



Australian Government

Department of Resources, Energy and Tourism

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

### **RELEASE AREAS W08-11, W08-12, W08-13, W08-14 AND W08-15 BEDOUT SUB-BASIN, ROEBUCK BASIN, WESTERN AUSTRALIA**

#### **SECTIONS - SUMMARY**

##### **RELEASE AREAS W08-11, W08-12, W08-13, W08-14 AND W08-15**

LOCATION

GRATICULAR BLOCK LISTINGS AND MAPS

RELEASE AREA GEOLOGY

Regional Tectonic Setting

Basin Evolution

EXPLORATION HISTORY

Well Control

Key Wells Listing

Seismic Coverage

HYDROCARBON POTENTIAL

Petroleum Systems

*Ordovician Larapintine 2*

*Late Carboniferous-Permian Gondwana 1*

*Early Triassic Gondwana 2*

*Westralian Petroleum Systems*

Play Types

Critical Risks

FIGURES

REFERENCES

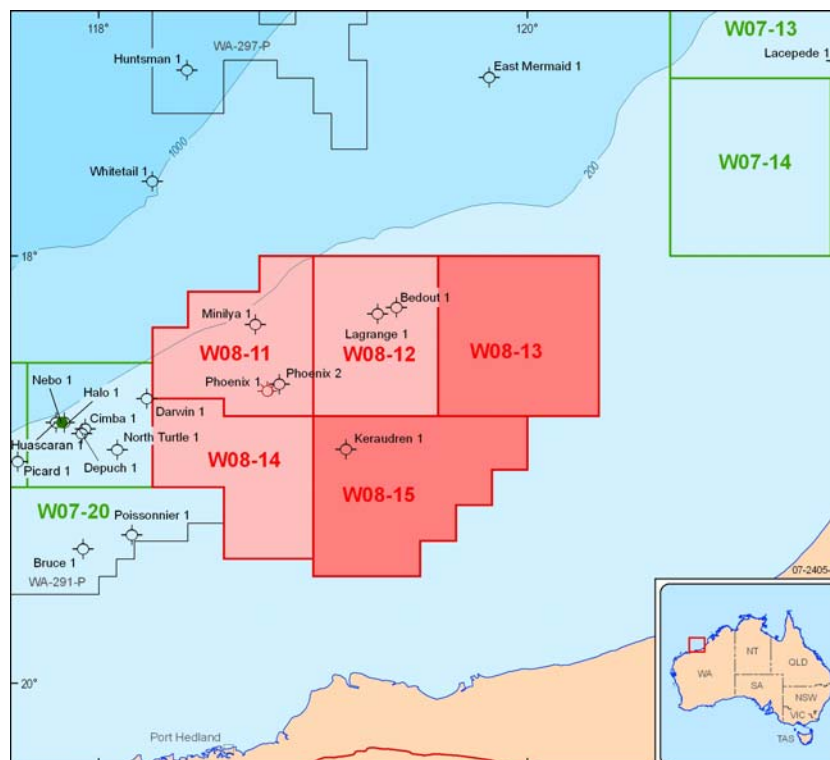


## SUMMARY

### RELEASE AREAS W08-11, W08-12, W08-13, W08-14 AND W08-15 BEDOUT SUB-BASIN, ROEBUCK BASIN WESTERN AUSTRALIA

#### BIDS CLOSE - 9 APRIL 2009

- **Designated Frontier Area Tax Concession applies to areas W08-13 and W08-15.**
- Under-explored areas adjacent to the proven Carnarvon Basin hydrocarbon province
- Interpreted gas column at Phoenix 1 suggests an active petroleum system in the area
- Shallow water depths between 35 and 265 m
- Special Notices apply, refer to Guidance Notes



Well symbols supplied by Geoscience Australia (basic data open file) and Encom Petroleum Information Pty Ltd (basic data confidential).  
These were generated from open file data as at 31 Jan 2008.





Australian Government

Department of Resources, Energy and Tourism

## 2008 RELEASE OF AUSTRALIAN OFFSHORE PETROLEUM EXPLORATION AREAS

**RELEASE AREAS W08-11, W08-12, W08-13, W08-14 AND W08-15  
BEDOUT SUB-BASIN, ROEBUCK BASIN  
WESTERN AUSTRALIA**

**BIDS CLOSE - 9 APRIL 2009**

### LOCATION

Release areas W08-11, W08-12, W08-13, W08-14, and W08-15 lie approximately 100 km north of Port Hedland and 200 km west of Broome, Western Australia, in 35-265 m water depth ([Figure 1](#)). The Release areas are located within the Bedout Sub-basin of the Roebuck Basin ([Figure 2](#)). No economic discoveries have been made in the sub-basin, although a tight gas column has been interpreted in Phoenix 1.

Release Area W08-11 comprises 61 full graticular blocks, covers an area of 4955 km<sup>2</sup> and contains 3 wells (Minilya 1 and Phoenix 1 and 2).

Release Area W08-12 comprises 63 full graticular blocks, covers an area of 5120 km<sup>2</sup> and contains 2 wells (Bedout 1 and Lagrange 1).

Release Area W08-13 comprises 81 full graticular blocks and covers an area of 6580 km<sup>2</sup>.

Release Area W08-14 comprises 60 full graticular blocks and covers an area of 4855 km<sup>2</sup>.

Release Area W08-15 comprises 84 full graticular blocks, covers an area of 6790 km<sup>2</sup> and contains 1 well (Keraudren 1).

## GRATICULAR BLOCK LISTINGS AND MAP

### RELEASE AREA W08-11

#### BEDOUT SUB-BASIN, ROEBUCK BASIN, WESTERN AUSTRALIA

##### *Map Sheet SE 50 (Rowley Shoals)*

1786	1787	1788	1858	1859	1860
1926	1927	1928	1929	1930	1931
1932	1998	1999	2000	2001	2002
2003	2004	2068	2069	2070	2071
2072	2073	2074	2075	2076	2140
2141	2142	2143	2144	2145	2146
2147	2148	2212	2213	2214	2215
2216	2217	2218	2219	2220	2284
2285	2286	2287	2288	2289	2290
2291	2292	2360	2361	2362	2363
2364					

Assessed to contain 61 full blocks

### RELEASE AREA W08-12

#### BEDOUT SUB-BASIN, ROEBUCK BASIN, WESTERN AUSTRALIA

##### *Map Sheet SE 50 (Rowley Shoals)*

1789	1790	1791	1792	1793	1794
1795	1861	1862	1863	1864	1865
1866	1867	1933	1934	1935	1936
1937	1938	1939	2005	2006	2007
2008	2009	2010	2011	2077	2078
2079	2080	2081	2082	2083	2149
2150	2151	2152	2153	2154	2155
2221	2222	2223	2224	2225	2226
2227	2293	2294	2295	2296	2297
2298	2299	2365	2366	2367	2368
2369	2370	2371			

Assessed to contain 63 full blocks

**RELEASE AREA W08-13  
BEDOUT SUB-BASIN, ROEBUCK BASIN, WESTERN AUSTRALIA**

***Map Sheet SE 50 (Rowley Shoals)***

1796	1797	1798	1799	1800	1868
1869	1870	1871	1872	1940	1941
1942	1943	1944	2012	2013	2014
2015	2016	2084	2085	2086	2087
2088	2156	2157	2158	2159	2160
2228	2229	2230	2231	2232	2300
2301	2302	2303	2304	2372	2373
2374	2375	2376			

***Map Sheet SE 51 (Broome)***

1729	1730	1731	1732	1801	1802
1803	1804	1873	1874	1875	1876
1945	1946	1947	1948	2017	2018
2019	2020	2089	2090	2091	2092
2161	2162	2163	2164	2233	2234
2235	2236	2305	2306	2307	2308

Assessed to contain 81 full blocks

**RELEASE AREA W08-14  
BEDOUT SUB-BASIN, ROEBUCK BASIN, WESTERN AUSTRALIA**

***Map Sheet SE 50 (Rowley Shoals)***

2356	2357	2358	2359	2428	2429
2430	2431	2432	2433	2434	2435
2436	2500	2501	2502	2503	2504
2505	2506	2507	2508	2572	2573
2574	2575	2576	2577	2578	2579
2580	2644	2645	2646	2647	2648
2649	2650	2651	2652	2720	2721
2722	2723	2724	2792	2793	2794
2795	2796	2864	2865	2866	2867
2868	2936	2937	2938	2939	2940

Assessed to contain 60 full blocks

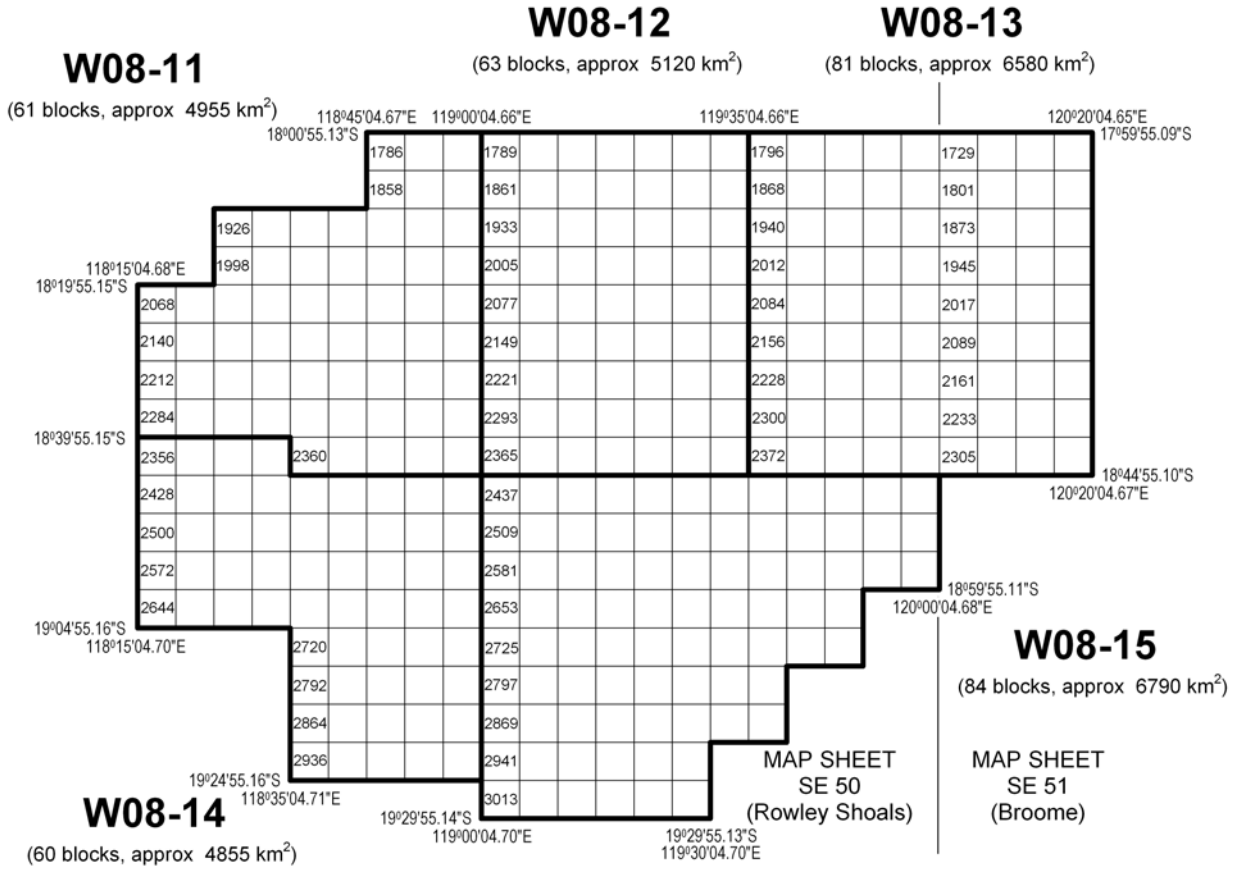
**RELEASE AREA W08-15  
BEDOUT SUB-BASIN, ROEBUCK BASIN, WESTERN AUSTRALIA**

***Map Sheet SE 50 (Rowley Shoals)***

2437	2438	2439	2440	2441	2442
2443	2444	2445	2446	2447	2448
2509	2510	2511	2512	2513	2514
2515	2516	2517	2518	2519	2520
2581	2582	2583	2584	2585	2586
2587	2588	2589	2590	2591	2592
2653	2654	2655	2656	2657	2658
2659	2660	2661	2662	2725	2726
2727	2728	2729	2730	2731	2732
2733	2734	2797	2798	2799	2800
2801	2802	2803	2804	2869	2870
2871	2872	2873	2874	2875	2876
2941	2942	2943	2944	2945	2946
3013	3014	3015	3016	3017	3018

Assessed to contain 84 full blocks

# 2008 Release Areas Bedout Sub-basin, Roebuck 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.

## RELEASE AREA GEOLOGY

### REGIONAL TECTONIC SETTING

The Roebuck Basin forms the central part of the North West Shelf Westralian Superbasin, which is a northeast-trending passive margin of Late Palaeozoic and Mesozoic age. The inboard part of the Roebuck Basin overlies a major northwest-trending intra-cratonic basin (offshore Canning Basin) of Palaeozoic age (Colwell and Stagg, 1994). The temporal boundary between the intra-cratonic and passive margin successions is marked by a major Late Carboniferous transpressional event (Meda Transpression) which probably represents the peak of the Alice Springs Orogeny in Central Australia (Shaw et al, 1992). Descriptions of the central North West Shelf basin elements are given in Lipski (1993; 1994), Colwell and Stagg (1994), Smith (1999) and Smith et al (1999), and the adjacent onshore Canning Basin is described by Kennard et al (1994).

The central North West Shelf has been divided into a number of major structural elements ([Figure 2](#)). 'Westralian' passive margin sediments of the Bedout and Rowley sub-basins comprise the Roebuck Basin. Sediments in these depocentres disconformably overlie the Palaeozoic intra-cratonic succession in the Oobagooma Sub-basin (the offshore extension of the Fitzroy Trough) and in the offshore Willara Sub-basin, which are separated by the west-northwest-trending structural high of the Broome Platform.

The **Bedout Sub-basin** consists of an east-northeast to west-southwest trending Mesozoic depocentre that is filled with approximately 2.5 km of Palaeozoic sediments and 7 km of Mesozoic section (Smith et al, 1999). The sub-basin is separated from the Beagle Sub-basin to the west by the North Turtle Hinge Zone, and bounded to the northwest by the Bedout High ([Figure 3](#)). The Mesozoic section has generally experienced gentle structuring, and thickens to the west before pinching out against and partly draping over the Bedout High. To the east and south the Mesozoic sediments thin and progressively onlap the older Palaeozoic section.

The **Bedout High** locally separates the Bedout Sub-basin to the south from the Rowley Sub-basin to the north ([Figure 4](#)). The high consists of uplifted and eroded Permo-Carboniferous sediments above an interpreted faulted basement core, and is capped by Late Permian volcanics (Colwell and Stagg, 1994; Smith et al, 1999). It has a maximum relief of approximately 6 km above the surrounding major basin depocentres, and is associated with a Moho uplift of about 7-9 km. Early-Middle Triassic sediments onlap the feature from all directions and approximately 3 km of Late Triassic-Cenozoic sediments are draped over the top. The Bedout High is approximately 30 km wide at its upper surface which is expressed as a peneplain. Two culminations can be distinguished which are separated by a north-northwest to south-southeast trending normal fault that terminates below the interpreted top-Permian reflection (Smith et al, 1999; Müller et al, 2005).

Three possible concepts for the origin of the Bedout High have been proposed:

1. A pre-Triassic fault-bounded high that is capped by extrusive volcanics and that developed as a large volcanic island over a mantle hotspot (Lipski, 1994);

2. A faulted core of partly thrust-controlled 'basement' rocks that are overlain by a sequence of Carboniferous (or older) to Permian sediments (Colwell and Stagg, 1994);
3. The uplifted core of a circular crater, formed by the impact of a large extraterrestrial body near the end of the Permian (Gorter, 1996; Becker et al, 2004).

Smith et al (1999) noted that the Bedout and Oobagooma highs form a northeast-southwest structural lineament that forms a hinge line between the Rowley Sub-basin and the Bedout and Oobagooma sub-basins ([Figure 2](#)), and concluded that these evolved during the same tectogenetic processes. This lineament terminates older northwest-southeast trending Palaeozoic structures (including the Broome Platform), and appears to have developed through crustal thinning associated with a deep crustal detachment.

The **Rowley Sub-basin** is a major Mesozoic depocentre situated on the outer continental shelf where it covers an area of approximately 85,000 km<sup>2</sup>. It contains about 9 km of Permo-Carboniferous or older strata and up to 6 km of Mesozoic-Recent sediments (Smith et al, 1999). Tectonically, the sub-basin is separated from the Beagle Sub-basin of the Carnarvon Basin to the southwest by the North Turtle Hinge Zone and Thouin Graben, and from the Bedout and Oobagooma sub-basins by the Bedout High and Oobagooma High, respectively. Palaeozoic and Early Mesozoic strata in the Rowley Sub-basin onlap the Bedout and Oobagooma highs and the Broome Platform to the southeast ([Figure 4](#)). These sediments thicken seaward and are terminated at the present continent-ocean boundary by massive rift faults. An Early Jurassic unconformity is developed at the top of this sediment wedge which is overlain by prograding packages of Early Jurassic–Recent sediments.

## **BASIN EVOLUTION**

The offshore Canning and Roebuck basins developed as a result of multi-phase rifting and have undergone a complex structural evolution (Kennard et al, 1994; Smith et al, 1999).

Little is known about the nature of Palaeozoic sedimentation offshore, as no wells in the Bedout Sub-basin have penetrated this succession, but it is presumed to be an extension of the one seen in the onshore Canning Basin (Passmore, 1991; Lipski, 1993; Colwell and Stagg, 1994; Smith, 1999). Ordovician to Middle Carboniferous sediments in the onshore primarily comprise alternating sequences of marine clastics and carbonates (Kennard et al, 1994). The Palaeozoic sequence in the offshore onlaps the Lambert Shelf and Broome Platform and is overlain by a prominent regional unconformity that is related to the Bedout and/or Fitzroy movements (Colwell and Stagg, 1994).

The post-Carboniferous stratigraphy of the sub-basin is summarised in [Figure 5](#) (after Smith, 1999; Smith et al, 1999). Representative seismic transects across the sub-basin are shown in [Figures 3](#) and [4](#). A series of major basin-wide tectonic events have been identified and can be used to divide the basin-fill into a series of megasequences.

**Late Carboniferous–Permian:** The onset of formation of the Westralian Superbasin in the Late Carboniferous defines the boundary between the northwest-oriented structures associated with the Canning Basin and the

predominantly northeast-oriented structures of the Roebuck Basin. This was a period of transition from a Palaeozoic regime of northeast–southwest intra-cratonic extension to one of northwest–southeast passive-margin extension during the separation of the Sibumasu terrane from Gondwana (Smith et al, 1999). In the onshore and offshore parts of the Canning Basin, syn-rift sedimentation continued along pre-existing intracratonic fractures formed during the northeast–southwest extension. Here, Late Carboniferous fluvial deposits are overlain by a thick succession of Permian glacial deposits (upper Grant Group), in turn overlain by Permian marine and fluvio-deltaic clastics (Poole Sandstone, Noonkanbah Formation, Liveringa Group). The nature of the basin fill during this initial evolutionary stage is poorly understood for reasons outlined above. Basin-wide tectonism produced extensive uplift, faulting and volcanism in the Late Permian to Early Triassic (Bedout Movement), leading to the development of the Bedout High.

**Triassic–Early Jurassic:** This period was dominated by thermal sag and transgressive marine and fluvio-deltaic sediments (Locker Shale, Keraudren and Bedout formations). However, deposition was punctuated by a series of Triassic to Early Jurassic northwest–southeast transpressional events which were focussed along the margins of the sub-basins (Fitzroy Movement). Smith et al (1999) identified three phases of the Fitzroy Movement:

1. Fitzroy Movement I (Ladinian) responsible for large transpressional ‘flower structures’ along the North Turtle Hinge Zone;
2. Fitzroy Movement II (Norian) responsible for major en echelon anticlines in the Fitzroy Trough, and a subtle unconformity in the Phoenix 1 and 2 wells; and
3. Fitzroy Movement III (Sinemurian) which marks a major change in gross stratal geometries within the Roebuck Basin from predominantly back-stepping to prograding and aggrading. The Middle Triassic Cossigny Member is a widespread limestone bed that separates the Lower and Upper Keraudren Formation. It is seismically expressed as an extensive high-amplitude reflection event.

**Early Jurassic–Early Cretaceous:** Following Early Jurassic uplift and erosion, basin subsidence enabled a broad prograding wedge of fluvio-deltaic sediments (Depuch Formation) to be deposited across the shelf. Continent breakup in the Callovian resulted in a second phase of prominent uplift and erosion that marked the end of active rifting in areas adjacent to the Roebuck Basin. Thermal relaxation promoted rapid transgression and the accumulation of condensed marine mudstones (Baleine and Egret formations) until the Early Cretaceous. Further uplift and rejuvenation of the source province in the Valanginian, when Greater India moved away from the western margin of Australia, resulted in an influx of siliciclastic material (Broome Sandstone).

**Early Cretaceous–Recent:** Thermal relaxation of the crust soon after the Valanginian led to the development of a passive-margin succession of marine mudstones and marls. Full ocean circulation was established by the end of the Aptian. Reactivation of older Palaeozoic features, probably related to the separation of Antarctica and Australia and the northward drift of the Australian Plate, resulted in inversion and oblique slip movement, especially in the Oobagooma Sub-basin (Smith et al, 1999). A major progradational carbonate wedge developed across the entire North West Shelf in the Tertiary. Collision of the Australian and Eurasian plates in the mid-Miocene led to transpressional

inversion of older north-northwest-trending Palaeozoic faults in the northeast Oobagooma Sub-basin.

## EXPLORATION HISTORY

The first significant phase of exploration in the Bedout Sub-basin occurred between 1971 and 1974, with the drilling of Bedout 1, Keraudren 1 and Minilya 1. The remaining three wells in the sub-basin (Phoenix 1 and 2 and Lagrange 1) were drilled between 1980 and 1983. Recent exploration activity in the Roebuck Basin has been confined to the outboard Rowley Sub-basin, where the deep water potential has been unsuccessfully tested by Whitetail 1 (2003) and most recently Huntsman 1 (2006).

Exploration in the adjacent Beagle Sub-basin has been more intensive, with the drilling of 25 exploration wells between 1971 and 2003. Oil was discovered in the Callovian Calypso Formation sandstones at Nebo 1 (Osborne, 1994), but no economic discoveries have been made to date.

Geoscience Australia conducted a hydrocarbon seepage survey of the Roebuck and offshore Canning basins in June 2006 (Survey SS06/06; Jones et al, 2007). No definitive evidence of natural hydrocarbon seepage was detected. Head space gas analyses of gravity core sub-samples, and biomarker screening of sediments and carbonate concretions, revealed no thermogenic hydrocarbons or biomarkers diagnostic of methane oxidation. Careful re-evaluation of vertical seismic features distributed throughout the region, with a strong clustering over the Bedout High, suggests that they more likely represent 1) zones of small-scale faulting or fracture with little or no displacement, and 2) velocity pull-ups associated with Late Miocene channels, rather than hydrocarbon related diagenetic zones (HRDZs) or gas chimneys as previously interpreted by O'Brien et al (2003).

### WELL CONTROL

A total of 9 wells have been drilled in the Roebuck Basin; none with commercial success (**Figure 1**). Six wells were drilled in the Bedout Sub-basin (Bedout 1, Keraudren 1, Lagrange 1, Minilya 1 and Phoenix 1 and 2), with the only significant hydrocarbon indications being the tight gas column in Phoenix 1. The deep water potential of the Rowley Sub-basin has been unsuccessfully tested in three wells (East Mermaid 1, Huntsman 1 and Whitetail 1). Ten wells have been drilled to date in the eastern part of the Beagle Sub-basin, adjacent to the Release areas (Bruce 1, Cimba 1, Darwin 1, Depuch 1, Halo 1, Huascaran 1, Nebo 1, North Turtle 1, Picard 1 and Poissonnier 1). The only significant discovery in the Beagle Sub-basin is a small oil pool at Nebo 1. The following summaries of these key wells are based on the relevant well completion reports and, for the Beagle Sub-basin wells, a review presented by Blevin et al (1994).

#### **Bedout 1 (1971)**

Bedout 1 (1971) was drilled by BOC of Australia Ltd to test the seismically-delineated, un-faulted anticlinal dome of the Bedout High. The well reached a total depth of 3073 mRT ([Figure 6](#)). The well penetrated Late Cretaceous claystones and carbonates (465 m thick), Early Cretaceous clastic sediments (450 m thick), and a thick Jurassic succession (1113 m) of deltaic sandstones with interbedded claystone and coal, including potential source rocks. A thin section (52 m) of Triassic sandstone and claystone overlies volcanic conglomerate in the base of the well. It was not expected to intersect these volcanic rocks which represent

basement. Good reservoirs were confirmed in the Early Cretaceous, Jurassic and Late Triassic intervals, but no hydrocarbons shows were encountered in the well.

### **Picard 1 (1972)**

Picard 1 was drilled by BOC of Australia Ltd as the first well to test structures in the main Mesozoic depocentre of the Beagle Sub-basin. The well was an apparent crestal test of a large north-trending Middle-Early Jurassic horst block, draped by an Early Cretaceous seal. The well reached a total depth of 4216 mRT, and intersected a thick section of Middle-Early Jurassic sandstones with interbedded claystones, siltstone and minor coal, including a 216 m thick predominantly claystone interval (3665-3881 mRT). Analysis by Surdam and Warne (1984) and Robertson Research (1986) concluded that the Early-Middle Jurassic Athol and Legendre Formation claystones have good to very good oil source potential. Only minor fluorescence and gas shows were recorded in thin shaly sandstone interbeds within the Early Jurassic section, and wireline logs indicated that all sandstones were water saturated. Reactivation of north-trending bounding faults during the Late Cretaceous to Early Tertiary may have breached the Picard structure (Blevin et al, 1994).

### **East Mermaid 1 (1973)**

East Mermaid 1 was drilled by Shell Development Australia Pty Ltd to test a northeast-southwest series of low relief anticlinal highs that were mapped in the south-eastern part of the Rowley Sub-basin and which display closure in the Middle Jurassic and throughout the Cretaceous. East Mermaid 1 ST1 reached a total depth of 4068 mRT ([Figure 6](#)), intersecting a predominantly fine-grained Cretaceous succession and a thick (1184 m) Jurassic succession of sandstone, siltstone and coal. The well confirmed the predicted structural configuration and identified the primary target Jurassic sandstones as terrestrial in nature. No hydrocarbons were encountered in the well, which was attributed to the lack of a proximal source rock. Recent research suggests that the tested anticlinal structures are associated with the 'Mermaid Fault Zone', in which faults extend to or near the seabed, and are currently active (Jones et al, 2007). Therefore trap integrity is also a high risk at this site.

### **Keraudren 1 (1973)**

Keraudren 1 was drilled by Hematite Petroleum Pty Ltd to test a complex northward-tilting fault wedge structure mapped at top-Palaeozoic and intra-Triassic levels, with minor draping at the top-Triassic interval. Due to low penetration rates, bad weather conditions and the failure to encounter any hydrocarbon shows, drilling was abandoned at a total depth of 3844 mRT ([Figure 6](#)), significantly short of the planned total depth of 4600 m. The well intersected thick Cretaceous, Jurassic and Triassic successions of claystones, siltstones and sandstones with rare thin coals. The well confirmed the presence of thick porous sandstones in the prospective Triassic section, and also in the Jurassic and Early Cretaceous intervals. However, wireline log evaluation suggests these units are 100% water-saturated. No significant hydrocarbon shows were recorded, but minor traces of sample fluorescence were noted within a Middle Triassic claystone-siltstone unit at depths of 3180 and 3245 mRT. The following factors may have contributed to well failure in Keraudren 1:

1. Possible lack of suitable and/or timely structural closure;
2. Inadequate number or thickness of claystones with obvious source-rock potential;

3. Unsuitability of intra-Triassic claystones as cap rocks (or fault seals) because of their limited thickness and frequent association with sandstone interbeds or stringers.

#### **Poissonnier 1 (1974)**

Poissonnier 1 was drilled by BOC of Australia Ltd targeting Permian-Triassic sandstones in a downthrown fault block along the south-eastern basin margin fault against the Lambert Shelf. The well was intended to test the potential of pre-Locker Shale sandstones down-faulted against impermeable basement. Overlying Jurassic-Triassic sandstones truncated by the basal Cretaceous unconformity represented a secondary objective. The well drilled into basic igneous basement at 1947 mKB, which is unconformably overlain by a thick sequence of sandstones, claystones, siltstones and minor coal of Early Jurassic and Triassic age. No significant hydrocarbon shows were recorded, but minor fluorescence was observed above the objective horizons in the upper Locker Shale and overlying sandstones of the Mungaroo Formation. Remapping of the area indicates there is little or no closure at the Triassic and Middle Jurassic unconformity levels (Blevin et al, 1994).

Sandstones beneath the Locker Shale have been reassessed as Early Carboniferous (Visean) in age, rather than earliest Triassic as originally thought (Ingram, 1990). The revised age of this pre-Locker Shale sandstone, however, does not eliminate the concept of basal Triassic transgressive sandstone plays, and also implies that Palaeozoic sandstones could be considered targets in inboard portions of the sub-basin.

#### **Depuch 1 (1974)**

Depuch 1 was drilled by BOC of Australia Ltd to test a fault-controlled Jurassic horst block draped by Early Cretaceous claystone on the eastern margin of the Thouin Graben in the central eastern portion of the Beagle Sub-basin. The well reached a total depth of 4300 mKB and intersected a thick section of Early-Middle Jurassic interbedded sandstones, claystones, siltstones and minor coal (Legendre Formation), overlain by 60 m of Callovian sandstones and claystones (Calypso Formation) and 180 m of Neocomian claystones (Forestier Claystone). No significant hydrocarbon shows were recorded, but fluorescence was noted over several intervals within the Calypso and Legendre formations, albeit being associated with the occurrence of carbonaceous material.

Regional mapping indicates that the well was placed on the flanks of a Jurassic fault lying barely within closure at the top-Legendre level and outside of closure at the top-Calypso level (Kufpec, 1994).

#### **Minilya 1 (1974)**

Minilya 1 was drilled by BOC of Australia Ltd to test what was interpreted to be a fault controlled positive feature located in the outboard part of the Bedout Sub-basin. The well reached a total depth of 2400 mRT ([Figure 6](#)). The well primarily intersected Cretaceous claystones, sandstones and carbonates, terminating in a succession of Middle Jurassic sandstones and claystones with minor coal. These sandstones, the primary objective, showed variable but good porosity. Sandstones with effective porosity were also intersected in Late Cretaceous sediments. No significant hydrocarbon shows were recorded in the well. Subsequent acquisition

of seismic data over Minilya in 1992 (C92A) suggests that there is no closure on the Minilya 1 structure (Esso, 1994).

### **Bruce 1 (1979)**

Bruce 1 was drilled by Stirling Petroleum NL to test a Middle Triassic anticline downdip of the south-eastern basin margin fault against the Lambert Shelf, approximately 15 km west-southwest of Poissonier 1. The structure is interpreted as the result of Late Triassic-Middle Jurassic right lateral wrench movement along small scale antithetic faults that propagated orthogonal to the main basin-margin fault (Blevin et al, 1994). The well reached a total depth of 2168 mKB after intersecting a thick succession of Late-Middle Triassic sandstones, siltstones and claystones with minor carbonates (Mungaroo Formation) below which a Middle-Early Triassic section of claystones and minor siltstones and sandstones (Locker Shale) is developed. The Triassic section is unconformably overlain by 50 m of Early Cretaceous claystones. Sidewall cores in Middle Triassic sandstones (Mungaroo Formation) directly beneath a 54 m thick siltstones and claystone unit (Cossigny Member) showed good bright gold fluorescence, bright silver blue solvent fluorescence and visible brown oil stains.

The Bruce 1 well confirmed the existence of a regional mid-Triassic seal (Cossigny Member) that is exemplified by a distinctive seismic character and the local generation of relatively immature hydrocarbons. Post-drill mapping suggests the well was drilled inside closure at the Middle Triassic level, but outside closure near the Early Cretaceous seal. It appears that faulting above the Middle Triassic Cossigny Member is responsible for seal failure (Blevin et al, 1994).

### **Phoenix 1 (1980)**

Phoenix 1 was drilled by BP Petroleum Development Australia Pty Ltd to test an interpreted large northeast-southwest trending, elongate anticline transected by a series of north-northeast – south-southwest trending faults. These faults were interpreted to have formed four main culminations, with Phoenix 1 in the most central of these. More recent seismic data suggest, however, that structuring in the area is more complex (Apache, 1995). The primary objective of the well was Middle to Late Triassic sandstones of the Keraudren Formation, while Middle Jurassic sandstones directly below the Callovian breakup unconformity were a secondary target, but seismic data indicated a lack of closure at that level. The well reached a total depth of 4880 mRT ([Figure 6](#)); exceeding the planned total depth of 4450 m after gas-bearing Middle Triassic sandstones were intersected. Reservoirs in the Keraudren Formation provided good hydrocarbon indications. Despite good reservoir characteristics in the upper Keraudren sandstones (average porosity of 14%, range 19% decreasing with depth to 12%), hydrocarbon shows were limited to oil staining and cut fluorescence. The lower Keraudren Formation sandstone reservoirs exhibited gas shows and fluorescence (all sandstones below 4223 mRT are gas bearing; net gas-bearing pay is estimated to be 110.5 m), but logs and core analysis indicate very low porosity (average porosity of 9%, range 4% to 15%).

Hydrocarbon types in the lower Keraudren Formation sandstones show fractionation with depth, which suggests intra-formational sourcing of gas and existence of discrete reservoirs that are not in communication due to intercalated sealing shales. Drilling was suspended without testing when it was deemed unsafe to continue operations with the available pressure-control equipment. The well was

re-entered and abandoned by BP Petroleum Development Australia Pty Ltd without further drilling or testing in January 1983.

### **Phoenix 2 (1982)**

Phoenix 2 was drilled by BP Petroleum Development Australia Pty Ltd to test Triassic sandstones in a fault block that forms part of the 'Phoenix structure'. The well reached a total depth of 4967 mRT ([Figure 6](#)). The sedimentary succession intersected in Phoenix 2 is very similar to that in Phoenix 1, but the basal 591 m of Early to Middle Triassic claystone is interpreted to represent an equivalent of the Locker Shale (interpreted to be part of the lower Keraudren Formation in Phoenix 1). Gas is interpreted to be present at low saturations in thin zones within the primary objective sandstones, which have extremely low permeabilities and generally poor reservoir qualities. Oil indications, such as natural fluorescence and possible staining, were also identified. The targeted reservoirs showed significantly lower permeabilities compared to Phoenix 1, and had therefore lower hydrocarbon saturations. Calculations, based on low permeabilities, indicated that commercial hydrocarbon flows could not be obtained from the reservoir sandstones, therefore no production testing was carried out.

Modelling by Lisk et al (2000) suggests the Triassic Keraudren Formation is mature for gas/condensate and minor oil generation in the deep sections of the Bedout Sub-basin. This unit is mature in Phoenix 1 and predominantly gas prone, with fluorescence and oil staining assessed by Forth and Jourdan (1982) to be sourced from thin shales in the unit. The Keraudren Formation at Phoenix 2 is overall early mature for oil and predominantly gas prone, but one thin zone is modelled to be capable of generating light oil. Modelling indicates that the Keraudren Formation would be more generative down-dip in the deeper part of the basin where maturity levels are higher (Lisk et al, 2000).

### **Lagrange 1 (1983)**

Lagrange 1 was drilled by BP Petroleum Development Australia Pty Ltd to test Late Triassic sandstones on the irregular anticlinal crest of the Bedout High, with secondary targets in the Early to Middle Jurassic and, more speculative, in Palaeozoic sediments. The well reached a total depth of 3260 mRT ([Figure 6](#)) and penetrated a sedimentary succession that is very similar to that in Bedout 1. Palaeozoic targets were not reached because an unexpectedly thick horizon of volcanics was encountered. Lagrange 1 was plugged and abandoned as a dry hole.

### **Nebo 1 (1993)**

Nebo 1 was drilled by Kufpec Australia Pty Ltd targeting a large fault-dependent anticlinal structure (Nebo High) located in the southern Thouin Graben of the Beagle Sub-basin. Closure at the Nebo High was mapped in both time and depth at several levels extending from the Oxfordian unconformity up to the Aptian unconformity. The structure below the Oxfordian unconformity comprises a major tilted fault block beneath the central Nebo High and separate tilt blocks beneath the flanks. The primary objective was deltaic sandstones of the Middle Jurassic Legendre Formation, sealed by claystones of the overlying Callovian Calypso Formation. Sandstones of the Tithonian Angel Formation were predicted as a possible secondary objective, but these were absent over the crest of the structure. The well reached a total depth of 3132 mRT in the Legendre Formation. Sandstones within the Legendre Formation are porous (15-19% average log

porosity) but water wet. However, oil was discovered in thin sandstones within the overlying Calypso Formation. A total of 5.9 m of potential net oil pay was interpreted in six discrete thin sandstone horizons (17-26% average log porosity) below 2663 mRT over a gross interval of 33 m. A drill stem test of the interval 2664.5-2668 mRT was conducted over the best reservoir zone, and the well flowed 42°API oil at a maximum flow rate of 1840 BPD on a ½" choke. The lack of shows in the underlying primary target (Legendre Formation) was attributed to the poor seal quality of the overlying Calypso Formation.

### **Cimba 1 (1994)**

Cimba 1 was drilled by Kufpec Australia Pty Ltd to test a tilted horst block on the up-thrown eastern margin of the Thouin Graben, 3.1 km to the north-northeast of Depuch 1 in the eastern Beagle Sub-basin. The primary objectives were deltaic sandstones of the Middle Jurassic Legendre Formation while marine sandstones within the overlying Calypso Formation provided a potential secondary objective. The well reached a total depth of 2603 mRT within the Legendre Formation. No hydrocarbon shows were encountered and all potential reservoirs were interpreted to be water-bearing. The demonstrated structural relief between Cimba 1 and Depuch 1 suggests that the well tested a valid trap.

### **Darwin 1 (1995)**

Darwin 1 was drilled by Apache Beagle Pty Ltd to test the crest of a four-way dip closure situated along the axis of the North Turtle Graben near the eastern margin of the Beagle Sub-basin. Mapped at base-Cretaceous level, the structure is controlled by drape over normal faults antithetic to the main graben-bounding faults, and by regional dip. The primary objective was the Callovian Calypso Formation, with secondary targets in the Early Cretaceous Muderong Shale and Forestier Claystone, Late Jurassic Angel Formation, and the deeper Middle Jurassic Legendre Formation in which the well reached TD at 2723 mRT. No hydrocarbon shows were encountered, and targeted reservoir intervals of the Calypso Formation were water-wet (including two very good quality sandstones with 12-30%, average 25%, calculated log porosity), as were sandstones in the Forestier Claystone and Legendre Formation. The Late Jurassic Angel Formation and Dingo Claystone are missing in this location. Post-drill depth conversion confirmed that the well was a valid structural test at the Calypso and Legendre reservoir levels, but that sandstones within the younger Forestier Claystone lie outside closure. The complete lack of any hydrocarbon shows in the Jurassic reservoir intervals indicates that there has been no hydrocarbon migration into the Darwin structure. Ineffective migration may be related to problems in the migration pathways from the Beagle Trough and North Turtle Graben kitchens, and to diminished migration capacities within a low net-to-gross section. Other potential problems involve the type, distribution and volume of mature source rocks and their expulsion efficiency in a sand-dominated depositional system.

### **Halo 1 (1995)**

Halo 1 was drilled by Kufpec Australia Pty Ltd on the eastern flank of the Nebo High within the Thouin Graben to test prognosed Late Jurassic sandstones of the Angel Formation that were not encountered on the crest of the structure at the Nebo 1 oil discovery 1.25 km to the west. The thin oil-bearing sandstones of the Calypso Formation intersected in Nebo 1 were not considered an objective in Halo 1 due to its structurally lower position. The well reached a total depth of 3000 mRT within a thicker than prognosed section of the Calypso Formation (a

greater upper thickness of the unit preserved below the Oxfordian unconformity). A thickened section of Early Cretaceous (Berriasian) claystones was intersected (Forestier Claystone and "Halo Claystone"), but the targeted underlying Angel Formation sandstones were not present. Beneath the Halo Claystone, a thin Kimmeridgian belemnitic limestone unit (the "Thouin Limestone") was drilled above the Oxfordian unconformity. No hydrocarbons were encountered, and thin potential reservoir units within the Calypso Formation were water-bearing as anticipated (these sediments occur below the highest known water level in Nebo 1). Correlation with Nebo 1 suggests that the top of the Legendre Formation is likely to lie only a short interval (2-7 m) below total depth.

### **Huascaran 1 (2002)**

Huascaran 1 was drilled by IB Resources Pty Ltd to test the Middle Jurassic Legendre Formation in a rotated fault block in the eastern central Beagle Sub-basin, approximately 3 km west of the Nebo 1 oil discovery. Interbedded shallow marine sandstones of the overlying Middle Jurassic Calypso Formation were a secondary target. The well reached a total depth of 2970 mRT without any significant hydrocarbon shows. The reservoir facies in the Legendre Formation consists of fine to medium sandstones that are 100% water saturated and interbedded with claystones. Minor fluorescence shows were recorded in the Calypso Formation, consisting of trace to 10% moderately bright yellow pin point to solid direct sample fluorescence, with a very slow diffuse cut, and a thick residual ring. No gas resistivity anomalies were associated with these shows, which were considered to be either residual or evidence of migration at a stratigraphic level equivalent to the oil-bearing sandstones in Nebo 1.

### **Whitetail 1 (2003)**

Whitetail 1 was drilled by Woodside Energy Ltd in 953 m water depth to test the gas potential of a large structure in the Rowley Sub-basin. Whitetail 1 was plugged and abandoned after reaching a total depth of 2504 mRT. Detailed interpretative results were not available at the time of this review.

### **Huntsman 1 (2006)**

Huntsman 1 was drilled by Woodside Energy Ltd as a rank wildcat in 1468 m water depth. It tested both the Middle and Lower Jurassic objectives and encountered reservoir quality sandstones but no hydrocarbons. Lack of charge is deemed to be the cause of failure (DoIR, 2007, p. 15). Detailed interpretative results have not been released at the time of this review.

**KEY WELLS LISTING – RELEASE AREAS W08-11, W08-12, W08-13, W08-14, AND W08-15, BEDOUT SUB-BASIN**

Well	Operator	Total Depth (m)	Year <sup>§</sup>	Data Avail <sup>*</sup>	Basic Avail	Interp Avail	Source <sup>#</sup>
Bedout 1	BOC of Australia Ltd	3073	1971	A	-	-	-
Bruce 1	Stirling Petroleum NL	2168	1979	A	-	-	-
Cimba 1	Kufpec Australia Pty Ltd	2603	1994	A	-	-	-
Darwin 1	Apache Beagle Pty Ltd	2723	1995	A	-	-	-
Depuch 1	BOC of Australia Ltd	4300	1974	A	-	-	-
East Mermaid 1	Shell Development (Australia) Pty Ltd	2077.8	1973	A	-	-	-
Halo 1	Kufpec Australia Pty Ltd	3000	1995	A	-	-	-
Huascaran 1	IB Resources Pty Ltd	2970	2002	A	-	-	-
Keraudren 1	Hematite Petroleum Pty Ltd	3844	1973	A	-	-	-
Lagrange 1	BP Petroleum Development Australia Pty Ltd	3260	1983	A	-	-	-
Minilya 1	BOC of Australia Ltd	2400	1974	A	-	-	-
Nebo 1	Kufpec Australia Pty Ltd	3132	1993	A	-	-	-
North Turtle 1	BP Petroleum Development Australia Pty Ltd	4420	1982	A	-	-	-
Phoenix 1	BP Petroleum Development Australia Pty Ltd	4880	1980	A	-	-	-
Phoenix 2	BP Petroleum Development Australia Pty Ltd	4967	1982	A	-	-	-
Picard 1	BOC of Australia Ltd	4216	1972	A	-	-	-
Poissonnier 1	BOC of Australia Ltd	1962	1974	A	-	-	-
Whitetail 1	Woodside Energy Ltd	2504.3	2003	B	-	13/02/2008	WAPIMS
<b>Huntsman 1</b>	<b>Woodside Energy Ltd</b>	<b>4375</b>	<b>2006</b>	<b>C</b>	<b>7/09/2008</b>	<b>7/09/2011</b>	<b>WAPIMS</b>
East Mermaid 1 ST1	The Shell Company Of Australia Ltd	4067.6	1973	A	-	-	-

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

## SEISMIC COVERAGE

Seismic coverage of the Release areas varies from moderately sparse in the east (W08-12, W08-13 and W08-15) to relatively dense in the west (W08-11 and W08-14). The first significant phase of seismic acquisition in the region occurred between 1971 and 1974, with the acquisition of the Bedout-Broome Swell, Jaubert and Bedout North regional seismic grids. Regional speculative seismic was acquired across the sub-basin in 1987 by JNOC (Japanese National Oil Company), and this grid was tied to the wider North West Shelf regional grid by an AGSO (Australian Geological Survey Organisation, now Geoscience Australia) seismic survey. The most recent seismic exploration activities in the Bedout Sub-basin occurred in the early to mid-1990s with the acquisition of relatively dense industry seismic grids (e.g. C92A and H93B) in the western Release areas.

### Seismic Surveys – W08-11

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
Bedout Broome Swell	Hematite Petroleum	3502	1972	Yes	Yes	613	S6720080
Montebello Turtle	Burmah Oil	2660	1972	Yes	Yes	595	S6720066
Steamboat Spit	Burmah Oil	1783	1972	Yes	Yes	612	S6730045
Bedout North	Hematite Petroleum	658	1974	No	Yes	646	S6740024
Bedout Halo	Hematite Petroleum	330	1975	No	Yes	647	S6750006
Minilya	Woodside	385	1977	Yes	Yes	2450	S6770006
Rowley	Getty Oil	1308	1978	Yes	Yes	350	S6790019
North Keraudren	Oxoco	317	1979	Yes	Yes	2516	S6790005
WA-62-P 1981	BP	1230	1981	No	No	649	S6810031
2 SL/1986 (Bedout Sub-Basin)	Geophysical Service Inc	563	1986	Yes	Yes	272	S6860019
SPA 4 SL 1986	JNOC	5445	1987	Yes	Yes	167	S6860021
AGSO 110 Southern NW Shelf 2	Geoscience Australia	2889	1992	Yes	Yes	2407	S6900062
C92A	Esso Australia	2749	1992	Yes	Yes	91	S6920016
AGSO 120 S NW Shelf	Australian Geological Survey Org	9162	1993	Yes	Yes	600	S6930072
H93B	Hadson Energy	7598	1993	Yes	Yes	187	S6930020
C94A	Esso Australia	863	1994	Yes	Yes	143	S6940022
Tarantula	Woodside	18523	1999	Yes	Yes	2844	S6990009

## Seismic Surveys – W08-12

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
Bedout Broome Swell	Hematite Petroleum	3502	1972	Yes	Yes	613	S6720080
Jaubert	Hematite Petroleum	176	1973	No	Yes	2445	S6730028
East Mermaid	Era South Pacific Pty Ltd	259	1980	No	Yes	2442	S6800003
Leveque Shelf Margin Ph 2	Weaver Oil & Gas	860	1982	No	Yes	382	S6820008
Lorikeet Phase 2	Weaver Oil & Gas	829	1982	No	Yes	284	S6820005
2SL/1986 (Bedout Sub-Basin)	Geophysical Service Inc	563	1986	Yes	Yes	272	S6860019
SPA 4 SL 1986	JNOC	5445	1987	Yes	Yes	167	S6860021
AGSO 120, S NW Shelf	Australian Geological Survey Org	9162	1993	Yes	Yes	600	S6930072
H93B	Hadson Energy	7598	1993	Yes	Yes	187	S6930020

## Seismic Surveys – W08-13

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
Bedout Broome Swell	Hematite Petroleum	3502	1972	Yes	Yes	613	S6720080
Montebello Turtle	Burmah Oil	2660	1972	Yes	Yes	595	S6720066
Steamboat Spit	Burmah Oil	1783	1972	Yes	Yes	612	S6730045
Minilya	Woodside	385	1977	Yes	Yes	2450	S6770006
North Keraudren	Oxoco	317	1979	Yes	Yes	2516	S6790005
WA-62-P 1981	BP	1230	1981	No	No	649	S6810031
2 SL/1986 (Bedout Sub-Basin)	Geophysical Service Inc	563	1986	Yes	Yes	272	S6860019
SPA 4 SL 1986	JNOC	5445	1987	Yes	Yes	167	S6860021
AGSO 110 Southern NW Shelf 2	GeoScience Australia	2889	1992	Yes	Yes	2407	S6900062
C92A	Esso Australia	2749	1992	Yes	Yes	91	S6920016
AGSO 120 S NW Shelf	AGSO	9162	1993	Yes	Yes	600	S6930072
H93B	Hadson Energy	7598	1993	Yes	Yes	187	S6930020
Outer Beagle	Mobil	3616	1993	Yes	Yes	317	S6930064
AGSO 136, Carnarvon Tertiary Tie	AGSO	4221	1994	Yes	Yes	1828	S6940033

### Seismic Surveys – W08-14

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
Bedout Broome Swell	Hematite Petroleum	3502	1972	Yes	Yes	613	S6720080
Jaubert	Hematite Petroleum	176	1973	No	Yes	2445	S6730028
North Keraudren	Oxoco	317	1979	Yes	Yes	2516	S6790005
Lorikeet Phase 2	Weaver Oil & Gas	829	1982	No	Yes	284	S6820005
2SL/1986 (Bedout Sub-Basin)	Geophysical Service Inc	563	1986	Yes	Yes	272	S6860019
AGSO 120, S NW Shelf	AGSO	9162	1993	Yes	Yes	600	S6930072
H93B	Hadson Energy	7598	1993	Yes	Yes	187	S6930020
SPA 4 SL 1986	Hadson Energy	5445	1993	Yes	Yes	167	S6860021

### Seismic Surveys – W08-15

Survey Name	Client	Line km's	Year	Processed Data	Field Data	Snip ID	PIMS ID
Bedout Broome Swell	Hematite Petroleum	3502	1972	Yes	Yes	613	S6720080
Jaubert	Hematite Petroleum	176	1973	No	Yes	2445	S6730028
North Keraudren Marine Seismic	Oxoco	317	1979	Yes	Yes	2516	S6790005
Lorikeet Phase 2	Weaver Oil & Gas	829	1982	No	Yes	284	S6820005
2SL/1986 (Bedout Sub-Basin) Marine Seismic	Geophysical Service Inc	563	1986	Yes	Yes	272	S6860019
SPA 4 SL 1986	JNOC	5445	1987	Yes	Yes	167	S6860021
AGSO Marine Survey 120, S NW Shelf	Australian Geological Survey Org	9162	1993	Yes	Yes	600	S6930072
H93B	Hadson Energy	7598	1993	Yes	Yes	187	S6930020

Data is accurate as at 17 December 2007.

# HYDROCARBON POTENTIAL

## PETROLEUM SYSTEMS

Because of the perceived absence of a prolific source rock (Smith et al, 1999), the petroleum potential of the offshore Canning and Roebuck basins is currently considered to be poor compared to other provinces along the North West Shelf. Interpreted mild structural deformation in the Late Jurassic and Early Cretaceous suggests that restricted depocentres did not exist, thus claystone source rocks typical of the adjacent Carnarvon and Browse basins could not accumulate in the Roebuck Basin.

Several petroleum systems could potentially operate in the offshore Canning and Roebuck basins (Kennard et al, 1994; Smith 1999; Smith et al, 1999; [Figure 7](#)):

1. Ordovician Larapintine 2
2. Devonian Larapintine 3
3. Early Carboniferous Larapintine 4
4. Late Carboniferous-Permian Gondwana 1
5. Early Triassic Gondwana 2
6. Early-Middle Jurassic Westralian 1

The Larapintine 3 and 4 systems are considered to be absent in the Bedout Sub-basin and are not discussed further. The Ordovician Larapintine 2 system is likely to be poorly developed and deeply buried in the Bedout Sub-basin, and is not regarded as highly prospective for this region. However, there is some potential for this system to be active in the offshore extension of the Willara Sub-basin, where the system is only shallowly buried beneath the inboard Bedout Sub-basin.

### ***The Ordovician Larapintine 2 Petroleum System***

Organic-rich marine shales are well documented within the Ordovician succession of the onshore Canning Basin. These sources are characterised by the occurrence of the oil-prone alga *Gloeocapsomorpha prisca*, and are particularly well developed on the terraces along the northern flank of the Broome Platform, but generally have poor source quality within the Willara Sub-basin (Kennard et al, 1994). Sub-salt algal coals on the northern margin of the Willara Sub-basin locally have excellent source quality (Kennard et al, 1994; McCracken 1994). Some of these potential Ordovician source facies could be developed in the offshore Willara Sub-basin/Sapphire Embayment, where they occur at 2-3.5 sec TWT depth and are likely to be mature.

### ***The Late Carboniferous-Permian Gondwana 1 Petroleum System***

Transgressive Early Permian marine shales of the Poole Sandstone and Noonkanbah Formation are known to be organic-rich in the Fitzroy Trough (Kennard et al, 1994), and form part of a global Pennsylvanian-Early Permian source unit (Warris, 1993). These sources may also be present, and are likely to be mature, in the Bedout Sub-basin, Rowley Sub-basin and offshore Willara Sub-basin. Marine shales of the underlying upper Grant Group are also locally organic-rich, but generally have poor generative potential. Hydrocarbon accumulations and shows within the Grant Group are believed to be sourced from the underlying Laurel Formation (Goldstein, 1989; Kennard et al, 1994).

## ***The Early Triassic Gondwana 2 Petroleum System***

Early Triassic transgressive marine shales (Locker Shale) have frequently been proposed as a potential source unit along the northwest Australian margin ([Figure 7](#)), including the Bedout and Rowley sub-basins (Smith, 1999) and adjacent Beagle Sub-basin (Blevin et al, 1994), but such a source remains unproven. The Early Triassic section in Phoenix 1, 2 and Keraudren 1 in the Bedout Sub-basin contains potential source rock facies (JNOC, 1987), although Smith et al (1999) noted that they appear to be gas-prone, and that previous sampling may have been biased due to hand-picking of samples richer in oil-prone algal material. The interpreted tight gas column in the lower Keraudren Formation (Middle Triassic) at Phoenix 1 could have been charged from this Early Triassic source (Smith, 1999), which is early mature to marginally mature at Phoenix 1 and Keraudren 1. Basin modelling indicates that postulated Early Triassic source rocks could presently be expelling liquids in the outer Rowley Sub-basin and on the flanks of the Bedout High (O'Brien et al, 2003). However, the lack of reported hydrocarbon shows in wells on the Bedout High (Bedout 1, Lagrange 1) and within the Rowley Sub-basin (East Mermaid 1, Whitetail 1 and most recently Huntsman 1) suggests that this postulated source is probably not effective.

## ***Westralian Petroleum Systems***

As noted earlier, the petroleum potential of the Mesozoic section in the Roebuck Basin is considered to be poor compared to other North West Shelf basins due to the absence of proven effective source rocks. Nevertheless, based on sequence stratigraphic interpretation and integration of available geochemical well data, Smith et al (1999) identified several possible potential source intervals in the Triassic-Cretaceous section of the Roebuck Basin ([Figure 7](#)). However, the oldest of these, designated Tr1 and Tr2 by Smith et al (1999) and characterised by Early Triassic transgressive marine shales of the Locker Shale and deltaic Lower Keraudren Formation, are here assigned to the older Early Triassic Gondwana 2 system following Bradshaw et al (1994), Kennard et al (1994) and Geoscience Australia and Geomark (2005).

Early-Middle Jurassic sediments of the Roebuck Basin were deposited under fluvio-deltaic conditions, and are likely to be dominated by gas-prone terrestrial organic matter (Westralian 1 Petroleum System; Geoscience Australia and Geomark, 2005). Although thin coaly and algal-rich oil prone layers have been identified in well cuttings, the temporal and spatial extent of these facies is poorly constrained (Smith et al, 1999). Sedimentary modelling suggests that high-quality transgressive pro-delta marine shales could also be present (Smith et al, 1999), but this is not supported by any significant hydrocarbon shows in the basin.

The Westralian 2 petroleum system is characterised by Late Jurassic, rift-related, restricted marine source rocks in the Bonaparte and Carnarvon basins (Geoscience Australia and GeoMark, 2005), but equivalent rift structures and facies have not been developed in the Roebuck Basin. Similarly, potential Early Cretaceous source rocks documented in the Browse Basin and parts of the Bonaparte Basin (Westralian 3 Petroleum System; Geoscience Australia and GeoMark, 2005), are absent or immature in the Roebuck Basin.

A detailed fluid inclusion investigation of potential reservoir horizons within the offshore Canning and Roebuck basins suggested that widespread oil migration has occurred at multiple Mesozoic and Palaeozoic levels (Lisk et al, 2000).

Samples from multiple horizons from key wells in the region (Bedout 1, East Mermaid 1, Keraudren 1, Lagrange 1 and Phoenix 1) were tested. Grains with oil inclusions (GOI<sup>TM</sup>) were discovered in each well, but the proportion of GOI were below 0.6%, except for Phoenix 1 where it reached 3.3%. The widespread distribution of oil inclusions lead Lisk et al (2000) to propose that a lack of valid traps, rather than a lack of oil charge, might be the principal reason for the discouraging results experienced to date.

## **PLAY TYPES**

The Early Triassic Gondwana 2 petroleum system, interpreted to have charged the Phoenix trap, may be considered a valid play type. The Triassic succession is thicker and more deeply buried to the west of the well (Smith 1999), with better generative potential down-dip in the deeper part of the basin at higher maturities (Lisk et al, 2000). Seismic data acquired subsequent to the drilling of Phoenix 1 and 2 suggest that structuring is widespread at the top Cossigny Member level (Apache, 1995). Quartz overgrowths and dolomite cement that drastically reduced porosity and permeability in the Phoenix 1 target sandstones are likely to be spatially variable as they are potentially controlled by depositional facies variations (Trewin and Fallick, 2000). This is demonstrated in even lower permeabilities in the target interval in Phoenix 2 relative to Phoenix 1, even though the wells are approximately 7 km apart. It is therefore possible that similar prospects in other parts of the sub-basin will not show diagenetically-induced porosity reduction.

The Jaubert Prospect is a faulted anticline prospect that is high-graded by favourable water depth, depth to basement, reservoir thickness and structural closure (approximately 300 msec) at the postulated top-Triassic level ([Figure 8](#); Hematite Petroleum, 1973). The lack of suitable structural closure is one factor that may have contributed to the lack of success of this play type in Keraudren 1, which is unlikely to be the case at Jaubert. Oil indications (cut fluorescence) in Triassic strata in Keraudren 1 are indicative of generative potential at this level landward of the sub-basin depocentre. However, the Triassic succession is thinner and shallower at Jaubert relative to Keraudren 1, therefore this prospect may require long-distance migration or a Palaeozoic source.

Another potential play that has not been adequately tested involves Middle Jurassic sandstones directly below the Callovian breakup unconformity, which was the primary objective in Minilya 1 and the secondary objective in Phoenix 1, but a lack of closure at that level was demonstrated at both sites (Esso, 1994). Industry seismic acquired subsequent to the drilling of Minilya 1 and Phoenix 1 demonstrates widespread closed structures on the base-Cretaceous surface ([Figure 9](#); Apache, 1995).

## **CRITICAL RISKS**

The key risk to the presence of hydrocarbon accumulations within the Bedout Sub-basin is that an effective Mesozoic source rock has not been clearly demonstrated (Smith et al, 1999; Lisk et al, 2000). Late Jurassic and Early Cretaceous claystone source rocks, present in other North West Shelf basins, did not develop in the Roebuck Basin due to mild deformation and a consequent lack of restricted depocentres at that time. However, the interpreted gas column at Phoenix 1 suggests there is an active Triassic petroleum system in the area, and there is potential for this play to be exploited in stratigraphically equivalent structures that may have favourable porosity and permeability.

Other risks for the Release areas include: minor or gentle structuring that affects trap development, size and distribution (Colwell and Stagg, 1994; Lisk et al, 2000); trap-forming structures may succeed major hydrocarbon migration; seal efficiency problems, including relative timing of seal development versus hydrocarbon migration; early charged oil fields could experience late gas flushing (Lisk et al, 2000).

## FIGURES

- Figure 1:** Location of Release areas W08-11 to 15, Bedout Sub-basin showing existing petroleum title areas and significant wells.
- Figure 2:** Structural elements of the Bedout Sub-basin (after JNOC, 1989; Smith et al, 1999).
- Figure 3:** Seismic line 120-4 through Minilya 1 and Lagrange 1 (location of line shown in **Figure 2**).
- Figure 4:** Seismic line 120-01 through Lagrange 1 (location of line shown in **Figure 2**).
- Figure 5:** Stratigraphy of the Bedout Sub-basin (after Smith, 1999; Smith et al, 1999).
- Figure 6:** Chronostratigraphic chart of key wells in the region (after JNOC, 1989; Smith et al, 1999).
- Figure 7:** Petroleum systems of the Roebuck Basin (modified after Smith, 1999 and Smith et al, 1999).
- Figure 8:** Structural contour map of the postulated top-Triassic horizon over the Jaubert Prospect in W08-13 (Hematite Petroleum, 1973).
- Figure 9:** Faults and mapped closure (yellow polygons) on the base-Cretaceous time structure map over the Release areas (Apache, 1995).

## REFERENCES

- APACHE, 1995—H93B Marine Seismic Survey Final Report, unpublished.
- BECKER, L., POREDA, R.J., BASU, A.R., POPE, K.O., HARRISON, T.M., NICHOLSON, C. AND IASKY, R., 2004—Bedout: a possible end-Permian impact crater offshore Northwestern Australia. *Science*, 304, 1469 - 1476.
- BLEVIN, J.E., STEPHENSON, A.E. AND WEST, B.G., VUCKOVIC, V., MIYAZAKI, S. AND LAVERING, I.H., 1994—Beagle Sub-basin Petroleum Prospectivity Bulletin, 2nd edition, Bureau of Resource Sciences, AGPS, Canberra.
- BRADSHAW, M.T., BRADSHAW, J., MURRAY, A.P., NEEDHAM, D.J., SPENCER, L., SUMMONS, R.E., WILMOT, J. AND WINN, S., 1994—Petroleum systems in west Australian basins. In: Purcell, P.G. and Purcell, R.R. (editors), *The Sedimentary Basins of Western Australia: Proceedings of Petroleum Exploration Society Australia Symposium*, Perth, 1994, 63–76.
- COLWELL, J.B. AND STAGG, H.M.J., 1994—Structure of the Offshore Canning Basin: First impressions from the new regional seep-seismic data set. In: Purcell, P.G. and Purcell, R.R. (editors), *The Sedimentary Basins of Western Australia: Proceedings of Petroleum Exploration Society Australia Symposium*, Perth, 1994, 757–768.
- DoIR, 2007—Department of Industry and Resources, Western Australia – Petroleum in Western Australia, Publication, April 2007, 69 pp.
- ESSO, 1994—Exploration Permit WA-236-P Interpretation Report for C92A Seismic Survey, unpublished.
- FORTH, P.A. AND JOURDAN, C.A., 1982—Drilling proposal for Phoenix-3, WA137P, North West Shelf. British Petroleum Petroleum Development Australia Pty Ltd
- GEOSCIENCE AUSTRALIA AND GEOMARK RESEARCH, 2005—The Oils of Western Australia II. Regional Petroleum Geochemistry and Correlation of Crude Oils and Condensates from Western Australia and Papua New Guinea. Unpublished proprietary report Geoscience Australia and GeoMark Research Ltd, Canberra and Houston.
- GOLDSTEIN, B.A., 1989—Waxings and wanings in stratigraphy, play concepts and prospectivity in the Canning Basin. *The APEA Journal*, 29, 466-508.
- GORTER, J.D., 1996—Speculation on the origin of the Bedout High – A large, circular structure of pre-Mesozoic age in the offshore Canning Basin, Western Australia. *PESA News*, October/November, 32-33.
- HEMATITE PETROLEUM, 1973—Final Report, 1973 Jaubert Marine Seismic and Magnetometer Survey, Western Australia, unpublished.
- INGRAM, B., 1990—Review of twelve wells from the Beagle Sub-basin, palynology report WP11/90. Kufpec Australia Pty Ltd, unpublished.
- JNOC, 1987—A petroleum analysis of six wells from the Offshore Canning Basin, unpublished.

JNOC, 1989—Geological and geophysical study of the northeastern part of the offshore Canning Basin on the Northwest Shelf of Australia, unpublished.

JONES, A.T., KENNARD, J.M., RYAN, G.J., BERNARDEL, G., EARL, K., ROLLET, N., GROSJEAN, E. AND LOGAN, G.A., 2007—Geoscience Australia Marine Survey SS06/06 Post Survey Report: Natural hydrocarbon seepage survey on the central North West Shelf. GA Record 2007/21.

KENNARD, J.M., JACKSON, M.J., ROMINE, K.K., SHAW, R.D. AND SOUTHGATE, P.N., 1994—Depositional sequences and associated petroleum systems of the Canning Basin. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia: Proceedings of Petroleum Exploration Society Australia Symposium, Perth, 1994, 657–676.

KUFPEC, 1994—Cimba-1 well completion report, unpublished.

LIPSKI, P., 1993—Tectonic setting, stratigraphy and hydrocarbon potential of the Bedout Sub-basin, North West Shelf. The APEA Journal, 33(1), 138–150.

LIPSKI, P., 1994—Structural framework and depositional history of the Bedout and Rowley Sub-basins. In: Purcell, P.G. and Purcell, R.R. (editors), The sedimentary basins of Western Australia. Proceedings of the West Australian Basins Symposium, Petroleum Exploration Society of Australia, Perth, 14-17 August, Perth, 769-777.

LISK, M., OSTBY, J., RUSSEL, N.J. AND O'BRIEN, G.W., 2000—Oil migration history of the offshore Canning Basin. The APPEA Journal, 40, 133-151.

McCracken, S., 1994—Timing of hydrocarbon migration into the Admiral Bay Fault Zone, Canning Basin. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia: Proceedings of Petroleum Exploration Society Australia Symposium, Perth, 739–751.

MÜLLER, R.D., GONCHAROV, A. AND KRITSKI, A., 2005—Geophysical evaluation of the enigmatic Bedout basement high, offshore northwestern Australia. Earth and Planetary Science Letters, 237, 264-284.

O'BRIEN, G.W., COWLEY, R., LAWRENCE, G., WILLIAMS, A.K., WEBSTER, M., TINGATE, P. AND BURNS, S., 2003—Migration, leakage and seepage characteristics of the offshore Canning Basin and northern Carnarvon Basin: Implications for hydrocarbon prospectivity. The APPEA Journal, 43, 149-166.

OSBORNE, D.G., 1994—Nebo Oil discovery, Beagle Sub-basin. In: Purcell, P.G. and Purcell, R.R. (editors), The Sedimentary Basins of Western Australia 2: Proceedings of Petroleum Exploration Society of Australia Symposium, Perth, WA, 1998, p 653

PASSMORE, V.L., 1991—Promising hydrocarbon potential seen in Canning Basin off Australia. Oil and Gas Journal, August 26, 1991, 65-70.

ROBERTSON RESEARCH, 1986—Petroleum geology and geochemistry, Northwest Shelf, Australia: Phase II. Robertson Research Australia Pty Ltd, unpublished.

SHAW, R.D., ZEITLER, P.K., McDOUGALL, I. AND TINGATE, P.R., 1992—The Paleozoic history of an unusual intracratonic thrust belt in central Australia based on  $^{40}\text{Ar}$ - $^{39}\text{Ar}$ , K-Ar and fission track dating. *Journal of Geological Society*, London, 149, 937-954.

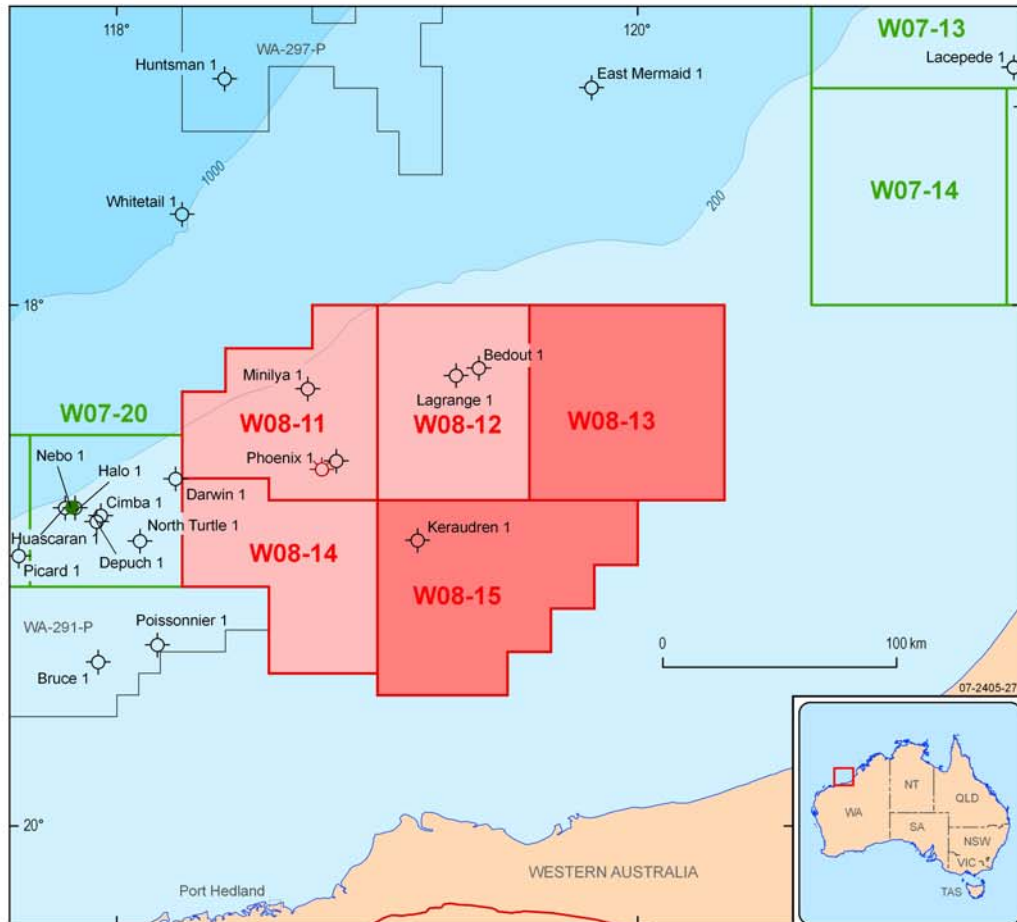
SMITH, S.A., TINGATE, P.R., GRIFFITHS, C.M. AND HULL, J.N.F., 1999—The structural development and petroleum potential of the Roebuck Basin. *The APPEA Journal*, 39(1), 364–385.

SMITH, S.A., 1999—The Phanerozoic basin-fill history of the Roebuck Basin. PhD Thesis, University of Adelaide, unpublished.

SURDAM, R. AND WARME, J., 1984—Rock-Eval pyrolysis data on samples from 58 wells in the Canning Basin, Western Australia. Colorado School of Mines, unpublished.

TREWIN, N.H. AND FALLICK, A.E., 2000—Quartz cement origins and budget in the Tumblagooda Sandstone, Western Australia. In: Worden, R.H. and Morad, S. (eds) *Quartz cementation in sandstones*, Special Publication of the International Association of Sedimentologists, 29, 219-229.

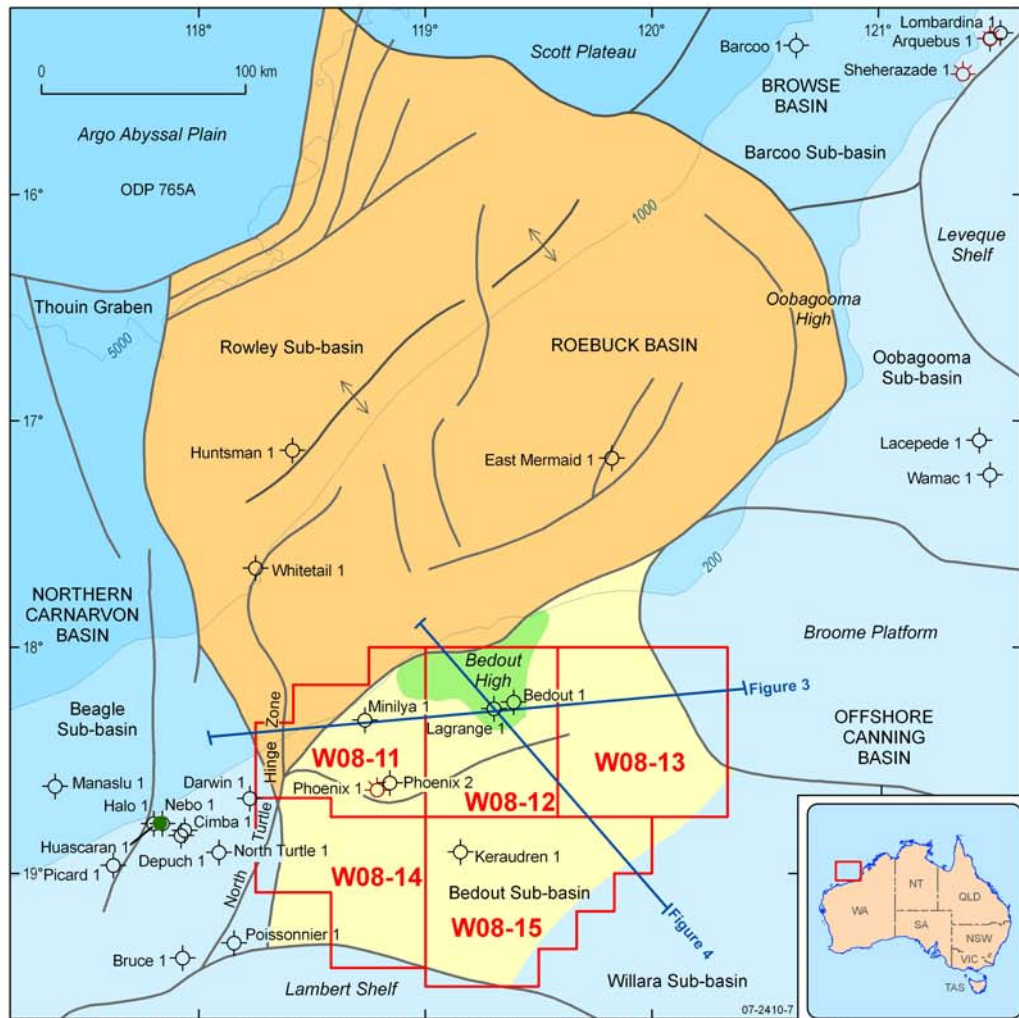
WARRIS, B.J., 1993—The hydrocarbon potential of the Palaeozoic basins of Western Australia. *The APEA Journal*, 33, 123-137.



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.

- 2008 release area
- 2008 designated frontier release area
- 2007 release area
- Existing petroleum title
- Gas pipeline
- Bathymetry contour (depth in metres)
- Petroleum exploration well - dry hole
- ⊗ Petroleum exploration well - gas show
- Petroleum exploration well - oil discovery

Figure 1. Location of Release areas W08-11 to 15, Bedout Sub-basin showing existing petroleum title areas and significant wells.



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.

- |  |  |
|--|--|
|  2008 release area                    |  Petroleum exploration well - dry hole      |
|  Fault                                |  Petroleum exploration well - gas show      |
|  Anticline                            |  Petroleum exploration well - oil discovery |
|  Bathymetry contour (depth in metres) |  |

Figure 2. Structural elements of the Bedout Sub-basin (after JNOC, 1989; Smith et al, 1999).

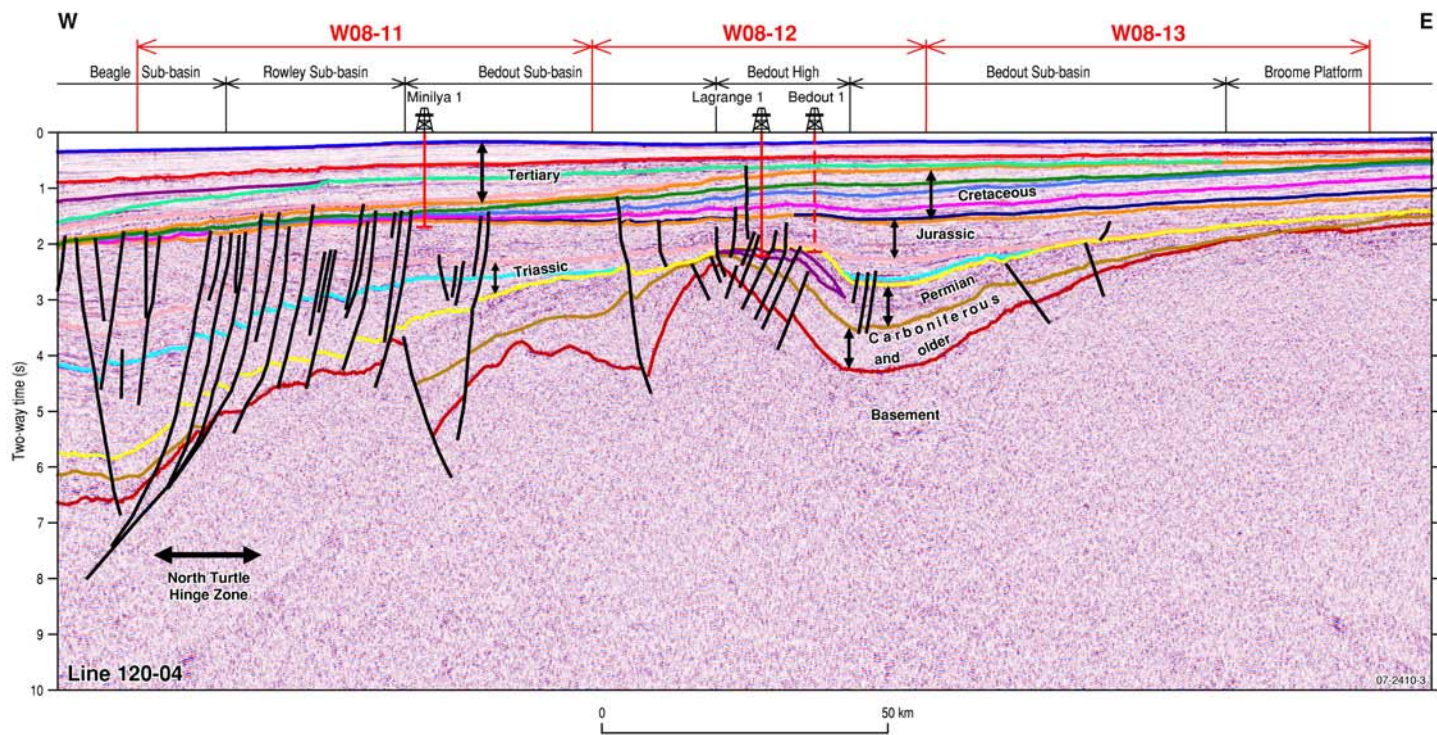


Figure 3. Seismic line 120-04 through Minilya 1 and Lagrange 1 (location of line shown in Figure 2).

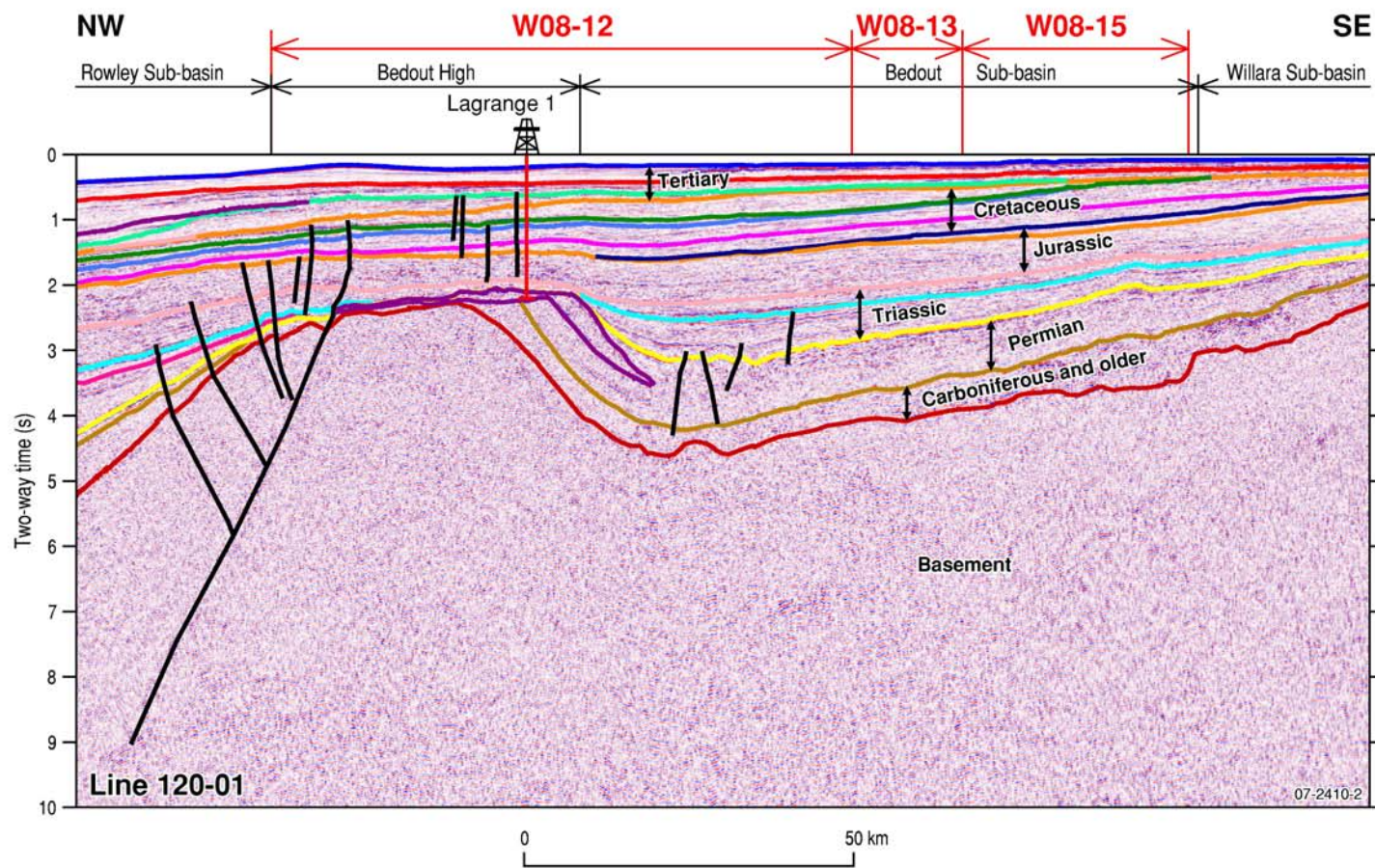


Figure 4. Seismic line 120-01 through Lagrange 1 (location of line shown in Figure 2).

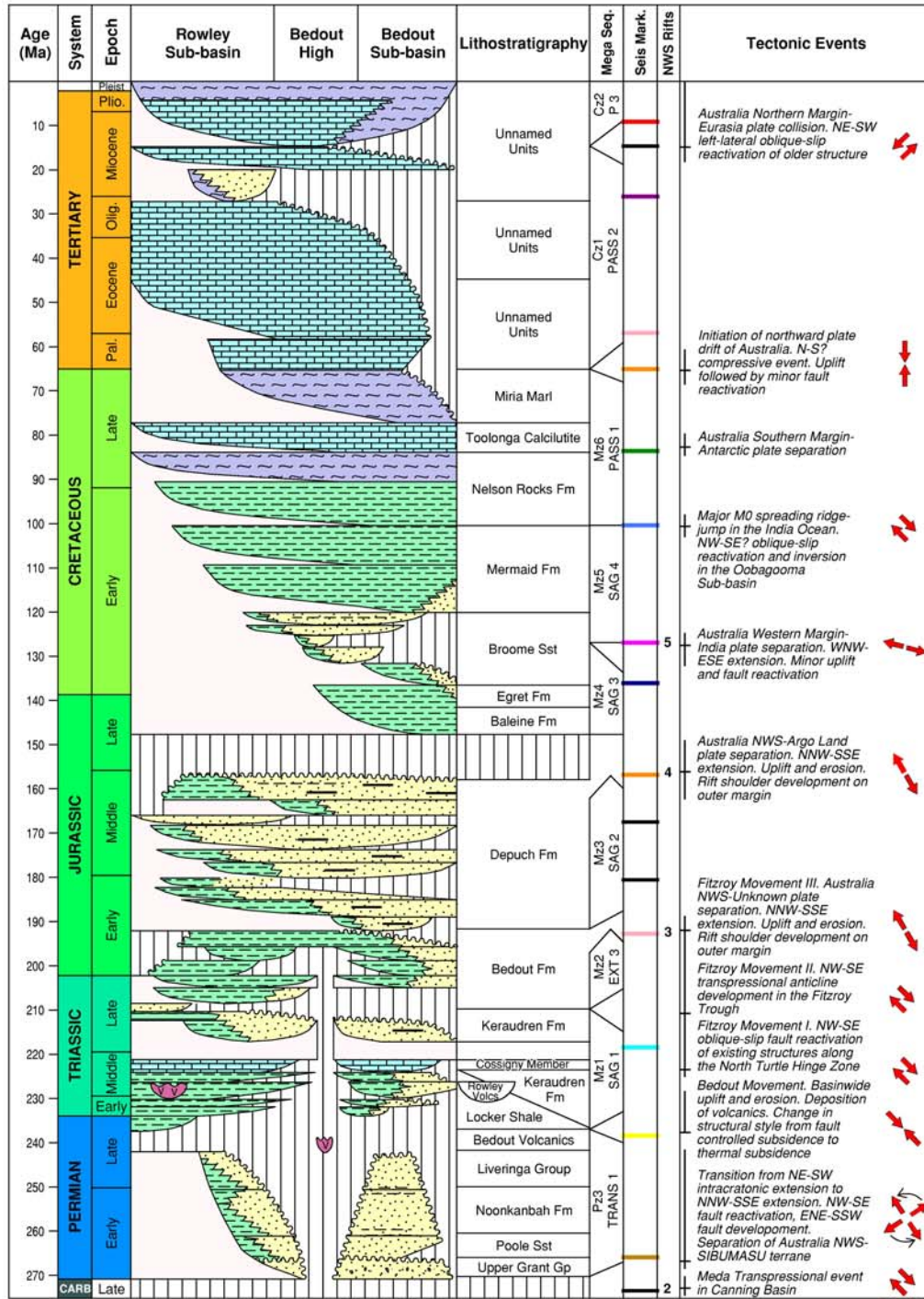


Figure 5. Stratigraphy of the Bedout Sub-basin (after Smith, 1999; Smith et al, 1999).

07-2410-4

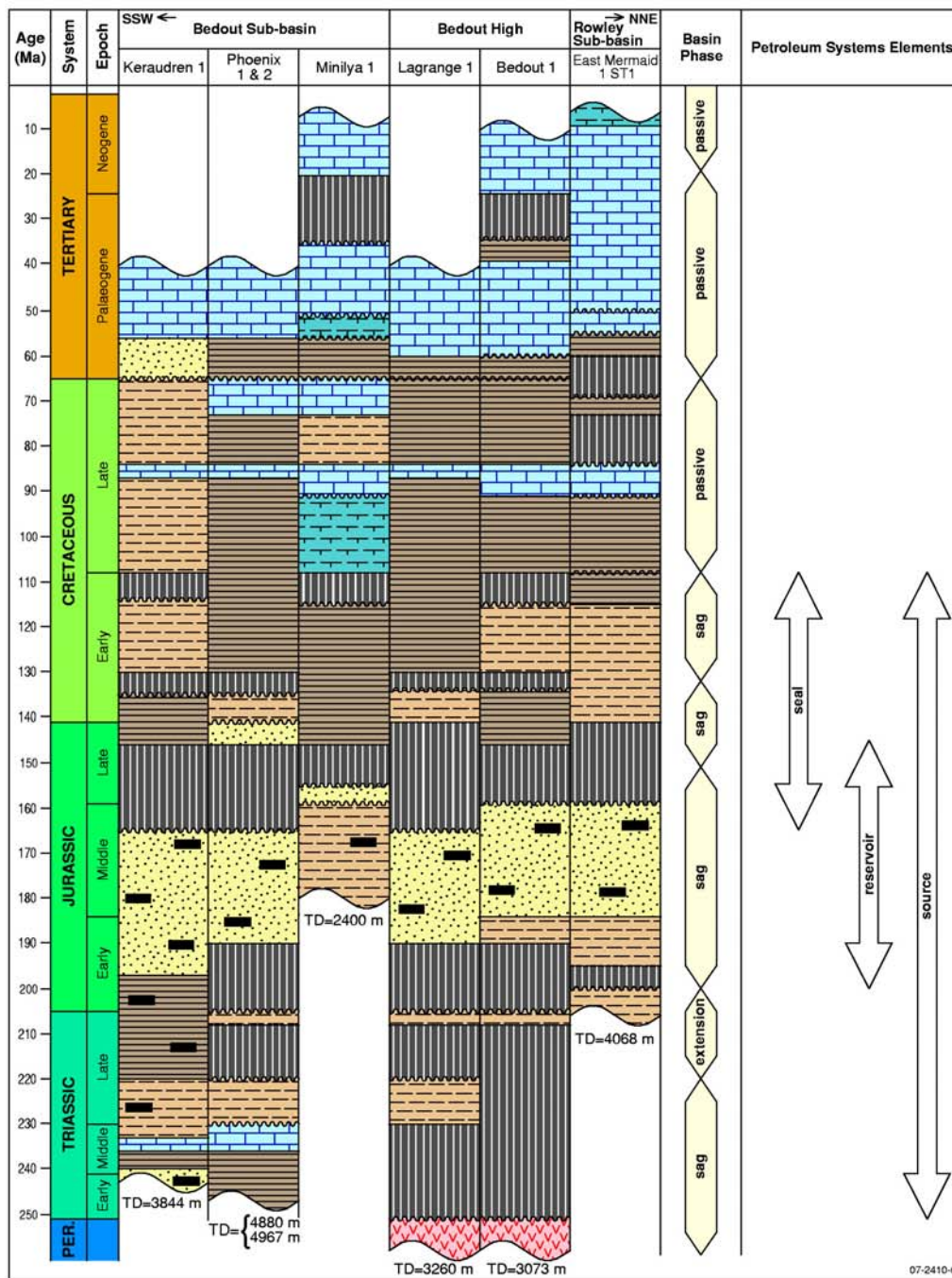


Figure 6. Chronostratigraphic chart of key wells in the region (after JNOC, 1989; Smith et al, 1999).

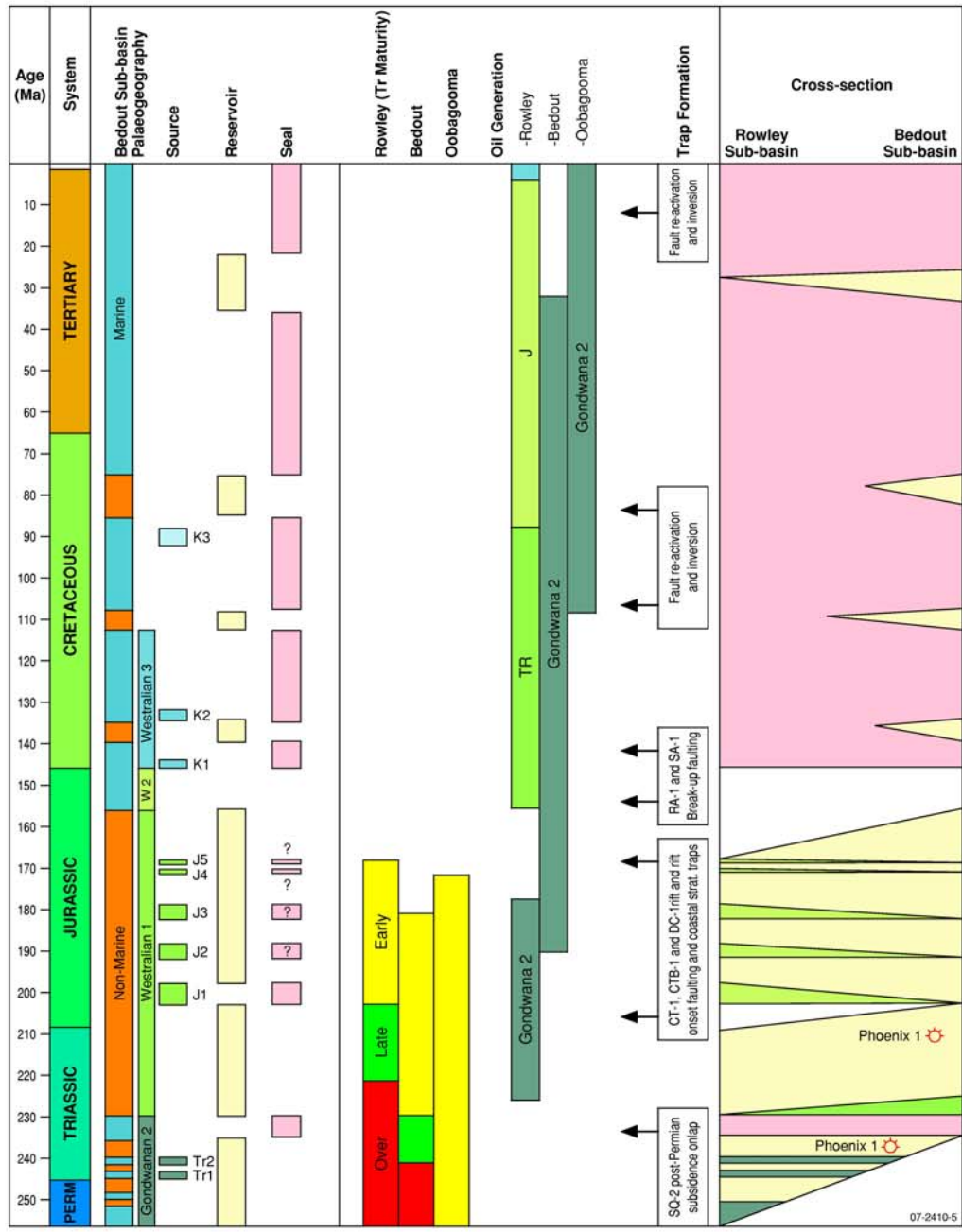


Figure 7. Petroleum systems of the Roebuck Basin (modified after Smith, 1999 and Smith et al, 1999).

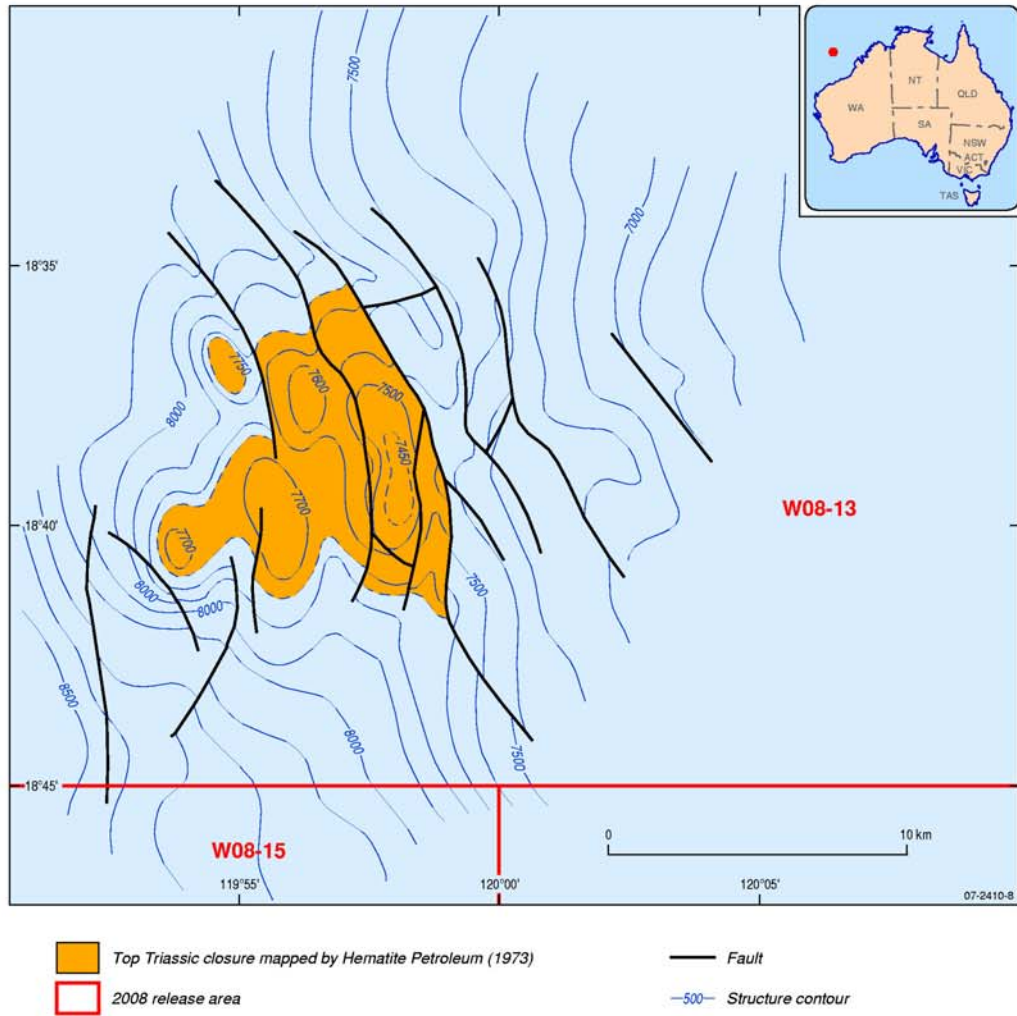


Figure 8. Structural contour map of the postulated top-Triassic horizon over the Jaubert Prospect in W08-13 (Hematite Petroleum 1973).

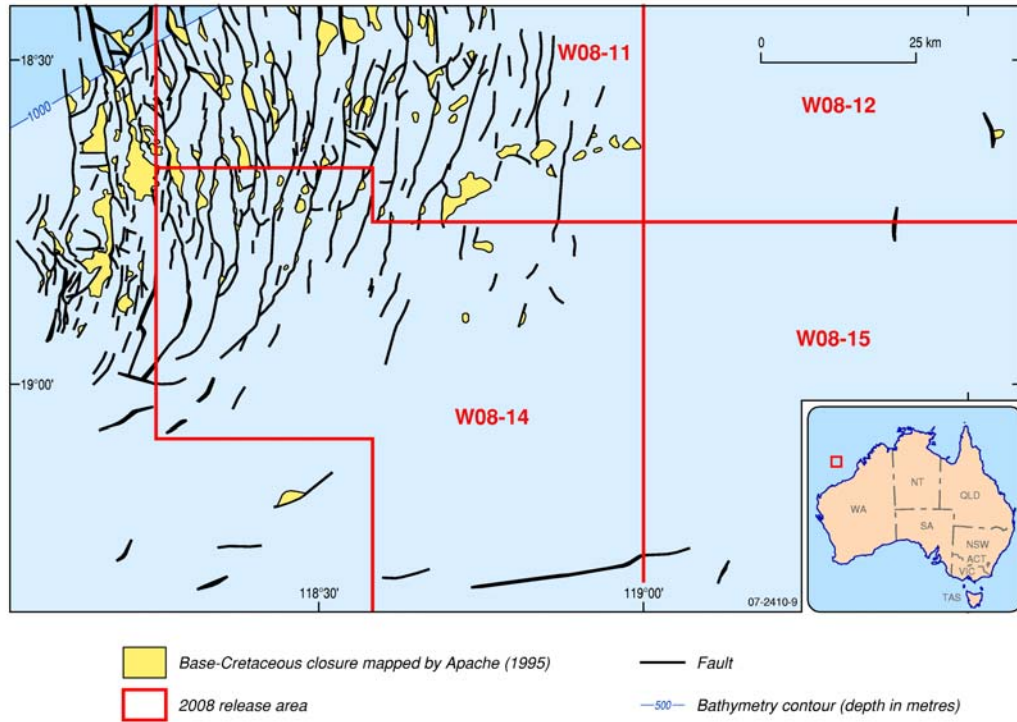


Figure 9. Faults and mapped closure on the base-Cretaceous time structure map over the Release areas (Apache, 1995).