# Rediscovering North Perth Basin in Unconventional Arena*

**Steve Broome[1], Arijit Chaudhuri[2], D.P. Singh[2], and Arnab Nag[2]**

Search and Discovery Article #10785 (2015)
Posted November 2, 2015

*Adapted from extended abstract prepared in conjunction with poster presentation at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015, AAPG/SEG © 2015.

[1]Technical, Norwest Energy NL, Perth, WA, Australia (Steve.Broome@norwestenergy.com.au)
[2]G & G, BPRL, Mumbai, Maharashtra, India

## Abstract

North Perth Basin, known for its potential since its initial commercial discovery in 1964, holds about 10km thick sediments. Irwin River Coal Measure (IRCM) and Carynginia Shale (both Permian), Kockatea Shale (Triassic) and Catamarra Coal Measure (Jurassic) are proven source in the basin. Dandaragan trough, the main depocentre and source area in North Perth sinks deep into the realm of metagenesis towards east. Hydrocarbon fields Woodada (gas), Behara Springs (gas), Jingemia (oil), Hovea (oil), and Dongara etc. are located on its gentler western flank. Such preferential migration towards the gentle flank of half grabens is well known, e.g., Cauvery, India and Reconcavo, Brazil. Though endowed with multiple zones of reservoir and source facies, the conventional hydrocarbon pools in North Perth are limited in size. Considered sub-commercial based on conventional practices at that time, well AS-1 flowed 4-mmscfd gas during testing (1965). Mountain Bridge-1 (1993) demonstrated gas flows from other prospective formations during DST widening and deepening the resource potential of North Perth Basin. Decades later, basin wide review led to exploration and hydraulic stimulation of the unconventional zones demonstrated that sustained hydrocarbon flow could be maintained from the formations and provided critical evidence to underpin multi TCF unconventional resource bookings in Perth basin (GIIP 167TCF, EIA, 2013). Recent wells drilled with shale objectives from north to south at Senecio, Arrowsmith (AS), Woodada Deep and Drover flowed oil and gas from three of the four identified source facies in addition to tight sands. The current paper discusses results of vertical well AS-2 (five tested zones) in conjunction with public domain information of the other three wells to bring out its significance in North Perth Basin as a whole. Fault breach has been cited as reason for absence of a hydrocarbon pool in recently drilled shallow offshore well Red Hill South. The low permeability inherent to unconventional shale reservoirs makes them less prone to leakage. The encouraging flow of gas from multiple hydrocarbon zones in Permo-Traissic from four wells located wide apart in the axial direction has put North Perth on a firm footing for future hydrocarbon search within these reservoirs. Aid of 3D seismic, sweet spot identification and a few horizontal wells to fracture-test would give fillip to further unconventional hydrocarbon exploration in North Perth basin.

## Introduction

The North Perth Basin, known for its potential since its initial commercial discovery in 1964 holds approximately12km of thick sediments. The Irwin River Coal Measures (Permian), Carynginia Shale (Permian), Kockatea Shale (Triassic) and Cattamarra Coal Measures (Jurassic) are all proven sources in the basin (Figure 1a and b).

## Discussion

Dandaragan Trough, the main depocentre and source area in the North Perth Basin sinks deep into the realms of metagenesis towards east. Hydrocarbon fields Woodada (gas), Beharra Springs (gas), Jingemia (oil), Hovea (oil), Dongara (gas) etc. are located on its gentler western flank (Figure 2). Such preferential migration towards the gentle flank of half-grabens is also seen in Cauvery, India and Reconcavo, Brazil (Figure 3a and b).

Though endowed with multiple zones of reservoir and source facies, the discovered conventional hydrocarbon pools in the North Perth Basin are limited in size. This was corroborated by the lack of hydrocarbons in a recent shallow offshore well, Red Hill South-1 located on the far western flank. An explanation for the absence of hydrocarbons in this well could be fault breach. The low permeability inherent to unconventional formations makes them a good prospect, as they are less prone to leakage. With success harder to find in conventional targets, exploration has focused on the unconventional plays.

Historical discovery well Arrowmsith-1 was drilled in 1965, and a thin sandstone layer within the Carynginia Shale was tested. Although gas flowed at a rate of four MMscfd (million standard cubic feet per day), this was short-lived and considered sub-commercial based on conventional practices at that time. In the same well oil bleeding from core within Kockatea shale and oil fluorescence from IRCM and HCSS were also reported. Mountain Bridge-1 drilled in 1993 demonstrated gas flows from IRCM/HCSS Formations during the DST, thereby widening and deepening the resource potential of the North Perth Basin.

Decades later, a basin-wide review leading to drilling and hydraulic stimulation of the unconventional zones demonstrated that sustained hydrocarbon flow could be maintained from the formations and provided critical evidence to underpin multi TCF unconventional resource bookings within the basin (GIIP 167TCF, EIA, 2013). These recent unconventional well discoveries trending from north to south at Senecio, Arrowsmith (AS), Woodada Deep and Drover all identified gas and oil from multiple source facies in addition to tight sands (Figure 4).

## Results and Conclusions

The results of vertical well Arrowsmith-2 (five tested Permo-Traissic zones) in conjunction with available information on a few recently drilled wells underscore the potential of unconventional plays in the Northern Perth Basin. The composite plot in Figure 5 summarizes the attributes of target zones along with the successful testing of hydrocarbons at unconventional well AS-2. The average geochemical characteristics of the target zones within the various formations tested in the AS-2 well is presented in Table 1.

Finally, Table 2 summarizes the flow rates which were measured during short individual flowback periods post stimulation in the AS-2 zones. Further testing and commingled production of the zones high-graded the IRCM and Carynginia formations as the dominant gas production zones. The western gentle flank of the Northern Perth Basin, dotted with discoveries and a relatively shallow occurrence of source rock facies may turn out to be a focus area for future exploration and exploitation of unconventional hydrocarbon resources. 3D seismic, sweet spot identification and trial horizontal wells will provide the necessary certainty for future unconventional development in the Northern Perth Basin.

## Acknowledgements

The authors are grateful to the authorities from Norwest Energy (NWE), AWE Limited (AWE) and Bharat PetroResources Limited (BPRL) for granting permission to work on this paper and utilization of the well information pertaining to well AS-2.

## Selected References

Agência Nacional do Petróleo, Bid Round 4, 2002, Seção Geológica Esquemática da Bacia do Recôncavo, Recôncavo Basin Schematic Cross Section: Web Accessed October 17, 2015

Crostella, A., 1995, An evaluation of the hydrocarbon potential of the onshore northern Perth Basin: Geological Survey of Western Australia, Report 43.

Geoscience Australia, Northern Perth Basin Stratigraphy. Web Accessed October 17, 2015

Mory, A.J., and R.P. Iasky, 1996, Stratigraphy and structure of the onshore northern Perth Basin, Western Australia: Geological Survey of Western Australia, Report 46.

Penteado, H.L.B., 1999, Modélisation compositionnelle 2D de la genèse, expulsion et migration du pétrole dans le Compartiment Sud du Bassin de Recôncavo, Brésil: PhD. Thesis, Université Pierre et Marie Curie, Paris, France.

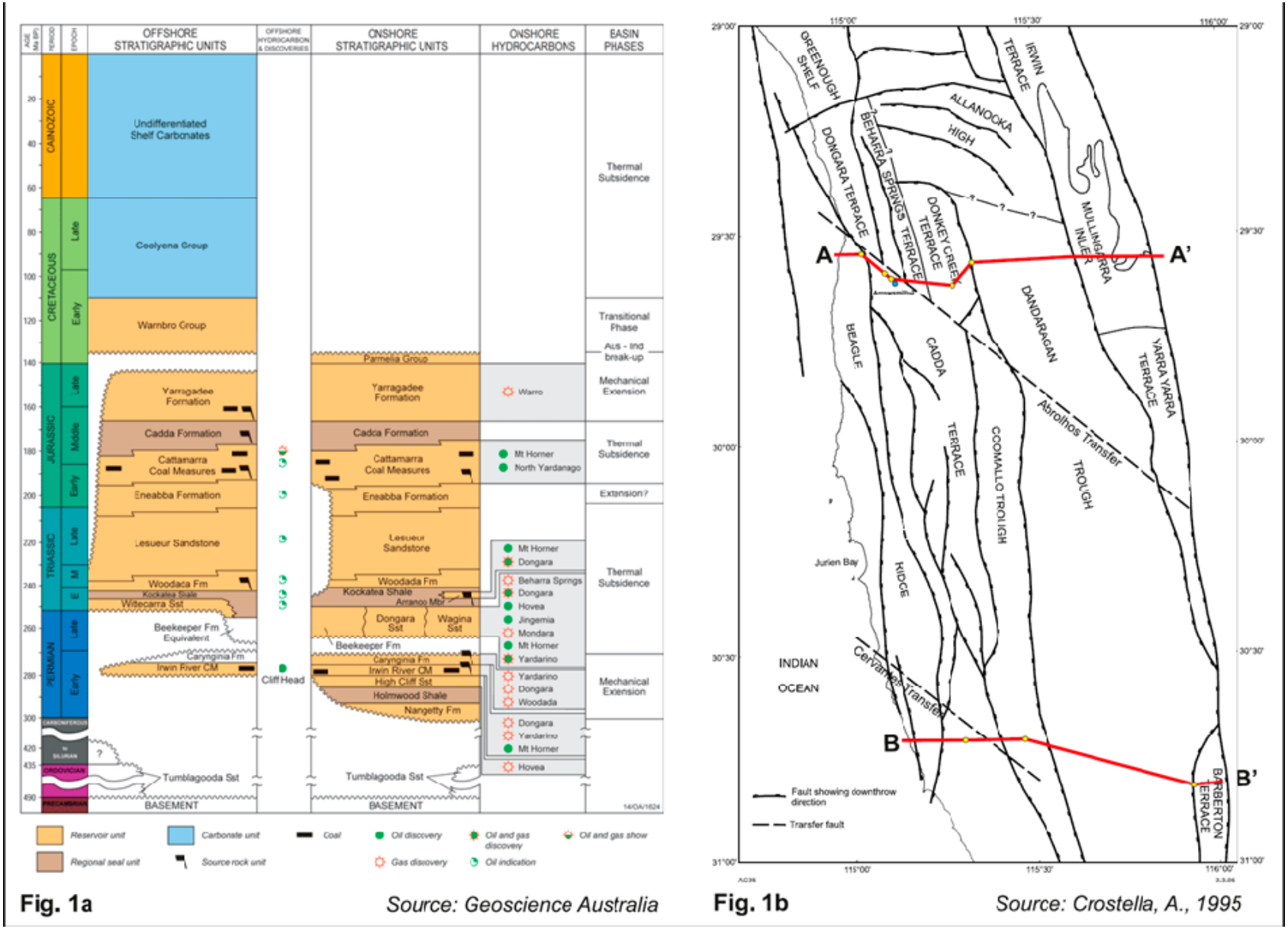


Figure 1a and b. Generalized stratigraphy and index map with major structural elements of the North Perth Basin. Lines A-A' and B-B' on the index map indicate orientation of the geological sections in Figure 2.

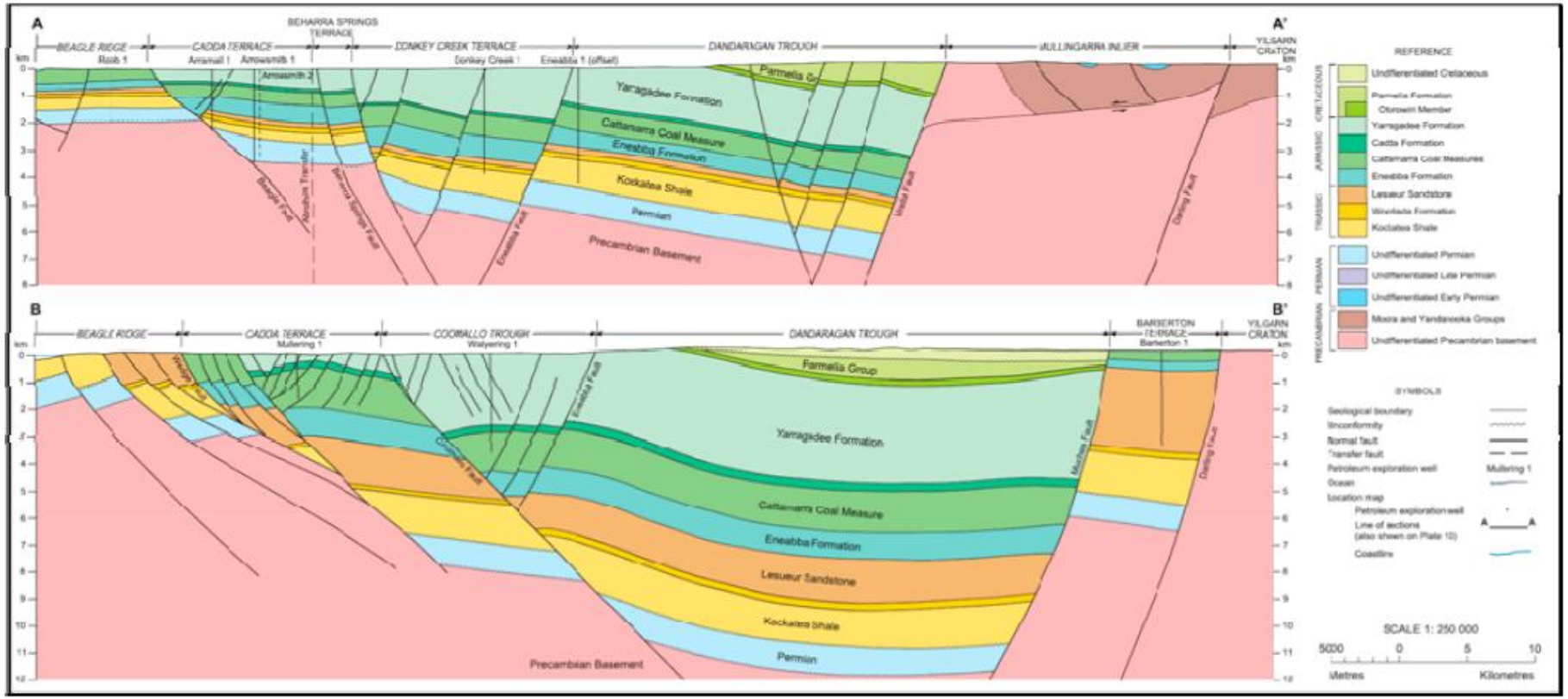


Figure 2. Representative geological sections across the northern and southern sectors of the North Perth Basin. The hydrocarbon finds are on the western gentle flank. The Dandaragan Trough represents a sedimentary column of thickness ~12km (from Mory et. al. 1996). The Permian section represents three tested unconventional zones in well Arrowsmith-2, viz., High Cliff Sandstone (HCSS), Irwin River Coal Measures (IRCM) and the Carynginia Shale.

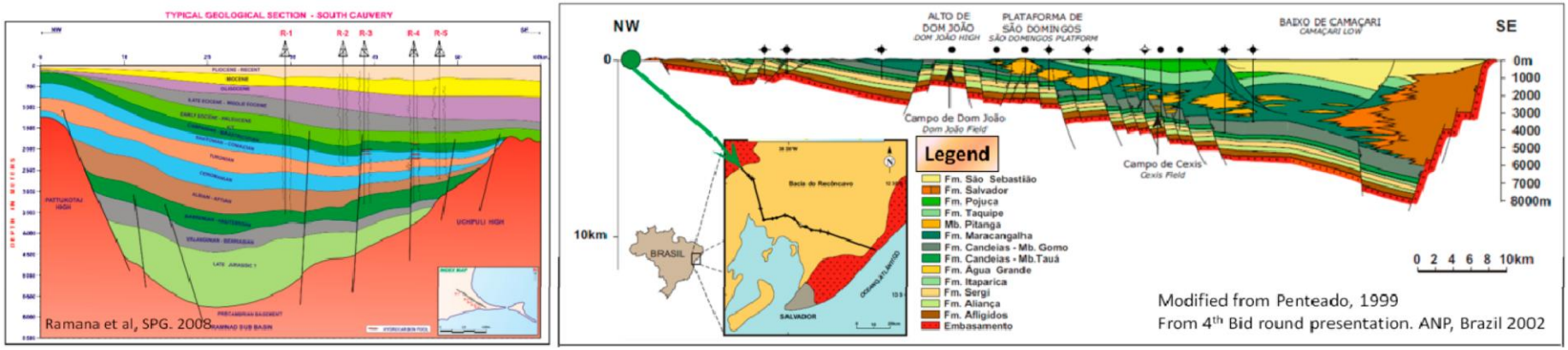


Figure 3a and b. Representative geological sections across the Cauvery Basin, India and the Reconcavo Basin, Brazil. The crowding of successful wells on the gentle flank of the half-grabens indicates higher propensity for hydrocarbons.

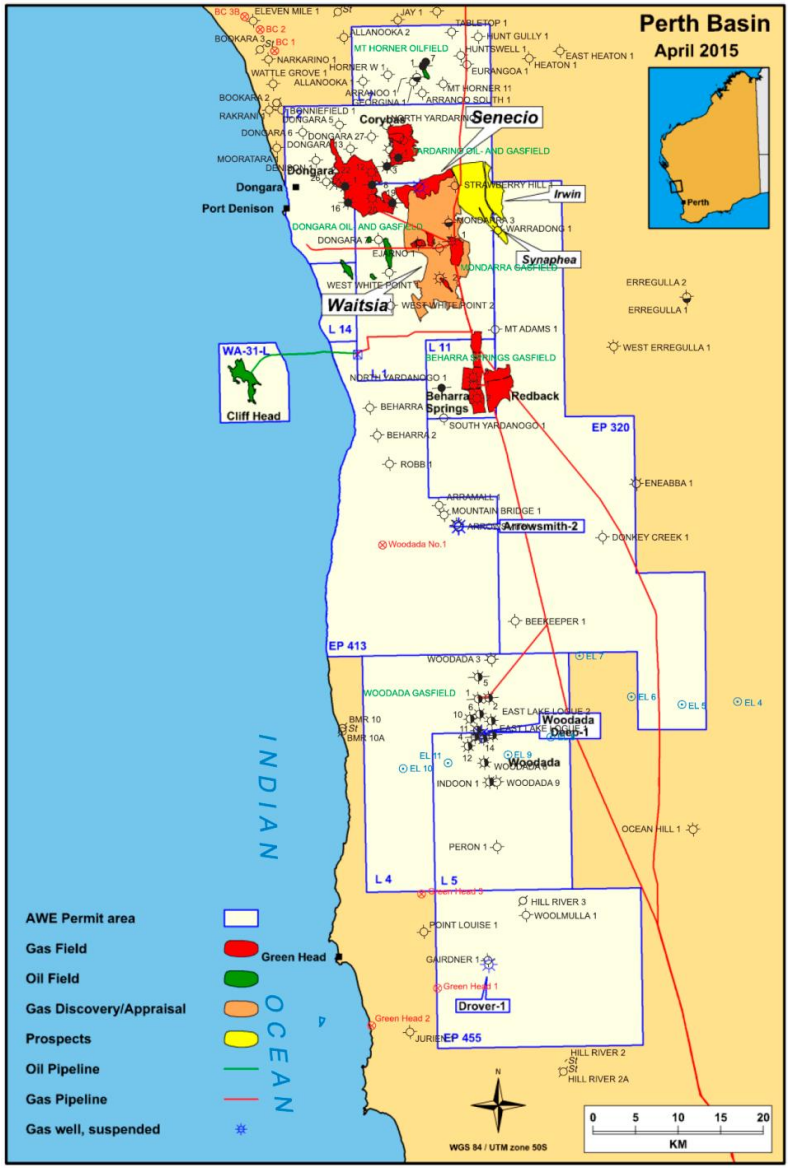


Figure 4. Index map of drilled wells and oil and gas fields in the North Perth Basin. The North-South trend of conventional oil and gas discoveries occurring on the gentle flank of the Dandaragan trough coincides with the trend of success emerging in the unconventional arena. Starting from south, wells Drover, Woodada Deep, Arrowsmith-2, and Senecio have indicated the presence of producible hydrocarbons from Shale and Tight gas formations (Modified after AWE).

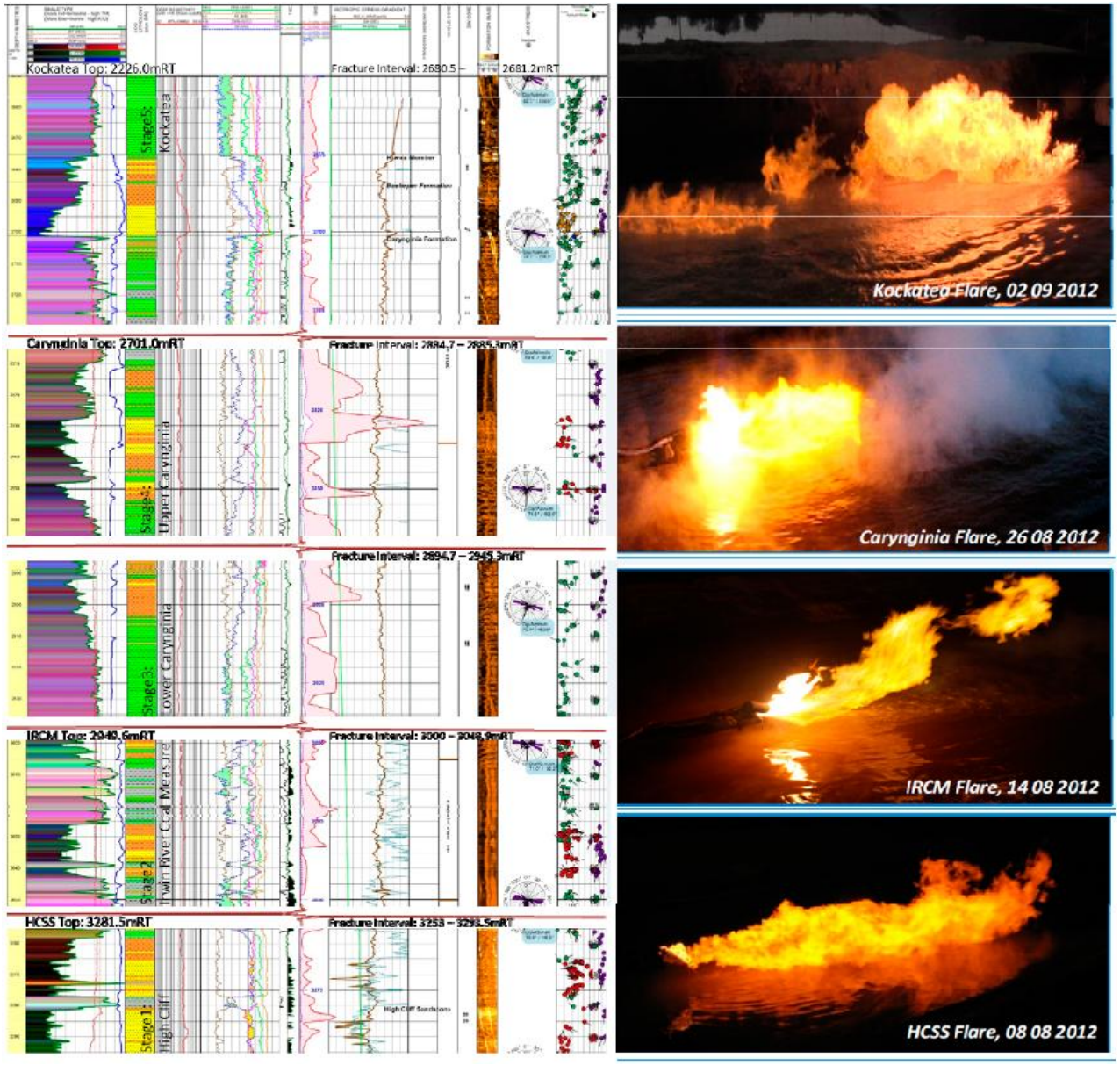


Figure 5. Results of well Arrowsmith-2. Five zones were hydro-fractured with slick water and tested. Zones three and four within the Carynginia Shale were flowed back together. The lower four zones within the Permian flowed gas, whereas the Triassic Kockatea shale produced wax-rich oil.

| Formation Name | Lithology | TOC wt% | HI | Production Index | S1 (mg/g) | PhiE % | Max.Total Gas Unit | Gas Saturation |
|---|---|---|---|---|---|---|---|---|
| Kockatea | SHALE | 0.51-0.60 | 194-210 | 0.19-0.15 | 0.22-0.23 | 1.55 | 92 | 5 - 10% |
| Upper Carynginia | SHALE with occasional interbedded SANDSTONE. | 1.36-0.17 | 30-55 | 0.25-0.54 | 0.04-0.33 | 2.67-6.08 | 275 | > 20% |
| Lower Carynginia | SHALE with interbedded SANDSTONE | 1.48-0.33 | 53-30 | 0.25-0.47 | 0.09-0.27 | 3.95 | 216 | >25% |
| IRCM | SILTSTONE | 7.0-0.06 | 33-107 | 0.6-0.12 | 0.88-0.03 | 2.54 | 111 | > 30% |
| HCSS | SANDSTONE with occasional interbedded SHALE | 0.13 | 23 | 0.63 | 0.05-0.11 | 5.81 | 107 | > 35% |

Table 1. Geochemical characteristics of target formations and fracture intervals in Arrowsmith-2.

| Frac Stage | Formation | Type | Depth | Hydrocarbons Encountered | Gas Flow Rates (scf/d) | Discovery Ranking (D&M) |
|---|---|---|---|---|---|---|
| 1 | HCSS | Tight Sandstone | 3279-3301m | Gas | 777,000 | Yes |
| 2 | IRCM | Sandstone / Shale | 3000-3050m | Gas | Yet to be evaluated | Yes |
| 3 | Lower Carynginia | Shale | 2890-2940m | Gas and Condensate | 500,000+ Combined rate Stages 3&4 | Yes |
| 4 | Middle Carynginia | Shale | 2824-2875m | Gas and Condensate | | Yes |
| 5 | Kockatea Shale | Shale | 2639-2681m | Gas and Oil | 414,000 | Yes |

Table 2. Flow back results of Arrowsmith-2. Though not evident in the table, production logging during commingled flow brought out higher hydrocarbon potential in the IRCM and the Carynginia Shale Formation.