Australian Government
Department of Resources, Energy and Tourism

2008 RELEASE OF AUSTRALIAN OFFSHORE PETROLEUM EXPLORATION AREAS

RELEASE AREAS W08-18, W08-19 AND W08-20 EXMOUTH SUB-BASIN, CARNARVON BASIN WESTERN AUSTRALIA

SECTIONS

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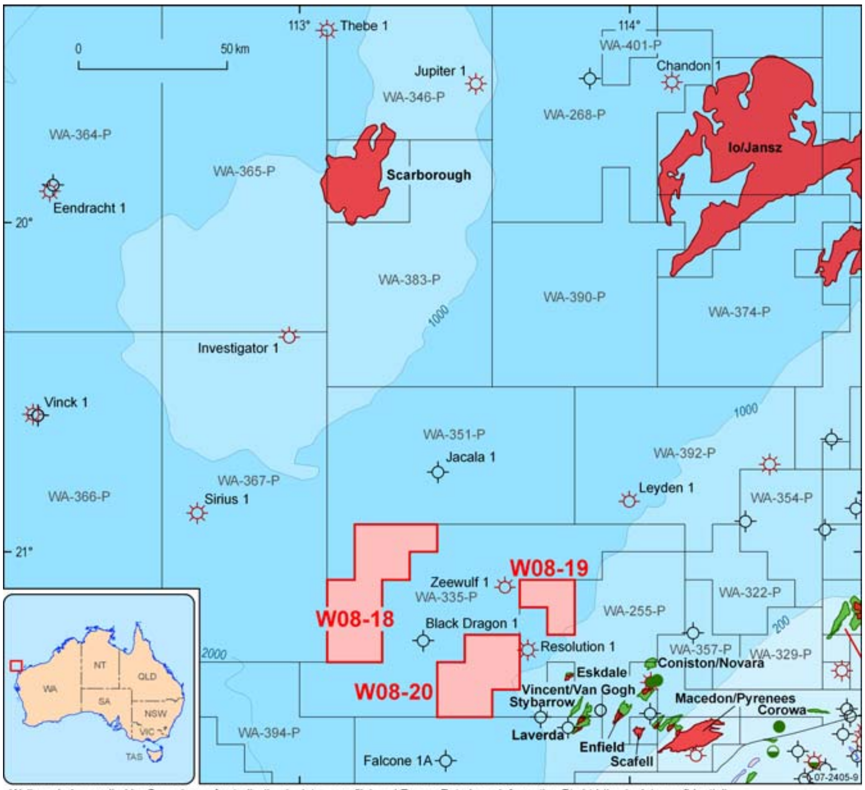
SUMMARU

RELEASE AREAS W08-18, W08-19 and W08-20
EXMOUTH SUB-BASIN, CARNARVON BASIN
WESTERN AUSTRALIA

BIDS CLOSE - 9 OCTOBER 2008

- Adjacent to Australia's major new oil producing province
- Barrow Group and Triassic fault block plays
- W08-20 and W08-19 near to recently discovered oil and gas fields
- Special Notices apply, refer to Guidance Notes



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CARNARVON BASIN REGIONAL GEOLOGY

The Carnarvon Basin is the southernmost component of the Late Palaeozoic to Cenozoic Westralian Super-basin that underlies the northwestern continental margin of Australia from North West Cape in the south to the Arafura Sea in the north. The basin contains a series of major Mesozoic depocentres, most of which lie offshore (**Figure 1**). The southern part of the basin consists of Palaeozoic depocentres, with Palaeozoic strata being exposed onshore.

The northern, offshore part of the Carnarvon Basin evolved from a pre-rift, predominantly sag-type basin in the Late Palaeozoic, through a tectonically active period of syn-rift sub-basins in the Jurassic, to a passive margin carbonate shelf in the Cenozoic (**Figure 2**). The geological evolution of the basin has been discussed in detail by many authors, and the summary presented below is derived from the work of Kopsen and McGann (1985), Boote and Kirk (1989), Hocking (1990), Jablonski (1997), Westphal and Aigner (1997), Tindale et al (1998), Bussell et al (2001), Norvick (2002), and Longley et al (2002).

The offshore part of the Carnarvon Basin comprises the Investigator, Exmouth, Barrow, Dampier and Beagle sub-basins, the Exmouth Plateau (including the Investigator Sub-basin) and the Rankin Platform (**Figure 1**). The tectonic elements of the region are dominated by a northeasterly trend that developed as a result of rift tectonism initiated in the Early Jurassic and continuing until the Late Jurassic. Proximal basin-bounding faults are similarly oriented, and subsequent tectonic movements have variably inherited this structural alignment. The last major rift-related tectonism occurred in the Valanginian, preceding the final continental separation of Greater India from Australia.

As a result of the Jurassic and Early Cretaceous rift tectonism, the Barrow and Dampier sub-basins formed a northeast-trending graben, bounded on the distal side by the buried fault escarpment of the Rankin Platform and the Exmouth Plateau. The oceanic crust of the Argo, Cuvier and Gascoyne abyssal plains bound the distal area of the Exmouth Plateau, and the Exmouth and Investigator sub-basins.

BASIN EVOLUTION AND TECTONIC DEVELOPMENT

The Palaeozoic evolution and stratigraphy of the northern offshore part of the Carnarvon Basin is poorly known, mainly because the area has not been considered an exploration target to date. The Mesozoic and Cenozoic successions are divided into several mega-sequences, variably influenced by tectonic phases associated with major rifting and sea-floor spreading. A generalised stratigraphy of the basin is shown in **Figure 2** and comprises the following mega-sequences:

- Pre-rift active margin (Triassic to mid-Pliensbachian)
- Early syn-rift (mid-Pliensbachian to mid-Callovian)
- Main syn-rift (mid-Callovian to latest Tithonian)
- Late syn-rift Barrow Delta (latest Tithonian to mid-Valanginian)
- Post-rift active margin (mid-Valanginian to mid-Santonian)
- Passive margin (mid-Santonian to Miocene)

Depositional environments and hydrocarbon generation, migration and entrapment are strongly controlled by rift-related tectonism in the basin. During the pre-rift phase, marine and fluvio-deltaic sediments were deposited in a broad basin. This basin subsequently fragmented into smaller depocentres in which marine and deltaic sediments were deposited during the early syn-rift phase and restricted marine sediments accumulated during the main syn-rift phase. During the late syn-rift phase, various marine sediments were deposited within the framework of the large-scale Barrow delta system. In the post-rift phase, transgressive shaly marine deposition prevailed. During the subsequent passive margin phase, a variety of marine carbonate sediments accumulated in open marine shelfal environments.

Clastic sediments were predominantly sourced from the southeastern cratonic flank throughout the Mesozoic and Cenozoic evolution of the basin (Longley et al, 2002). However, in the Triassic, sediments may also have been delivered into the Carnarvon Basin from regions to the north and east (Norvick, 2002; Jablonski and Saitta, 2004). In addition, tectonic uplift in the Jurassic and syn-depositional inversions in the Cretaceous provided depocentres for reworked sediments from uplifted areas within the basin.

PRE-RIFT ACTIVE MARGIN (TRIASSIC TO MID-PLIENSBACHIAN)

A regional marine transgression, as a result of post-rift sagging of the previous Palaeozoic rift cycle, commenced at the beginning of the Triassic, leading to the deposition of the Locker Shale unconformably overlying Permian sediments (**Figure 2**). The Locker Shale accumulated in broad, relatively unfaulted downwarps and grades upwards into the fluvio-deltaic Mungaroo Formation, which is composed of thick sandstone sequences and claystones with minor coals. The fluvio-deltaic system prograded to the northwest where it covered much of the offshore part of the Carnarvon Basin. The Mungaroo Formation represents deposition in a broad, low relief, rapidly subsiding coastal plain, which included an extensive swamp system that was cross-cut by fluvial channels. The Mungaroo Formation also contains distinct limestone units.

The fluvial sandstones of the Mungaroo Formation form the principal reservoir facies of the giant gas accumulations on the Rankin Platform. The uppermost, marine part of the Mungaroo Formation consists of shoreline sandstones and claystones. The uppermost part of the Mungaroo Formation is absent due to erosion in the eastern part (around the North Rankin gas field) of the Rankin Platform. In contrast, this part of the formation is well preserved on the western distal portion of the Rankin Platform where it is one of the major reservoirs in the Gorgon, Geryon, Maenad, Orthrus and Chandon gas accumulations (**Figure 3**).

Throughout much of the Triassic, the onshore portions of the Carnarvon Basin and the onshore Pilbara Block underwent active uplift and erosion, providing sediment sources for the Locker Shale and Mungaroo Formation. However, some of the large sediment volume in the Mungaroo Delta, which stretched across the Exmouth Plateau, may have been derived from much further away. Sandy sediments from eastern and central Australia may have been delivered via transcontinental river systems emerging into the Westralian Superbasin through the onshore Canning Basin. Other potential sediment source areas lay to the north (Argo Land/West Burma) and south (Greater India) of the Exmouth Plateau in the Triassic prior to rifting (Norvick, 2002; Jablonski & Saitta 2004).

However, whatever the various contributions, the abundant sediment supply was disrupted by the end of the Triassic (Hocking, 1990). Marking rapid subsidence at the onset of the Early Jurassic, the transgressive Brigadier Formation and Murat Siltstone were deposited in a marine shelf environment and comprise thinly bedded marine siltstones, claystones and marls. The Brigadier Formation is well preserved below a widespread Late Jurassic unconformity in the outer part of the Carnarvon Basin, and the top of the formation represents the maximum flooding surface of the Early Jurassic marine transgression. Within the Kangaroo Syncline in the southern Exmouth Plateau, the preserved Early to Middle Jurassic section, including the Brigadier Formation, is thicker than on the Rankin Platform (Bussell et al, 2001). Thin, reservoir-quality sandstones on some horst blocks along the Rankin Platform are known as the North Rankin Formation.

EARLY SYN-RIFT (MID-PLIENSBACHIAN TO MID-CALLOVIAN)

The pre-rift active margin to syn-rift transition is represented by the rift-onset Pliensbachian unconformity (JP1 seismic horizon; **Figure 2**). Extensional rift-faulting and warping produced northeast-trending tilted fault blocks, horsts and grabens (Barber, 1988). The development of the Exmouth, Barrow and Dampier sub-basins and Rankin Platform was initiated during this early syn-rift phase, and these elements remained tectonically active throughout the Jurassic.

The early syn-rift mega-sequence (mid-Pliensbachian to mid-Callovian) comprises restricted marine claystones of the Athol Formation and deltaic sandstones of the Legendre Formation. The Legendre Delta developed in the early Bathonian in the Dampier Sub-basin, but sedimentation ceased by the early Callovian.

MAIN SYN-RIFT (MID-CALLOVIAN TO LATEST TITHONIAN)

The mid-Callovian unconformity surface (JC seismic horizon; **Figure 2**) defines the boundary between the early syn-rift (mid-Pliensbachian to mid-Callovian) and main syn-rift (mid-Callovian to latest Tithonian) mega-sequences. This unconformity represents the onset of the continental breakup of the northwest Australian margin (Jablonski, 1997). Claystones of the transgressive Callovian Calypso Formation were deposited in the Barrow and Dampier sub-basins over the unconformity surface.

Major rift-faults developed along the northern edge of the Exmouth Plateau in the Callovian, but continuous oceanic crust was not created until the Late Oxfordian (Norvick, 2002). The basal Oxfordian unconformity (‘Breakup Unconformity’; JO seismic horizon; **Figure 2**) represents this phase of continental breakup and the onset of sea-floor spreading to form the Argo Abyssal Plain.

The term ‘Main Unconformity’ (MU seismic horizon; **Figure 2**) has been used widely to refer primarily to the basal Oxfordian (JO) unconformity. In practice, however, this horizon is often a composite sequence boundary, ranging in age from basal Jurassic in one part of the basin to Aptian in another (Jablonski, 1997). For instance, in some areas on the Rankin Platform, the Norian

Mungaroo Formation underlies the Albian Windalia Radiolarite or Gearle Siltstone, indicating that the Main Unconformity represents a 92 million year hiatus (Newman, 1994). A large and inconsistent time break at the Main Unconformity has led to confusion regarding the nature and timing of erosion. Because of the diachronous nature of the unconformity surface, the composite Main Unconformity is also called the 'Intra-Jurassic unconformity (IJU seismic horizon; **Figure 2**) (Sibley et al, 1999).

Following continental breakup, active faulting continued in the Late Jurassic. This resulted in uplift and tilting of the shelf and Rankin Platform. Reworked sediments were deposited in depocentres adjoining the uplifted areas. Tectonic subsidence rates far exceeded sedimentation rates in regional depocentres, resulting in a thick succession of the deep-water Dingo Claystone, which gradually filled the graben depocentres and progressively overlapped the flanks of high blocks (Tindale et al, 1998). This deep-water marine sedimentation was confined to the graben depocentres of the Barrow, Dampier and Exmouth sub-basins. The Oxfordian maximum flooding phase of the graben system provided a favourable depositional environment for high quality, oil-prone source rocks (Norvick, 2002).

Although marine claystones dominate the main syn-rift (mid-Callovian to latest Tithonian) mega-sequence, paradoxically this is also the time when reservoir-quality turbidite, submarine fan, shoreline and fluvial sandstones were deposited locally at the edge of tectonically active grabens.

On the eastern portion of the Exmouth Plateau, Late Jurassic deposition of sandy shelfal facies occurred within restricted shallow basins. The Kangaroo Syncline was also tectonically active during the Late Jurassic across the southern Exmouth Plateau and northern Exmouth Sub-basin, in response to footwall uplift of the Triassic tilted fault blocks on the Rankin Platform. The uplift created a hinterland that provided a source for coarse clastic sediments eroded from the Mungaroo Formation and transported into the shallow marine environment of the syncline. By the Tithonian, the gradual subsidence and peneplanation of the provenance area limited clastic input to the syncline (Jenkins et al, 2003).

Oxfordian shallow-marine sandstones (Jansz Sandstone) represent the major reservoir interval in a stratigraphic trap for the giant Jansz/Io gas accumulation (Jenkins et al, 2003). The Biggada Sandstone, Dupuy and Angel formations are other significant reservoir-quality sandstones deposited in this mega-sequence. For example, turbidite sandstones of the Angel Formation, which are the major oil- or gas-bearing reservoirs in the Dampier Sub-basin, were deposited in the Tithonian when reactivation of horsts and grabens resulted in further erosion of marginal areas with reworking of quartz-rich sandstones (Hocking, 1990).

Further inshore, an Oxfordian shallow-marine sandstone (Linda Sandstone) was deposited in the eastern Barrow Sub-basin, which has traditionally been viewed as a deep-water depocentre. Late Jurassic shore-face and shallow-marine sandstones may be aligned parallel to shorelines elsewhere in the Carnarvon Basin (Moss et al, 2003).

LATE SYN-RIFT BARROW DELTA (LATEST TITHONIAN TO MID VALANGINIAN)

Latest Jurassic uplift and erosion marked the onset of late syn-rift (latest Tithonian to mid-Valanginian) sedimentation. The large Barrow Delta system abruptly and briefly developed in the Carnarvon Basin during this tectonically quiescent phase. The Barrow Delta was extensive, and its sediments are up to 2500 m thick. The delta prograded in two major phases, and two main delta lobes were developed. The initial depositional phase occurred over the Exmouth Sub-basin in response to a prominent supply of sediments from the south. The delta then prograded rapidly to the north over a thick pile of turbidites and pro-delta shales to a maximum northward limit roughly west from Barrow Island across the Exmouth Plateau. On the Exmouth Plateau, the Barrow Group consists of turbidites, basin floor fans and fluvio-deltaic sediments of the lower Barrow Delta lobe. A turbidite fan formed the sandstone complex at the Scarborough gas accumulation to the north of the delta front (Norvick, 2002).

While the Barrow Delta resumed progradation in the late Berriasian, erosion of the lower delta lobe occurred in the inshore part of the Exmouth Sub-basin. The new depocentre of the delta retreated 250 km to the east and extended beyond the eastern limit of the first phase. As a result, a back-stepped delta (upper Barrow Delta lobe) developed in the Barrow and Dampier sub-basins. The second phase of delta progradation reached its northern limit around the Gorgon horst structure.

The sediments of the lower (or western) Barrow Delta lobe are collectively known as the Malouet Formation comprising bottom-set submarine fan sandstones and pro-delta claystones, and those of the upper (or eastern) lobe are known as the Flacourt Formation, comprising basinal turbidites, fore-set claystones and top-set sandstones. The boundary between the two lobes is markedly diachronous and cannot always be picked as a continuous regional seismic horizon (Baillie and Jacobson, 1997). The lower Barrow Delta lobe contains approximately 75% of the sediments deposited by the Barrow Delta system (Ross and Vail, 1994). Barrow Group sandstones are predominantly quartzose with minor clay matrix and are weakly cemented by calcite, pyrite or siderite. Porosity and permeability in these sandstones tend to be excellent in the outer part of the Carnarvon Basin.

Sandy units within the top-Barrow Group are variously named, and their nomenclature is somewhat confusing. They include; the top-sandstone of the Barrow Group, top-sandstone of the Flacourt Formation, Zeepaard Formation, and Flag Sandstone. The Zeepaard Formation was deposited across wide areas of the Barrow and Exmouth sub-basins, Rankin Platform and Exmouth Plateau as progradational top-set units of the Barrow Delta in front of multiple distributaries at slightly different times in the early Valanginian. In contrast, the Flag Sandstone was deposited as a submarine fan sandstone in the northeastern proximal part of the Barrow Sub-basin, in front of the last fore-set of the Barrow Delta.

Sediment supply to the Barrow Delta system ceased due to the disruption of a major fluvial distributary system in the Valanginian, when continental breakup commenced to the southwest of the Exmouth Plateau (Hocking, 1990). The

Exmouth Sub-basin and Exmouth Plateau were tectonically inverted during breakup, but subsidence and marine sedimentation continued throughout the Barrow and Dampier sub-basins.

POST-RIFT ACTIVE MARGIN (MID-VALANGINIAN TO MID-SANTONIAN)
After tectonic uplift and faulting associated with the separation of Greater India and Australia in the Valanginian, a large portion of the Carnarvon Basin was subjected to peneplanation. This event was followed by regional post-rift sag sedimentation in the offshore part of the basin from the mid-Valanginian to mid-Santonian.

Post-rift marine deposition commenced on the Valanginian unconformity surface (KV seismic horizon; **Figure 2**), and the Birdrong Sandstone and glauconitic Mardie Greensand Member were deposited in smaller deltas. This localised sedimentation cycle was followed by the basin-wide deposition of the transgressive marine Muderong Shale, Windalia Radiolarite and Gearle Siltstone. The Muderong Shale is a regional seal, but also contains economically important petroleum-bearing marine sandstones such as the *M. australis* Sandstone (also known as the Stag Sandstone) and Windalia Sandstone in the Barrow and Dampier sub-basins. These diachronous sandstones overlie the intra-Valanginian unconformity and are characteristically glauconitic.

The Windalia Sandstone of the Muderong Shale was historically a major exploration target in the Barrow Sub-basin. More than 90% of the initial oil reserves of the Barrow Island oil field, which is the largest in the Carnarvon Basin, are contained within this sandstone (Ellis et al, 1999).

PASSIVE MARGIN (MID-SANTONIAN TO MIOCENE)
Siliciclastic sedimentation ceased by the mid-Santonian as a result of tectonic stability and a decreasing supply of terrigenous sediments. Shelfal carbonate sediments were deposited on the passive continental margin in the Late Cretaceous and Cenozoic, as the whole region continued to subside after cessation of the rifting process. On the deep-water Exmouth Plateau, sedimentary section deposited during this period was relatively thin, as subsidence rates outstripped sediment input. Towards the end of the Cretaceous, however, the Kangaroo Syncline on the Exmouth Plateau became the major depocentre of the Carnarvon Basin.

During the Campanian, uplift of the hinterland resulted in a phase of inversion in the Exmouth Sub-basin and Exmouth Plateau, forming the Exmouth Plateau Arch. This tectonic event also marked the onset of transpressional structural growth of pre-existing rift-related structures within the Barrow and Dampier sub-basins (Longley et al, 2002).

In the Miocene, a major compressional event associated with the collision of the Australia-India and Eurasia plates affected the entire northwest Australian margin, including the Carnarvon Basin (Longley et al, 2002). This event caused tilting, inversion, renewed movement on faults, and the creation of new strike-slip or wrench faults (Malcolm et al, 1991). This is also the time when many structural traps within the Cretaceous and Cenozoic strata were formed.

REGIONAL HYDROCARBON POTENTIAL

The Carnarvon Basin is Australia's most prolific hydrocarbon-producing basin; 70.9 MMbbl (11.3 GL) of oil, 980 Bcf (27.4 Bcm) of gas and 35.9 MMbbl (5.7 GL) of condensate were produced in 2006 (DoIR, 2007).

This represents more than half of Australia's total hydrocarbon production. During 2006, 26 new field wildcats were drilled in the offshore Carnarvon Basin and there were 46 producing fields, including Barrow Island (Petroleum and Royalties Division and Geological Survey of Western Australia, 2007).

The majority of the hydrocarbons discovered to date in the Carnarvon Basin are hosted by highly porous reservoirs beneath the Early Cretaceous Muderong Shale, which forms the regional seal. The presence of this effective regional seal is a major contributing factor to exploration success in the basin (Baillie and Jacobson, 1997). One of the notable exceptions is the Barrow Island oil field, where the oil-bearing Windalia Sandstone of the Muderong Shale is top-sealed by the Aptian Windalia Radiolarite. Another exception is the Maitland gas accumulation, in which a Paleocene sandstone is the reservoir. Intra-formational seals are also an important element of hydrocarbon accumulations in the basin, resulting in stacked hydrocarbon-bearing reservoirs beneath a regional unconformity surface. Individual pools in gas accumulations on the Rankin Platform are top-sealed by a combination of the regional seal and intra-formational claystones. **Figure 3** shows the major oil and gas accumulations discovered in the Carnarvon Basin.

The main trap styles in the basin are drape anticlines, horsts, fault roll-over structures and stratigraphic pinch-outs beneath the regional seal. The stratigraphic level of top-porosity, ranging from the Late Triassic Mungaroo Formation to the Early Cretaceous Mardie Greensand Member beneath the regional seal, generally becomes progressively younger in the landward direction.

EXPLORATION HISTORY

The first flow of oil to the surface in Australia was recorded in 1953, with the drilling of Rough Range 1 in the onshore Carnarvon Basin, on the eastern edge of the Exmouth Sub-basin. However, the success of Rough Range 1 (an oil flow of 500 barrels a day) was not repeated with the next wells drilled on the structure, a surface anticline located to the south of Exmouth Gulf (Bradshaw et al, 1999). The sustained success that established the Carnarvon Basin as a major hydrocarbon province came in the offshore, in the 1960s and early 1970s, with the WAPET's island and shallow water drilling program (Mitchelmore and Smith, 1994). Giant discoveries were made including in 1964 a billion barrels of oil-in-place at Barrow Island in the Barrow Sub-basin and multi-Tcf gas fields on the Rankin Platform found in 1972. The Legendre oil discovery in 1968 demonstrated that the Dampier Sub-basin, was also petroliferous; and the Beagle Sub-basin was added to the list of proven hydrocarbon-bearing areas in the Carnarvon Basin with the Nebo oil discovery in 1993.

Two major exploration campaigns have focussed on the deepwater Exmouth Plateau, the first in 1979 to 1980 for oil targets, and the second currently underway searching for gas. A giant gas accumulation in an Early Cretaceous Barrow Group basin floor fan was discovered in the Scarborough 1 well in 1980 (Figure 3). The largest discovery yet made in Australia is Jansz, a super-giant gas field in a new play type drilled in 2000 on the Exmouth Plateau in the Carnarvon Basin (Jenkins et al, 2003). Other large gas finds have been made at Wheatstone, Pluto, Xena, Chandon and Clio and exploration effort on the Exmouth Plateau has stepped up a notch with the arrival of new explorers. 3D seismic and AVO technology are key exploration tools and contribute to high success rates (Longley et al, 2002; Korn et al, 2003; Williamson & Kroh, 2007). The Carnarvon Basin has also continued to yield oil discoveries, with the extension of the productive oil trend in the Dampier Sub-basin north to the Mutineer/Exeter field. In the Exmouth Sub-basin, the 1999 Enfield discovery has been followed by a string of oil finds including Coniston, Laverda, Stybarrow, Ravensworth and Stickle, and oil production is now established in this sub-basin.

HYDROCARBON RESERVES

INITIAL RESERVES – CARNARVON BASIN

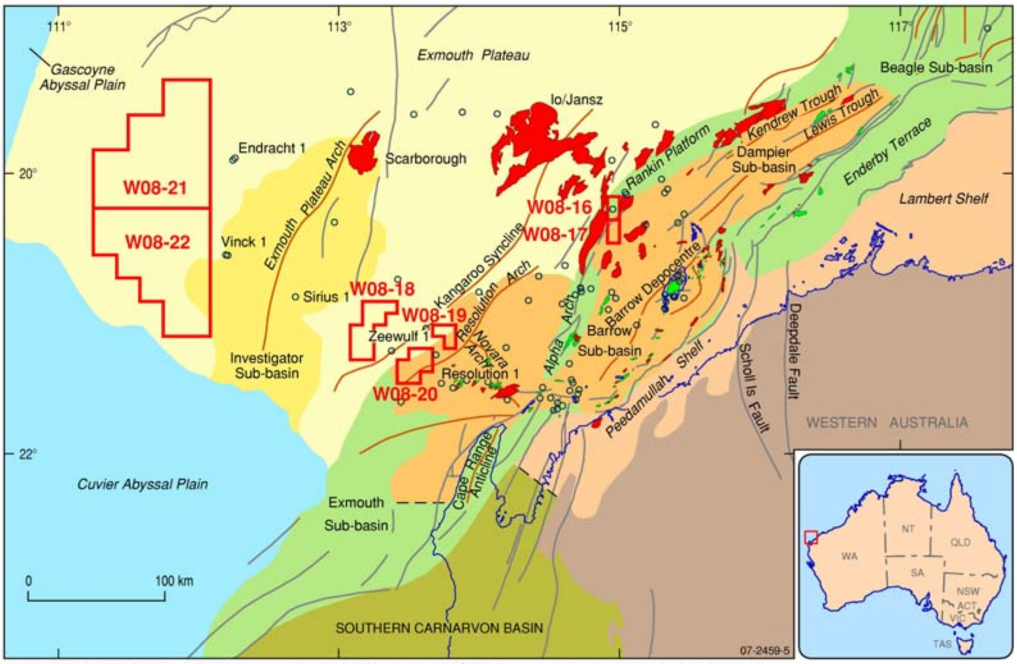
Field	Liquids MMbbl*	Gas Tcf	Gas MMboe[1]	Date	Source
Agincourt	3.67	0.00	0.17	Dec-06	DoIR
Albert	0.27	0.00	0.02	Dec-06	DoIR
Alkimos	0.19	0.01	0.95	Dec-06	DoIR
Angel	84.28	1.85	314.52	Dec-06	DoIR
Artreus	0.26	0.00	0.02	Dec-06	DoIR
Bambra	8.25	0.01	2.43	Dec-06	DoIR
Bambra East	0.88	0.04	7.42	Dec-06	DoIR
Barrow Island	363.83	0.22	37.67	Dec-06	DoIR
Campbell	1.87	0.08	14.41	Dec-06	DoIR
Caribou	0.57	0.04	6.62	Dec-06	DoIR
Chamois	2.33	0.00	0.62	Dec-06	DoIR
Chandon	11.01	2.77	470.68	Dec-06	DoIR
Chervil	4.81	0.01	1.15	Dec-06	DoIR
Chinook/Scindian	32.36	0.07	12.27	Dec-06	DoIR
Chrysaor	16.05	1.88	320.29	Dec-06	DoIR
Clio	20.15	3.16	537.39	Dec-06	DoIR
Corvus	0.50	0.12	21.15	Dec-06	DoIR
Cossack	99.53	0.01	2.48	Dec-06	DoIR
Cowle	3.41	0.00	0.52	Dec-06	DoIR
Crest	1.75	0.00	0.33	Dec-06	DoIR
Crosby	45.92	0.01	1.20	Dec-06	DoIR
Dionysus	11.62	1.50	255.79	Dec-06	DoIR
Dixon	33.34	0.15	24.79	Dec-06	DoIR
Dockrell	5.66	0.25	42.14	Dec-06	DoIR
Doric/Ulidia	0.25	0.03	4.33	Dec-06	DoIR
Double Island	5.47	0.00	0.22	Dec-06	DoIR
East Spar	14.25	0.25	42.43	Dec-06	DoIR
Echo/Yodel	59.38	0.46	78.02	Dec-06	DoIR
Egret	15.72	0.03	5.58	Dec-06	DoIR
Endymion	0.51	0.02	4.18	Dec-06	DoIR
Enfield	80.95	0.00	0.43	Dec-06	DoIR
Eskdale	10.06	0.00	0.00	Dec-06	DoIR
Eurytion	1.40	0.55	92.78	Dec-06	DoIR
Exeter	16.71	0.00	0.02	Dec-06	DoIR
Gaea	3.14	0.12	19.57	Dec-06	DoIR
Geryon/Callirhoe	8.81	3.32	563.55	Dec-06	DoIR
Gibson	0.17	0.00	0.01	Dec-06	DoIR
Gipsy	2.53	0.00	0.46	Dec-06	DoIR
Goodwyn	348.25	6.81	1157.48	Dec-06	DoIR
Goodwyn S	11.95	0.21	35.06	Dec-06	DoIR
Gorgon	121.00	16.80	2855.18	Dec-06	DoIR
Griffin	139.60	0.06	10.91	Dec-06	DoIR
Gudrun	0.75	0.00	0.04	Dec-06	DoIR
Gungurru	1.20	0.01	1.30	Dec-06	DoIR
Harriet	52.72	0.05	8.81	Dec-06	DoIR
Harrison	4.40	0.00	0.00	Dec-06	DoIR
Hermes	74.42	0.03	4.61	Dec-06	DoIR
Hoover	0.33	0.00	0.02	Dec-06	DoIR
Iago	10.88	1.07	182.26	Dec-06	DoIR

Io	16.18	6.27	1066.70	Dec-06	DoIR
Jansz	0.00	13.84	2353.37	Dec-06	DoIR
John Brookes	14.16	1.41	239.83	Dec-06	DoIR
Keast	1.89	0.13	22.75	Dec-06	DoIR
Kultaar	0.38	0.03	4.64	Dec-06	DoIR
Lambert	40.77	0.01	2.31	Dec-06	DoIR
Lambert Deep	2.52	0.26	44.19	Dec-06	DoIR
Laverda	30.19	0.00	0.00	Dec-06	DoIR
Lee	1.26	0.05	8.66	Dec-06	DoIR
Legendre	44.77	0.06	10.13	Dec-06	DoIR
Linda	2.16	0.05	8.49	Dec-06	DoIR
Little Sandy	0.58	0.00	0.05	Dec-06	DoIR
Macedon	0.00	0.65	110.46	Dec-06	DoIR
Maitland	1.65	0.16	28.01	Dec-06	DoIR
Meanad	0.86	0.32	54.91	Dec-06	DoIR
Mohave	0.93	0.00	0.10	Dec-06	DoIR
Monet	0.93	0.00	0.04	Dec-06	DoIR
Moondyne	3.77	0.04	6.60	Dec-06	DoIR
Mutineer	43.02	0.00	0.04	Dec-06	DoIR
Narvik	0.00	0.03	4.33	Dec-06	DoIR
Nasutus	2.52	0.01	1.48	Dec-06	DoIR
North Alkimos	0.17	0.00	0.08	Dec-06	DoIR
North Gipsy	0.69	0.00	0.47	Dec-06	DoIR
North Herald	4.11	0.00	0.47	Dec-06	DoIR
North Pedirka	0.13	0.00	0.01	Dec-06	DoIR
North Rankin	202.85	12.28	2088.01	Dec-06	DoIR
Orthrus	2.22	0.84	143.59	Dec-06	DoIR
Oryx	3.21	0.00	0.06	Dec-06	DoIR
Pedirka	2.55	0.00	0.13	Dec-06	DoIR
Pemberton	5.66	0.19	32.84	Dec-06	DoIR
Persephone	15.72	0.80	135.98	Dec-06	DoIR
Perseus	283.21	10.72	1821.64	Dec-06	DoIR
Pluto	33.96	3.26	554.18	Dec-06	DoIR
Pueblo	3.14	0.08	14.17	Dec-06	DoIR
Rankin/Sculptor	3.14	0.09	15.67	Dec-06	DoIR
Ravensworth	45.29	0.01	1.80	Dec-06	DoIR
Reindeer	1.95	0.45	76.37	Dec-06	DoIR
Roller	45.45	0.03	4.46	Dec-06	DoIR
Rose	1.22	0.03	5.88	Dec-06	DoIR
Rosette	0.29	0.01	1.86	Dec-06	DoIR
Sage	4.65	0.00	0.00	Dec-06	DoIR
Saladin	98.72	0.06	10.31	Dec-06	DoIR
Scarborough	0.00	5.19	882.51	Dec-06	DoIR
Searipple	4.40	0.03	5.94	Dec-06	DoIR
Simpson	5.33	0.00	0.41	Dec-06	DoIR
Sinbad	1.47	0.07	12.09	Dec-06	DoIR
Skate	1.73	0.00	0.56	Dec-06	DoIR
Skiddaw	3.77	0.00	0.00	Dec-06	DoIR
South Pepper	16.57	0.02	4.16	Dec-06	DoIR
South Plato	4.47	0.00	0.24	Dec-06	DoIR
Spar	6.50	0.26	44.20	Dec-06	DoIR
Stag	62.15	0.01	2.10	Dec-06	DoIR
Stickle	33.96	0.01	1.20	Dec-06	DoIR
Stybarrow	74.85	0.00	0.00	Dec-06	DoIR

Talisman	7.73	0.00	0.08	Dec-06	DoIR
Tanami	3.24	0.00	0.52	Dec-06	DoIR
Taunton	3.38	0.00	0.49	Dec-06	DoIR
Tidepole	15.72	0.52	88.37	Dec-06	DoIR
Tusk	1.82	0.00	0.62	Dec-06	DoIR
Urania	0.21	0.08	13.96	Dec-06	DoIR
Van Gogh	58.50	0.00	0.00	Dec-06	DoIR
Victoria	0.32	0.00	0.03	Dec-06	DoIR
Vincent	72.96	0.00	0.00	Dec-06	DoIR
Wanaea	332.90	0.39	67.09	Dec-06	DoIR
Wandoo	93.81	0.03	5.14	Dec-06	DoIR
West Tryal Rocks	38.00	2.58	437.75	Dec-06	DoIR
Wheatstone	26.00	3.97	674.99	Dec-06	DoIR
Wilcox	19.50	0.33	56.07	Dec-06	DoIR
Wonnich	2.16	0.12	19.57	Dec-06	DoIR
Woollybutt	47.65	0.00	0.71	Dec-06	DoIR
Xena	5.03	0.49	82.97	Dec-06	DoIR
Yammaderry	5.39	0.00	0.58	Dec-06	DoIR
Zephyrus	0.23	0.00	0.01	Dec-06	DoIR

*Liquids includes crude oil and condensate, [1] Conversion factor for gas (Tcf to MMboe) is 0.17x1000.
All reserves are P_{50}. All developed field resources from DoIR have been compiled using the remaining reserves plus the cumulative production as of December 2006. All other fields are reserves as of 31st December 2006.
DoIR - Department of Industry and Resources, Western Australia,
http://www.doir.wa.gov.au/documents/mineralsandpetroleum/PWA_Sept_2007.pdf.

FIGURES



Field outlines supplied by Encom Petroleum Information Pty Ltd. Field outlines in GPinfo are sourced from the operators of the fields only. Outlines are updated at irregular intervals but with at least one major update per year.

- *Mesozoic Sub-basins (Northern Carnarvon Basin)*
- *Palaeozoic Sub-basins (Southern Carnarvon Basin)*
- *Early Cretaceous Depocentre*
- *Jurassic to Early Createcous Depocentre*
- *Oil field*
- *Gas field*
- *Major fault*
- *Depocentre axis*
- *Coastline*
- *Well*

Figure 1. Structural elements of the northern Carnarvon Basin showing the 2008 Release areas.

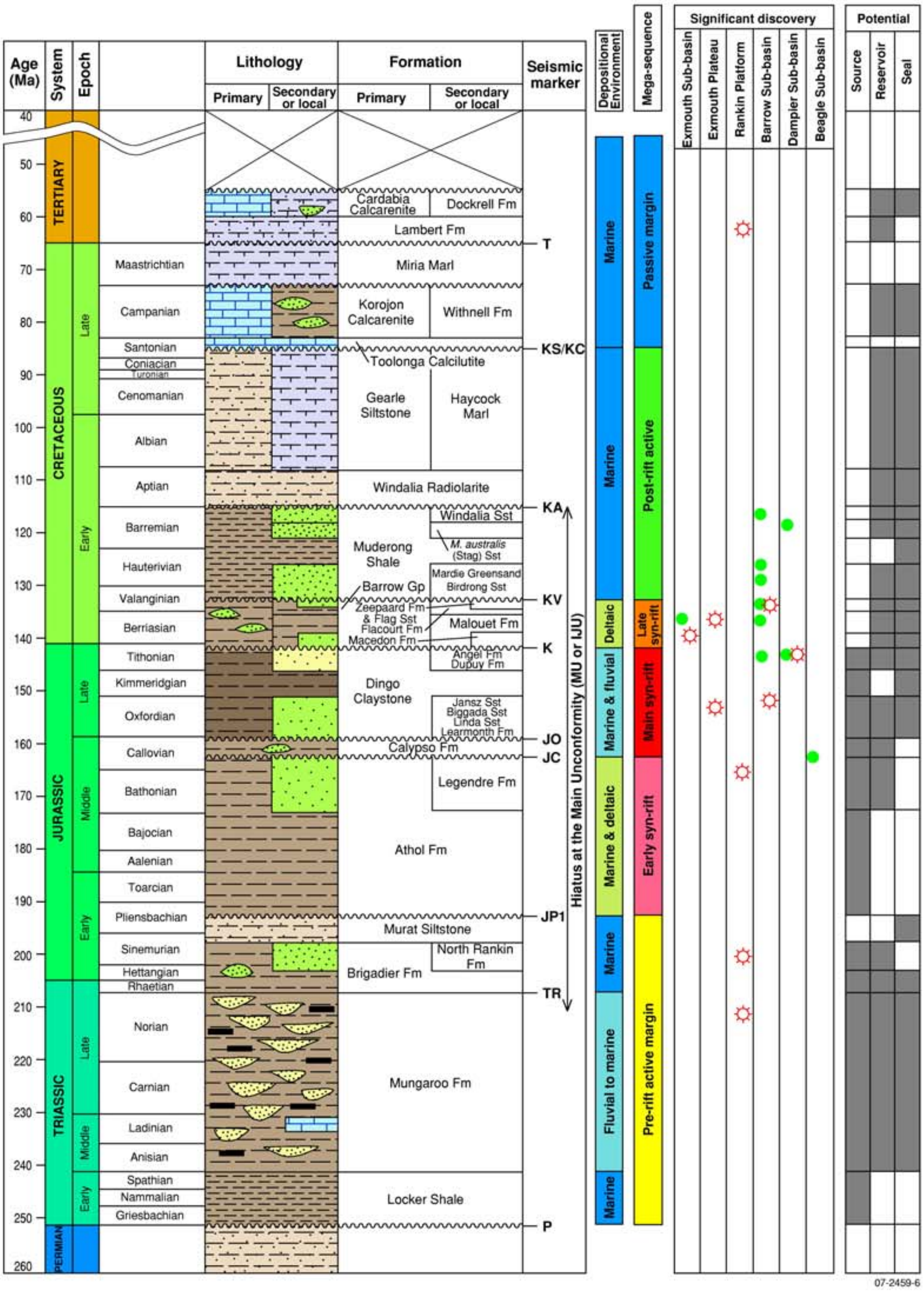


Figure 2. Regional stratigraphy of the northern Carnarvon Basin.

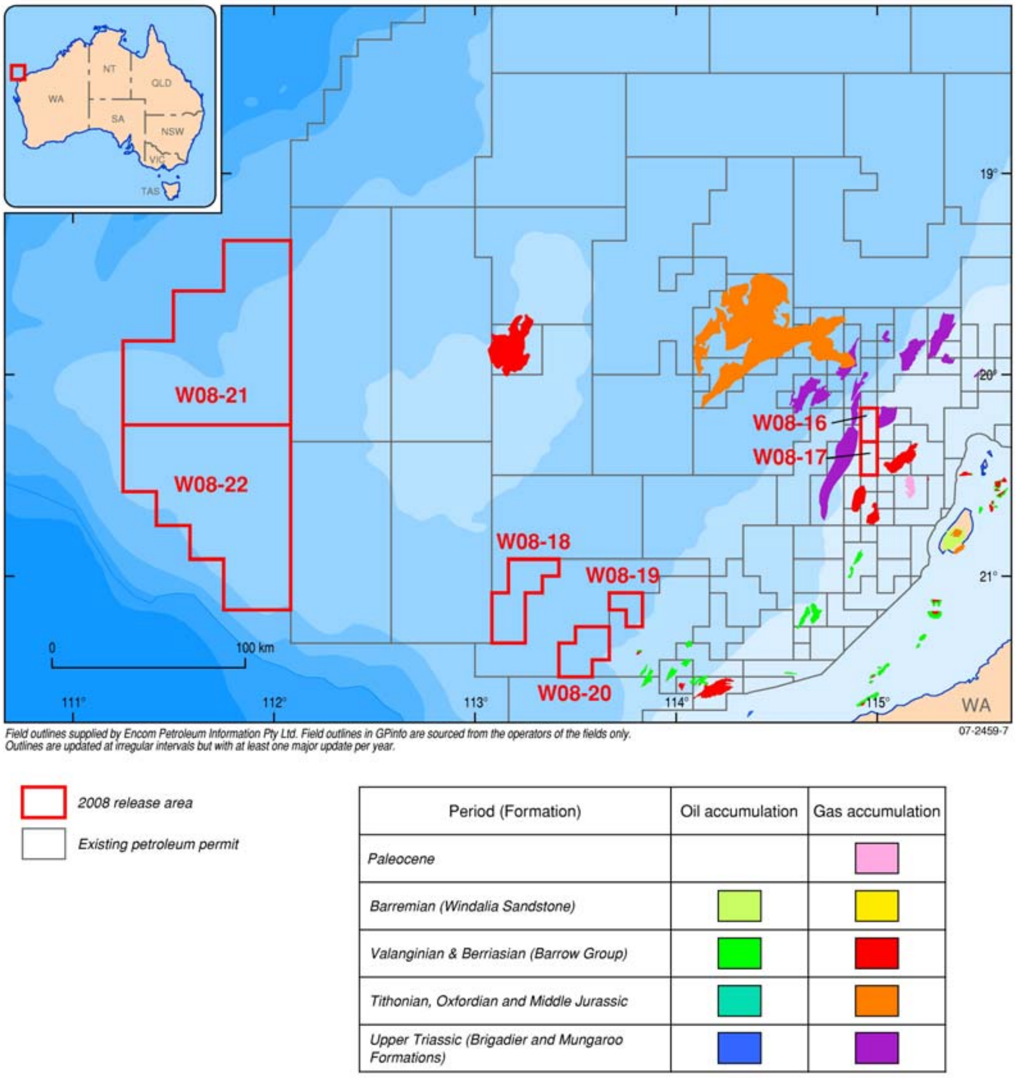


Figure 3. Major oil and gas accumulations in the northern Carnarvon Basin indicating age of main reservoir.

2008 RELEASE OF AUSTRALIAN OFFSHORE PETROLEUM EXPLORATION AREAS

RELEASE AREAS W08-18, W08-19 AND W08-20
EXMOUTH SUB-BASIN, CARNARVON BASIN
WESTERN AUSTRALIA

BIDS CLOSE - 9 OCTOBER 2008

LOCATION

Release Areas W08-19 and W08-20 are located in the Exmouth Sub-basin and lie approximately 80 km offshore from North West Cape on the Western Australian coastline (**Figure 1**). Release area W08-18 is located further to the west, approximately 130 km offshore and extends onto the eastern edge of the Exmouth Plateau. Water depths in these areas are generally within the range of 1000 m.

Release Area W08-18 comprises 11 full graticular blocks with a total area of approximately 880 km^2.

Release Area W08-19 comprises 3 full graticular blocks with a total area of approximately 240 km^2.

Release Area W08-20 consists of 7 full graticular blocks covering an area of approximately 560 km^2.

The Exmouth Sub-basin is the southernmost in a series of oil-bearing sub-basins that make up the inboard Carnarvon Basin. Oil production commenced in the Exmouth Sub-basin in 2006 and since 1993, 11 oil and gas fields have been discovered to the east of the Release areas. Eskdale is the closest oil and gas discovery to the Release areas and is located less than 20 km from W08-19 and W08-20. Gas shows were recorded in Zeewulf 1 and Resolution 1 located immediately adjacent to W08-19 and W08-20 (**Figure 1**). No wells have been drilled in the Release areas.

GRATICULAR BLOCK LISTING AND MAP

RELEASE AREA W08-18
EXMOUTH SUB-BASIN, CARNARVON BASIN, WESTERN AUSTRALIA

Map Sheet SF 49 (Cloates)

855	856	857	927	928	998
999	1070	1071	1142	1143	

Assessed to contain 11 full blocks

RELEASE AREA W08-19
EXMOUTH SUB-BASIN, CARNARVON BASIN, WESTERN AUSTRALIA

Map Sheet SF 49 (Cloates)

1005	1006	1078

Assessed to contain 3 full blocks

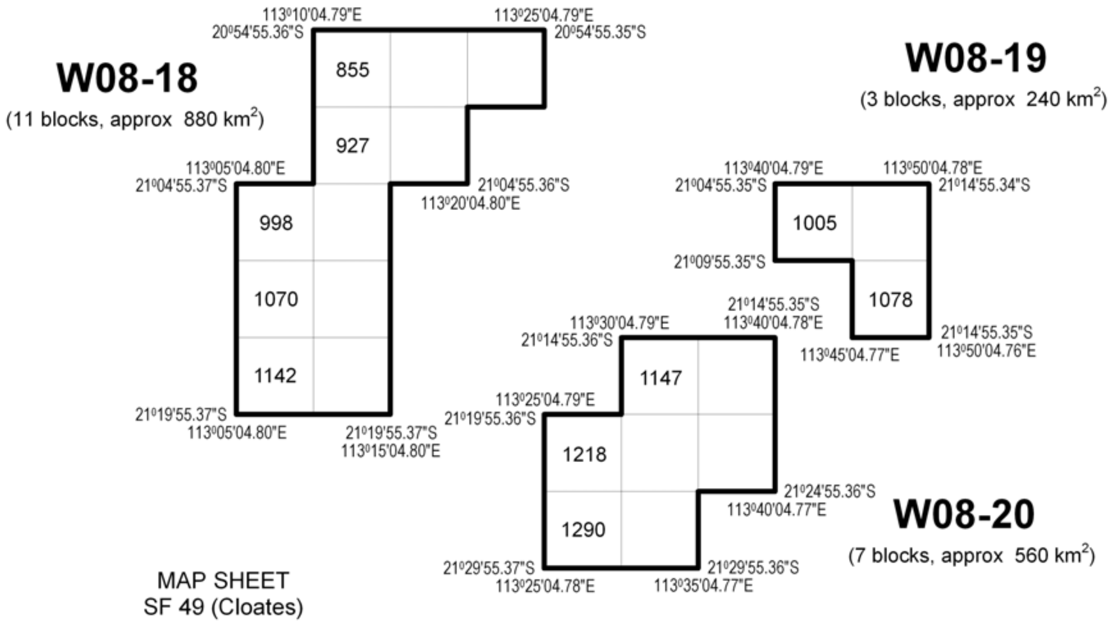
AREA W08-20
EXMOUTH SUB-BASIN, CARNARVON BASIN, WESTERN AUSTRALIA

Map Sheet SF 49 (Cloates)

1147	1148	1218	1219	1220	1290
1291					

Assessed to contain 7 full blocks

2008 Release Areas
Exmouth Sub-basin, Carnarvon Basin
Western Australia



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

ASPD 7161-9

RELEASE AREA GEOLOGY

REGIONAL TECTONIC SETTING

Release areas W08-19 and W08-20 are located on the western edge of the Exmouth Sub-basin. Along with the Barrow, Dampier and Beagle sub-basins, the Exmouth Sub-basin formed as a series of northeast-southwest-trending, en-echelon structural depressions during the Pliensbachian through to the Oxfordian (Tindale et al, 1998; Smith et al, 2003; Scibiorski et al, 2005). The sub-basins are Jurassic depocentres representing a failed rift system that developed during the early syn-rift phase of breakup in the Carnarvon Basin.

The north-south-trending Triassic high block of the Alpha Arch marks the eastern boundary of the Exmouth Sub-basin and separates it from the Barrow Sub-basin (**Figure 2**). The western edge of the Exmouth Sub-basin is bounded by the broad, faulted Triassic platform of the Exmouth Plateau. Release Area W08-18 is located on the Exmouth Plateau west of the Jurassic depocentre of the Exmouth Sub-basin and to the east of the thick Early Cretaceous sedimentary strata of the Investigator Sub-basin (**Figure 2**) deposited as part of the Barrow Delta (Tindale et al, 1998).

Rifting between Australia and Greater India at the end of the Jurassic produced uplift along the Cape Range Fracture Zone to the south of the Exmouth Sub-basin and provided the sediment source for the Barrow Delta which prograded across the Exmouth Sub-basin and southern Exmouth Plateau and into the Barrow Sub-basin during the Early Cretaceous (latest Tithonian to mid-Valanginian). Release areas W08-18, W08-19 and W08-20 lie in a saddle between the main Barrow Group accumulations of the Exmouth and Investigator sub-basins (Tindale et al, 1998; **Figure 3**). Continental breakup in the Valanginian terminated sediment supply to the Barrow Delta resulting in reworking and re-deposition of the older delta deposits. This was followed by a regional marine transgression and post-rift subsidence.

Basin inversion and uplift in the Late Cretaceous formed the Exmouth Plateau Arch, the Resolution Arch and the Novara Arch (**Figure 2**). The Novara Arch trends west-northwest to east-southeast and extends towards Release Area W08-19. Uplift began in the early Santonian and overprinted and reactivated previously formed structures. Erosion is recognised at the base-Santonian unconformity over the Novara Arch which continued to develop during tilting to the southwest until the Oligocene (Tindale et al, 1998).

The Resolution Arch strikes northeast to southwest across Release areas W08-19 and W08-20. It was initiated possibly as early as the Campanian, though the major growth on the arch was in the Oligocene and Miocene (Tindale et al, 1998). The Kangaroo Syncline is the corresponding down-warp developed to the west of and parallel to, the Resolution Arch. In the Late Cretaceous, deposition shifted westwards from the Exmouth Sub-basin to the Kangaroo Syncline which remained the depocentre until the Cenozoic (Tindale et al, 1998). Release Area W08-20 is located on the western limb of the Kangaroo Syncline, in a similar structural position to the giant Jansz gas field to the north (**Figure 2**).

STRATIGRAPHY

The western Exmouth Sub-basin and Exmouth Plateau are underlain by a thick sequence (10-15 km) of Late Palaeozoic to Cenozoic sediments. The stratigraphy of the un-drilled Release areas W08-18, W08-19 and W08-20 is based on open file information from wells drilled in the vicinity of the Release areas as well as on seismic data. No units older than Middle Triassic have been intersected on the Exmouth Plateau, but low-amplitude reflections towards the base of the interpreted Triassic section are the probable correlatives of the Locker Shale which has been drilled in the inboard parts of the Carnarvon Basin (Stagg et al, 2004). The Locker Shale was deposited in shallow shelf environments during a widespread Early Triassic marine transgression which is recognised all along the western Australian margin from the Bonaparte Basin to the Perth Basin.

The overlying Middle to Late Triassic, fluvio-deltaic Mungaroo Formation is the oldest unit intersected on the Exmouth Plateau. The Jupiter 1 well, located to the north of the Release areas on the central Exmouth Plateau, reached TD after penetrating a 682 m thick sequence of interbedded grey-brown siltstones, claystones and light-grey sandstones, with minor coals and dolomites. Palynological data indicate that this interval ranges from Carnian to Anisian (*S. quadrifidus* spore/pollen zone) in age (Nicoll, 2002). The Mungaroo Formation intersection in Resolution 1 (~125 m), located adjacent to Release Area W08-20, is restricted to the younger *M. crenulatus* spore/pollen zone that is considered Norian in age (Backhouse et al, 2002; Nicoll, 2002). The deeper Mungaroo Formation intersection in Zeewulf 1 (~409 m) extends further into the Norian and possibly Carnian as both the *M. crenulatus* and the underlying *S. speciosus* spore/pollen zones are recognised. The Late Triassic Mungaroo Formation sequence in these wells is composed of interbedded sandstones, siltstones and claystones with minor coal seams, and was deposited in upper delta plain environments.

A marine transgression inundated the Exmouth Plateau in the latest Triassic; however, the Rhaetian to Early Jurassic marls of the Brigadier Formation which cap the Mungaroo Formation in wells further to the west on the Exmouth Plateau (Sirius 1, Vinck 1, Investigator 1 and Eendracht 1) are not present in Resolution 1 and Zeewulf 1. In these wells, the sandy facies of the Mungaroo Formation is unconformably overlain by fine-grained Late Jurassic sediments that are Dingo Claystone equivalents (**Figure 3**). Only 5 m of Oxfordian to Kimmeridgian glauconitic siltstones, dolomitic shales and dolomite represent the Jurassic section on the Triassic high block drilled in Zeewulf 1. In contrast, Resolution 1 intersected 797 m of Dingo Claystone which thickens to the east beyond the Release areas into the deep central trough of the Exmouth Sub-basin. Here, over 2 km of Dingo Claystone accumulated in a low-energy, marine anoxic environment and became the source rock pod for the oil accumulations in the sub-basin (Tindale, et al 1998).

During the Early Cretaceous, the Barrow Delta prograded northward over the Exmouth Sub-basin and the southern and central Exmouth Plateau. It had covered the Alpha Arch by the mid-Berriasian (Smith et al, 2003) and extended into the Barrow Sub-basin as far as the southern end of the Gorgon field (**Figure 4**). Deep water, fine grained prodelta sediments were deposited to the north of the Release areas. Final separation of Australia and Greater India in the early Valanginian along the southern edge of the Exmouth Plateau cut off the sediment supply for the Barrow Delta. The delta sediments were eroded, reworked and re-deposited in the parasitic deltaic wedges of the Zeepaard and Birdrong formations (Arditto, 1993). During the regional transgressive phase, these sequences formed a series of back-stepping delta fronts along a trend that developed at high angle to the older delta system (**Figures 4** and **5**).

Resolution 1, located immediately to the east of Release Area W08-20, intersected a 1000 m of this stratigraphically complex Barrow Group, which is 643 m thick in Zeewulf 1, located close to the western boundary of Release Area W08-19. The dominant lithologies are coarse, medium and fine-grained quartz sandstones interbedded with siltstones and claystones that were deposited in lower delta plain environments.

The thin, glauconitic Mardie Greensand Member (**Figure 5**) above the Barrow Group represents the reworked upper portion of the delta in shallow marine, sediment starved conditions. The basin margin subsided after continental breakup and marine silts and shales of the Muderong and Gearle formations were deposited across the Exmouth Sub-basin and Exmouth Plateau (**Figures 3** and **5**). The Late Cretaceous to Recent sedimentary section in the Exmouth Plateau and western Exmouth Sub-basin is dominated by deep-water fine-grained carbonates, including calcilutites and marls. To the east of the Release areas in the eastern Exmouth Sub-basin and across the Dampier and Barrow sub-basins, a major carbonate platform developed during the Late Oligocene. The shallow shelf has advanced westward, built by successive wedges of carbonates, but the Release areas are nevertheless located in deep water distant from the shelf break (**Figures 1** and **6**).

EXPLORATION HISTORY

Exploration in the Exmouth Sub-basin has been episodic over the last 35 years. The area did receive some attention during the first phase of island and shallow water drilling by WAPET in the 1960s and early 1970s (Mitchelmore and Smith, 1994). The first gas shows were recorded in 1972 when West Muiron 2 was drilled on the feature later recognised as the Pyrenees/Macedon gas and oil accumulation. This indicated that the Exmouth Sub-basin was petroliferous. However, the focus of exploration was elsewhere in the Carnarvon Basin, namely in the Barrow and Dampier sub-basins, where giant discoveries were made including a billion barrels of oil-in-place at Barrow Island in 1964 and multi-Tcf gas fields on the Rankin Platform found in 1972.

In the late 1970s and early 1980s, some exploration targeted the region of the Release areas during the first deepwater drilling campaign on the Exmouth Plateau. These initial exploration programs on the plateau were undertaken by Esso and Phillips (Barber, 1988) exclusively searching for oil. Eleven deepwater (740–1375 m water depth) wells had been drilled by the early 1980s (Walker, 2007), guided by the concept of a major oil charge from the Jurassic Dingo Claystone (Figure 3). These drilling activities resulted in a giant gas discovery in an Early Cretaceous basin floor fan (Barrow Group) in the **Scarborough 1** well (Figure 1 and 6). The Scarborough domal anticline, which developed in response to inversion tectonics during the Campanian, is a low-relief but extensive structure covering approximately 350 km^2 and containing around 6 Tcf of dry gas (Walker, 2007). At the time of this discovery (1979), the available technology and the undeveloped LNG market rendered this remote, deepwater gas accumulation uneconomic to develop.

During the initial exploration phase on the Exmouth Plateau, gas was also discovered in Late Triassic Mungaroo Formation sandstones in **Jupiter 1,** in a tilted fault block trap (~0.15 Tcf, Walker, 2007). Both the Jupiter and Scarborough accumulations are characterised by prominent DHIs (flat spots) on seismic (Korn et al, 2003).

After the 1979-1980 drilling campaign, no further exploration on the deepwater Exmouth Plateau was undertaken for over a decade. The Carnarvon Basin remained a target for oil exploration in shallower water. In the shallow water section of the Exmouth Sub-basin **Jurabi 1** was drilled by Esso Australia Ltd in 1982 as another test of the West Muiron structure: but this failed again to intersect a significant hydrocarbon column. There was eventual success on this structure in the 1990s (Mitchelmore and Smith, 1994). In the southern Exmouth Sub-basin, 3D seismic-based deepwater exploration was successful in the late 1990s. Success has continued since with the discovery of a string of oil accumulations in the Barrow Group play which cumulatively have added several hundred million barrels to Australia's oil reserves.

In the past two to three years, 3 wells have been drilled westward from the proven oil trend in the eastern Exmouth Sub-basin**. Falcone 1A**, located to the south of Release Area W08-20 in the western Exmouth Sub-basin, was drilled by Woodside in 2005 as a test of a Triassic fault block and recovered gas (Waker, 2007). On the southern Exmouth Plateau, however, the recent wells drilled were unsuccessful, probably due to the lack of a significant charge after trap formation. **Black Dragon 1** was drilled by Apache to the north of Release Area W08-20 in 2004, and the nearby **Jacala 1** was drilled by BHP Billiton in 2006 to test a large anticline in the Barrow Group formed by compaction over the delta top-sets (Walker, 2007)

Following the 2004 offshore acreage release, Chevron and Shell were awarded four large, deepwater petroleum exploration permits on the Exmouth Plateau, WA-364-P, WA-365-P, WA-366-P and WA-367-P, the latter abutting Release Area W08-18 to the west. During 2006, the 4144 km^2 Bonaventure 3D marine seismic survey was acquired by the Chevron Shell joint venture over exploration permit WA-364-P and WA-365-P.

Market conditions have changed markedly since the first phase of exploration on the Exmouth Plateau in the 1970s, with major gas contracts secured to supply LNG to China, in addition to the established trade with Japan. The viability of the deepwater frontier plays on the Exmouth Plateau was highlighted by the competitive bidding for the 2006 Release areas and the entry of a number of new players including Hess and OMV (DRET, 2007).

Almost the entire Exmouth Plateau is now under permit. Projected expenditures totalling approximately $1 billion, including the drilling of 40 guaranteed deepwater wells.

WELL CONTROL

Over forty deepwater (greater than 500 m water depth) wells have been drilled on the Exmouth Plateau and Sub-basin (**Figure 1**). No wells have been drilled in the Release areas W08-18, W08-19, and W08-20.

Zeewulf 1 (1979)

Zeewulf 1, located to the west of Release Area W08-19, was the first well drilled in the southern Exmouth Plateau. It was drilled by Esso Australia Ltd to test a tilted Triassic fault block and resulted in the recovery of minor gas and condensate from the Mungaroo Formation.

Resolution 1 (1979),

Resolution 1, located immediately to the east of Release Area W08-20, was drilled by Esso Australia Ltd in late 1979 to test a Triassic Mungaroo Formation objective in a narrow northeast-trending faulted horst. There was no closure at the Barrow Group level and no significant hydrocarbons were found at either level. On well logs, a thin (2.5 m) and tight gas-bearing sandstones were identified at the top of the Mungaroo Formation (Esso Australia Ltd, 1980a).

Sirius 1 (1980)

Sirius 1, located in WA-367-P to the west of Release Area W08-18, was drilled by Esso Australia Ltd as a test of the Barrow Group play within a large low relief anticline. Triassic sandstones were a secondary objective. The Cretaceous test failed due to the lack of intra-Barrow Group seals within the sandy Early Cretaceous section while gas shows were recorded within the Late Triassic section.

Novara 1 (1982)
There was some success in the 1982 at Novara 1 when Esso Australia Ltd drilled in 372 m water depth on a large faulted anticline. An 8 m oil-bearing sandstone was intersected in the Barrow Group; however the oil (API 16.7°) was biodegraded (Esso Australia Ltd, 1983). Although the Novara accumulation was interpreted to be around 220 MMbbl in place, it was deemed uneconomic to develop such heavy oil at these water depths. The perceived risk of un-producible heavy oil seriously down-graded the prospectivity of the Exmouth Sub-basin (Smith et al, 2003) and exploration stalled for a decade.

West Muiron 3 (1992) & West Muiron 5 (1993)
A renewed effort in the early 1990s paid off on the West Muiron structure when West Muiron 3 intersected gas in sandstones at the base of the Barrow Group, (Macedon Member, **Figure 5**) and West Muiron 5 discovered the separate Pyrenees oil and gas field reservoired in the Pyrenees Member (Mitchelmore and Smith, 1994). Both the gas and oil were biodegraded but producible especially in high quality reservoirs (Smith et al, 2003).

Leyden 1B ST (1996)
Deepwater exploration resumed on the Exmouth Plateau and in the Exmouth Sub-basin during the mid-1990s. Leyden 1B ST, located to the north and east of Release Area W08-19, was drilled in 1996 by BHP Petroleum Pty Ltd in 1025 m water depth. The well targeted the Mungaroo Formation in a tilted Triassic fault block that is unconformably overlain by claystones of the Barrow Group. The Leyden horst structure has a vertical relief of 700 m at the top of the Mungaroo Formation. Strong gas shows were encountered in the basal Barrow Group and the Mungaroo Formation. Similar to other wells drilled in the Exmouth Sub-basin, the Mungaroo Formation is over-pressured indicating the presence of an effective regional seal above the formation.

Vincent 1 (1988)
Woodside discovered oil in Barrow Group sands at Vincent in 1998. The well was drilled in 379 m of water and intersected a 28 m hydrocarbon column with a significant oil leg (Polomka, et al, 1999).

Enfield 1 (1999)
The major Enfield oil discovery was made by Woodside in 1999. Enfield lies in 544 m water depth with 128 MMbbl in initial reserves. In 2006, it was the first field to come onto production in the Exmouth Sub-basin (Walker, 2007).

Laverda 1 (2000)
Woodside made a further discovery to the west of Enfield, at Laverda 1, in 840 metres of water. The field is located a few tens of km to the south-east of Release areas W08-19 and W08-20 **(Figure 4).**

Coniston 1 (2000)
BHP Petroleum Pty Ltd made another Barrow Group oil discovery in 2000 at Coniston 1, drilled on the Novara structure, targeting the base Muderong anticline up-dip of the Novara titled fault block. However, in contrast to Novara 1, Coniston 1 achieved a flow of 2119 bopd from a 13 m oil column below 11.5 m of gas (Smith et al, 2003).

Stybarrow 1 (2003)
In 2003, the 40-60 MMbbl Stybarrow oil discovery by Eskdale 1, extended the basal Barrow Group reservoir play to the north and west of the Laverda and Vincent fields (Walker, 2007).

Eskdale 1 (2003)
Eskdale 1 is the most westerly discovery in the Exmouth Sub-basin. It was drilled by BHP Billiton and is located a further 12 km northwest of Stybarrow. Its thin oil rim will be produced as part of that development. The combined mean recoverable oil reserves are estimated at 90 MMbbl (Malek, 2006).

Ravensworth 1 and Crosby 1 (2003)
In 2003, Ravensworth 1 and Crosby 1 were drilled by BHP Billiton, close to each other between the Enfield and Pyrenees/Macedon fields. They proved the viability of the Pyrenees Member (**Figure 5**) as a high quality oil reservoir (Willink, 2003).

Stickle 1 and Harrison 1 (2004)
In 2004, Stickle 1 and Harrison 1 were successfully drilled targeting the “Pyrenees Terraces” in the Ravensworth area (Ferdinando, 2004). BHP Billiton and its joint venture partner Apache, plan to produce the Ravensworth, Crosby and Stickle fields by 2010 in a joint “Pyrenees Oil Field Development”. According to BHP Billiton (2007) the estimated recoverable reserves are between 80 and 120 MMbbl.

Black Dragon 1 (2004)
Black Dragon 1 was drilled by Apache to the north of Release Area W08-20 in 2004. Only basic data is currently available for this well.

Falcone 1A (2006)
Located to the south of Release Area W08-20 in the western Exmouth Sub-basin, Falcone 1A was drilled by Woodside in 2005 as a test of a Triassic fault block and recovered gas (Waker, 2007). Only basic data is currently available for this well.

KEY WELLS LISTING – RELEASE AREAS W08-18, W08-19 AND W08-20, EXMOUTH SUB-BASIN

Well	Operator	Total Depth (m)	Year$	Data Avail*	Basic Avail	Interp Avail	Source
Blackdragon 1	Apache Northwest Pty Ltd	2640	2004	B	-	16/05/2009	WAPIMS
Coniston 1	BHP Petroleum Pty Ltd	1350	2000	A	-	-	-
Eskdale 1	BHP Billiton Petroleum Pty Ltd	3127	2003	B	-	13/05/2008	WAPIMS
Falcone 1	Woodside Energy Ltd	2084	2005	B		14/02/2010	RRD
Falcone 1A	Woodside	3822	2005	B	-	2/03/2010	WAPIMS
Investigator 1 (Esso)	Esso Australia Ltd	3745.6	1979	A	-	-	-
Leyden 1	BHP Petroleum Pty Ltd	1614	1996	A	-	-	-
Leyden 1A	BHP Petroleum Pty Ltd	1095	1996	A	-	-	-
Leyden 1B	BHP Petroleum Pty Ltd	3441	1996	A	-	-	-
Leyden 1B ST1	BHP Petroleum Pty Ltd	4300	1996	A	-	-	-
Resolution 1	Esso Australia Ltd	3797.2	1979	A	-	-	-
Resolution 1 ST1	Esso Explor and Prod Aust Ltd	3885.8	1979	A	-	-	-
Sirius 1 (Esso)	Esso Explor and Prod Aust Inc	3500	1980	A	-	-	-
Stybarrow 1	BHP Billiton Petroleum Pty Ltd	2477	2003	B	-	11/04/2008	WAPIMS
Stybarrow 1 ST1	BHP Billiton Petroleum Pty Ltd	2265	2003	B	-	9/04/2008	RRD
Zeewulf 1	Esso Australia Ltd	3500	1979	A	-	-	-

$Year is based on Rig-released date, *A = All data (Basic and Interpretive) is available, B = basic data only available. # RRD = Rig release date. Data is accurate at 16 January 2008.

SEISMIC COVERAGE

Release areas W08-18, W08-19 and W08-20 have good coverage of regional 2D seismic lines of various vintages including the parts of the large surveys acquired by Esso Australia Ltd in 1978 and 1979 (X78 and X79) and those acquired by BHP Petroleum Pty Ltd. in the 1990s (HE94 and HC97X). The HC97X high resolution survey in particular, significantly improved interpretation and depth conversion for shallow targets (Smith et al, 2003).

Release Area W08-18 is covered by a 2 to 5 km grid of seismic data, while Release areas W08-19 and W08-20 have a denser coverage with line spacings of under a kilometre and some 3D coverage acquired by BHP Petroleum Pty Ltd (HCA 2000A 3D) in the eastern part of Release Area W08-20.

Deep seismic data was acquired by Geoscience Australia across the Exmouth Plateau and Exmouth Sub-basin on its former research vessel Rig Seismic between 1991 and 1995 (Stagg et al, 2004, Alcock et al, 2006). These include long regional lines from AGSO Survey 110 and Survey 136.

Seismic Surveys – W08-18

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
GSI Scientific 10SL Marine Seismic, Gravity & Magnetic	Geophysical Service Inc	772	1976	Yes	Yes	2529	S6760001
X78A	Esso Australia	17899	1978	Yes	Yes	199	S6780003
X79B	Esso Australia	6563	1979	Yes	Yes	172	S6790017
AGSO Marine Survey 101, Southern Carnarvon	AGSO	1660	1991	Yes	Yes	740	S6910031
AGSO Marine Survey 110, Southern NW Shelf 2	Geoscience Australia	2889	1992	Yes	Yes	2407	S6900062
SPA Carnarvon Tie (SPA 4SL/92-3 and IT/93-3) (GPCT93)	Geco Prakla	5181	1993	Yes	Yes	662	S6930009
HE94	BHP	6398	1994	Yes	Yes	419	S6940010
HC97X	BHP	632	1997	Yes	Yes	1810	S6970017

Data is accurate as at 17 December 2007.

Seismic Surveys – W08-19

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
GSI Scientific 10SL Marine Seismic, Gravity & Magnetic	Geophysical Service Inc	772	1976	Yes	Yes	2529	S6760001
X78A	Esso Australia	17899	1978	Yes	Yes	199	S6780003
X79A	Esso Australia	484	1979	Yes	Yes	245	S6790011
X79B	Esso Australia	6563	1979	Yes	Yes	172	S6790017
X80A	Esso Australia	255	1980	No	Yes	2565	S6800017
C81B (DW)	Esso Australia	2987	1981	Yes	Yes	467	S6810011
AGSO Marine Survey 110, Southern NW Shelf 2	Geoscience Australia	2889	1992	Yes	Yes	2407	S6900062
SPA Carnarvon Tie (SPA 4SL/92-3 and IT/93-3) (GPCT93)	Geco Prakla	5181	1993	Yes	Yes	662	S6930009
AGSO Marine Survey 136, Carnarvon Tertiary Tie	AGSO	4221	1994	Yes	Yes	1828	S6940033
HE94	BHP	6398	1994	Yes	Yes	419	S6940010
HE96 2D Marine Seismic	BHP	1782	1996	Yes	Yes	666	S6960017
HC97X	BHP	632	1997	Yes	Yes	1810	S6970017

Data is accurate as at 17 December 2007.

Seismic Surveys – W08-20

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
GSI Scientific 10SL Marine Seismic, Gravity & Magnetic	Geophysical Service Inc	772	1976	Yes	Yes	2529	S6760001
X78A	Esso Australia	17899	1978	Yes	Yes	199	S6780003
X79B	Esso Australia	6563	1979	Yes	Yes	172	S6790017
X80A	Esso Australia	255	1980	No	Yes	2565	S6800017
X81A	Esso Australia	698	1981	Yes	Yes	2566	S6810040
AGSO Marine Survey 101, Southern Carnarvon	AGSO	1660	1991	Yes	Yes	740	S6910031
SPA Carnarvon Tie (SPA 4SL/92-3 and IT/93-3) (GPCT93)	Geco Prakla	5181	1993	Yes	Yes	662	S6930009
AGSO Marine Survey 136, Carnarvon Tertiary Tie	AGSO	4221	1994	Yes	Yes	1828	S6940033
HE94	BHP	6398	1994	Yes	Yes	419	S6940010
Exmouth South 1996 Marine Seismic (SPA 6SL/95-96)	PGS Nopec	1841	1996	Yes	Yes	743	S6960016
HC97X	BHP	632	1997	Yes	Yes	1810	S6970017
Jawa	Woodside	1695	1998	Yes	Yes	861	S6980013
HCA2000A 3D Marine Seismic Survey	BHP	51196	2001	Yes	No	2832	S6200029

Data is accurate as at 17 December 2007.

HYDROCARBON POTENTIAL

The nearby oil and gas fields in the Exmouth Sub-basin, the giant gas fields on the Exmouth Plateau and the hydrocarbon shows in adjacent wells indicate that the Release areas W08-18, W08-19 and W08-20 are highly prospective. This view is underpinned by the existence of proven plays at the Triassic and Early Cretaceous levels and by two potential source rock intervals.

PETROLEUM SYSTEMS

Two proven petroleum systems are recognised in the Release areas. The extensive Locker-Mungaroo/Barrow petroleum system assessed by the USGS (2000) is mapped to extend across the Exmouth Plateau including the un-drilled Release areas W08-18, W08-19 and W08-20. Geochemical studies (Boreham et al, 2001; Geoscience Australia and GeoMark, 2005; Edwards et al, 2007) indicate that the coals of the Mungaroo Formation are the primary source for this widespread petroleum system rather than the underlying marine Locker Shale. The system may therefore be better described as the Locker/Mungaroo-Mungaroo/Barrow petrolelum system. The recent discovery of gas in the Mungaroo Formation at Falcone 1A may prove to be an extension of this system to the south into the Exmouth Sub-basin, bracketing the Release areas between Mungaroo Formation accumulations at Zeewulf 1 and Falcone 1A.

Accumulations of the productive Dingo-Barrow petroleum systems of the Exmouth Sub-basin lie a few tens of km to the east of Release areas W08-19 and W08-20. Although the hydrocarbon charge history is complex (Tindale et al, 1998; Smith et al, 2003), the Late Cretaceous migration from oil-mature Dingo Claystone may have been directed to the west out of the Exmouth Sub-basin towards the Release areas (see Figure 10, Smith et al, 2003). Barrett (2004) mapped a minimum distribution of petroleum accumulations derived from Jurassic oil source rocks in the Exmouth Sub-basin to identify two areas for resource assessment. The larger and western assessment unit encompasses the Eskdale field (Barrett, 2004; fig. 3.1) but does not extend to Release areas W08-10 and W08-20 as currently mapped.

Source Rocks

The thick Permian to Triassic sedimentary section on the Exmouth Plateau has the greatest potential for mature source facies, including possible organic-rich units in the Early Triassic (marine Locker Shale equivalents) and Late Triassic (deltaic Mungaroo Formation facies and marine equivalents). Recent exploration activities on the Exmouth Plateau are based on a model that invokes gas charge from the deeply buried coals and carbonaceous claystones of the Mungaroo Formation. Peak gas generation from these Triassic source rocks is interpreted to occur now at depths greater than 5 km below sea floor (Bussell et al, 2001).

Well data from Resolution 1 (average TOC of 2.53%) indicate that the upper delta plain facies of the Late Triassic Mungaroo Formation in the eastern Exmouth Plateau has both gas and oil source potential (Esso Australia Ltd, 1980a). In Resolution 1, the formation is thermally over-mature (VR 2.2%) reflecting the uplift and erosion on the Resolution Arch, while it is thermally immature in Zeewulf 1 (Esso Australia Ltd, 1979). However, the gas and condensate recovered from the Mungaroo Formation sandstones at Zeewulf 1 indicate access to a thermally mature to over-mature source at depth.

The Late Jurassic Dingo Claystone is the principal source for oil in the Exmouth Sub-basin (Tindale et al, 1998), and some of this charge may have migrated westward into the Release areas (Smith et al, 2003). The Dingo Claystone is generally thin or absent on the Exmouth Plateau and variable thicknesses occur in the Release areas providing a possible local charge. On the Zeewulf horst structure, only 5 m of Dingo Claystone equivalent sediments were intersected, while in Resolution 1 nearly 800 m of fine-grained Late Jurassic sediments were drilled. The lower 500 m was described as early mature, being ‘characterised by moderate to abundant organic residue, very prominent sapropel and microfossil components’ (Esso Australia Ltd, 1980a).

Reservoirs and Seals

Reservoir facies in Release areas W08-18, W08-19 and W08-20 are represented by sandstones in the Late Triassic Mungaroo Formation and the Early Cretaceous Barrow Group.

Porous and permeable reservoir quality sandstones of the Mungaroo Formation were encountered in Resolution 1 and Zeewulf 1. Several point bar deposits and a 57 m thick braided stream sequence with some good quality reservoir intervals were intersected in Resolution 1 (Esso Australia Ltd, 1980a). However, porosity reduction due to siderite, calcite and pyrite cements and abundant kaolinitic clay matrix is frequently observed in these sandstones.

A higher quality reservoir facies is developed in the nearshore sandstones and stream mouth bar deposits of the Early Cretaceous Barrow Group. These sandstones are composed predominantly of quartz grains, weakly cemented by siderite and pyrite, with a small amount of clay matrix and log-derived porosities at 20-26% range (Esso Australia Ltd, 1980a). In Coniston 1 (BHP Petroleum Pty Ltd, 2001) the Barrow Group is a massive quartz sandstone 88 m thick with excellent reservoir quality, with average porosities of 27% and permeabilities calculated at 4565 mD and measured in core at 3547 mD.

The overlying Mardi Greensand Member is another potential reservoir unit being composed of friable glauconitic sandstone in Resolution 1. However, the reservoir quality is poor in the silty glauconitic sandstones in Zeewulf 1. Only 1.6 m of Mardie Greensand Member is recognised in Coniston 1 where it is composed of moderately silica-cemented silty claystones and glauconitic sandstones (BHP Petroleum Pty Ltd, 2001).

Both regional and intraformational seals are present in the Release areas. The Early Cretaceous Muderong Shale is the regional seal across the Exmouth Sub-basin and Exmouth Plateau (**Figures 3** and **5**). Interbedded claystones within the deltaic sequences of the Triassic Mungaroo Formation and Early Cretaceous Barrow Group have the potential to form intra-formational seals. The Late Jurassic Dingo Claystone caps the Mungaroo Formation sandstones in Resolution 1 and Zeewulf 1, though the Rhaetian marls which provide a conformable regional seal over the Mungaroo Formation in the more westerly parts of the Exmouth Plateau are not preserved in these wells.

Timing of Generation and Expulsion

The complex history of hydrocarbon charge in the Exmouth Sub-basin has been discussed by Tindale et al (1998) and Smith et al (2003). Generation and expulsion from the Late Jurassic Dingo Claystone oil source rocks commenced in the Early Cretaceous in response to loading by the Barrow delta system. Modelling suggests that the initial hydrocarbon charge from the southern and central Exmouth Sub-basin occurred as early as the Berriasian, prior to the deposition of the regional Muderong Shale seal. Traps reliant on Muderong seals may have been charged from the northern part of the sub-basin where generation occurred from the Hauterivian through to the mid Cretaceous. Campanian inversion and uplift terminated hydrocarbon generation, re-ordered migration pathways, formed new traps and kept oil reservoirs shallow and cool, maximising the risk of biodegradation. The progradation of the Miocene to Recent carbonate wedge over the eastern part of the Exmouth Sub-basin has produced a late gas charge which has mixed with biogenic gas in accumulations located to the east of the Release areas.

The Investigator Sub-basin, located to the west of the Release areas, is another Late Jurassic to Early Cretaceous depocentre that generated liquid hydrocarbons prior to inversion in the Late Cretaceous (Tindale et al, 1998; Bradshaw et al, 1998). Up-dip migration eastwards towards Release Area W08-18 may have occurred in the Early Cretaceous.

Some hydrocarbon generation from the gas-prone Mungaroo Formation system and older Triassic source rocks presumably occurred in the Exmouth Sub-basin during the Jurassic with the deposition of km of Dingo Claystone and other sediments in the main depocentre. In the Early Cretaceous, generation from the Triassic source rocks may have extended across the sub-basin and onto parts of the Exmouth Plateau. Burial by the Barrow delta sediments, possibly coupled with elevated heatflows related to continental breakup, may have been sufficient to push suitable source rocks into the gas and oil generation window. The Campanian inversion re-directed the migration pathways and established new traps. On the Exmouth Plateau generation from the Mungaroo Formation continues today as demonstrated by the giant Scarborough gas field that accumulated in a Late Cretaceous inversion structure.

PLAY TYPES

The proven traditional Triassic fault block play, which hosts most of the hydrocarbon reserves in the Carnarvon Basin, extends into the Release areas. Mungaroo Formation sandstones in fault block traps are sealed by either the Dingo Claystone or the fine-grained pro-delta sediments of the Barrow Group. The gas accumulations at Zeewulf 1 and Falcone 1A are examples of this play type.

Barrow Group sandstones sealed by Muderong Shale or inter-bedded claystones, in stratigraphic and structural traps are the other target in the Release areas. Within Release Area W08-18 in particular, there is a complex geometry of prograding and back-stepping deltas (**Figures 4** and **5**) which may enable trap configuration. The Scarborough giant gas field was a successful test of the Barrow Group on the Exmouth Plateau, and all the oil and gas fields in the Exmouth Sub-basin are examples of these play types (**Figure 6**).

Apart from reservoir sandstones in Triassic (Mungaroo Formation) and Early Cretaceous (Barrow Group) deltaic sequences, other potential reservoirs include the Early Cretaceous Mardie Greensand Member and Jurassic sandstones reworked from Triassic high blocks. Play types based on these reservoirs have proved to be viable elsewhere in the Carnarvon Basin.

CRITICAL RISKS

Biodegradation of an early oil charge, the termination of generation and the disruption of migration pathways and traps are risks resulting from the Late Cretaceous inversion event in the Exmouth Sub-basin. Smith et al (2003) noted that these risks can be mitigated by high quality reservoirs that allow viscous oil to flow, and that less biodegraded oil will be hosted in the deeper and hotter reservoirs, beneath seals other than the Muderong Shale. In the Release areas, the main risk affecting the Barrow Group play is hydrocarbon charge and the timing of trap formation. Oil migration is required from outside the Release areas from the main Exmouth Sub-basin or Investigator Sub-basin depocentres. Furthermore, it is critical that trapping and preservation were linked to Late Cretaceous inversion.

For the Mungaroo Formation play, the gas charge is considered to be locally derived from the underlying Triassic sequence. Diminished reservoir qualities due to diagenetic overprints is another risk: however, the application of amplitude analysis with 3D seismic coverage can image gas within reservoirs and improve success rates.

FIGURES

REFERENCES (ALL CARNARVON BASIN RELEASE AREAS)

Online Technical Papers
The Petroleum Exploration Society of Australia (PESA) sponsored online document search and delivery website PROFDOCS contains many of the technical papers referenced below, and can be found at http://www.profdocs.com.

Van AARSSEN, R., ALEXANDER, R. AND KAGI, R.I., 1996—The origin of Barrow Sub-basin crude oils: a geochemical correlation using land-plant biomarkers. The APPEA Journal, 36(1), 131–144.

ALCOCK, M.B., STAGG, H.M.J., COLWELL, J.B., BORISSOVA, I., SYMONDS AND BERNARDEL, G., 2006—Seismic transects of Australia's frontier continental margins. Geoscience Australia Record 2006/004

ARDITTO, P.A., 1993—Depositional sequence model for the post-Barrow Group Neocomian succession, Barrow and Exmouth Sub-basins, Western Australia. The APEA Journal, 33 (1), 152-160.

AULD, K., THOMAS, B., GOODALL, J., ELLIOTT, L. AND BENSON, J., 2002—John Brookes Gas – the voyage to discovery. In: Keep, M. and Moss, S.J. (editors), The Sedimentary Basins of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 491–509.

BACKHOUSE, J., BALME, B.E., HELBY, R., MARSHALL, N.G. AND MORGAN, R., 2002—Palynological zonation and correlation of the latest Triassic Northern Carnarvon Basin. . In: Keep, M. and Moss, S.J. (editors), The Sedimentary Basins of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 179–201.

BACKHOUSE, J., 2006—Triassic biostratigraphic study of greater Exmouth Plateau, synthesis report. Geoscience Australia Repository Destructive Analysis Report 1297 unpublished.

BAILLIE, P.W. AND JACOBSON, E.P., 1997—Prospectivity and exploration history of the Barrow Sub-basin, Western Australia. The APPEA Journal, 37(1), 117–135.

BARBER, P., 1988—The Exmouth Plateau deepwater frontier: a case study. In: Purcell, P.G. and Purcell, R.R. (editors), The North West Shelf, Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 173–187.

BARRETT, A. G. 2004—Opportunity for growth, Medium-term potential for the Exmouth Sub-basin. Chapter 3 in Oil and Gas Resources of Australia 2004. Geoscience Australia.

BLEVIN, J.E., STEPHENSON, A.E. AND WEST, B.G., VUCKOVIC, V., MIYAZAKI, S. AND LAVERING, I.H., 1994a—Beagle Sub-basin Petroleum

Prospectivity Bulletin, 2nd edition, Bureau of Resource Sciences, AGPS, Canberra.

BLEVIN, J.E., STEPHENSON, A.E. AND WEST, B.G., 1994b—Mesozoic structural development of the Beagle Sub-basin – Implications for the petroleum potential of the Northern Carnarvon Basin. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia: Proceedings of Petroleum Exploration Society of Australia Symposium, Perth, 479–495.

BHP PTY LTD, 2001—Coniston 1, Well Completion Report, Interpretative Volume, unpublished

BHP BILLITON, 2007—Pyrenees Oil Field Development, Exmouth Sub-basin. Boucher June 2007. BHP Billiton.

BHP BILLITON, 13 Aug 2007b—[Web page] BHP Billiton announces gas discovery at Thebe-1, offshore Australia. http://www.qni.com.au/bb/investorsMedia/news/2007/bhpBillitonAnnouncesGasDiscoveryAtThebe1OffshoreAustralia.jsp (last accessed 25 January 2008)

BOOTE, D.R.D. & KIRK, R.B., 1989— Depositional wedge cycles on evolving plate margin, western and northwestern Australia. AAPG Bulletin 73(2), 216-243.

BRADSHAW, J., SAYERS, J., BRADSHAW, M., KNEALE, R., FORD, C., SPENCER, L. & LISK, M., 1998—Palaeogeography and its impact on the Petroleum Systems of the North West Shelf, Australia, In: Purcell, P.G. & R.R. (Eds), 1998, The Sedimentary Basins of Western Australia 2: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 1998, 95-121

BRADSHAW, M.T., FOSTER, C.B., FELLOWS, M.E. AND ROWLAND, D.C., 1999—The Australian search for petroleum-patterns of discovery. The APPEA Journal, 39 (1), 1-18.

BURNS, B., 1981—Geochemical Report. In: Esso Australia Limited, 1981—Eendracht 1 Well Completion Report, unpublished.

BUSSELL, M.R., JABLONSKI, D., ENMAN, T., WILSON, M.J. AND BINT, A.N., 2001—Deepwater exploration: northern Western Australia compared with Gulf of Mexico and Mauritania. The APPEA Journal 41(1), 289–319.

CHEVRON 2007—[Web page] www.chevron.com/countries/australia/?view=3 (last accessed 25 January 2008)

COOK, A.C., SMYTH, M. AND VOS, R.G., 1985—Source potential of Upper Triassic fluvio-deltaic systems of the Exmouth Plateau. The APEA Journal 25 (1), 204–215.

CRAIG, A., SIT, H., SHERIDAN, P. AND MacLEAN, 1997—A geophysical appraisal of the east Spar gas/condensate field. The APPEA Journal 37(1), 12–30.

DoIR. 14 June 2007—[Web page] Production http://www.doir.wa.gov.au/mineralsandpetroleum/Publications.asp (last accessed 24 January 2008)

Department of Resources Energy and Tourism (DRET) 2007—[Web page] Australian Petroleum News, April 2007 http://www.ret.gov.au/General/Resources-Exp/Pages/AustralianPetroleumNewsApril2007.aspx (last accessed 5 February 2007).

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

EDWARDS, D.S., ZUMBERGE, J.E., BOREHAM, C.J., KENNARD, J.M., BARRETT, A. AND BRADSHAW, M.T., 2007—Petroleum Systems and Supersystems of the Australian North West Shelf: A Geochemical Approach. Abstract, Geological Society of London: Emerging Plays in Australasia Symposium July 2007.

ELLIS, G.K., PITCHFORD, A. AND BRUCE, R.H., 1999—Barrow Island oil field. The APPEA Journal 39 (1), 158–175.

ESSO AUSTRALIA LIMITED, 1979—Zeewulf 1 Well Completion Report, unpublished.

ESSO AUSTRALIA LIMITED, 1980a—Resolution 1 Well Completion Report, unpublished.

ESSO AUSTRALIA LIMITED, 1980b—Vinck 1 Well Completion Report, unpublished.

ESSO AUSTRALIA LIMITED, 1981—Eendracht 1 Well Completion Report, unpublished.

ESSO AUSTRALIA LIMITED, 1983—Novara 1 Well Completion Report, unpublished.

EXON, N.F., COLWELL, J.B., WILLIAMSON, P.E. AND BRADSHAW, M.T., 1991—Reefal complexes in Mesozoic sequences: Australia's North West Shelf Region. 1991 Indonesian Petroleum Association Conference Proceedings, 51–66.

FERDINANDO, D., 2004—Review of 2004 Upstream Petroleum Activity in Western Australia. Petroleum in Western Australia Magazine, April 2004. Available at: http://www.doir.wa.gov.au/mineralsandpetroleum/0CA444B595864BFDB27E90C916582B38.asp

GEOSCIENCE AUSTRALIA AND GEOMARK, 2005—The Oils of Western Australia II. Geoscience Australia and GeoMark Research, Ltd., Proprietary report, Canberra and Houston, unpublished.

HAQ, B.U., von RAD, U., O'CONNELL, S. ET AL., 1990—Proceedings of Ocean Drilling Program, Initial Reports, 122. Ocean Drilling Program, College Station, Texas, 862 pp.

HEARTY, D.J. AND BATTRICK, M.A., 2002—Woollybutt 2001: a geoscience odyssey. Hearty and Battrick, 2002. In: Keep, M. and Moss, S.J. (editors), The Sedimentary Basins of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 551-576.

HEARTY, D.J., ELLIS, G.K. AND WEBSTER, K.A., 2002—Geological history of the western Barrow Sub-basin: implications for hydrocarbon entrapment at Woollybutt and surrounding oil and gas fields. In: Keep, M. and Moss, S.J. (editors), The Sedimentary Basins of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 577-598.

HOCKING, R.M., 1990—Carnarvon Basin. In: Geology and Mineral Resources of Western Australia. Western Australia Geological Survey, Memoir 3, 457–495.

INGRAM, B., 1990—Review of Twelve Wells from the Beagle Sub-basin, Palynology Report WP11/90. Kufpec Australia Pty. Ltd., unpublished.

JABLONSKI, D., 1997—Recent advances in the sequence stratigraphy of the Triassic to Lower Cretaceous succession in the Northern Carnarvon Basin, Australia. The APPEA Journal 37 (1), 429–454.

JABLONSKI, D AND SAITTA, A.J., 2004—Permian to Lower Cretaceous plate tectonics and its impact on the tectono-stratigraphic development of the western Australian margin. The APPEA Journal 44 (1) 287-327.

JENKINS, C.C., MAUGHAN, D.M., ACTON, J.H., DUCKETT, A., KORN, B.E. AND TEAKLE, R.P., 2003—The Jansz gas field, Carnarvon Basin, Australia. The APPEA Journal 43 (1), 303–324.

JOURNAL OF PETROLEUM TECHNOLOGY, 2007—Regional Update, Australia. Journal of Petroleum Technology, volume 59, Number 11, November 2007, page 10.

KOPSEN, E. AND McGANN, G., 1985—A review of the hydrocarbon habitat of the eastern and central Barrow-Dampier Sub-basin, Western Australia. The APEA Journal 25 (1), 154–176.

KORN, B.E., TEAKLE, R.P., MAUGHAN, D.M., & SIFFLEET, P.B., 2003—The Geryon, Orthrus, Maenad and Urania gas fields, Carnarvon Basin, Western Australia. APPEA Journal 43 (1), 285-301.

LONGLEY, I.M., BRADSHAW, M.T. AND HEBBERGER, J., 2001—Australia petroleum provinces of the twenty-first century. In DOWNEY, M.W., THRETT, J.C. AND MORGAN, W.A., (editors) Petroleum Provinces of the Twenty-first Century; AAPG Memoir 74, 87-317.

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.J. (editors), The Sedimentary Basins of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 27–88.

MALCOLM, R.J., POTT, M.C. AND DELFOS, E., 1991—A new tectono-stratigraphic synthesis of the North West Cape area. The APEA Journal 31(1), 154–176.

MALEK, R., 2006—Western Australia's developing hydrocarbon potential. In Australia in Focus, PESA News October/November 2006. Petroleum Exploration society of Australia.

MOBIL EXPLORATION AND PRODUCING AUSTRALIA, 1999—John Brookes 1/ST1 Well Completion Report, unpublished.

MOSS, S., BARR, D., KNEALE, R., CLEWS, P. AND CRUSE, T., 2003—Mid to Late Jurassic shallow marine sequences of the eastern Barrow Sub-basin: the role of low-stand deposition in new exploration concepts. The APPEA Journal 43 (1), 231–255.

NEWMAN, S., 1994—Clues to the structural history of the Rankin Trend, from 3-D seismic data. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 497–507.

NICOLL, R.S., 2002—Conodont biostratigraphy and palaeogeography of the Triassic on the western, northwestern and northern margins of the Australian Plate. In: Keep, M. and Moss, S.J. (editors), The Sedimentary Basins of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 168–177.

NORVICK, M.S., 2002—Palaeogeographic Maps of the Northern Margins of the Australian Plate: Final Report. Unpublished report for Geoscience Australia.

PETROLEUM AND ROYALTIES DIVISION AND GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 2007—The Petroleum Explorer's Guide to Western Australia, Third Edition: Department of Industry and Resources of Western Australia, page 47.

POLOMKA, S.M., BRUINS, J., SPANNINGA, G.A. AND MENNIE, J.P., 1999—WA-271-P, Exmouth Sub-basin – integrated prospectivity evaluation. The APPEA Journal 39 (1), 115-127.

von RAD, U., HAQ, B.U., ET AL., 1992—Proceedings of Ocean Drilling Program, Initial Reports, 122. Ocean Drilling Program, College Station, Texas, 934 pp.

ROBERTSON RESEARCH, 1986—Petroleum Geology and Geochemistry, Northwest Shelf, Australia: Phase II. Robertson Research Australia Pty. Ltd. Report, unpublished.

ROSS, M.I. AND VAIL, P.R., 1994—Sequence stratigraphy of the lower Neocomian Barrow Delta, Exmouth Plateau, northwestern Australia. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 435-447.

SAYERS, J., BORISSOVA, I, RAMSEY, D, AND SYMONDS, P. A., 2002—Geological framework of the Wallaby Plateau and adjacent areas. Geoscience Australia Record 2002/21.

SCIBIORSKI, J.P., MICENKO, M. AND LOCKHART, D., 2005—Recent discoveries in the Pyrenees Member, Exmouth Sub-basin: a new oil play fairway. The APPEA Journal 45 (1), 233-251.

SCOTT, J. AND HARTUNG-KAGI, B., 1998—Oil families and effective source rocks of Western Australia. PESA Journal, No 26, 22–36.

SEGGIE, R.J., LAND, S.C., MARSHALL, N.M., CUBITT, C.J., ALSOP, D., KIRK, R. AND TWARTZ, S., 2007—Integrated multi-disciplinary analysis of the Rankin Trend gas reservoirs, North West Shelf, Australia. The APPEA Journal, 47 (1), 53-67.

SIBLEY, D., HERKENHOFF, F., CRIDDLE, D. & McLERIE, M., 1999—Reducing resource uncertainty using seismic amplitude analysis on the southern Rankin Trend, northwest Australia. APPEA Journal 39(1), 128-147.

SIT, K.H., HILLOCK, P.M., AND MILLER, N.W.D., 1994—The Maitland gas discovery – a geophysical/petrophyscial case history. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia: Proceedings of Petroleum Exploration Society of Australia Symposium, Perth, 597–613.

SMITH, N., DEMPSEY, C., JACKSON, M., AND PRESTON, J., 2003—Overcoming historical bias: an integrated geological and engineering assessment of the Coniston prospect, Exmouth Sub-basin. The APPEA Journal 43(1), 363–383.

STAGG, H.M.J., ALCOCK, M.B., BERNARDEL, G., MOORE, A.M.G., SYMONDS, P.A. AND EXON, N.F., 2004—Geological framework of the Outer Exmouth Plateau and adjacent ocean basins. Geoscience Australia Record 2004/13.

TINAPPLE, W., 2007—Exploration picks up in WA. Petroleum in Western Australia, April 2007. Department of Industry and Resources, Western Australia, page 12. Available at:
http://www.qni.com.au/bb/investorsMedia/news/2007/bhpBillitonAnnouncesGasDiscoveryAtThebe1OffshoreAustralia.jsp

TINDALE, K., NEWELL, N., KEALL, J. AND SMITH, N., 1998—Structural evolution and charge history of the Exmouth Sub-basin, Northern Carnarvon Basin, Western Australia. In: Purcell, P.G. and Purcell, R.R.(editors), The Sedimentary Basins of Western Australia 2: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 447–472.

U.S. GEOLOGICAL SURVEY WORLD ENERGY ASSESSMENT TEAM, 2000—Northwest Shelf Geologic Province 3948. U.S. Geological Survey World Petroleum Assessment 2000.

WALKER, T.R., 2007—Deepwater and frontier exploration in Australia – historical perspectives, present environment and likely future trends. The APPEA Journal 47(1), 15-38.

WAPET, 1983—Bluebell 1 Well Completion Report, unpublished

WAPET, 1997—Dionysus 1 Well Completion Report, unpublished

WESTPHAL, H. AND AIGNER, T., 1997—Seismic stratigraphy and subsidence analysis in the Barrow-Dampier Sub-basin, northwest Australia. AAPG Bulletin 81(10), 1721–1749.

WILLIAMSON, P.E. AND KROH, F., 2007—The role of amplitude versus offset technology in promotion offshore petroleum exploration in Australia. The APPEA Journal, 47 (1), 161-174.

WILLINK, R., 2004—2003 Exploration Highlights. The APPEA Journal, 44 (2), 93-116.

WOODSIDE 29 Jan 2008—[Web page] Pluto LNG Project http://www.woodside.com.au/NR/exeres/C62233EE-653C-4D62-B6C6-5E9D8697403B%2Cframeless.htm (last accessed 25 January 2008)

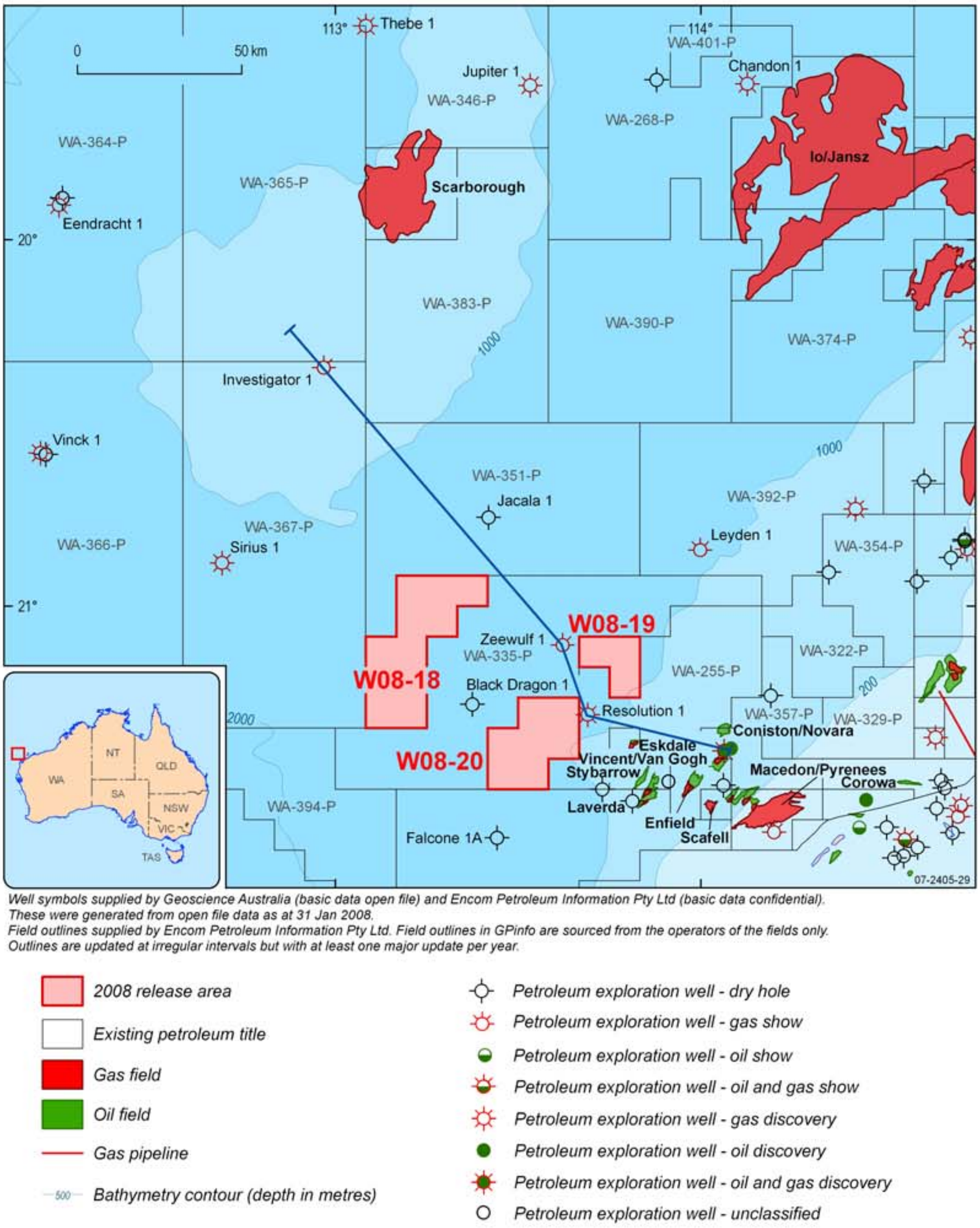


Figure 1. Location map of areas W08-18, W08-19 and W08-20, showing existing petroleum permits, known fields and discoveries, and the cross-section shown in Figure 5.

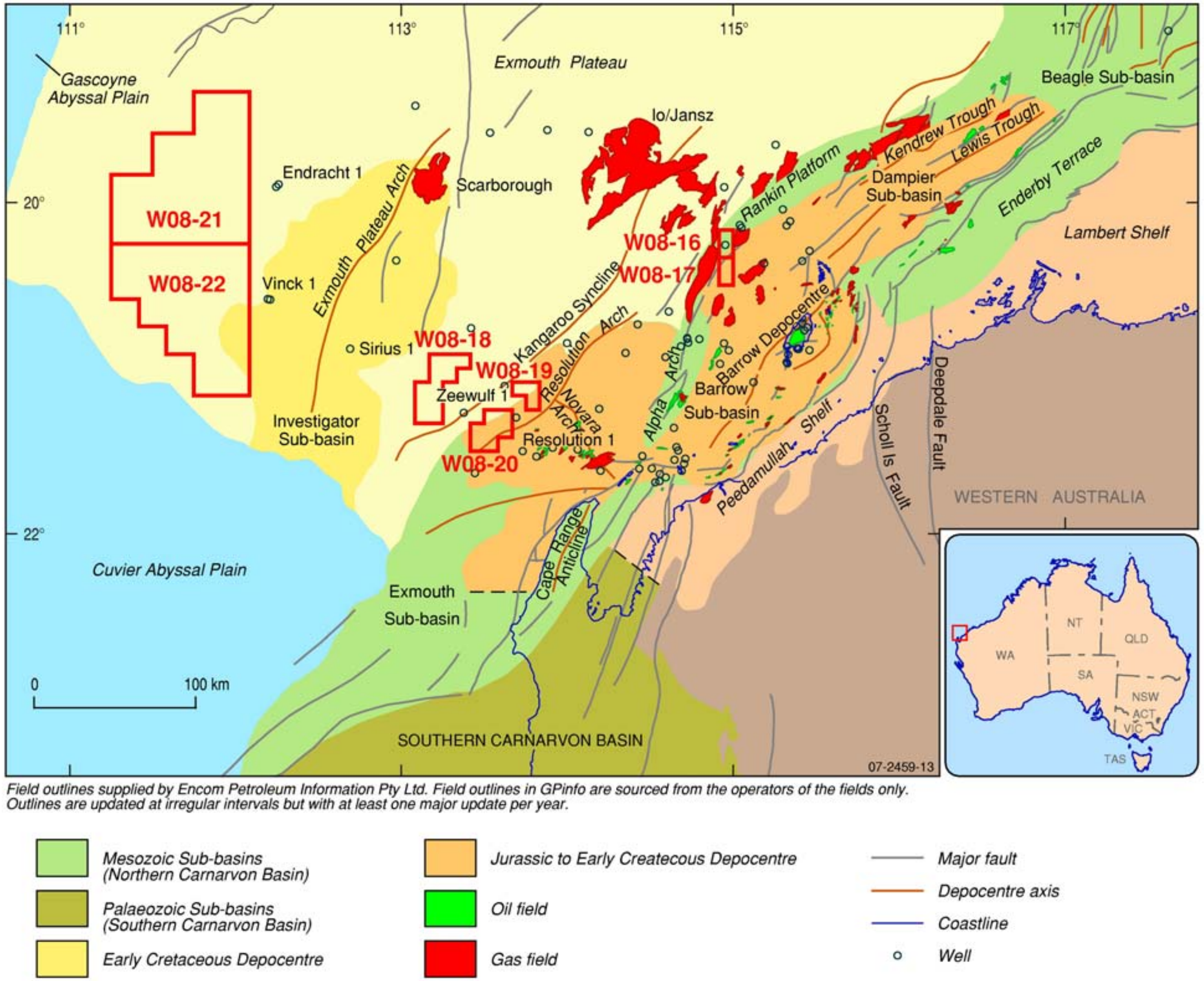


Figure 2. Structural elements of the northern Carnarvon Basin showing the 2008 Release areas.

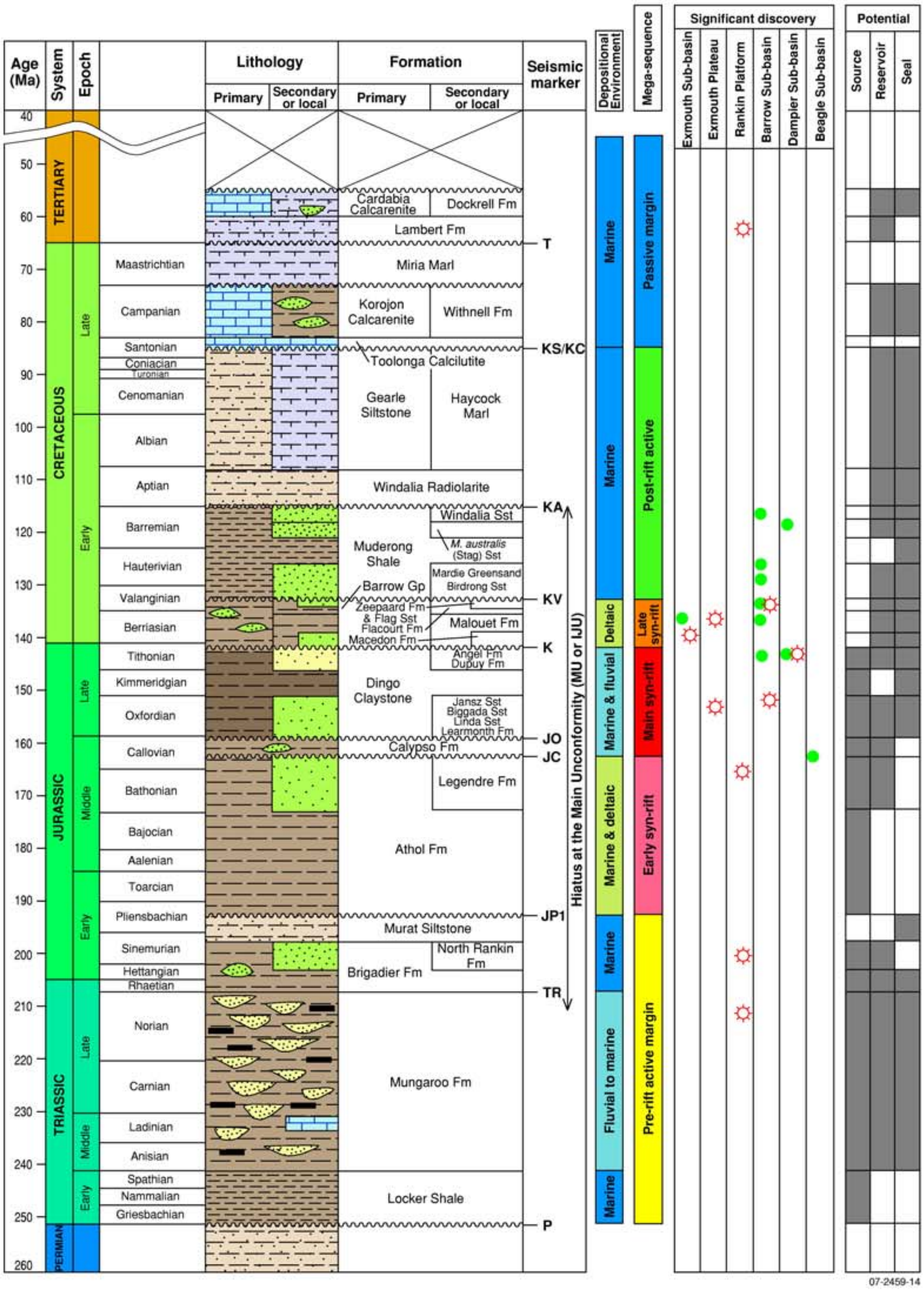
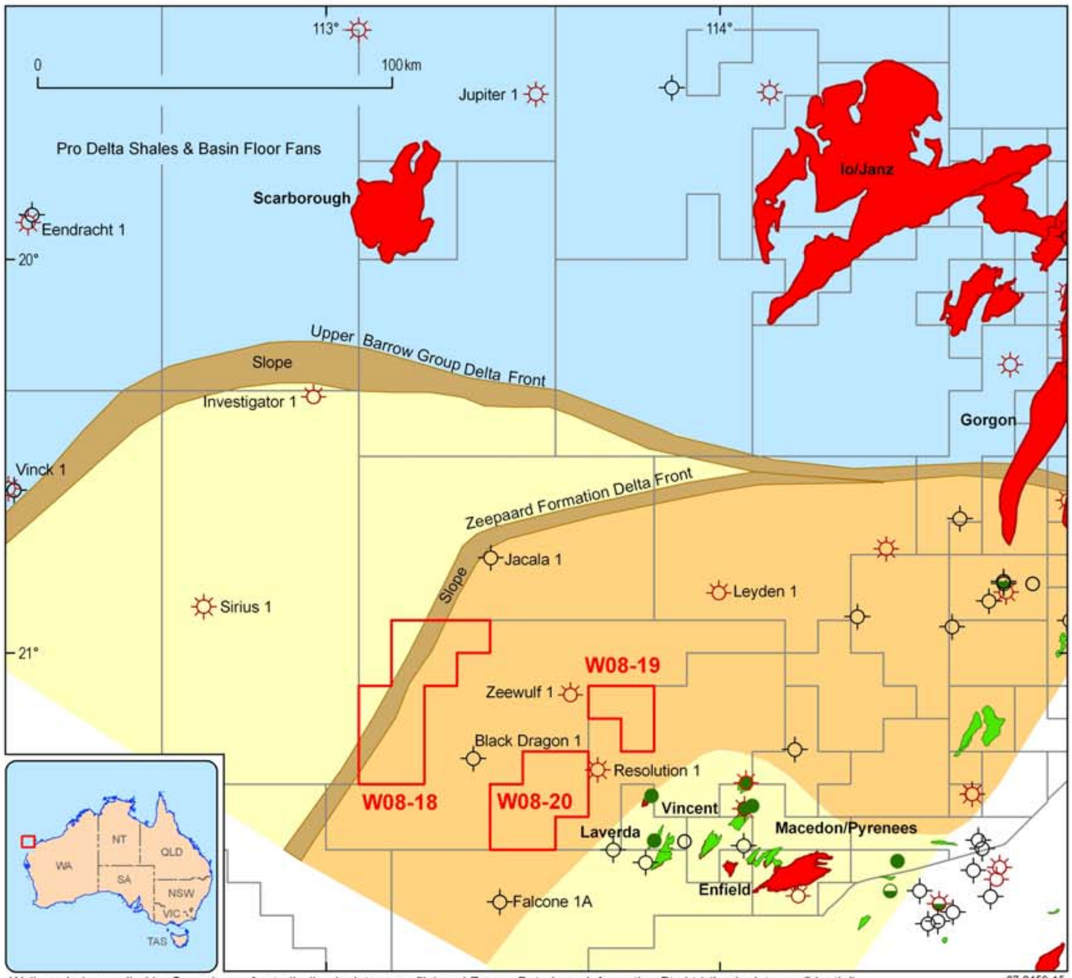


Figure 3. Regional stratigraphy of the northern Carnarvon Basin.



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

Zeepaard & Birdrong Formations
Barrow Group Sediments
2008 release area
Existing petroleum title
Gas field
Oil field

Petroleum exploration well - dry hole
Petroleum exploration well - gas show
Petroleum exploration well - oil show
Petroleum exploration well - oil and gas show
Petroleum exploration well - gas discovery
Petroleum exploration well - oil discovery
Petroleum exploration well - oil and gas discovery
Petroleum exploration well - oil discovery with gas show
Petroleum exploration well - unclassified

Figure 4. Palaeogeographic map for the Early Cretaceous (Neocomian) Exmouth Sub-basin showing location of the Release areas W08-18, W08-19 and W08-20 (modified from Smith et al, 2003).

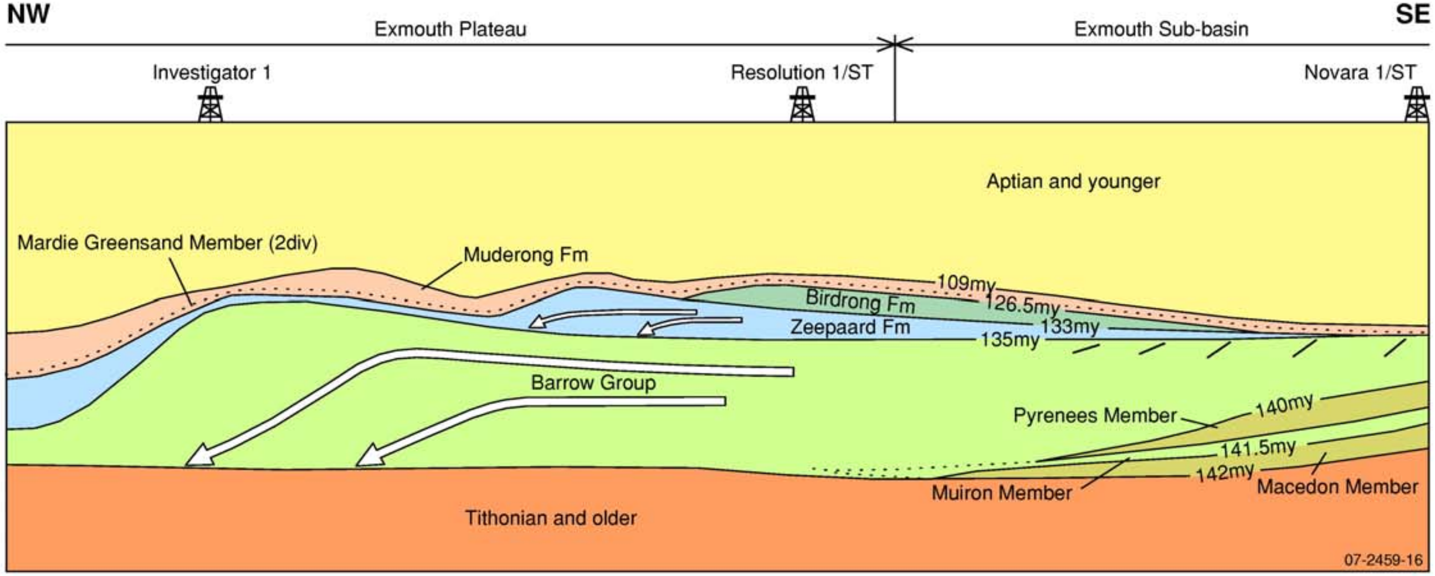


Figure 5. Schematic Neocomian reservoir stratigraphy across the Exmouth Plateau and Exmouth Sub-basin (modified from Smith et al, 2003). See Figure 1 for location of section.

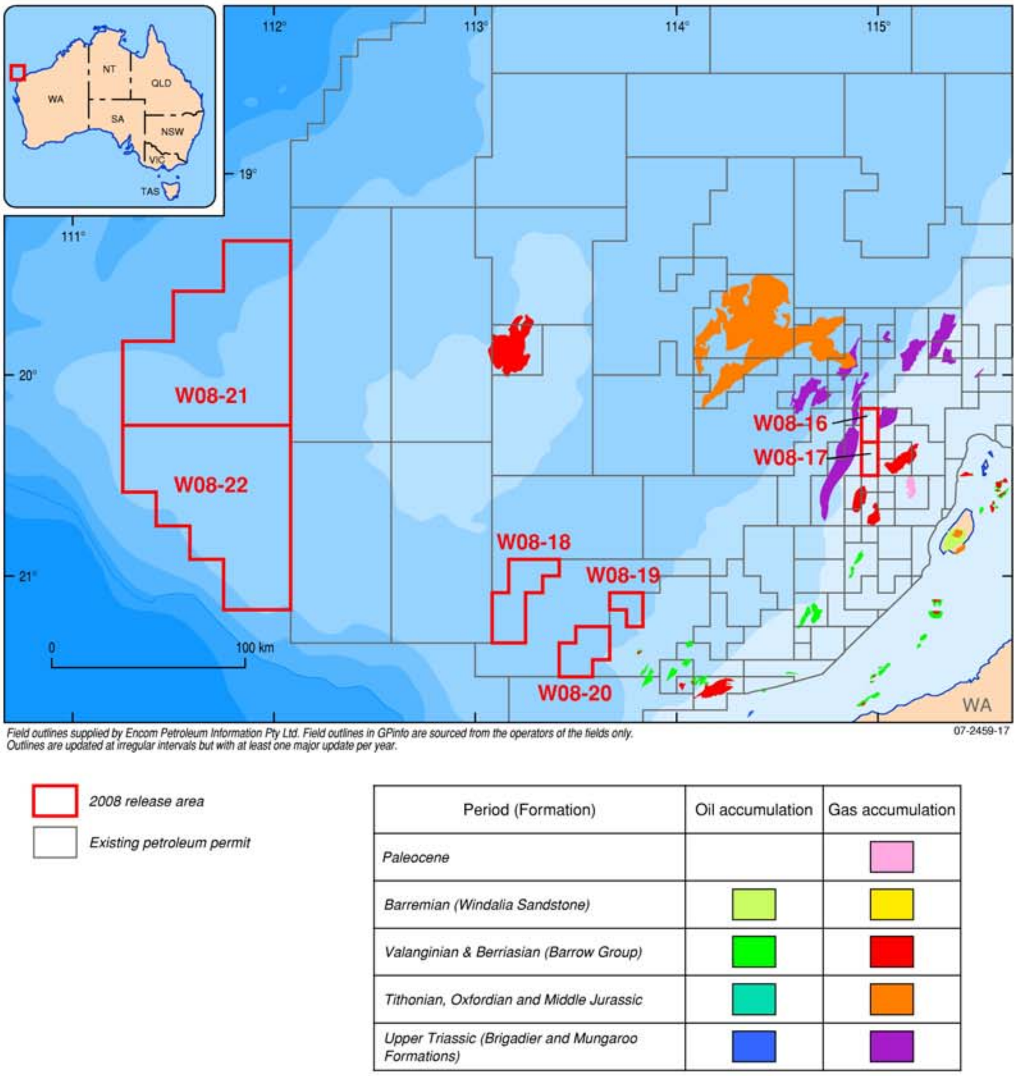


Figure 6. Major oil and gas accumulations in the northern Carnarvon Basin indicating age of main reservoir.