Government of **Western Australia**
Department of **Mines and Petroleum**

# GEOLOGY AND PETROLEUM PROSPECTIVITY OF STATE ACREAGE RELEASE AREAS L12-3, L12-4 AND L12-5, OFFICER BASIN, WESTERN AUSTRALIA

**by**
**PW Haines**

**Perth 2012**

**Geological Survey of Western Australia**

**REFERENCE**
**The recommended reference for this publication is:**
Haines, PW 2012, Geology and petroleum prospectivity of State Acreage Release Areas L12-3, L12-4 and L12-5, Officer Basin, Western Australia: Geological Survey of Western Australia, 8p.

**Published 2012 by Geological Survey of Western Australia**
**This publication is released in digital format (PDF) and as part of a digital dataset on CD.**

**Further details of geological products and maps produced by the Geological Survey of Western Australia are available from:**

Information Centre
Department of Mines and Petroleum
100 Plain Street
EAST PERTH WESTERN AUSTRALIA 6004
Telephone: +61 8 9222 3459 Facsimile: +61 8 9222 3444
**www.dmp.wa.gov.au/GSWApublications**

# Contents



## Figures



## Table

# Geology and petroleum prospectivity of State Acreage Release Areas L12-3, L12-4 and L12-5, Officer Basin, Western Australia

by

PW Haines

## Introduction

State Acreage Release Areas L12-3 (18 306 km$^2$), L12-4 (22 476 km$^2$) and L12-5 (22 694 km$^2$) lie in the western Officer Basin in south-central Western Australia (Figs 1 and 2). The intracratonic Officer Basin is intermittently exposed over 1500 km from west-central South Australia, to the flank of the Pilbara Craton in central Western Australia (WA). It ranges in age from Neoproterozoic to late Paleozoic, although the portion in WA (about 310 000 km$^2$) is predominantly of Neoproterozoic age. The Officer Basin overlies older Precambrian rocks, including metamorphic and igneous provinces, and older sedimentary basins of unknown petroleum potential. It is also extensively covered by relatively thin, younger Phanerozoic deposits that are not considered to have hydrocarbon prospectivity due to insufficient burial. The area is relatively flat, arid, and very sparsely populated. The most significant site of habitation in the area is Warburton Aboriginal Community, which lies 32 km north of L12-5. The unsealed Great Central Road passes across the northern parts of L12-3 and L12-4. Side roads and tracks provide access to some other parts of the Release Areas in dry weather. Previous hydrocarbon exploration has mainly focused on the thicker and more deformed parts of the basin in the northeastern portion of the Release Areas, and further to the north (commonly referred to as the Yowalga area). Although no significant hydrocarbon discoveries have been made in the western Officer Basin, oil and gas shows have been reported from a number of wells. Importantly, the area remains significantly underexplored. Similar Neoproterozoic successions in Russia and Oman have commercial accumulations of oil and gas (Ghori et al., 2009).

## Regional geology and stratigraphy

The Western Australian Officer Basin is predominantly of Neoproterozoic age with a total sedimentary thickness of up to 8 km. Its depositional history shows marked similarities to similar-aged basins (Amadeus, Ngalia, Georgina) elsewhere in central Australia, leading to the concept of a Neoproterozoic Centralian Superbasin that was tectonically fragmented during the Petermann and Alice Springs Orogenies in the latest Neoproterozoic and mid to late Paleozoic (Walter et al., 1995). The current interpretation of the basin stratigraphy is summarized in Grey et al. (2005) and Haines et al. (2008).

The basin infill is a mixed carbonate, siliciclastic, and evaporitic succession, of shallow marine, glacial, and non-marine facies (Fig. 3). It has been subdivided into four supersequences common throughout the Centralian Superbasin. Supersequence 1 (collectively Buldya Group) includes basal sandy and coarser siliciclastics (Townsend Quartzite), overlain by a mixed siltstone, shale, carbonate, and evaporite succession (Lefroy, Browne, Hussar, Kanpa, and Steptoe Formations). The Browne Formation contains one or more salt intervals that are associated with extensive halotectonics in thicker parts of the basin (Simeonova and Iasky, 2005). Supersequence 2, including the older (Sturt) glacial succession, is probably absent in the Release Areas, and only locally preserved elsewhere in WA (Haines et al., 2008). Supersequence 3 is represented by the glacial Wahlgu Formation, inferred to be the local representative of the widespread Elatina Glaciation (Grey et al., 2005). Supersequence 4 includes the non-marine Lungkarta Formation deposited synchronously with the latest Neoproterozoic – early Cambrian Petermann and Paterson Orogenies. Post-Supersequence 4 rocks (collectively 'Gunbarrel Basin' in some publications; Figs 1 and 3) include the Cambrian basaltic Table Hill Volcanics, and overlying Lennis and Wanna Formations of uncertain Paleozoic age. Permian and younger strata are excluded from the Officer Basin. The basin succession will be most complete over the thicker, northern parts of the Release Areas, but is expected to be attenuated and incomplete in the south and west.

The main structural zones of the basin are defined by halotectonic style, with salt mobilisation occurring during several tectonic episodes, principally the mid-Neoproterozoic (correlated with the Areyonga Movement of the Amadeus Basin) and the latest Neoproterozoic to early Cambrian (Petermann/Paterson Orogeny) (Simeonova and Iasky, 2005). Four distinct structural zones (Figs 2 and 4) are present in the main part of the basin in WA: a Marginal Overthrust Zone along the northeastern margin of the basin adjacent to the basement Musgrave Province, an adjoining Salt-ruptured Zone, a central Thrusted Zone, and a thin Western Platform Zone

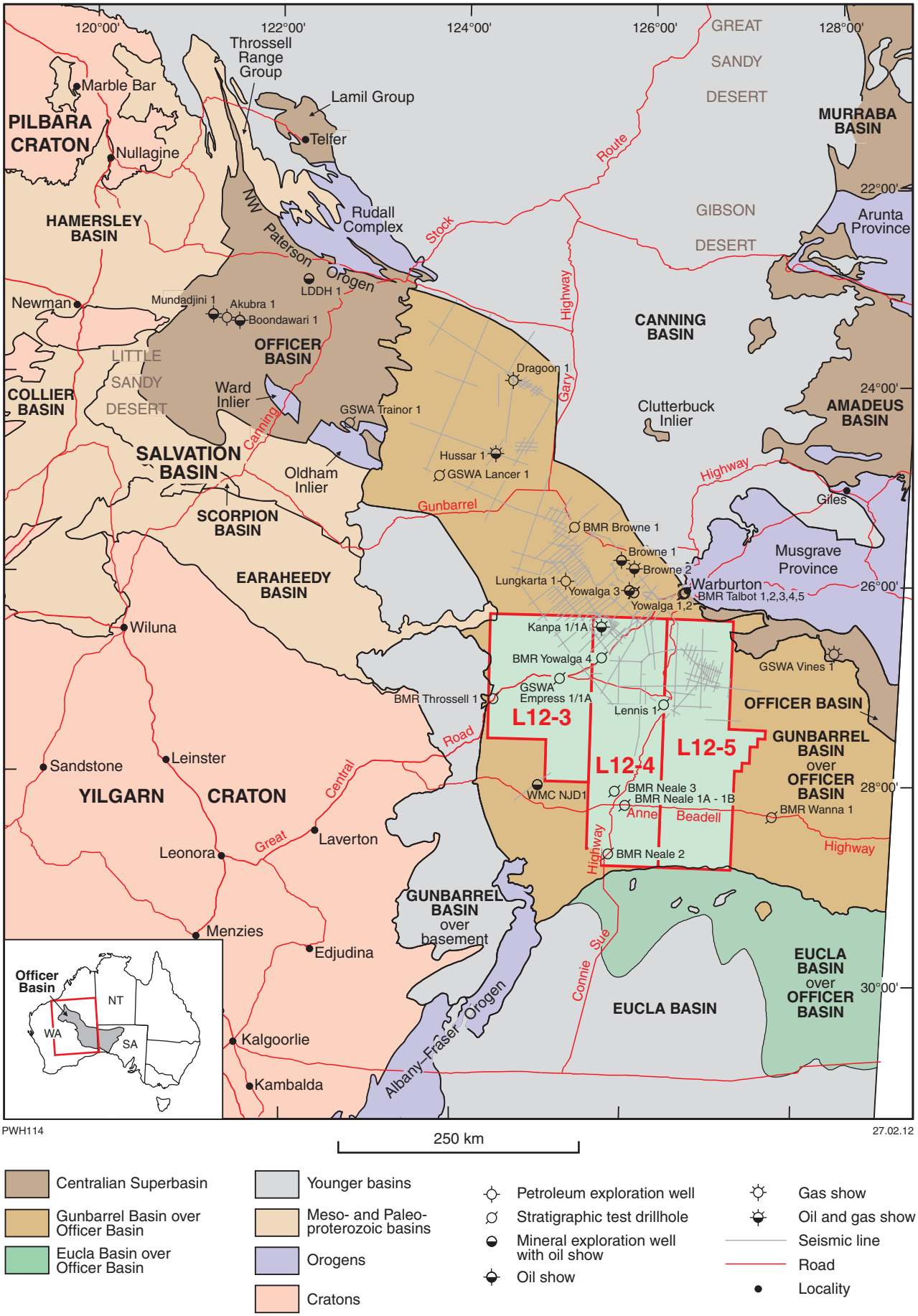


**Figure 1. Regional map of the western Officer Basin showing the location of State Acreage Release Areas L12-3 to L12-5**

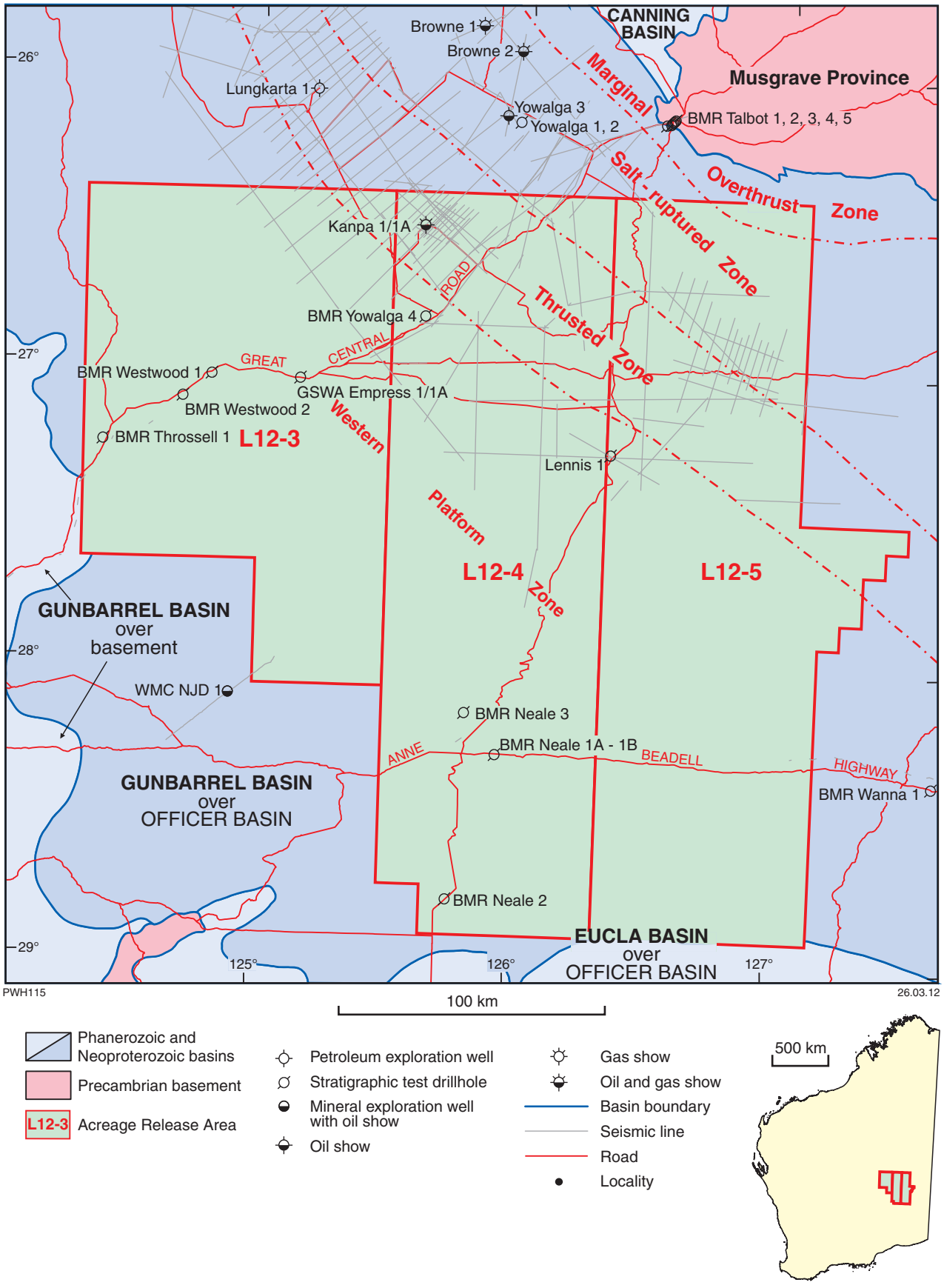


**Figure 2. Detailed map of the central part the western Officer Basin showing tectonic zones, petroleum exploration wells, seismic lines, and the location of State Acreage Release Areas L12-3 to L12-5. Boundaries of structural zones are approximate only; see Simeonova and Iasky (2005) for details**

(Simeonova and Iasky, 2005). A large part of the combined Release Areas lies over the Western Platform Zone, with the Thrusted Zone and Salt Ruptured Zone present in the northern parts of L12-4 and L12-5. A small area of the Marginal Overthrust Zone is present at the northern end of L12-5 (Fig. 2).

## Petroleum exploration history of State Acreage Release Areas L12-3, L12-4 and L12-5

The first petroleum exploration in the Release Areas involved limited seismic acquisition in the 1960s by Hunt Oil Company. This program culminated in the drilling of four stratigraphic wells, Browne 1 and 2, and Yowalga 1, to the north of L12-4, and Lennis 1 in L12-5 (Hunt Oil Company, 1965). Browne 1 and 2 encountered minor oil and gas shows in the Browne Formation. A second phase of exploration was undertaken by Shell Company of Australia, commencing in the early 1980s. Shell acquired a sparse seismic grid across the northern halves of L12-4 and L12-5, and the northeastern corner of L12-3. The program culminated in the drilling of three exploration wells, of which Kanpa 1/1A was within L12-4. This well encountered a minor oil show in the Steptoe Formation and located three potential source intervals in the Browne Formation (Shell Company of Australia, 1983). Japan National Oil Corporation held a Special Prospecting Authority (SPA) over a large area of the Officer Basin, including northern parts of the Release Areas, in 1995–96. The company aquired a high resolution aeromagnetic survey, reprocessed 50 key seismic lines (2165 line-km), and analysed existing drill cuttings for source rock potential and maturation history (Japan National Oil Corporation, 1997).

The area has also been studied by State and Federal Government agencies. The Bureau of Mineral Resources (BMR; now Geoscience Australia) drilled a number of shallow stratigraphic holes across the area in the early 1970s (Jackson and van der Graaff, 1981), and the Geological Survey of Western Australia (GSWA) drilled a deep stratigraphic hole, Empress 1/1A in L12-3 in 1997 (Stevens and Apak, 1999). This hole provides a complete cored stratigraphic section through the basin succession, terminating in a late Mesoproterozoic basin beneath. A deep crustal seismic line, sponsored in part by Geoscience Australia and GSWA, was shot along the Great Central Road in 2011. A preliminary interpretation of this line, which crosses L12-3 and L12-4, is due for release at the 2012 APPEA Conference.

There has also been sparse mineral exploration through the area, which provides some additional data of relevance to hydrocarbon prospectivity. Of greatest significance is WMC NJD 1, drilled about 9 km southwest of L12-3 in 1981 (Hocking et al., 2002). Although the Neoproterozoic succession is thin and shallow at this location, the core displayed oil staining and excellent source rock potential was identified in a thin interval of shaly siltstone near the base of the Neoproterozoic succession (probably in the lowermost Kanpa Formation).

## Summary of petroleum prospectivity in State Acreage Release Areas L12-3, L12-4 and L12-5

The petroleum prospectivity of the western Officer Basin has previously been discussed by Perincek (1998), Ghori (1998, 2002, 2007), Carlsen et al. (1999, 2003), Apak and Moors (2000), Apak et al. (2002), D' Ercole et al. (2005), and Simeonova and Iasky (2005). Based on these studies, the prospectivity of the Release Areas is largely restricted to the early to middle Neoproterozoic Buldya Group, although it is also possible that hydrocarbons sourced in that group may migrate to traps higher in the stratigraphy. There is also the possibility that hydrocarbons could be sourced from underlying (probably Mesoproterozoic) basins, although the geology of such basins is very poorly known. Although hydrocarbon shows have been small, the Neoproterozoic of the western Officer Basin shows similarities to Neoproterozoic Basins overseas with commercial hydrocarbon accumulations, such as those in Oman and Russia (Ghori et al., 2009). As part of the former Centralian Superbasin, the succession is also very similar to the nearby Amadeus Basin, which has recorded more significant Neoproterozoic oil and gas occurrences, including the subeconomic Dingo gasfield.

Potential source rocks have been identified within the Browne, Kanpa, and Hussar Formations. If the richest of these, that identified in WMC NJD 1, thickens and extends into deeper and more mature locations within the Release Areas, it has potential to source significant volumes of hydrocarbons. Potential sandstone reservoirs with porosities greater than 20% and permeabilities ranging from hundreds of millidarcies to more than one darcy, are present at several levels, particularly in the Hussar Formation. Halite in the Browne Formation, intraformational shales at higher levels in the Buldya Group, and glacial diamictite overlying the Buldya Group offer potential seals. The presence of salt is particularly significant as halotectonic activity has resulted in wide range of possible trapping configurations (Fig. 4). Movement of salt during the Neoproterozoic produced two laterally persistent structural domains: the Salt-ruptured and Thrusted Zones which cross the northern part of the release areas. Japan National Oil Company (1997) mapped numerous structural leads within these zones, some of which extend into the far northern part of L12-4 (Fig. 5).

The widespread, though minor, hydrocarbon shows in wells across the western Officer Basin (including Kanpa 1/1A in L12-4) indicate that at least small volumes of hydrocarbons have been generated and have migrated through the system. Maturity modelling suggests that the most significant hydrocarbon traps formed before most of the potential source rocks entered the oil window, and much of the prospective section within the thicker parts of the western Officer Basin remains in the oil-maturation window today (Ghori, 1998, 2002). The northeastern third of the Release Areas (north and east of the Western Platform Zone) is likely to be more prospective due to somewhat thicker successions and more extensive halotectonic structuring; a region that also coincides with most of the existing seismic and other exploration data.

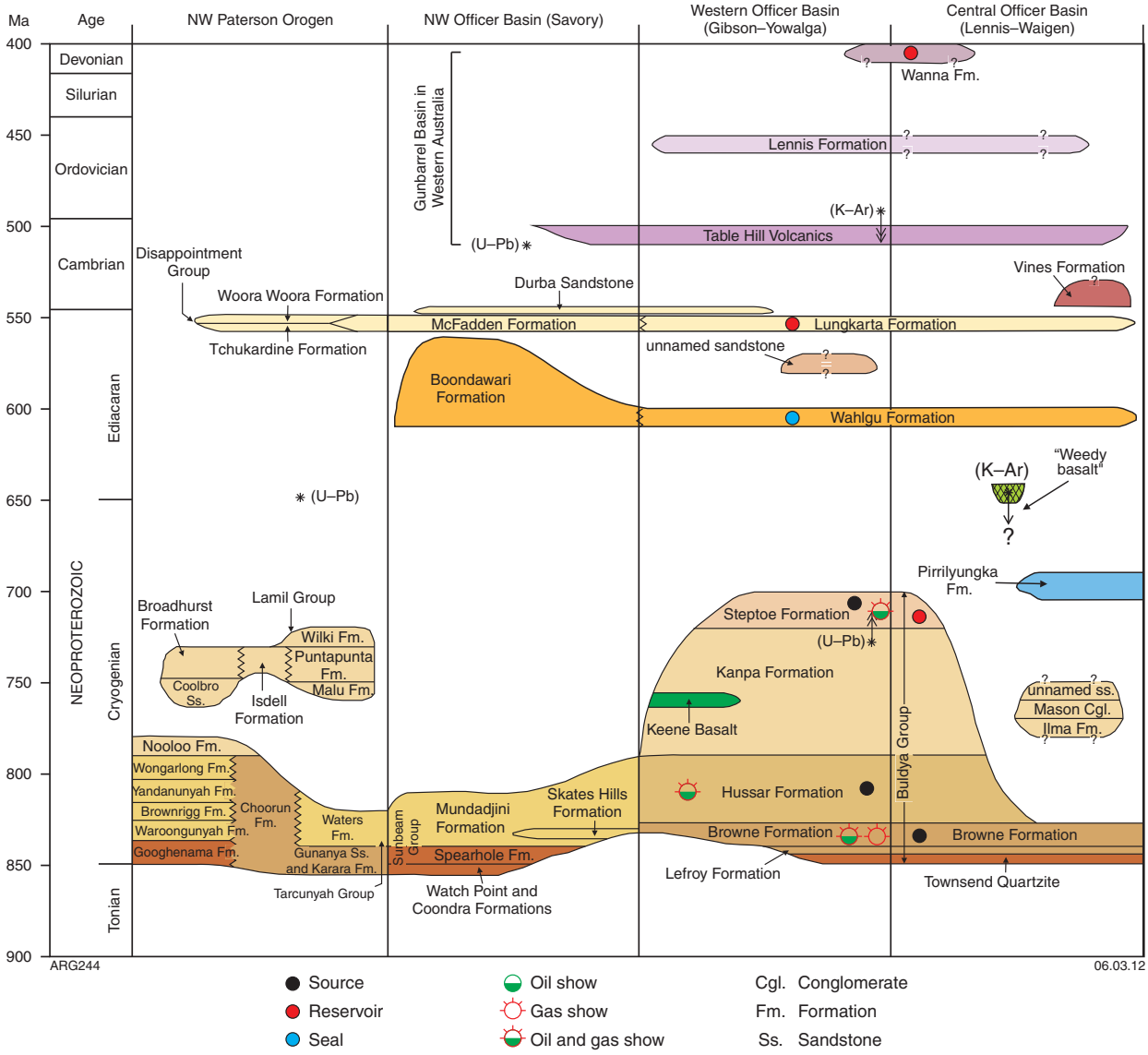


**Figure 3. Simplified stratigraphy and petroleum systems of the Officer Basin (modified after Grey et al., 2005 and Haines et al., 2008). The western and central Officer Basin columns are of most significance to the Release Areas.**

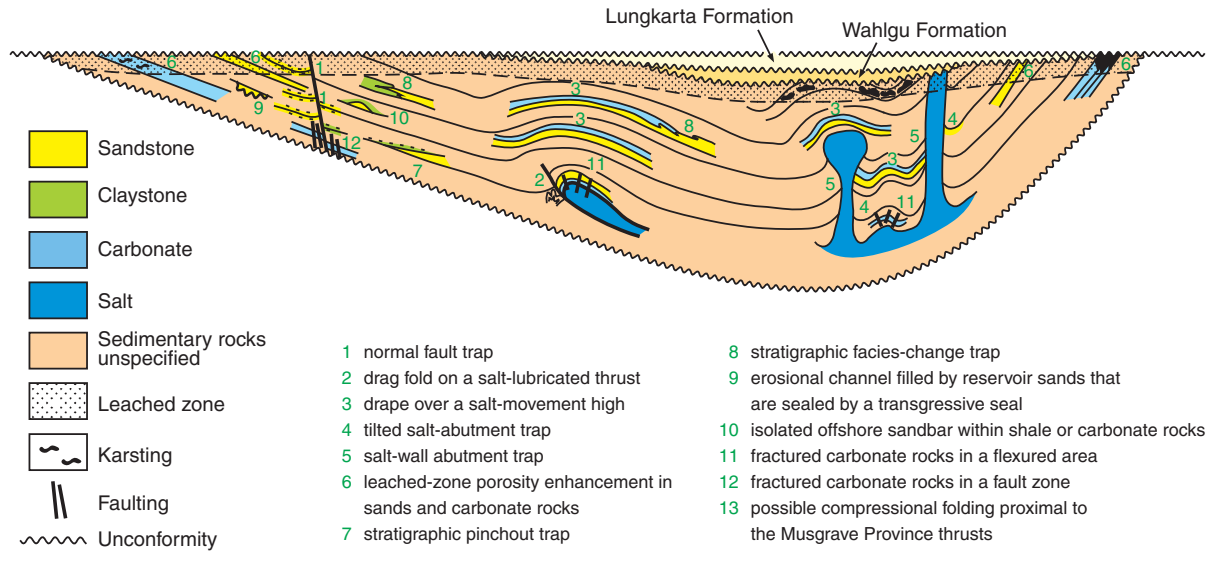


**Figure 4. Schematic cross section showing play types relevant to the Release Areas (after Apak et al., 2002). Play type 13 is off section**

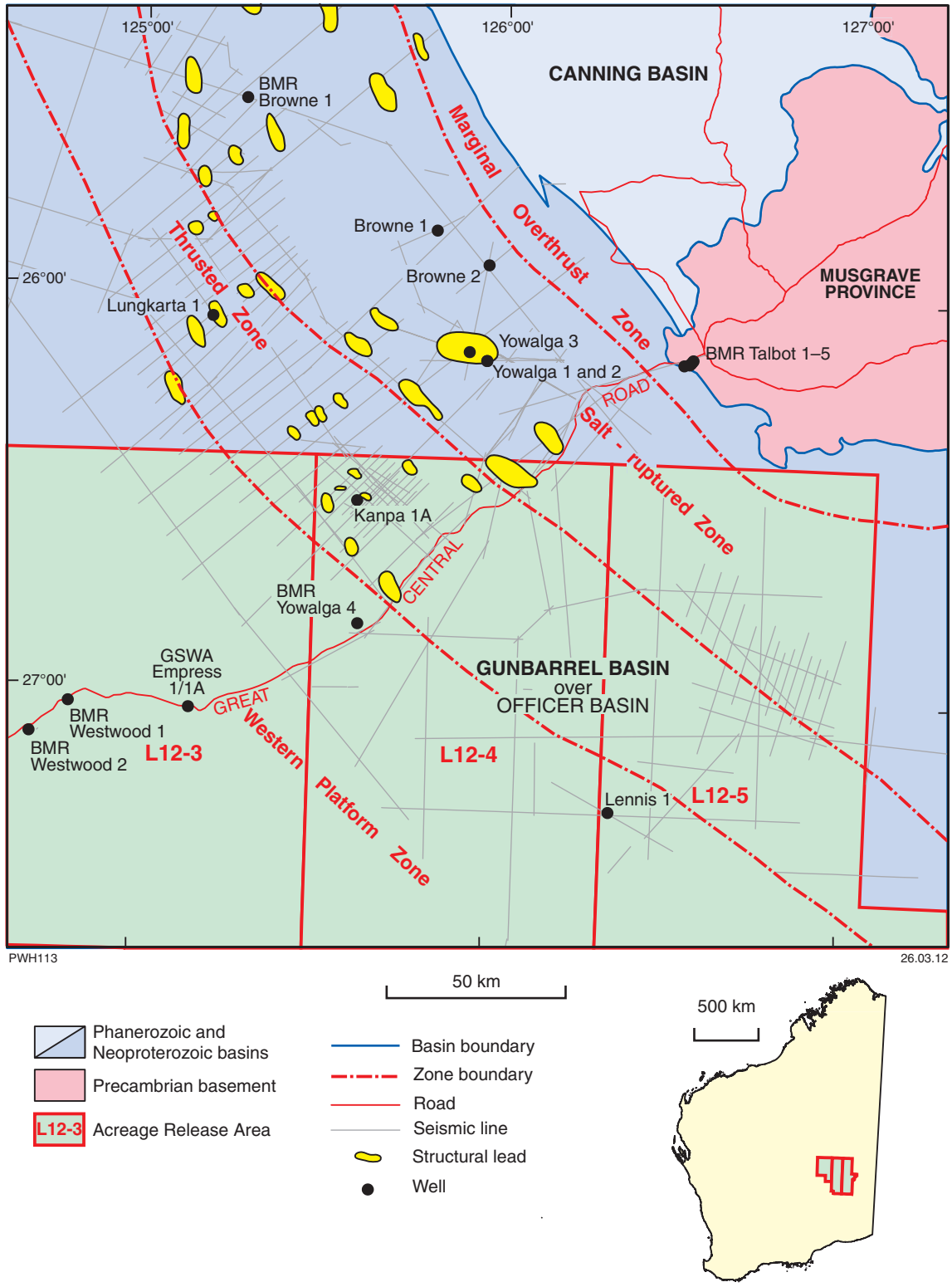


**Figure 5. Distribution of structural leads extending into the northern part of L12-4 (after Japan National Oil Company, 1997). Boundaries of structural zones are approximate only; see Simeonova and lasky (2005) for details**

**Table 1. Petroleum exploration and stratigraphic wells within, and select wells and mineral drill holes adjacent to State Acreage Release Areas L12-3, L12-4 and L12-5. Data extracted from Western Australian Petroleum and Geothermal Information Management System (WAPIMS) and well completion reports.**

| *Well Name* | *Latitude (S)* | *Longitude (E)* | *TD (m)* | *Age at TD* | *Class* | *Status* | *Operator* | *Year* | *Gas Shows* | *Oil Shows* |
|---|---|---|---|---|---|---|---|---|---|---|
| BMR Neale 1A-1B | -28.3036328 | 125.9447204 | 205.75 | Proterozoic | STR | P&A | BMR | 1972 | Nil | Nil |
| BMR Neale 2 | -28.7953389 | 125.7713934 | 74.8 | Permian | STR | P&A | BMR | 1972 | – | – |
| BMR Neale 3 | -28.1653 | 125.8213864 | 38.1 | Permian | STR | P&A | BMR | 1972 | Nil | Nil |
| BMR Throssell 1 | -27.2719746 | 124.4097187 | 198.12 | Cambrian | STR | P&A | BMR | 1972 | Nil | Nil |
| BMR Westwood 1 | -27.0436355 | 124.8197129 | 85.34 | Proterozoic | STR | P&A | BMR | 1972 | Nil | Nil |
| BMR Westwood 2 | -27.1208594 | 124.7113814 | 101.5 | Proterozoic | STR | P&A | BMR | 1972 | Nil | Nil |
| BMR Yowalga 4 | -26.8330262 | 125.6271722 | 42.97 | Permian | STR | P&A | BMR | 1972 | – | – |
| Browne 1 | -25.8500242 | 125.8160139 | 387 | Precambrian | STR | P&A | Hunt | 1965 | Poor | Poor |
| Browne 2 | -25.9319519 | 125.9638598 | 292.6 | Precambrian | STR | P&A | Hunt | 1965 | Poor | Poor |
| GSWA Empress 1/1A | -27.052325 | 125.1581306 | 1624.6 | Mesoproterozoic | STR | P&A | GSWA | 1997 | Nil | Nil |
| Kanpa 1/1A | -26.5268662 | 125.6157158 | 3803 | Proterozoic | NFW | P&A | Shell | 1982–3 | Nil | Poor |
| Lennis 1 | -27.2833 | 126.35 | 615 | Cambrian | STR | P&A | Hunt | 1965 | Nil | Nil |
| WMC NJD 1 | -28.118914 | 124.91622 | 517.37 | ?Mesoproterozoic | Mineral | P&A | WMC | 1981 | – | Fair |
| Yowalga 3 | -26.1494881 | 125.9169417 | 4196.5 | Proterozoic | NFW | P&A | Shell | 1980–1 | Poor | Poor |

NOTES:
TD Total depth from kelly bushing
NFW New field wildcat
STR Stratigraphic hole
P&A Plugged and abandoned
– No data
BMR Bureau of Mineral Resources
GSWA Geological Survey of Western Australia
Hunt Hunt Oil Company
Shell Shell Company of Australia, Ltd
WMC Western Mining Corporation

# Conclusions

State Acreage Release Areas L12-3, L12-4 and L12-5 lie in the remote and poorly unexplored western Officer Basin. Known prospectivity is largely restricted to the early to middle Neoproterozoic Buldya Group, which has at least local source potential and is associated with minor oil and gas shows in a number of wells and mineral exploration drill holes, including Kanpa 1/1A within L12-4. A cored mineral exploration drill hole, WMC NJD 1, sited just outside L12-3, displayed minor oil shows and an interval, probably in the lowermost Kanpa Formation, with excellent source potential. The Buldya Group contains a lower salt unit in the Browne Formation, responsible for extensive halotectonic structuring within the thicker sedimentary succession in the northeastern part of the combined Release Areas. Existing seismic data in this area is mostly sparse, but has been used to map a number of structural leads at the northern end of L12-4.

# References


Apak, SN, Ghori, KAR, Carlsen, GM and Stevens, MK 2002, Basin development with implications for petroleum trap styles of the Neoproterozoic Officer Basin, Western Australia, *in* The Sedimentary Basins of Western Australia 3 *edited by* M Keep and SJ Moss: Proceedings of Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 2002, p. 913–928.

Apak, SN and Moors, HT 2000, Basin development and petroleum exploration potential of the Yowalga area, Officer Basin, Western Australia: Geological Survey of Western Australia, Report 76, 61p.

Carlsen, GM, Apak, SN, Ghori, KAR, Grey, K and Stevens, MK 1999, Petroleum potential of the Neoproterozoic Western Officer Basin, Western Australia, based on a source-rock model from Empress-1A: APPEA Journal, v. 39, p. 322–341.

Carlsen, GM, Simeonova, AN and Apak, SN 2003, Petroleum systems and exploration potential in the Officer Basin, Western Australia: APPEA Journal, v. 43, p. 472–493.

D'Ercole, C, Irimies, F, Lockwood, AM and Hocking, RM 2005, Geology, geophysics, and hydrocarbon potential of the Waigen area, Officer Basin, Western Australia: Geological Survey of Western Australia, Report 100, 51p.

Ghori, KAR 1998, Petroleum source rock potential and thermal history of the Officer Basin, Western Australia: Geological Survey of Western Australia, Record 1998/3, 52p.

Ghori, KAR 2002, Modelling the hydrocarbon generative history of the Officer Basin, Western Australia: Petroleum Exploration Society of Australia Journal, v. 29, p. 29–43.

Ghori, KAR 2007, The Officer Basin in Western Australia, an example of an under-explored Infracambrian petroleum system, *in* April 2007 Petroleum in Western Australia *edited by* K Jonasson: Western Australia's Digest of Petroleum Exploration, Development and Production, Department of Industry and Resources, Perth, p. 42–45.

Ghori, KAR, Craig, J, Thusu, B, Lüning, S and Geiger, M 2009, Global Infracambrian petroleum systems: a review, *in* Global Neoproterozoic Petroleum Systems: The Emerging Potential in North Africa *edited by* J Craig, J Thurow, B Thusu, A Whitham and Y Abutarruma: Geological Society, London, Special Publications, v. 326, p.109–136.

Grey, K, Hocking, RM, Stevens, MK, Bagas, L, Carlsen, GM, Irimies, F, Pirajno, F, Haines, PW and Apak, SN 2005, Lithostratigraphic nomenclature of the Officer Basin and correlative parts of the Paterson Orogen, Western Australia: Geological Survey of Western Australia, Report 93, 89p.

Haines, PW, Hocking, RM, Grey K and Stevens, MK 2008, Vines 1 revisited: are older Neoproterozoic glacial deposits preserved in Western Australia?: Australian Journal of Earth Sciences, v. 55, p. 397–406.

Hocking, RM (compiler), 2002, Drillhole WMC NJD 1, western Officer Basin, Western Australia: Stratigraphy and petroleum geology: Geological Survey of Western Australia, Record 2002/18, 26p.

Hunt Oil Company 1965, Yowalga 1, Lennis 1, Browne 1 and 2: Geological Survey of Western Australia, Statutory petroleum exploration report, S234 (unpublished).

Jackson, MJ and van de Graaff, WJE 1981, Geology of the Officer Basin, Western Australia: Australia Bureau of Mineral Resources, Canberra, Bulletin 206, 102p.

Japan National Oil Company 1997, Geological and geophysical surveys in the western Officer Basin — integrated geological interpretation study: Geological Survey of Western Australia, Statutory petroleum exploration report, S10276 (unpublished).

Perincek, D 1998, A compilation and review of data pertaining to the hydrocarbon prospectivity of the Officer Basin: Geological Survey of Western Australia, Record 1997/6, 209p.

Shell Company of Australia, Ltd 1983, Kanpa-1/1A well completion report (Officer Basin, EP 178): Geological Survey of Western Australia, Statutory petroleum exploration report, S2281 A2 (unpublished).

Simeonova, AP and Iasky, RP 2005, Seismic mapping, salt deformation, and hydrocarbon potential of the central western Officer Basin, Western Australia: Geological Survey of Western Australia, Report 98, 51p.

Stevens, MK and Apak, SN (compilers) 1999, GSWA Empress 1 and 1A well completion report, Yowalga Sub-basin, Officer Basin, Western Australia: Geological Survey of Western Australia, Record 1999/4, 110p.

Walter, MR, Veevers, JJ, Calver, CR and Grey, K 1995, Neoproterozoic stratigraphy of the Centralian Superbasin, Australia: Precambrian Research, v. 73, p. 173–195.