Australian Government

Department of Industry
Tourism and Resources

2007 RELEASE OF AUSTRALIAN OFFSHORE PETROLEUM EXPLORATION AREAS

AREAS W07-12 TO W07-15 OFFSHORE CANNING BASIN, WESTERN AUSTRALIA

SECTIONS

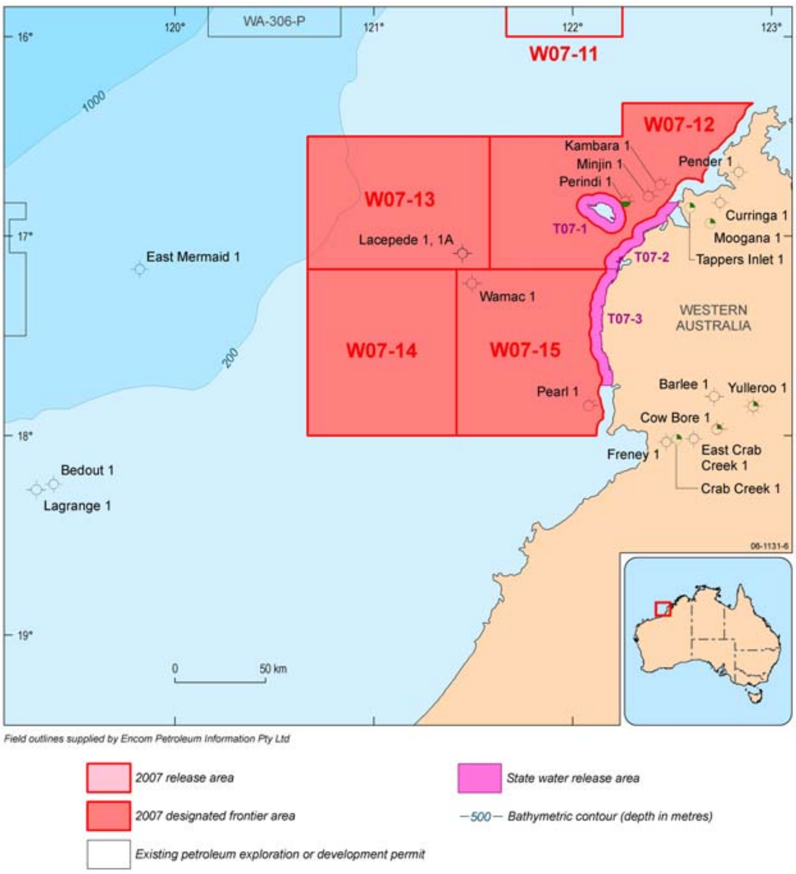
2007 RELEASE OF OFFSHORE PETROLEUM EXPLORATION AREAS

SUMMARY – OFFSHORE CANNING BASIN RELEASE AREA

AREAS W07-12, W07-13, W07-14 AND W07-15
OFFSHORE CANNING BASIN
WESTERN AUSTRALIA

BIDS CLOSE 17th APRIL 2008

- **Designated Frontier Tax Concession applies to all four areas.**
- Under-explored, shallow water frontier areas <500 m water depth.
- Offshore extension of proven onshore Palaeozoic oil and gas province, and potential Mesozoic petroleum systems.
- Evidence of local oil and gas generation and migration.
- Carboniferous, Permian, Triassic and Jurassic reservoir sands; potential Devonian clastic and carbonate reservoirs.
- Potential Middle Triassic and latest Triassic–earliest Jurassic regional seals.
- Potential stratigraphic pinchout traps against the Oobagooma High and the basin margin.
- Special Notices apply, refer to Guidance Notes.



Australian Government
Department of Industry
Tourism and Resources

2007 RELEASE OF OFFSHORE PETROLEUM EXPLORATION AREAS

AREAS W07-12, W07-13, W07-14 AND W07-15
OFFSHORE CANNING BASIN
WESTERN AUSTRALIA

BIDS CLOSE 17th APRIL 2008

LOCATION

Areas W07-12 to W07-15 cover an area of approximately 29,000 km^2 offshore from the Canning Basin, north of Broome, Western Australia (**Figure 1**). The release areas overlie the offshore extension of the Canning Basin's Fitzroy Trough and flanking shelves (Jurgurra Terrace, Broome Platform, Pender Terrace and Leveque Platform: **Figure 2**), which hosts several onshore oil and gas discoveries, and occurs immediately to the south of the highly prospective Browse Basin. Water depths are less than 100 m over the inboard release areas (W07-12 and W07-15), and less than 200 m over most of the outboard release areas (W07-13 and W07-14).

Area W07-12 comprises 108 graticular blocks covering approximately 7655 km^2 and contains three wells (Kambara 1, Minjin 1 and Perindi 1). Area W07-13 comprises 88 graticular blocks covering approximately 7210 km^2 and contains the wells (Lacepede 1 and 1A). Area W07-14 comprises 90 graticular blocks covering approximately 7345 km^2. Area W07-15 comprises 91 blocks covering approximately 6870 km^2 and contains two wells (Pearl 1 and Wamac 1).

The inboard release areas are adjacent to three Western Australia State Waters areas currently being released (**Figure 1)**. State release areas T07-1, T07-2 and T07-3 are scheduled for gazettal on 17 April 2007, with bids closing on 11 October 2007.

GRATICULAR BLOCK LISTINGS AND MAP

W07-12
Canning Basin, Western Australia
Map Sheet SE 51 (Broome)

316	317	318	319	320	321
322	323 part	388	389	390	391
392	393	394 part	395 part	452	453
454	455	456	457	458	459
460	461	462	463	464	465 part
466 part	524	525	526	527	528
529	530	531	532	533	534
535	536	537 part	596	597	598
599	600	601	602	603	604
605	606	607 part	608 part	609 part	668
669	670	671	672	673 part	674 part
675 part	676	677	678 part	679 part	740
741	742	743	744	745 part	747 part
748 part	749 part	750 part	812	813	814
815	816	817 part	818 part	819 part	820 part
821 part	884	885	886	887	888
889	890	891 part	892 part	956	957
958	959	960	961	962 part	963 part

Assessed to contain 108 blocks (includes 80 full blocks and 28 part blocks)

W07-13
Canning Basin, Western Australia
Map Sheet SE 51 (Broome)

441	442	443	444	445	446
447	448	449	450	451	513
514	515	516	517	518	519
520	521	522	523	585	586
587	588	589	590	591	592
593	594	595	657	658	659
660	661	662	663	664	665
666	667	729	730	731	732
733	734	735	736	737	738
739	801	802	803	804	805
806	807	808	809	810	811
873	874	875	876	877	878
879	880	881	882	883	945
946	947	948	949	950	951
952	953	954	955		

Assessed to contain 88 full blocks

W07-14
Canning Basin, Western Australia
Map Sheet SE 51 (Broome)

1017	1018	1019	1020	1021	1022
1023	1024	1025	1089	1090	1091
1092	1093	1094	1095	1096	1097
1161	1162	1163	1164	1165	1166
1167	1168	1169	1233	1234	1235
1236	1237	1238	1239	1240	1241
1305	1306	1307	1308	1309	1310
1311	1312	1313	1377	1378	1379
1380	1381	1382	1383	1384	1385
1449	1450	1451	1452	1453	1454
1455	1456	1457	1521	1522	1523
1524	1525	1526	1527	1528	1529
1593	1594	1595	1596	1597	1598
1599	1600	1601	1665	1666	1667
1668	1669	1670	1671	1672	1673

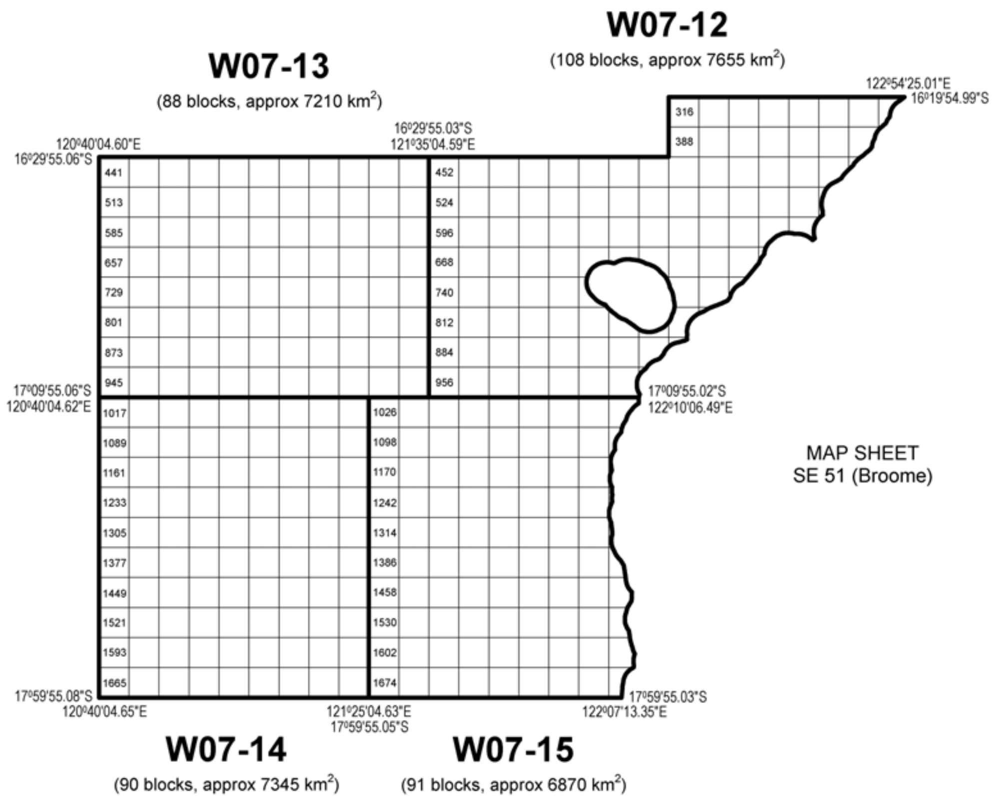
Assessed to contain 90 full blocks

W07-15
Canning Basin, Western Australia
Map Sheet SE 51 (Broome)

1026	1027	1028	1029	1030	1031
1032	1033	1034 part	1035 part	1098	1099
1100	1101	1102	1103	1104	1105
1106 part	1170	1171	1172	1173	1174
1175	1176	1177	1178 part	1242	1243
1244	1245	1246	1247	1248	1249
1250 part	1314	1315	1316	1317	1318
1319	1320	1321	1322 part	1386	1387
1388	1389	1390	1391	1392	1393
1394 part	1458	1459	1460	1461	1462
1463	1464	1465	1466 part	1530	1531
1532	1533	1534	1535	1536	1537
1538 part	1602	1603	1604	1605	1606
1607	1608	1609	1610 part	1674	1675
1676	1677	1678	1679	1680	1681
1682 part					

Assessed to contain 91 blocks (includes 80 full blocks and 11 part blocks)

2007 Release Areas
Canning 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 6118-10

CANNING BASIN GEOLOGY

The Offshore Canning Basin is a northeast-trending passive margin of Late Palaeozoic and Mesozoic age (part of the Westralian Superbasin), overlying a major northwest-trending intra-cratonic basin of mainly early Palaeozoic age (Colwell and Stagg, 1994). The temporal boundary between the intra-cratonic and passive margin systems is in the Late Carboniferous at the time of the Alice Springs Orogeny.

Structural framework

The Offshore Canning Basin can be divided into a number of major structural provinces (**Figure 2**). The offshore Fitzroy Trough (hereafter referred to as the Oobagooma Sub-basin) and offshore Willara Sub-basin (including the Samphire and Wallal embayments) are depocentres of the Palaeozoic intra-cratonic system. These are separated by the west-northwest-trending, largely unfaulted, structural high of the Broome Platform and are disconformably overlain by 'Westralian' passive margin sediments of the Bedout and Rowley sub-basins. These latter depocentres comprise the outboard Roebuck Basin, which in this report is distinct from the inboard Offshore Canning Basin. The release areas are primarily located over the Oobagooma Sub-basin and Broome Platform; therefore these depocentres will be described in more detail.

The Oobagooma Sub-basin is approximately 190 km in length and 100 km in width. A major change in Palaeozoic structural orientation, from northwest–southeast to north–south, occurs at approximately 17°S in the sub-basin (**Figure 2**). At this location a weakly developed graben structure also extends to the west-southwest creating a triple-point junction. The change in structural orientation occurs around an asymmetric intruded high (the Oobagooma High), which marks the western limit of the Oobagooma Sub-basin.

The style of bounding faults along the sub-basin margin changes from asymmetrical half-graben extension onshore (with the northeastern margin acting as a hinge and the southwestern margin faulted down on a shallow dipping detachment; Drummond et al, 1991), to symmetrical graben extension in the near offshore (Smith et al, 1999; **Figure 3**), to thin skinned detachment along a northeast-dipping surface and its southwest dipping antithetic in the outer offshore (Colwell and Stagg, 1994). The style of extension appears to be controlled by the location of the more rigid elements of the basin, with normal faults developing near the stable bounding Kimberley Craton and Leveque Shelf to the northeast and the Broome Platform to the southwest (Smith et al, 1999). Major offsets along the boundaries of the onshore Fitzroy Trough are interpreted as orthogonal transfer or accommodation zones. These zones have exerted a major control on the pattern of sediment dispersal and accumulation, especially in the Devonian (Kennard et al, 1994).

The Oobagooma High is a 25 km wide north–south-oriented elongate feature with approximately 3 km of relief from the surrounding basement and separates the Oobagooma Sub-basin from the Rowley Sub-basin at the Palaeozoic level (Smith et al, 1999; **Figure 4**). It consists of an asymmetric northeastward-dipping intruded high, which is fault-bound on it southern flank. At basement level the Oobagooma High trends from the Oobagooma Sub-basin to the Bedout High, truncating the Broome Platform. The Oobagooma High appears to be associated with volcanic lithologies, as evidenced by the presence of a strong magnetic anomaly associated with its western flank. The structural formation of the Oobagooma and Bedout highs appear to be related, although the mechanism is uncertain. The highs likely developed over areas of change in orientation of a zone accommodating differential northeast–southwest Palaeozoic extension (the North West Shelf Mega-shear). Orientation changes in these areas resulted in transpression along the mega-shear. Minor reactivation on the Palaeozoic detachment system and underplating (due to pure shear removal of the lower crust and simple shear) contributed to uplift of the highs. Development of the highs appears to have commenced in the Early to Middle Carboniferous to Late Permian (when sediments of that age are observed to onlap the feature), with reactivation during major tectonic events throughout the Late Carboniferous to Late Permian (major erosion during the Late Permian prevents the delineation of any finer tectonic history for the structure; Smith et al, 1999).

The Broome Platform is a mid-basinal swell or arch covered by less than 2 km of sediments (Kennard et al, 1994). It is a long-lived uplifted area of shallow basement, capped by a thin succession of Ordovician, Devonian and Permian rocks (around 1–2 km thick) gently dipping to the southeast. The platform is flanked on its northern margin by fault-bounded terraces tens of kilometres wide that preserve a thicker section (2–4 km) of mostly Ordovician and Devonian platform carbonates (the Jurgurra Terrace is the western-most of these terraces, which extends into the offshore; **Figure 2**). Fault bounded terraces up to 50 km wide also flank the Leveque Shelf along the northern margin of the Fitzroy Trough. These terraces also contain mostly Ordovician to Devonian carbonates capped by thin Permian sections (the Pender Terrace is the western-most of these terraces, which extends into the offshore; **Figure 2**).

Geological evolution and tectonic development

The Offshore Canning Basin is a long-lived, multiple phase basin which has undergone a complex structural evolution (Kennard et al, 1994; Smith et al, 1999). A series of basinwide tectonic events have been identified in the Onshore and Offshore Canning Basin and used to divide the basin-fill into megasequences (**Figure 5**):

1. Cambrian–Carboniferous. Earliest sedimentation occurred following northeast–southwest extension as the Chinese blocks separated from Gondwana (Samphire Marsh Movement). Intracratonic extensional and sag related deposition were periodically interrupted by folding and regional uplift or tilting and fault block movement associated with tectonic pulses in the earliest Devonian (Prices Creek Compressional Movement), Late Devonian (Van Emmerick Extension) and Early Carboniferous (Red Bluffs Extension).
2. Sedimentation was terminated in the mid-Carboniferous during uplift and erosion associated with inversion on Devonian faults during the northeast–southwest oblique slip Meda Transpressional Event, which probably represents the peak of the Alice Springs Orogeny in central Australia.
3. Late Carboniferous–Permian. The onset of formation of the Westralian Superbasin in the Early Permian defines the boundary between the northwest-oriented structures associated with the Canning Basin and the northeast-oriented structures associated with the Roebuck Basin. This was a period of transition from a regime of northeast–southwest extension to one of northwest–southeast extension during separation of the Sibumasu blocks from Gondwana. Landward of the Rowley Sub-basin synrift,

sedimentation was still occurring along pre-existing intracratonic fractures formed during the northeast–southwest extension. A major tectonic episode produced extensive uplift, faulting and volcanism in the Late Permian to Early Triassic (Bedout Movement).

4. Triassic–Early Jurassic. The Triassic was dominated by a period of thermal sag with transgressive marine sedimentation, punctuated by a series of Triassic to Early Jurassic northwest–southeast transpressional events (Fitzroy Movement). Here the Fitzroy Movement can be subdivided – Fitzroy Movement I in the Ladinian (Middle Triassic), Fitzroy Movement II in the Norian (Late Triassic – not widely documented offshore, but seen as an unconformity in the wells to the west; eg Phoenix), and Fitzroy Movement III in the Sinemurian (Early Jurassic). This last event marks a major change in gross stratal geometries within the basin from predominantly back stepping to prograding and aggrading.
5. Middle Jurassic–Early Cretaceous. Middle Jurassic structural development occurred as a result of thermal subsidence after Early Jurassic uplift and erosion. A broad prograding wedge system developed across the shelf. Callovian breakup resulted in a second phase of prominent uplift and erosion that marked the end of active rifting adjacent to the Roebuck Basin. Thermal relaxation resulted in rapid transgression and development of a condensed section until the Early Cretaceous, when rejuvenation of the source province occurred during uplift associated with the rifting of India away from the western margin of Australia during the Valanginian
6. Early Cretaceous–Recent. Thermal relaxation of the crust soon after the Valanginian led to the development of a passive margin. Full ocean circulation was established by the end of the Aptian. The separation of Antarctica and Australia reactivated older Palaeozoic features causing inversion and oblique slip movement, especially in the Oobagooma Sub-basin. Collision of the Australian and Eurasian plates in the mid-Miocene resulted in transpressional inversion of older north-northwest–south-southeast-trending Palaeozoic faults in the northeastern Oobagooma Sub-basin.

Basin fill

Basin fill in the Oobagooma Sub-basin consists of approximately 5.5 km of Palaeozoic section and 4.5 km of Mesozoic and Cainozoic section (Smith et al, 1999). Little is known about the nature of Palaeozoic sedimentation offshore, as few wells have penetrated this succession. Most authors believe that the Palaeozoic sequence in the offshore is merely an extension of that 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). Of particular note within this succession are widespread evaporitic halite deposits, which form highly effective seals in parts of the onshore Canning Basin, and the Devonian reef complexes that have been the target of numerous exploration wells.

A thick (approximately 4 km) sequence of probable Late Carboniferous and Permian sediments comprising interbedded sandstones, siltstones and claystones with some dolerite sills, minor coal and thin limestone beds, forms the bulk of the basin fill (Colwell and Stagg, 1994).

The Palaeozoic sequence onlaps the Leveque Shelf and Broome Platform and is overlain by a strong regional unconformity that marks the Bedout and/or Fitzroy movements (Colwell and Stagg, 1994). The Triassic–earliest Jurassic section is absent and Early–Middle Jurassic sediments unconformably overlie the Permo–Carboniferous succession in each of the offshore wells. The Early–Middle Jurassic section forms a broad, sag 'blanket' less than 1.5 km thick across the trough and onlaps the Leveque Platform to the northeast. The sequence shows little structuring, other than minor reactivation of faulting, and comprises interbedded fluvio-deltaic sandstones, siltstones, shale and coal. A regional unconformity produced by continental breakup along the northwestern margin of the Canning Basin (Argo Breakup) separates Jurassic sediments from the overlying, mainly Cretaceous and Tertiary.

The Tertiary sequence is dominated initially by fluvio-deltaic and shallow marine clastics, but includes, with increasing margin subsidence, an increasing proportion of carbonates in its upper part (Colwell and Stagg, 1994).

EXPLORATION HISTORY

Until the mid-1980s, exploration largely focussed on the onshore northern and central basin areas and targeted reefs within the Devonian section and overlying Permo–Carboniferous clastics. During the 1980s an extensive phase of petroleum exploration resulted in the acquisition of many thousands of kilometres of seismic data and the drilling of many additional wells, but this yielded little commercial success (Kennard et al, 1994). Production is limited to six small oil fields on or adjacent to the Lennard Shelf (Blina, Boundary, Lloyd, Sundown, West Kora and West Terrace), and development of the Point Torment gas field (also on the Lennard Shelf) is being considered to generate power for the West Kimberley region. The largest accumulation, Blina (approximately 2 MMbbls), is reservoired within dolomites of the Late Devonian Nullara Limestone carbonate bank and (to a lesser extent) within the Early Carboniferous Yellow Drum Formation. All other accumulations are within clastics of the Early Carboniferous Anderson Formation (Lloyd, Point Torment and West Kora) and Late Carboniferous Grant Group (Boundary, Sundown and West Terrace).

The small size of the discoveries made in the Devonian reef complexes and overlying Permo–Carboniferous clastics in the onshore northern and central basin areas, and the low oil price in the late 1980s meant that exploration languished (Black, 2006). Since that time, the Canning Basin has seen a low level of systematic exploration and, to date, there are only approximately 250 wells drilled onshore, which is low for a basin of this size. The basin is substantially under-explored with few valid structural tests.

A total of 15 wells have been drilled offshore from the Canning Basin, with the majority sited in the Mesozoic depocentres of the Rowley and Bedout sub-basins; none with commercial success. Six wells were drilled in the Offshore Canning Basin between 1970 and 1984, with the only significant hydrocarbon shows being recorded in Perindi 1.

Lacepede 1 and **1A** were drilled in 1970, approximately 129 km northwest of Broome in the central Oobagooma Sub-basin. Lacepede 1 was abandoned at 224 m due to technical difficulties and Lacepede 1A reached a total depth (TD) of 2286 m. The wells were drilled to test an elongate east–west-trending anticlinal structure. Lacepede 1A penetrated Miocene sediments unconformably overlying an Early Cretaceous to Late Carboniferous (originally interpreted to be Late Permian; Helby and Partridge, 1982) sedimentary section. Lacepede 1A penetrated the most complete Jurassic section in the Canning Basin at that time, with rocks of Early Jurassic age being recorded for the first time. The entire Triassic and most of the Permian section is absent, such that Jurassic (Tithonian–Toarcian) sediments unconformably overlie Early Permian (Asselian) to Late Carboniferous sediments. No significant hydrocarbons shows were encountered in the wells. Slight increases in the background gas readings occurred in the Jurassic and Permian sections. However, no fluorescence was observed and wireline logs indicated 100 % water saturation throughout the well. The wells confirmed the presence of thick, porous and permeable reservoirs in the Early Cretaceous and Jurassic sections and are thought to have adequately tested the Cretaceous, Jurassic and uppermost Permian sections of the Lacepede structure.

Wamac 1 was drilled in 1973 to a TD of 2764 m and is located 110 km northwest of Broome. The well was drilled as a test of the sedimentary section in the Wamac structural feature. This is a seismically mapped positive feature of Palaeozoic age with an east–west elongation and an areal closure of >250 km^2 in the ?intra-Devonian and also possible closure in the ?Early Permian. The structure was found to be a partly fault-controlled positive feature over a basement rise, with high interval velocities below the structure potentially due to a reefal section, or an igneous intrusion. Wamac 1 penetrated a sedimentary section ranging from Quaternary to Carboniferous age, being of similar character to that in Lacepede 1A. The Palaeozoic sediments are intruded by dolerite of Permian to Early Triassic age. It was programmed for 3659 m, but was terminated in a dolerite sill because of drilling problems associated with the collapse of fragments and blocks into the well. No hydrocarbon shows were recorded in clastic rocks, due mostly to lack of closed structure in the Mesozoic, and possibly also in the Late Palaeozoic. Slight increases in methane were observed at multiple levels and fluorescence was observed at 1830 m. Low porosity and negligible permeability (due to induration of sandstones by intrusions) may have been responsible for the lack of hydrocarbon indications throughout the Palaeozoic.

Kambara 1 was drilled in 1982, 136 km north of Broome on the Pender Terrace. The well was programmed to 3175 m to test an interpreted Devonian pinnacle reef, but terminated at 3150 m after passing through 700 m of tight platform limestones and 350 m of interbedded sandstones and limestones. No recognisable reef facies were encountered in the well; instead a sequence of Late Devonian platform limestones were penetrated, overlying interbedded basinal limestones and sandstones. The target reef was reinterpreted to be diffractions within a flat limestone platform, the result of erosional topography on the platform surface, or a pinnacle reef with a well developed lagoonal facies in the centre. The well intersected relatively thin Cretaceous (350 m) and Jurassic (~250 m) sections and relatively thick Permian (~550 m), Carboniferous (~850 m) and Devonian (>1 km) sections. In this respect, it is similar to the Onshore Canning Basin succession rather than the earlier wells drilled in the Oobagooma Sub-basin. The well intersected porous and permeable sandstones and good seal lithologies in the Permo–Carboniferous section. The Devonian sandstones and limestones lacked significant porosity. The sequence drilled was immature down to and including most of the Devonian section (~2650 m). The only good source material in the Permo–Carboniferous was immature. Kambara 1 reached a total depth without encountering any hydrocarbon shows. The lack of hydrocarbon shows probably indicated that there was no mature source adjacent to, or overlaying the limestone section. Also lack of significant porosity in the Devonian section and lack of sealing lithology over the limestone section probably precluded the occurrence of significant hydrocarbons.

Perindi 1 was drilled in 1983, 126 km north of Broome on the Pender Terrace. The well was programmed to 1921 m, primarily to test multiple sandstone horizons within the Poole Sandstone, Grant Group and Anderson Formation, in a domal structure formed by the emplacement of igneous intrusions. The secondary objective in the well was the underlying Devonian Pillara Formation limestones on the southern flank of the Tappers Inlet High. The well was terminated at 1867 m due to partial lost circulation in the Pillara Formation carbonates and lack of encouraging hydrocarbon shows. The Cretaceous and Jurassic sections are somewhat thicker than in the nearby Kambara 1 well, with a much thicker Permian section, but much thinner Carboniferous section. The Jurassic, Cretaceous and Permian (Grant Group) all contain porous and permeable sandstones. The Devonian carbonates (Pillara Formation) exhibit excellent porosity and permeability, which may be due to karst formation during fault block exposure. The presence of (the thin) Laurel Formation indicates that this unit occurs higher than anticipated on structural highs, and the lack of sandstone in the Poole Sandstone suggests it may have good seal quality in this offshore facies (also observed in Kambara 1). Eight zones with hydrocarbon shows were encountered in Perindi 1 within the Poole Sandstone, Grant Group, and Laurel and Pillara formations. Oil staining, cut and fluorescence occurred within the limestone units of the Poole Sandstone. Minor oil shows were recorded in sandstones at the top of the Grant Group, and in three zones below the dolerite intrusive body. The well penetrated 6 m of Laurel Formation siltstones and tight sandstones with observed oil staining, cut and fluorescence, before passing into limestones and dolomites of the Pillara Formation. Bitumen and minor gas shows were apparent within these carbonates, which show decreasing porosity with depth.

Thermal alteration index and vitrinite reflectance studies suggest that the top of maturity is anomalously high (828 m) compared to nearby wells (1750 m in Tappers Inlet 1, 34.5 km to the east). This elevated maturity is believed to be the direct result of heating during the emplacement of the intrusive dolerite cone sheet that surrounds the Perindi structure, which is penetrated between 1379 and 1535 m in Perindi 1. Preliminary biomarker analyses have shown that the Perindi 1 oil stains (Geoscience Australia unpublished data) are most similar to the Canning Basin oils at Lloyd, Sundown and West Terrace, as well as the Barnett and Turtle oils in the Petrel Sub-basin, Bonaparte Basin (AGSO and GeoMark, 1996; Edwards et al, 1997). The Barnett and Turtle oils have been typed to the Early Carboniferous (early–middle Tournaisian) Langfield Group by Gorter et al (2004). Therefore, by analogy, these data imply that the most likely source of hydrocarbons below the intrusion is the Early Carboniferous Laurel Formation (Fairfield Group, and time equivalent to the Langfield Group) located off-structure, rather than the underlying Ordovician sediments. The lack of oil shows beneath seals in the Grant Group above the intrusion suggests that migration of oil was from directly beneath the structure and that the cone sheet acted as a barrier to vertical migration. The shows at the top of the Grant Group and within the Poole Sandstone also appear to be sourced from the Laurel Formation with migration potentially occurring around the intrusive body. The lack of a significant oil accumulation may indicate charge limitations or the presence of leaking faults on the crest of the structure. Potentially, migrating hydrocarbon could be trapped off-structure between the doleritic cone sheet and seal lithologies within the Grant Group.

Pearl 1 was drilled in 1983, 25 km west-northwest of Broome on the Jurgurra Terrace. It was the first wildcat to be drilled within this area. It was drilled on a modest anticlinal closure mapped at the pre-Grant unconformity and two deeper levels (both of which were determined to be intrusive units). The primary objective was the Tandalgoo Formation with the secondary objective sandstones of the Grant Group. It encountered a Mesozoic section similar to that onshore and in Lacepede 1A and Wamac 1 (although no Triassic). The Carboniferous section is very thick (>1 km) being mostly lower Grant Group with porous sandstones between siltstone/shale sealing units offering good reservoir potential. Pearl 1 was plugged and abandoned after encountering no hydrocarbons. Log interpretation indicates the entire section to be water saturated. No formation testing or coring was conducted. Dolerite was encountered at 2144 m and after penetrating 59 m of such drilling was terminated. The primary objective (Tandalgoo Formation) was not reached. The operator concludes that dolerite intrusives occur in succession in the Early Carboniferous. Country rock is indurated and overmature for hydrocarbon generation. Early Carboniferous shales; above the intrusives are indicated to be good oil and gas source rocks and are mature for hydrocarbon generation. Porous sandstones of the Grant Group between siltstone/shale sealing units offer good reservoir potential.

Minjin 1 was drilled in 1984, 130 km north of Broome on the Pender Terrace. The well was programmed to 1940 m in a closed domal structure of early Permian age which was believed to have been formed by the emplacement of igneous intrusions. The primary objective was sandstones within the Permo- Carboniferous Grant Group and the secondary objective was the Devonian Pillara Formation limestones, which contained excellent porosities in Perindi 1. The well penetrated a Cretaceous to Devonian section and an 85 m thick doleritic intrusion was intersected within the Grant Group. The overall succession was similar to Perindi 1 although the Carboniferous was entirely absent. Porous and permeable sandstones were encountered throughout the Jurassic and Cretaceous sequences and within the Grant Group. The Pillara Formation contained no intragranular, vuggy or fracture porosity and is considered tight. The well terminated at 1850 m after drilling through 301 m of these tight limestones. There were no hydrocarbon shows encountered during drilling mainly due to lack of source beds. From vitrinite reflectance readings it is surmised that increased maturity levels are probably a result of the igneous intrusion superheating the formation fluids contained in the sediment during its emplacement.

There has been very little exploration in the Offshore Canning Basin since the mid-1980s, with no permits awarded since that time. Regional spec seismic was acquired across the basin in 1988, and this grid later was tied to the wider North West Shelf regional grid by an AGSO (now Geoscience Australia) seismic survey.

More recent exploration has been undertaken to the west in the Rowley Sub-basin, with the drilling of two unsuccessful deep-water wells; Whitetail 1 (Woodside, 2003) and Huntsman 1 (Woodside, 2006).

Geoscience Australia conducted a hydrocarbon seepage survey of the Offshore Canning Basin and Rowley Sub-basin in June 2006 (Survey SS06/06). Active fluid escape pockmarks and fluid vents were identified on side-scan sonar and seabed video footage near the junction of the Oobagooma Sub-basin and Broome Platform (within Area W07-14), but petrographic and geochemical analysis of sediments recovered from the pockmarks suggest that the fluids are of normal marine composition and show no evidence of thermogenic hydrocarbons (Kennard, 2007). Preliminary results of this seepage survey are available at http://www.marine.csiro.au/nationalfacility/voyagedocs/2006/index.htm

Relevant wells Listing – W07-12 to W07-15, Canning Basin

Well	Operator	Year	Total Depth (m)	Hydrocarbons
Barlee 1	WAPET	1960	2469	No shows
Bedout 1	B.O.C. of Australia Ltd	1971	3073	
Cow Bore 1	Aust Gulf Oil Co	1983	2940	Oil & gas indications
Crab Creek 1	Bridge Oil Ltd	1987	1778	Oil indication
Curringa 1	Esso Explor and Prod Aust Ltd	1982	2335	
East Crab Creek 1	Aust Gulf Oil Co	1984	2813	
East Mermaid 1	Shell Development (Australia) Pty Ltd	1973	4067.6	
Freney 1	Ampol Explor Ltd	1988	1115	
Kambara 1	Esso Exploration and Production Australia Inc	1982	3150	No shows
Lacepede 1	B.O.C. of Australia Limited	1970	224	
Lacepede 1A	B.O.C. of Australia Limited	1970	2286	No shows
Lagrange 1	BP Petroleum Development Australia Pty Ltd	1983	3260	No shows
Minjin 1	Esso Exploration and Production Australia Inc.	1984	1850	Gas indications
Moogana 1	Esso Australia Limited	1980	2213	Oil indication
Pearl 1 (Home Energy)	Home Energy Company Ltd.	1983	2203	Gas indications
Pender 1	WAPET	1972	912	
Perindi 1	Esso Exploration and Production Australia Inc.	1983	1867	Oil recovered, gas indication
Tappers Inlet 1	WAPET	1971	2856	Oil indication
Wamac 1	Amax Petroleum (Australia) Inc.	1973	2764	No shows
Yulleroo 1	Gewerkschaft Elwerath	1967	4572	Proven gas zone, oil indications

PETROLEUM POTENTIAL

The petroleum potential of the Offshore Canning and Roebuck basins is currently considered to be poor compared to other North West Shelf basins, primarily due to the perceived absence of a prolific source rock (Smith et al, 1999). Interpreted mild structural deformation in the Late Jurassic and Early Cretaceous suggests that restricted depocentres did not form and thus claystone source rocks typical of the adjacent Carnarvon and Bonaparte basins were not deposited in the Offshore Canning and Roebuck basins. However, seismic interpretation suggests that the proven onshore petroleum systems in Permian and pre-Permian sediments extend into the offshore area along the older Palaeozoic trends that underlie the Oobagooma Sub-basin and Broome Platform (Passmore, 1991). Reef plays similar to those on the onshore Broome Platform and northern flank of the Fitzroy Trough were probably deposited on the topographically higher offshore features, while more clastic sediments were deposited in the adjacent troughs. The organic-rich shales that are the source rocks for the onshore Ordovician and Carboniferous petroleum systems would have also been deposited in the now offshore part of the basin, and could be a source for shallower Palaeozoic and Mesozoic traps if they were preserved through pre-Permian erosion. Fluvial and deltaic clastics covered the present shelf by the mid-Jurassic, providing reservoir, source and seal (Passmore, 1991). Additionally, there is some potential for generation in the Mesozoic Rowley depocentre, with migration into the shallow Offshore Canning Basin a possibility (Smith, 1999).

This section includes a brief overview of the Palaeozoic petroleum systems documented for the Onshore Canning Basin by Kennard et al (1994), before providing details on potential Mesozoic offshore systems from Smith (1999), although the classification of Bradshaw et al (1994) has been retained in that the Early Triassic petroleum system has been grouped in the Gondwanan Petroleum Supersystem.

Palaeozoic Petroleum Systems

Several Palaeozoic petroleum systems are known in the Onshore Canning Basin: Larapintine 2, 3 and 4. The source rocks of the Gondwanan 1 and 2 petroleum systems range in age from latest Palaeozoic to earliest Mesozoic. The following section has been summarised from Kennard et al (1994) and Edwards et al (1997).

Larapintine 2

Source rocks in the Larapintine 2 Petroleum System comprise Ordovician organic-rich marine shales, with the oil-prone alga *Gloeocapsamorpha prisca*, occurring within the upper Goldwyer Formation (Llanvirn), with lesser abundances found throughout the lower Goldwyer and Nambeet formations, as well as locally in the lower Carribuddy Group (Foster et al, 1986). An additional potential source rock is the calcareous shales and siltstones of the Willara Formation. The Nambeet and lower Goldwyer source units matured prior to the Late Devonian, and probably generated large amounts of oil during the Ordovician–Silurian. The upper Goldwyer source unit is immature across much of the Broome Platform, but where it has been down-faulted, maturation commenced after Devonian deposition, and this source rock retains both some free expelled hydrocarbons and some limited potential to generate more hydrocarbons on further maturation. Most of the significant shows occur within Nita Formation carbonates where the best porosity/permeability occurs within dolomitised, supra-and inter-tidal parasequences. Other potential reservoirs are within Willara carbonates, Goldwyer carbonates and submarine fans, aeolian sandstones of the Tandalgoo and Worral formations. Where the Grant Group overlies and truncates the Ordovician–Silurian succession, it is feasible that reservoirs could be charged with hydrocarbons from the Larapintine 2 Petroleum System. The critical factors for commercial accumulations appear to be the maturation/migration history relative to timing of trap formation, and reservoir quality, particularly the controls on porosity development and distribution within carbonates of the Nita Formation.

Larapintine 3

The Larapintine 3 Petroleum System encompasses the classic Devonian reef play. The primary sources are basinal and intra-shelf algal marine shales of the Frasnian Pillara Reef complex. Where deeply buried, peak generation of the Pillara succession probably occurred during the Carboniferous and ceased prior to the Mesozoic. Along the Fitzroy Trough margins peak maturity was attained from Carboniferous to Mesozoic time, and over the shallow portion of the shelves peak generation was attained from Mesozoic to present. Production from this petroleum system occurs at the Blina oil field, where oil flows from transgressive peritidal carbonates of the Famennian Nullara reef complex and highstand carbonates of the latest Famennian ramp succession. Lowstand basin-floor and slope fans, outboard of the Frasnian–Famennian platform margin, generally occur adjacent to transfer zones that formed focal points for lowstand drainage channels. These plays could be more prospective than the carbonate reef complexes, as they are positioned to receive hydrocarbons from basinal shales. The critical factor for commercial accumulation appears to be reservoir quality of both the reefal carbonates and the lowstand fans.

Larapintine 4

Source rocks in the Larapintine 4 Petroleum System comprise organic-rich marine shales in the Early Carboniferous Laurel Formation. In the deeply buried Fitzroy Trough, the Laurel Formation source attained peak oil maturity from the Late Carboniferous to Mesozoic. In shallower portions, peak oil maturity was attained from the Mesozoic to present, and on the flanking shelves the Laurel Formation is immature to marginally mature and has less source potential. Oil production occurs at Lloyd 1 and West Kora 1, and gas was discovered at Point Torment 1 from sandstones of the Anderson Formation. Anderson Formation sandstones are the main exploration targets, but they are difficult to locate without detailed facies information. The relative timing of generation and structuring during the Fitzroy Movement is crucial in determining whether the large anticlines produced by this tectonism can be charged from the Laurel Formation.

Gondwanan 1

The major potential sources of the Gondwanan 1 Petroleum System are Early Permian transgressive marine shales of the Poole Sandstone and Noonkanbah Formation; however, they are thermally immature except along the southern margin of the Fitzroy Trough. Marine shales of the upper Grant Group are locally organic-rich, but have poor generative potential. Reservoir facies are widespread through the lower and upper Grant Group but there are problems with inadequate seals and water flushing. Other critical factors are suitable maturation histories and migration pathways from source units in underlying petroleum systems.

Gondwanan 2
The potential source rocks of the Gondwanan 2 Petroleum System are Early Triassic marine and deltaic shales of the Locker Shale equivalents and Keraudren Formation. These shales were first deposited during a phase of rapid thermal sag shortly after the Bedout Movement. The source rocks have average total organic carbon (TOC) values of 4 %, with values up to 6 %. The algal content of many Triassic samples in Keraudren 1 exceeds 40 %. Triassic samples are mature for oil generation in Phoenix 1 in the Bedout Sub-basin. While the Triassic sediments are in the early oil window and the system extends across the Oobagooma Sub-basin, the Triassic is poorly developed. Onlap plays have been identified in the Oobagooma Sub-basin through the Early and mid-Triassic.

Mesozoic Petroleum Systems
The following section has been modified from Smith (1999) and Smith et al (1999; **Figure 6**). The Westralian 1 Petroleum System as described in Smith's studies has been included as the Gondwanan 2 Petroleum System in this report. The Westralian 2 Petroleum System as described by Smith (1999) and Smith et al (1999) is documented as Westralian 1, and Smith's Westralian 3 has been divided into the Westralian 2 and 3 petroleum systems, herein.

Source
Source rocks were identified from the Mesozoic section of the Offshore Canning and Roebuck basins, and their distribution predicted using geochemical analysis, sequence stratigraphic correlation, seismic mapping and sedimentary modelling. The source rocks were sub-divided into four groups depending on their tectono-depositional setting.

Westralian 1
The potential source rocks of the Westralian 1 Petroleum System were deposited under fluvio-deltaic conditions during declining thermal sag in the Early–Middle Jurassic. Sapropelic and coal-rich material was deposited in lakes and restricted embayments that developed during period of rifting and subsequent rapid transgression. The source units have average TOC values from 4 % to 25 %. Algal-rich units have good to excellent oil generative potential, but these facies are thinly developed and highly variable. The Jurassic and earliest Cretaceous are predicted to lie in the oil window in the Rowley Sub-basin.

Westralian 2 and 3
The potential source rocks for the Late Jurassic Westralian 2 and Early Cretaceous Westralian 3 petroleum systems are sediments that prograded into gently sagging post-rift basins without major faulting. Average TOC contents of the source rocks are between 2 and 10 %, but maturity for oil generation only occurs beneath the Tertiary carbonate wedge in the Rowley Sub-basin, and reservoirs are scarce due to declining sediment input post-breakup.

Reservoirs
Early Permian clastic sediments form both reservoir and seal in several onshore fields and, where intersected in the offshore Fitzroy Trough, these sandstones are known to have good porosity.

Middle to Late Triassic fluvial sandstones of the Keraudren Formation are reasonable reservoirs, which have an interpreted 110 m of net gas pay in tight sands below 4322 m in Phoenix 1. These have not been intersected by wells in the Oobagooma Sub-basin, but seismic shows the Triassic pinching out over the sub-basin forming a potential stratigraphic trap similar to the postulated Hammerhead prospect in the Willara Sub-basin (Lipski, 1993).

Early to Middle Jurassic fluvio-deltaic sandstones of the Depuch Formation are an example of a shallower Mesozoic objective, but structuring associated with these reservoirs are mild and migration pathways from mature Triassic sources are probably limited away from basin margin faults.

Seals

A thick Early Cretaceous marine claystone (the Muderong Shale and equivalents) forms a regional seal over the North West Shelf; however, in this part of the basin the Early Cretaceous succession is relatively sandy as it grades from the Broome Sandstone to the predominately silty Mermaid Formation.

The thick Late Triassic to earliest Jurassic red-bed claystone of the Bedout Formation is expected to form a regional seal over the Late Triassic sandstones.

A Middle Triassic regional limestone marker (the Cossigny Member of the Keraudren Formation), which grades into claystone near the basin margins, acts as an intraformational seal between Middle Triassic sandstones, as with Phoenix 1 in the Bedout Sub-basin.

Traps

Structural movement associated with rifting and Miocene reactivation has resulted in limited trap formation in the Mesozoic section.

Stratigraphic pinchout traps are formed against the Oobagooma High and the basin margin.

Thermal Maturity

1D modelling of thermal maturity at Wamac (Smith, 1999) suggests the Early to Middle Jurassic section is early mature. The higher measured values in the well are likely related to dolerite intrusions. Based on the modelling, Carboniferous source rocks are presently within the oil window in much of the Oobagooma Sub-basin. Older (Ordovician and Devonian) rocks have not been sampled, but generated hydrocarbons are likely to have already migrated into Palaeozoic traps.

REFERENCES

AGSO and GeoMark, 1996—The Oils of Western Australia. Petroleum Geochemistry and Correlation. Australian Geological Survey Organisation and GeoMark Research, Inc., Proprietary report, Canberra and Houston, unpublished.

BLACK, H., 2006—Secret Canning Basin oil discoveries revealed. Oil and Gas Gazette, 2(68), 1–11, June 2006.

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.

DRUMMOND, B.J., SEXTON, M.J., BARTON, T.J. AND SHAW, R.D., 1991—The nature of faulting along the margins of the Fitzroy Trough, and implications for the tectonic development of the trough. Exploration Geophysics, 22, 111–116.

EDWARDS, D.S., SUMMONS, R.E., KENNARD, J.K., NICOLL, R.S., BRADSHAW, J., BRADSHAW, M., FOSTER, C.B., O'BRIEN, G.W. AND ZUMBERGE, J.E., 1997—Geochemical characteristics of Palaeozoic petroleum systems in northwestern Australia. The APEA Journal, 37(1), 351–379.

FOSTER, C.B., O'BRIEN, G.W. AND WATSON, S.T., 1986—Hydrocarbon source potential of the Goldwyer Formation, Barbwire Terrace, Canning Basin, Western Australia. The APEA Journal, 26(1), 142–155.

GORTER, J.D., MCKIRDY, D.M., JONES, P.J. AND PLAYFORD, G., 2004a—Reappraisal of the Early Carboniferous Milligans Formation source rocks system in the southern Bonaparte Basin, northwestern Australia. In: ELLIS, G.K., BAILLIE, P.W. and MUNSON, T.J. (editors), Timor Sea Petroleum Geoscience: Proceedings of the Timor Sea Symposium, Darwin, 19–20 June 2003. Northern Territory Geological Survey, Special Publication 1, 231–255.

HELBY, R. AND PARTRIDGE, A.D., 1982—Palynological Review Selected Stratigraphic Intervals in Lacepede-1A, Meda-1, Tappers Inlet-1 and Wamac-1. EAL report 1981/25.

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.

KENNARD, J.M., 2007—Central North West Shelf (Rowley) seepage survey. AusGeo News, 85, March 2007.
http://www.ga.gov.au/ausgeonews/download.jsp

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

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

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.

FIGURES

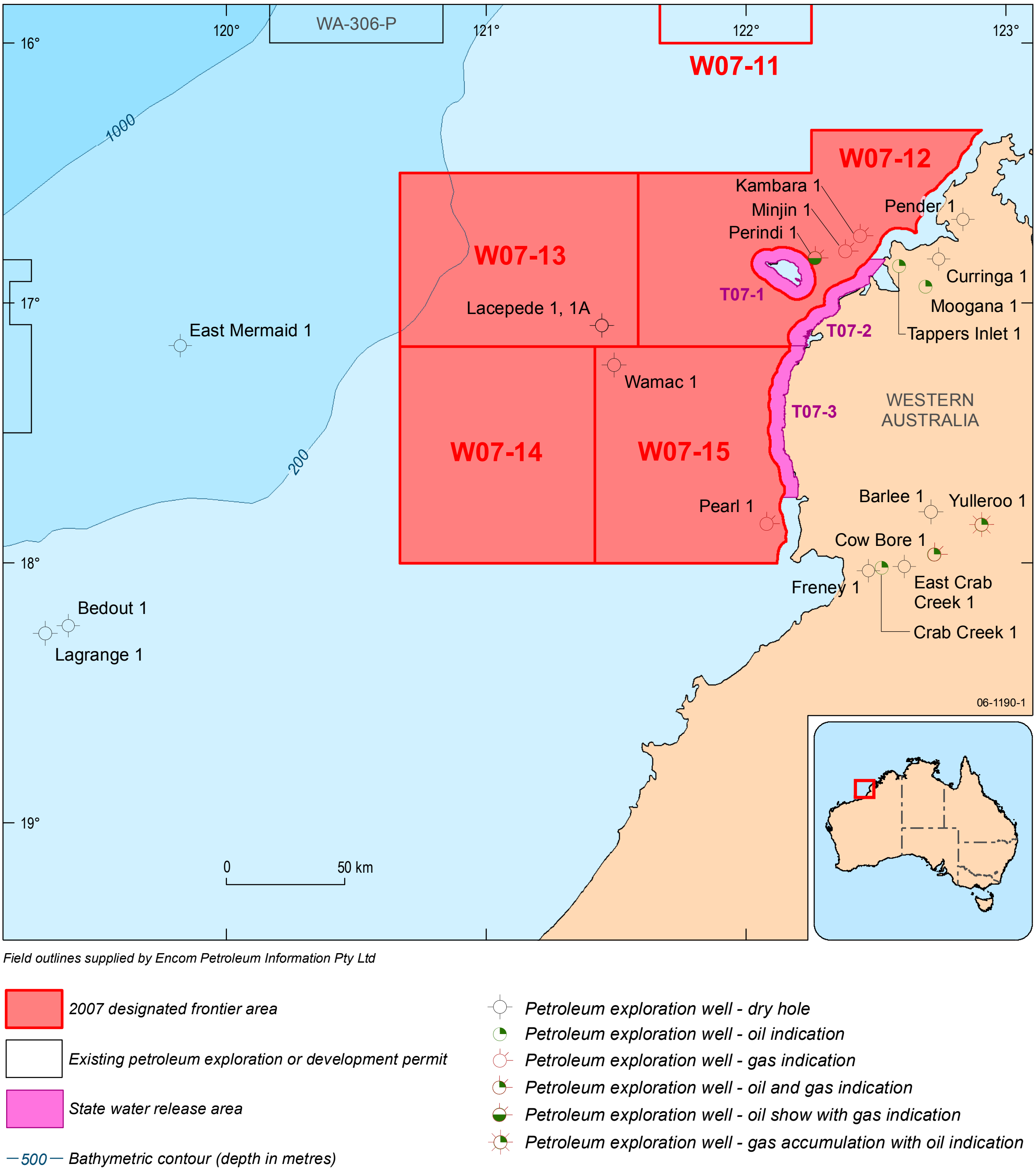


Figure 1. Location map of areas W07-12 to W07-15, Offshore Canning Basin.

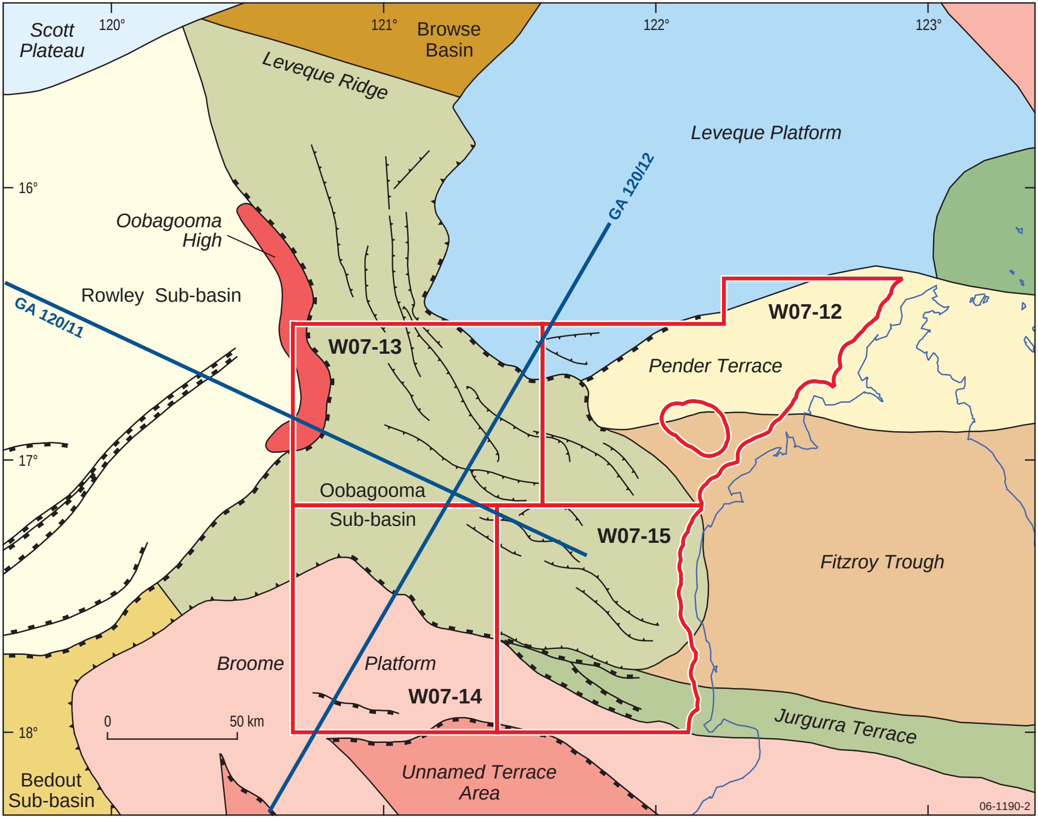


Figure 2. Structural framework of the Offshore Canning Basin (Smith et al, 1999)

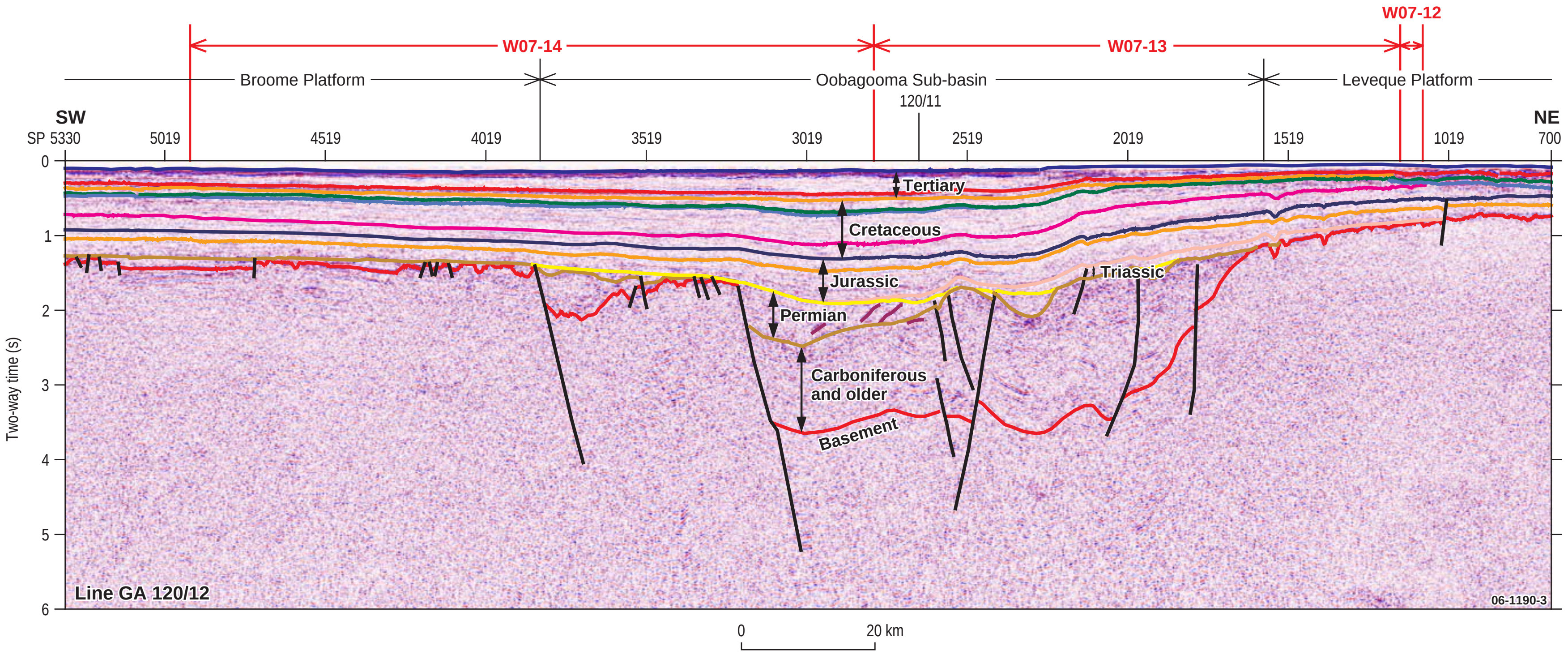


Figure 3. Seismic line GA 120/12 across the Oobagooma Sub-basin.

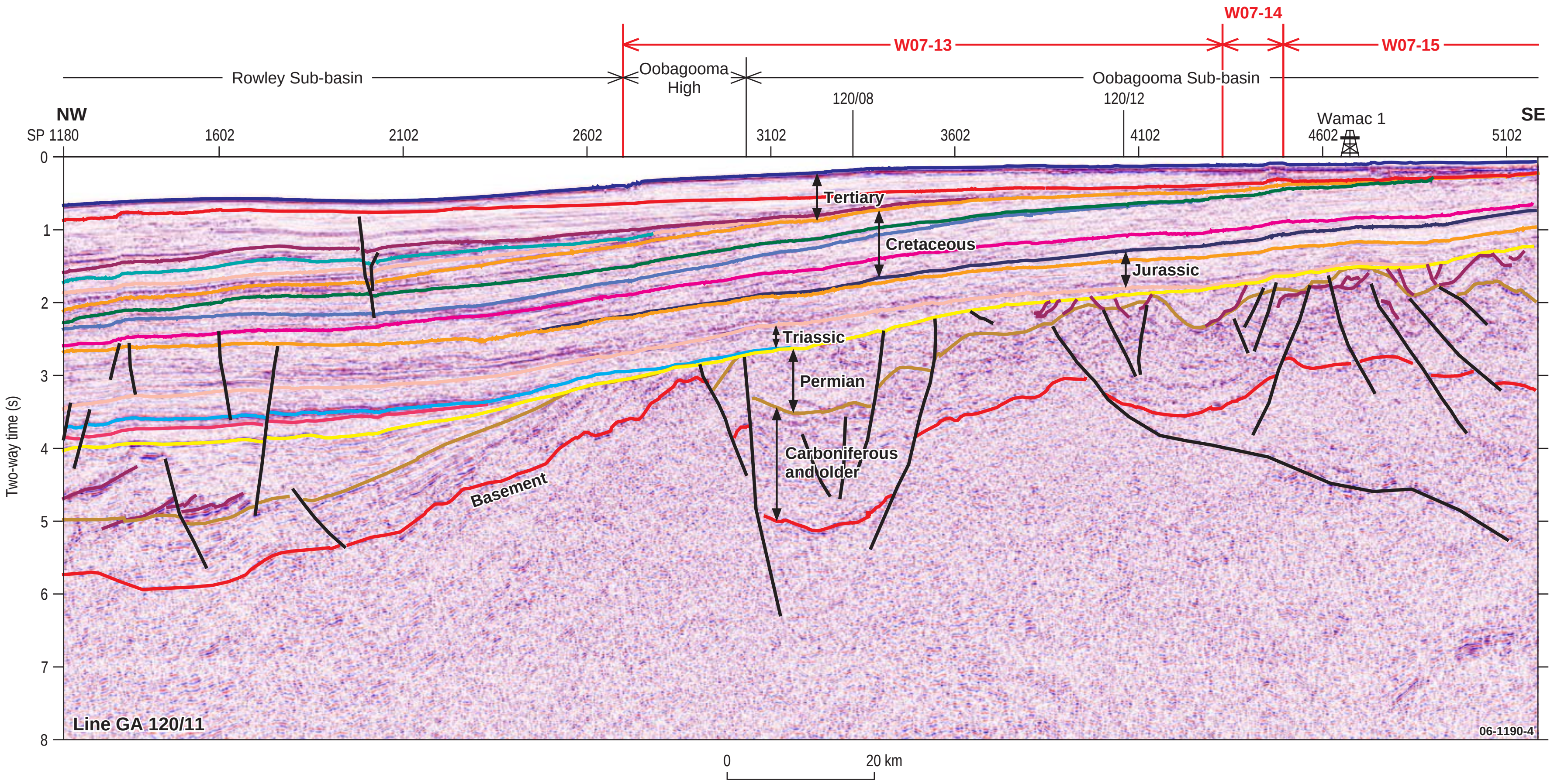


Figure 4. Seismic line GA 120/11 across the Oobagooma High and Oobagooma Sub-basin.

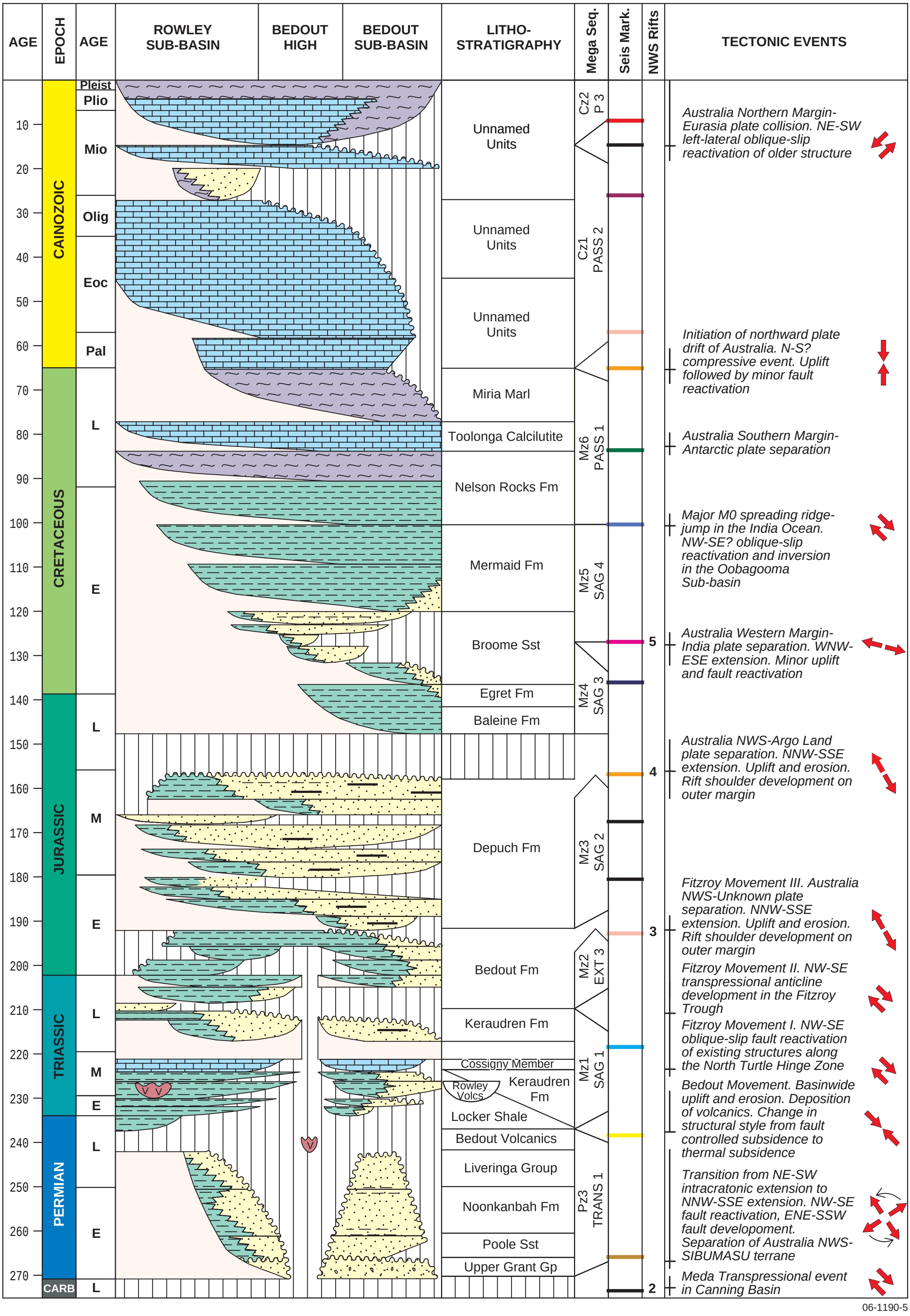


Figure 5. Stratigraphy of the Offshore Canning Basin (after Smith, 1999 and Smith et al, 1999). Coloured seismic markers correspond to horizons in Figures 3 and 4 (black markers are additional horizons defined by Smith, 1999 and Smith et al, 1999 that are not included in this report).

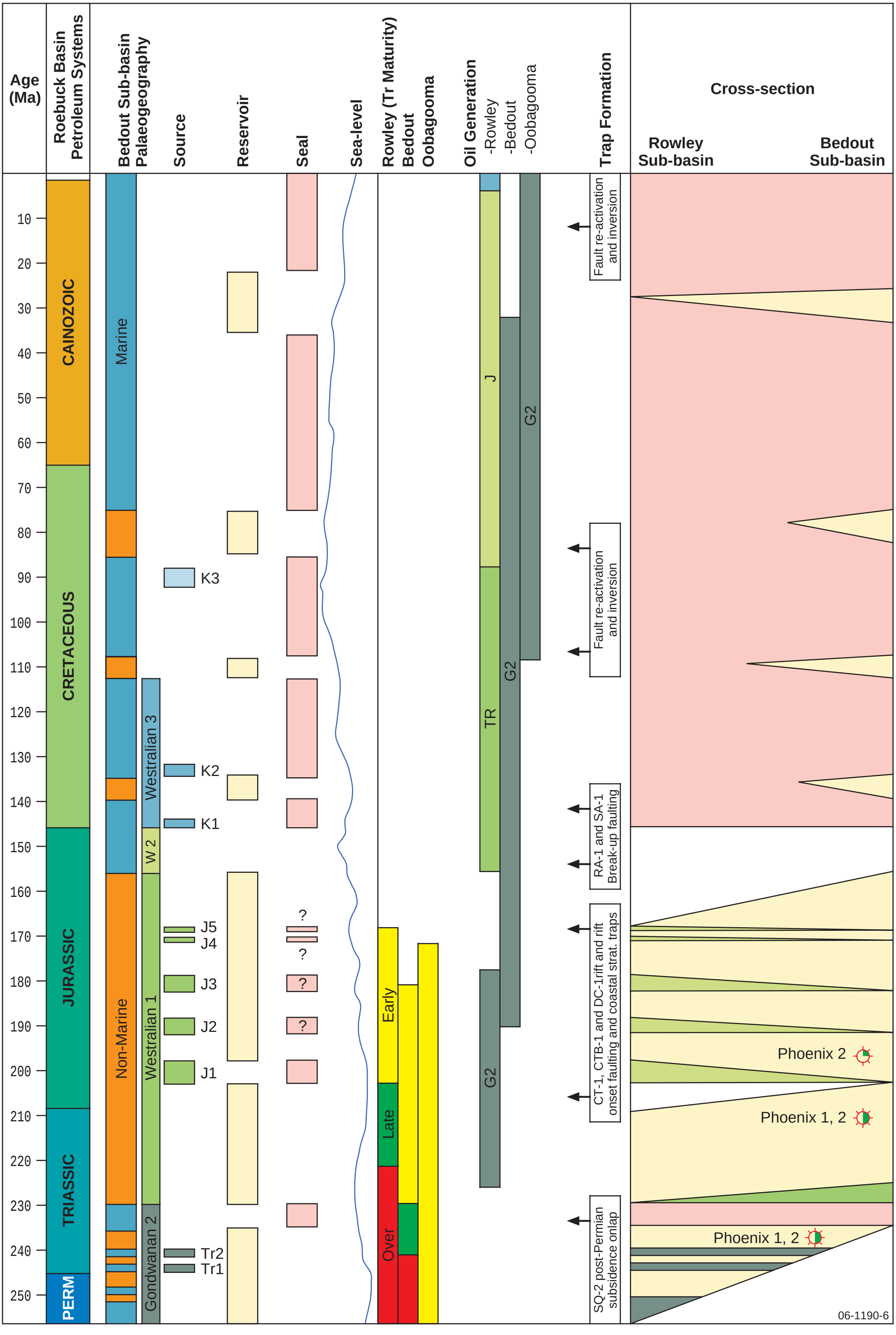


Figure 6. Petroleum systems of the Offshore Canning and Roebuck basins (after Smith, 1999 and Smith et al, 1999).