Petroleum Systems Modelling of the Perth Basin, Western Australia*

Khwaja A. Ghori[1]

Search and Discovery Article #10961 (2017)**
Posted June 19, 2017

*Adapted from oral presentation given at 2017 AAPG Annual Convention & Exhibition, Houston, Texas, April 2-5, 2017. Please see closely related article "Petroleum Systems of the Perth Basin, Western Australia", Search and Discovery article #10805.

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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

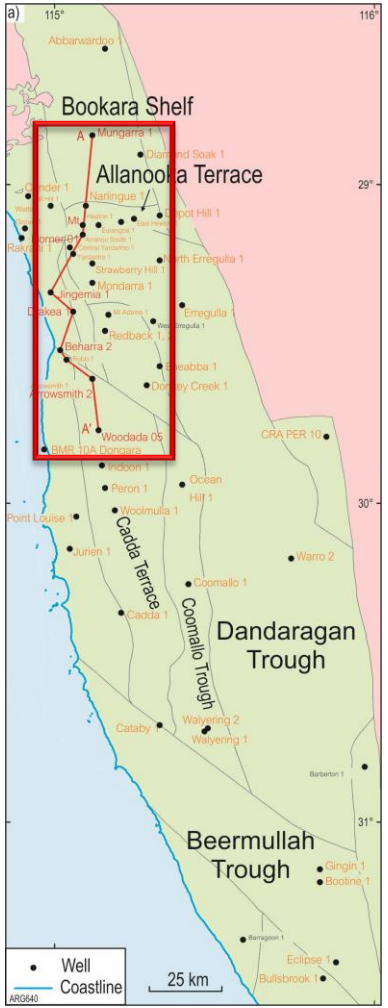
Khwaja (Ameed) Ghori

100 AAPG ANNIVERSARY ACE 2-4 APRIL, 2017, HOUSTON

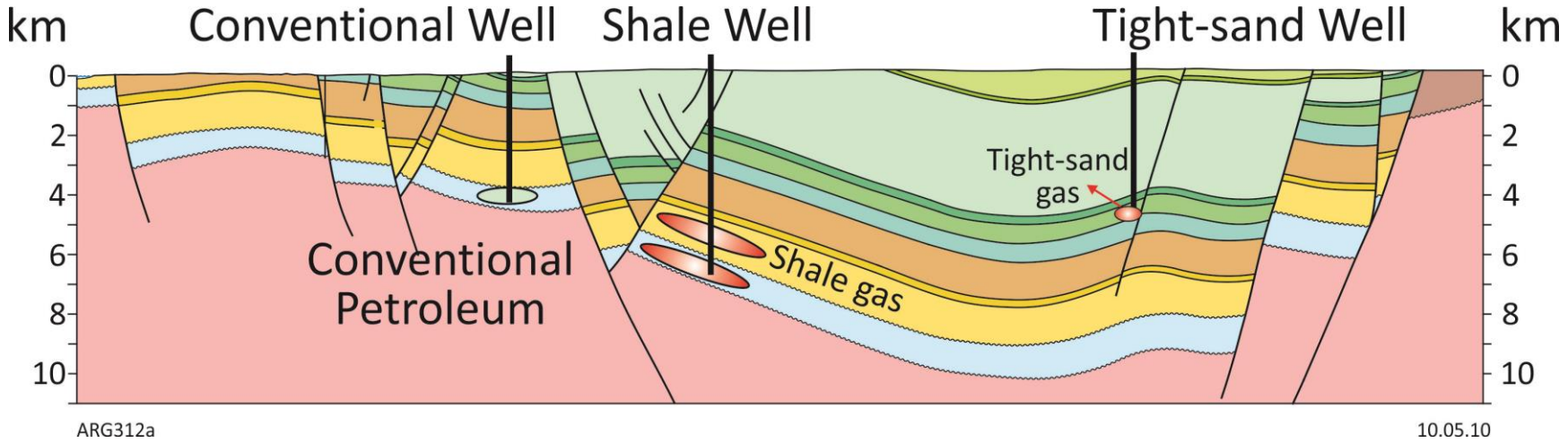
April 4, 2017: 11:30 – 11:50 AM

Petroleum System Modelling

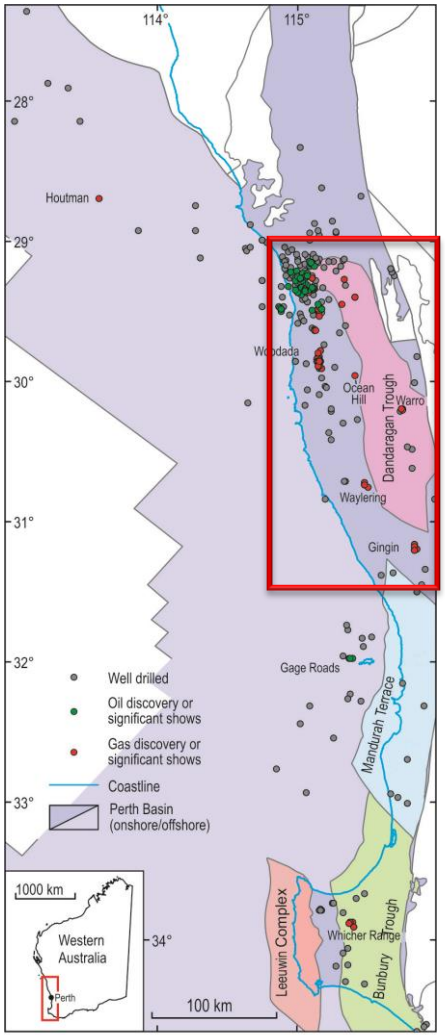
- 49 wells with petroleum geochemistry data are modelled using Platte River Associates' latest release - Petroleum Systems Suite of software 2017:
  - 1D BasinMod, BasinMod, BasinView, 2D BasinMod.
- Well models were calibrated using measured and calculated data including:
  - petroleum geochemistry, 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.

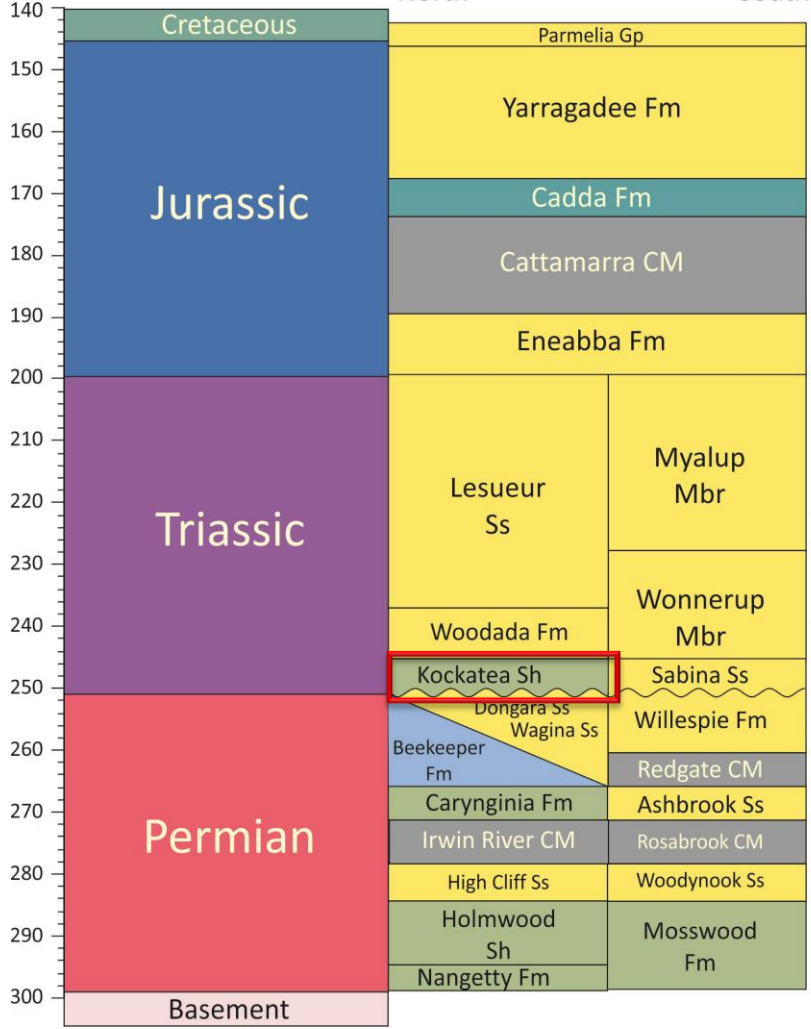


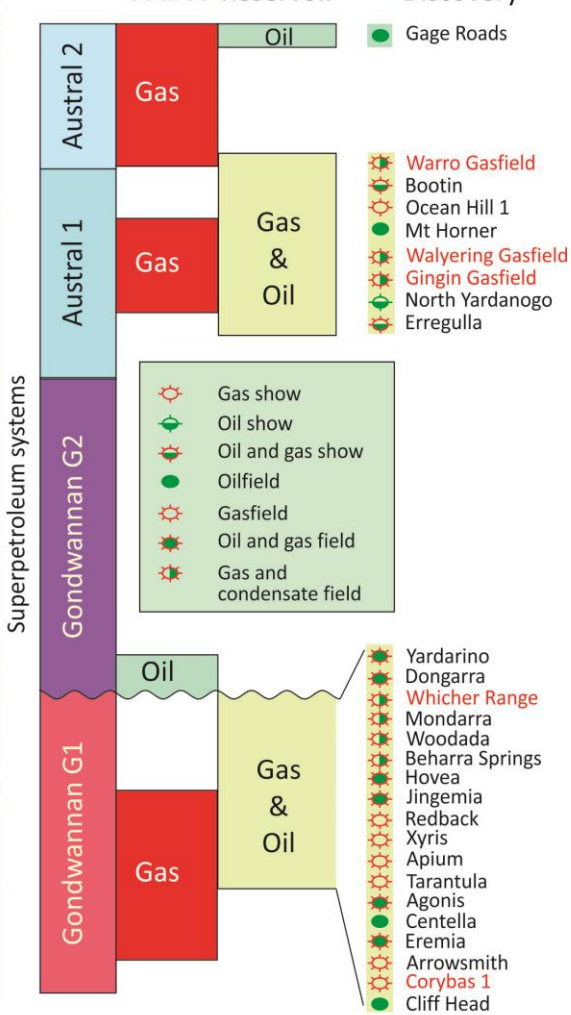
Perth Basin – Petroleum Systems



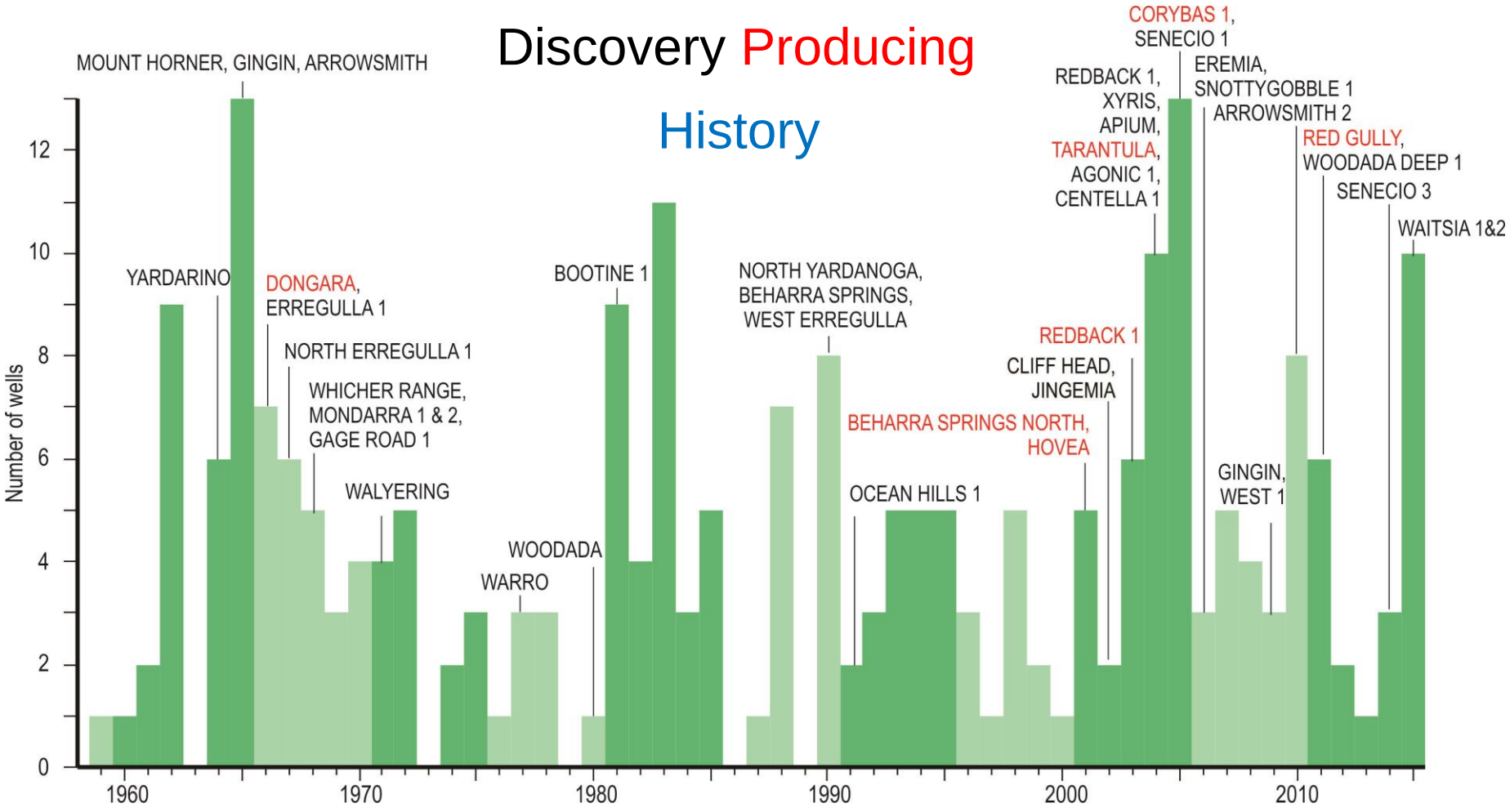
- Perth Basin & Prospectivity → Petroleum systems & modelling → Conclusions


114°
115°
28°
29°
30°
31°
32°
33°
34°
Houtman
Woodada
Ocean Hill
Warro
Dandaragan Trough
Waylering
Gingin
Gage Roads
Mandurah Terrace
Leeuwin Complex
Whicher Range
Bunbury Trough
Well drilled
Oil discovery or significant shows
Gas discovery or significant shows
Coastline
Perth Basin (onshore/offshore)
1000 km
Western Australia
Perth
100 km
ARG479c
30/06/15


Ma
North
South
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
Cretaceous
Jurassic
Triassic
Permian
Basement
Parmelia Gp
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Myalup Mbr
Wonnerup Mbr
Woodada Fm
Kockatea Sh
Sabina Ss
Dongara Ss
Wagina Ss
Willespie Fm
Beekeeper Fm
Redgate CM
Caryngina Fm
Ashbrook Ss
Irwin River CM
Rosabrook CM
High Cliff Ss
Woodynook Ss
Holmwood Sh
Mosswood Fm
Nangetty Fm

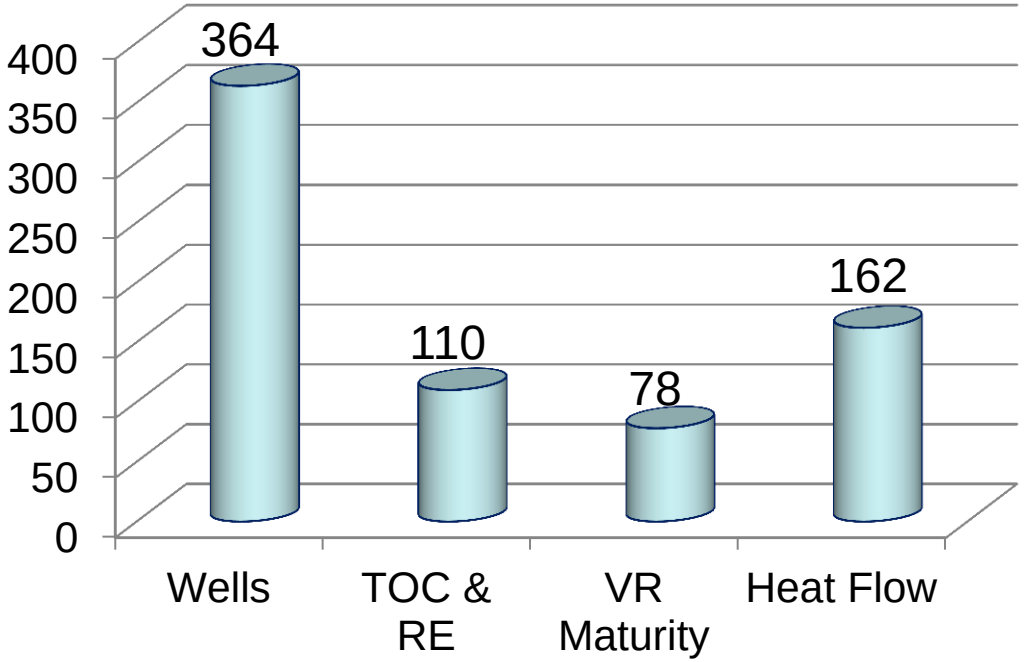

Source
Reservoir
Discovery
Superpetroleum systems
Austral 2
Austral 1
Gondwannan G2
Gondwannan G1
Gas
Oil
Gas & Oil
Gage Roads
Warro Gasfield
Bootin
Ocean Hill 1
Mt Horner
Walyering Gasfield
Gingin Gasfield
North Yardanogo
Erregulla
Gas show
Oil show
Oil and gas show
Oilfield
Gasfield
Oil and gas field
Gas and condensate field
Yardarino
Dongarra
Whicher Range
Mondarra
Woodada
Beharra Springs
Hovea
Jingemia
Redback
Xyris
Apium
Tarantula
Agonis
Centella
Eremia
Arrowsmith
Corybas 1
Cliff Head

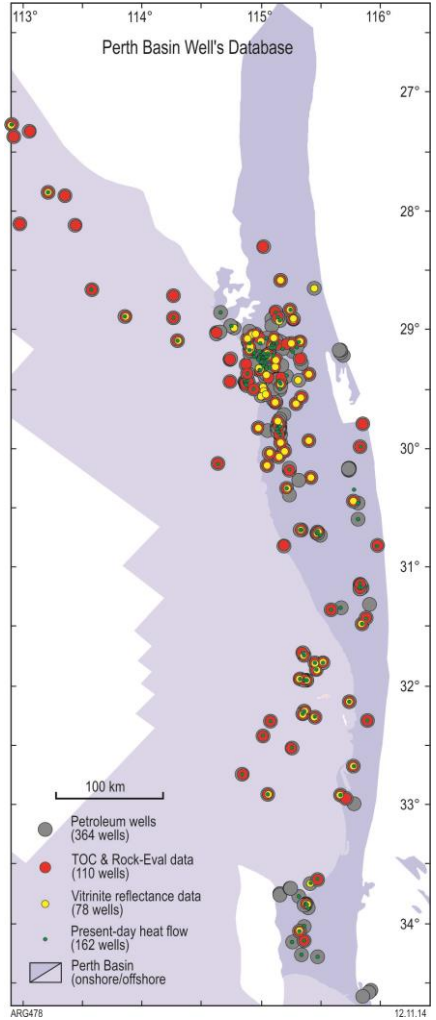
Discovery Producing History



Perth Basin

Data Distribution





Dandaragan Trough

Mandurah Terrace

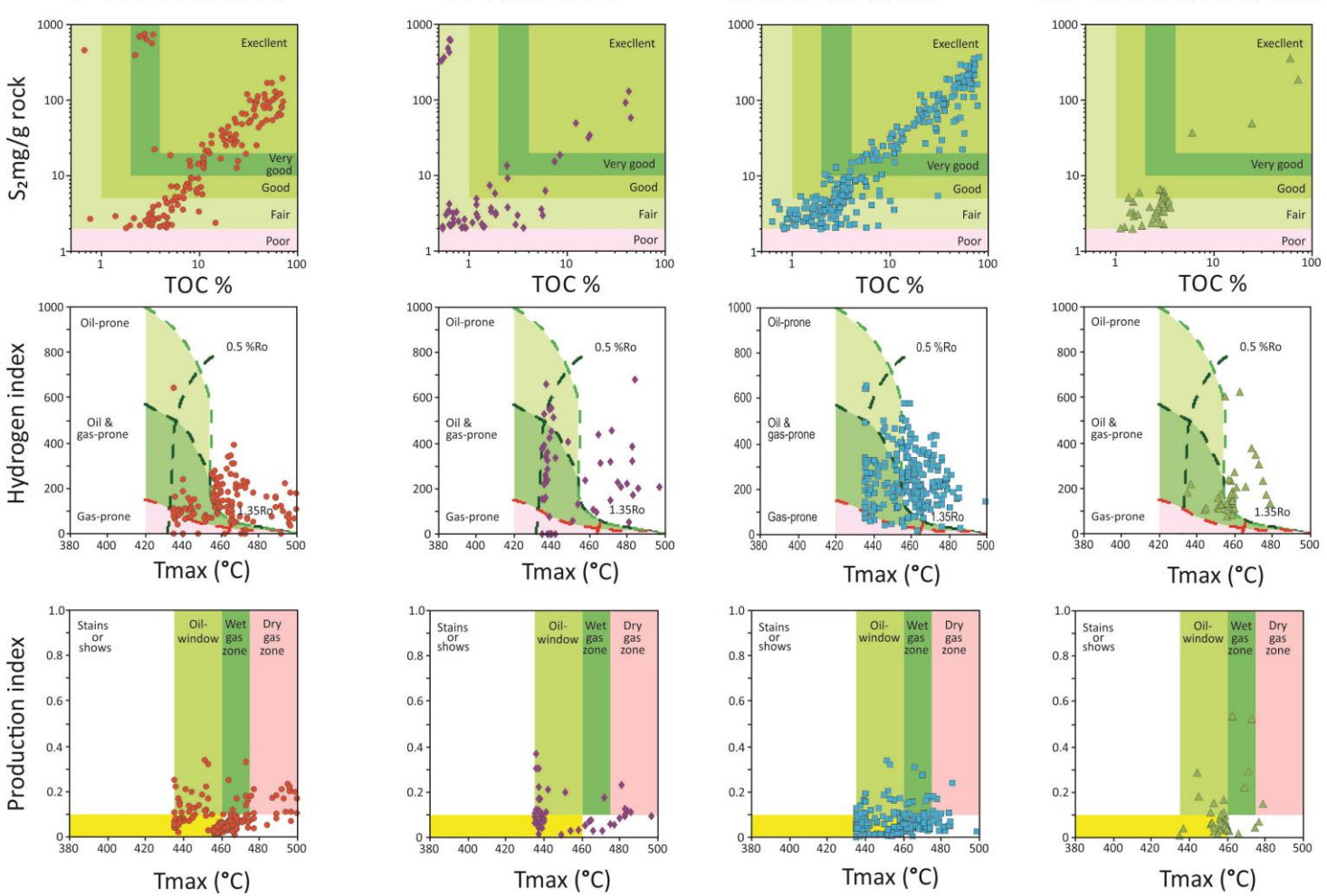
Bunbary Trough

Source Rock Quality

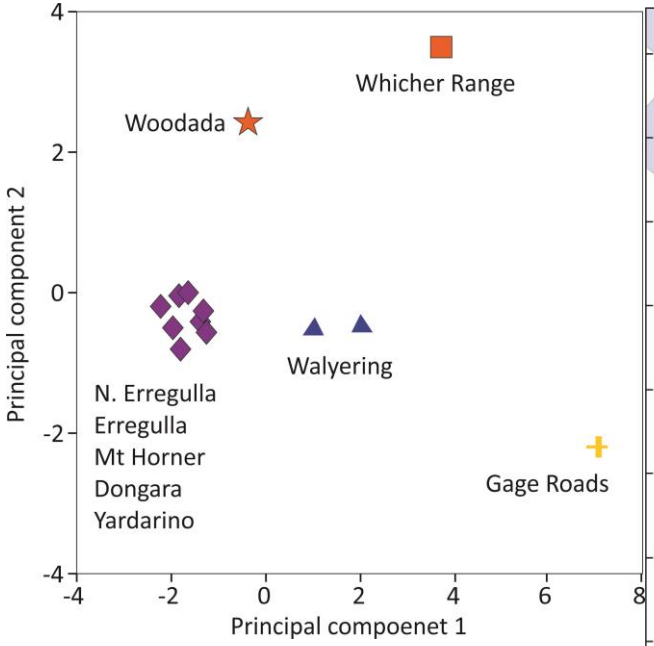
Potential

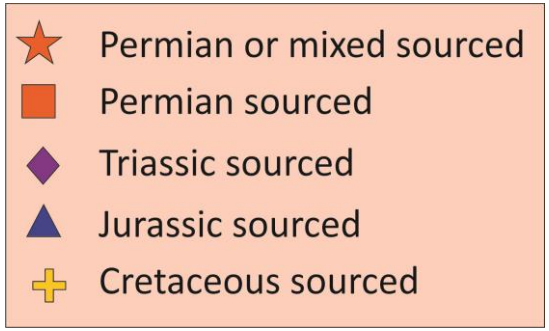
Facies

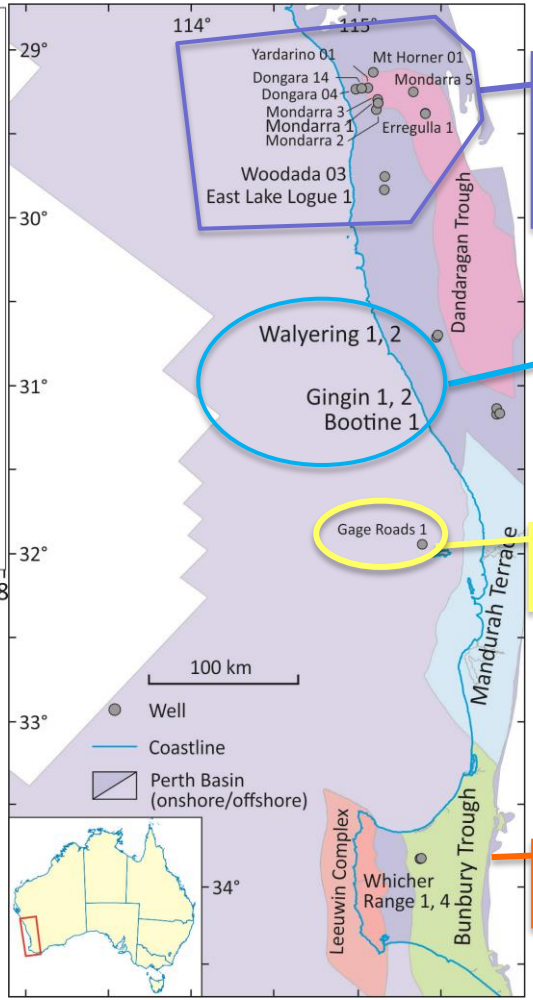
Maturity



Data source: AGSO & GeoMark 1996 GA 2005







Triassic

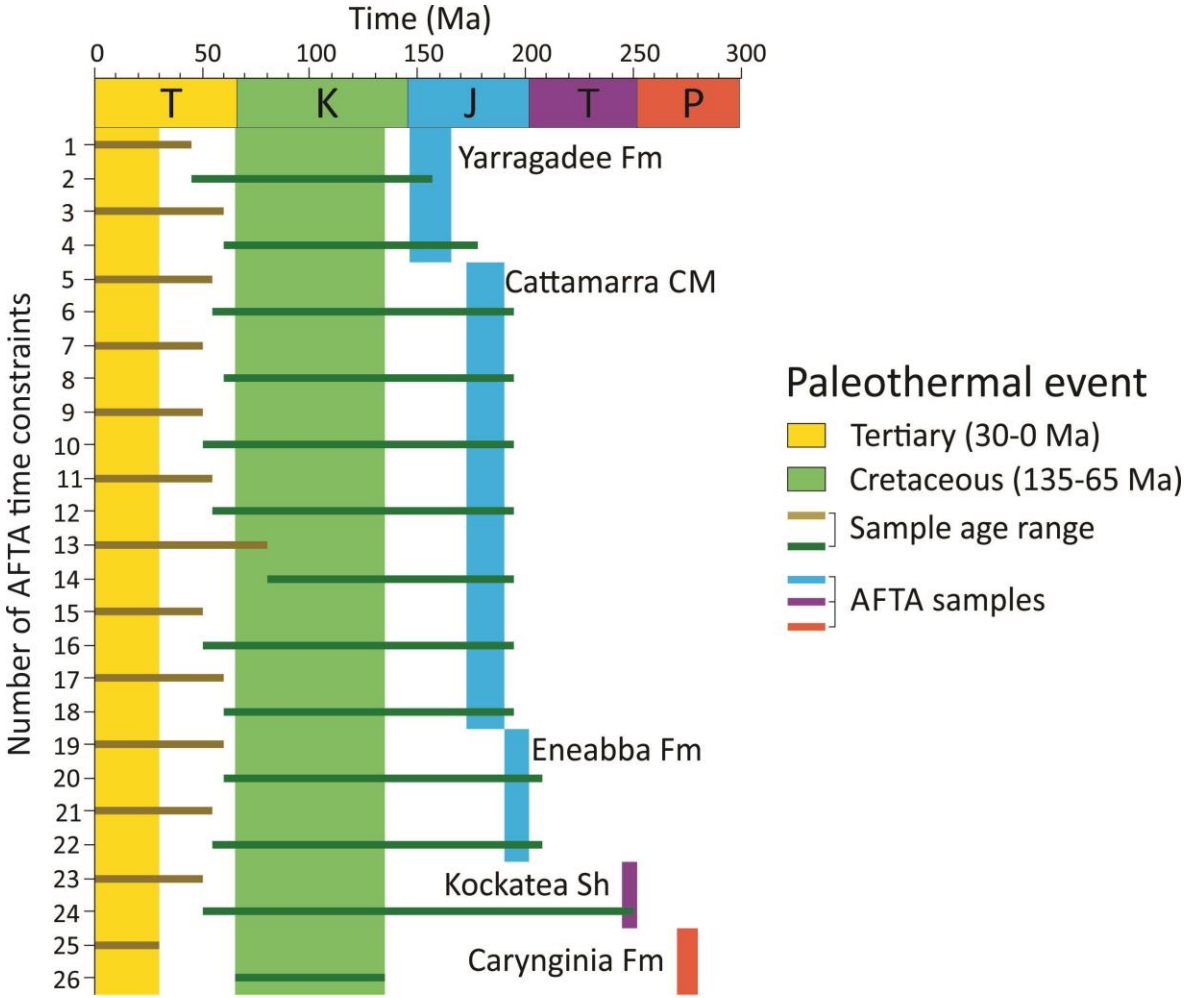
Jurassic

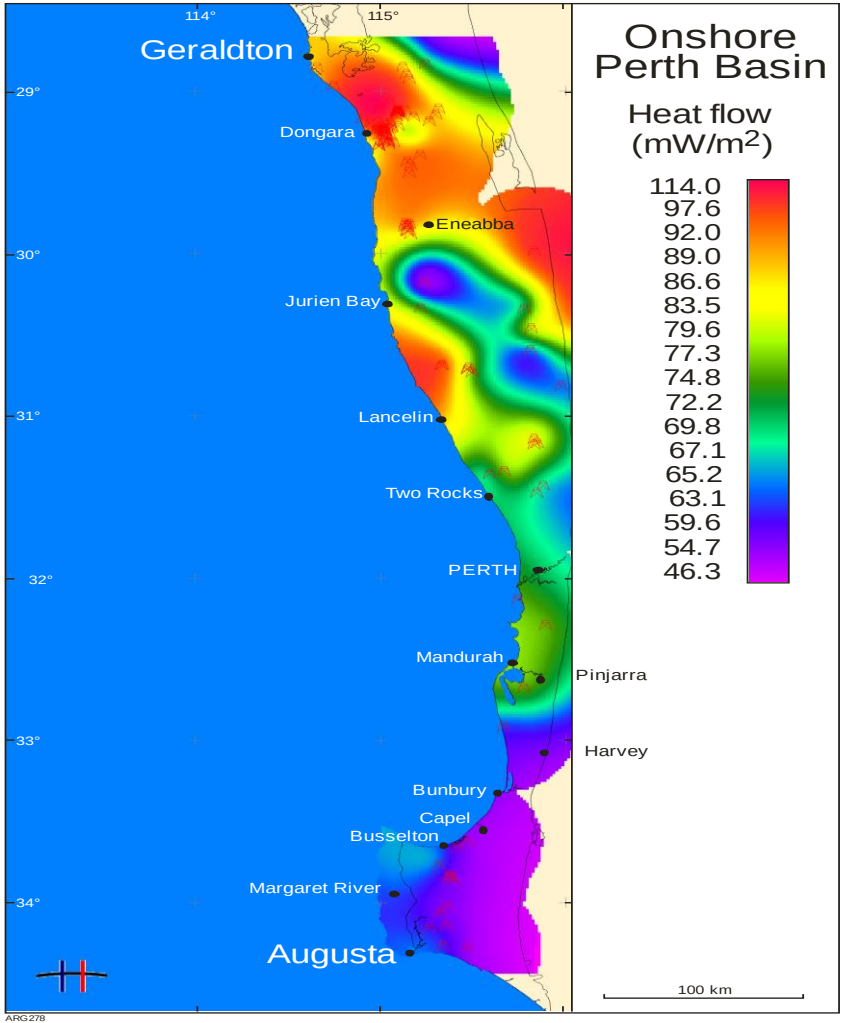
Cretaceous

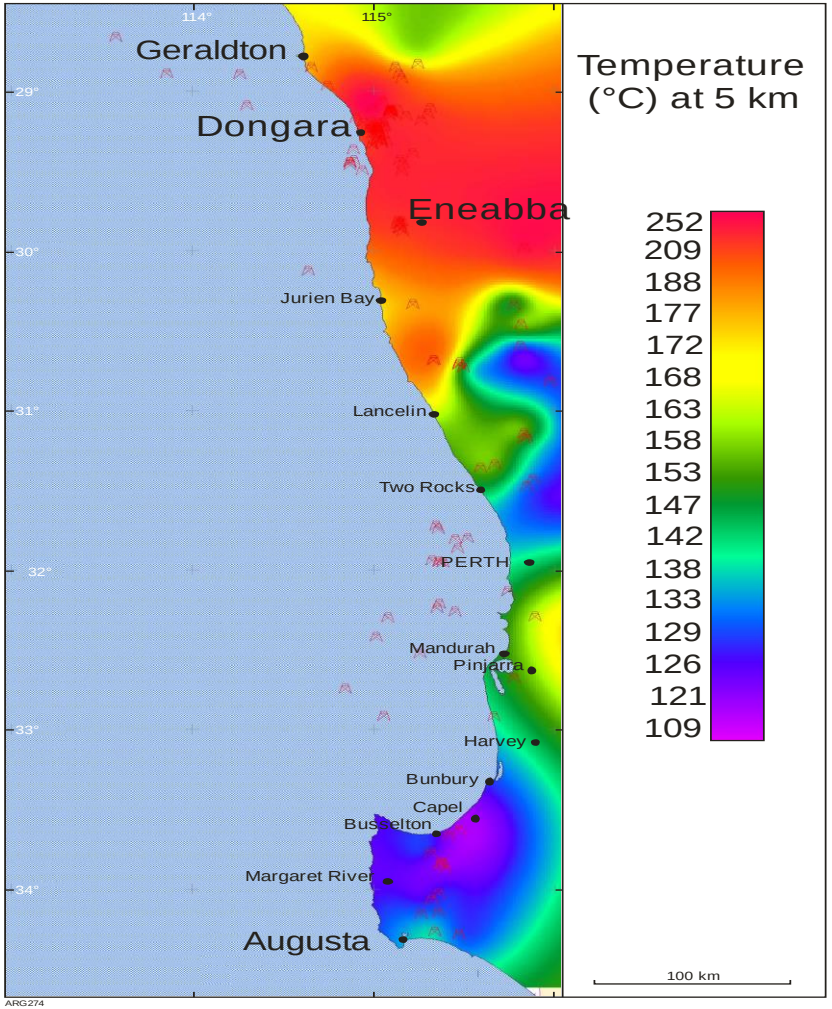
Permian

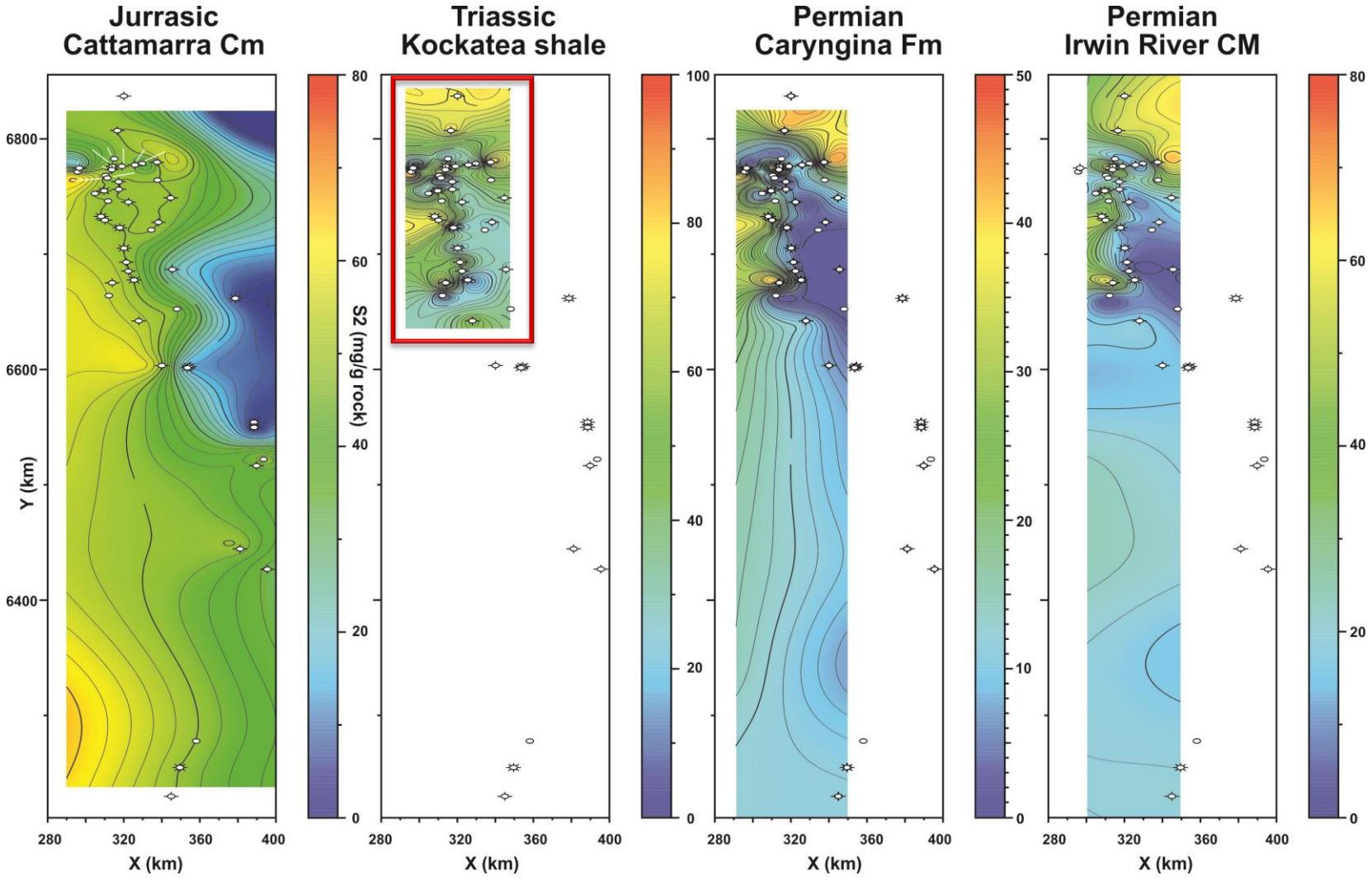
Apatite Fission Track Analysis

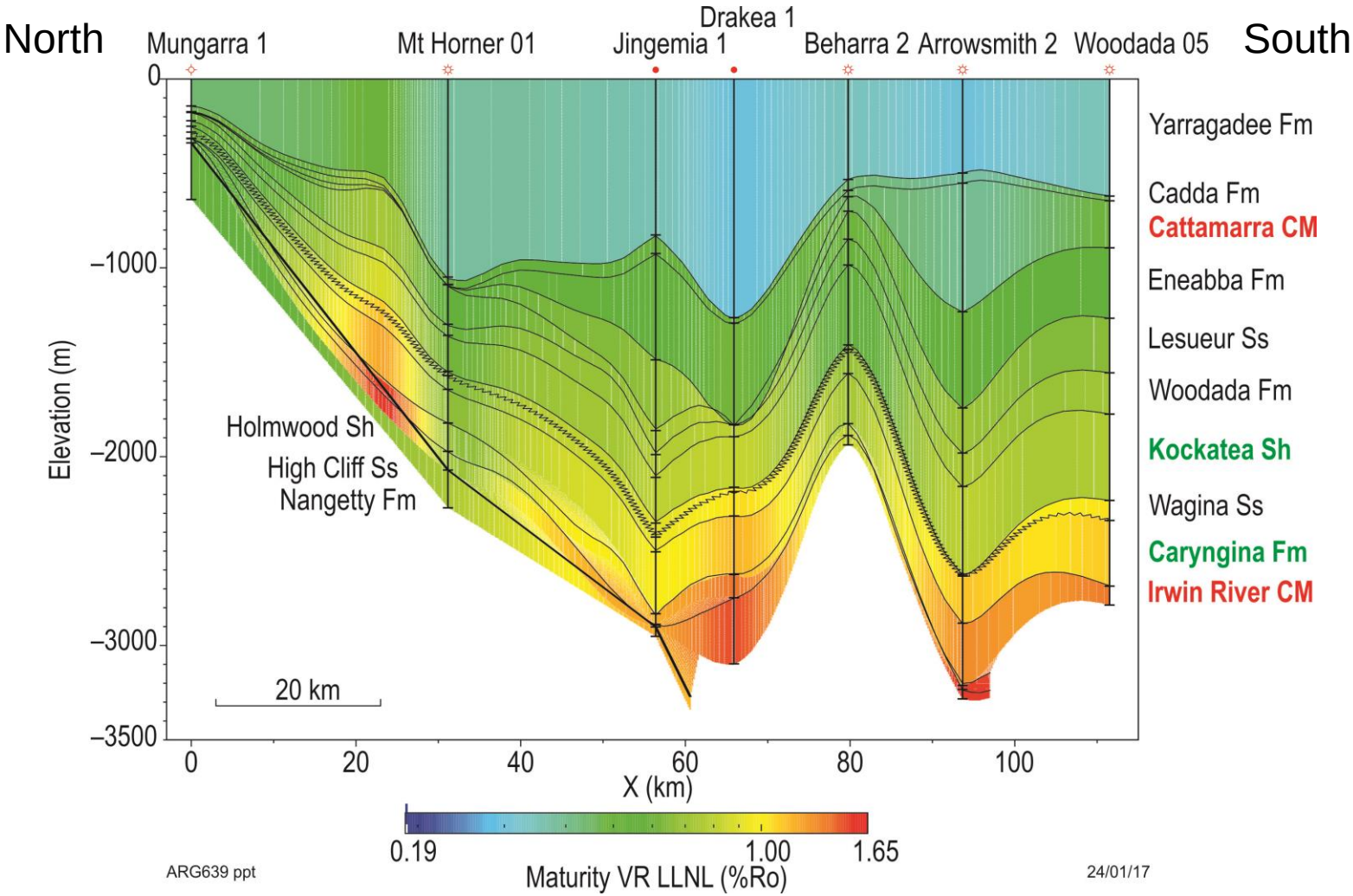
- Regional paleothermal event of the Perth Basin
- Identified from analysis of 15 samples representing 26 tracks of the Permian to Jurassic rocks from three wells:
  - Arranoo South 1
  - Cataby 1
  - West Erregulla 1

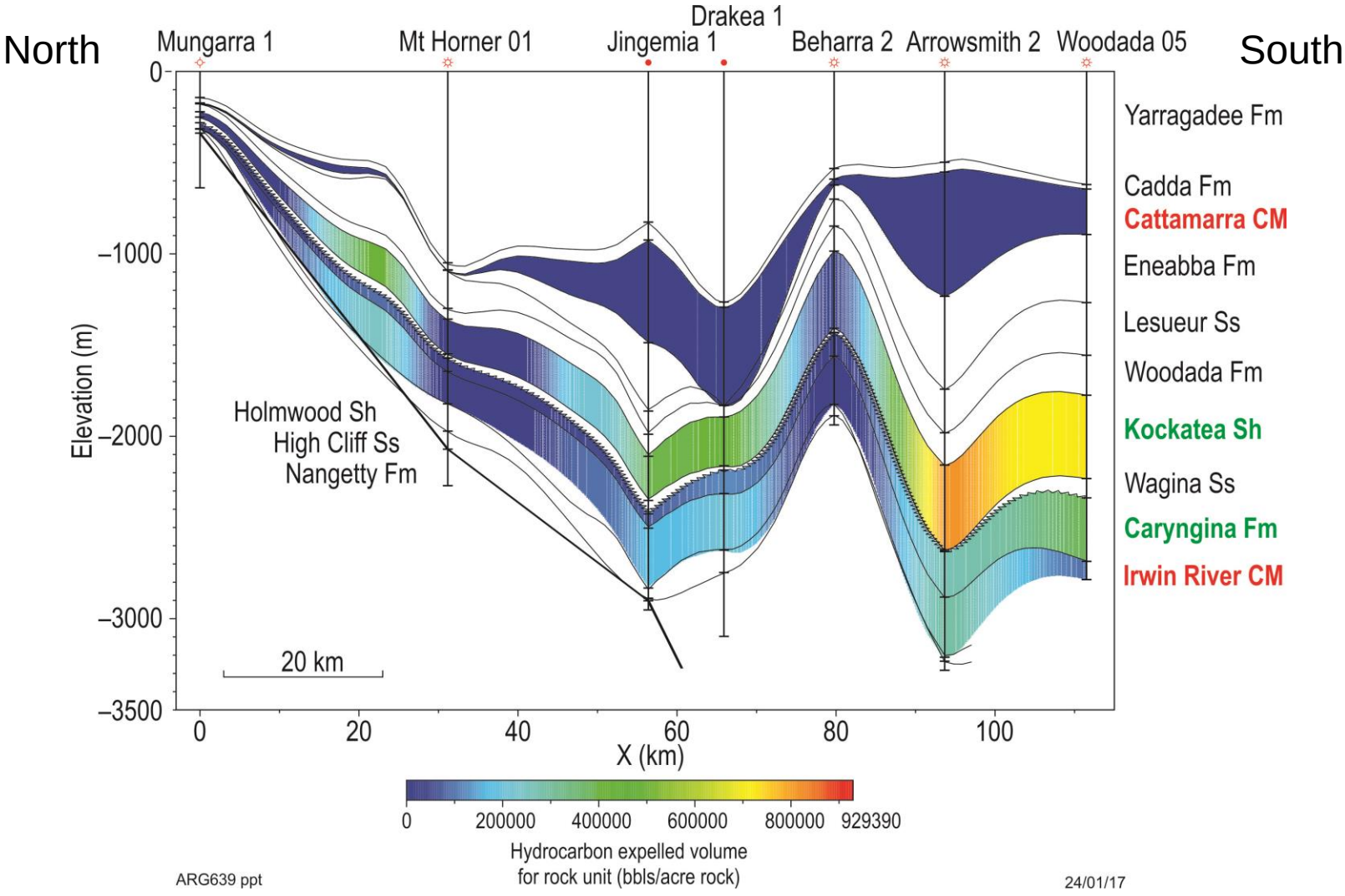


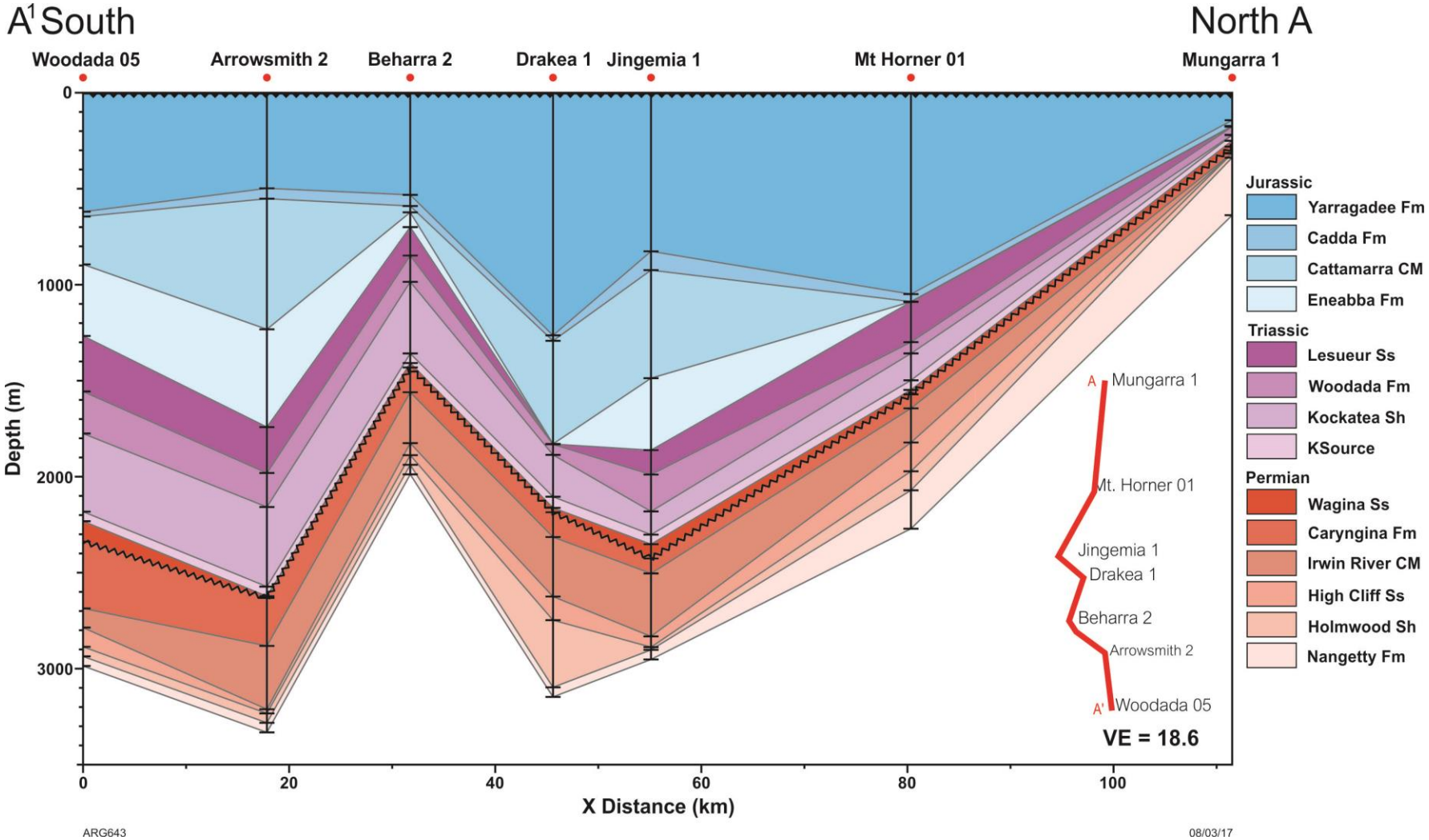

Onshore
Perth Basin
Heat flow
(mW/m2)
114.0
97.6
92.0
89.0
86.6
83.5
79.6
77.3
74.8
72.2
69.8
67.1
65.2
63.1
59.6
54.7
46.3
Geraldton
Dongara
Eneabba
Jurien Bay
Lancelin
Two Rocks
PERTH
Mandurah
Pinjarra
Harvey
Bunbury
Capel
Busselton
Margaret River
Augusta
114°
115°
29°
30°
31°
32°
33°
34°
100 km
ARG278

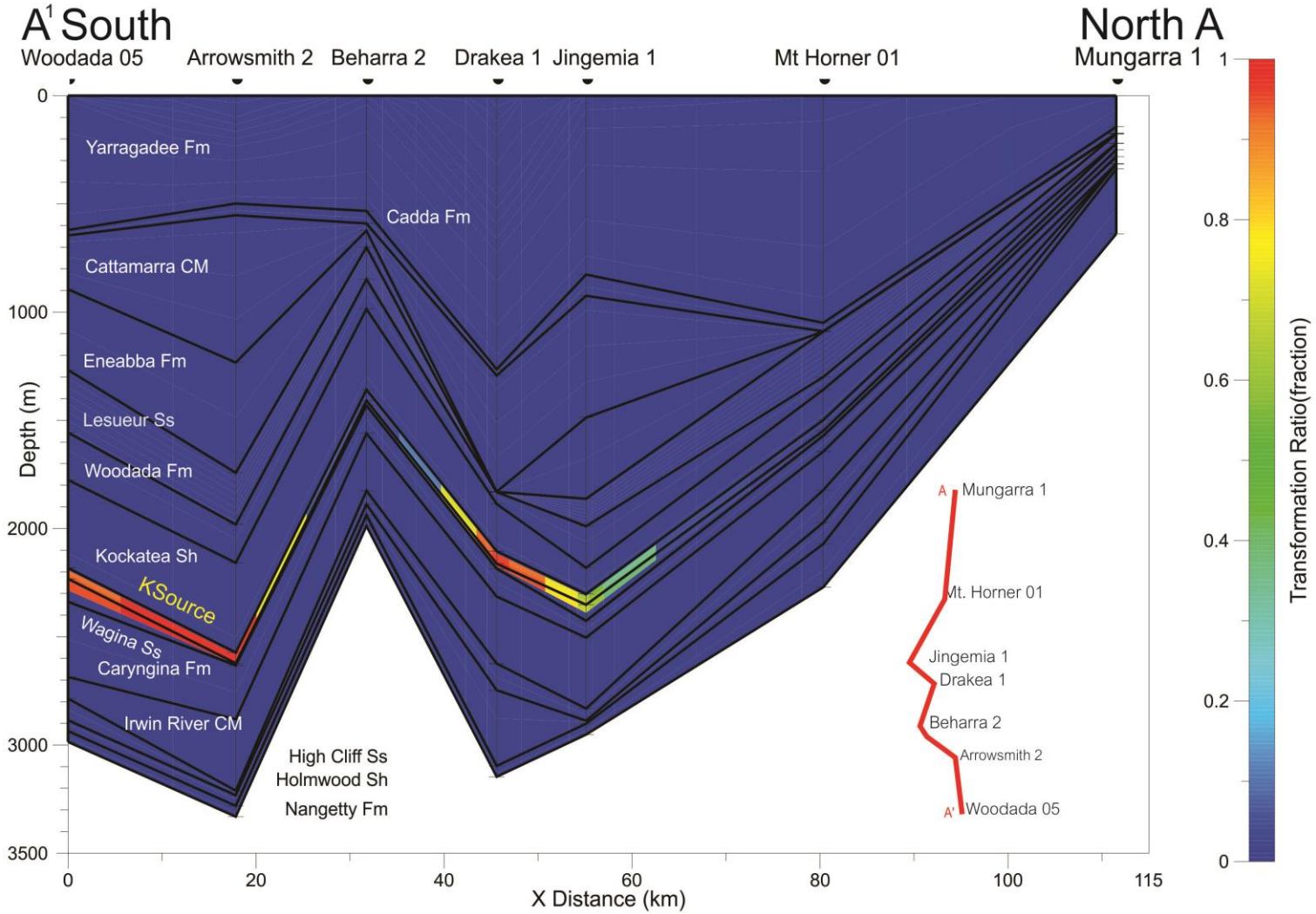

Temperature
(°C) at 5 km
252
209
188
177
172
168
163
158
153
147
142
138
133
129
126
121
109
Geraldton
Dongara
Eneabba
Jurien Bay
Lancelin
Two Rocks
PERTH
Mandurah
Pinjarra
Harvey
Bunbury
Capel
Busselton
Margaret River
Augusta
114°
115°
29°
30°
31°
32°
33°
34°
100 km
ARG274

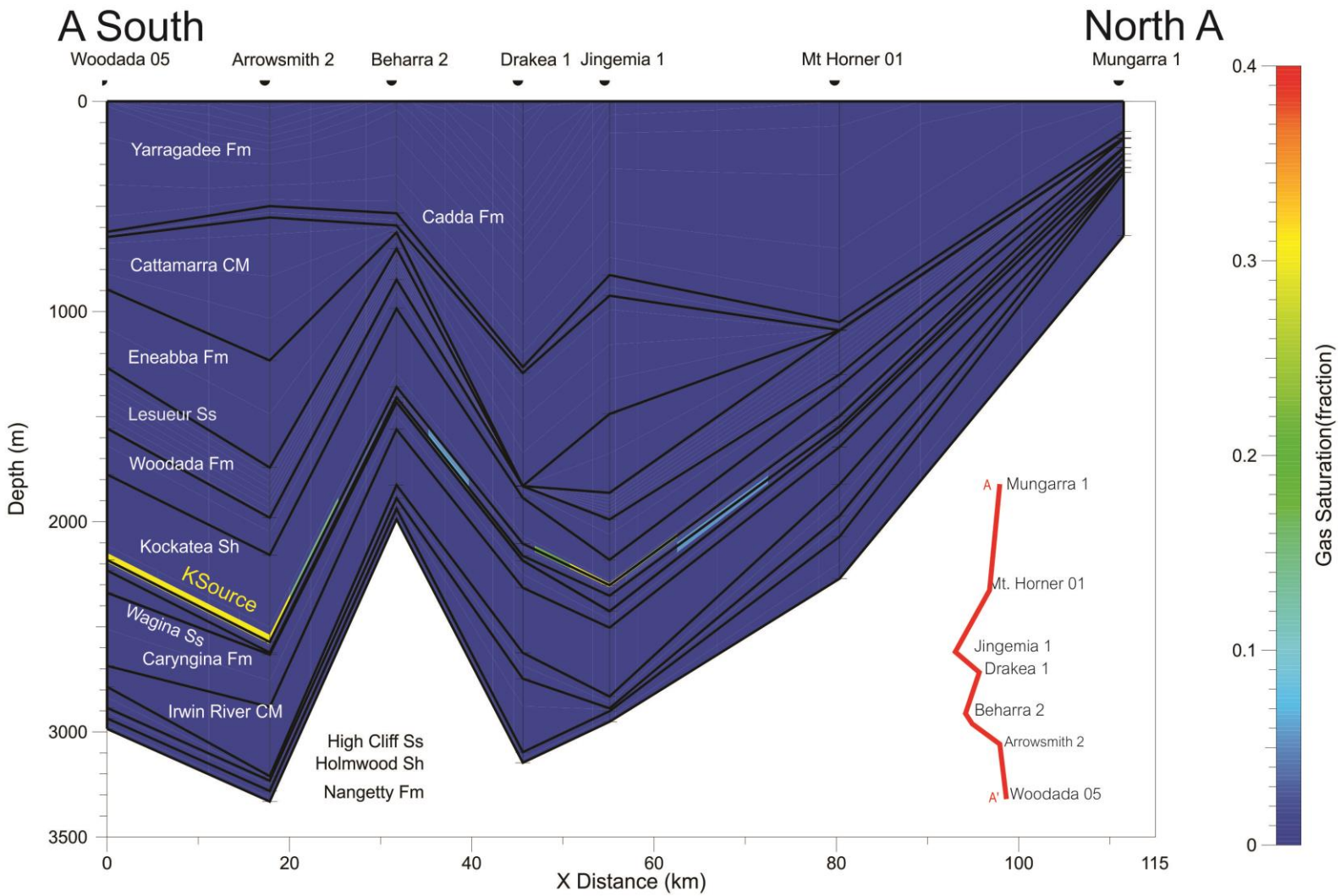

Jurrasic
Cattamarra Cm
Triassic
Kockatea shale
Permian
Caryngina Fm
Permian
Irwin River CM
Y (km)
6800
6600
6400
X (km)
280
320
360
400
S2 (mg/g rock)
0
20
40
60
80
100
10
30
50

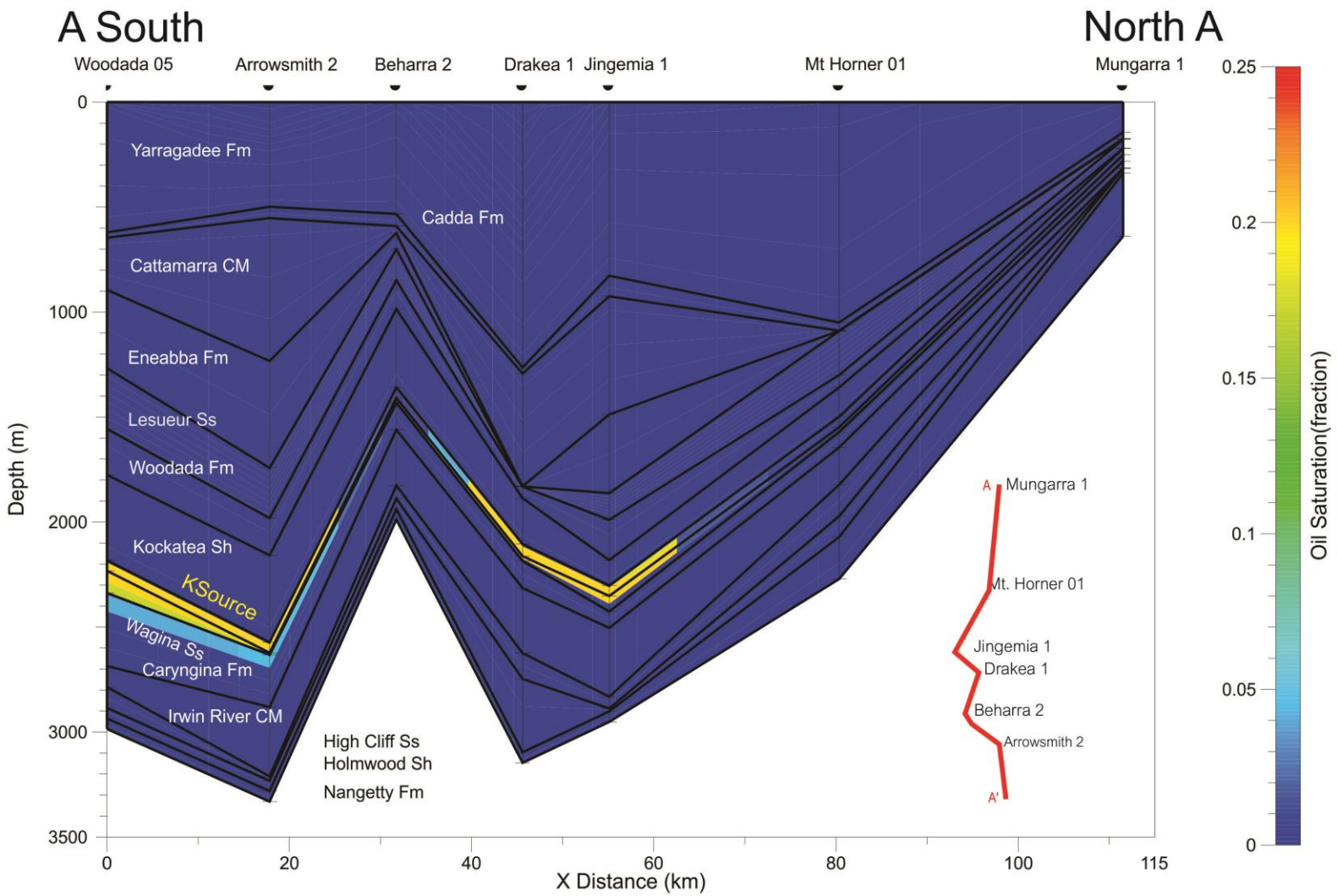

North
South
Mungarra 1
Mt Horner 01
Drakea 1
Jingemia 1
Beharra 2
Arrowsmith 2
Woodada 05
0
−1000
−2000
−3000
−3500
Elevation (m)
Holmwood Sh
High Cliff Ss
Nangetty Fm
20 km
0
20
40
60
80
100
X (km)
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Woodada Fm
Kockatea Sh
Wagina Ss
Caryngina Fm
Irwin River CM
0.19
1.00
1.65
Maturity VR LLNL (%Ro)
ARG639 ppt
24/01/17

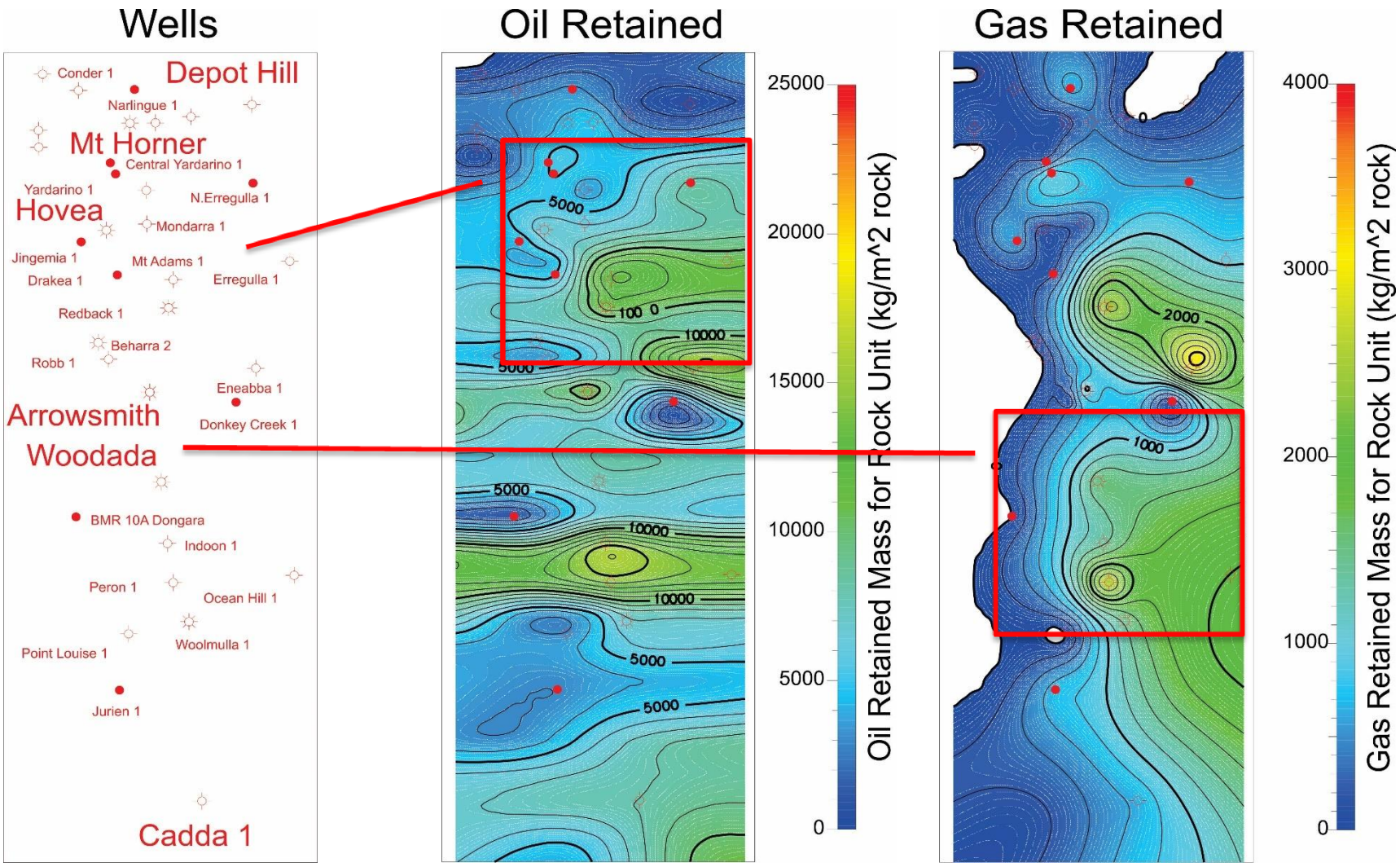

North
South
Drakea 1
Mungarra 1
Mt Horner 01
Jingemia 1
Beharra 2
Arrowsmith 2
Woodada 05
0
−1000
−2000
−3000
−3500
Elevation (m)
Holmwood Sh
High Cliff Ss
Nangetty Fm
20 km
0
20
40
60
80
100
X (km)
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Woodada Fm
Kockatea Sh
Wagina Ss
Caryngina Fm
Irwin River CM
0
200000
400000
600000
800000
929390
Hydrocarbon expelled volume
for rock unit (bbls/acre rock)
ARG639 ppt
24/01/17


A1 South
North A
Woodada 05
Arrowsmith 2
Beharra 2
Drakea 1
Jingemia 1
Mt Horner 01
Mungarra 1
0
1000
2000
3000
Depth (m)
0
20
40
60
80
100
X Distance (km)
Jurassic
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Triassic
Lesueur Ss
Woodada Fm
Kockatea Sh
KSource
Permian
Wagina Ss
Caryngina Fm
Irwin River CM
High Cliff Ss
Holmwood Sh
Nangetty Fm
A
Mungarra 1
Mt. Horner 01
Jingemia 1
Drakea 1
Beharra 2
Arrowsmith 2
A'
Woodada 05
VE = 18.6
ARG643
08/03/17


A' South
North A
Woodada 05
Arrowsmith 2
Beharra 2
Drakea 1
Jingemia 1
Mt Horner 01
Mungarra 1
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Woodada Fm
Kockatea Sh
KSource
Wagina Ss
Caryngina Fm
Irwin River CM
High Cliff Ss
Holmwood Sh
Nangetty Fm
Depth (m)
X Distance (km)
Transformation Ratio(fraction)
A
A'


A South
North A
Woodada 05
Arrowsmith 2
Beharra 2
Drakea 1
Jingemia 1
Mt Horner 01
Mungarra 1
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Woodada Fm
Kockatea Sh
KSource
Wagina Ss
Caryngina Fm
Irwin River CM
High Cliff Ss
Holmwood Sh
Nangetty Fm
Depth (m)
X Distance (km)
Gas Saturation(fraction)
A
A'
Mungarra 1
Mt. Horner 01
Jingemia 1
Drakea 1
Beharra 2
Arrowsmith 2
Woodada 05


A South
North A
Woodada 05
Arrowsmith 2
Beharra 2
Drakea 1
Jingemia 1
Mt Horner 01
Mungarra 1
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Lesueur Ss
Woodada Fm
Kockatea Sh
KSource
Wagina Ss
Caryngina Fm
Irwin River CM
High Cliff Ss
Holmwood Sh
Nangetty Fm
Depth (m)
X Distance (km)
Oil Saturation(fraction)
A
A'
Mungarra 1
Mt. Horner 01
Jingemia 1
Drakea 1
Beharra 2
Arrowsmith 2


Wells
Oil Retained
Gas Retained
Conder 1
Depot Hill
Narlingue 1
Mt Horner
Central Yardarino 1
Yardarino 1
N.Erregulla 1
Hovea
Mondarra 1
Jingemia 1
Mt Adams 1
Drakea 1
Erregulla 1
Redback 1
Beharra 2
Robb 1
Eneabba 1
Arrowsmith
Donkey Creek 1
Woodada
BMR 10A Dongara
Indoon 1
Peron 1
Ocean Hill 1
Woolmulla 1
Point Louise 1
Jurien 1
Cadda 1
5000
100
0
10000
5000
5000
10000
10000
5000
5000
0
2000
1000
25000
20000
15000
10000
5000
0
Oil Retained Mass for Rock Unit (kg/m^2 rock)
4000
3000
2000
1000
0
Gas Retained Mass for Rock Unit (kg/m^2 rock)

Fracturing Quality - Petrography

Permian Carynginia Formation

Redback 1: 3762.00 m

TOC = 2.38%

Ro = 1.40%

Brittleness: 0.38

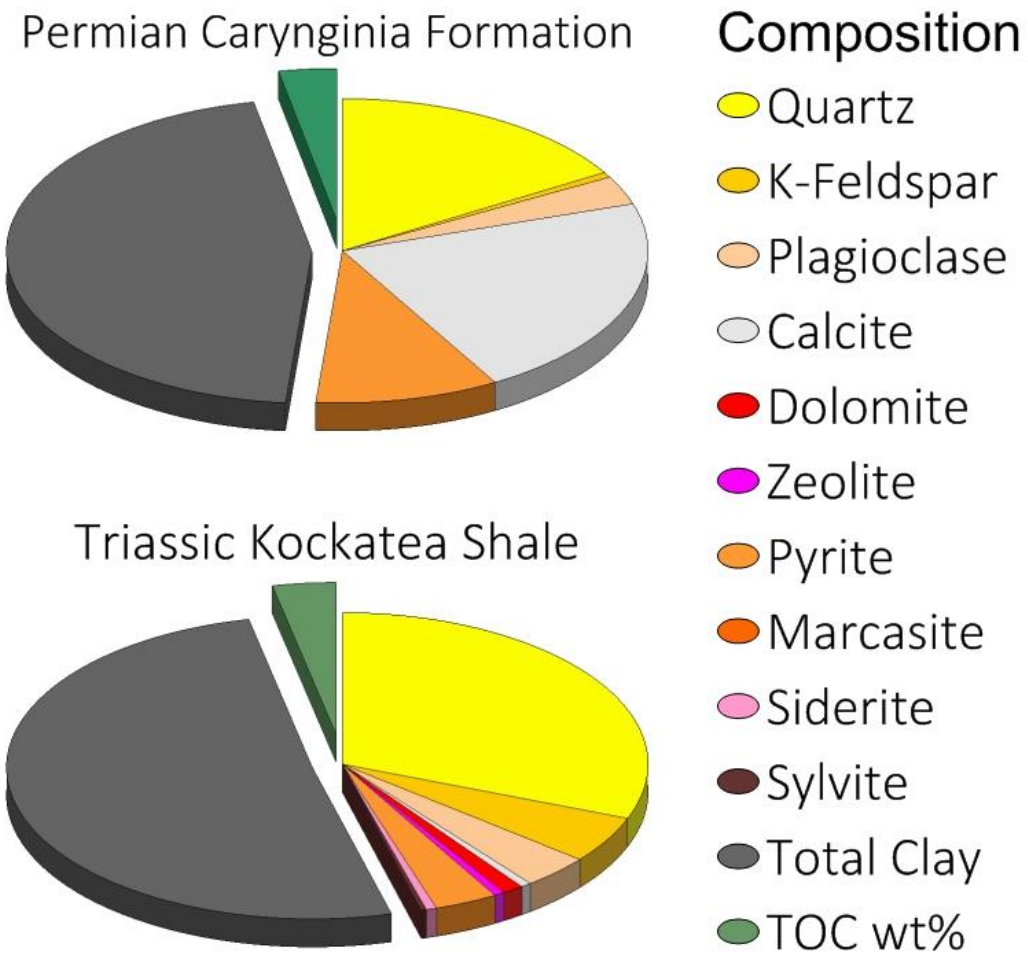
Triassic Kockatea Shale

Redback 2: 3788.52 m

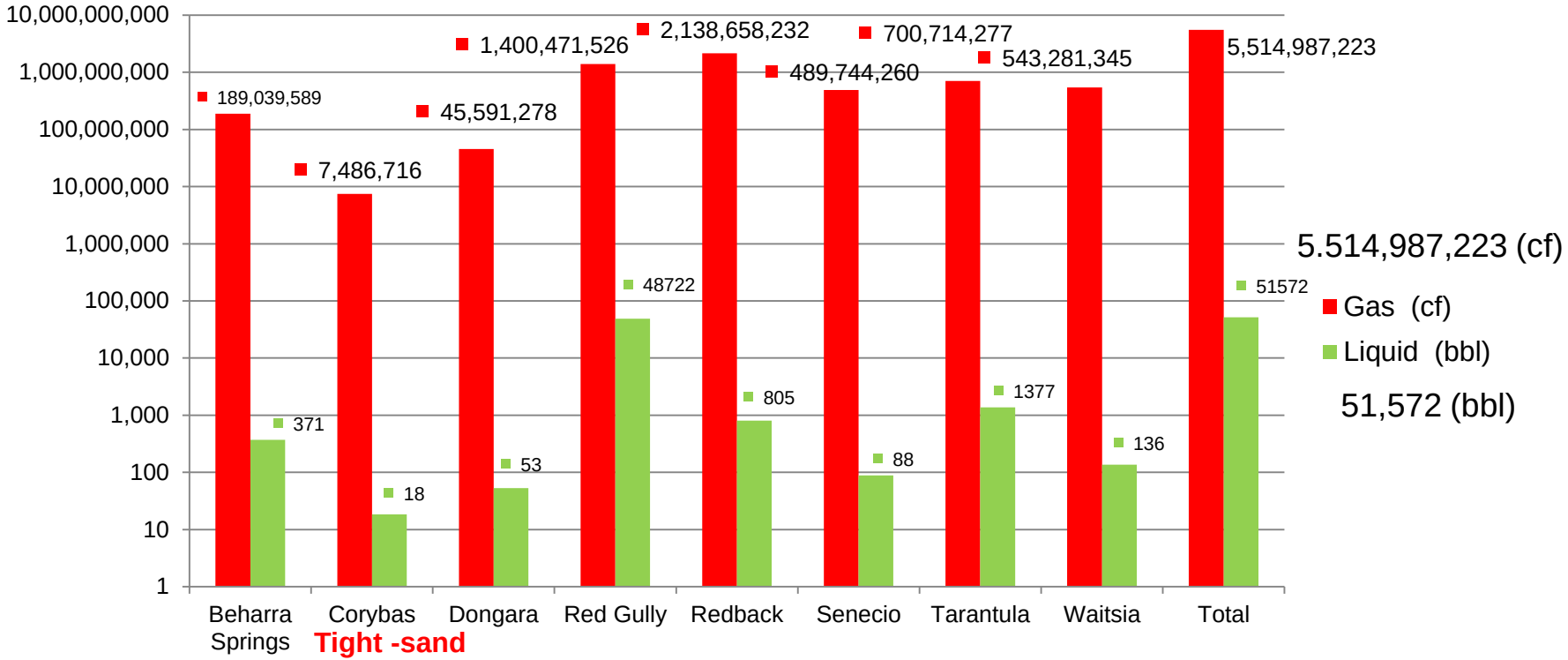
TOC = 2.29%

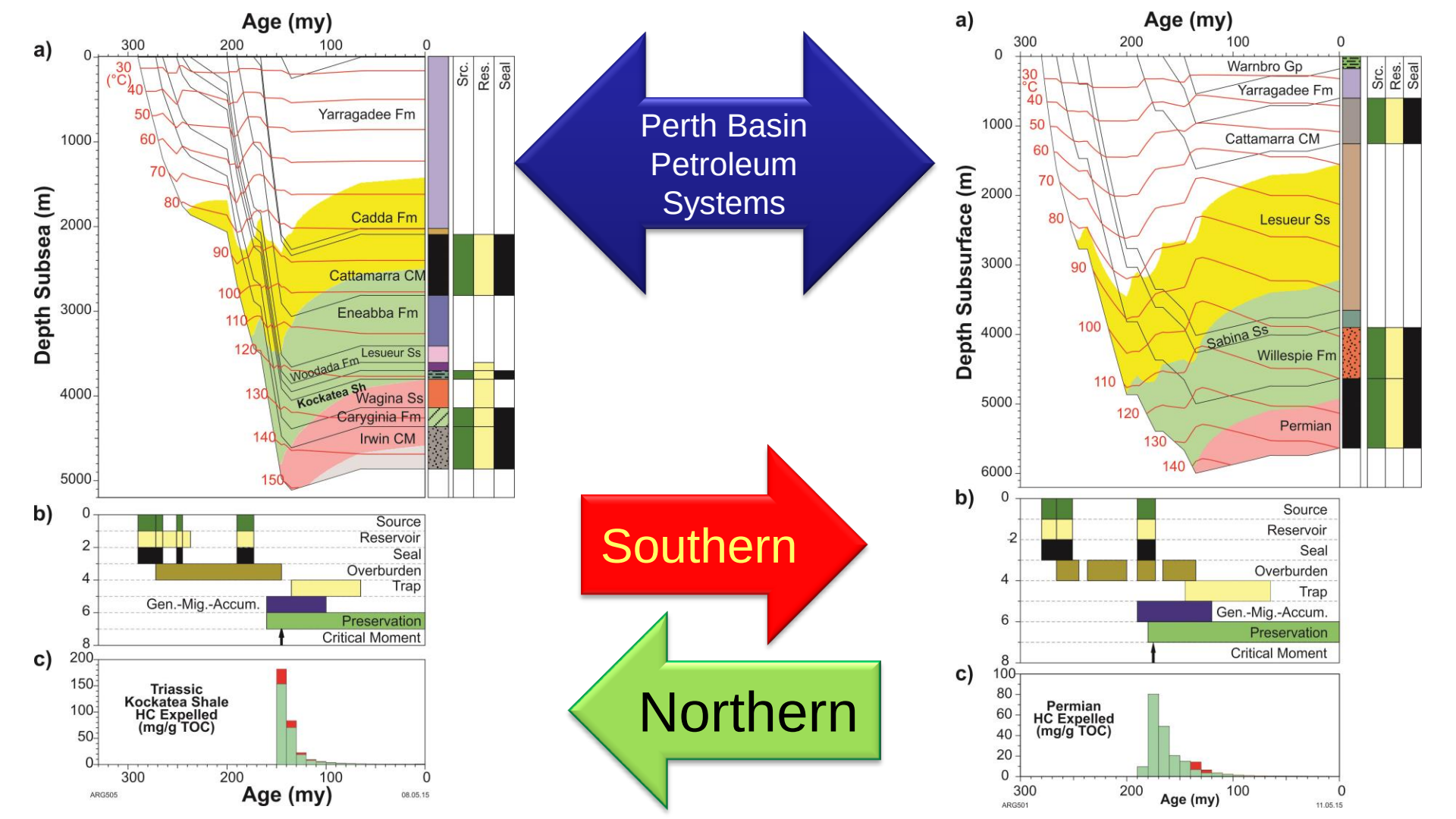
Ro = 1.32%

Brittleness: 0.29



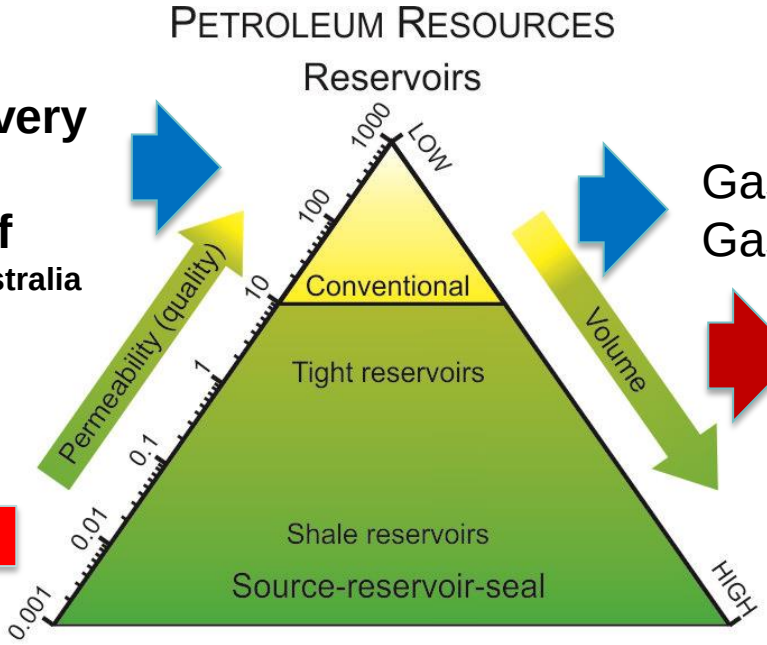
Gas-condensate Production - 2016




Perth Basin
Petroleum
Systems
Southern
Northern
a)
Age (my)
Depth Subsea (m)
Yarragadee Fm
Cadda Fm
Cattamarra CM
Eneabba Fm
Woodada Fm
Lesueur Ss
Kockatea Sh
Wagina Ss
Caryginia Fm
Irwin CM
Src.
Res.
Seal
b)
Source
Reservoir
Seal
Overburden
Trap
Gen.-Mig.-Accum.
Preservation
Critical Moment
c)
Triassic
Kockatea Shale
HC Expelled
(mg/g TOC)
ARG505
08.05.15
a)
Age (my)
Depth Subsurface (m)
Warnbro Gp
Yarragadee Fm
Cattamarra CM
Lesueur Ss
Sabina Ss
Willespie Fm
Permian
b)
Source
Reservoir
Seal
Overburden
Trap
Gen.-Mig.-Accum.
Preservation
Critical Moment
c)
Permian
HC Expelled
(mg/g TOC)
ARG501
11.05.15

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

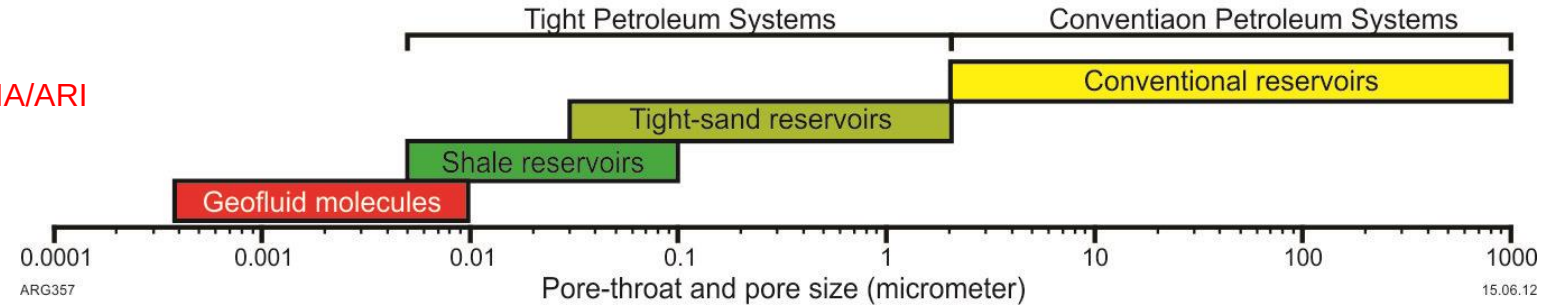


Gas Reserves: 0.05 Tcf (2P)
Gas Resources: 0.33 Tcf (2C)

Gas Reserves: 12 Tcf (GIIP)

Source: Department of Mines & Petroleum

Source: EIA/ARI 2013



Thanks: Questions Time

Coal+Oil+Gas Era: 84%