Australian Government
Department of Resources, Energy and Tourism

Regional Geology of the Browse Basin

Basin Outline

The Browse Basin is a northeast-trending, Paleozoic 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^2 and contains in excess of 15 km of Paleozoic, Mesozoic and Cenozoic sedimentary section (Struckmeyer et al, 1998). It hosts significant, but as yet undeveloped, reserves of gas and condensate. 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 other smaller gas discoveries (Adele 1, Caspar 1A, Cornea field, Echuca Shoals 1 and Psepotus 1) (**Figure 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 form the Westralian Superbasin underlying the North West Shelf region (Bradshaw et al, 1988; Willis, 1988). 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

Structural elements of the Browse Basin illustrated in **Figure 2** are based on the terminology introduced by Willis (1988), Elliot (1990), O'Brien et al (1993), Hocking et al (1994), Symonds et al (1994) and Struckmeyer et al (1998). The Browse Basin can be divided four major sub-basins, the Caswell, Barcoo and Seringapatam sub-basins and the Scott Plateau. A series of shallow basement elements, the Prudhoe Terrace, and the Yampi and Leveque shelves define the southeastern boundary (**Figure 2**).

Yampi Shelf, Leveque Shelf and Prudhoe Terrace

The southeastern margin of the Browse Basin is underlain by shallow basement, which is typically highly eroded with a distinct, rugose palaeotopographic relief, and is onlapped by Permian to Mesozoic sediments (Struckmeyer et al, 1998). This area is termed the Yampi Shelf in the central and northern parts of the basin, and the Leveque Shelf to the south (**Figure 2**) (Hocking et al, 1994). The basinward boundary of the Leveque and Yampi shelves is defined as the'hingepoint' from more or less flat lying basement to gently basinward-dipping basement, beyond which is the Prudhoe Terrace, a fault-bounded terrace at intermediate depth (Struckmeyer et al, 1998).

Caswell and Barcoo sub-basins

The Caswell and Barcoo sub-basins (Hocking et al, 1994) are the major depocentres of the Browse Basin. In the Caswell Sub-basin, Paleozoic to Cenozoic sediments are more than 15 km thick, whereas the maximum thickness in the Barcoo Sub-basin probably does not exceed 12 km (Struckmeyer et al, 1998). The Caswell Sub-basin is significantly wider (200 km) than the Barcoo Sub-basin (100 km) from which it is separated by a major north to north-northeast trending structural zone, the Buffon-Scott Reef-Brecknock Anticlinal Trend (**Figure 2**) (Struckmeyer et al, 1998).

Scott Plateau and Seringapatam Sub-basin

The Scott Plateau and Seringapatam Sub-basin (Hocking et al, 1994) are in deep water (approximately 1500-3000 m water depth), located to the west and northwest of the main Browse Basin depocentres (Struckmeyer et al, 1998). The Scott Plateau (**Figure 2**) is a subsided marginal plateau where up to 3 km of Mesozoic to Cainozoic rocks overlie ?Paleozoic and older basement (Stagg and Exon, 1981). Very little is known about the Seringapatam Sub-basin and the boundary with the adjacent Caswell Sub-basin shown by Hocking et al (1994) appears arbitrary (**Figure 2**) (Struckmeyer et al, 1998).

Basin Phases

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**).

The Browse Basin has undergone six major tectonic phases of basin development (Struckmeyer et al, 1998):

> Mississippian to Cisuralian extension.

> Cisuralian to Late 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 basin was initiated as a series of intracratonic extensional half-graben during the Mississippian to Cisuralian (**Figure 4a**) (Symonds et al, 1994). Further to the west this extensional event is thought to have led to breakup and separation of Sibumasu from northwest Australia in the Cisuralian (Metcalfe, 1990). 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 Paleozoic 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 Cisuralian sediments (mainly limestones and shales) were deposited in a marine environment. The later Permian section consists of sandstones grading into shales and limestones. The oldest Triassic rocks intersected in the Browse Basin are marine claystones, siltstones and volcaniclastic sediments (e.g., in Echuca Shoals 1) that were deposited during a regional Early Triassic marine transgression. Overlying Triassic rocks include fluvial and marginal to shallow-marine sandstones, limestones and shales.

The Permo-Triassic thermal subsidence (sag) phase (**Figure 4b**) was terminated by compressional reactivation in the Late Triassic to Early Jurassic, resulting in partial inversion of Paleozoic half-graben and the formation of large scale anticlinal and synclinal features within the hanging walls (**Figure 4c**). 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 Buffon-Scott Reef-Brecknock Anticlinal Trend (**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 (**Figure 4d**). Extensional faulting was concentrated in the northeastern part of the Caswell Sub-basin and along the adjacent outer margin of the Prudhoe Terrace (Struckmeyer et al, 1998). The Heywood Graben (**Figure 2**) also formed during this period. The Early-Middle Jurassic syn-rift sediments (Plover Formation) comprise sandstones, mudstones and coals that accumulated in deltaic and coastal-plain settings. Widespread erosion and peneplanation in the Callovian coincided 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 (**Figure 3**). Late Jurassic interbedded sandstones and shales onlap and drape the pre-Callovian structures, providing a thin, regional seal across much of the basin (**Figure 5**, **Figure 6** and **Figure 7**). 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 8**: Blevin et al, 1998a).

The Turonian-Cenozoic section represents a major progradational (regressive) cycle in which the shelf edge migrated northwestwards to the outer limits of the Buffon-Scott Reef-Brecknock Anticlinal Trend. 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 commenced in the Middle to Late Miocene as a result of the convergence of the Australia-India and Eurasia plates (Shuster et al, 1998).

Regional Hydrocarbon Potential

Regional Petroleum Systems

Geochemical analyses of oils, oil stains, fluid inclusion oils, condensates, gases and source rocks from the Browse Basin have been undertaken by AGSO and Geotech (2000), Boreham et al (1997, 2001), Blevin et al (1998a, b), Edwards et al (2000, 2004, 2006), Edwards and Zumberge (2005) and Volk et al (2005). **Figure 9** demonstrates that the stable ^{13}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):

> 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 (condensate/gas ratios <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);

> A central sub-basin, wet gas-prone system, the source 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 suggests that they did not receive a significant charge from the oil-prone Early Cretaceous petroleum system. Since the δ

13 > C isotopic data of the gas/condensates recovered from the Brewster reservoir in the Ichthys field are similar to those of Bayu and Undan in the northern Bonaparte Basin, a Jurassic source is implied, including a possible contribution from Late Jurassic source rocks (Vulcan Formation);

> 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 (1998b) defined this system as the Westralian (W3) Petroleum System. The Cornea and Gwydion oils and gases vary in degree of biodegradation.

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 δ^{13}C isotopic evidence presented in **Figure 9**, the samples of gas and condensate recovered from Crux 1 represent another hydrocarbon family within the Browse Basin.

Source Rocks

A comprehensive 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) (**Figure 8**). These studies recognised organic-rich rocks with fair to moderate oil potential at numerous stratigraphic levels within the Permian-Early Cretaceous section, and that some local, thin, high-quality coals and pro-delta shales with high source potential occur within the Early-Middle Jurassic, fluvio-deltaic Plover Formation.

Blevin et al (1998a) noted that although many potential source units within this succession have liquids potential (HI values >200 mg hydrocarbons/gTOC), they contain less than 2% TOC (**Figure 8**). At these low-to-moderate TOC levels, any generated oil may remain within the source rock (ie, not be expelled) and may be subsequently cracked to gas at higher maturities.

Figure 10 shows generalised distribution maps of Late Jurassic (Vulcan Formation) and Early Cretaceous (Echuca Shoals and Jamieson formations) potential source units in the basin. 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 and Prudhoe Terrace (**Figure 10a**), 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 10b**, **Figure 10c** and **Figure 10d**), and contain mixed marine and terrestrial organic matter with moderate to good source potential. However, 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, 1998b). However, hydrocarbons generated from this section are likely to be dominated by gas rather than oil.

Reservoirs and Seals

Reservoir facies are best developed within the fluvio-deltaic Early-Middle Jurassic Plover Formation as well as submarine fans and'ponded' turbidite mounds of Berriasian, Barremian, Campanian and Maastrichtian ages. Late Jurassic-Early Cretaceous (Vulcan Formation) and Early Cretaceous (Echuca Shoals Formation) claystones provide regional seals throughout much of the basin. Potential intraformational sealing shales occur within the Early-Middle Jurassic Plover Formation (Blevin et al, 1998b), while Late Cretaceous claystones of the Puffin Formation provide potential seals for Campanian-Maastrichtian ponded turbidites and unconfined fans (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 in the Heywood Graben; the Plover Formation in the Paleogene and Neogene and the Lower Vulcan Formation in the Neogene. These charges are likely to have sourced the thick palaeo-oil columns interpreted in 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. Indeed, an investigation of the fluid inclusions in the gas reservoirs of the Browse Basin has shown that the hydrocarbon charge consisted of an early oil charge, filling only the crests 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 have occurred 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) confirms the existence of potential source rocks that are thermally mature enough to generate both oil and gas, but which show little or no evidence of expulsion or effective regional charge (Radlinski et al, 2004). Similarly, fluid inclusion analysis provides no evidence of an effective regional oil charge of Cretaceous reservoirs in the Caswell Sub-basin (Brincat and Kennard, 2004; Brincat et al, 2004). However, because the organic-rich sediments within this succession occur as thin transgressive sheets deposited on a gently inclined ramp margin in response to fluctuating sea level, 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 1 and Caswell 2 ST2 accumulations, and is postulated as the probable source of the inferred gas accumulation at Marabou 1 ST1 (Benson et al, 2004).

Exploration History

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. This well 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 Buffon-Scott Reef-Brecknock Anticlinal Trend. 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). 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 1275000 m^3/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 sandstone in Early to Middle Jurassic sediments, of similar age to the reservoir section at Scott Reef 1 (Bint, 1988).

Other significant discoveries during the early 1980s include Brewster 1A ST1 (1980), Caswell 2 ST2 (1983) and Echuca Shoals 1 (1983). Log interpretations from Brewster 1A ST1 delineated gas-bearing sandstones of Berriasian age. Caswell 2 ST2 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 on the northern Caswell Sub-basin (Gryphaea 1 (1987), Asterias 1 ST1 (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 ST1 (1993) and Yampi 2 (1994)). Many of the wells reported minor hydrocarbon shows from Late Jurassic or Early Cretaceous reservoirs (Maung et al, 1994). Evidence of the hydrocarbon potential of the basin was demonstrated by the Gwydion 1 oil and gas discovery, and the Cornea 1 oil discovery (1997), both located on the Yampi Shelf.

Gwydion 1 intersected three gas-bearing zones and one oil/gas-bearing 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 basal 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 gas in Middle Jurassic (Plover Formation) sandstones, while 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 previously recognised gas provinces.

Brecknock South 1, located on the Buffon-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 same structural trend, Argus 1 encountered a 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 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 of Early Cretaceous lowstand fans and'ponded' turbidite oil targets 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.

Appraisal drilling in the Ichthys gas field was completed in 2003-2004 (Ichthys 1A, Ichthys 2A ST2, and Ichthys Deep 1). Here, gas is primarily reservoired within the Upper Vulcan Formation (Brewster Member) and the Plover Formation. Gas was also encountered within Callovian sandstones (named Ichthys Formation), and in basal Oxfordian sandstones of the Lower Vulcan Formation (Ban and Pitt, 2006). Drilling continued in this region in 2007 and 2008 with Prelude 1A, Dinichthys North 1, Tocatta 1 and Ichthys West 1 (DoIR, 2008a, b). Gas columns were recently discovered in the Fortissimo 1 well in WA-371-P (DoIR, 2008b) and in the Mimia 1 exploration well in WA-344P (PetroleumNews.net, 2008d).

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 Torosa 1, 2, 3, 4 and 6, Brecknock 2 and 3, and Calliance 1 and 2.

The appraisal of the Crux gas field continued in 2006-2008 with acquisition of a 3D seismic survey and the drilling of the Crux 2, Crux 2 ST1, Crux 3 and Crux 4 wells, which encountered gas and condensate-bearing sands in the Montara, Plover and Nome formations (Nexus Energy Ltd, 2007b; PetroleumNews.net, 2008b). The Libra 1'near-field' exploration well in AC/P41, which was testing the exploration potential around the greater Crux area, intersected a 206 m gross gas column in an accumulation interpreted to be separate to the Crux field (PetroleumNews.net, 2009).

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 reached a total depth of 3822 m in September 2007. Wireline logs indicate 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 the Echuca Shoals 1 well. Nexus reported that further studies will be required to assess the commercial implications of this result for the Echuca Shoals gas accumulation.

Hydrocarbon Reserves

The Browse Basin is one of Australia's most hydrocarbon-rich offshore basins. 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 , 2009).

A gas column was discovered by Shell in late 2007 in the Fortissimo 1 wildcat well, drilled approximately 8 km northeast of Prelude 1 in WA-371-P (DoIR, 2008b).

Appraisal wells Torosa 4 and Torosa 6 were drilled by Woodside Energy within the previously defined boundaries of the Torosa field during the 2007-2008 fiscal year. Torosa 4 was plugged and abandoned after encountering gas (DoIR, 2008b). Results of Torosa 6 are not available at the time of compilation.

Appraisal wells Crux 3 and Crux 4 were drilled by Nexus in Dec 2007-Jan 2008. Both the Crux 3 and Crux 4 wells intersected previously unseen younger Montara Formation gas-charged sand overlying the older Plover and Nome Formation sands, which were seen in the earlier Crux 1, Crux 2 and Crux 2 ST1 wells, and were suspended as future development wells (PetroleumNews.net, 2008b). Pressure data from the Crux wells confirm that the gas sands in each of the formations are in pressure communication across the field and form part of a single accumulation (PetroleumNews.net, 2008a). As a result of this appraisal drilling, P90 estimates for the Crux field increased from 54.9 MMbbl in October 2007 to 63.8 MMbbl in April 2008 (PetroleumNews.net, 2008c).

In May 2008 Inpex announced a significant increase in previously estimated reserves for its Ichthys gas accumulation, with the field now estimated to hold 12.8 Tcf of gas, up from the previous estimate of just over 8 Tcf, which makes it the largest gas field in the Browse Basin. Inpex also announced the Ichthys field holds approximately 527 million barrels of condensate, which makes it the largest liquid hydrocarbon accumulation found in Australia since the Bass Strait oil fields in the 1960s (Minister for Resources and Energy Press Release, 20 May 2008).

In August 2008 Inpex discovered a 72 m gas column in the Mimia 1 wildcat exploration well in WA-344-P, approximately 20 km northeast of WA-285-P, which contains the giant Ichthys gas-condensate field. A production test confirmed the well had found both gas and condensate (PetroleumNews.net, 2008d).

Table 1: Initial hydrocarbon reserves for the Browse Basin

Field	Oil	Condensate	Gas	Gas	Source
	MMbbl	MMbbl	Bcf	MMboe1	
Argus		6.8	600.0	102.0	RDPIFR
Brecknock		109.4	5272.5	896.3	DMP

Calliance (Brecknock S)		86.8	3951.7	671.8	DMP
Crux		75.2	1400.0	238.0	RDPIFR
Ichthys Brewster		474.0	9551.7	1623.8	DMP
Ichthys Plover		53.0	3183.9	541.3	DMP
Prelude			2000-3000	340-510	Shell
Torosa (Scott Reef)		121.0	11442.1	1945.2	DMP

1 Conversion factor for gas is 1 Bcf gas ≡ 0.17 million barrels of oil. All reserves are P50. All developed field resources. The initial recoverable resource estimates are at 31 December 2007

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Figures

Figure 1:	Location map of the Browse Basin showing existing petroleum accumulations, significant wells and 2008 and 2009 Release areas.
Figure 2:	Regional geological setting of the Browse Basin (after Struckmeyer et al, 1998), showing key discoveries and the location of seismic lines BBHR 175/10 (Figure 7).
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:	Schematic cross-sections illustrating major basin-forming events in the Browse Basin (sections are not to scale): a) Late Carboniferous to Early Permian extension (Late Permian basin geometry); b) Late Permian to Middle Triassic thermal subsidence (Middle Triassic basin geometry); c) Late Triassic inversion (Hettangian basin geometry); d) Early to Middle Jurassic extension (Callovian basin geometry) (from Struckmeyer et al, 1998).
Figure 5:	Seismic line BBHR 175/10 through Argus 1, Echuca Shoals 1 and Rob Roy 1, northern Caswell Sub-basin. Location of the line is shown in Figure 3.
Figure 6:	Seismic line BBHR 175/05, southern Caswell Sub-basin. Location of the line is shown in Figure 3.

Figure 7:	Seismic line BBHR 175/03 through Arquebus 1 and across Release Area W09-05, Barcoo Sub-basin and Leveque Shelf. Location of the line is shown in Figure 3.
Figure 8:	Plots of age (a) present day and initial TOC, and (b) present day and initial S2 values for Browse Basin wells drilled prior to 1998 (after Blevin et al, 1998a).
Figure 9:	Carbon isotopic composition for gases and C7+ n-alkanes of condensates and oils recovered from the Browse Basin (after Edwards et al, 2004, 2006).
Figure 10:	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.

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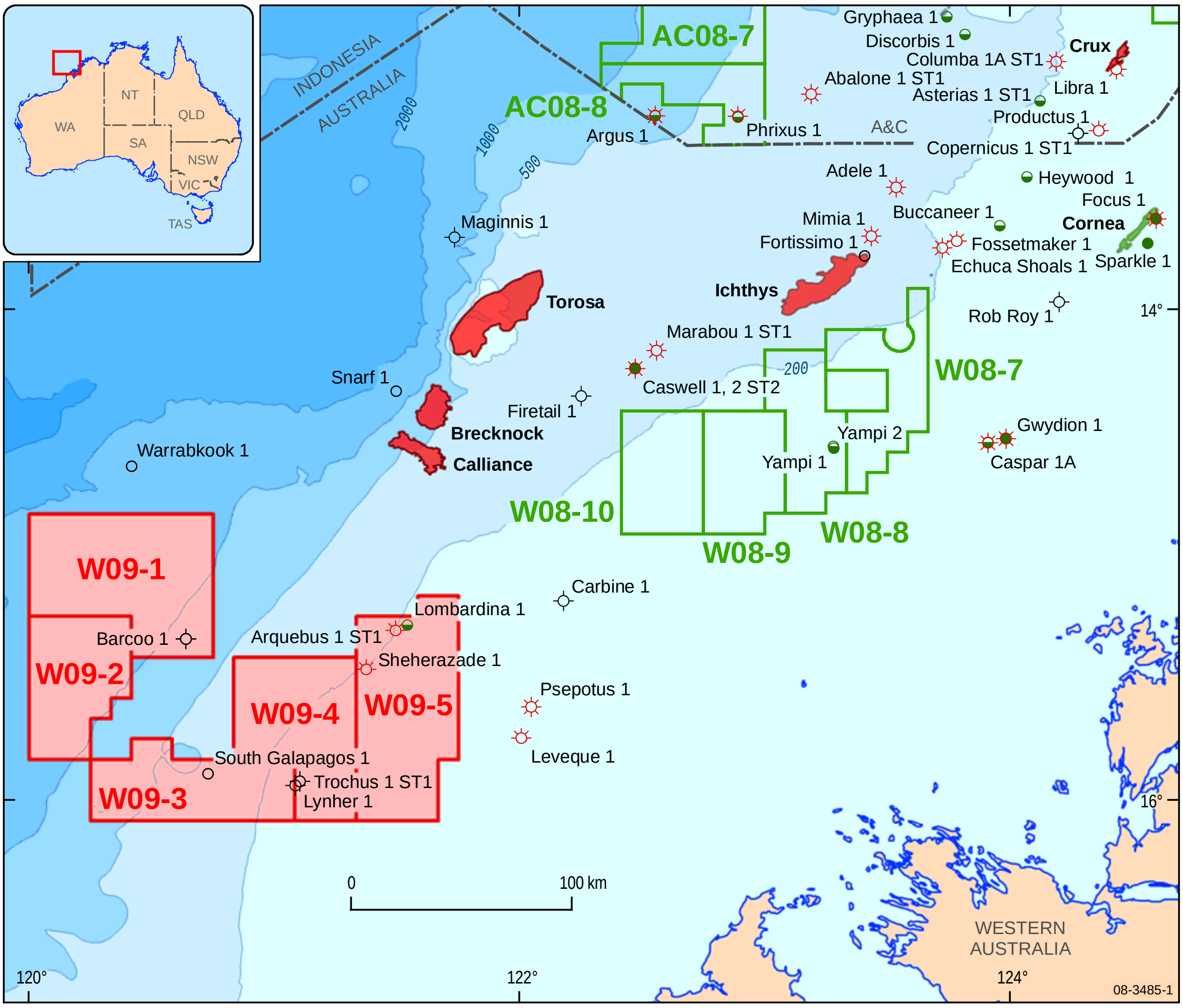

Where well symbol information is sourced from publicly available "open file" data, it has been provided by Geoscience Australia from Well Completion Reports. These symbols were generated from open file data as at 31 March 2009. Where well symbol information is not publicly available from titleholders' 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 outlines for Ichthys and Cornea are sourced from IHS Energy, 2006.

- *2009 Offshore Petroleum Acreage Release Area*
- *2008 Offshore Petroleum Acreage Release Area*
- *Gas field*
- *Oil field*
- *Scheduled area boundary (OPGGSA 2006)*
- 200 *Bathymetry contour (depth in metres)*

- *Petroleum exploration well - Not classified*
- *Petroleum exploration well - Dry hole*
- *Petroleum exploration well - Gas discovery*
- *Petroleum exploration well - Oil and gas discovery*
- *Petroleum exploration well - Gas discovery and oil show*
- *Petroleum exploration well - Gas show*
- *Petroleum exploration well - Oil and gas show*
- *Petroleum exploration well - Oil discovery and gas show*
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- *Petroleum exploration well - Oil show*

Figure 1. Location map of the Browse Basin showing existing petroleum accumulations and significant wells and 2008 and 2009 Release Areas.

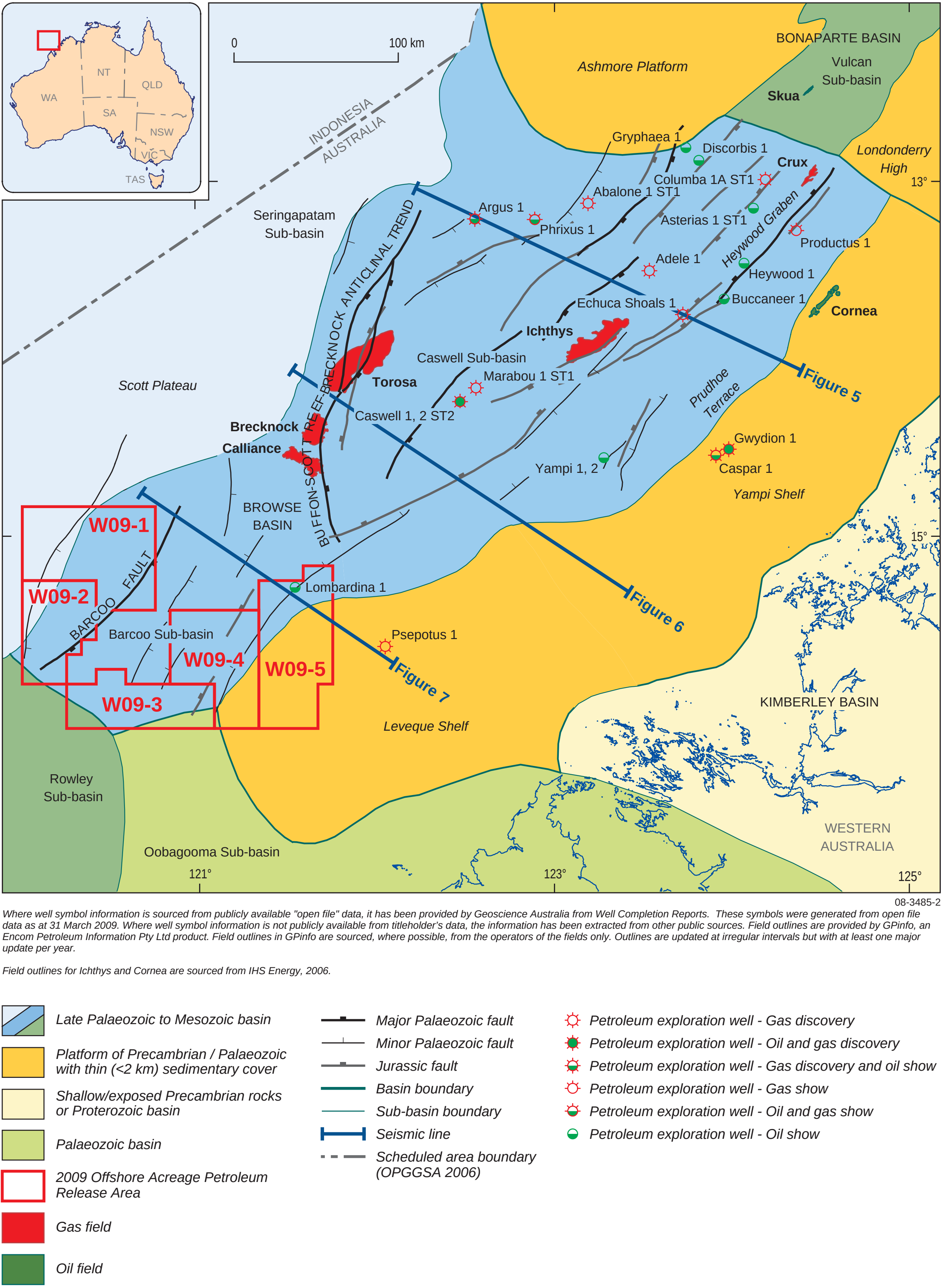

Figure 2. Regional geological setting of the Browse Basin (after Struckmeyer et al, 1998), showing key discoveries and the location of seismic lines BBHR 175/10 (Figure 5), BBHR 175/05 (Figure 6) and BBHR 175/03 (Figure 7).

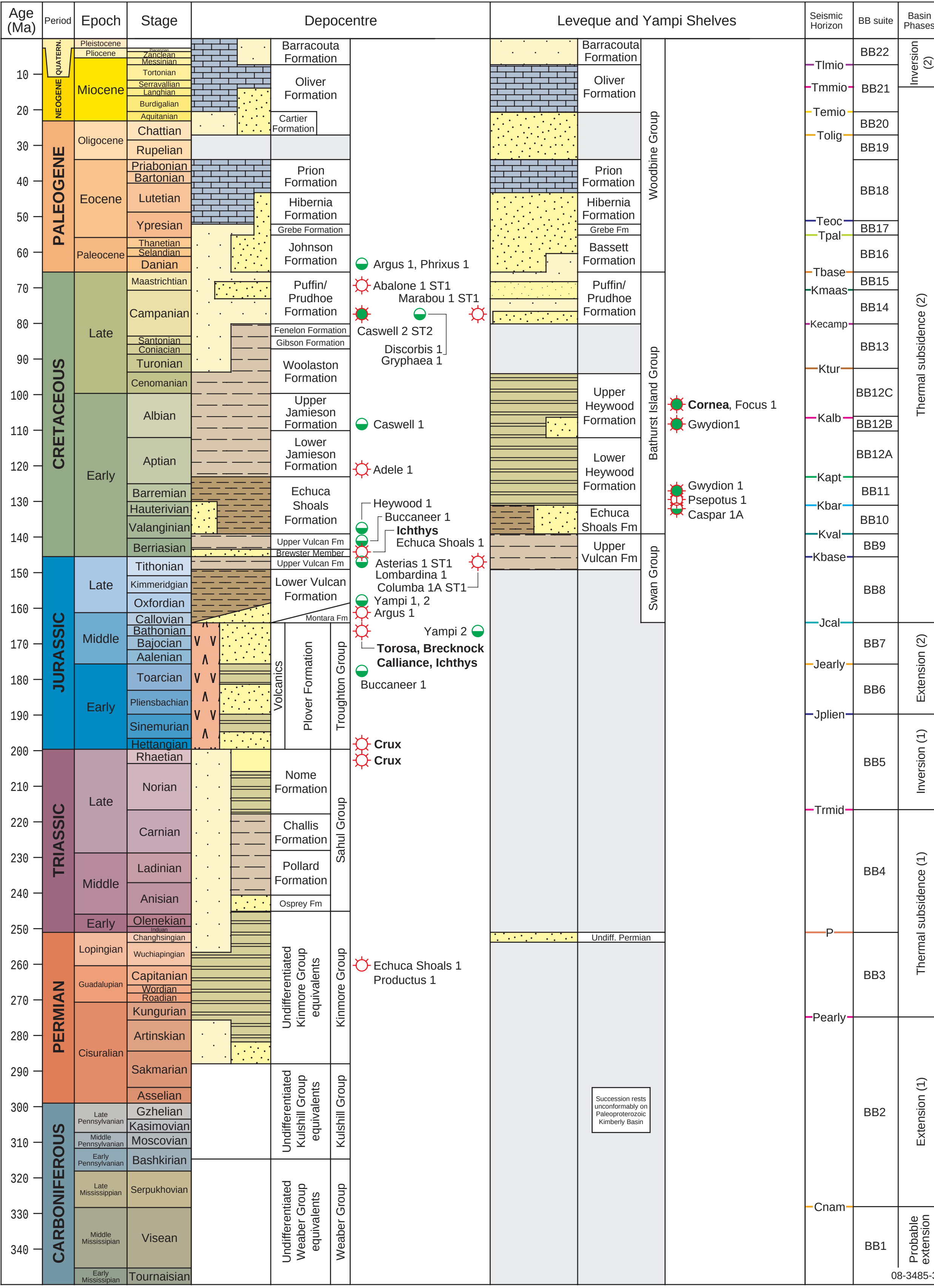

Figure 3. Tectonostratigraphic summary and hydrocarbon discoveries for the Browse Basin. Formation boundaries and unconformity bounded sequences defined in Blevin et al. (1997) matched to the timescale of Gradstein et al. (2004).

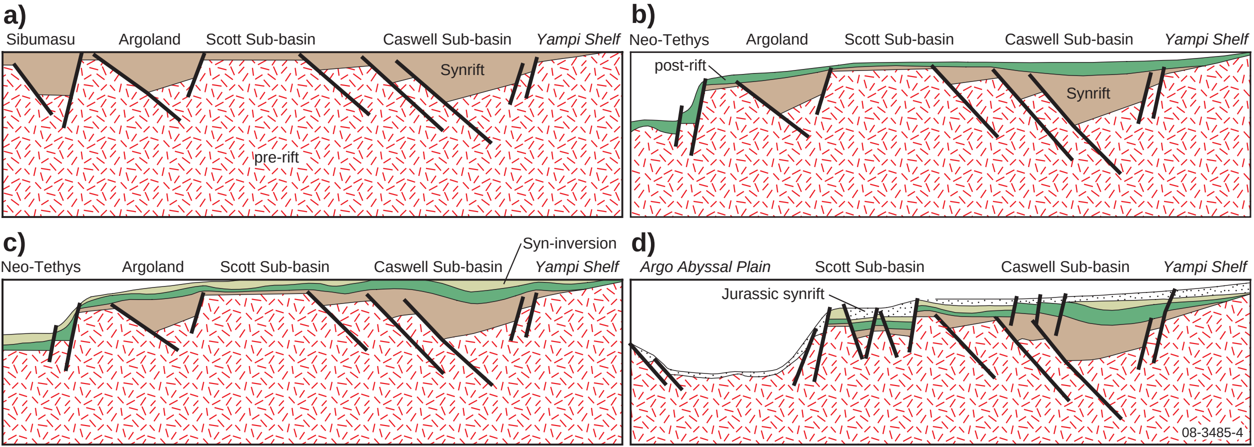

Figure 4. Schematic cross-sections illustrating major basin-forming events in the Browse Basin (sections are not to scale): a) Late Carboniferous to Early Permian extension (Late Permian basin geometry); b) Late Permian to Middle Triassic thermal subsidence (Middle Triassic basin geometry); c) Late Triassic inversion (Hettangian basin geometry); d) Early to Middle Jurassic extension (Callovian basin geometry) (from Struckmeyer et al, 1998).

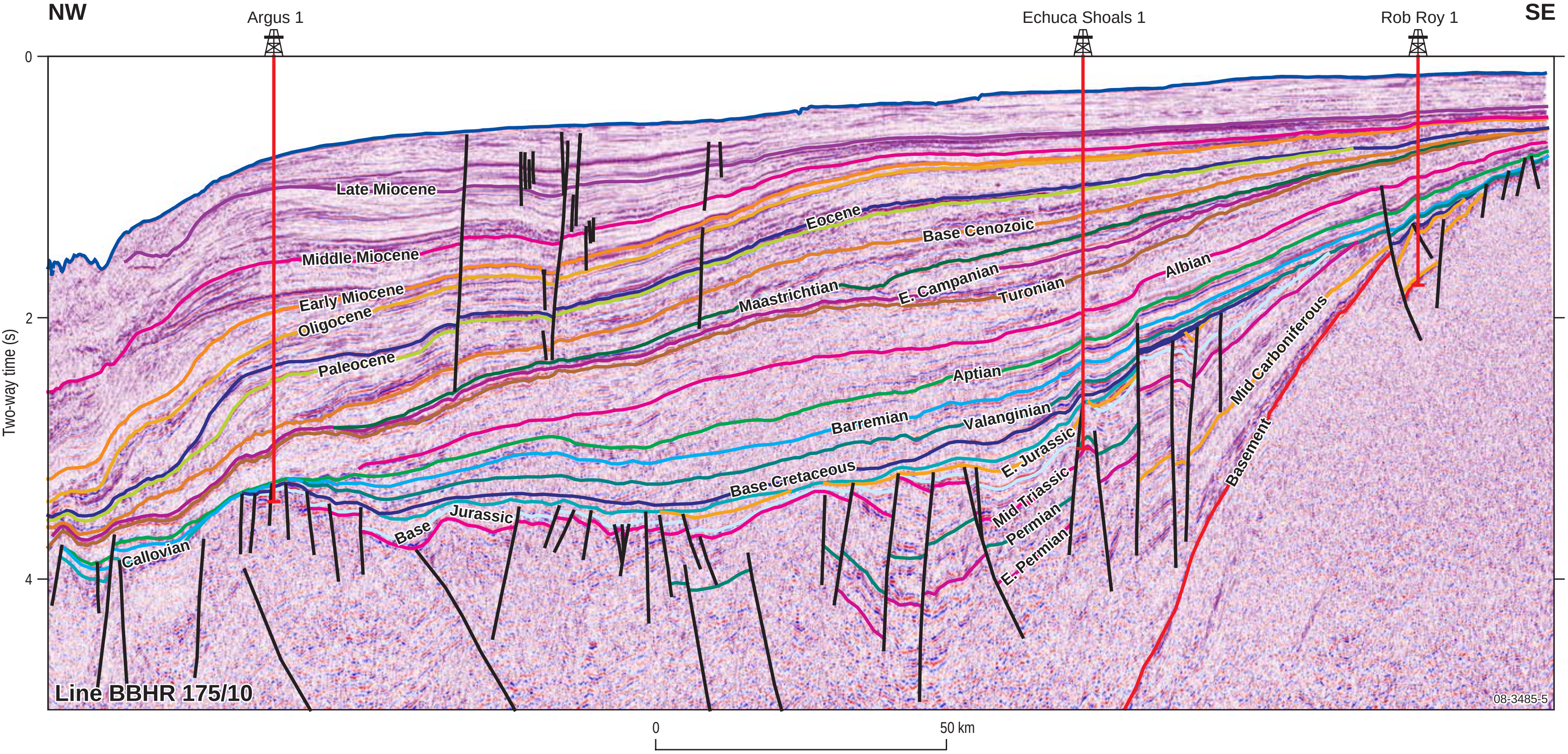

Figure 5. Seismic line BBHR 175/10 through Argus 1, Echuca Shoals 1 and Rob Roy 1, northern Caswell Sub-basin. Location of the line is shown in Figure 2. Regional seismic horizons are shown in Figure 3.

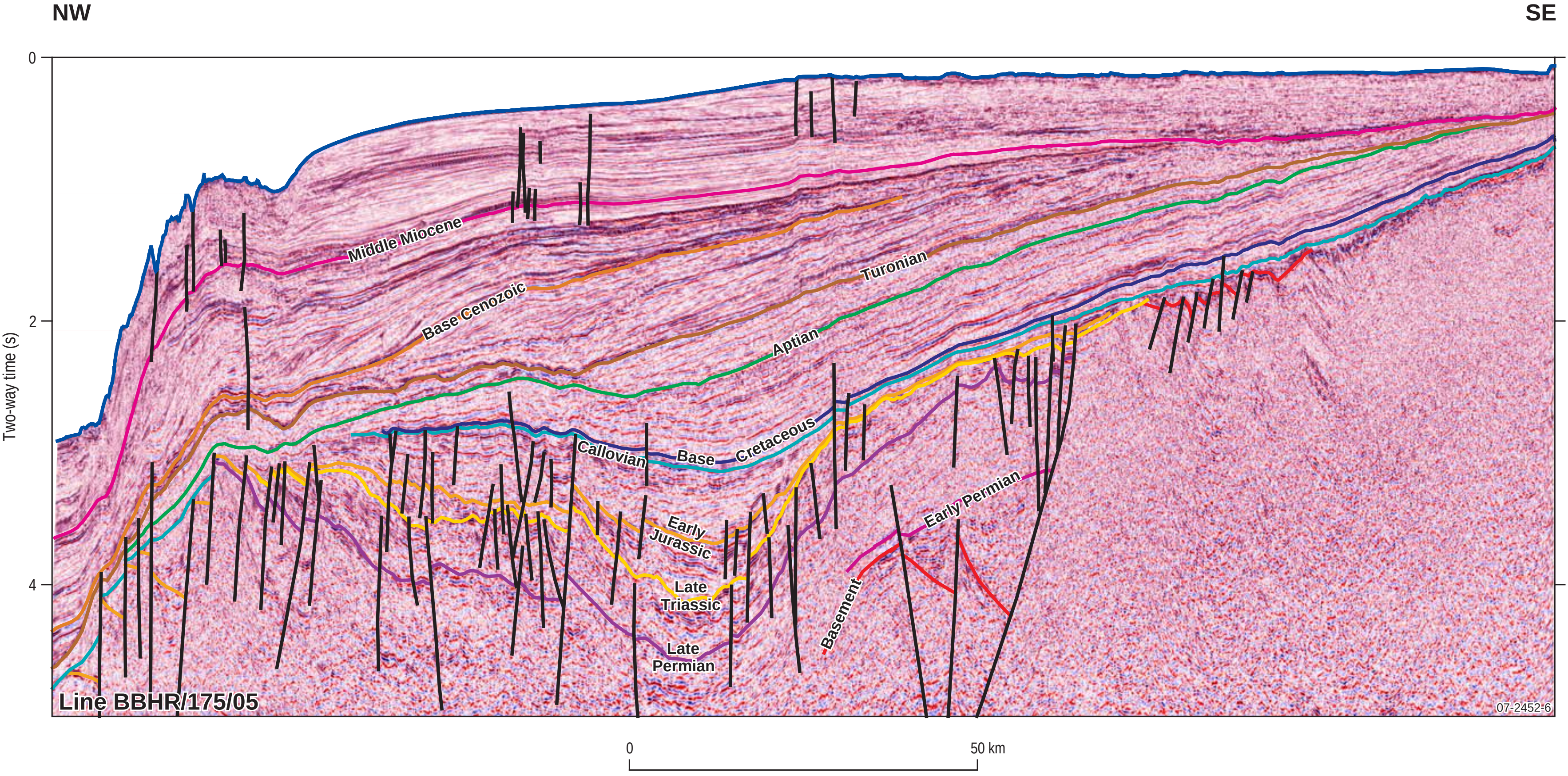

Figure 6. Seismic line BBHR 175/05, southern Caswell Sub-basin. Location of the line is shown in Figure 2. Regional seismic horizons are shown in Figure 3.

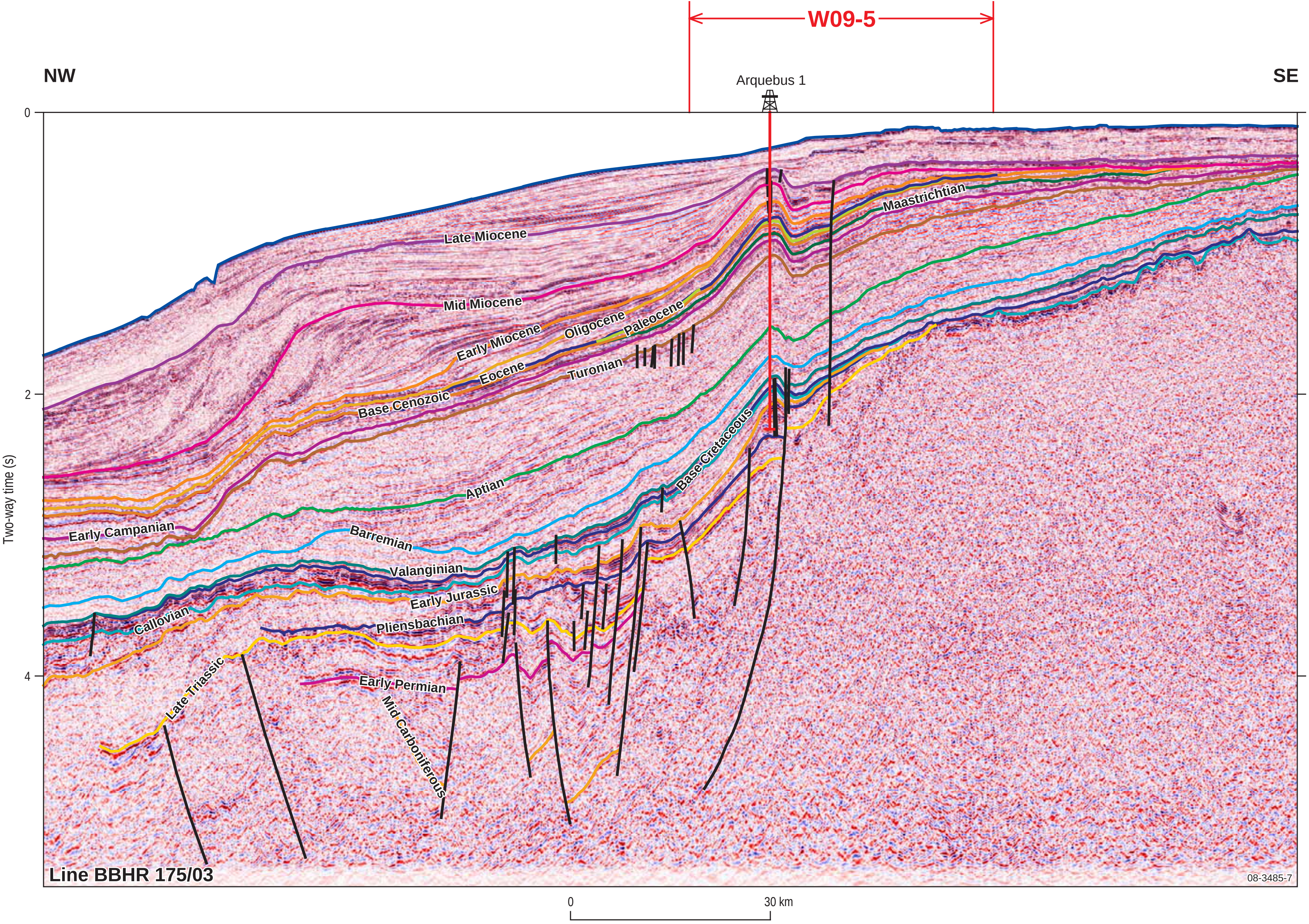

Figure 7. Seismic line BBHR 175/03 through Arquebus 1 and across Release Area W09-05 over the Barcoo Sub-basin and Leveque Shelf. Location of the line is shown in Figure 2. Regional seismic horizons are shown in Figure 3.

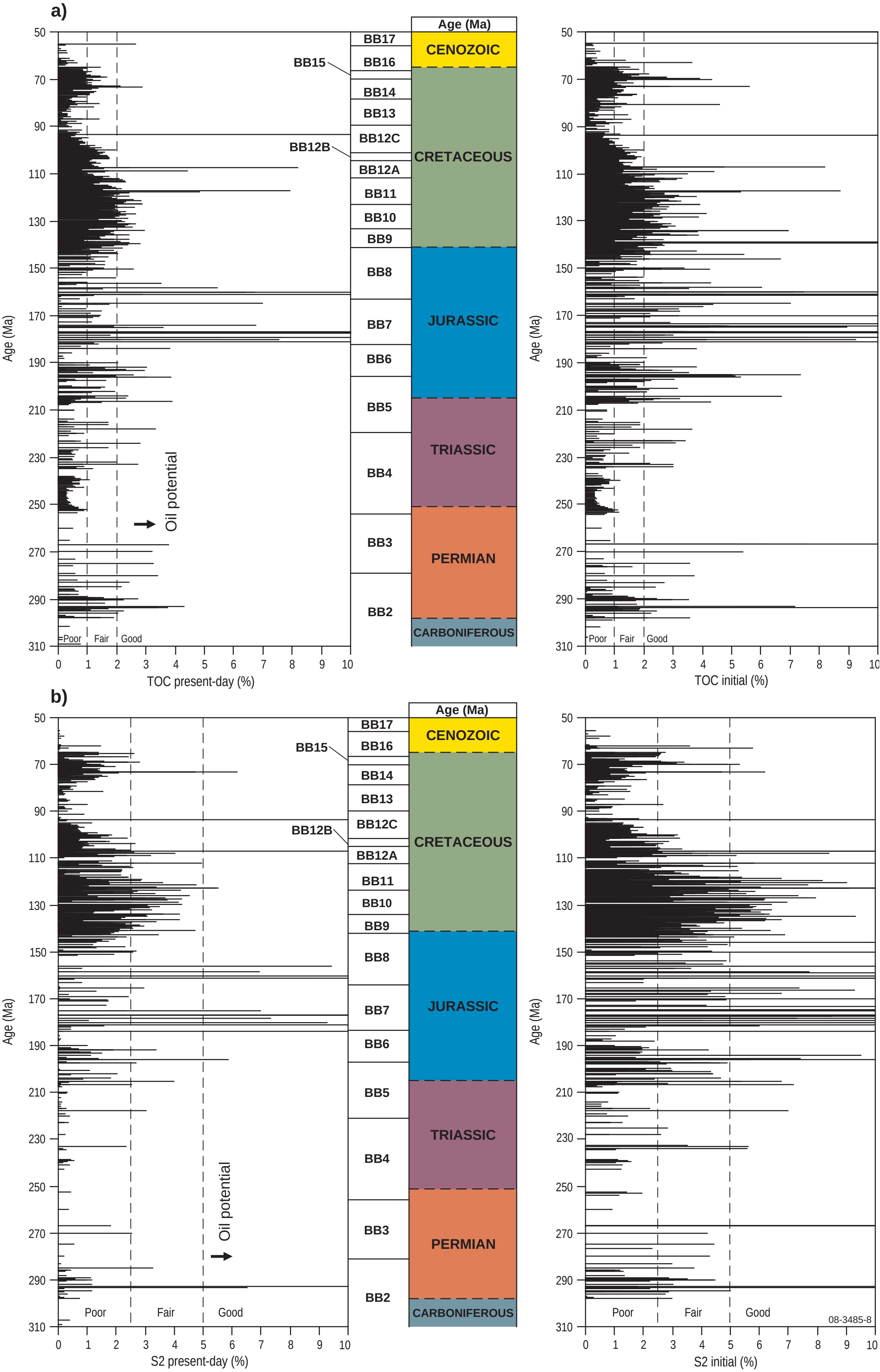

Figure 8. Plots of age (a) present day and initial TOC, and (b) present day and initial S2 values for the Browse Basin wells drilled prior to 1998 (after Blevin et al, 1998a).

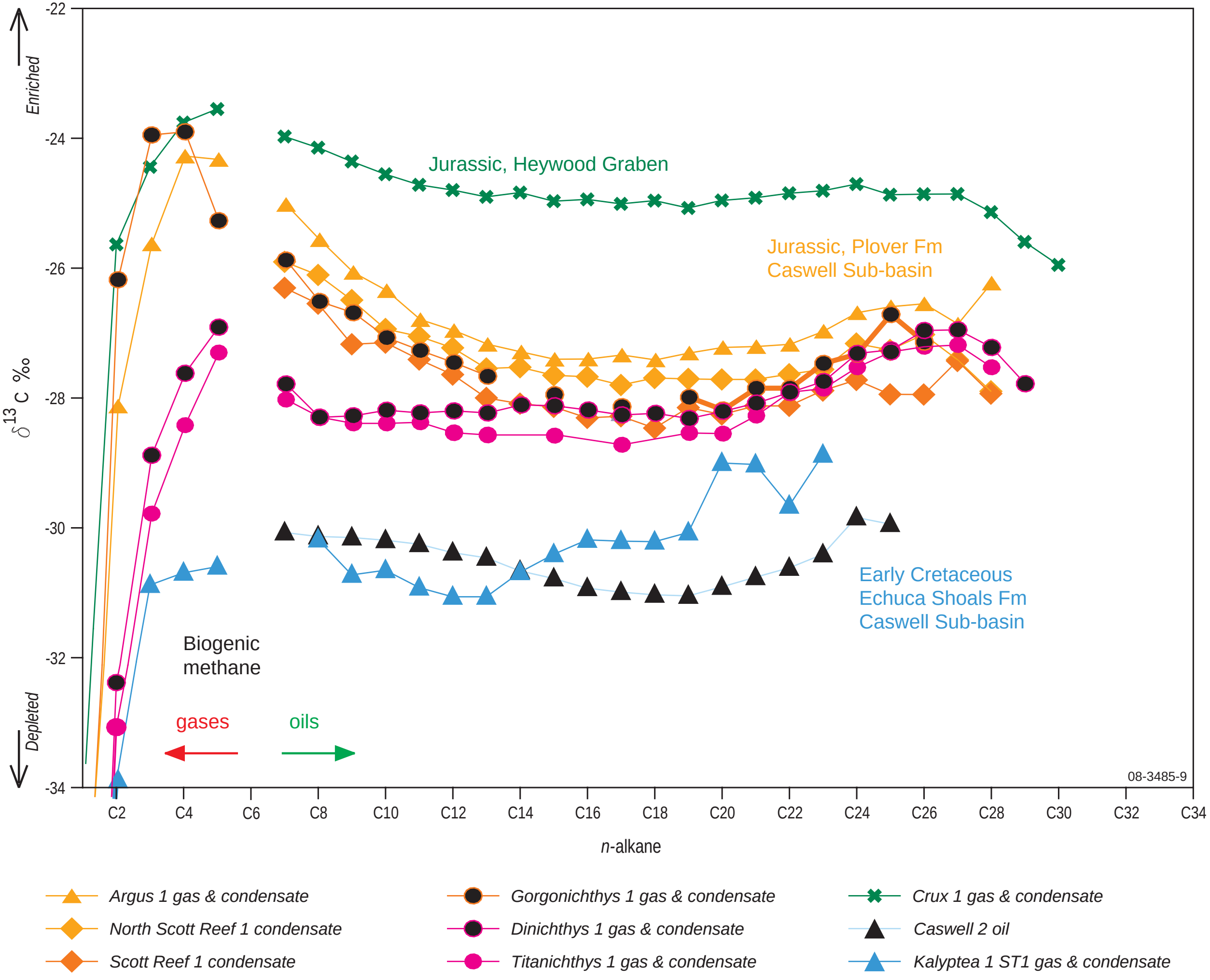

Figure 9. Carbon isotopic composition for gases and C_{7+} *n*-alkanes of condensates and oils recovered from the Browse Basin (after Edwards et al, 2004, 2006).

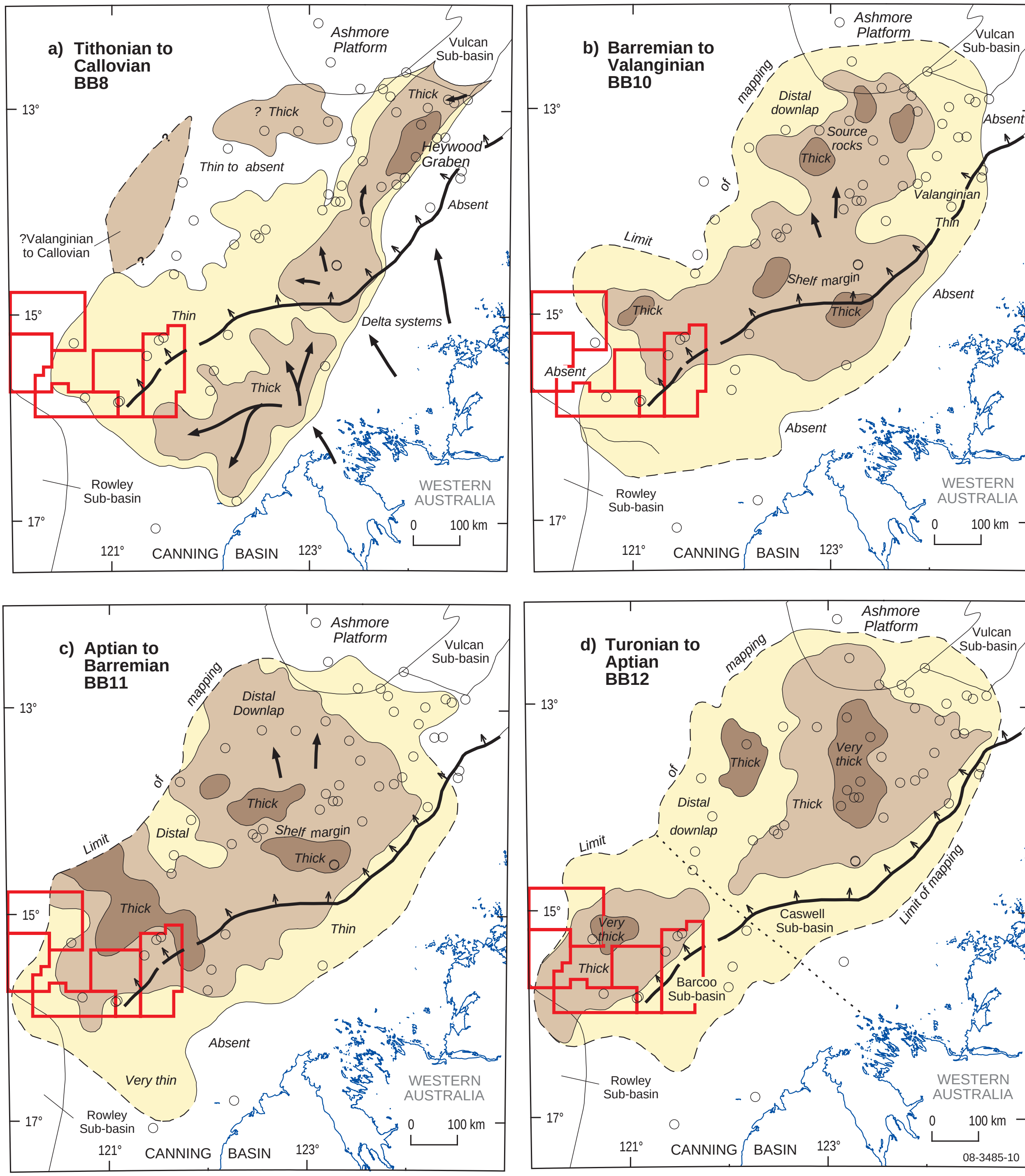

Figure 10. Generalised distribution map of (a) Tithonian to Callovian, (b) Barremian to Valanginian, (c) Aptian to Barremian, and (d) Turonian to Aptian sediments in the Browse Basin (based on two-way time isopach maps; after Blevin et al, 1998a). The shelf margin hinge is shown in black and arrows indicate the direction of sediment transport. The 2009 Release Areas are shown in red.