

The Paleozoic prospectivity of the Offshore Canning area, Australia

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SUMMARY

The recent oil, gas and condensate discoveries in the Bedout Sub-basin have triggered a change in thinking in this hitherto underexplored region. Recent drilling at Phoenix South-1 (2014), Roc-1 (2015) and Dorado-1 (2018) all found success within the Triassic Lower Keraudren Formation. These discoveries suggest new play concepts need to be developed that may have previously been overlooked or deemed non-prospective. Their success also suggests that, apart from the charge system, entrapment and sealing mechanisms are the key to exploration success. Dorado-1 is a classic example where vintage seismic data failed to reveal an entrapment and sealing mechanism, while the modern Bilby Non-Exclusive 2D seismic data clearly shows the trap geometry, as well as reservoir-seal content through geophysical quantitative interpretation (QI) techniques.

Although the Mesozoic has been the primary exploration target, the understanding of the prospectivity of the Paleozoic remains limited. Inadequate knowledge of the Paleozoic stratigraphy is attributed to the lack of well penetration and paucity of seismic data. The Paleozoic sequences for the region are best described from the Onshore Canning Basin where several commercial hydrocarbon fields have been discovered. Here they are over 11,000 m thick in the Fitzroy Trough, thinning to <5,000 m on the Broome Platform.

Integration of the Onshore Canning data with regional geology and the Bilby 2D seismic data reveals the Paleozoic potential, e.g. Carboniferous carbonates and clastics, Devonian reefs, and Permian carbonates, as well as several potential reservoir-seal pairs. This paper discusses the unexplored Paleozoic hydrocarbon potential in the Offshore Canning area, inspired by the recent landmark oil, gas and condensate discoveries in the Bedout Sub-basin and extension of the Onshore Canning Basin geology.

Key words: Permian carbonate, Canning Basin, Bilby 2D seismic, Devonian reef, Carboniferous Laurel Formation.

INTRODUCTION

The Offshore Canning area is a NE-SW trending region on the North West Shelf (NWS) of Australia consisting of the Roebuck and Offshore Canning Basins (Figure 1). In comparison with the other regions of the NWS, the area is conspicuous by the absence of commercial oil and gas developments and has been relatively underexplored. Prior to the recent (2014-2018) exploration success, only two wells were considered discoveries in the general region (i.e. Phoenix-1, gas, 1980 and Nebo-1, oil, 1993). The recent oil, gas and condensate discoveries in the Bedout Sub-basin of the Roebuck Basin have caused a change in thinking in this hitherto underexplored region. Commencing in 2014, Phoenix South-1

discovered oil, which was closely followed by Roc-1 in 2015 that discovered gas and condensate, and in 2018 Dorado-1 discovered oil. These discoveries targeted reservoirs in the Triassic Lower Keraudren Formation (Formation) that are older than the traditional Triassic plays on the NWS (Thompson et al., 2018; stratigraphic chart, Figure 1).

The knowledge of the prospectivity and petroleum potential of the Offshore Canning area is gradually evolving as oil and gas companies are expanding their exploration and appraisal programs. Although the Mesozoic has been the primary target for exploration, the understanding of the prospectivity of the Paleozoic remains limited. The main reason for inadequate knowledge of the Paleozoic petroleum systems in the area is due to lack of well penetration and high-quality regional seismic data.

MODERN SEISMIC DATA AIDS SUCCESS

Searcher Seismic's modern Bilby Non-Exclusive 2D Seismic Survey acquired long-offset, high resolution seismic in the Bedout Sub-basin, Pardoo Shelf and Broome Platform, Western Australia. The Bilby data provides a grid of modern, high quality data to help identify prospective stratigraphic and structural trends in the region and ties the recent hydrocarbon discoveries and sits inboard of them (Figure 1). The Bilby data also addresses multiple issues with the legacy data in the area, including an 8 km streamer with improved frequency response, a larger source array to improve signal penetration, and a broadband anisotropic PSTM processing workflow.

The Bilby data reveals several potential reservoir-seal pairs in the Mesozoic strata and deeper Paleozoic character (Amiribesheli and Weller, 2018; Weller and Amiribesheli, 2018; stratigraphic chart, Figure 1). The Paleozoic potential in the region has seemingly been overlooked due to a lack of understanding of the petroleum systems and a paucity of seismic data. The Bilby data unequivocally sheds light onto the hitherto underexplored Paleozoic potential in the Offshore Canning area.

THE PALEOZOIC ONSHORE CANNING BASIN AS AN ANALOGUE TO THE OFFSHORE'S PROSPECTIVITY

The Paleozoic sequences for the region are best described from the Onshore Canning Basin where they overlie Pre-Cambrian crystalline basement of the Pilbara and Kimberley Blocks (Insight Petroleum and Searcher Seismic, 2015). Onshore, in the Fitzroy Trough the Paleozoic sediments are more than 11,000 m thick and thin to less than 5,000 m on the Broome Platform. The oldest sedimentary sequence known in the Canning Basin is the Lower Ordovician to Silurian (Error! Reference source not found.), which consist of marine shales, carbonates and evaporites with minor thin sandstones. The

reservoir level of the Theia-1 (2015) oil and gas discovery is the Middle Ordovician Goldwyer Formation.

In general, the Carboniferous (and older) sedimentary units have been assumed not to be present and unimaged to date in the offshore (stratigraphic chart, Figure 1). Analogues for the Paleozoic prospectivity of the Offshore Canning area are therefore best appraised from the onshore (e.g. **Error! Reference source not found.**).

The Base Devonian represents the angular unconformity associated with the Lower Devonian Prices Creek Compressional Movement. The mega-sequence above this unconformity includes an Upper Devonian syn-rift succession, initiated by the Pillara Extension, which comprises an Upper Devonian Reef Complex (Insight Petroleum and Searcher Seismic, 2015; **Error! Reference source not found.**). The onshore Blina oil field was discovered in 1981 in an Upper Devonian Reef Complex and Playford (1982) hypothesised that the reef complex exists in the Offshore Canning area too. Vintage seismic data in the offshore region is beset with short streamer lengths and imaging of the Paleozoic is generally poor. With an 8 km streamer length, the superior Bilby data has imaged what we interpret to be the offshore extension of the Devonian Reef Complex, which potentially lies in the oil window (**Error! Reference source not found.a**). This warrants further investigation.

The Carboniferous Laurel Formation of carbonates and shoreface clastics overlain by marine carbonates and shales (**Error! Reference source not found.**) hosts most of the oil and gas occurrences on the Lennard Shelf (e.g. Kingsley and Streitberg, 2013). From a geochemistry perspective, the Lower Carboniferous looks ambiguous with fair-to-good total organic carbon analysis (Ghori, 2013), although it is prospective (Kingsley and Streitberg, 2013). In the offshore, there is certainly Carboniferous character that can be observed in the Bilby data (**Error! Reference source not found.b**); the Bilby data can therefore answer questions about the extension of the Laurel Formation into the offshore area.

The sedimentary sequence overlying the Carboniferous angular unconformity representing the erosional surface after the Meda Transpressional Event consists of the Reeves Formation (Apak and Backhouse, 1998), the fluvial and glaciogenic Grant Group, the shallow marine Poole Sandstone, the marine shale Noonkanbah Formation and the fluvio-deltaic Liveringa Group (**Error! Reference source not found.**; Insight Petroleum and Searcher Seismic, 2015). Organic-rich marine shales within the Upper Grant Group are the main source rock interval within the Upper Carboniferous and Lower Permian onshore. Additionally, the Permian Noonkanbah Formation has demonstrated good source potential onshore although it is immature (Mory, 2010). Noonkanbah (and Grant Group) character is observed offshore on the Bilby data (**Error! Reference source not found.b**) and is relatively deeper than observed onshore and is therefore potentially more mature in the offshore section.

PERMIAN CARBONATE PLAY

Recent work by Paschke et al. (2018) suggests that the Upper Paleozoic section across the NWS is probably part of the East Gondwana interior rift setting. This Carboniferous-Permian intracontinental rift was later modified by Upper Permian extension. Integration of regional geology, a tectonic evolution model, and stratigraphy suggests that the Offshore Canning area

is a prime location to host an Upper Permian carbonate factory. The interpretation of open-file 3D seismic data also demonstrates typical carbonate bank geometry with possible development of back reef, shelf edge carbonates and reefs (**Error! Reference source not found.**). It is important to note that most of the shelf edge margin remained in shallow waters for long periods of time and is less affected by thermal subsidence, which promotes the development of karstified limestone. The subsidence is more pronounced toward the north of the area during the Upper Permian to Lower Triassic. **Error! Reference source not found.c** shows an example of Permian reef and back reef setting from the Bilby data. Seismic facies analysis suggests the presence of a barrier reef along with possible karstified limestone. The feature is located close to the deeper basin where possible source rock can be developed. Additionally, lagoonal environments can act as potential settings for source rock development. Wavy and discontinuous high seismic amplitude reflections of the Permian horizon imply the development of porosity within the limestone. This may also suggest presence of fractured and karstified limestone which can provide a fluid-flow pathway and act as conduits to improve the limestone's permeability (**Error! Reference source not found.c**).

CONCLUSIONS

The recent significant oil, gas and condensate discoveries in the Bedout Sub-basin, offshore Australia unequivocally demonstrates an underexplored area. The recent discoveries suggest that new play concepts previously overlooked or deemed to be non-prospective need to be targeted. Although the Mesozoic has been the primary target for exploration, the understanding of the Paleozoic prospectivity remains limited. Inadequate knowledge of Paleozoic stratigraphy in the Offshore Canning area is attributed to lack of well penetration and paucity of seismic data. Integration of the onshore data, regional geology, and the modern Bilby data reveals several potential reservoir-seal pairs in the Paleozoic section, which previously has been assumed not to be present as it was unimaged. With the modern, high-quality Bilby data and knowledge of the Onshore Canning Basin's fields and discoveries, we can demonstrate that similar Paleozoic plays and concepts are present in the Offshore Canning area including Carboniferous carbonates and clastics, Devonian reefs, as well as Permian carbonates.

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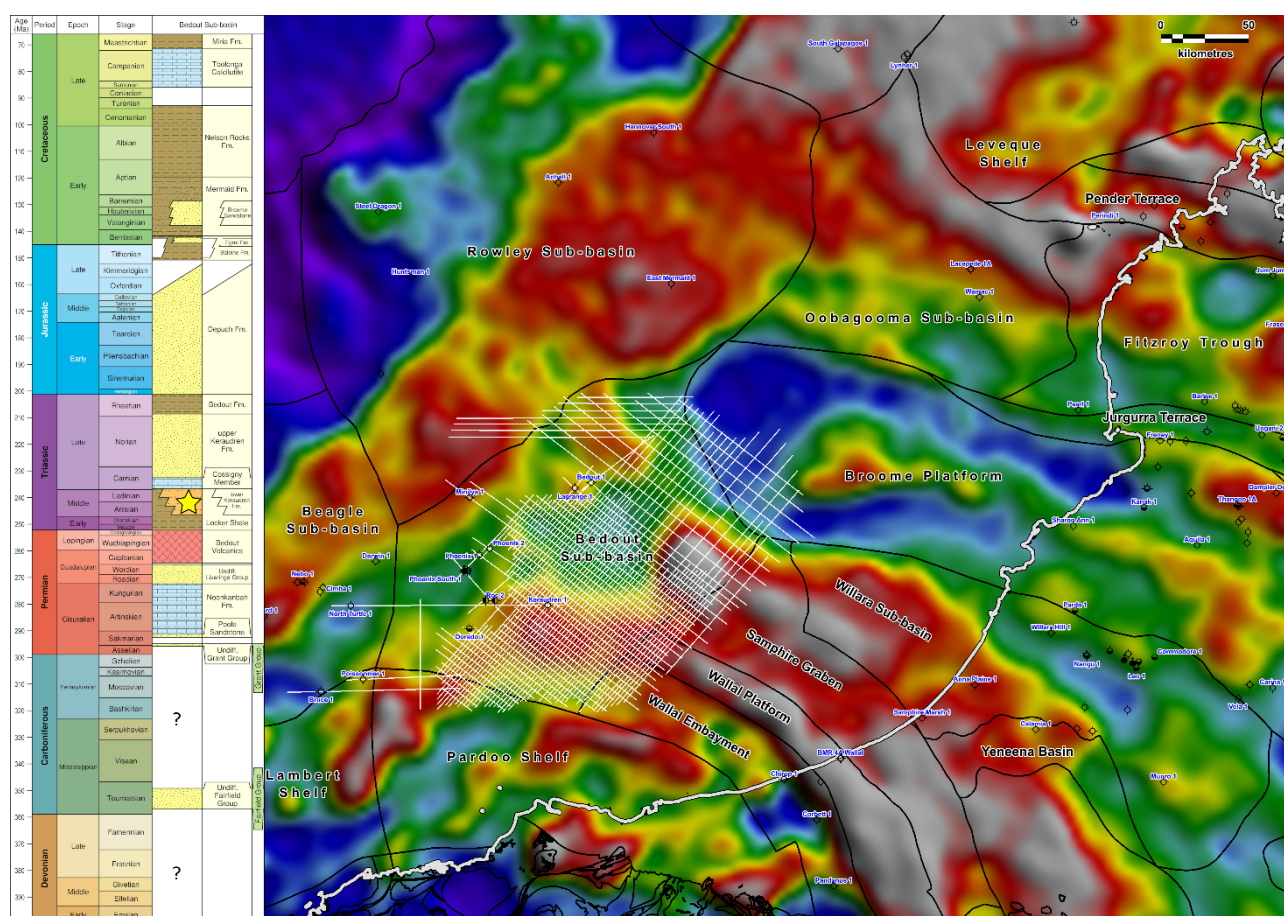


Figure 1. The Bilby Non-Exclusive 2D Seismic Survey is shown in white in the Bedout Sub-basin. Structural elements of the Canning area (black lines, from the Department of Mines, Industry Regulation and Safety, Western Australia) overlaying the free-air gravity anomaly indicating relative highs in whites/reds and lows in blue (Bureau Gravimétrique International, WGM2012 Model). Generalised stratigraphy of the Bedout Sub-basin is modified after Geoscience Australia. Note: a) the Lower Keraudren Formation (yellow star); and b) the general absence of Carboniferous and Devonian stratigraphy.

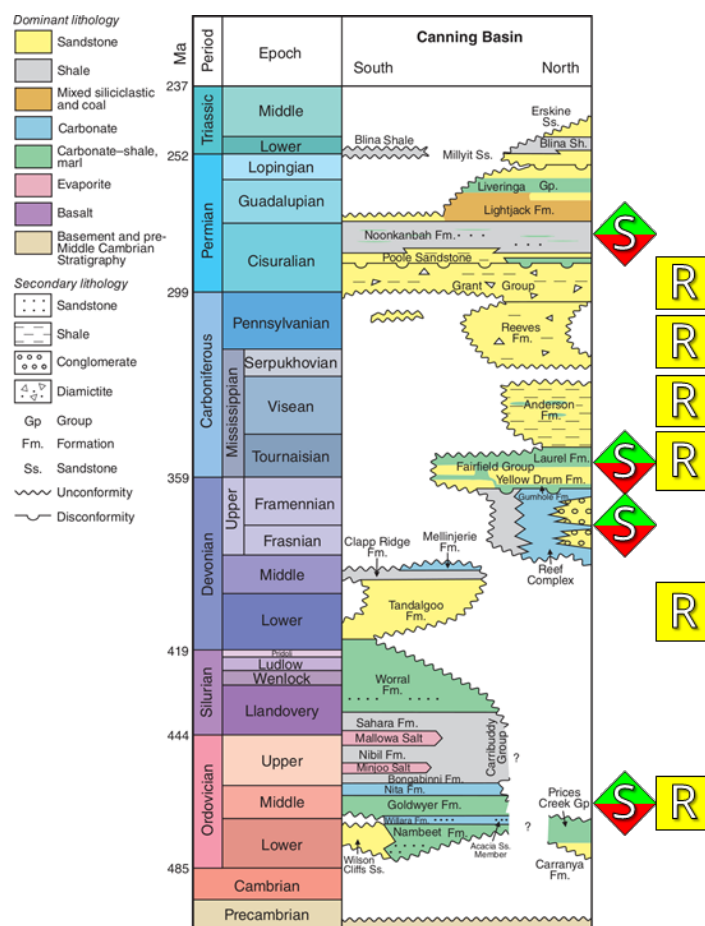


Figure 2. Generalised Paleozoic stratigraphy of the Onshore Canning Basin (after Haines et al., 2013). “S” means potential source; “R” means potential reservoir, denoting the plays that hypothetically extend offshore that are discussed in the text.

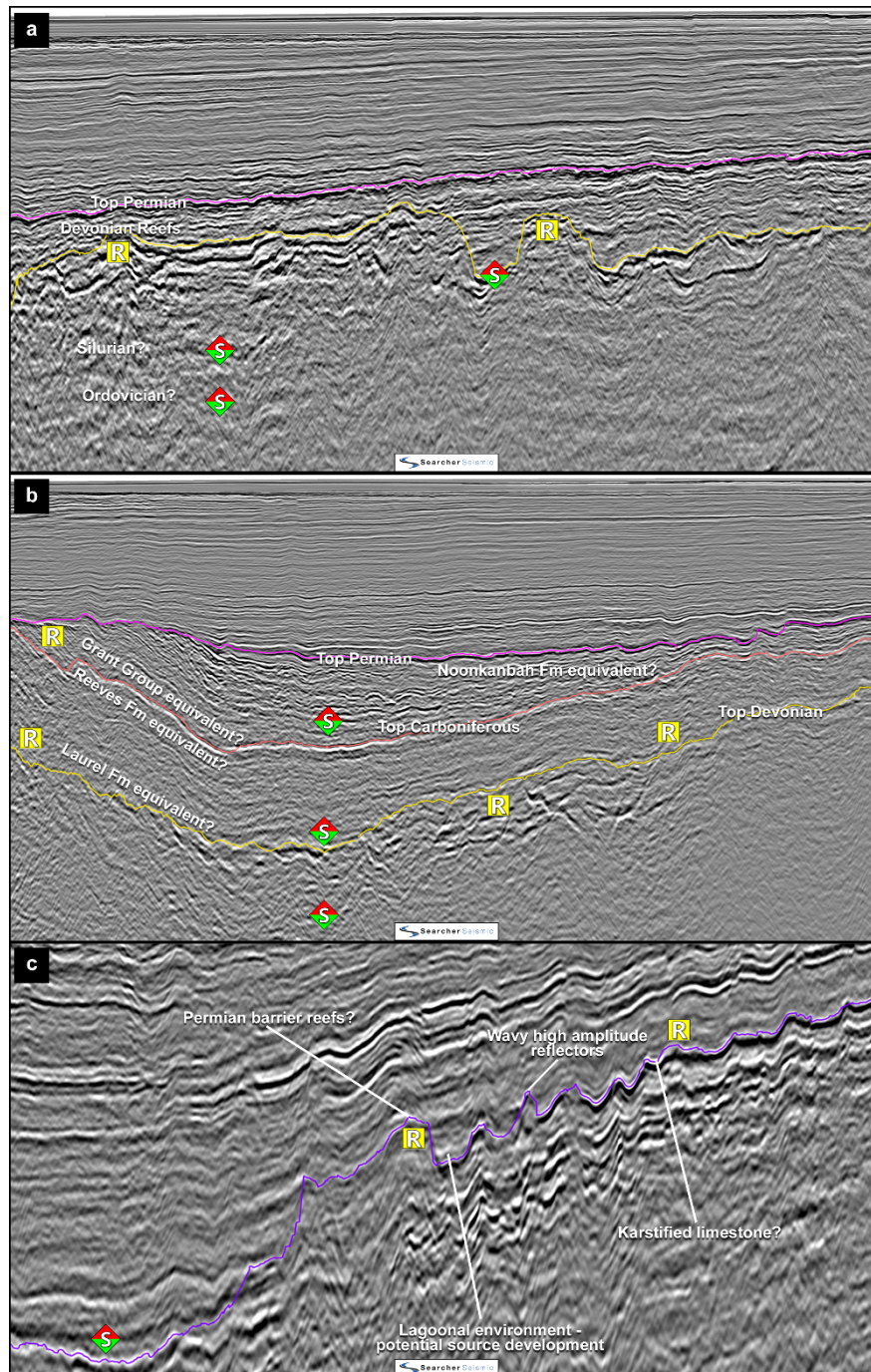


Figure 3. Paleozoic character and potential observed in the Bilby seismic data. A: The extension of the Devonian Reef Complex in the Offshore Canning area hypothesised by Playford (1982). B: Generalised Paleozoic character highlighting the Devonian, Carboniferous and Permian sedimentary sequences. The Laurel Formation, Reeves Formation, Grant Group and Noonkanbah equivalents highlighted remain untested in the Offshore Canning area. C: Permian reef and back reef setting; seismic facies analysis suggests the presence of a barrier reef along with possible karstified limestone. “S” means potential source; “R” means potential reservoir.

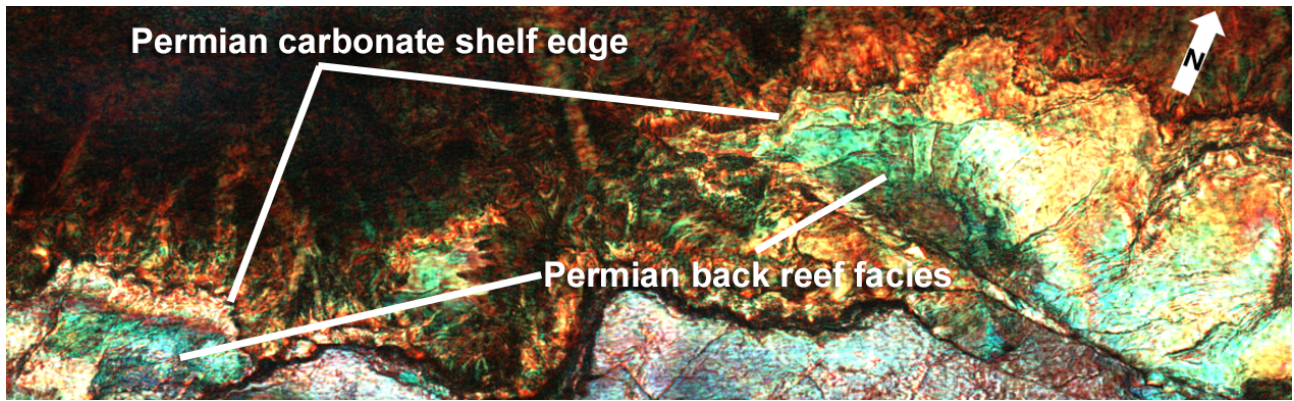


Figure 4. The interpretation of open-file 3D seismic data demonstrating likely carbonate bank geometry with possible development of back reef and shelf edge carbonates and reefs.