Petroleum Systems Modelling of the Perth Basin, Western Australia*

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Abstract

Petroleum geochemistry of over 4000 rock and oil samples identified source beds within the: (a) Permian Irwin Coal Measures and Carynginia Formation, which are predominantly gas prone, and sourced petroleum to the Whicher Range Gas Field, southern Perth Basin, (b) Triassic Kockatea shale, which is oil prone, and sourced petroleum to the Dongara, Erregulla, Mount Horner, and Yardarino oilfields, northern Perth Basin, and (c) Jurassic Cattamarra Coal Measures, which are gas and oil prone, and sourced petroleum to the Walyering Gas Field, central Perth Basin.

Organic petrology and Apatite Fission Track Analysis (AFTA) of 15 samples from Arranoo South 1, Cataby 1, and West Erregulla 1 identified two regional paleothermal events, the first during the Cretaceous (135-56 Ma) and the second in the Tertiary (30-0 Ma). These events differ locally. Petroleum system modelling of over 60 wells with source rock data indicates major subsidence and burial occurred during the Permian-Jurassic. Source rock maturities and time of petroleum generation were influenced by the Cretaceous and Tertiary paleothermal events. These models were used to calibrate measured data in order to predict the regional distribution of Rock-Eval and other parameters: potential yield S2, hydrogen index, production index, transformation ratio, temperature, and %Ro for the Permian, Triassic, and Jurassic source rocks.

The Triassic Kockatea Shale contains the best source units of the northern Perth Basin; their maximum organic richness is 11% TOC, potential yield is 81 S2 mg/g, and hydrogen index is 800 mg HC/g TOC. In the central Perth Basin, the Jurassic
Cattamarra Coal Measures contain the main source beds; their maximum organic richness is 50% TOC, potential yield is 76 S2 mg/g, and hydrogen index is 760 mg HC/g TOC. The Permian Irwin River Coal Measures and Carynginia Formation contain the most important source rocks of the southern Perth Basin; their maximum organic richness is 47% TOC and 31% TOC, potential yield is 20 S2 mg/g and 15 S2 mg/g, and hydrogen index is 150 mg HC/g TOC and 200 mg HC/g TOC, respectively. The timing of petroleum generation-expulsion-accumulation was spread over the Cretaceous-Tertiary interval within the northern Perth Basin, varying from Early Cretaceous in the Erregulla area to Late Cretaceous-Tertiary in the Jingemia area.
Petroleum System Modelling of the Perth Basin
Western Australia

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100 AAPG ANNIVERSARY ACE 2-4 APRIL, 2017, HOUSTON
April 4, 2017: 11:30 – 11:50 AM
Petroleum System Modelling

- 49 wells with petroleum geochemistry data are modelled using Platte River Associates’ latest release - Petroleum Systems Suite of software 2017:
  - 1D BasinMod, BasinMod, BasinView, 2D BasinMod.
- Well models were calibrated using measured and calculated data including:
  - petroleum geochemistry, organic petrology, apatite fission track analysis (AFTA), heat-flow data, subsurface temperatures, and other exploration data from the onshore Perth Basin.
- These wells are from different structure units, mostly within the northern Perth Basin.
Perth Basin – Petroleum Systems

- Perth Basin & Prospectivity → Petroleum systems
  & modelling → Conclusions
Discovery Producing History

- MOUNT HORNER, GINGIN, ARROWSMITH
- YARDARINO
- DONGARA, ERREGULLA 1
- NORTH ERREGULLA 1
- WHICHER RANGE, MONDARRA 1 & 2, GAGE ROAD 1
- WALYERING
- WOODADA
- WARRO
- NORTH YARDANOGA, BEHARRA SPRINGS, WEST ERREGULLA
- BOOTINE 1
- BEHARRA SPRINGS NORTH, HOVEA
- OCEAN HILLS 1
- CORYBAS 1, SENECIO 1
- REDBACK 1, XYRIS, APIUM, TARANTULA, AGONIC 1, CENTELLA 1
- EREMIA, SNOTTYGOBBLE 1, ARROWSMITH 2
- RED GULLY, WOODADA DEEP 1, SENECIO 3
- GINGIN, WEST 1
- WAITSIA 1 & 2
Perth Basin Data Distribution

- **Wells**: 364
- **TOC & RE**: 110
- **VR Maturity**: 78
- **Heat Flow**: 162

Map showing the distribution of data with areas labeled:
- **Dandaragan Trough**
- **Mandurah Terrace**
- **Bunbar Trough**
Apatite Fission Track Analysis

- Regional paleothermal event of the Perth Basin
- Identified from analysis of 15 samples representing 26 tracks of the Permian to Jurassic rocks from three wells:
  - Arranoo South 1
  - Cataby 1
  - West Erregulla 1
A' South
Woodada 05  Arrowsmith 2  Beharra 2  Drakea 1  Jingemia 1  Mt Horner 01

North A
Mungarra 1

Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Woodada Fm
Kockatea Sh
Wagina Ss
Carynina Fm
Irwin River CM
High Cliff Ss
Holmwood Sh
Nangetti Fm

Transformation Ratio (fraction)

X Distance (km)
0 20 40 60 80 100 115
0 20 40 60 80

3500 3000 2500 2000 1500 1000 500 0
Fracturing Quality - Petrography

Permian Carynginia Formation
Redback 1: 3762.00 m
TOC = 2.38%
Ro = 1.40%
Brittleness: 0.38

Triassic Kockatea Shale
Redback 2: 3788.52 m
TOC = 2.29%
Ro = 1.32%
Brittleness: 0.29
Gas-condensate Production - 2016

Government of Western Australia  Department of Mines and Petroleum

Tight - sand

Beharra Springs
Corybas
Dongara
Red Gully
Redback
Senecio
Tarantula
Waitsia
Total

Gas (cf)
Liquid (bbl)

51,572 (bbl)
5,514,987,223 (cf)
Perth Basin Petroleum Systems

Northern

Southern

Northwest:

Yarragadee Fm
Catta Marra CM
Eneabba Fm
Lesueur Ss
Kockatea Sh
Wagina Ss
Caryginya Fm
Irwin CM

Southwest:

Wambro Gp
Yarragadee Fm
Cattamara CM
Lesueur Ss
Sabina Ss
Willespie Fm

Depth Subsurf (m)

Depth Subsea (m)

Age (my)

Age (my)

Permian

Triassic

Kockatea Shale
HC Expelled (mg/g TOC)

Source
Reservoir
Trap

Critical Moment

Preservation
Gen.-Mig.-Accum.
Overburden
Seal

Critical Moment

Permian

HC Expelled (mg/g TOC)

Age (my)
Total Gross: + 700 Bcf
Waitsia Gasfield 2014
largest on shore discovery
Reserves: 460 Bcf (2P)
Accessed Gas ~100 bcf
Source: AWE 2015 + Oil & Gas Australia
February 2017

Permian Carynginia
Formation: Gas 24.8 Tcf
Triassic Kockatea
Shale: Gas 7.9 Tcf
Oil: 0.54 billion bbl

Gas Reserves: 0.05 Tcf (2P)
Gas Resources: 0.33 Tcf (2C)
Source: Department of Mines & Petroleum

Gas Reserves: 12 Tcf (GIIP)
Source: EIA/ARI 2013

Permian Carynginia
Formation: Gas 24.8 Tcf
Triassic Kockatea
Shale: Gas 7.9 Tcf
Oil: 0.54 billion bbl

Source: EIA/ARI 2013
Thanks: Questions Time
Coal + Oil + Gas Era: 84%