Emerging Shale and Tight-Sand Plays, Perth Basin, Western Australia*

Ameed Ghori[1]

Search and Discovery Article #10849 (2016)**
Posted July 5, 2016

*Adapted from oral presentation given at AAPG Asia Pacific Region, Geosciences Technology Workshop, Characterization of Asian Hydrocarbon Reservoirs, Bangkok, Thailand, March 31 - April 1, 2016

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Abstract

Exploration of shale petroleum in the Perth Basin was driven by the rapid increase in shale gas production in the US after 2005. Since the early 70s, hydrocarbon trapped within the source rocks was known and addressed in many publications, but the production of these hydrocarbons was proved when US gas reserves globally rated the highest in 2009. Production from these reservoirs has changed the position of the US from importer to exporter; it achieved the world's highest oil and gas production in 2014. In shale reservoir, trapping mechanisms are typically subtle and cover large basinal areas; the timing of charge versus trap formation is not as critical as it is in conventional reservoir systems. The US achieved production from shale reservoirs by using a combination of horizontal drilling and hydraulic fracturing. The geological understanding and petroleum prospectivity of the Perth Basin is gradually growing with regard to tight and conventional reservoirs. The Perth Basin has a well-developed infrastructure to explore and exploit shale petroleum resources.

Reference Cited

Saucier, H., 2015, How the U.S. Became the World's Top Producer: AAPG Explorer, June 2015, Web Accesses June 19, 2016, http://www.aapg.org/publications/news/explorer/details/articleid/20368/how-the-u-s-became-the-world

Emerging Shale and Tight-sand Plays, Perth Basin Western Australia

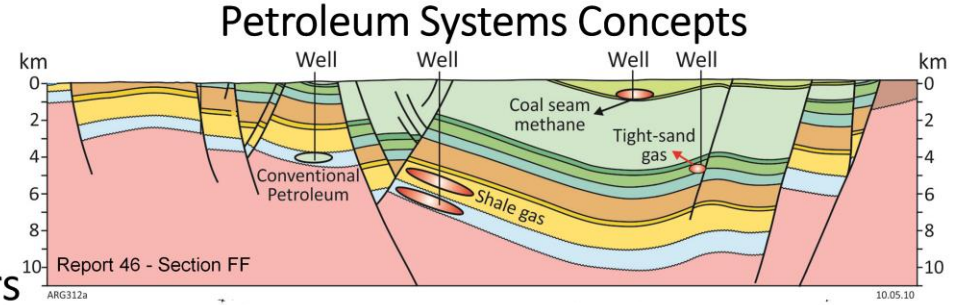
Ameed Ghori

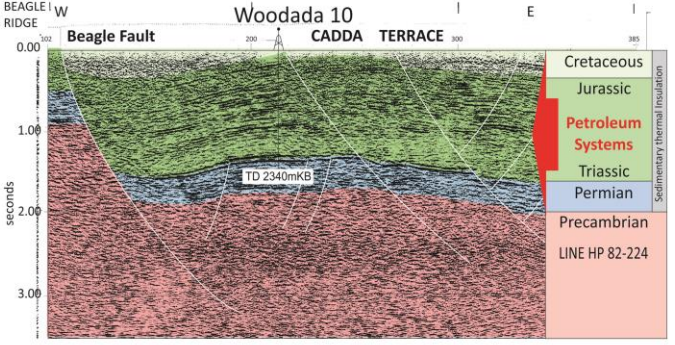
AAPG GTW "Characterization of Asian Hydrocarbon Reservoirs"
Bangkok, Thailand

Friday 1 April 2016: 1:40 – 2:05 PM

Presentation - Overview

- Perth Basin
- Tight-Reservoirs
- Shale-play modelling
- Petroleum production
- Conclusions





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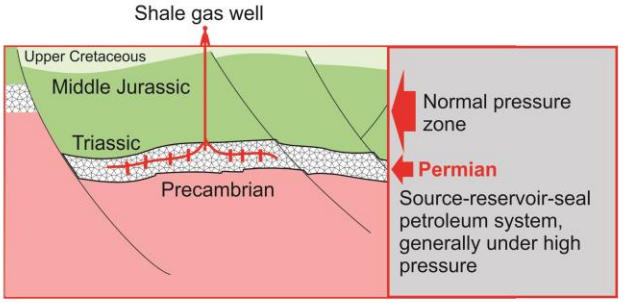
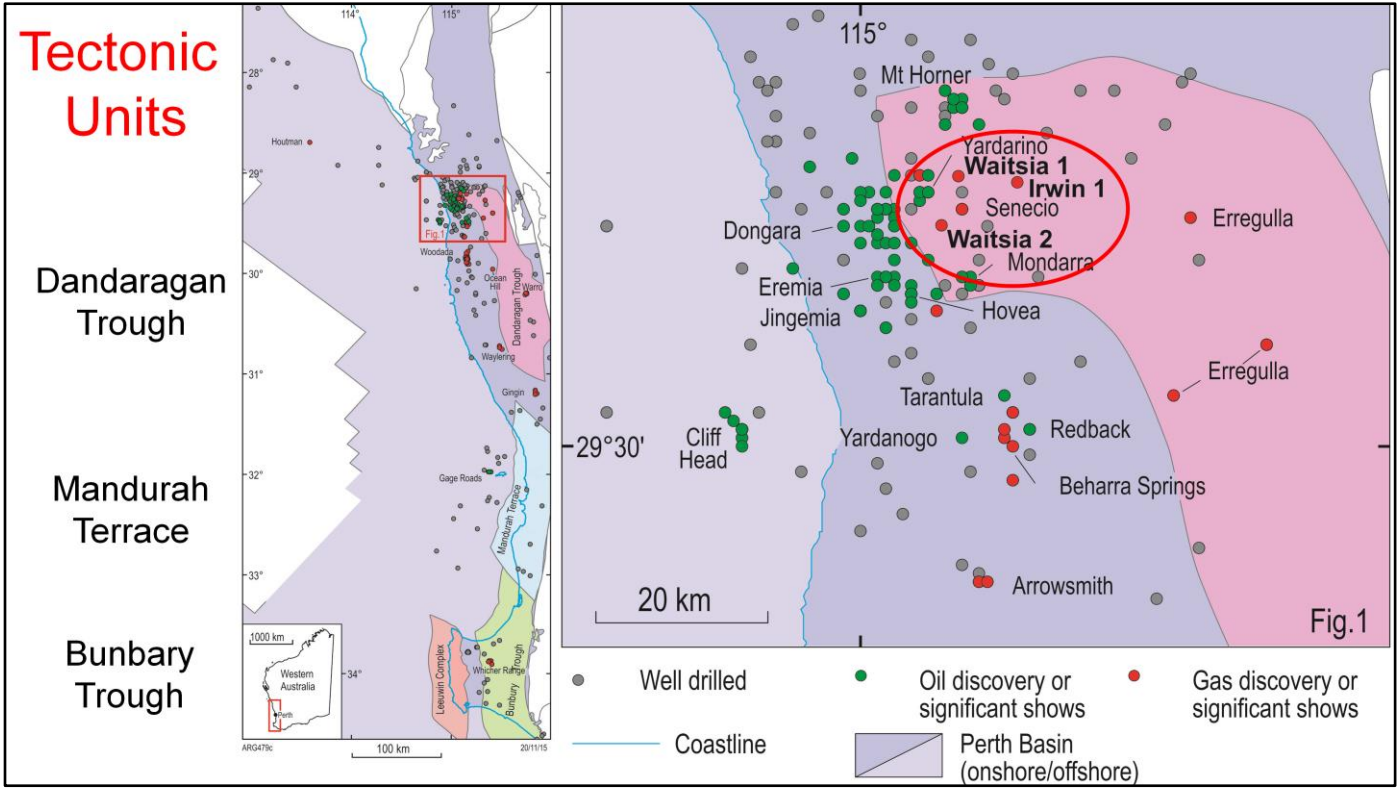
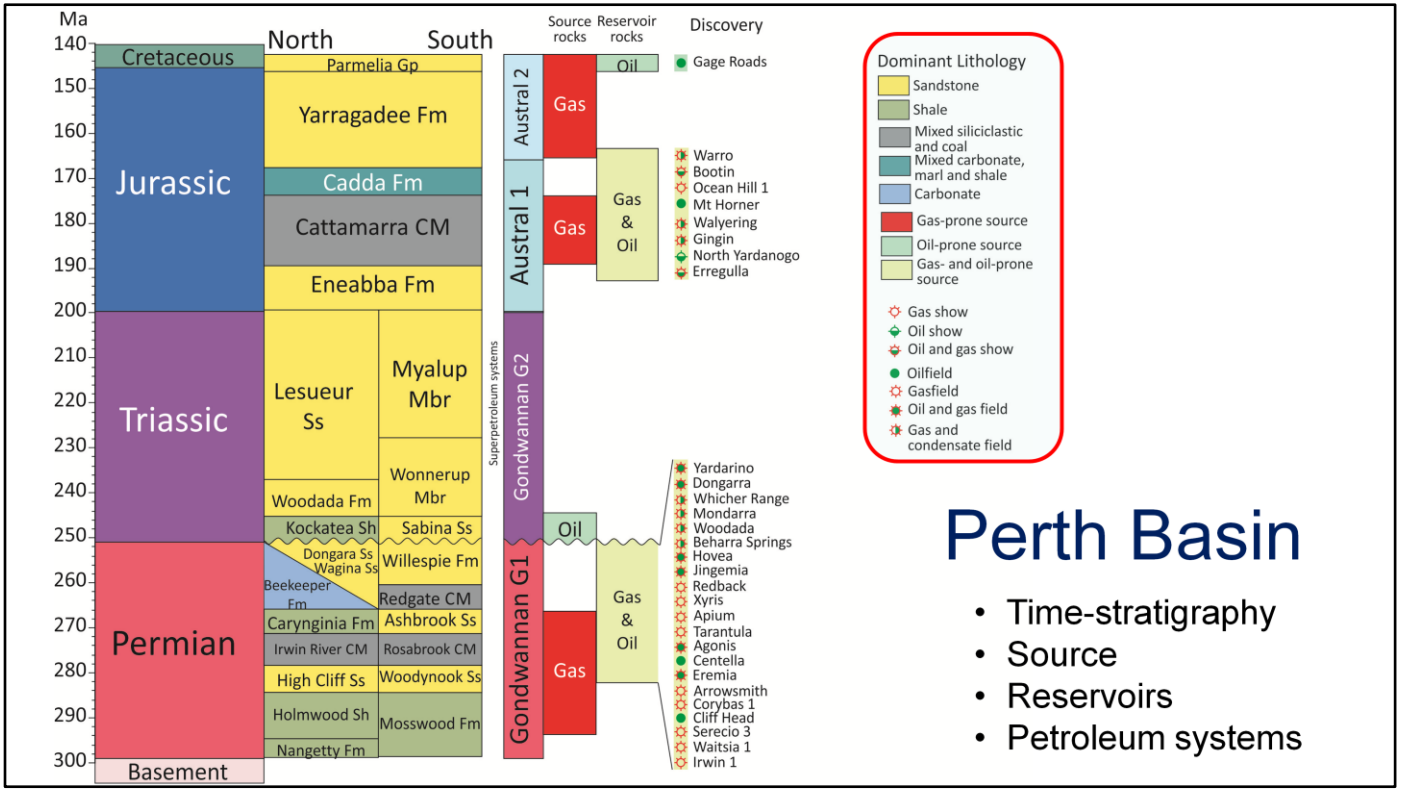
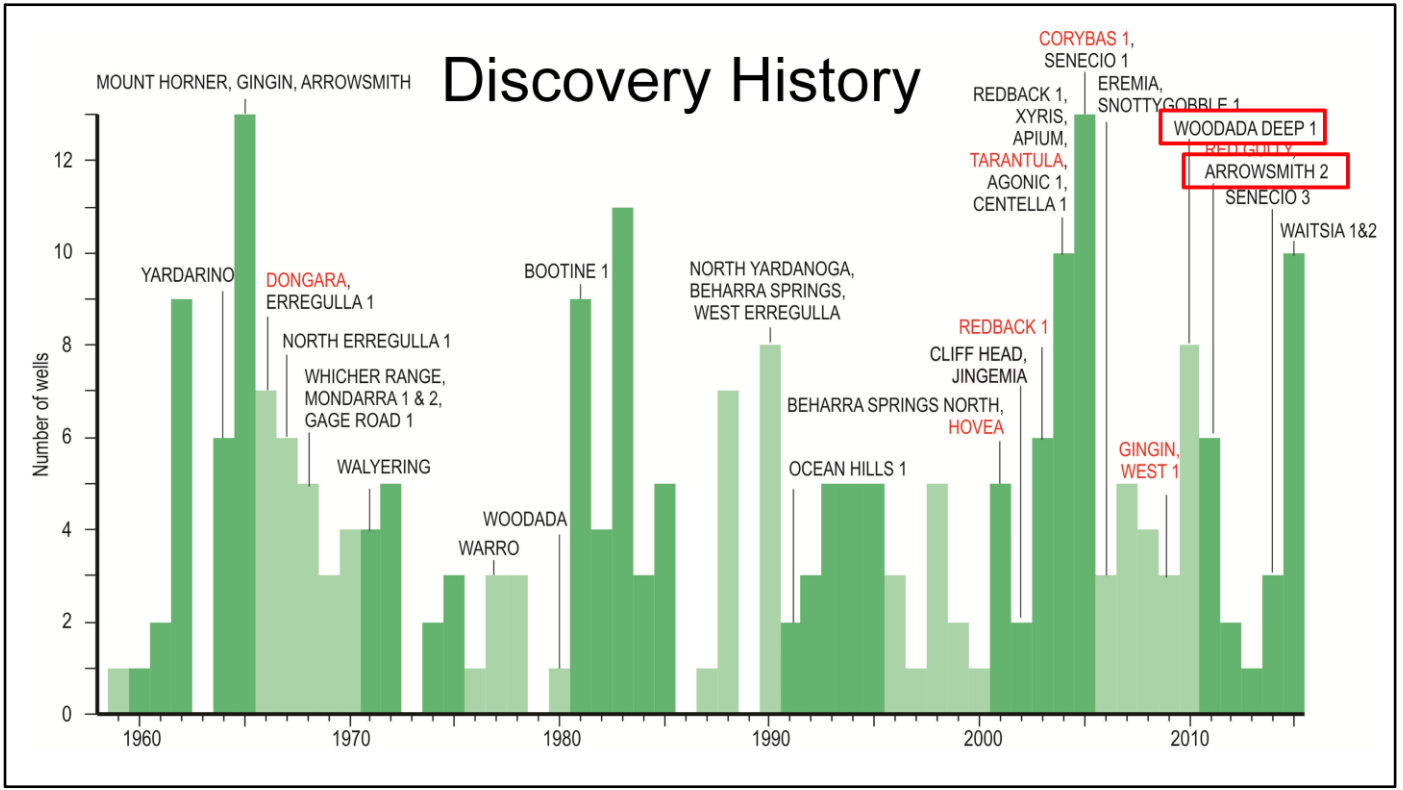



Tectonic Units
Dandaragan Trough
Mandurah Terrace
Bunbary Trough
Houtman
Woodada
Fig.1
Ocean Hill
Wamo
Dandaragan Trough
Waylering
Gingin
Gage Roads
Mandurah Terrace
Leeuwin Complex
Whicher Range
Bunbury
1000 km
Western Australia
Perth
ARG479ic
100 km
20/11/15
115°
Mt Horner
Yardarino
Waitsia 1
Irwin 1
Senecio
Waitsia 2
Mondarra
Dongara
Eremia
Jingemia
Hovea
Erregulla
Erregulla
Tarantula
Redback
29°30'
Cliff Head
Yardanogo
Beharra Springs
Arrowsmith
20 km
Fig.1
Well drilled
Oil discovery or significant shows
Gas discovery or significant shows
Coastline
Perth Basin (onshore/offshore)



Perth Basin

- Time-stratigraphy
- Source
- Reservoirs
- Petroleum systems


Discovery History
Number of wells
0
2
4
6
8
10
12
1960
1970
1980
1990
2000
2010
MOUNT HORNER, GINGIN, ARROWSMITH
YARDARINO
DONGARA, ERREGULLA 1
NORTH ERREGULLA 1
WHICHER RANGE, MONDARRA 1 & 2, GAGE ROAD 1
WALYERING
WOODADA
WARRO
BOOTINE 1
NORTH YARDANOGA, BEHARRA SPRINGS, WEST ERREGULLA
BEHARRA SPRINGS NORTH, HOVEA
OCEAN HILLS 1
REDBACK 1
CLIFF HEAD, JINGEMIA
CORYBAS 1, SENECIO 1
REDBACK 1, XYRIS, APIUM, TARANTULA, AGONIC 1, CENTELLA 1
EREMIA, SNOTTYGOBBLE 1
GINGIN, WEST 1
WOODADA DEEP 1
REDGULLY
ARROWSMITH 2
SENECIO 3
WAITSIA 1&2

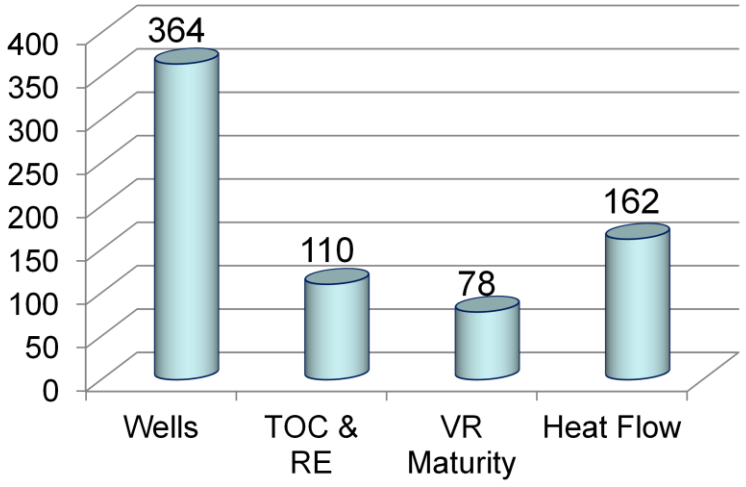
Woodada Deep 1

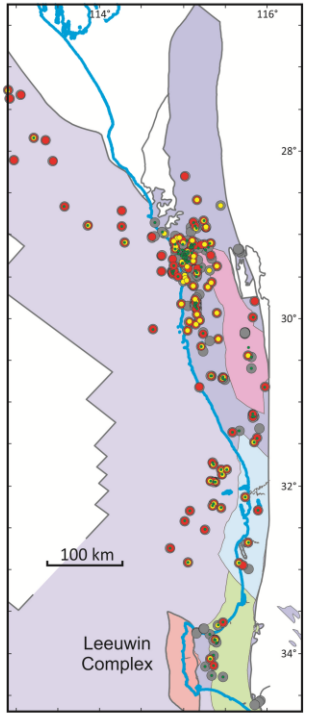
Gas Flare - 11 August 2012

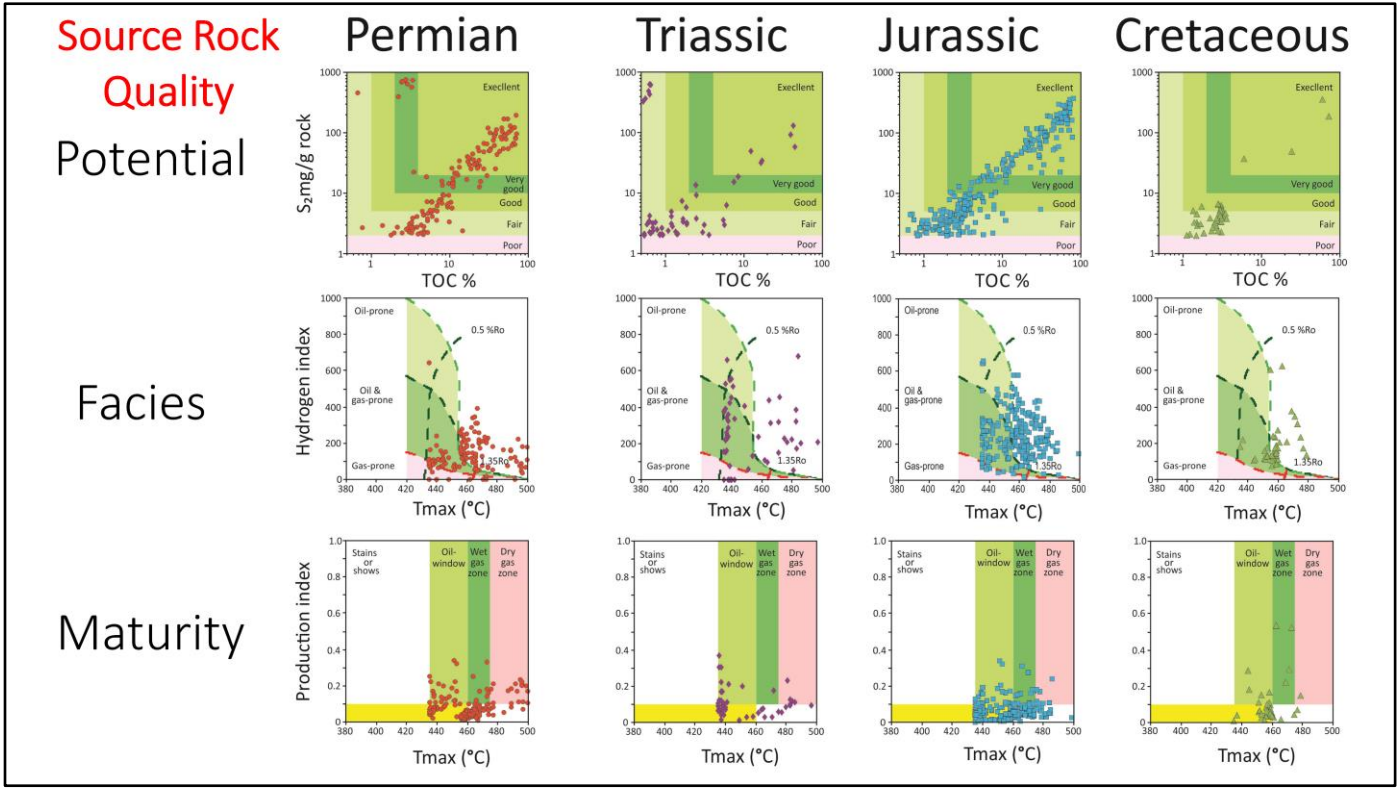
Triassic Core

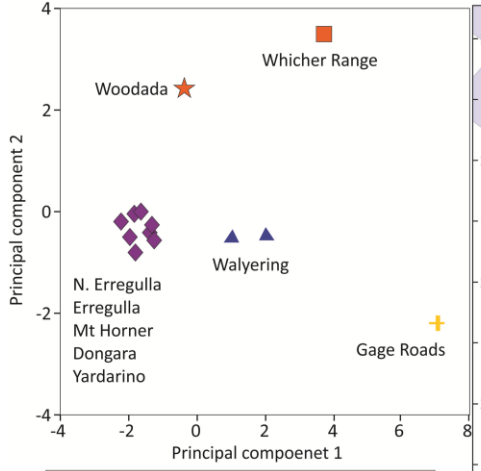
Perth Basin

Data Distribution

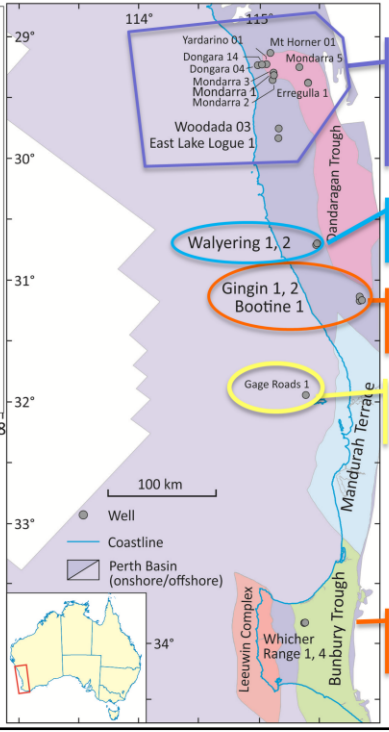





Source Rock Quality
Potential
Facies
Maturity
Permian
Triassic
Jurassic
Cretaceous
S2mg/g rock
TOC %
Execllent
Very good
Good
Fair
Poor
Hydrogen index
Oil-prone
Oil & gas-prone
Gas-prone
0.5 %Ro
1.35Ro
Tmax (°C)
Production index
Stains or shows
Oil-window
Wet gas zone
Dry gas zone



- Permian or mixed sourced
- Permian sourced
- Triassic sourced
- Jurassic sourced
- Cretaceous sourced



Triassic

Jurassic

Permian

Cretaceous

Petroleum Systems Distribution

Permian

Data source: AGSO & GeoMark 1996 GA 2005

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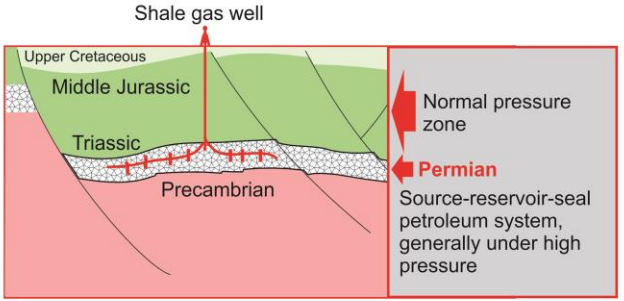
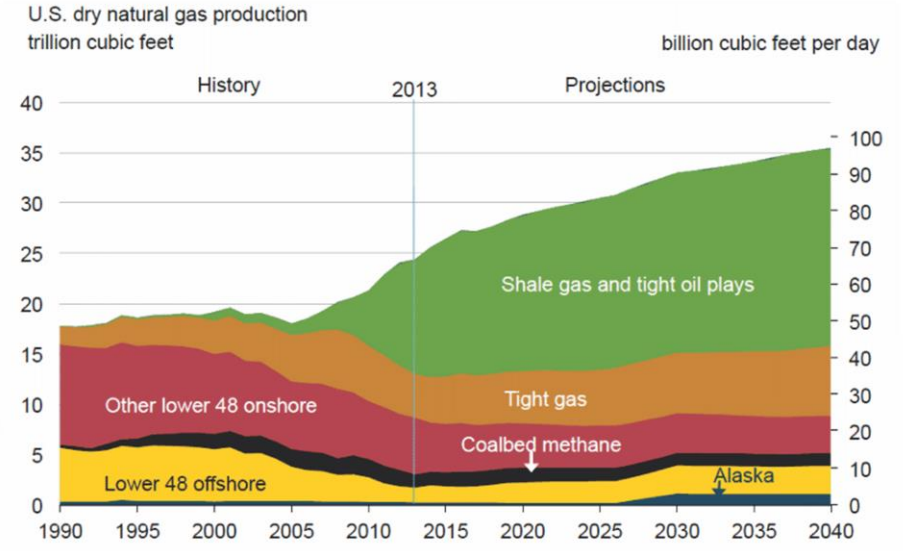


Shale-plays

United States



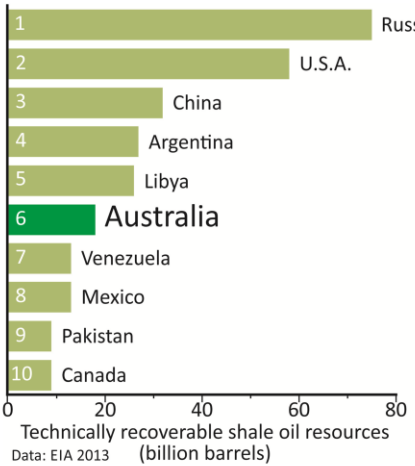
Boom inception 2005 – World's largest oil and gas producer 2014

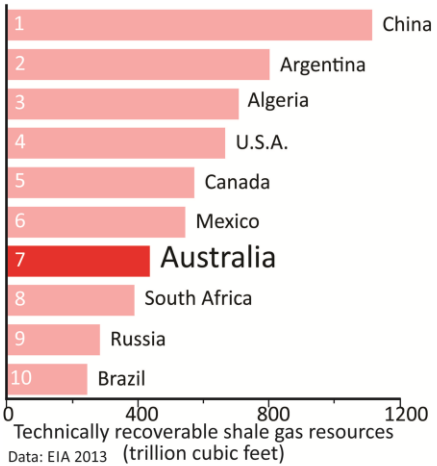
AAPG Explorer June 2015

Shale Petroleum

95 basins - 137 Shale Formations - 42 countries

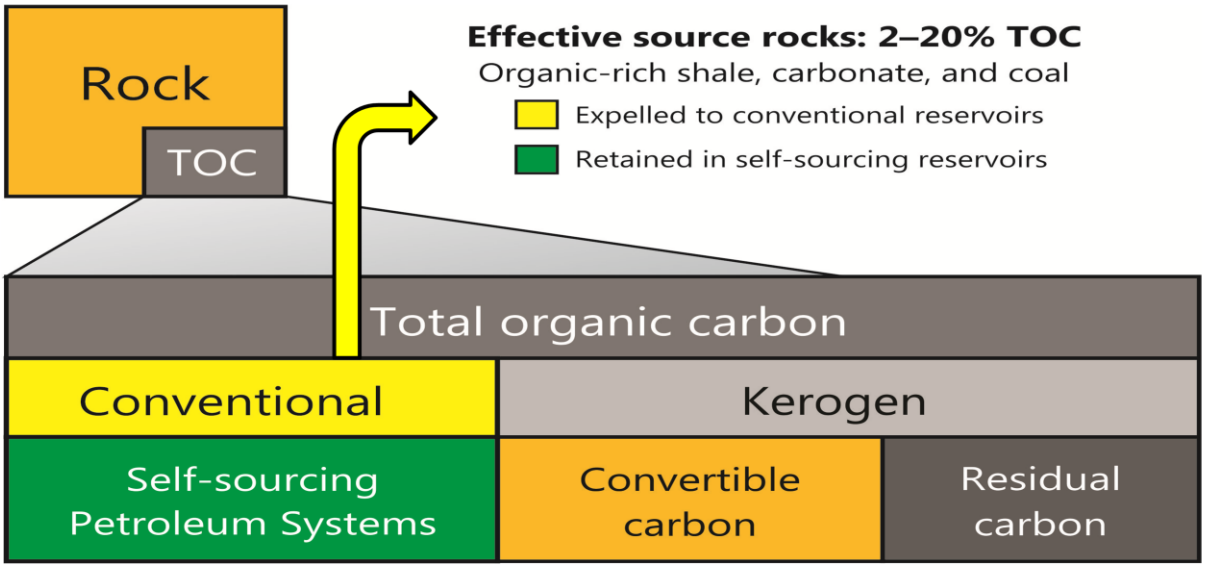
Oil - top ten countries - Gas





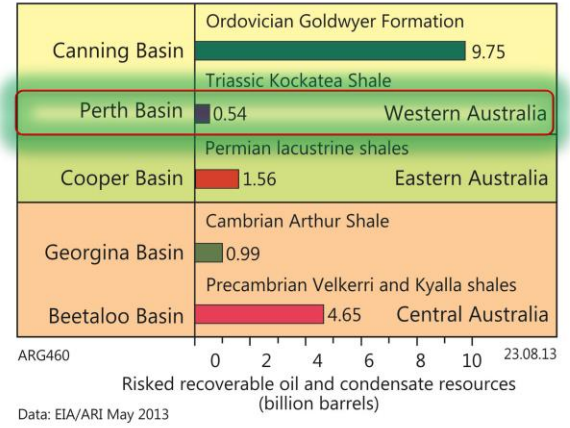
Status
Exploring
Developing
Exploring
Developing
Developing
Exploring
Exploring

Self-sourcing Petroleum System

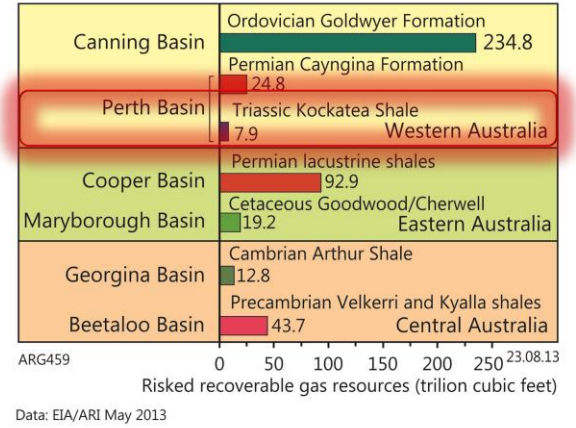


Shale Petroleum Australia

Oil - Australian basin- Gas



Data: EIA/ARI May 2013



Data: EIA/ARI May 2013

Fracturing Quality - Petrography

Permian Carynginia Formation

Redback 1: 3762.00 m

TOC = 2.38%

Ro = 1.40%

Brittleness: 0.38

Triassic Kockatea Shale

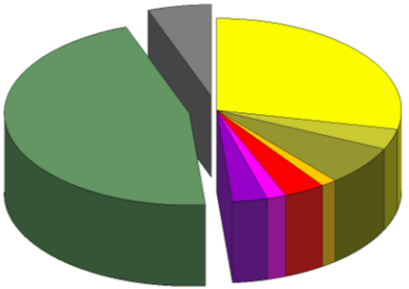
Redback 2: 3788.52 m

TOC = 2.29%

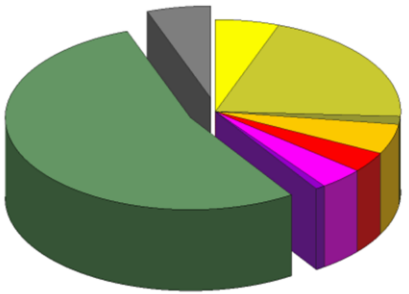
Ro = 1.32%

Brittleness: 0.29

Permian Carynginia Formaion

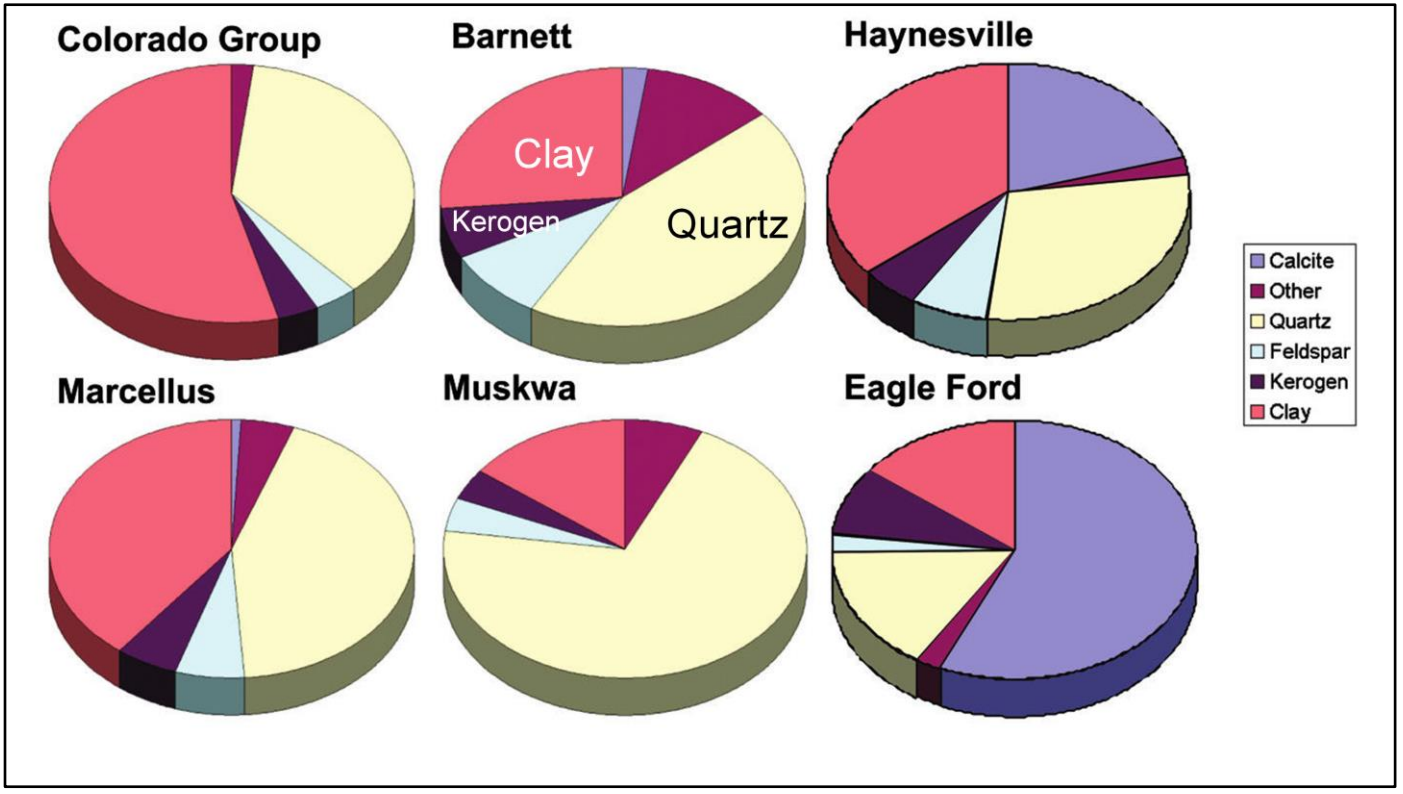


Triassic Kockatea Shale



Composition

- Quartz
- K-Feldspar
- Plagioclase
- Calcite
- Zeolite
- Pyrite
- Sylvite
- Vclay
- Kerogen


Colorado Group
Barnett
Haynesville
Clay
Kerogen
Quartz
Marcellus
Muskwa
Eagle Ford
Calcite
Other
Quartz
Feldspar
Kerogen
Clay

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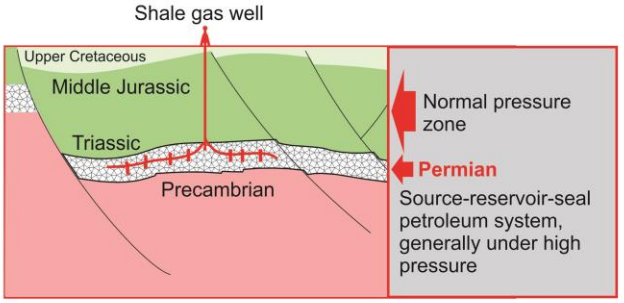
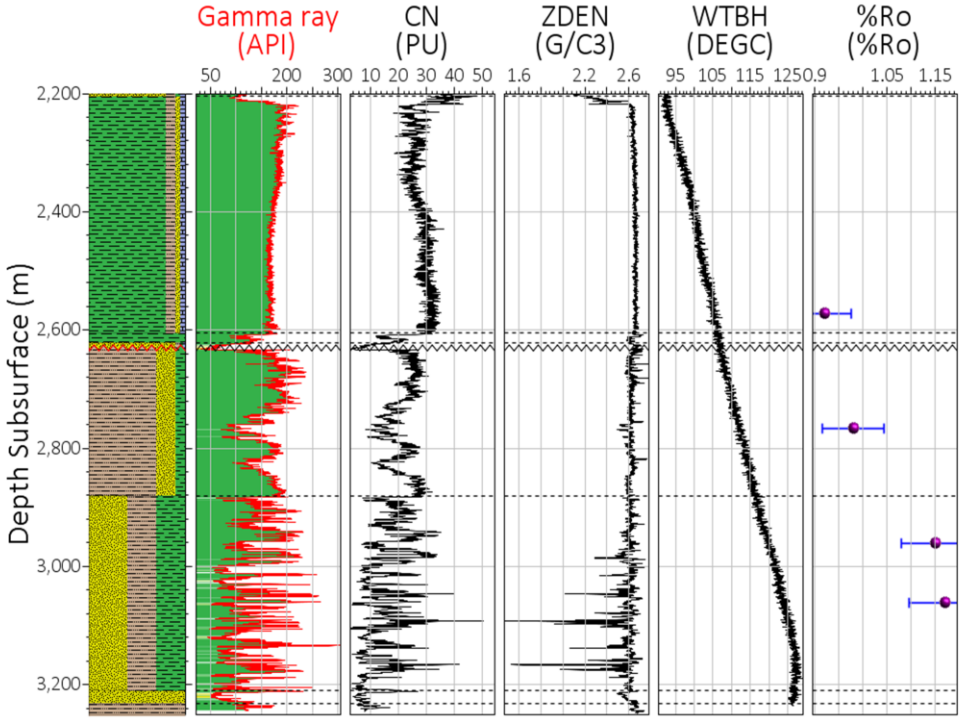


Shale-plays Modelling – Arrowsmith 2

- Petroleum generation modelling plays a critical role in assessing richness of self-contained (source-reservoir-seal) petroleum systems:
  - Organic-richness and maturity
  - Source-rock trapped hydrocarbon-richness
  - Source-rock fracturing quality (clay-richness)



Arrowsmith 2

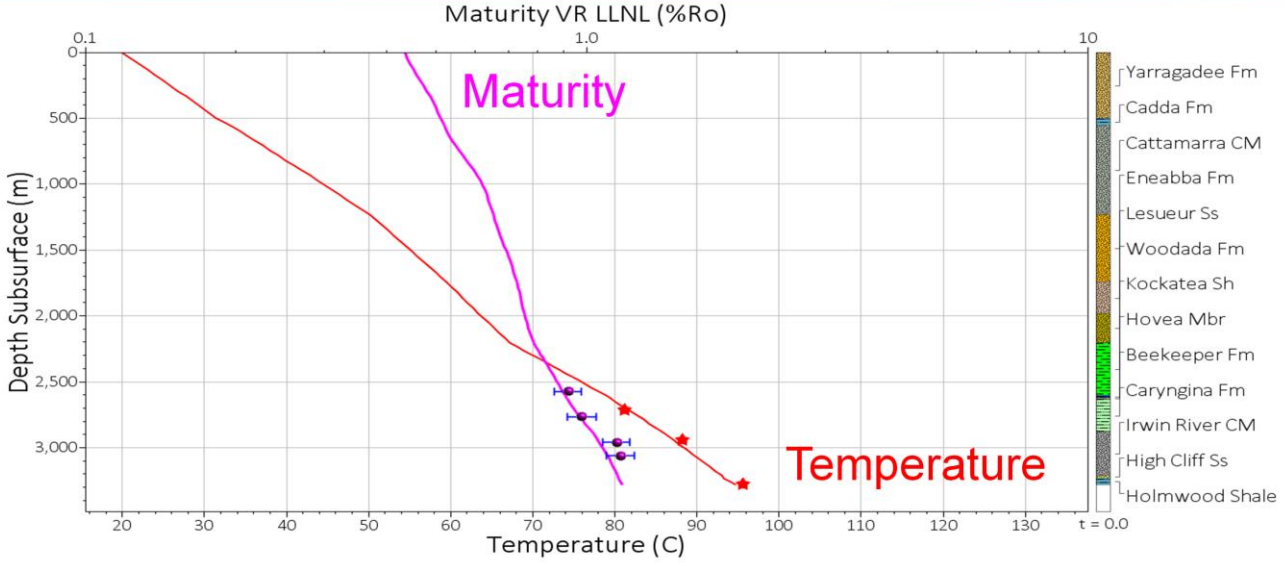
Kockatea Shale

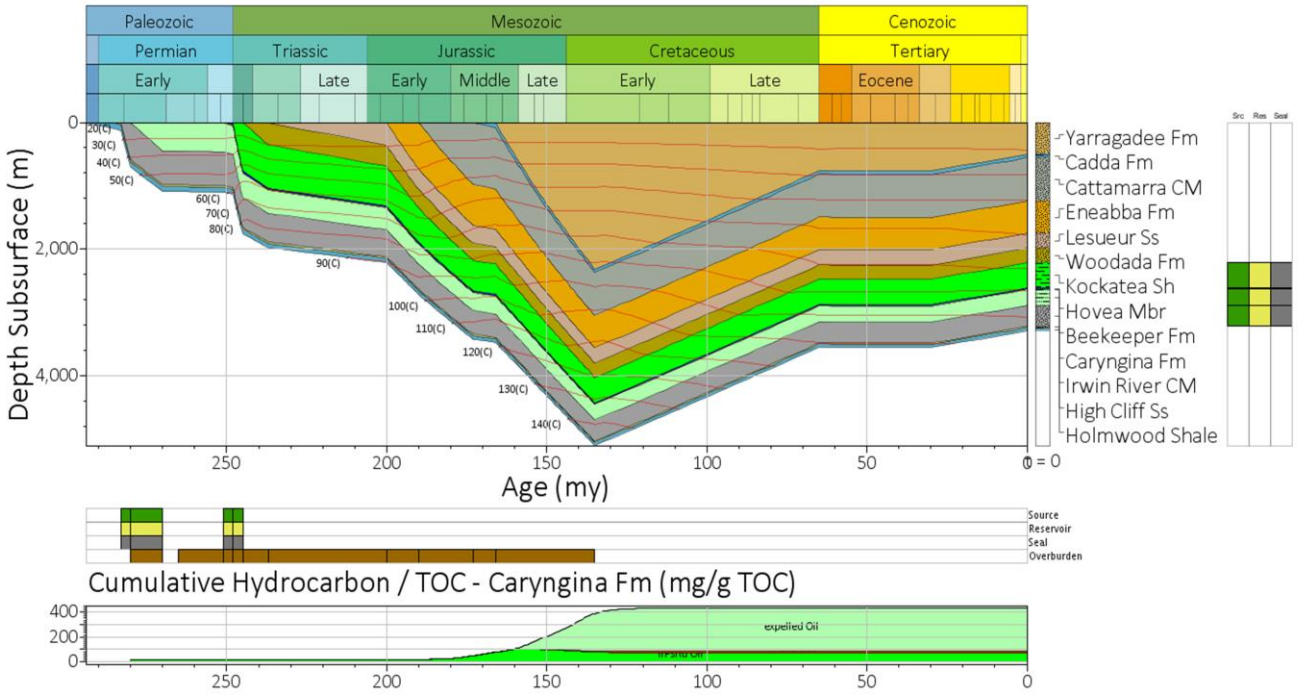
Hovea Member

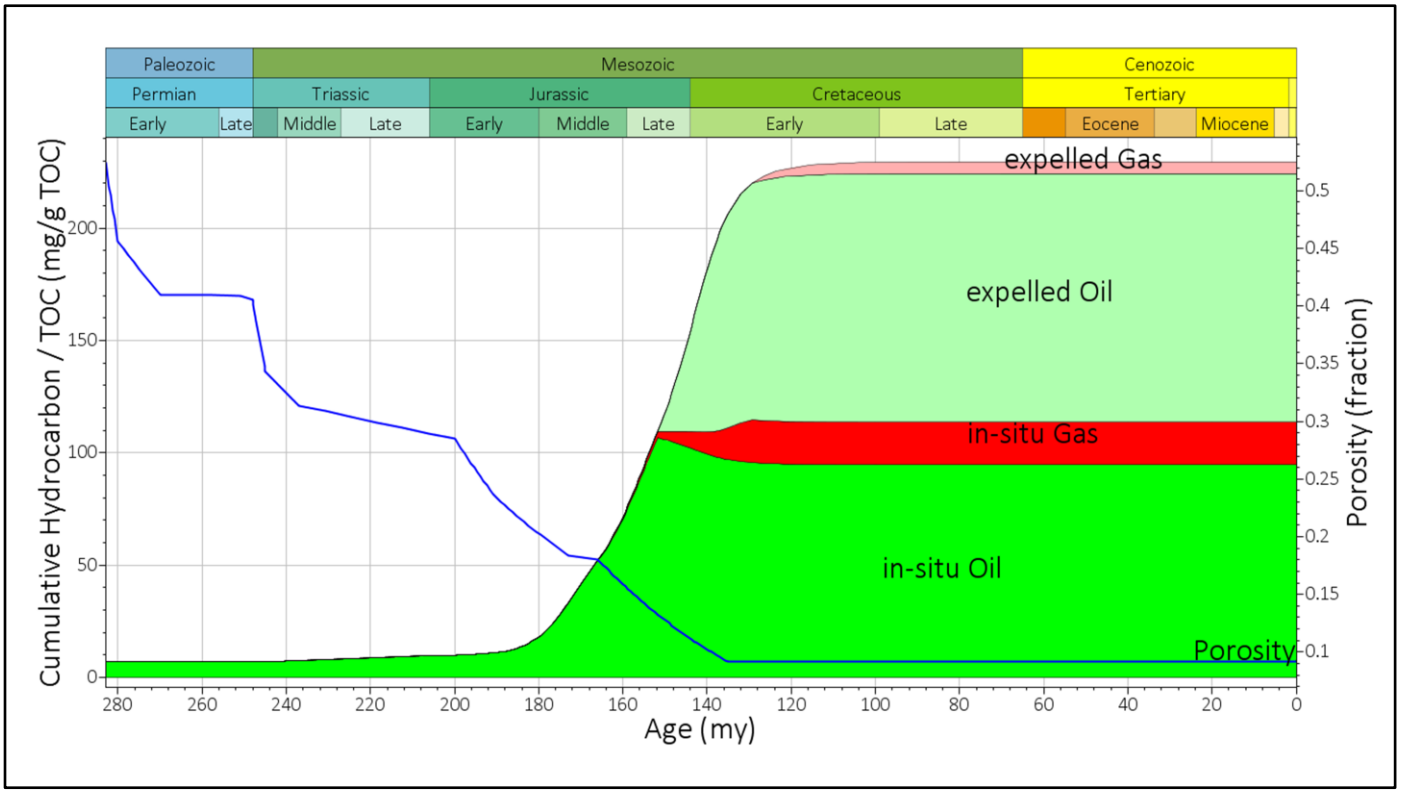
Carynginia Formation

Cattamarra Coal Measures

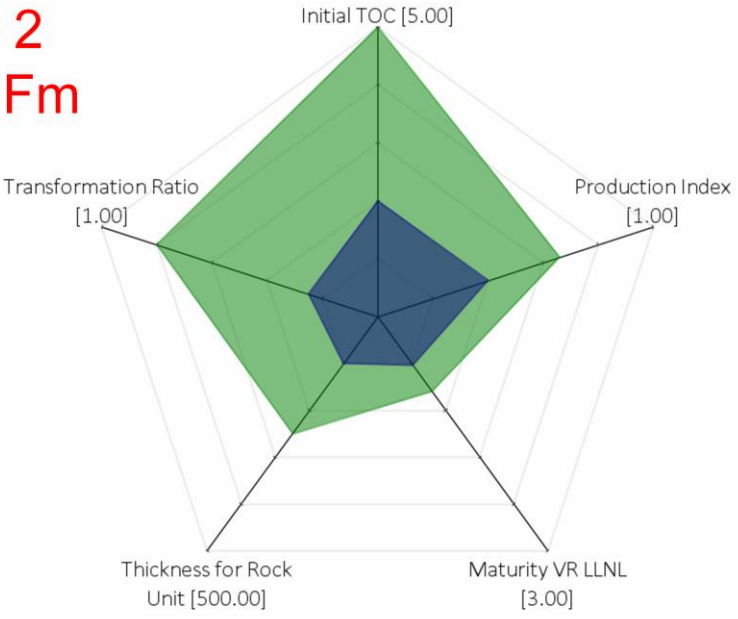
Arrowsmith 2 – Maturity Modelling



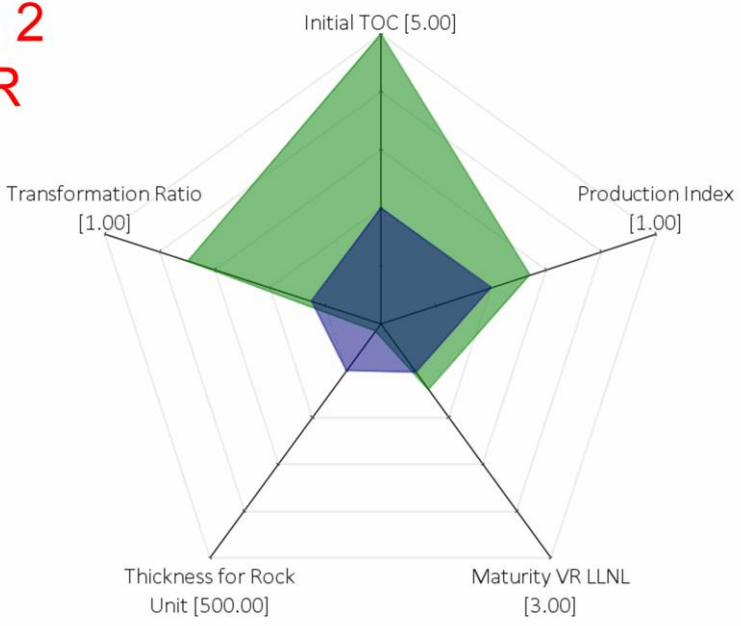

Paleozoic
Mesozoic
Cenozoic
Permian
Triassic
Jurassic
Cretaceous
Tertiary
Early
Late
Early
Middle
Late
Early
Late
Eocene
Depth Subsurface (m)
0
2,000
4,000
20(C)
30(C)
40(C)
50(C)
60(C)
70(C)
80(C)
90(C)
100(C)
110(C)
120(C)
130(C)
140(C)
250
200
150
100
50
0
Age (my)
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Woodada Fm
Kockatea Sh
Hovea Mbr
Beekeeper Fm
Caryngina Fm
Irwin River CM
High Cliff Ss
Holmwood Shale
Src
Res
Seal
Source
Reservoir
Seal
Overburden
Cumulative Hydrocarbon / TOC - Caryngina Fm (mg/g TOC)
400
200
0
expelled Oil
250
200
150
100
50
0


Paleozoic
Mesozoic
Cenozoic
Permian
Triassic
Jurassic
Cretaceous
Tertiary
Early
Late
Middle
Late
Early
Middle
Late
Early
Late
Eocene
Miocene
expelled Gas
expelled Oil
in-situ Gas
in-situ Oil
Porosity
Cumulative Hydrocarbon / TOC (mg/g TOC)
Porosity (fraction)
Age (my)
0
50
100
150
200
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

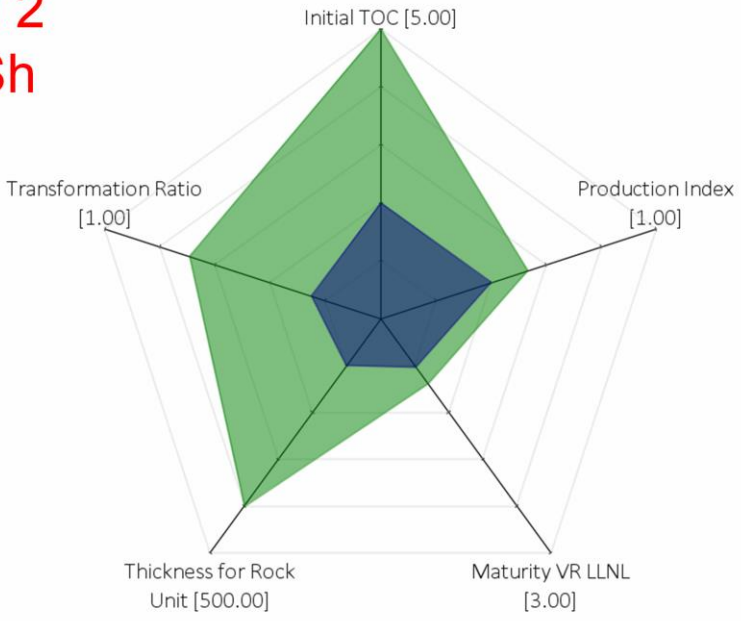
Arrowsmith 2
Carynginia Fm

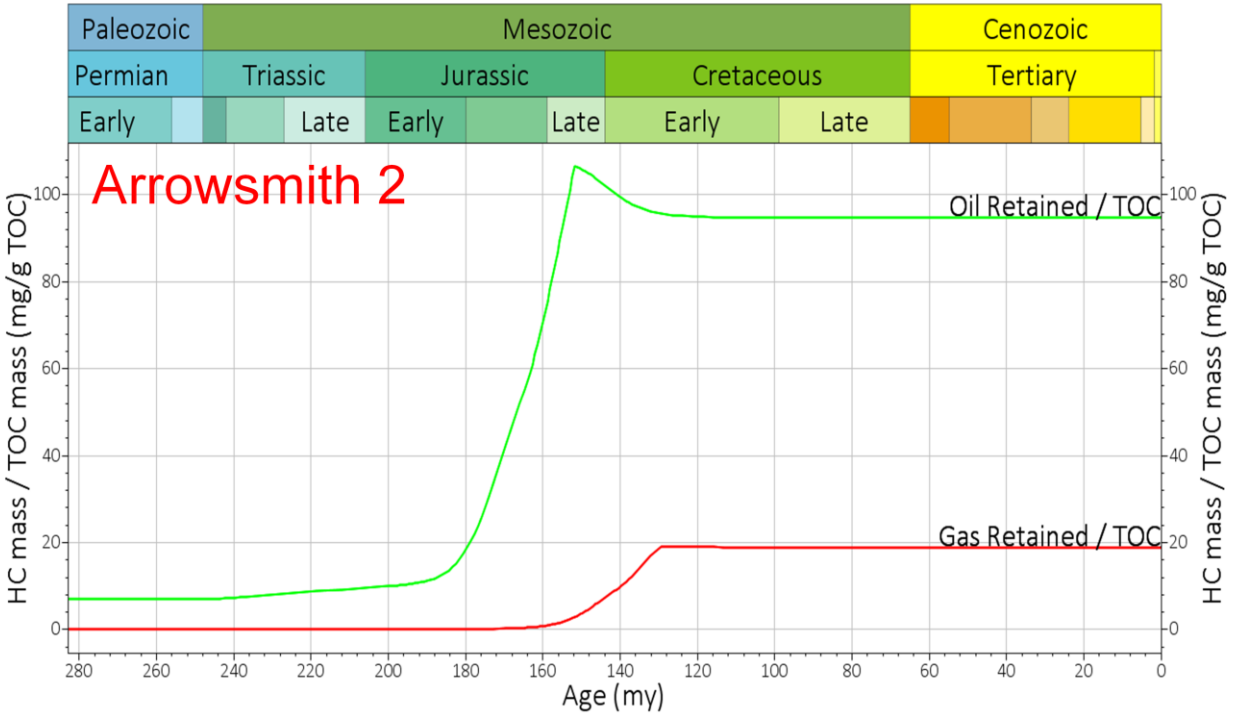


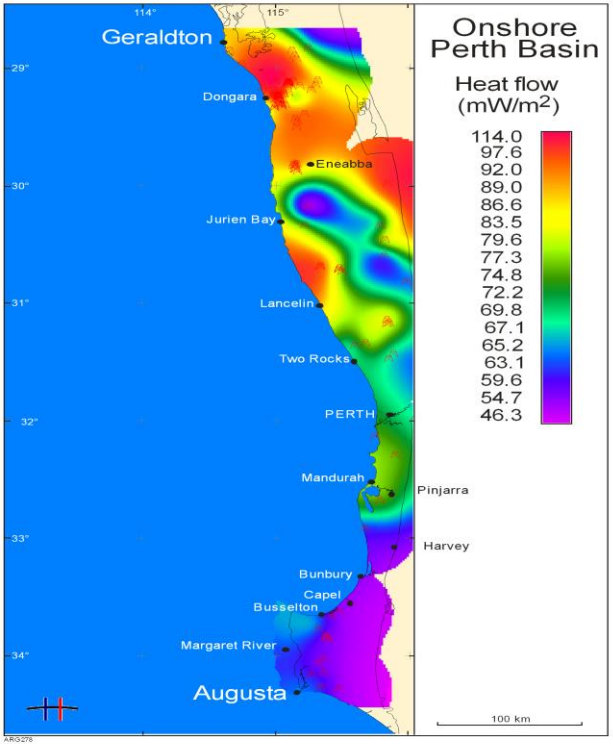
Arrowsmith 2
Hovea MBR

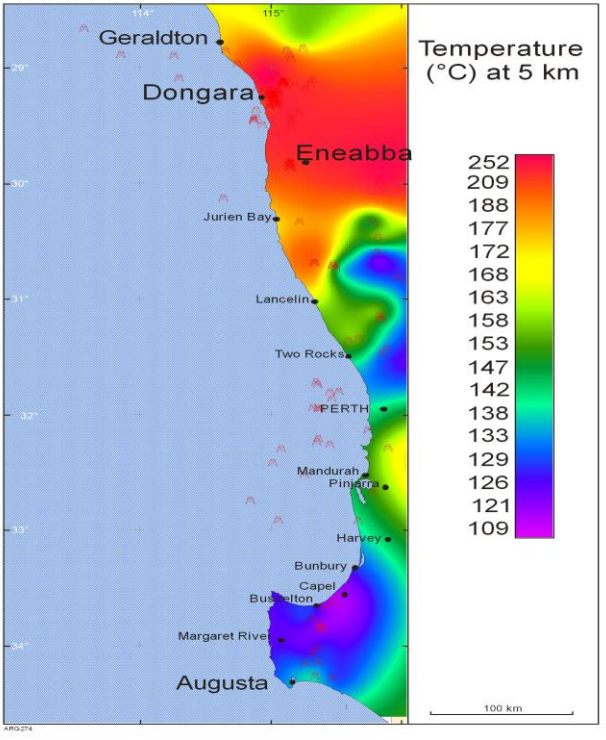


Arrowsmith 2
Kockatea Sh




Paleozoic
Mesozoic
Cenozoic
Permian
Triassic
Jurassic
Cretaceous
Tertiary
Early
Late
Early
Late
Early
Late
Arrowsmith 2
Oil Retained / TOC
Gas Retained / TOC
HC mass / TOC mass (mg/g TOC)
HC mass / TOC mass (mg/g TOC)
0
20
40
60
80
100
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Age (my)

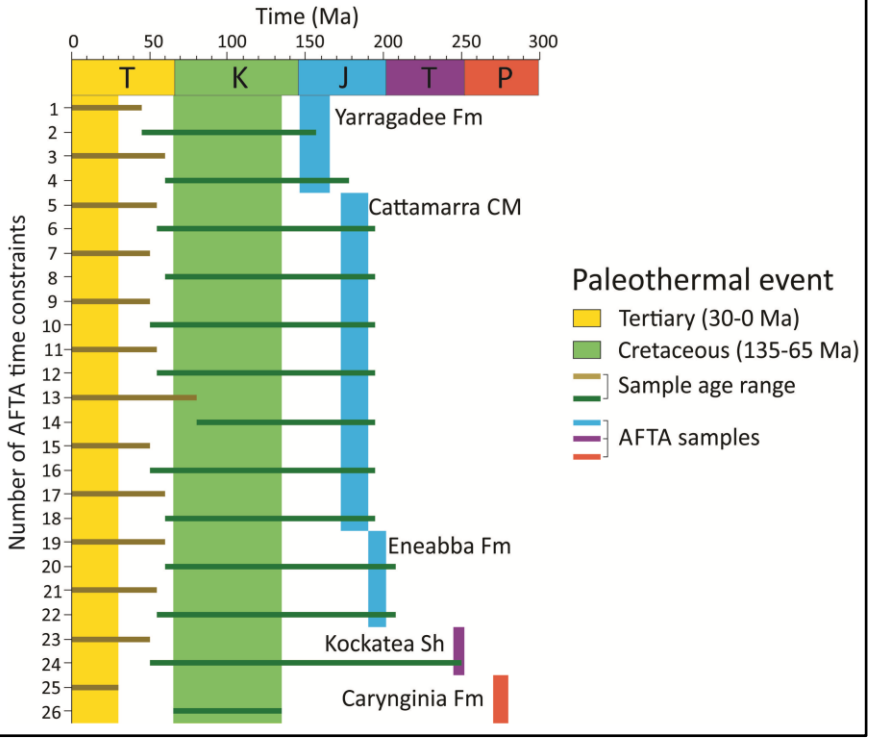




Presenter's notes: Perth Basin heat flow distribution on the left and subsurface temperatures distribution on the right. Heat flow values ranges from low value of about 46 to high value of about 114 milliwatts per square metre. The temperature distribution in centigrade to a depth of 5-kilometre range from a low temperature of about 110 degree centigrade in the south to high temperatures of about 250 degree centigrade in the north. These figures indicate that northern parts of the Perth Basin are comparatively more prospective for developing geothermal energy.

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



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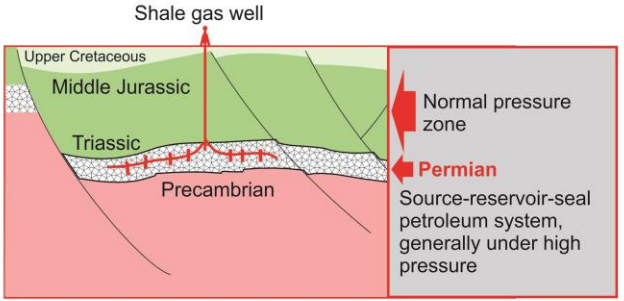
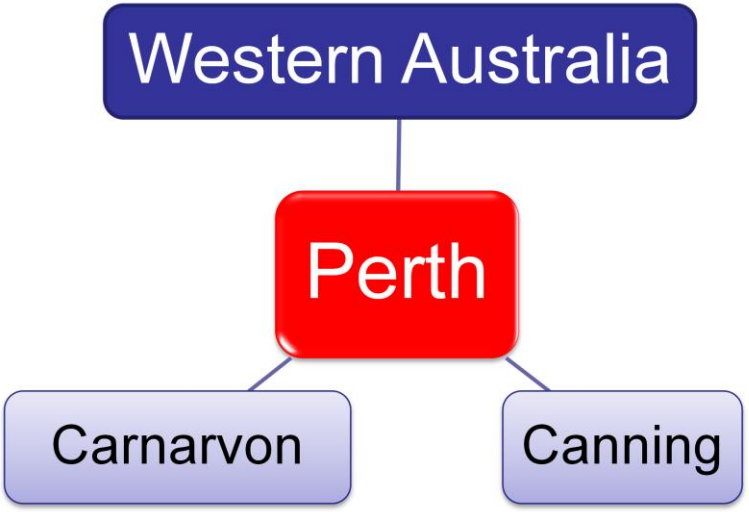
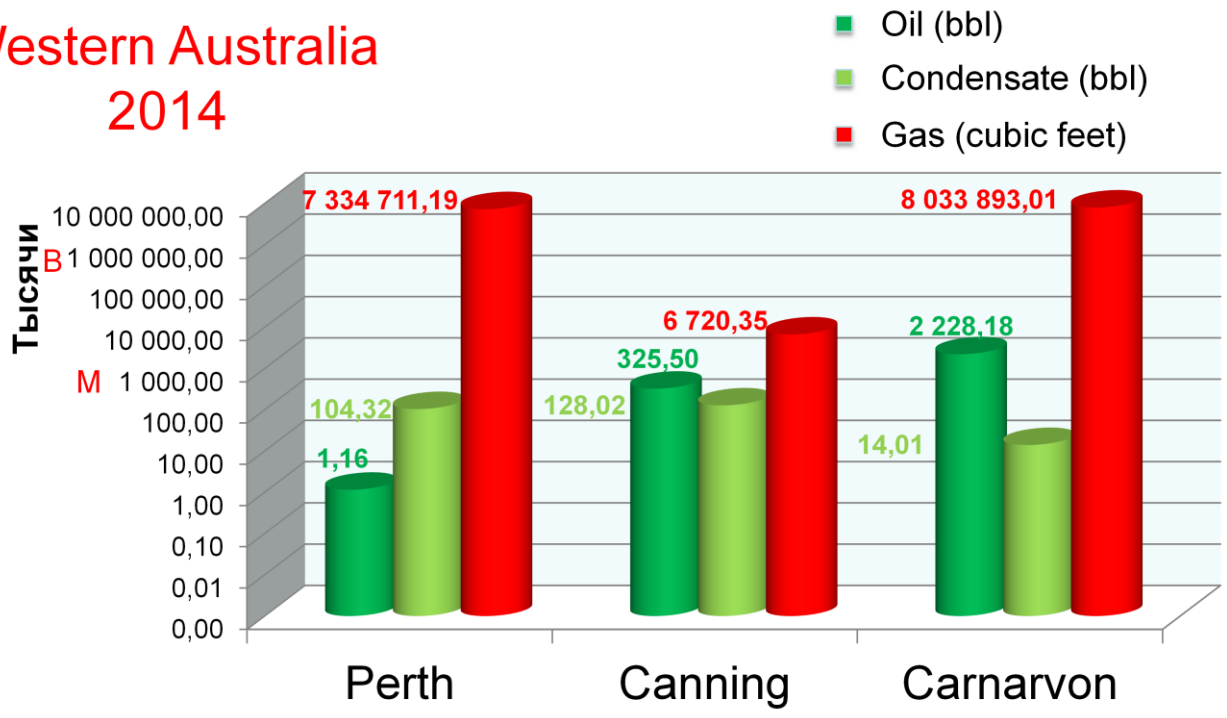
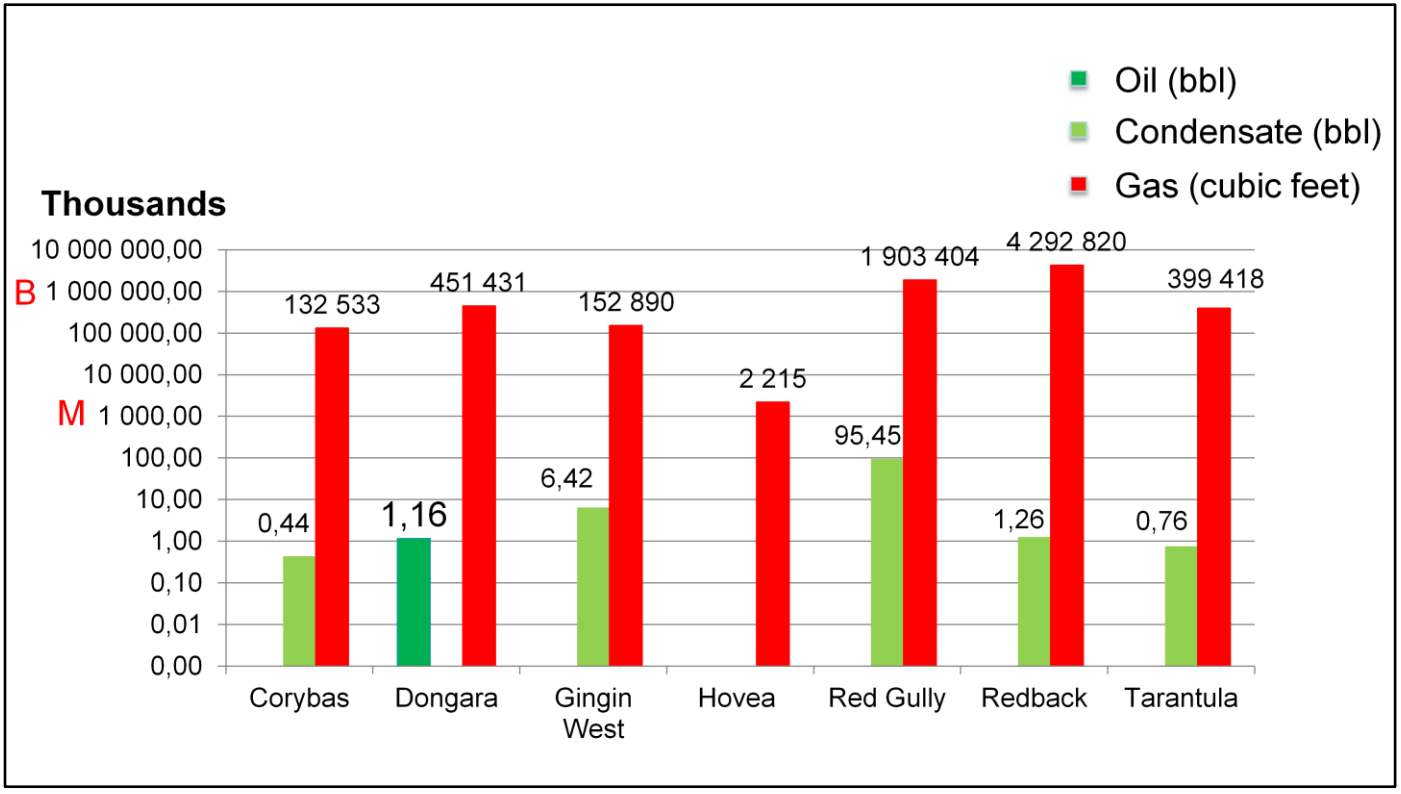


Petroleum Production - 2014

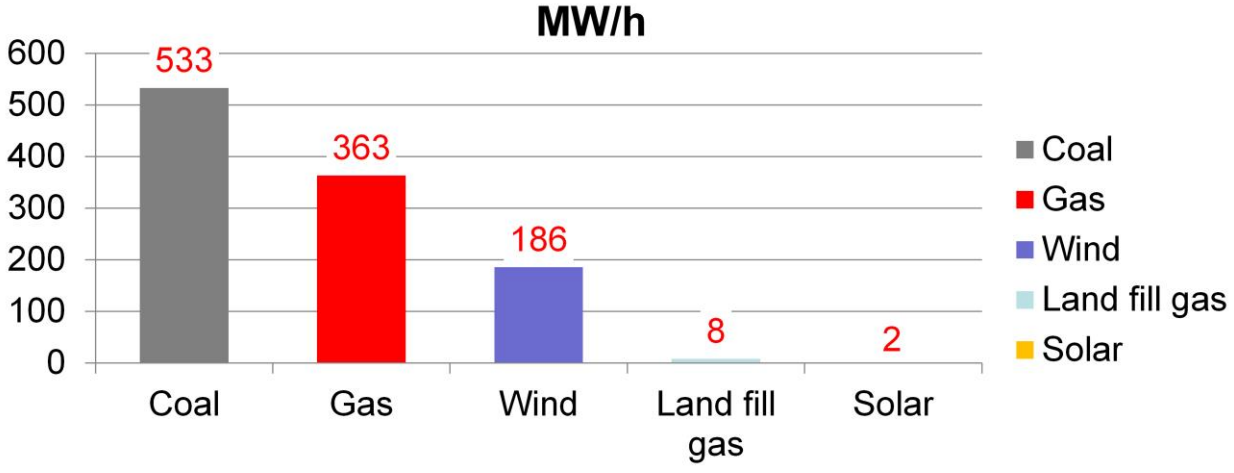


Western Australia 2014




Oil (bbl)
Condensate (bbl)
Gas (cubic feet)
Thousands
10 000 000,00
B 1 000 000,00
100 000,00
10 000,00
M 1 000,00
100,00
10,00
1,00
0,10
0,01
0,00
132 533
451 431
152 890
2 215
1 903 404
4 292 820
399 418
0,44
1,16
6,42
95,45
1,26
0,76
Corybas
Dongara
Gingin West
Hovea
Red Gully
Redback
Tarantula

AEMO: Australian Energy Market Operators



AEMO - independent energy market operator and independent power system operator in Western Australia

Presenter's notes: Most Australian gas markets are based on bilateral arrangements between producers, major users and retailers linked together through pipeline hubs connecting gas fields to gas consumers.

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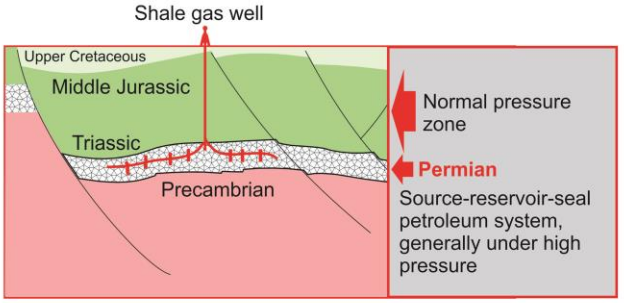
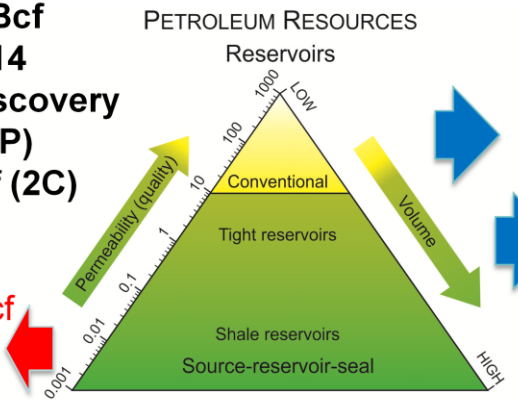
- Petroleum production
- Conclusions



Total Gross: + 700 Bcf
Waitsia gasfield 2014
largest on shore discovery
Reserves: 89 Bcf (2P)
Resources: 153 Bcf (2C)
Source: AWE 2015

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

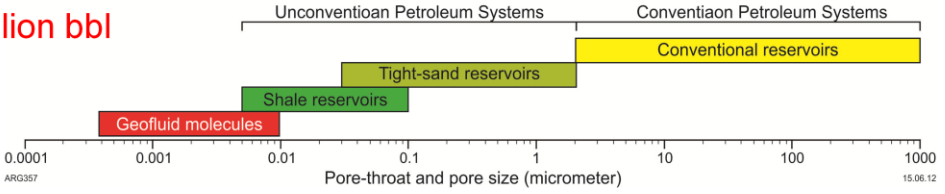
Source: EIA/ARI 2013



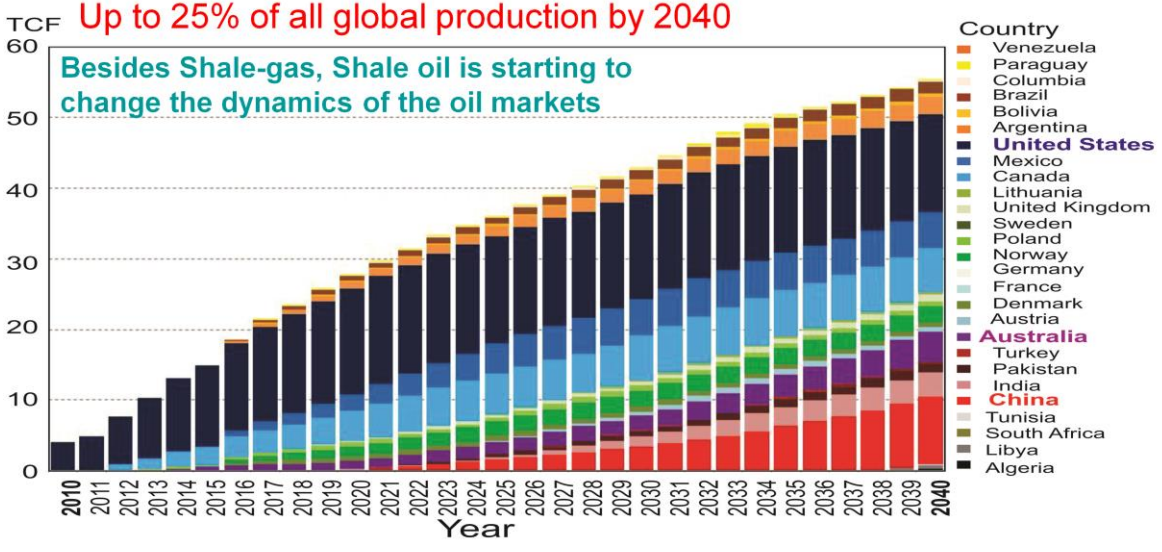
Gas Reserves: 0.05 Tcf (2P)
Gas Resources: 0.33 Tcf (2C)

Gas Reserves: 12 Tcf (GIIP)

Source: Department of Mines & Petroleum



Shale Production Out Look



Source: Kenneth B Medlock III

Presenter's notes: Another outlook for shale-gas for many countries including Australia. Up to 25% will be contributed by shale gas by 2040, hopefully correct.


Thanks
Questions