

PS A New Look at the Petroleum Potential of the Caswell Sub-Basin, Browse Basin*

Jenny Greenhalgh¹, Dushyan Rajeswaran¹, and Tom Paten¹

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¹Reservoir, PGS Australia Pty Ltd, West Perth, WA, Australia (jennifer.greenhalgh@pgs.com)

Abstract

The Caswell Sub-basin is a major depocentre within the Browse Basin, situated offshore in the northern region of the Australian North West Shelf. The 2014 Lasseter-1 discovery in the basin has resulted in renewed interest. The 2013 acquisition of 9224 km² of MultiClient 3D GeoStreamer® dual-sensor deep-tow seismic over the Caswell Sub-basin has given new insights into this hydrocarbon province, and allows detailed inversion work in the primary reservoir fairway, and greater penetration and imaging of deeper sediments and structures that had been impossible to image. This presentation will discuss the benefits of using dual-sensor acquisition data in the Caswell Sub-basin with an examination in terms of potential local hydrocarbon prospectivity. The basin was initiated as an extensional half-graben intra-cratonic rift during the Paleozoic, and has undergone multiple episodes of extension, subsidence and inversion. The major hydrocarbon discoveries in the Caswell Sub-basin produce from reservoirs and generate from source intervals deposited during the second period of extension and subsidence (Early Jurassic- Early Cretaceous). The first gas discovery in the Browse Basin came in 1971 with the drilling of Scott Reef-1, encountering gas in a thick succession of fluvio-deltaic sediments of the Lower-Middle Jurassic Plover Formation. A number of prospects were later drilled along the Buffon-Scott Reef-Brecknock Anticlinal Trend, encountering significant amounts of gas and condensate. Discoveries continued during the 1980s, including Brewster-1A ST1, Caswell-2 ST2 and Echuca Shoals-1. Each well encountered gas in Lower Cretaceous (Berriasian) reservoirs, with the Caswell- 2 ST2 and Echuca Shoals-1 also encountering gas in Late Jurassic sediments. In addition, Caswell-2 ST2 encountered the first oil in the Caswell Sub-basin, in Upper Cretaceous sandstones. More recent discoveries, including the Crown and giant Ichthys gas fields, highlight potential in this area. This paper will focus on new discoveries e.g. Lasseter and Crown, a demonstration of the uplift and benefits of newly acquired data vs. legacy datasets and a comparison of depth vs. time imaging. In addition, the improved imaging of the Triassic interval in this area will be demonstrated, which with the oil discovery of the Phoenix South-1 in the offshore Canning Basin to the southwest, is being viewed as a major potential new play fairway previously bypassed due to imaging challenges.

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PGS Australia Pty Ltd

Introduction

The Caswell Sub-basin is a major depocentre within the Browse Basin, situated entirely offshore in the northern region of the Australian North West Shelf. The 2014 Lasseter-1 discovery in the basin has resulted in renewed interest.

The 2013 acquisition of 9 224 sq km of MultiClient 3D GeoStreamer® dual-sensor deep-tow seismic over the Caswell Sub-basin gives new insights into this hydrocarbon province, allowing detailed inversion work in the primary reservoir fairway, and greater penetration and imaging of deeper sediments and structures than previously possible. This poster will discuss the benefits of using dual-sensor acquisition data in the Caswell Sub-basin with an examination in terms of potential prospectivity.

Location

The Browse Basin is part of the larger Westralia Superbasin, underpinning much of the Australian North West Shelf region (Figure 1 (inset)). The basin is bounded to the southeast by the Australian craton, by the Bonaparte Basin (Vulcan Sub-basin) to the northeast and the Roebuck Basin (offshore Canning Basin) to the southwest. To the west and northwest is the deepwater Scott Plateau which lies outboard of the major Browse Basin depocentres.

Tectonic History

The Browse Basin and its component structures were formed as extensional half-grabens. This first phase of extensional block faulting began in the Paleozoic, leading to the formation of the main Caswell and Barcoo sub-basin depocentres. Structures and alignments formed during the early period of basin development control subsequent reactivation events and the locus of sedimentation (GeoScience Australia, 2014).

Extensional block faulting was followed by thermal subsidence) throughout the Late Permian- Middle Triassic. Sediments deposited during the Permian were sandstones grading into shales, and limestones. Triassic sediments were dominated by a regional Early Triassic marine transgression, leading to the deposition of fluvial and marginal to shallow-marine sandstones, limestones and shales.

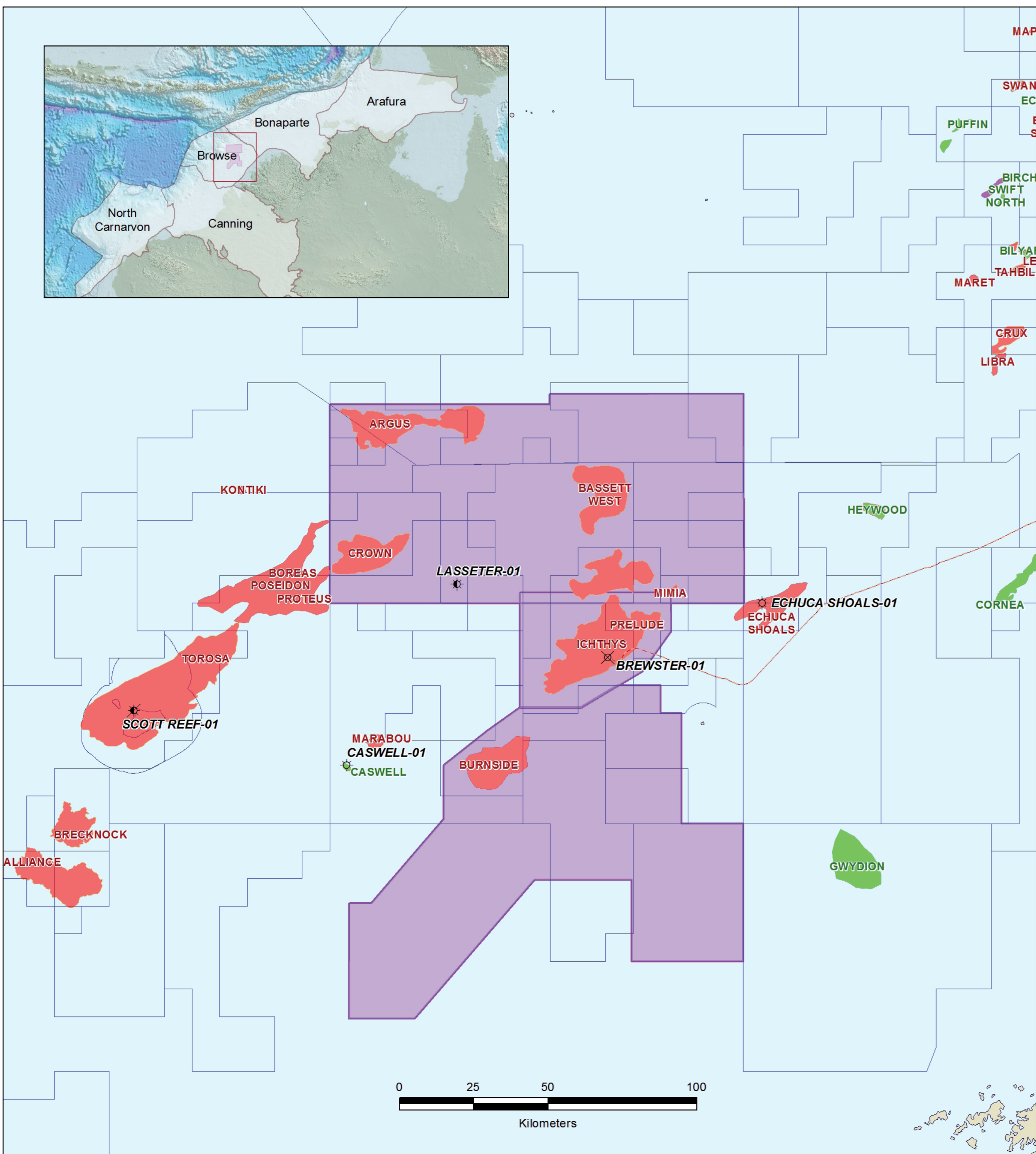


Figure 1: Location map showing position of Browse Basin, major fields and MC3D GeoStreamer surveys

Paleozoic faults were reactivated during the Late Trassic to Early Jurassic, as a major contractional event affected the region (Fitzroy Movement). This resulted in inversion of half-graben structures formed during the earlier extensional phase, and the formation of large anticlines and synclines. The Buffon-Scott Reef- Brecknock Anticlinal Trend was also formed at this time.

A second extensional phase occurred through the Early to Middle Jurassic, causing the collapse of the anticlinal structures. The formation of the Heywood Graben also occurred at about this time. Sedimentation was dominated by sandstones, mudstones and coals of deltaic and coastal plain origin (Plover Formation) and this sequence contains both source and reservoir rocks. The Browse Basin then underwent widespread erosion and peneplanation during the Middle Jurassic due to continental breakup and the initiation of sea-floor spreading in the Argo Abyssal Plain (Figure 2).

From the Late Jurassic onwards, the Browse Basin became a passive margin. Marine conditions were established and sediments containing potential source rocks intervals and regional seals, onlapped and draped the older structures. Sea level reached a maximum in the Turonian, and then a major regressive cycle followed during which the shelf-edge migrated to the northwest. Major erosion occurred on the shallow Yampi Shelf area, and turbidites were deposited within the Caswell Sub-basin. The deposition of carbonate sediments increased, though fluvial-deltaic to nearshore sediments were still deposited on the basin margins.

A second period of inversion began in the Miocene, as the northwestern margin of the Australian plate collided with the Eurasian plate. This collision led to the reactivation of older faults within the Browse Basin area. Carbonate deposition became dominant across the area.

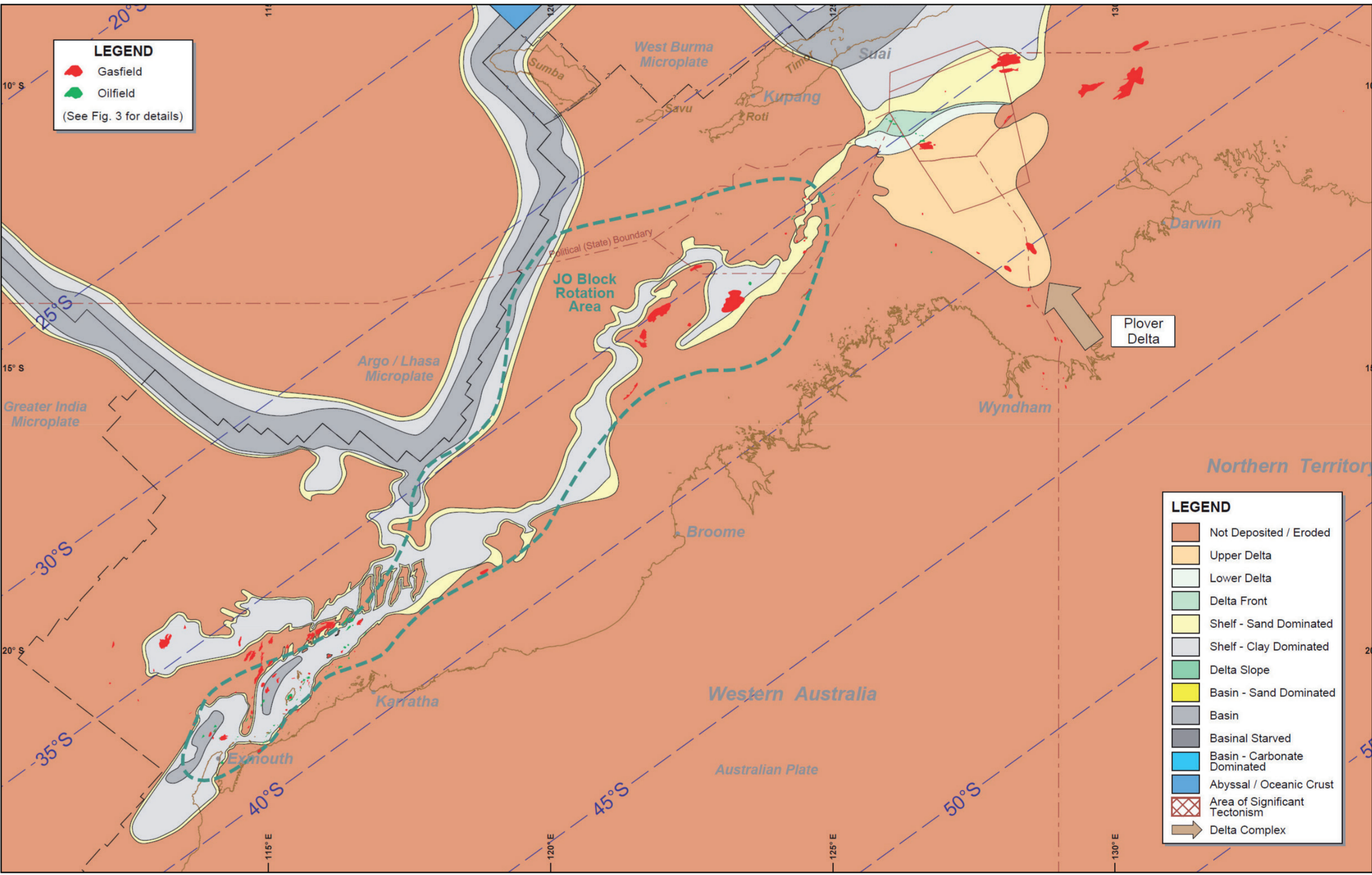


Figure 2: Simplified J30 sequence (Callovian) palaeogeographic map (Longley et al. 2002)

Exploration History

The first discovery of gas in the Browse Basin came in 1971 with the drilling of Scott Reef-1, encountering gas in the Lower-Middle Jurassic Plover Formation. A number of associated prospects were later drilled along the Buffon-Scott Reef-Brecknock Anticlinal Trend, encountering further hydrocarbons. Discoveries continued to be made, encountering gas in Lower Cretaceous (Berriasian) sandstone reservoirs and in Late Jurassic sediments. More recent discoveries in the Caswell Sub-basin, including the Crown and giant Ichthys gas fields, highlight the potential in this area.

The first discovery of oil in the Browse Basin was in 1978, when the Caswell-2 well encountered oil in Upper Cretaceous sandstones. Further oil discoveries were made in Cretaceous sandstones at the Gwydion-1 well, on the Yampi Shelf, in 1995. This discovery proved that there had been oil charge and migration through the area. Figure 3 shows the distribution of hydrocarbon populations in the basin.

The most recent discovery in the Browse Basin is the Lasseter-1, drilled in 2014, a significant gas-condensate discovery. The Lower Vulcan reservoir system, which is developed between the major Ichthys and Poseidon structural trends, holds great promise as it suggests much more remaining potential away from the previously recognized fairways.

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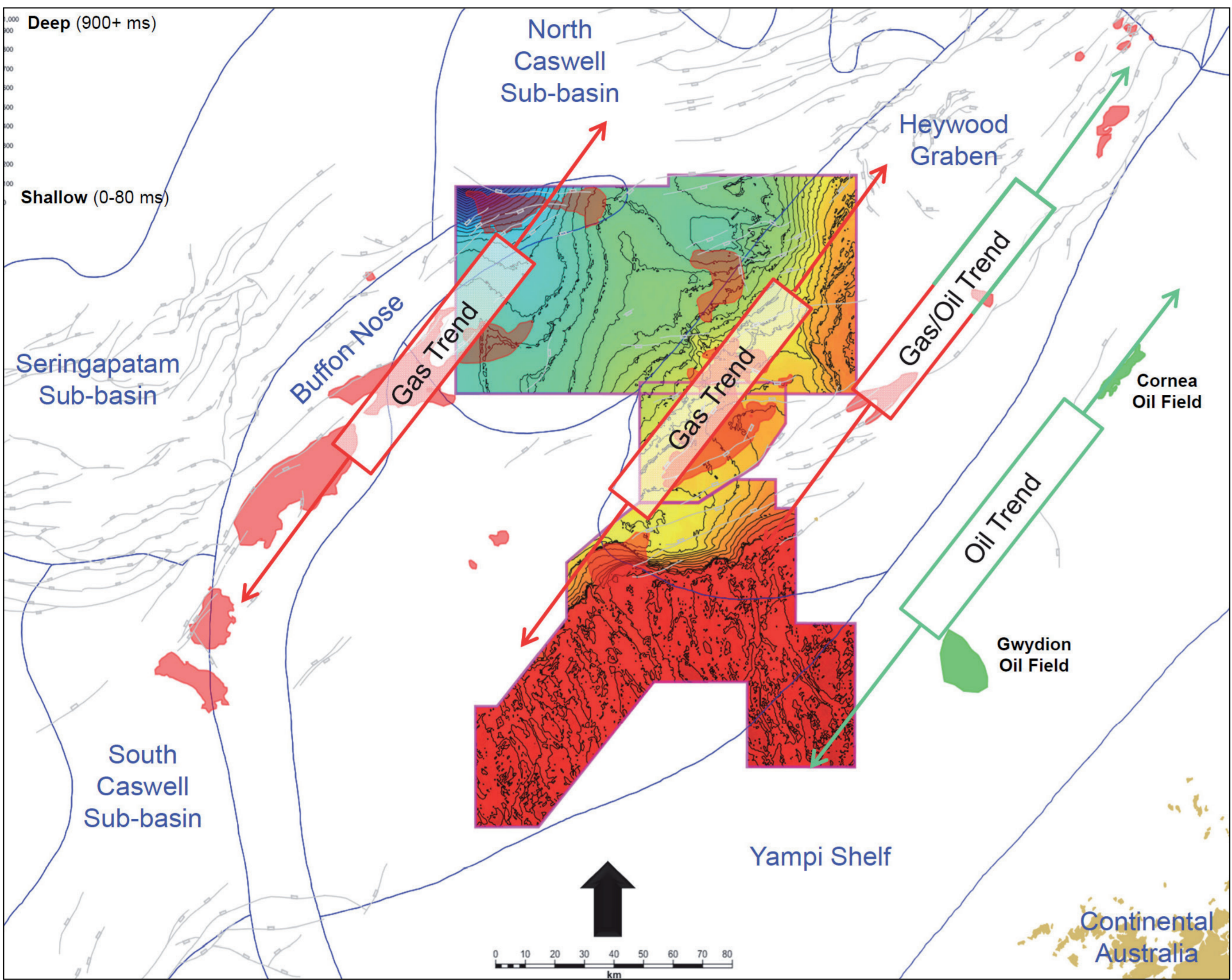


Figure 3: Hydrocarbon distribution in the Browse Basin

Petroleum Systems

SOURCE

The majority of hydrocarbons in the Browse Basin, if not all, are sourced from the Lower –Middle Jurassic Plover Formation, the Upper Jurassic Vulcan Formation, and the Lower Cretaceous Echuca Shoals and Jamieson formations.

The Plover Formation hydrocarbon potential comes from thin beds of coals and pro-delta shales. The sediments are distributed across the Browse Basin and are predominantly gas-prone. The marine Vulcan Formation is also widely distributed across the Browse Basin, it is usually a thin unit, only thickening locally in the Heywood Graben area and parts of the shelf.

Restricted conditions in the Heywood Graben suggest that this area has the best-developed source rock potential for oil. The Echuca Shoals and Jamieson formations are distributed across the Caswell and Barcoo sub-basins and contain both marine and terrestrially-derived plant material. The more distal sediments have a higher potential for oil.

RESERVOIR

Exploration focus has focused on the Caswell Sub-basin. The major reservoir targets lie underneath the main regional seal of the Jamieson Formation.

The most laterally extensive reservoir unit is the Plover Formation. The reservoir sandstones were deposited in a delta plain, initially fluvial-dominated, but becoming more tidally influenced up-section. Distribution of this unit is strongly controlled by the anticlinal structural trends formed during the Fitzroy Movement. Plover Formation sandstones are the producing reservoir in the Torosa, Brecknock and Calliance fields of the Buffon-Scott Reef- Brecknock Anticlinal Trend, and are among the producing reservoirs in the Ichthys, Prelude and Concerto fields (Figure 4).

The Brewster Member of the upper Vulcan Formation is also a widespread reservoir unit and was deposited as turbidity currents. It also contains mudstone and frequently exhibits poorer reservoir properties, and is among the producing reservoirs in the Ichthys, Prelude and Concerto fields. The Middle-Upper Jurassic Montara Formation exhibits good reservoir properties, but has a restricted distribution within the Browse Basin. This unit is also one of the producing reservoirs in the Ichthys, Prelude and Concerto fields.

There are further reservoir targets across the Browse Basin. In areas with reduced overburden, the Triassic Nome Formation sandstones are a recognized target, and successfully produce gas in the Crux Field in the Heywood Graben area. Triassic targets are not targeted elsewhere due to the inability of conventional seismic data to successfully image them. Further targets exist in Cretaceous-aged sediments, such as the oil-charged Echuca Shoals Formation sandstones at the Gwydion discovery on the Yampi Shelf, proof of oil charge and migration in the inner rim of the Browse Basin (Figure 5).

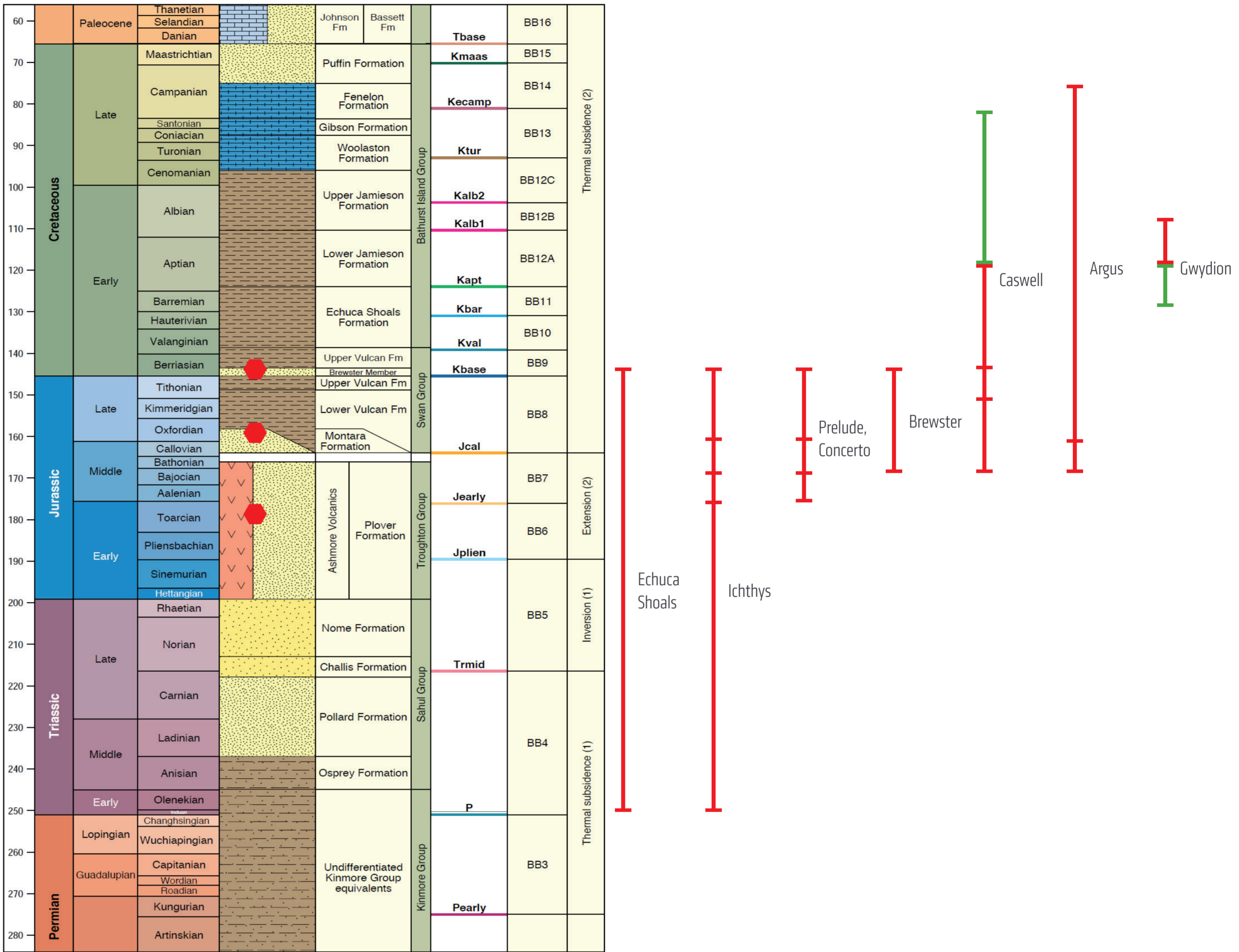


Figure 4: Tectonostratigraphic summary and hydrocarbon discoveries for the Browse Basin, after GeoScience Australia, 2011

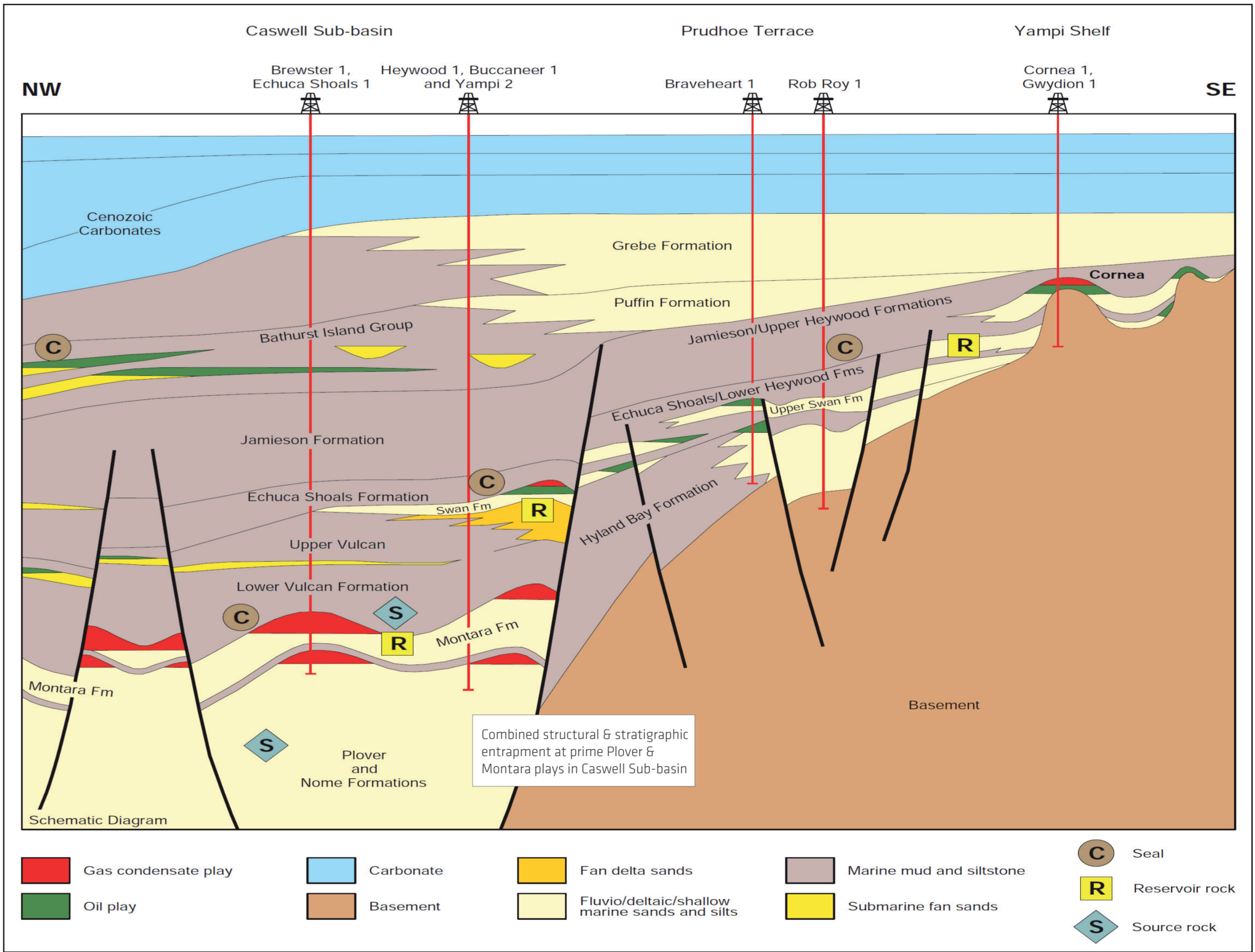


Figure 5: Play types in the Caswell Sub-basin, Prudhoe Terrace and Yampi Shelf, GeoScience Australia 2012

Prospectivity

Focus on the large structures targeted in gas exploration has meant that search for subtle stratigraphic traps is overlooked. There is proof of generation and migration of oil in the Browse Basin (discussed above) and high-quality datasets can be used to identify the presence of turbidite sandstones on the basin margins that could have been charged. The depositional model proposed by Benson et al. (2004) focuses on the identification of ponded turbidity currents and accumulation of sands within topographic lows. The geometry of the Browse Basin margins (Figure 6) demonstrates a suitable area for the formation and accumulation of these stratigraphically trapped sandstones.

Reactivation of faults due to ongoing inversion in the Browse Basin also provides a potential for migration of hydrocarbons into stratigraphically shallower targets, especially on the shelf and slope area, where the thickness of the Jamieson Formation regional seal does not exceed the throw of the faults.

The use of dual-sensor acquisition and bespoke imaging flows allows the improved definition of reservoir horizons with greater clarity. Much of the exploration effort in the Browse Basin is focused on the gas play, identifying sandstones of the Plover Formation, Montara Formation and Vulcan Formation, and their distribution around anticlinal structures which form the major traps. The higher resolution at depth available using the new acquisition technology

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also reveals structures at depth not currently observable on legacy conventional data (Figure 7).

The discovery of the Phoenix South-1 oil well in the offshore Canning Basin has highlighted the importance of a large stratigraphic interval that has not previously been subject to systematic interpretation due to imaging challenges. This can now change, with a more in-depth focus now possible.

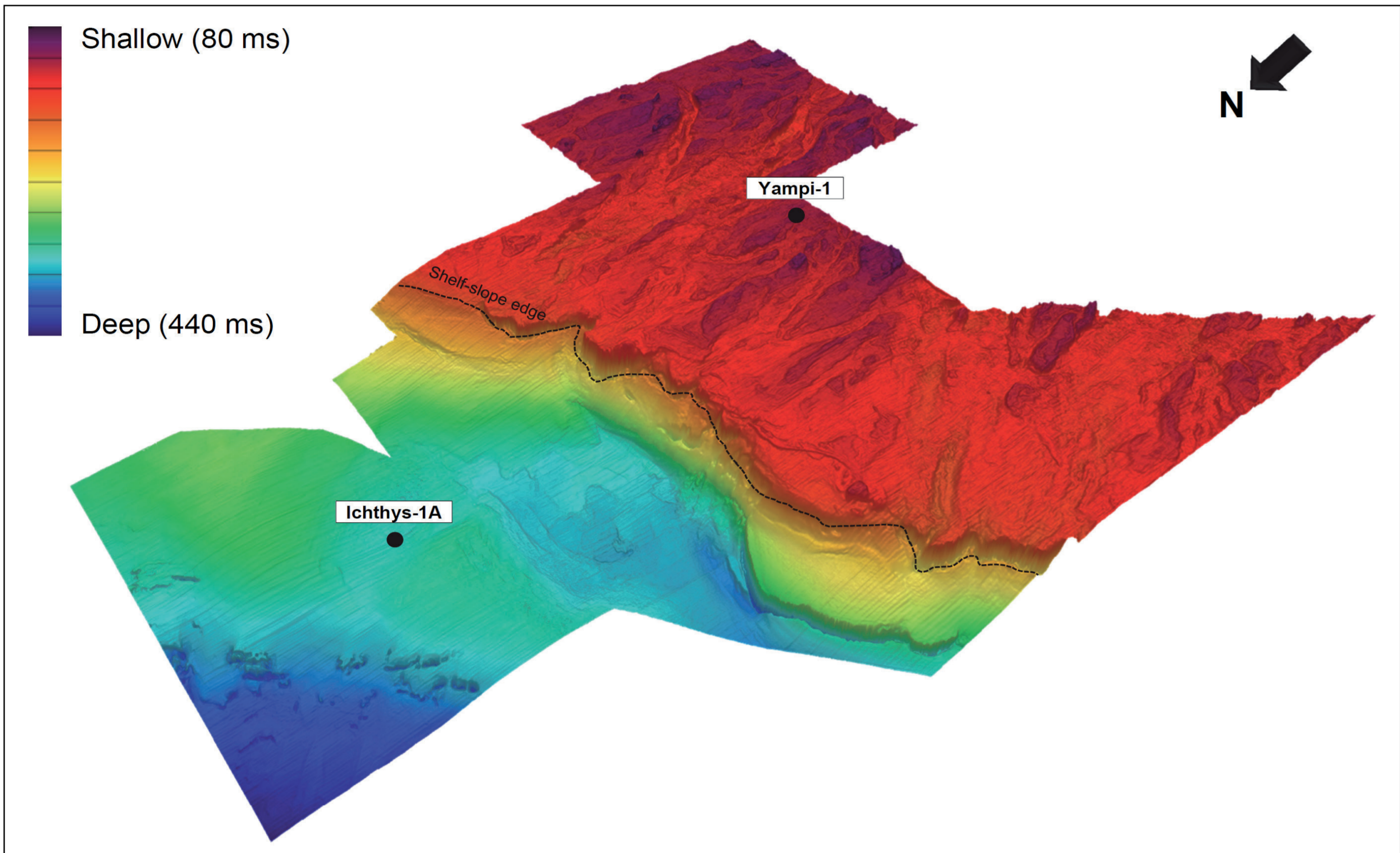


Figure 6: 3D Seafloor TWT over the Browse Basin margins (Yampi Shelf)

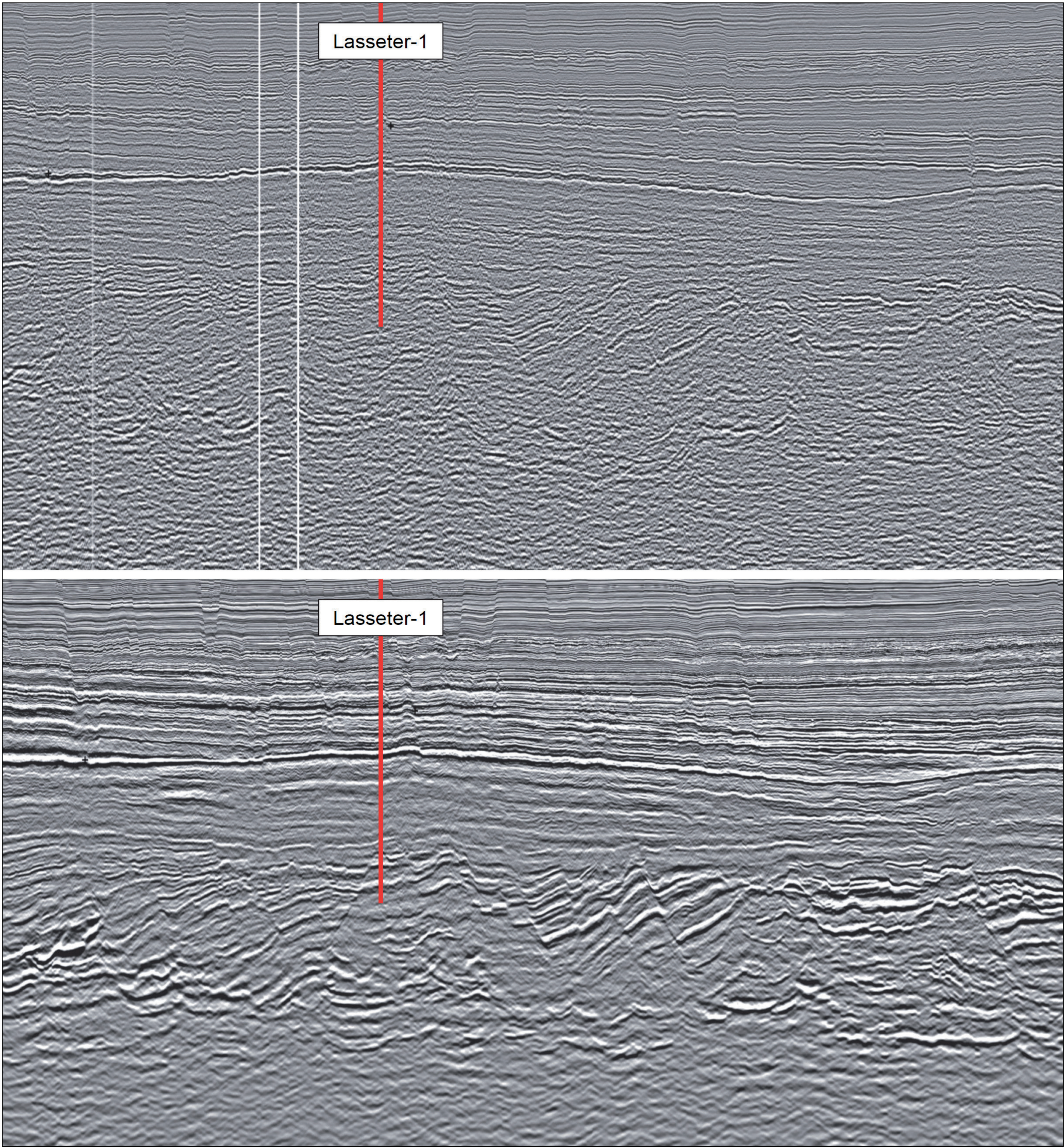


Figure 7: Comparison of legacy data with recent GeoStreamer broadband seismic over the Lasseter discovery

Imaging Challenges

The major challenge that faces interpretation geologists and geophysicists in the Browse Basin is that of acquiring data of sufficient quality that allows us to resolve the detail of reservoir distribution around target structures, a lack of penetration into the Triassic, and sufficient clarity to image subtle stratigraphic traps.

True Broadband also allows relative inversion of the dataset, using the ultra-low frequency benefits. We gain the ability to distinguish between the populations of sand and shale, and hydrocarbon-bearing sandstones (Figure 8). We can use the new acquisition technology to benefit the entire Exploration & Production cycle, enabling exploration from a regional extent to the prospect level, and with greater clarity regarding shallow drilling hazards such as faulting and carbonate mounds.

Conclusions

With the new acquisition of broadband data in the Browse Basin, we see better resolution of structures and reservoir distribution in the main gas-prone fairway. We also have better data integrity which improves imaging of the previously unresolved Triassic sequence and allows interpreters to use the improved low frequency content of the data for QI work at the reservoir level which offers geological confidence in quantitative amplitude analysis and prospect de-risking.

Interpreters can have increased confidence in the interpretation of the structural and stratigraphic framework, which in turn gives us a better understanding of the potential for a findable oil leg in the margins of the Browse Basin.

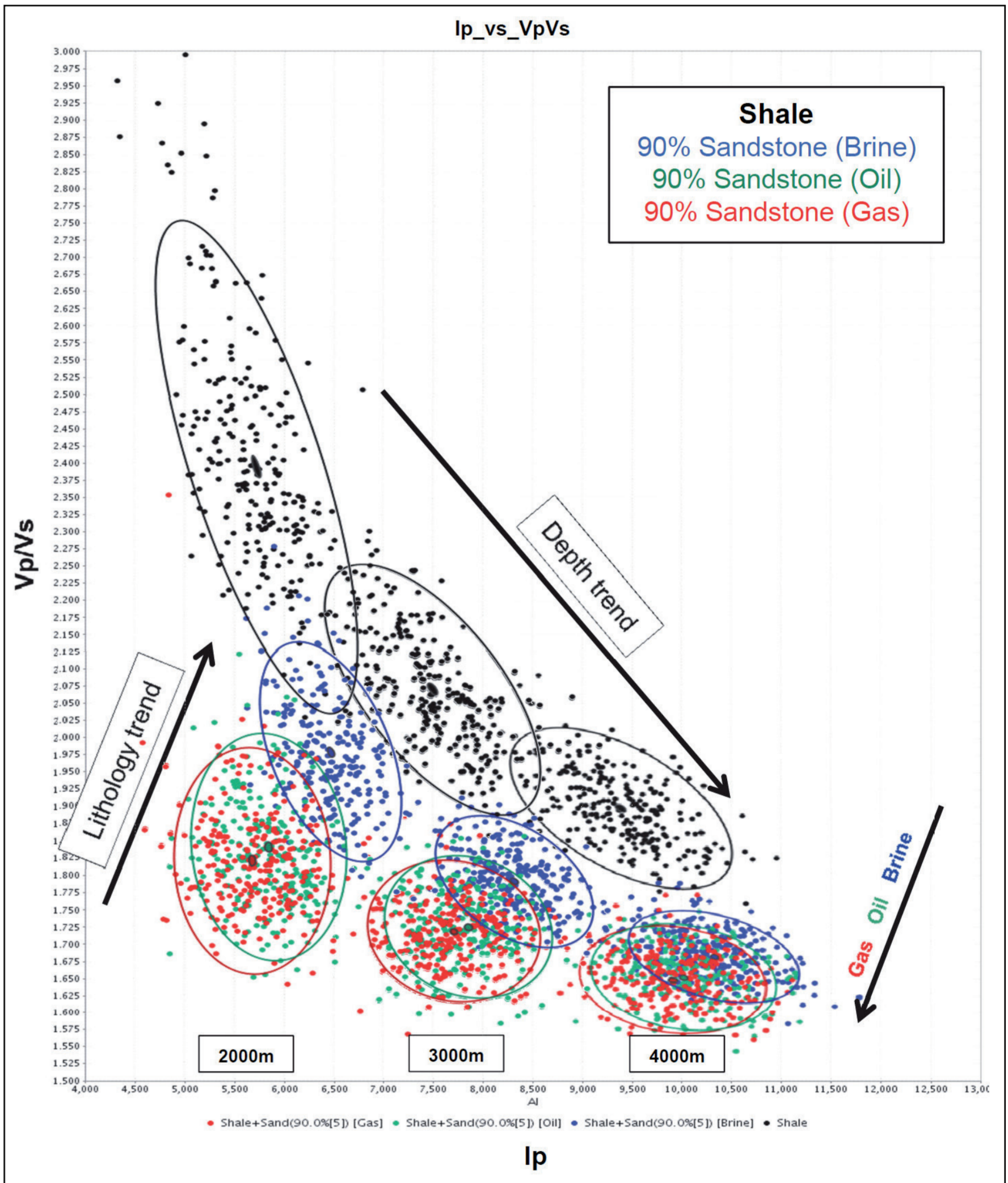


Figure 8: Inversion results from Caswell MC3D survey showing discriminators between lithology and brine and hydrocarbon-bearing sandstones

References

GeoScience Australia, 2011 Regional Geology of the Browse Basin, Offshore Petroleum Exploration Acreage Release 2011

GeoScience Australia, 2012 Petroleum Geological Summary, Release Areas W12-3, W12-4 and W12-5, Caswell Sub-basin, Browse Basin, Western Australia

GeoScience Australia, 2014 Regional Geology of the Browse Basin, Offshore Petroleum Exploration Acreage Release 2014

Benson, J.M., Brealey, S.J., Luxton, C.W., Walshe, P.F. and Tupper, N.P., 2004. Late Cretaceous ponded turbidite system: a new stratigraphic play fairway in the Browse Basin. The APPEA Journal, 44, pp 269-285

Longley, I.M., Buessenschuett, C., Clydsdale, L., Cubitt, C. J., Davis, R.C., Johnson, M.K., Marshall, N.M., Murray, A.P., Somerville, R., Spry, T.B. and Thompson, N.B. , 2002. The North West Shelf of Australia – A Woodside Perspective, in Keep, M. & Moss, S.J., (Eds), in The Sedimentary Basin of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, WA, 2002 pp 27-88.