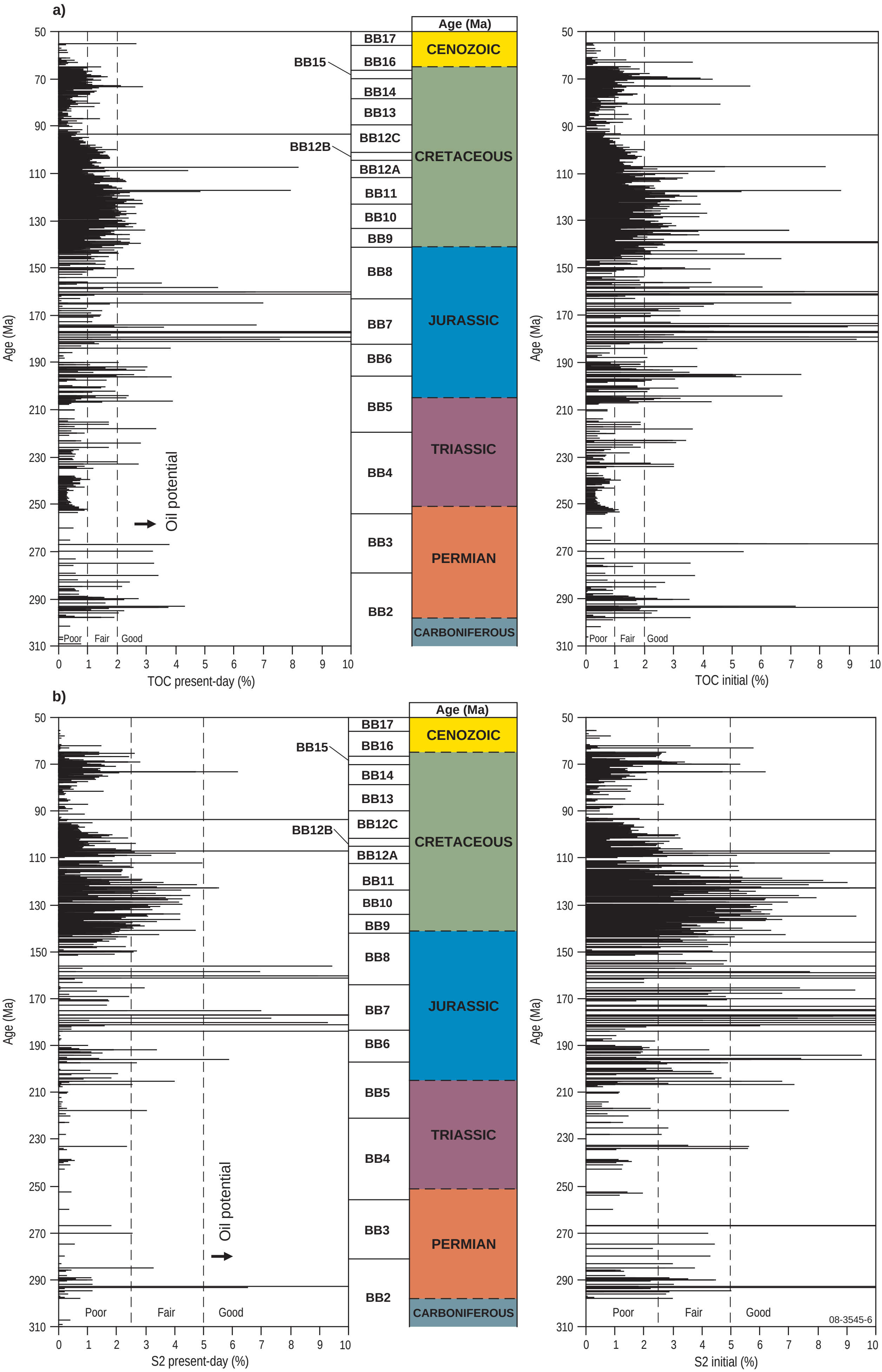


Figure 6. Plots of age (a) present day and initial TOC, and (b) present day and initial S2 values for the Browse Basin wells drilled prior to 1998 (Blevin et al, 1998a).

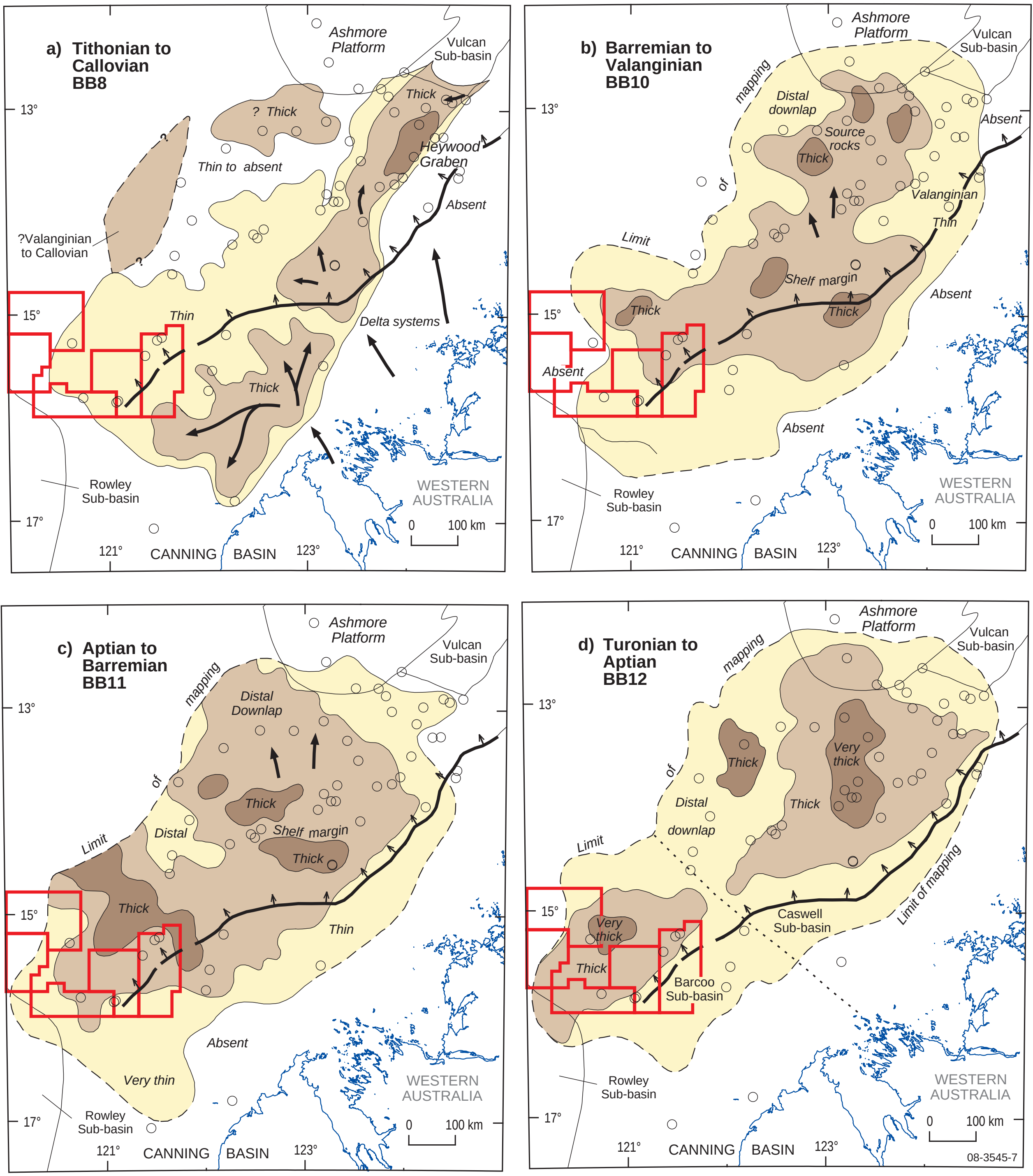
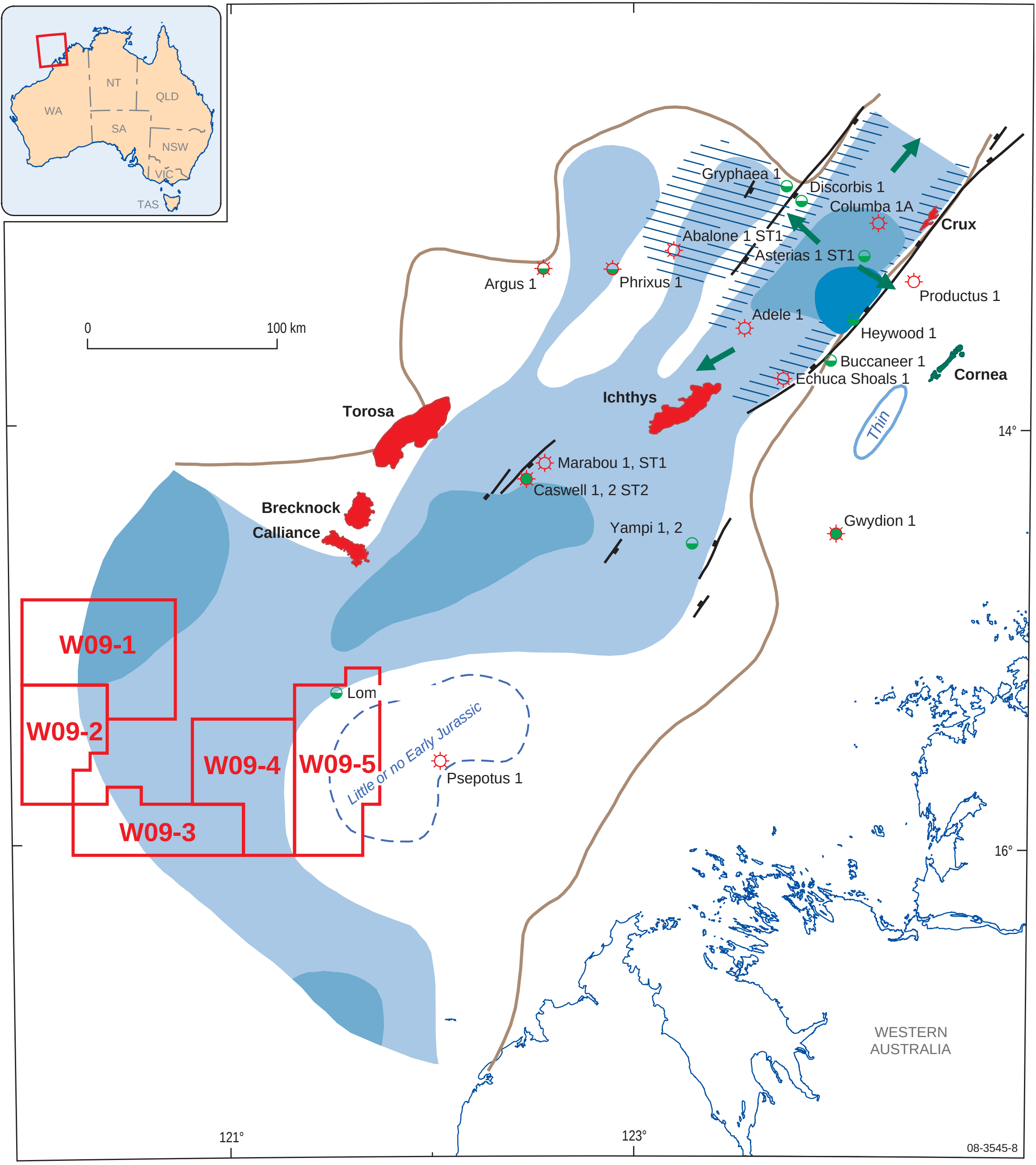


Figure 7. Generalised distribution map of (a) Tithonian to Callovian, (b) Barremian to Valanginian, (c) Aptian to Barremian, and (d) Turonian to Aptian sediments in the Browse Basin (based on two-way time isopach maps; after Blevin et al, 1998a). The shelf margin hinge is shown in black and arrows indicate the direction of sediment transport. The 2009 Release Areas are shown in red.



Where well symbol information is sourced from publicly available "open file" data, it has been provided by Geoscience Australia from Well Completion Reports. These symbols were generated from open file data as at 31 March 2009. Where well symbol information is not publicly available from titleholder's data, the information has been extracted from other public sources. Field outlines are provided by GPinfo, an Encom Petroleum Information Pty Ltd product. Field outlines in GPinfo are sourced, where possible, 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 Ichthys and Cornea are sourced from IHS Energy, 2006.

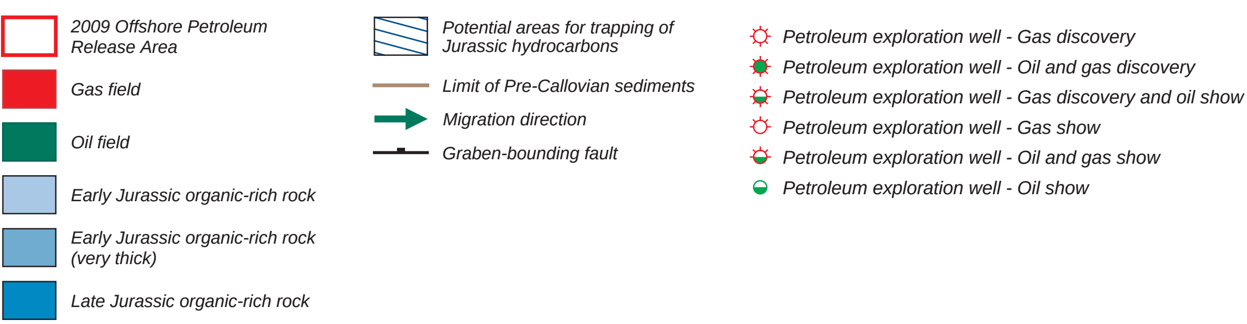
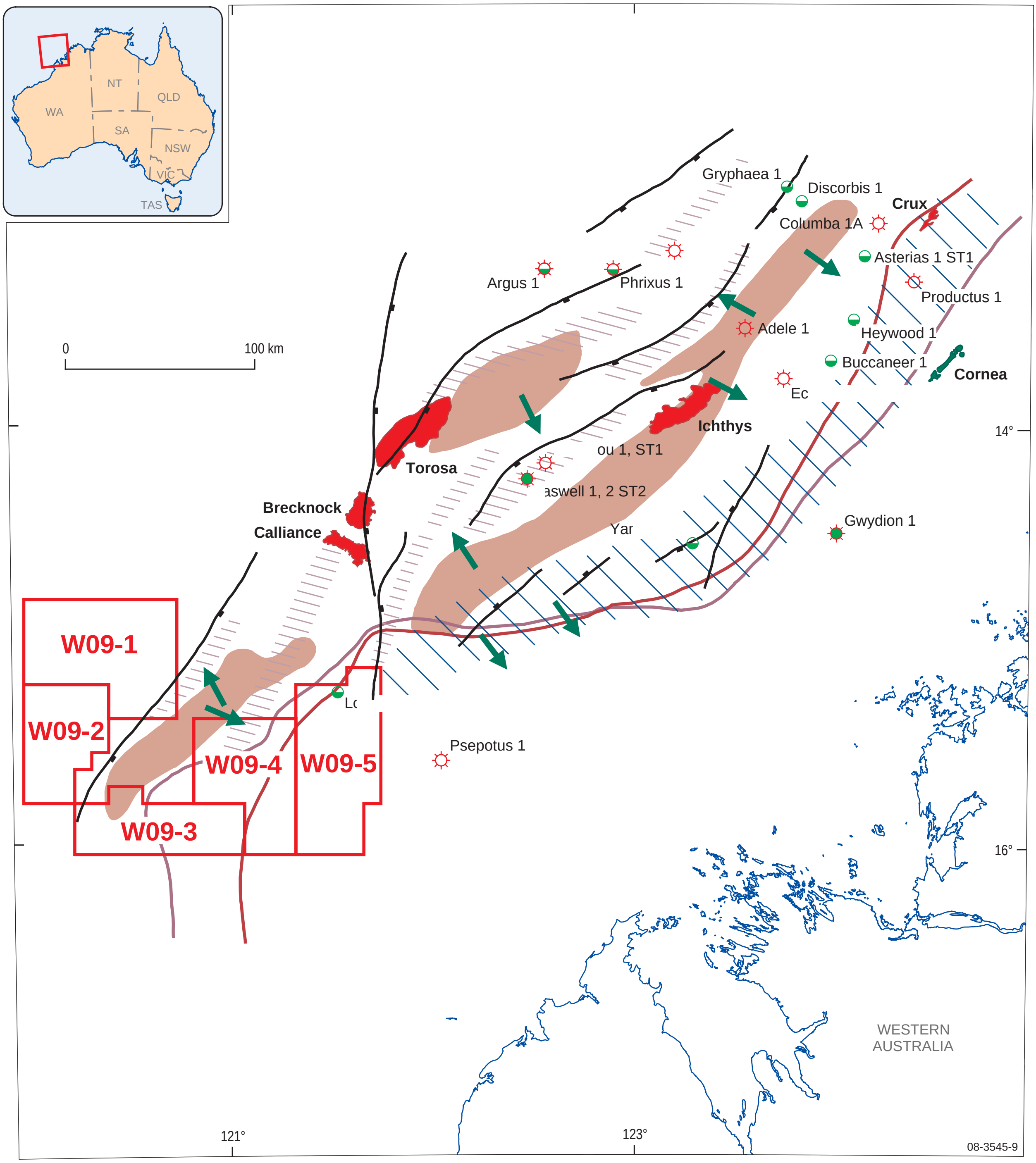


Figure 8. Map of play elements for Jurassic Petroleum Systems and Play Families in the Browse Basin from Blevin et al. (1997).



Where well symbol information is sourced from publicly available "open file" data, it has been provided by Geoscience Australia from Well Completion Reports. These symbols were generated from open file data as at 31 March 2009. Where well symbol information is not publicly available from titleholder's data, the information has been extracted from other public sources. Field outlines are provided by GPinfo, an Encom Petroleum Information Pty Ltd product. Field outlines in GPinfo are sourced, where possible, 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 Ichthys and Cornea are sourced from IHS Energy, 2006.

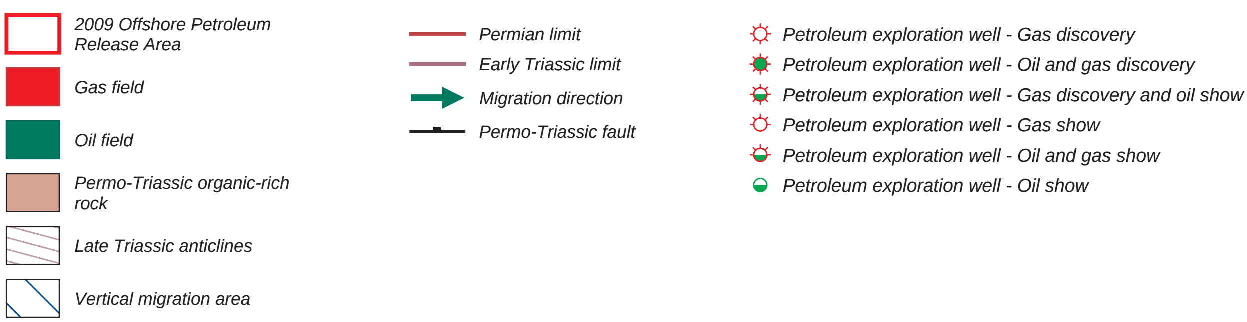


Figure 9. Map of play elements for Carboniferous to Late Triassic Petroleum Systems and Play Families in the Browse Basin from Blevin et al. (1997).

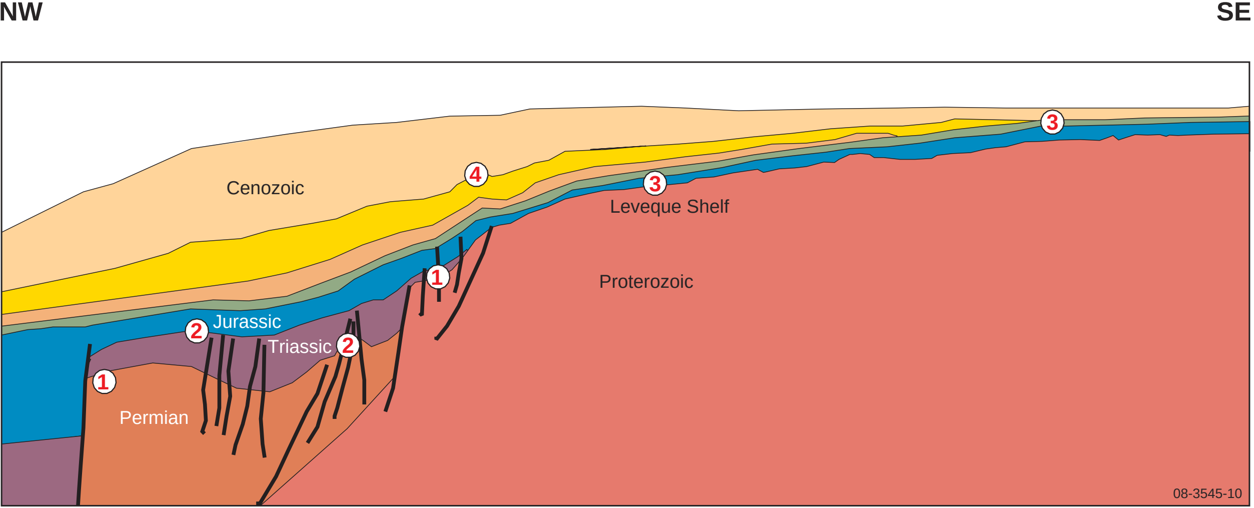


Figure 10. Schematic stratal geometry for the Barcoo Sub-basin and Leveque Shelf near seismic line BBHR 175/03, annotated with potential plays in the Release Areas ('play numbers' described in the text) (modified from Blevin et al, 1997).