AEGC Australasian Exploration Geoscience Conference Brisbane 2023

Unlocking the Canning Basin: Gas Resources for Western Australia

Jarvis Moore
Black Mountain O&G
Jarvis.moore@blackmtn.com

Perry Richmond
Black Mountain O&G
Perry.richmond@blackmtn.com

Sean Taylor
Black Mountain O&G
Sean.taylor@blackmtn.com

Robert Hull
Black Mountain O&G
Rob.hull@blackmtn.com

SUMMARY

The Canning Basin, located on and inland of the northern coast of Western Australia, is one of Australia's largest basins at over 400,000 km^2. Within the northern portion of the Basin, Black Mountain Energy (BME) is focused on sustainable development of its ~3,600 km^2 Valhalla Project permit area (Figure 1).

Few wells have been drilled on the Lennard Shelf and basin margins bounding the deep Fitzroy Trough depocenter, but a number have encountered significant gas shows and have tested conventional and unconventional resources. The BME tight gas acreage has 1.5 trillion cubic feet (TCF) of contingent gas resources and 11.8 TCF of prospective gas resources. These resources are contained within the prograding Laurel marine siliciclastics and carbonates that were deposited in a transitional ramp setting. Multiple tectonic phases have altered this basin, creating an extensive set of both transpressional and extensional fault systems.

Ahead of the planned 2023-2024 appraisal program, key well testing and a 2D seismic program will be initiated to further understand and define the hydrocarbon bearing resources. This paper highlights some of the key aspects of the Basin Centered Gas Play for the Valhalla area and the associated data to help assess the reservoir characteristics. We discuss the interpretation of the key reservoirs and their future well testing. We further highlight a potential horizontal landing zone within the Laurel as it relates to the prospectivity of future unconventional wells.

We are excited to bring our expertise to Australia, emerging as an industry leader in responsibly developed and environmentally conscious natural gas supplies. We believe Project Valhalla will create energy security, socio-economic uplift to the project area's Traditional Owners, local employment opportunities, connections to southeast Asian LNG markets, and a leading cost advantage for WA's manufacturing industry as we build Australia's next great energy company.

Key words: Canning Basin, Lennard Shelf, Fitzroy Trough, tight gas, Laurel Formation reservoirs.

INTRODUCTION

Building upon prior geologic work in the Canning Basin, Black Mountain Energy has progressed a robust evaluation of the basin-centered resource focused on the northern margin of the Fitzroy Trough (Figure 2). This evaluation has extensively utilized existing data within the northern part of the basin and is outlined in the past work of Moore et al. (2020) and Shelokov et al. (2021). Our current plans for the Canning include well testing along with a 2D seismic acquisition program. Beyond these efforts, we have submitted an Exploration and Appraisal Program to the government for drilling and stimulation of unconventional wells to help better delineate these Canning resources.

A review of the geochemical, petrophysical, and vintage 2D seismic data establishes an extensive basin-centered gas fairway beginning at 2000m and continuing to over 4500m in depth. This fairway steps down from the basin margins into the depths of the Fitzroy Trough and is analogous and correlative to a similar petroleum system that hosts significant gas discoveries on the opposite margin of the trough.

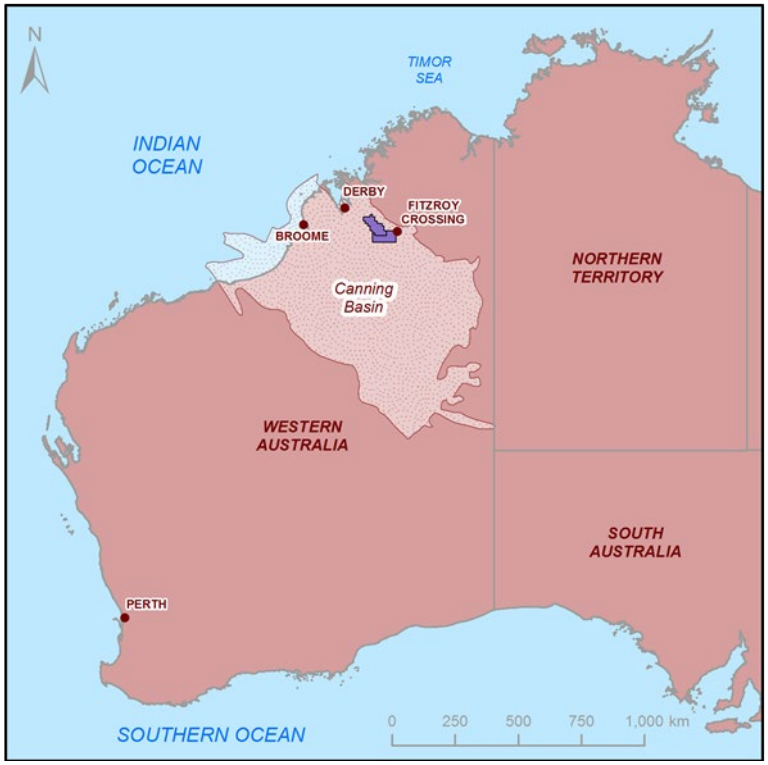

Figure 1. The Canning Basin in Western Australia is shown along with in purple the locations of the Exploration block EP-371 and a Special Prospecting license area SPA-0065. The exploration block and prospecting area cover 1.7 million acres (6,767 km^2) and are located 2,500 km northeast of Perth, Western Australia.

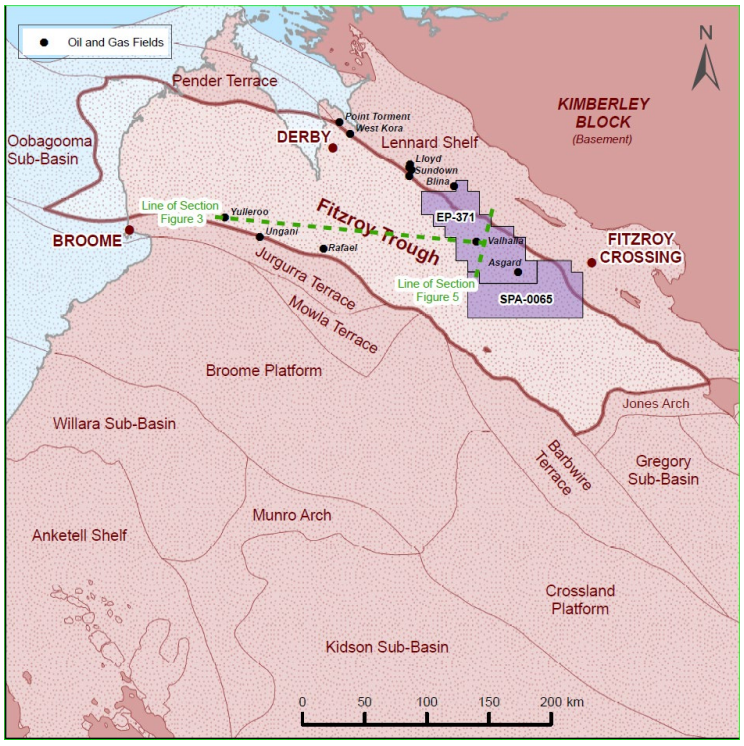

Figure 2. The EP-371 block and SPA-0065 along with several of the recent oil and gas fields and discoveries along the northern margin of the Fitzroy Trough are shown.

In this paper, we provide a short overview of the overall basin-centered gas petroleum system and a brief workflow integrating various datasets to better define key targets within the play. Specifically, we highlight reservoirs that exist behind pipe within the Laurel Formation that we propose to test in the Valhalla-2 well.

Current interpretations of a widely spaced grid of 2D vintage seismic data have been combined with the existing well control to map the down-dip expanded Carboniferous aged carbonate and clastic sequences of the Laurel Formation. Petrophysical analyses, well pressure data, and an understanding of structure from seismic data suggest the potential for stimulation of clastic rock facies within the Laurel. The tight sands could be charged directly from adjacent higher TOC source rocks or by hydrocarbons migrating through fault systems. Well log data suggest that the upper Laurel clastics can be correlated over large areas.

The key significance of this play is that if development is economically successful, it provides increased energy independence for Australia and LNG export. The state government of Western Australia, which had banned hydraulic fracture stimulations in the past, has lifted these restrictions for programs which can be shown to be safe and environmentally responsible.

The data integrated includes reservoir pressures, 2D seismic, detailed advanced unconventional petrophysical analysis, remote sensing, geochemistry along with well test data from previous hydraulic fracs (Table 1). Lastly, we outline our future development plans for a large exploration block the size of the Delaware basin in the United States.

Project Valhalla Laurel	
Basin/area	Canning Basin Western Australia
Age	Carboniferous
Estimated basin area (km2)	19,700 (1)
Typical depth for shale gas (m)	2000-4000
Gross Thickness (m)	1000-1500 (1300)
Net Thickness (m)	200-400
Porosity (%)	4-9 (7)
Permeability range	10nd-.17md
Pressure Gradient (psi/ft}	.55-.65
Gas-filled porosity(%)	1.5-6 (3)
Water Saturation (%)	20-50
Reported Silica Content (%)	50-90
Reported Clay Content(%)	20-40
Reported Carbonate Content(%)	10-20
%Ro (average-range)	.9-2
HI present-day	50-140 (100)
TOC present-day (average in wt%)	.5-4.5 (1.4)
1 USGS Fitzroy Trough Carboniferous–Permian Tight Gas AU	

Table 1 – Key reservoir characteristics of Project Valhalla.

CANNING BASIN

The Canning Basin has Ordovician sedimentary rocks deposited onto Precambrian basement. The Fitzroy Trough is a structural feature on the northern edge of the basin that extends to a depth of up to 18 km (Cadman et al. 1993). Significant infilling of the basin took place from Carboniferous to Permian and in the Cretaceous, during which period the basin was a shallow seaway. Thick sections of Permian and Carboniferous terrigenous clastics then prograded over the deeper petroleum prone targets. Multiple tectonic phases within the basin took place both syndepositionally and post-depositionally, modifying the petroleum system with an extensive set of both transpressional and extensional fault systems (Zhan, and Mory, 2013). Tertiary and Triassic sections are notably absent in the basin. The USGS (Schenk et al. 2017) estimates that the Canning contains mean undiscovered technically recoverable resources of 34.4 TCF of gas and 1.3 billion barrels of oil. For the USGS assessment unit for which our block is within, the Fitzroy Trough Carboniferous -Permian Tight Gas the mean assessment is 14.7 TCF and 353 MMBNGL.

PETROLEUM HISTORY

Over 340 wells have been drilled in the expansive Canning Basin, most with limited success. Early wells were drilled beginning in the 1920's after surface seeps were observed around Fitzroy Crossing. Minor oil and gas fields (figure 2) have been discovered on both the northeastern and southwestern margins of the Fitzroy trough. The petroleum resources of the basin are well described in Cadman et al. (1993) and some of the more recent unconventional aspects related to fluids and their origins are described in Feiner et al. (2017). More recently, several vertical wells have been stimulated in our block in the last seven years demonstrating the basin-centered gas potential of the Laurel system in the Canning basin.

The initial discovery of the Laurel Gas System in the Canning dates to 1966 and continues to the present day. The Valhalla project here is based on these Laurel gas accumulations that occur within a basin-centered gas system (BCGS). The BCGS is well described in the work of Kingsley and Streitberg (2013) and illustrated in figure 3. It is recognized by these authors as having the characteristics of an overpressured section with no indications of gas or water contacts. Further, maturity and hydrocarbon phase are tied to the basin depth with oil shallow transitioning to dry gas in the basin center. It should be noted that the wells that have encountered this basin-centered system generally have continuous mud gas shows in the tight Laurel Formation of 1600m or more (Hashimoto, et al., 2018, and Kingsley and Streitberg, 2013). This observation is further confirmed in our assessment. The testing of unconventional opportunities over the past decade like those found in North America have shown there is significant potential for a basin-centered gas play in and around the Fitzroy Trough.

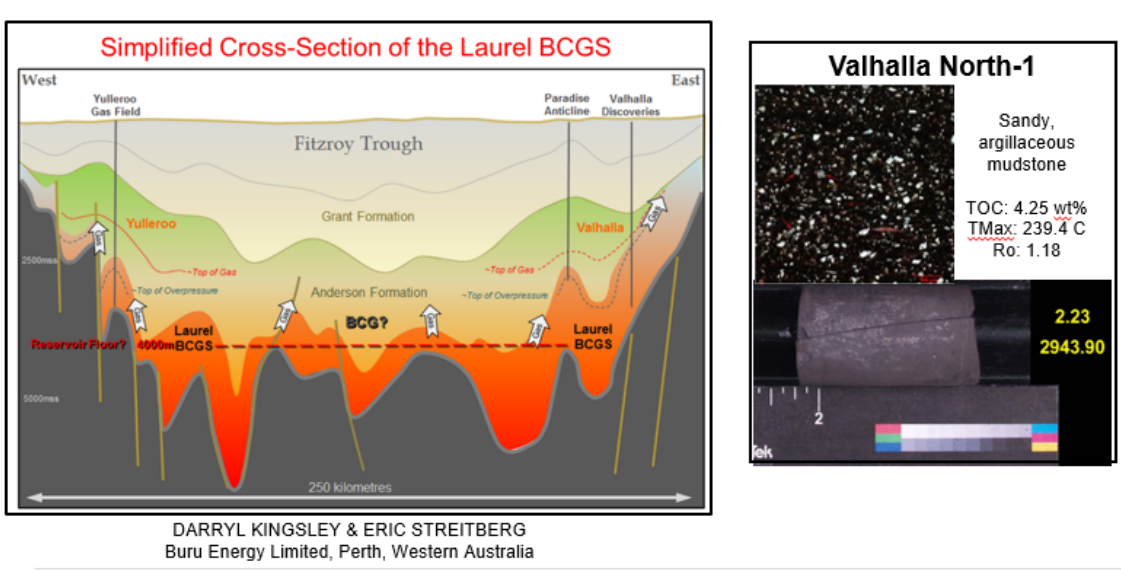

Figure 2. Several plays are recognized in the northern margin of the Fitzroy Trough. The basin centered tight gas carbonate and sand play is outlined on the left. Evidence from sidewall cores highlights the potential for high TOC unconventional siltstones that can both source this play and potentially expand out onto the block as discrete unconventional targets.

GEOLOGY

The Paleozoic petroleum systems of the Canning Basin are well described in Ghori and Haines (2007) and Hashimoto et al. (2018). One component to the petroleum system that we ~~do~~ recognize, not noted by past authors, is a sealing component related to the presence of the Anderson shale for the downdip Laurel Basin Centered Gas Play.

Within the block there are at least three key play types. Past drilling has clearly demonstrated a basin-centered tight gas carbonate and sand play (Figure 3). The sources for these hydrocarbons can be deeper or intraformational as there are some units within the Laurel with TOCs of up to 4% documented in SWCs. With limited wells currently, the extent and thickness of these high TOC units is still to be determined. Further, the evolution of the structure and observed core containing in situ fractures along with FMI data indicate that a fractured tight gas play is also possible. Mapping also highlights the existence of a Fitzroy-River expanded downdip exploratory potentially unconventional sandstone play. Beyond these extensive plays there are several conventional leads on the block that could be oil or gas prone. As it relates to the total petroleum system, Buru Energy's 2021 Rafael well also brings optimism as it discovered multiple thick hydrocarbon bearing sequences within the Laurel. This conventional gas/condensate discovery is located just west of EP-371.

There are multiple active petroleum systems within the Canning basin, but the primary focus of our operations are understanding the hydrocarbon-prone Carboniferous Laurel Formation of the Fairfield Group. Hydraulic fracture stimulations of the Laurel have yielded positive results in vertical wells (Figure 4). The Upper Laurel Clastics typically have better reservoir characteristics than the Lower Laurel clastics. The Laurel Formation steps into the basin in a series of benches; many of which are targets for existing and future gas wells (Figure 5). A key well, the Valhalla 2 (Figure 6), demonstrates tight oil to wet gas in the upper normal pressured sections with increasingly drier gas existing in the unconventional and overpressured lower section. A significant opportunity also exists to move downdip from the existing well control to positions where these upper Laurel higher quality reservoir facies occur within the more mature over-pressured dry gas window (Figure 5).

Figure 4. Flare on the Valhalla- North 1 well during initial testing.

Good analogs to the basin-centered gas system and reservoirs are the Greater Green River and Piceance Basins unconventional plays in North America. Only with additional well data and long-term production testing can we be certain of the downdip extent and overall size of this unconventional resource play.

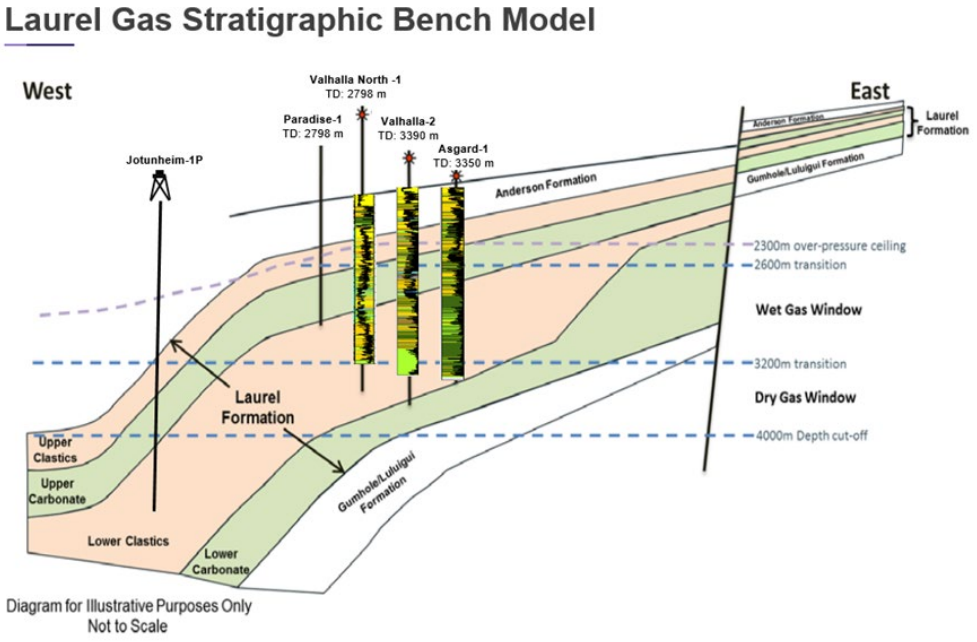

Figure 5. Key updip vertical wells have tested producible quantities of thermogenic gas. A future well is envisioned targeting downdip upper Laurel reservoirs that are optimal in reservoir quality as well as in a dry gas window of higher pressure.

WORKFLOW

The workflow applied to this study was designed to understand the petroleum system and unconventional opportunities of the block (Moore et al. 2020). Even with good data and past analysis, there are significant unknowns in this basin related to the unconventional play. One of the key unknowns is the relationship of the gas shows encountered during drilling to reservoir producibility. Assessing hydrocarbon producibility is often based on well tests or core data; of which there are very limited data for the Laurel. To address this, it is our intent to propose additional testing on the Valhalla-2 well. We believe understanding producibility of the key reservoirs within the Laurel section should be our initial focus. Upon success of vertical testing, this wellbore can also provide an opportunity to drill and complete a short lateral within a sufficiently thick Upper Laurel reservoir.

GEOLOGICAL AND PETROPHYSICAL WORKFLOW

Detailed geological correlations have been made over the Laurel Formation. Key Upper Laurel clastic sections can be correlated over 6 km (Figure 7).

The petrophysical workflow reviewed log and core data that was obtained from 1966-2012 drilling programs to develop a model to characterize the Laurel over the expansive 1.8-million-acre block. Focus was placed on observing calculated reservoir properties to mud gas shows, including seals and probable hydrocarbon phase present. The model developed is calibrated to core and captures lithology, porosity, saturation, and permeability. Geomechanical aspects of the units were evaluated in relation to hydraulic stimulations to understand the producibility of the unconventional system. For individual wells like Valhalla-2, (Figure 6) the petrophysical assessment defined over 11 potential hydrocarbon bearing zones over 1350m of gross reservoir thickness.

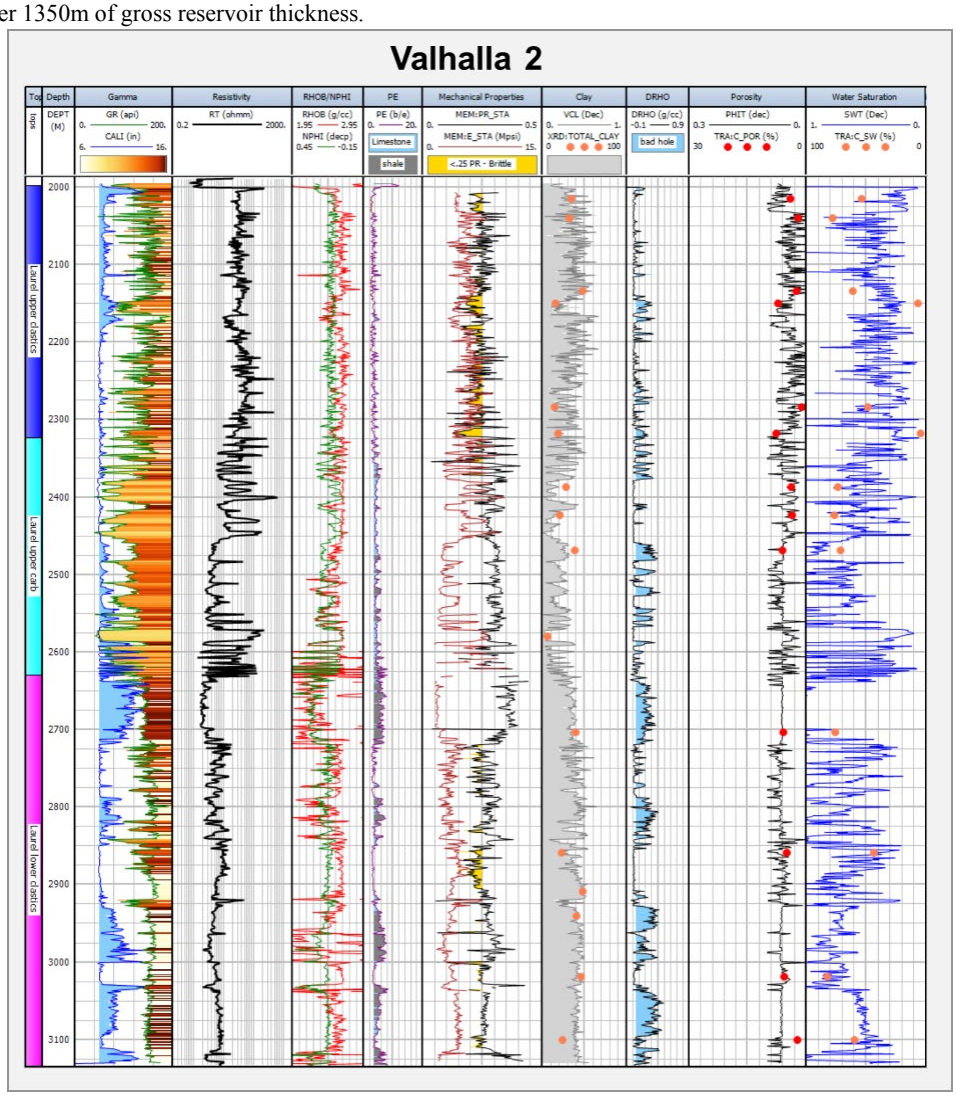

Figure 6. Valhalla-2 vertical well displaying the overall Laurel Section, key log characteristics along with calibrated sidewall core data.

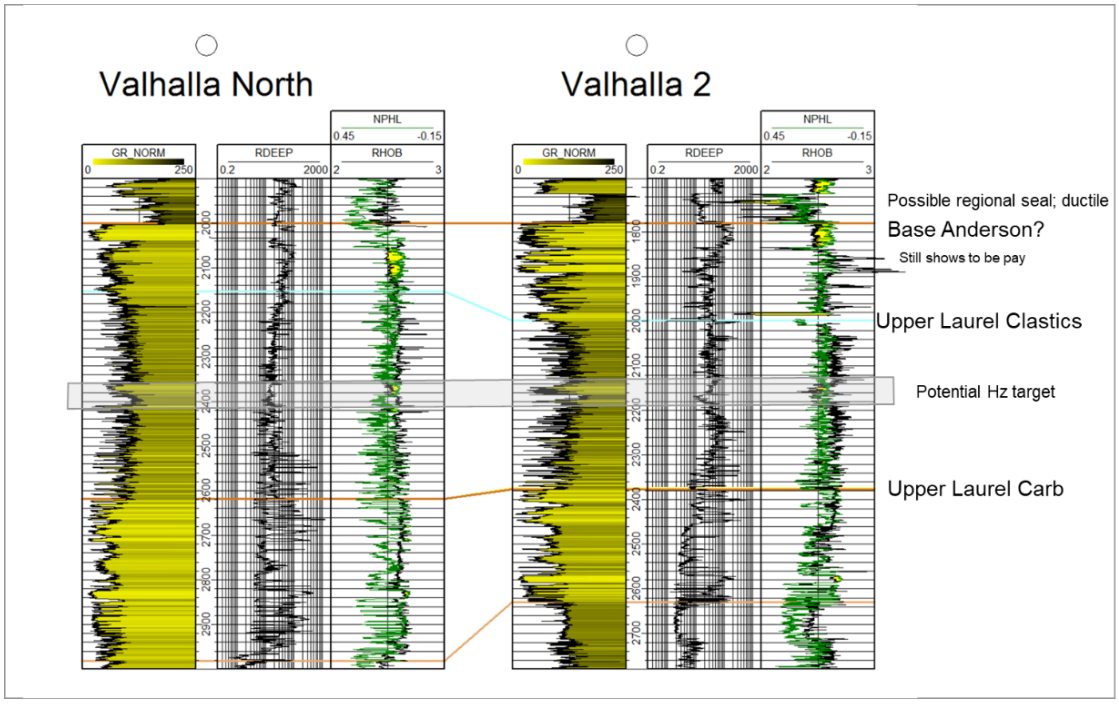

Figure 7. A cross section for the Upper Laurel between two wells in EP-371 that are ~6 km. apart. Correlated tight sandstone reservoir facies highlight a possible horizontal target. Note the overall prograding sequence in the Upper Laurel through Anderson capped by a regional Anderson shale seal.

GEOPHYSICAL WORKFLOW

The interpretation of the deepest part of the Fitzroy Trough has been challenging due to the sparse 2D vintage seismic data. As a result, to further evaluate the block, a 2D seismic program of over 100 km has been permitted and cleared. The existing seismic data demonstrate a relatively steep deepening of the Laurel section into the basin with numerous normal downthrown faults parallel to the shelf margin; typically, with throws of over 100m (Figure 8 and 9). Complex structuring that occurred during the basin's extensional phases appears to have influenced the Laurel sequences. The Permian Carboniferous Meda transpressional event caused reactivation and inversion on numerous basement faults.

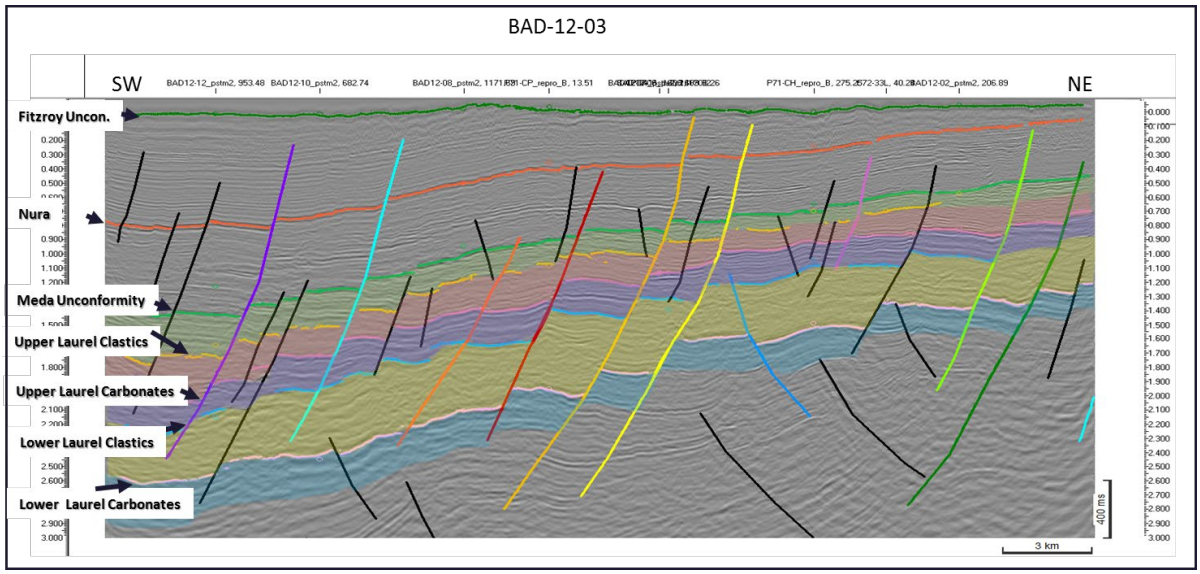

Figure 8. The northern edge of the Fitzroy Trough showing the Laurel Formation benches down stepping into the basin. Some expansion of the Anderson and Laurel sequence is shown. Note the Meda unconformity appears to cut into the Anderson in the most updip portion of the section. An extensive database of 2D seismic was used to map in three dimensions the structural style of the basin margin. The location of this 30 km long line is shown in figure 9.

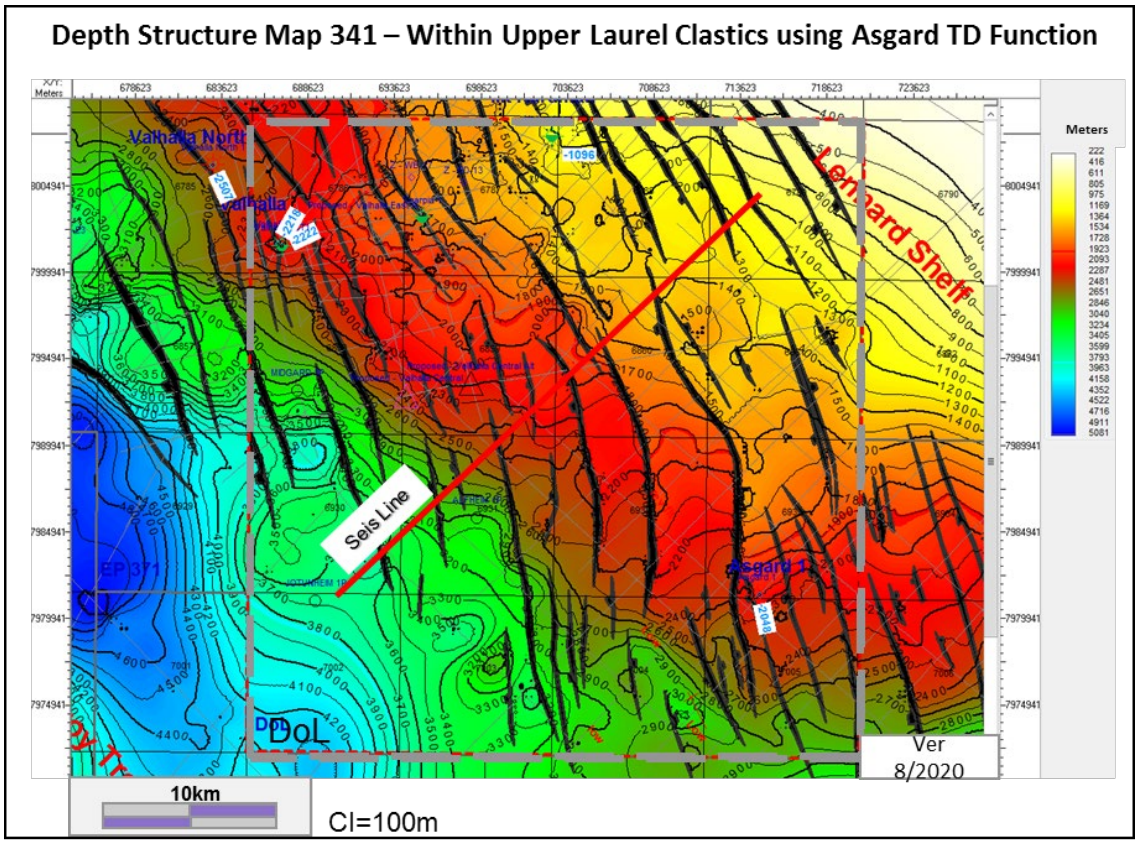

Figure 9. The upper Laurel Depth Structure map highlights downthrown normal faults stepping into the basin. The location of the seismic line in figure 8 is noted. A regulatory declaration for future well locations (DOL) is marked with the grey box.

Beyond mapping and tying in key reflectors, efforts also included an examination of the recent 11 stages of hydraulic stimulations in the vertical Valhalla North 1 and Asgard 1 wells within EP-371 and a study of their relationships to key units within the Laurel. Key units were mapped and recently drilled wells tied in to better understand the thickness and downdip extent of the Laurel Formation and its relationship to the basin-centered gas system.

SUMMARY

A thorough examination of the existing data, including vintage 2D seismic and advanced petrophysics, has confirmed the earlier work of Kingsley and Streitberg (2013) indicating the presence of a basin-centered gas system. The recent conventional Rafael discovery confirms the overall generative petroleum system within the Laurel just west-southwest of our block. While there still are gaps in the understanding of the basin, in particular the relationship of source rocks to reservoir, as well as reservoir productivity, it is clear the unconventional opportunity here is quite large. Potential analogs to these reservoirs might include the unconventional Greater Green River and Piceance Basins in North America.

Understanding the relationship of producibility to reservoir characteristics still needs to be further established. We are proposing a well test in the currently drilled Valhalla-2 well to better define these reservoirs and their producibility.

The Carboniferous Laurel Formation has a handful of well penetrations along which there are two wells within the EP-371 block that have undergone hydraulic stimulations that open a window to the unconventional potential of the formation. While these wells substantiate the presence of producible free gas, additional wells and well tests along with 2D seismic data are needed to better understand the unconventional potential of the Laurel Formation within the Fitzroy Trough. Beyond testing of an existing well, additional vertical and horizontal wells will need to be drilled to confirm the potential for commercial unconventional gas within the basin.

REFERENCES

Cadman, S. J., Pain, L., Vuckovic, V. and le Poidevin, S. R., 1993. Canning Basin, W.A. Bureau of Resource Sciences, Australian Petroleum Accumulations Report 9, 1993.

Feiner S., Lishansky R. , Phiukhao W., Chao J., Moore R., Hall D., and Kubacki C. 2017. Unconventional Reservoir Potential from Trapped Fluid Analysis Onshore Canning Basin, Australia, Unconventional Resources Technology Conference (URTeC) 2670926

Ghori K., and Haines P., 2007. Paleozoic Petroleum Systems of the Canning Basin, Western Australia: A review Search and Discovery Article #10120

Hashimoto, T., Bailey, A. and Chirinos, A., 2018. Onshore basin inventory volume 2: the Canning, Perth and Officer basins. Record 2018/18. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2018.018

Kingsley D. and Streitberg E., 2013. The Exploration History of the Laurel Basin-Centered Gas System Canning Basin, Western Australia, W. Australian Basin Symposium.

Moore J., Hull R., Shelokov V., Rudge T., and Shields J., 2020. The Canning Basin of Western Australia, Discovering Unconventional Opportunity, Unconventional Resources Technology Conference (URTeC) DOI 10.15530/urtec-2020-3297.

Schenk, C, Tennyson M., Mercier T., Woodall C., Finn T., Le P., Brownfield M., Gaswirth S., Marra K, and Leathers-Miller H., Assessment of Undiscovered Oil and Gas Resources in the Canning Basin Province, Australia, 2017 USGS

Shelokov, V., Hull R., Rudge T., and Richmond P.. 2021 Petrophysical Analysis of the Unconventional Reservoirs of the Lennard Shelf and Fitzroy Trough in Canning Basin, Australia January 2021 The APPEA Journal 61(2):714 DOI:10.1071/AJ20087

Zhan, Y. and Mory, A.J., 2013. Structural interpretation of the Northern Canning Basin, Western Australia. In: Keep, M. & Moss, S.J. (Editors), The Sedimentary Basins of Western Australia IV. Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, 2013, pp. 1–18.