UNCONVENTIONAL OIL AND GAS OPPORTUNITIES IN SOUTH AUSTRALIA

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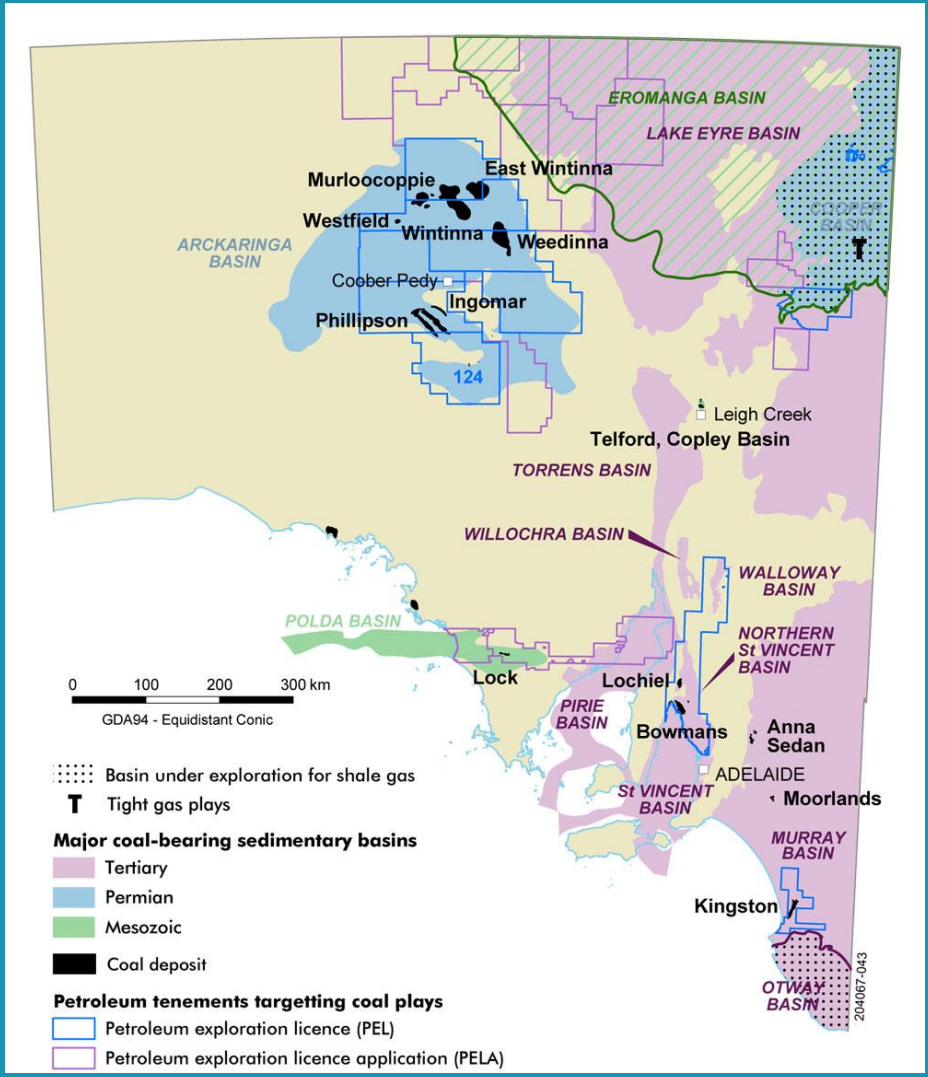
Unconventional Gas and Oil



Prospective plays in the mix:

1. **Shale gas in the Cooper (> 3 JVs)**
2. **Shale gas in the Otway (> 2 JVs)**
3. **Shale gas in the Officer (2 JVs)**
4. **Gas in low permeability reservoirs (tight gas) – Cooper Basin (> 3 JVs)**
5. **Fracture stimulation of coals, Cooper Basin (> 3 JVs)**
6. **Coal Seam Gas in the Eromanga (> 3 JVs)**
7. **Underground coal gasification – Walloway, Arckaringa, Pedirka and other basins (2 JV)**
8. **Coals mining - Arckaringa & Tertiary basins for power generation, syngas and synfuel (>4 JVs)**
9. **Other Coal -Sourced Gas in Jurassic and Tertiary Basins (>2 JVs)**

SA Roundtable for Unconventional Gas

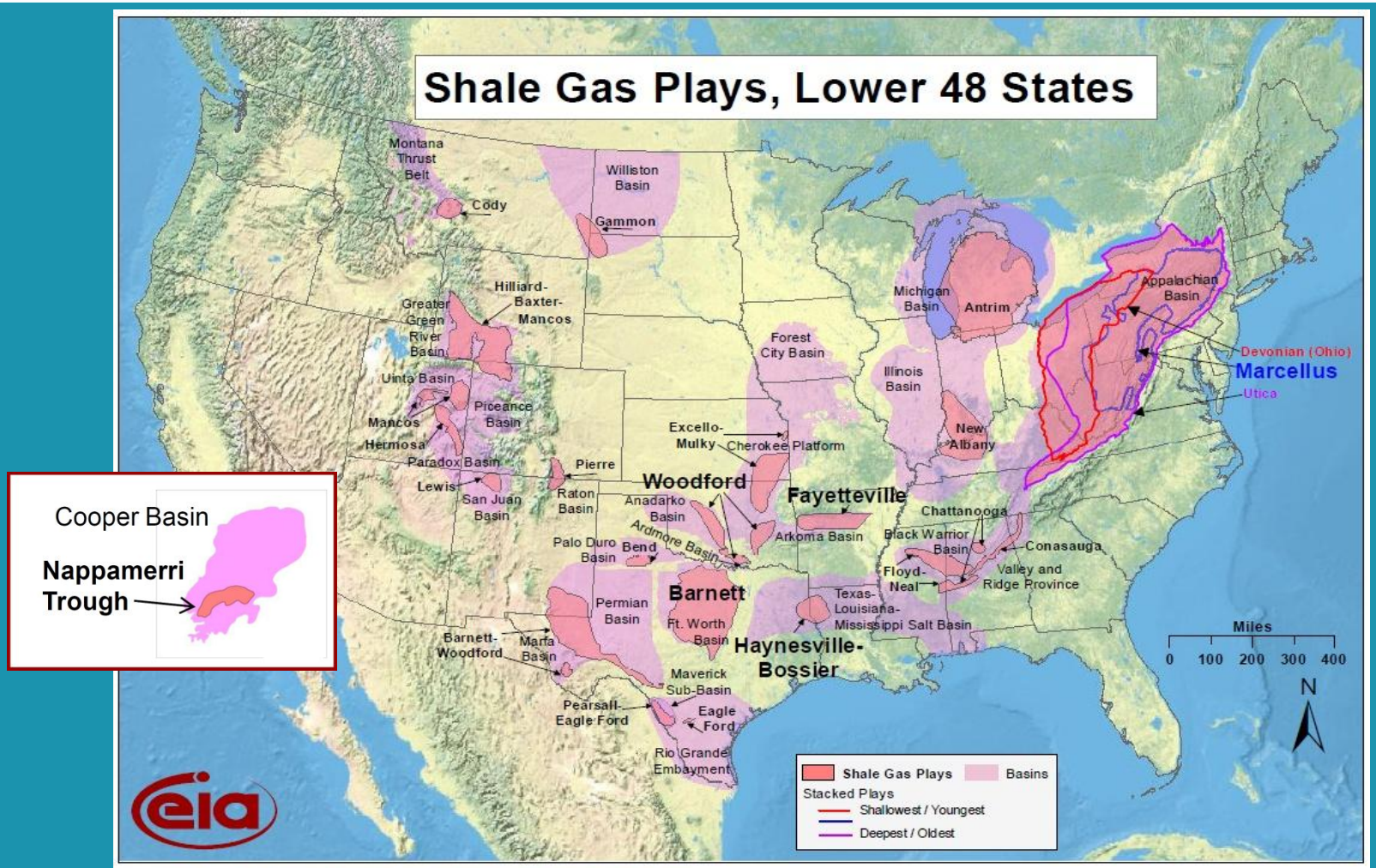
Objective: Inform industry strategies and government policies to underpin optimum life-cycle upstream-downstream planning for the deployment of technologies and infrastructure for exporting unconventional petroleum gas and liquids

Strategy: Convene a Roundtable (government and Industry) focused on unconventional petroleum gas and liquids to rank opportunities and threats in a roadmap for the development of unconventional gas

Outcomes (via roadmap to be released in May 2012):

- Informed industry investment and infrastructure strategies
- Informed government legislation, policies and programs

Cooper Basin and US shale gas basins



Cooper Basin inset from Beach Energy Presentation, "Cooper Basin Shale Gas", April 2010

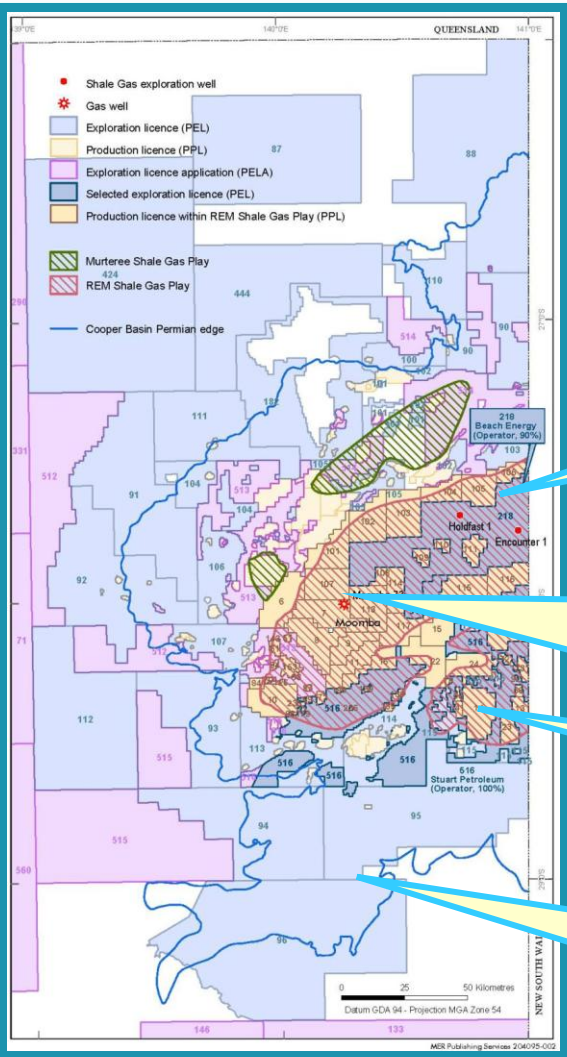
Comparison with US Shale Gas Plays

Parameter	Barnett	Fayetteville	Marcellus	Haynesville	Cooper Basin
Depth (ft)	5400 - 9600'	1200 - 7500'	1500 - 8000'	10000 - 13000'	9500 - 11500'
Thickness (ft)	250 - 500'	50 - 200'	75 - 300'	200 - 300'	400 - 500'
Petrology	Siliceous Mudstone	Siliceous Mudstone	Argillaceous Mudstone	Argillaceous/ Calcareous Mudstone	Siltstone/ Siliceous Mudstone
Age	Carboniferous	Carboniferous	Devonian	Jurassic	Permian
Porosity %	7	6.5	6	10	To be measured
TOC Av%	5	4	6	4	5
Ro %	1-1.3 (type II)	>1	>1	2.2 - 3 (type III)	0.9 - 3.4 (type II to III)
Temp F	200			240 - 322	300 - 390
GIP (Av) Bcf/sq.mile	100	48	100	200	~25 (prelim)

Modified from Beach Energy Presentation, "Cooper Basin Shale Gas", April 2010

This is a file of presentation slides

Unconventional gas Cooper Basin



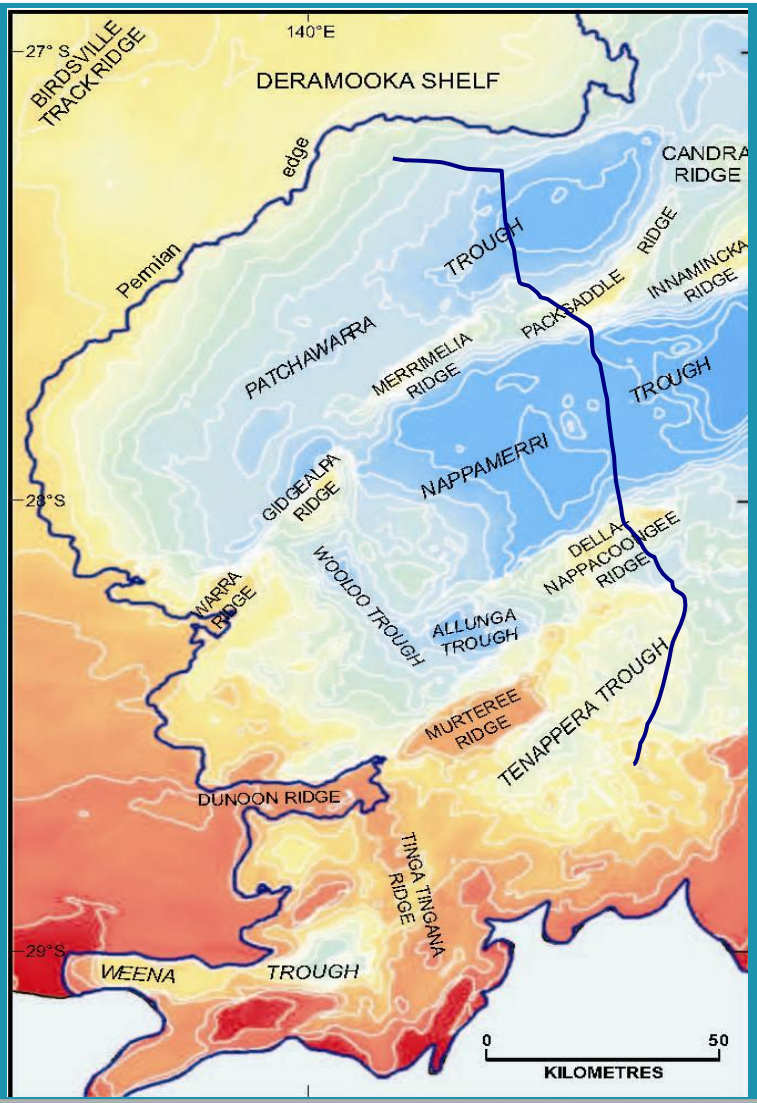
Beach Energy: PEL 218
Holdfast 1 flowed gas at up to 2 MMscf/d after seven stage fracture stimulation of gas saturated Early Permian succession.
Beach estimate potential 300 TCF gas in place in PEL 218 (Nappamerri Trough, SA) – almost 100 TCF in shales and >200 TCF in sands (BCGA)

Santos:
Booked 2C (contingent, probable, recoverable, Santos share) unconventional gas resources (shale gas, tight gas, deep coal) of ~2.22 TCF (2,345 PJ)

Senex Energy, PEL 516: Estimate 75-110 TCF gas in place in shales and coals

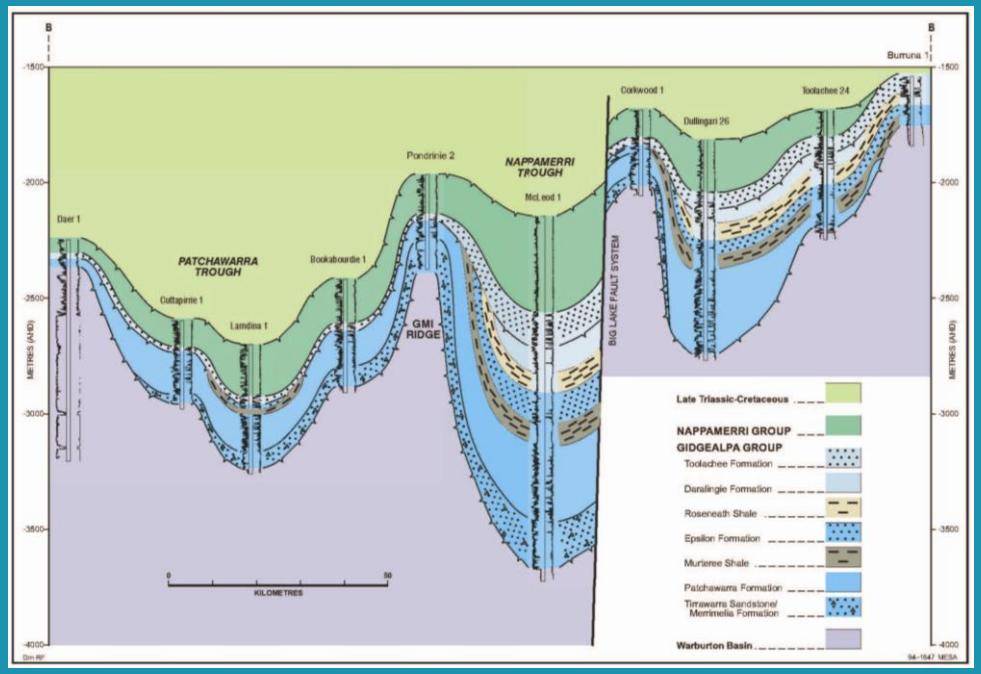
Strike, Beach, PELs 94, 95, 96: Mean prospective resource estimate 12.39 TCF gas and 113 MMbbls liquids in coals and shales

Cooper Basin Structural Elements

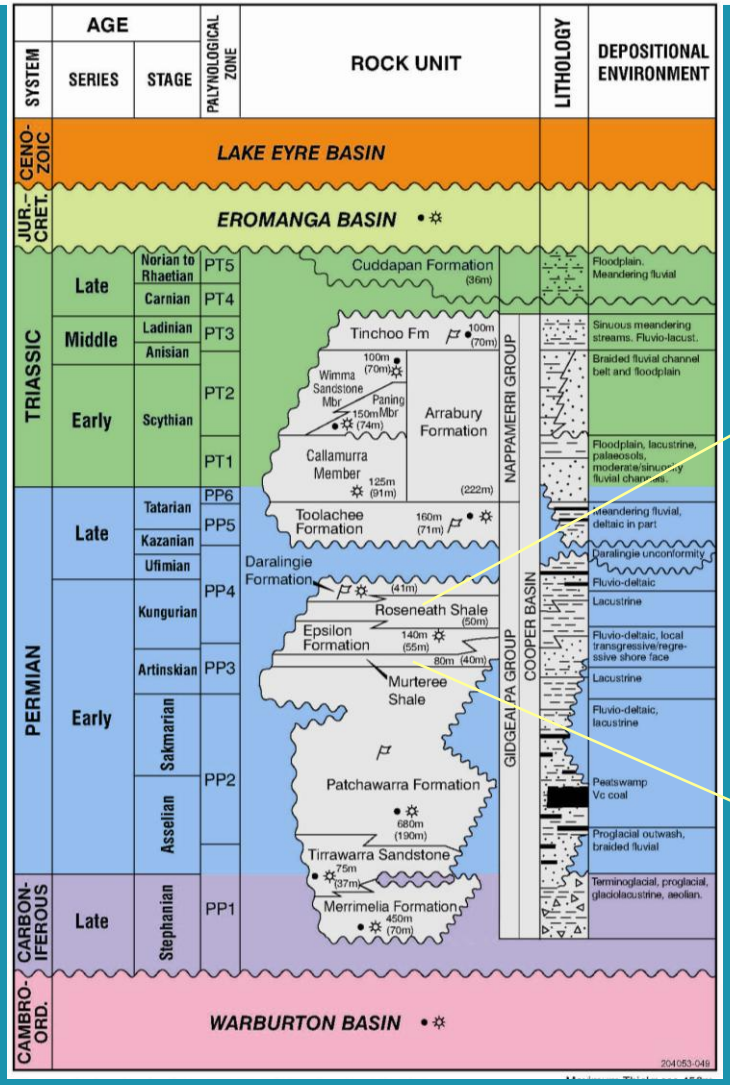


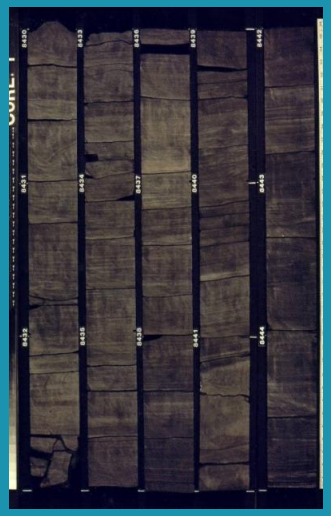
3 Main Troughs

- Patchawarra
- Nappamerri (current shale gas focus)
- Tenapperra



Cooper Basin shale gas targets





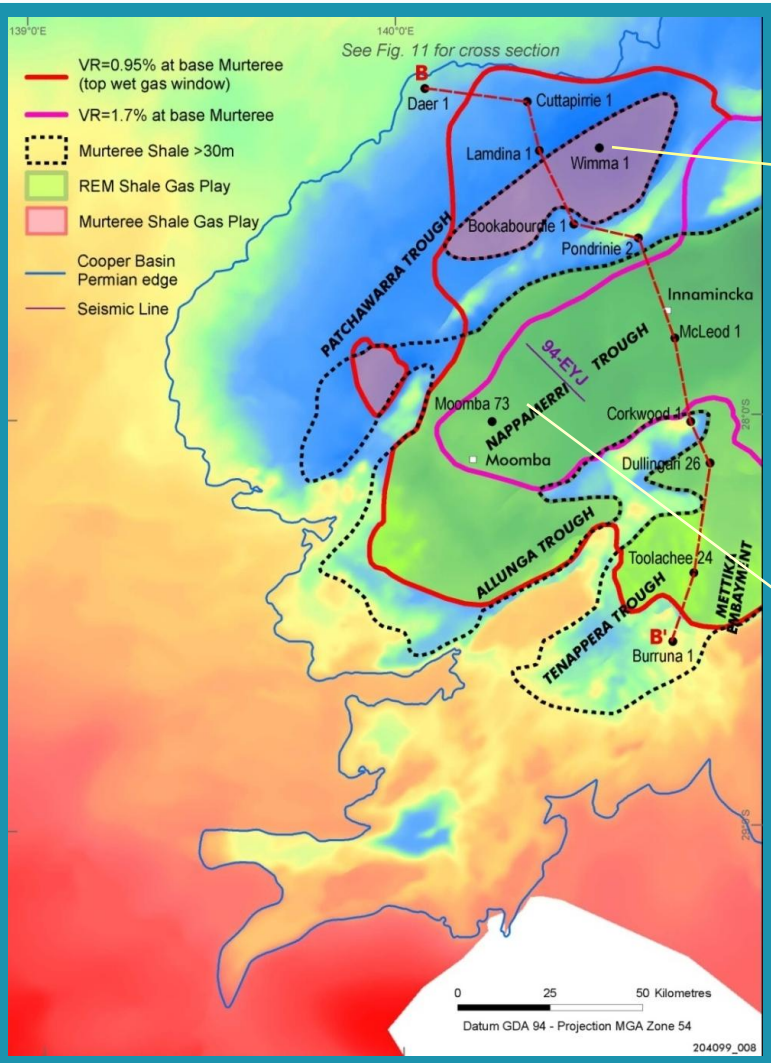
Roseneath Shale (Lacustrine)

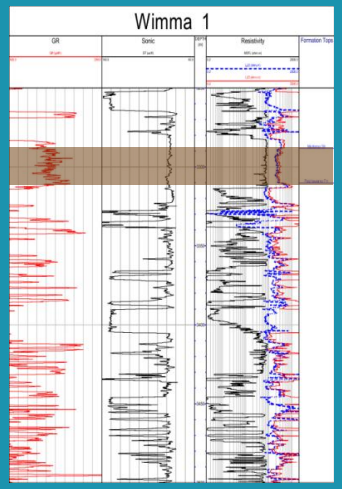
Comprises light and dark brown siltstone, mudstone and minor sandstones.
Siltstones are micaceous with minor fine grained pyrite.

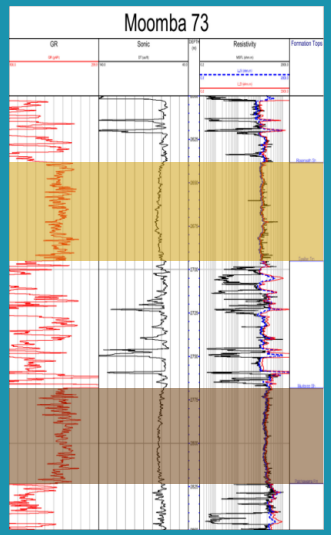
Murteree Shale (Lacustrine)

Comprises black to dark grey - brown argillaceous siltstone and minor sandstones, becoming sandier to the southern Cooper Basin.

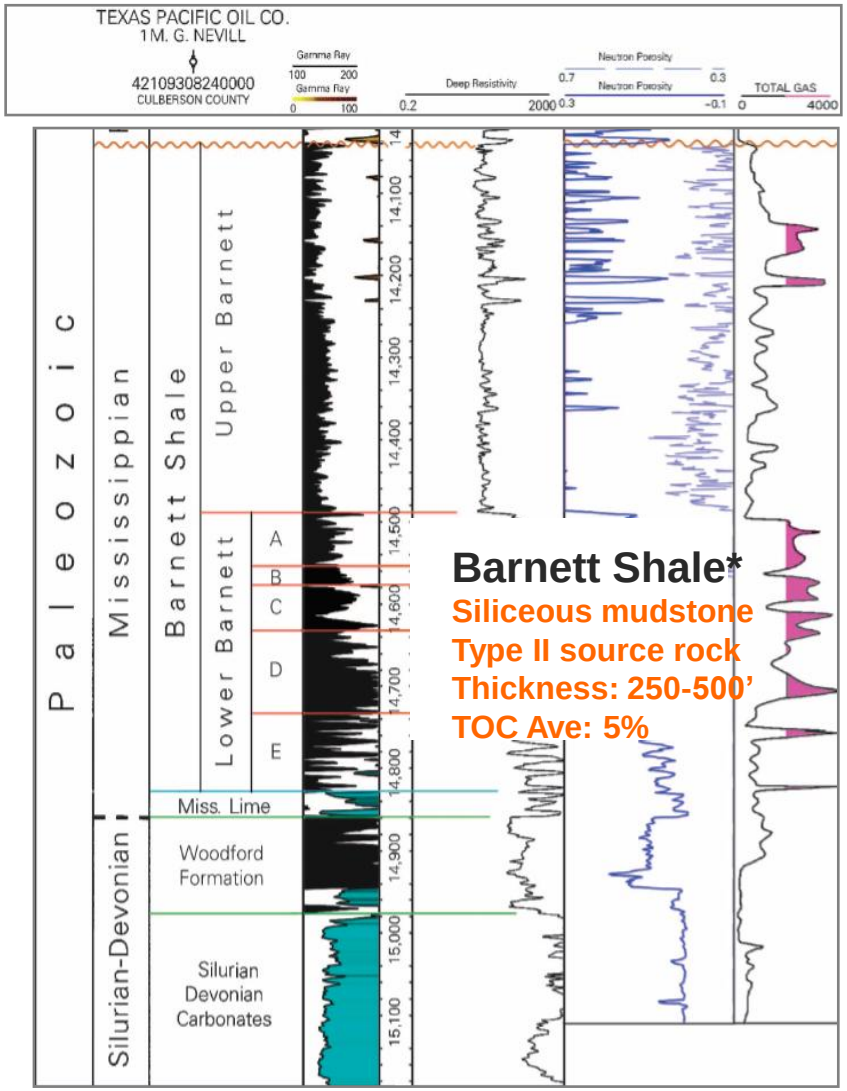
Cooper Basin shale gas fairways



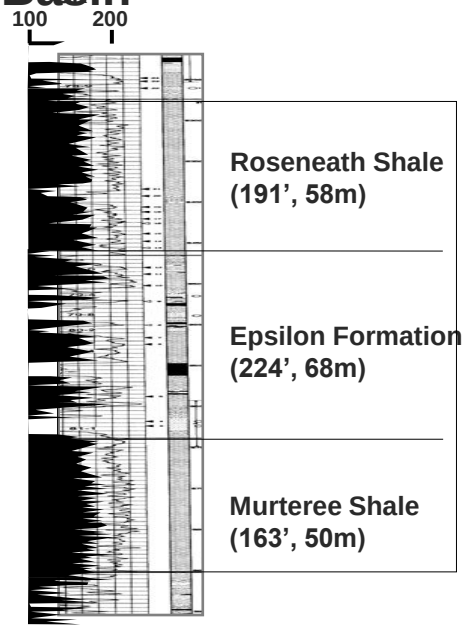




Comparison of Barnett (USA) and Cooper REM Shale Gas Plays ….and unlike CSG – Shale Gas can be rich in ethane, LPG & condensate



Moomba 77 – Cooper Basin



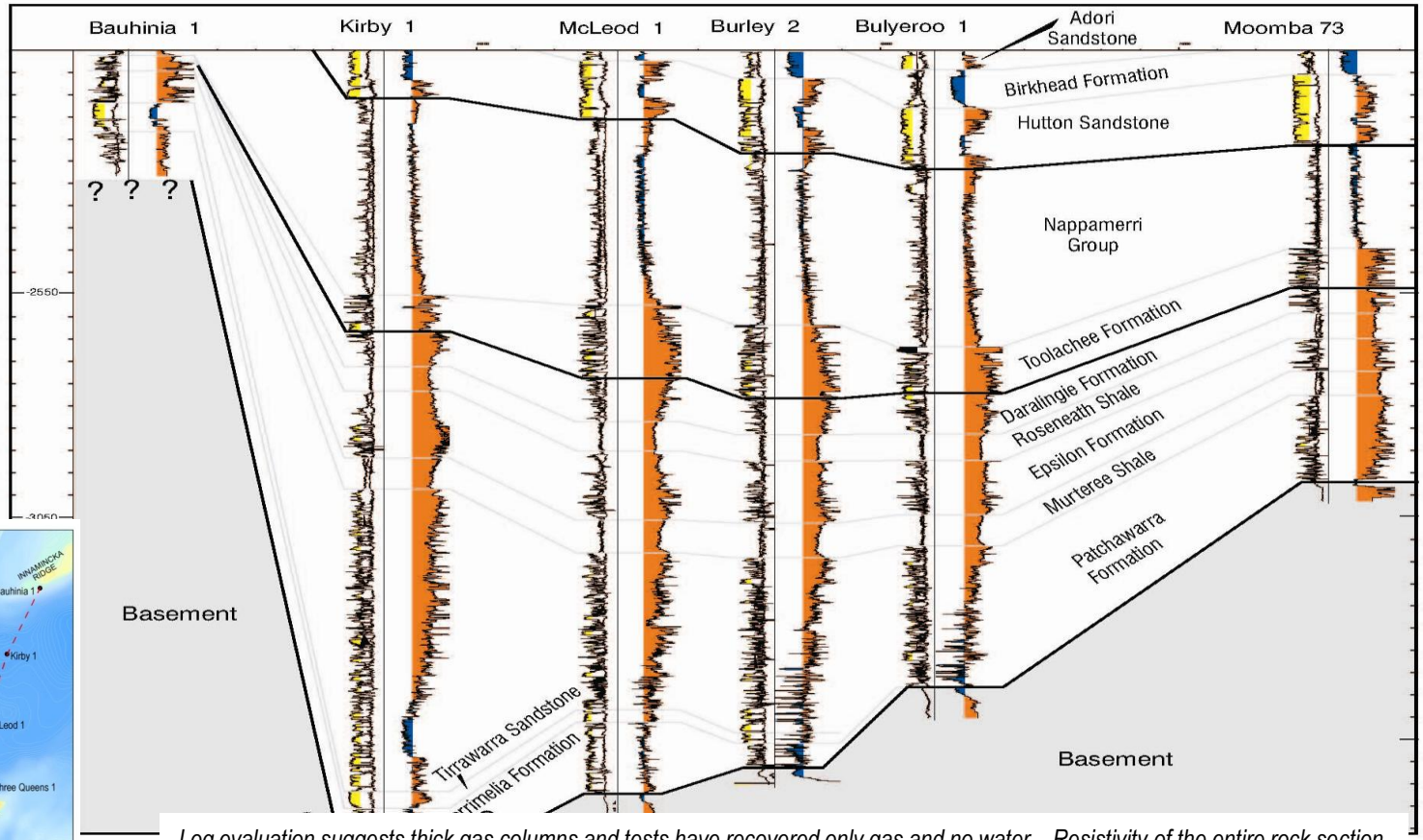
REM* Roseneath-Epsilon-Murteree

Siliceous mudstone
Type II source rock
Thickness: 400-500'
TOC Ave: 5%

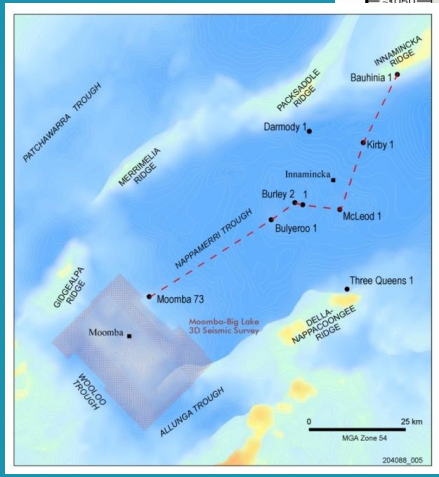
**From Beach Energy presentation "Cooper Basin Shale Gas", Gordon Moseby, 30 March 2010*

Wireline log through Barnett Shale from Kinley et al, 2008 "Hydrocarbon Potential of the Barnett Shale (Mississippian), Delaware Basin, west Texas and southeastern New Mexico" AAPG v92, No 8

Evidence for Basin Centred Gas Accumulation



Log evaluation suggests thick gas columns and tests have recovered only gas and no water . Resistivity of the entire rock section exceeds 20 Ωm over large intervals (Hillis et al, 2001)



Research in SA

GeoFrac (Dennis Cooke, ASP):

- Fracture stimulation and geomechanics research for unconventional reservoirs
- Natural fracture density, critically stressed natural fractures, local stress, geomechanical causes of frac complexity, proppant embedment, proppant placement

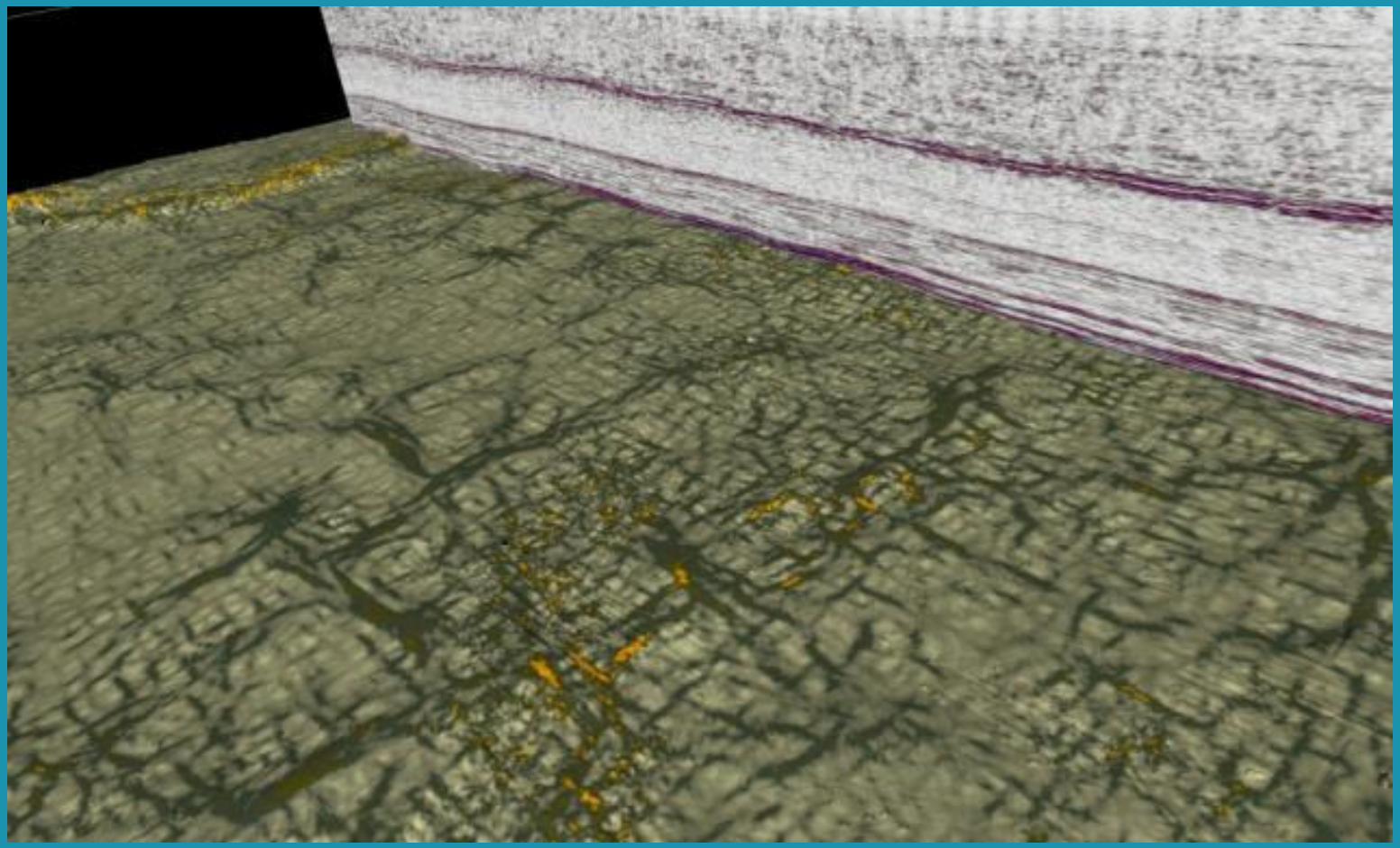
ASP

- Elizabeth Baruch – PhD student (has worked with Conoco-Phillips Eagleford Shale research team in US) will be researching geological and geomechanical characteristics of REM in Cooper Basin (project not finalised – Mark Tingay supervisor)
- Engineering students researching proppant emplacement in coals (Proffesor Pavel Bedrikovetsky supervisor)

Adelaide University:

- Dr Martin Kennedy recently appointed to staff professorial position. Research focuses on new source rock model that considers preservative effects, depositional controls, and influence on cracking T of the mineral surfaces hosting organic matter

Moomba-Big Lake: Attribute analysis - Most positive curvature



From "Geomechanical Characterization of Unconventional Play on the Cooper Basin of Australia" Presentation by Guillaume Backé and Ros King, 2010
Research by the GEOFRAC consortia at the University of Adelaide

SA Cooper Basin JV (Santos operator) Unconventional Gas Project

Targeting production and ~5,000 PJ resource by 2015

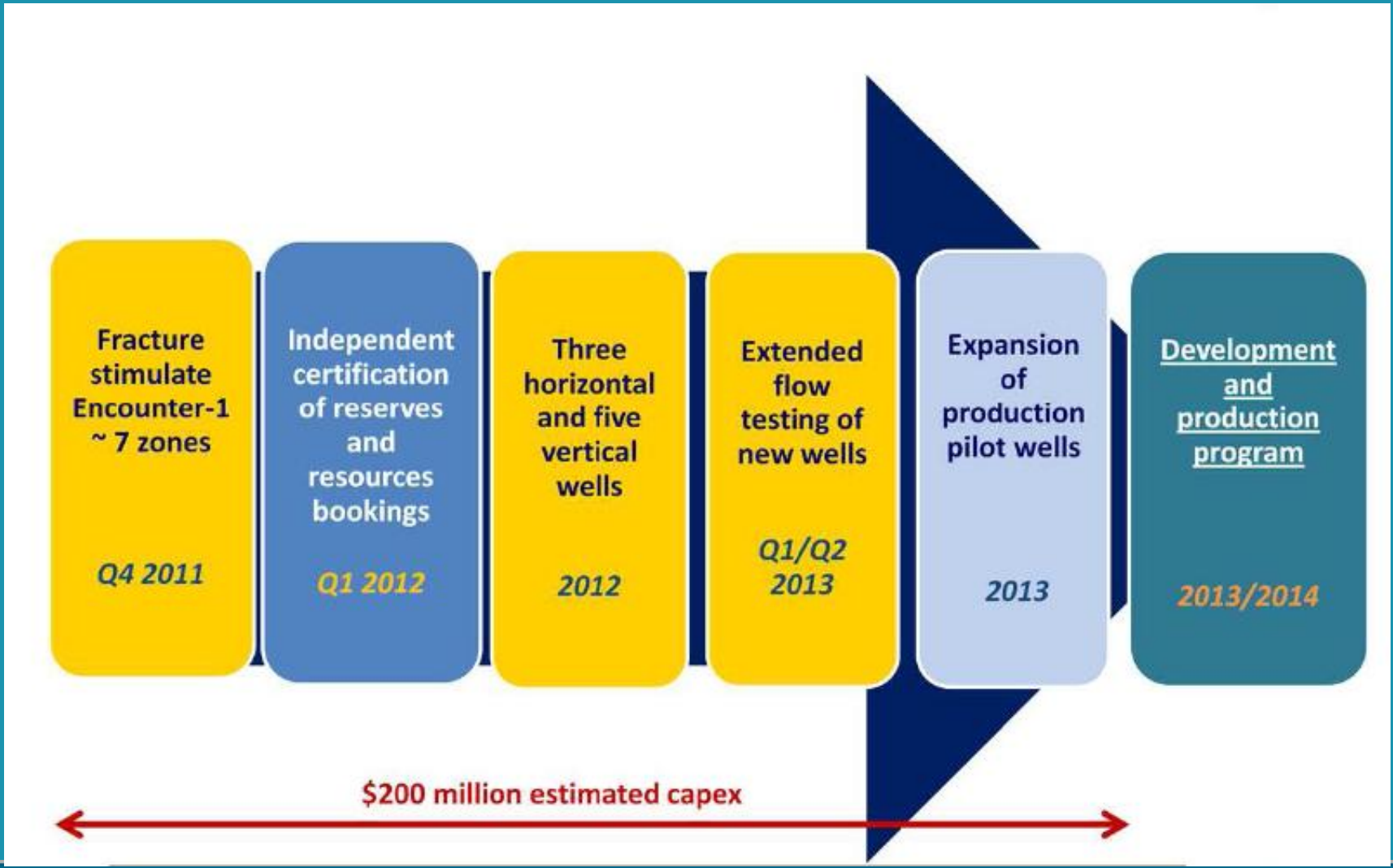
Prove gas content and recoverable volumes	Achieve gas flow to surface	Demonstrate commercial flows	2P reserve bookings
2004–2010	**2011–2012**	**2012–2013**	**2013+**
Acquired the resource understanding	**Vertical well technology trials and optimisation**	**Horizontal well technology trials and optimisation**	**Evaluation across broader Santos Cooper acreage**
▪ Australia's first shale fracture and coring program in 2006 ▪ Australia's first independently certified shale and unconventional resource bookings achieved in 2008	▪ Acquiring further data to enable appraisal optimisation ▪ Dedicated shale well including dedicated shale fracturing	▪ Dedicated shale horizontal drilling trial ▪ Extensive fracturing trials beyond levels currently tested in the Cooper	▪ Multiple horizontal and vertical appraisal wells ▪ **Targeting initial shale reserve bookings in 2013, and production in 2015**
2C* 2,345 PJ	2C* 2,600 PJ *Outlook*	2C* 4,000 PJ *Outlook*	2C* 4,800 PJ *Outlook*

28 ** Santos share – total shale and other unconventional resources*

Santos
We have the energy.

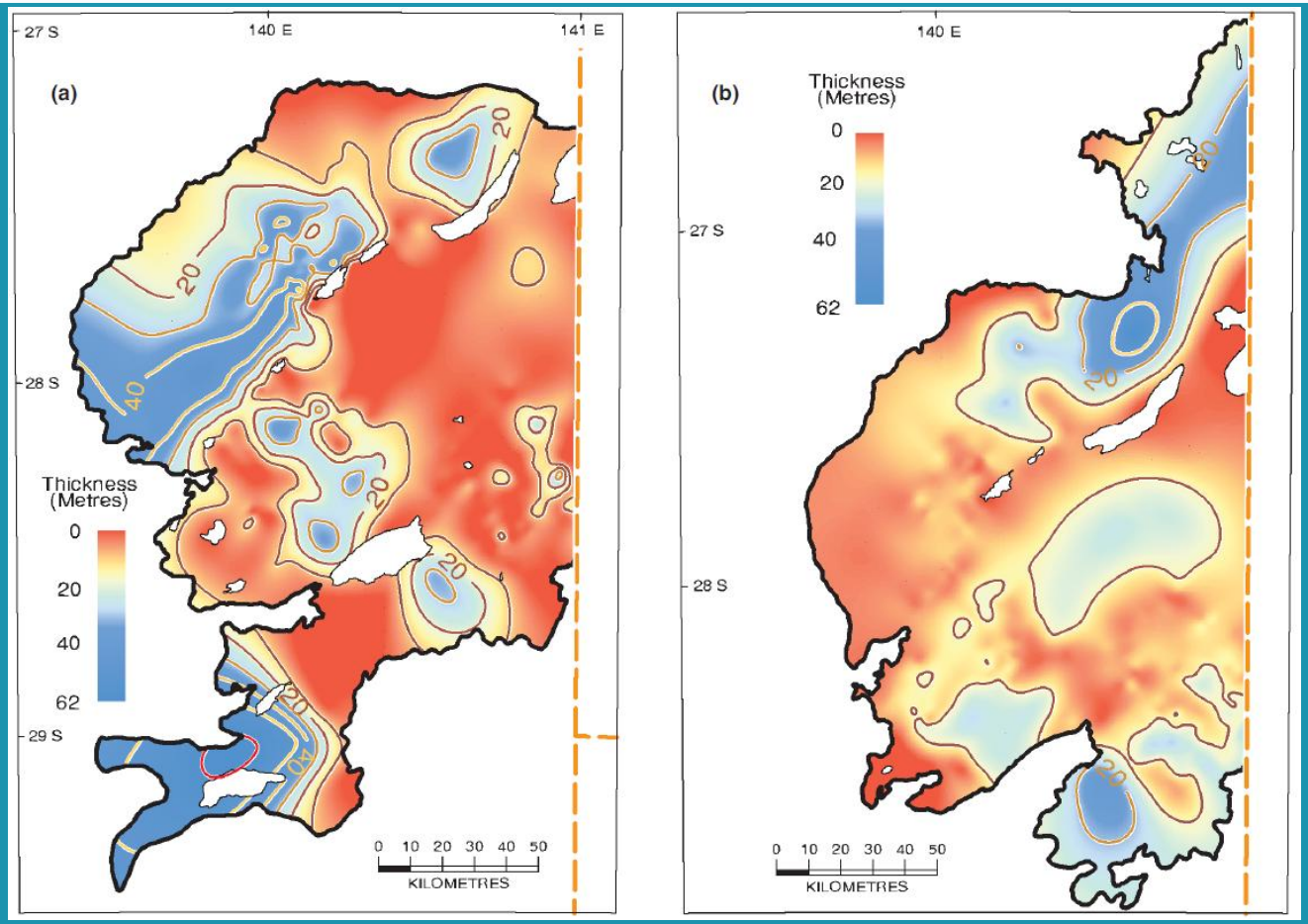
Source: Santos Investor Seminar, 10 November 2011

Beach Energy Nappamerri Trough Project (PEL 218)



Source: Beach Energy Limited, AGM Presentation, November 2011

Deep coal seam gas play – Cooper Basin



Patchawarra Formation

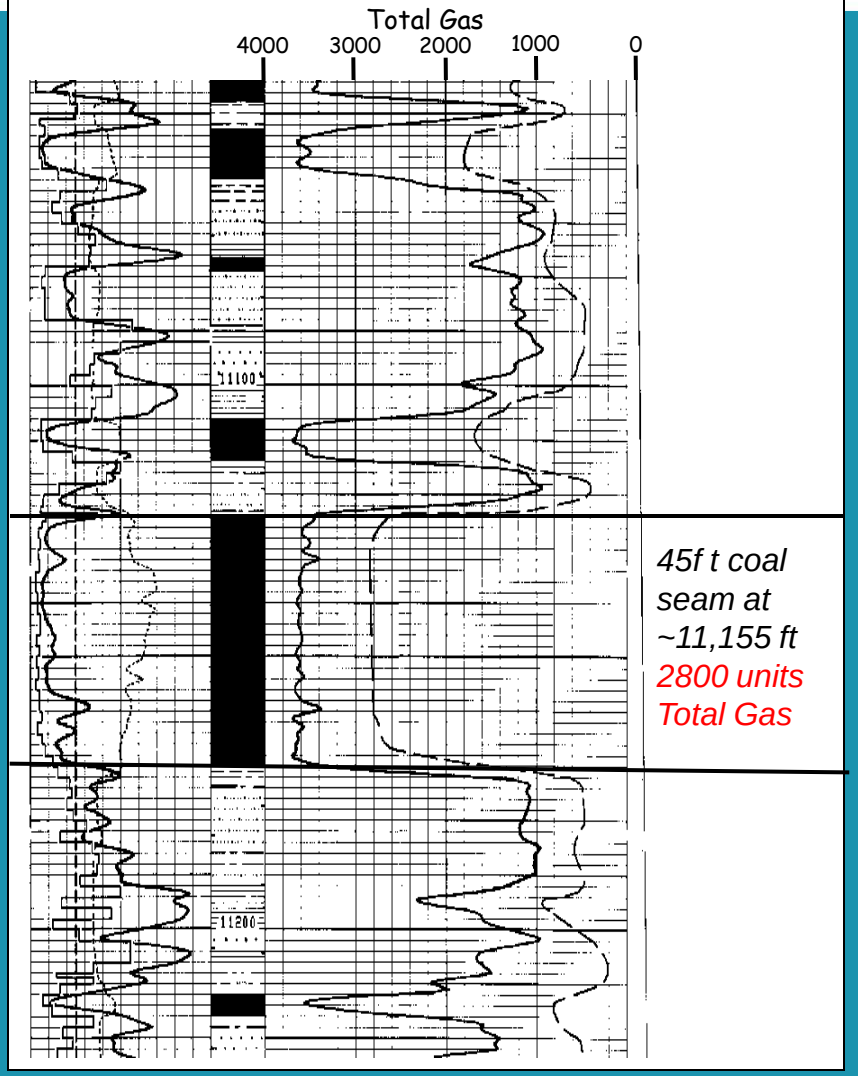
Toolachee Formation

High rank bituminous to anthracitic coal

- 375 billion cubic metres of Patchawarra coal
- 525 billion tonnes (assuming density 1.4 g/cc)
- Seams up to 22m thick; combined thickness >60m in Patchawarra Fm
- 12,440 TCF *energy equivalent* (assuming 0.000025 PJ/tonne specific energy)
- Current Australian gas market 1 TCF/annum

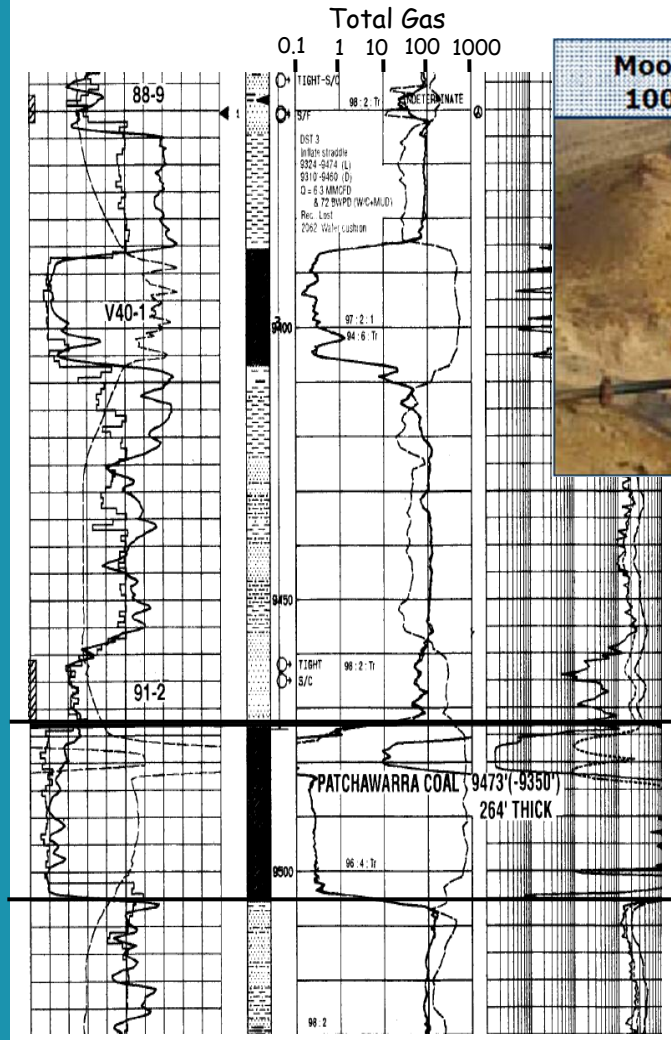
COOPER BASIN COALS
fraccing coals a potential play

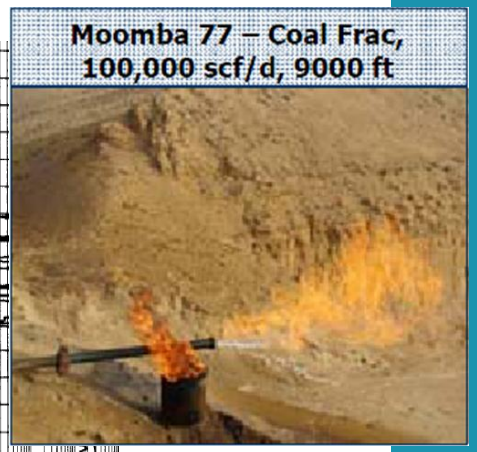
Wimma 1 – Patchawarra Formation



45f t coal seam at ~11,155 ft
2800 units Total Gas

Moomba 77 – Patchawarra Formation

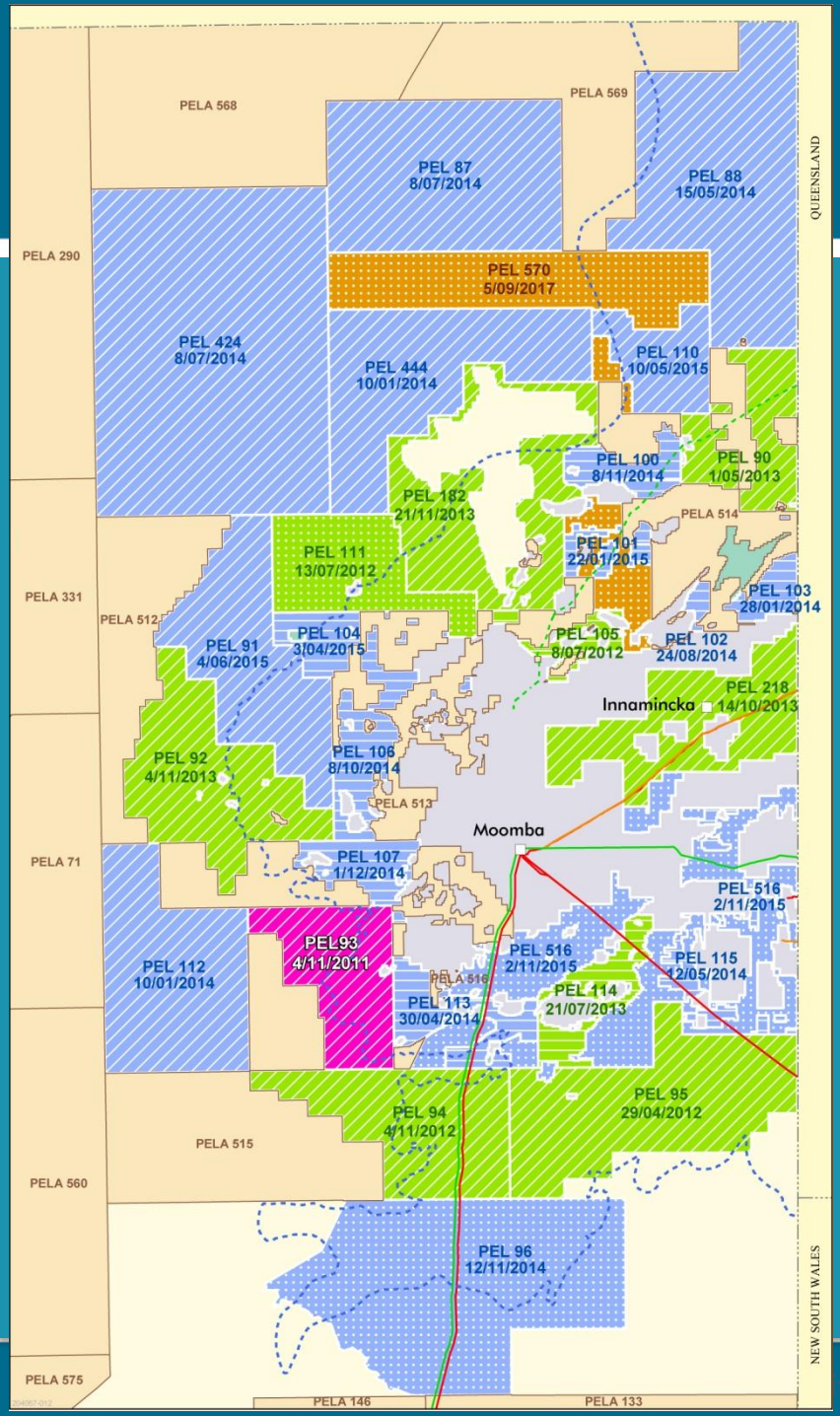




http://www.santos.com/library/110909_International_Investor_Presentation.pdf

30 ft coal seam at ~9514 ft
~900 units Total Gas

Cooper Basin



New release planned for mid 2012: PEL 111 relinquished acreage (likely to be oil play)

- **Avg area PELs 386,370 acres (1563 sqkm)**
- **Formerly 1 PEL, 3 major releases 1998-2000**

CO2010

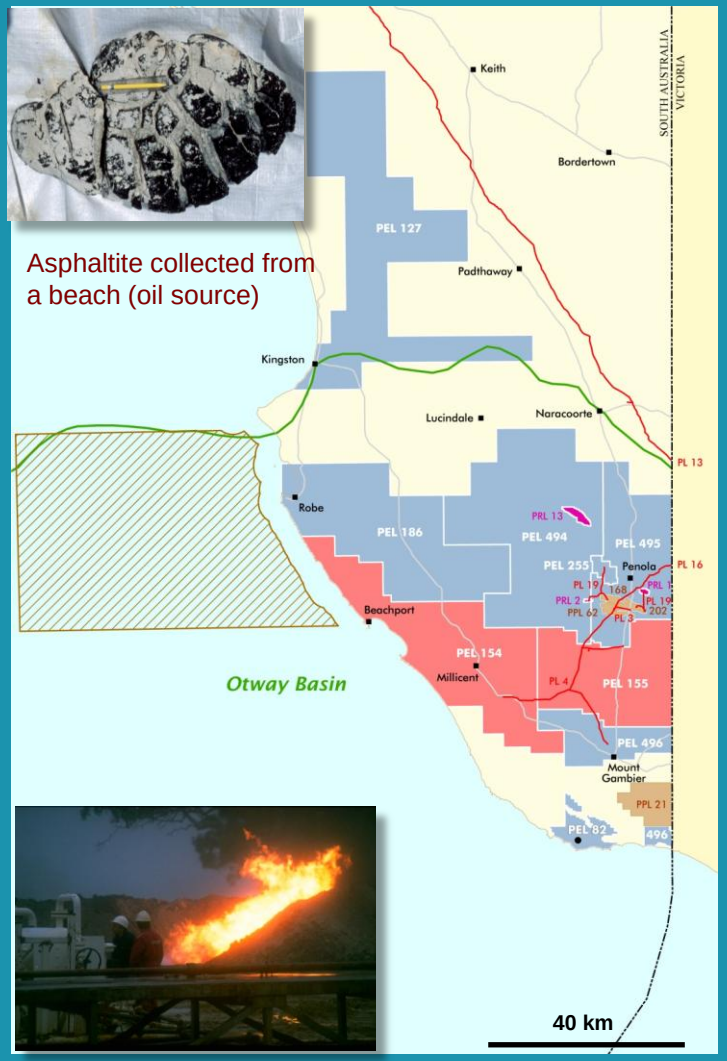
Expiry year

- 2010 – 2011
- 2012 – 2013
- 2014 – 2015
- 2016 – 2017

Relinquishment upon renewal

- Half
- Third
- All

Otway Basin



- Conventional gas, oil, CO_2
- Competitive tender region, no current onshore acreage release
- Vacant acreage + licences with relinquishments in 2012
- Some unconventional gas and shale oil potential
- Infrastructure – pipelines and plant
- Offshore acreage release in May 2012

Current licence

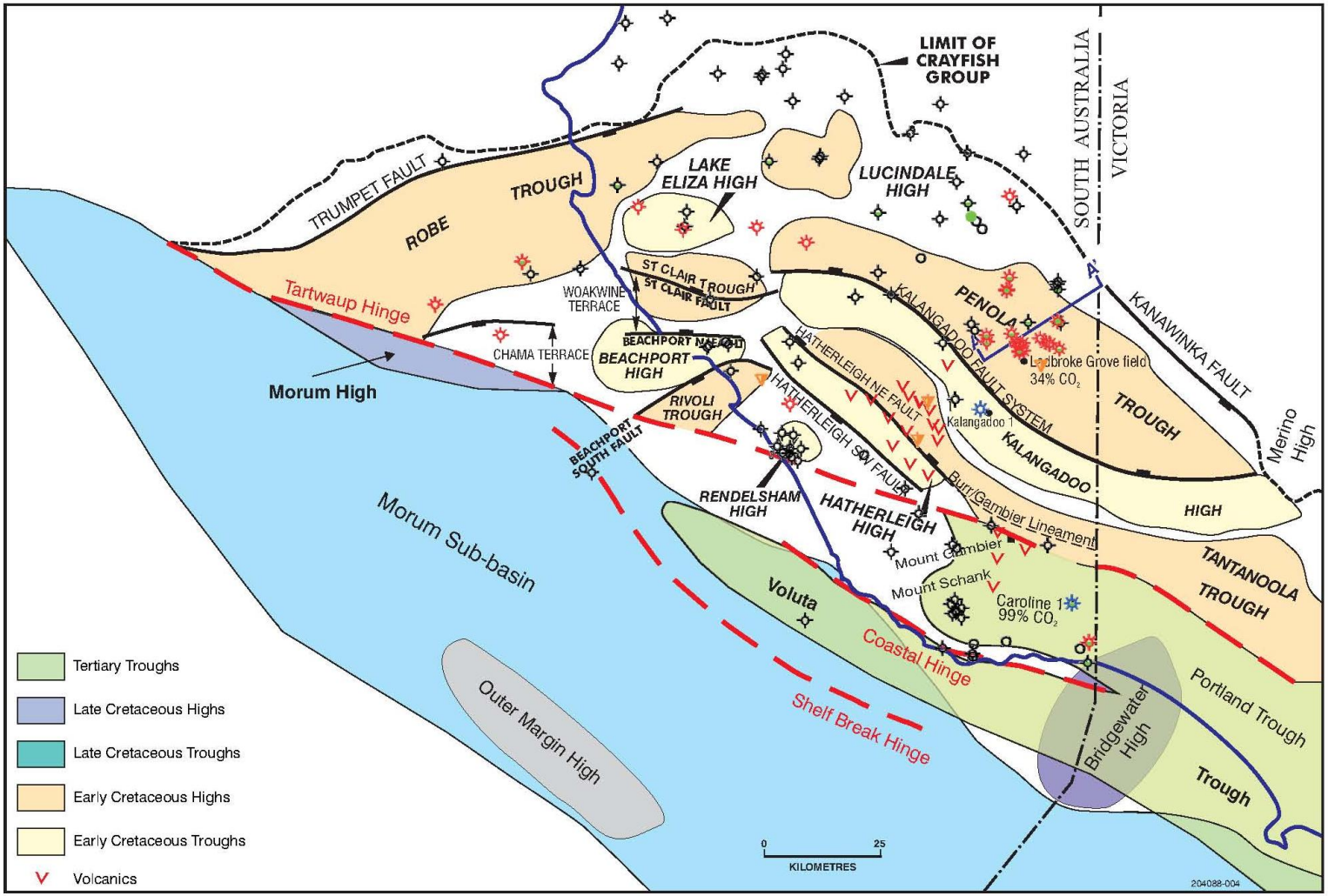
2011 relinquishment

Retention licence (PRL)

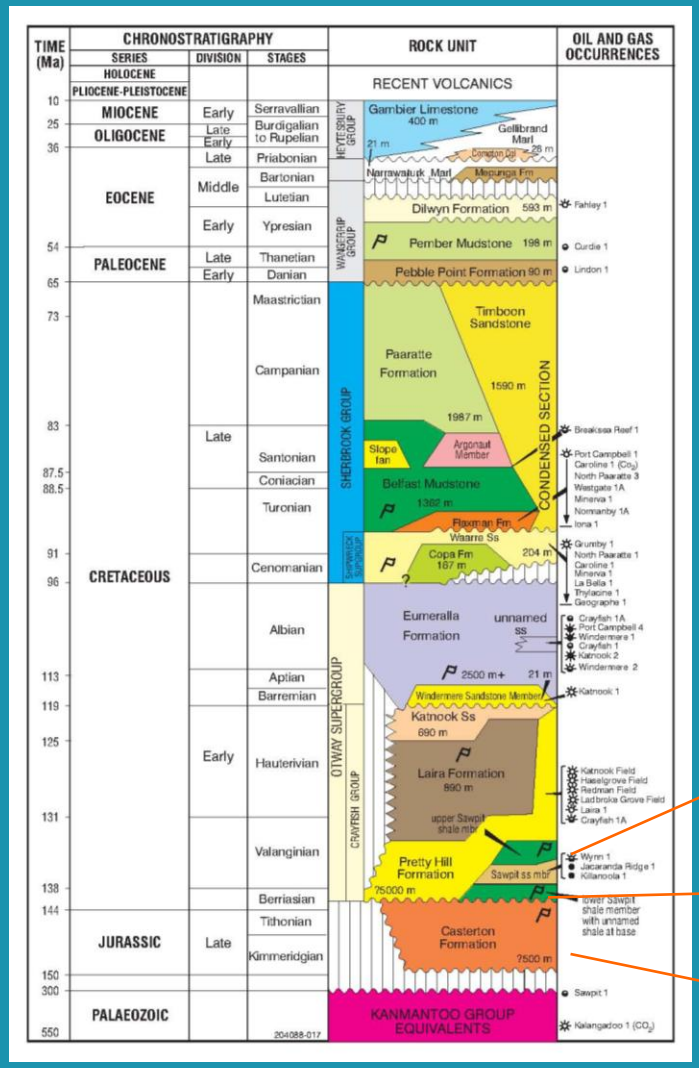
Production licence (PPL)

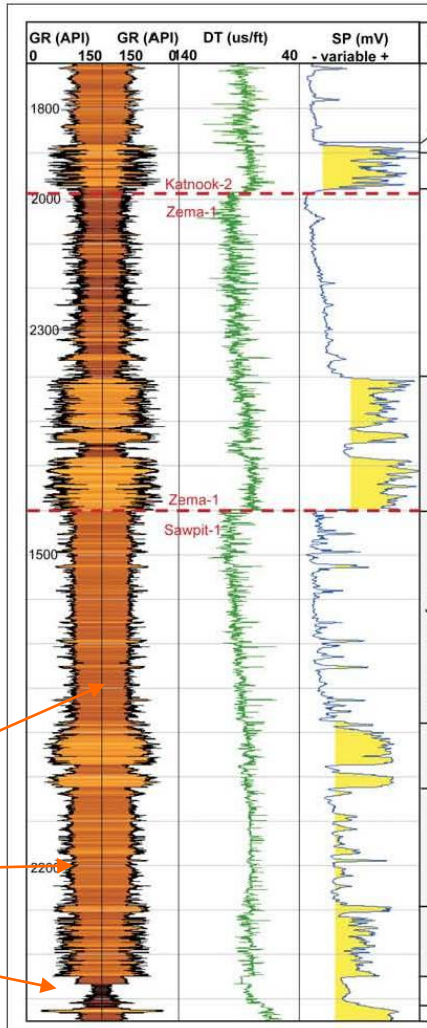
Gas pipeline

Otway Basin – Structural elements



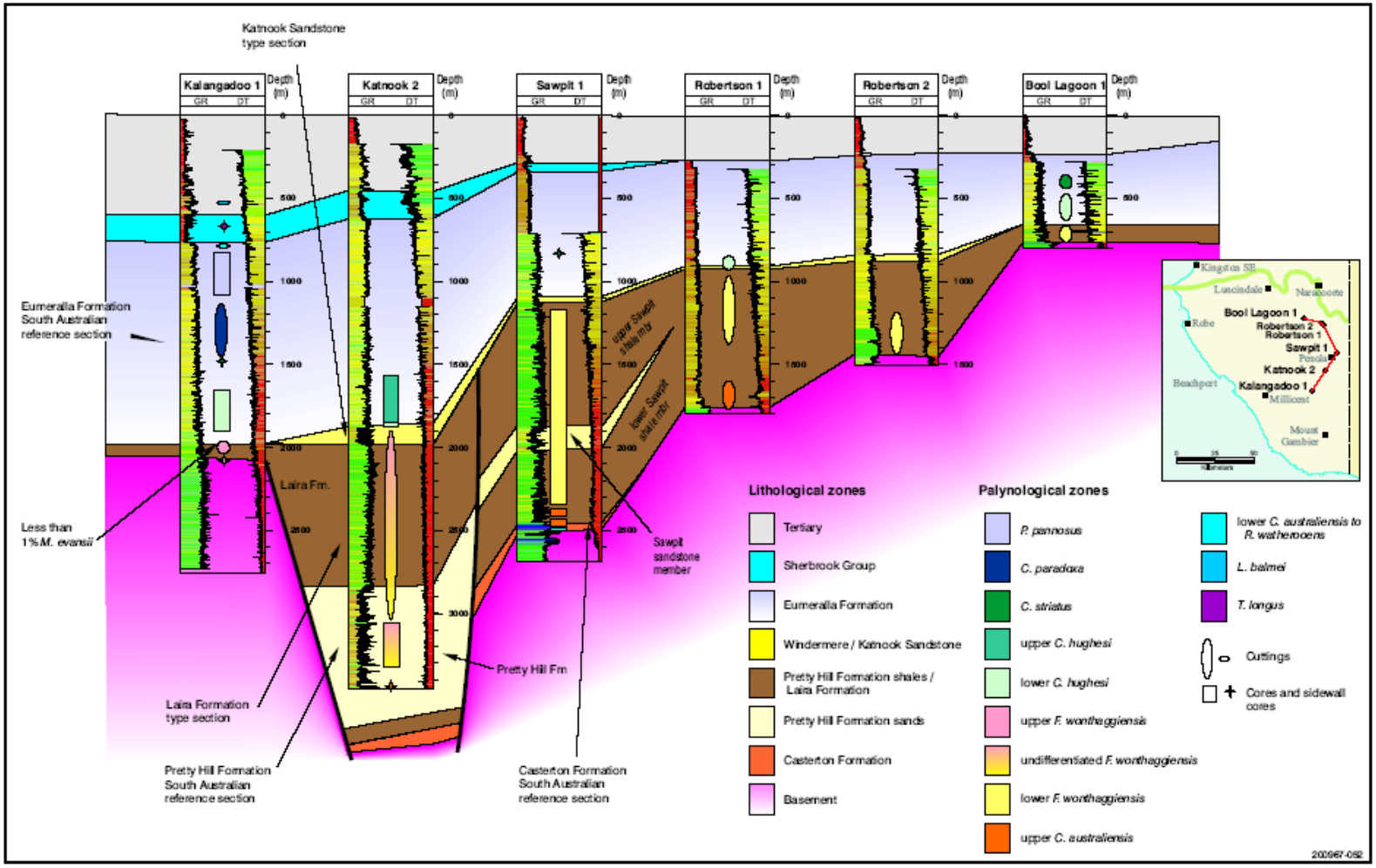
Otway Basin – Potential shale gas and shale oil targets



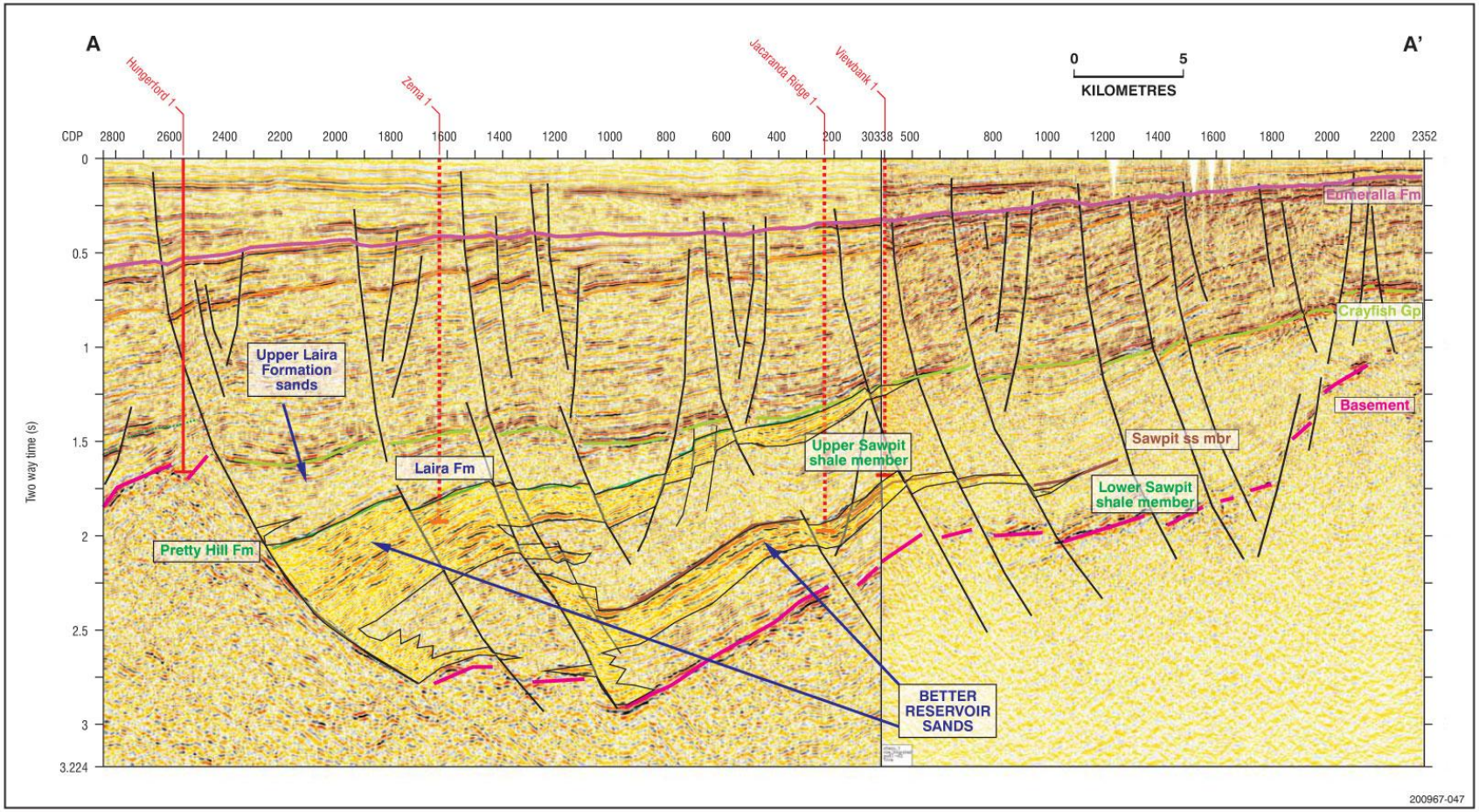


Lithostratigraphy	Thickness	Depositional Environments
Eumeralla Fm	max. 2500 m, typically >1500 m	shallow fluvial-lacustrine, local deep lacustrine at base
Windermere Ss	max 160 m, typically 5 – 20 m	low-sinuosity fluvial
Katnook Ss	77 – 683 m	base = high-sinuosity fluvial top = low-sinuosity fluvial
Laira Fm	132 – 888 m, typically > 400 m	fluvial floodplain to shallow lacustrine; local coals and palaeosols
Pretty Hill Formation: Pretty Hill Sandstone	up to 875 m, typically > 200 m	high-energy, low-sinuosity channel and bar sandstones grading into interbedded floodplain deposits
Pretty Hill Formation: upper Sawpit Shale	50-900 m	shallow lacustrine, overbank and floodplain
Pretty Hill Formation: Sawpit Sandstone	typically 100-200 m	low- to high-sinuosity fluvial, overall fining upward
Pretty Hill Formation: lower Sawpit Shale	typically 100 – 250 m	fluvial channel, lacustrine , swamp
Pretty Hill Formation: McEachern Sandstone	variable, up to 250 m	stacked braided fluvial channels. Coarse grained proximal alluvial facies
Casterton Fm	60 – 500m ?	volcanic, deep lacustrine
Basement		

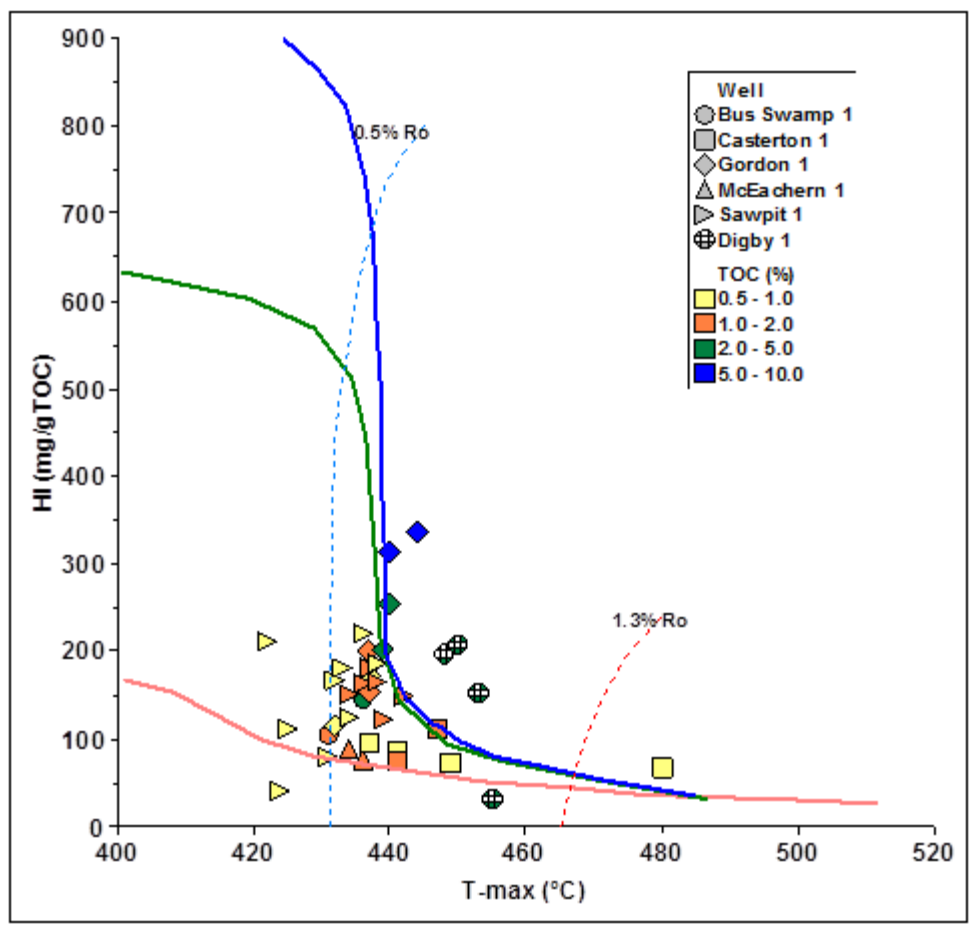
Penola Trough, Otway Basin



Penola Trough, Otway Basin



Otway Basin – HI vs Tmax plot, Casterton Fm



Total Organic Carbon (TOC)

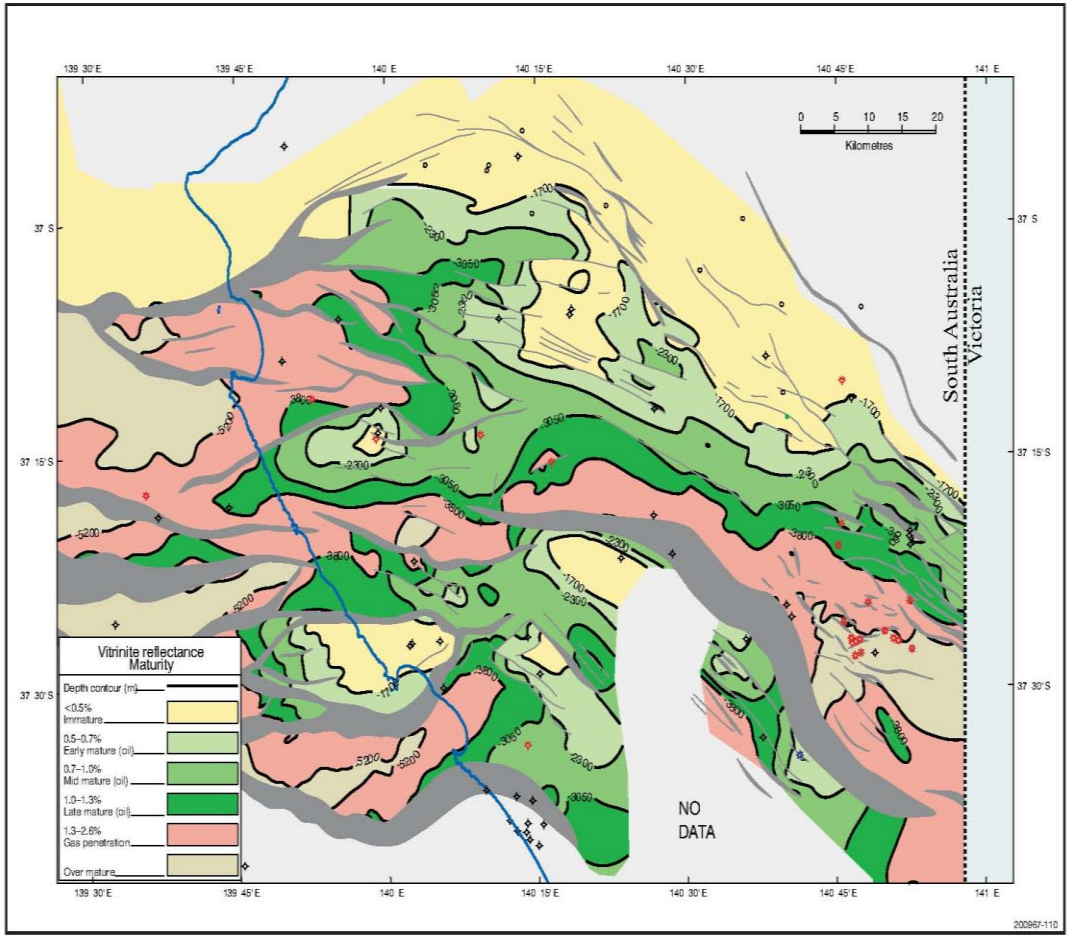
Range: 0.6 to 9%
Average: 1.9% (39 samples; 6 wells).

Type II (algal rich oil prone kerogen) to Type III (Gas prone) source rocks

Casterton Fm possibly up to 500m thick in onshore Robe Trough

Courtesy: Hector Gordon, Somerton Energy

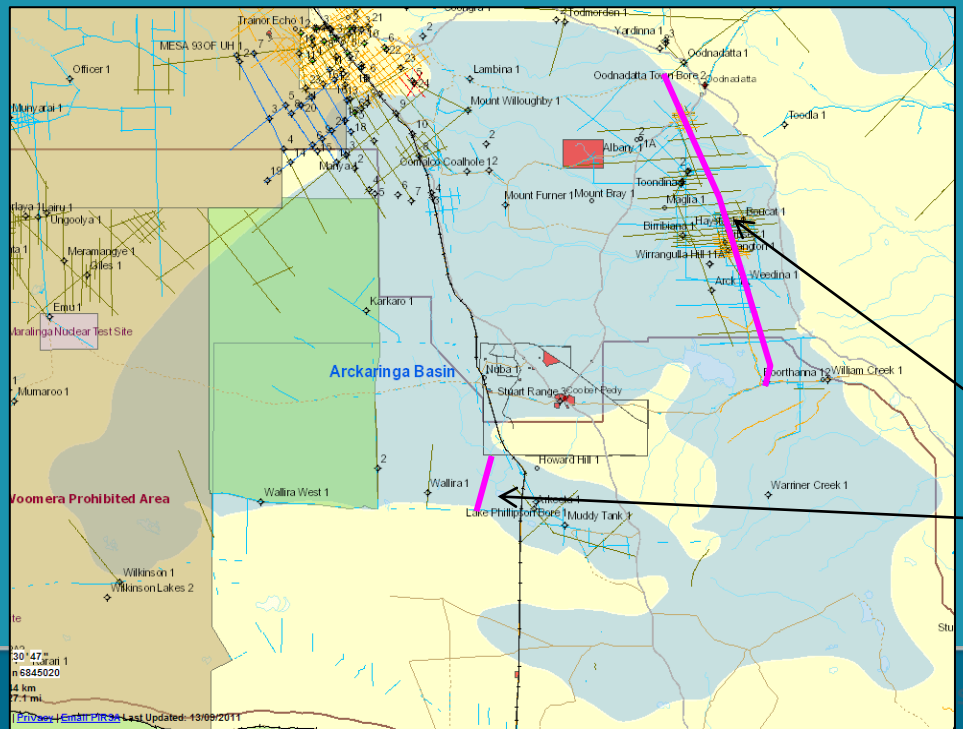
Otway Basin – Shale gas play

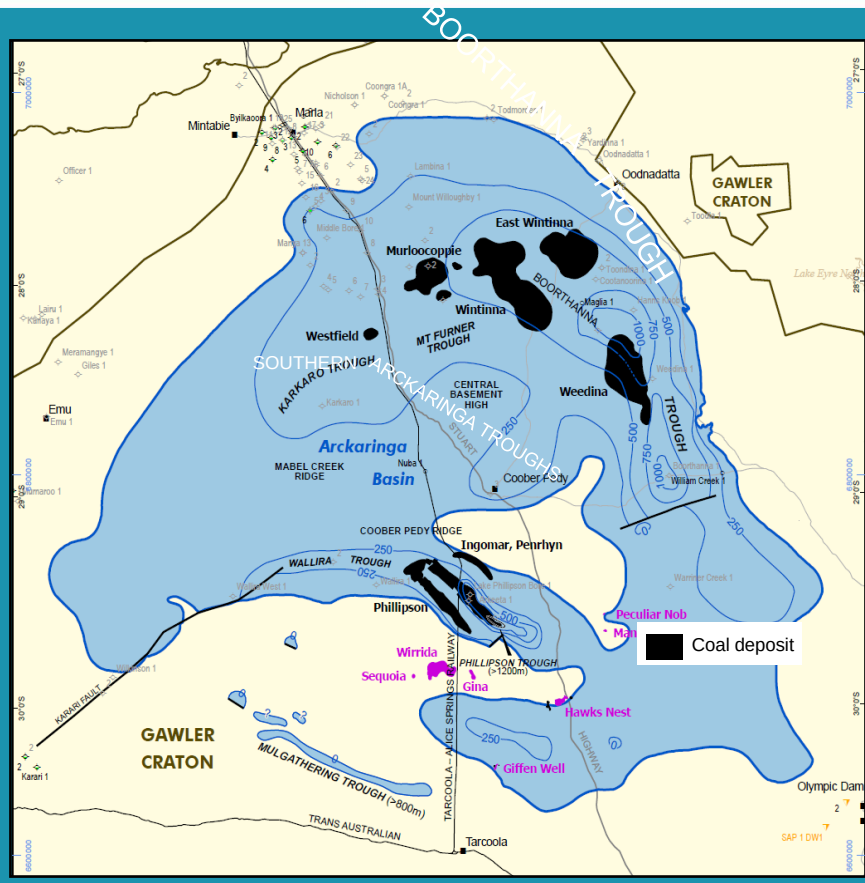


Bed maturity map for top Casterton Formation as a proxy for the base Lower Sawpit Shale.

The main shale gas play for the Casterton Formation and Upper and Lower Sawpit Shales is highlighted in pink and corresponds to a VR range of 1.3 to 2.6% (depth >3800m);

Arckaringa Basin

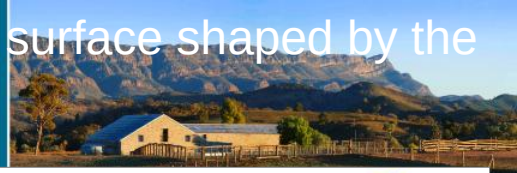


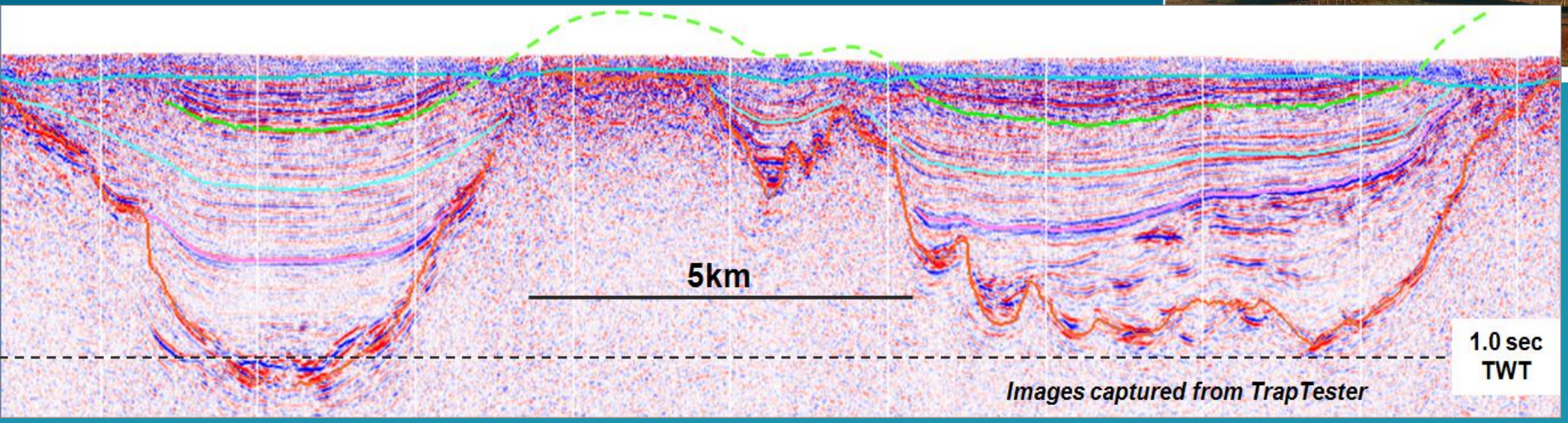


Permian Isopach

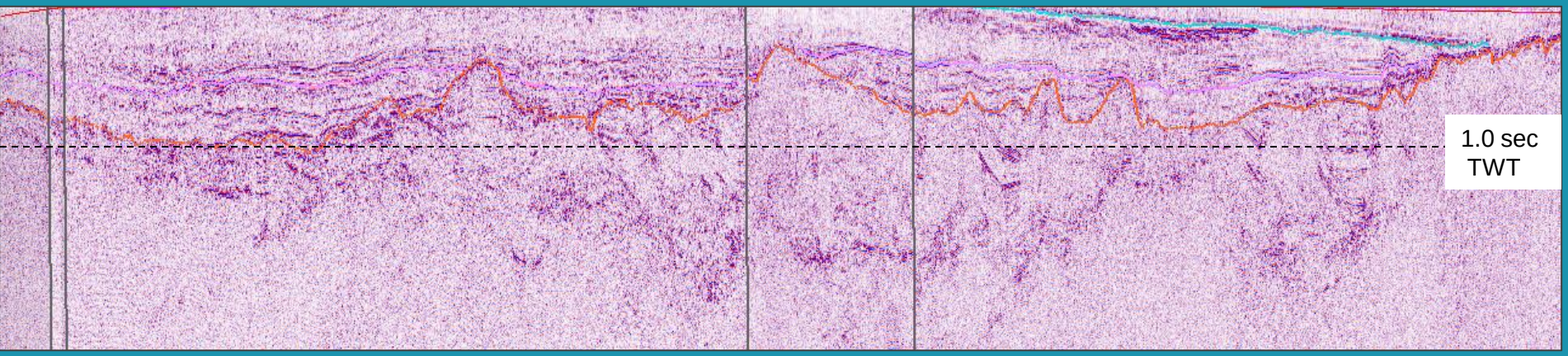
Seismic lines – next slide

Arckaringa Basin – Early Permian sediments infill erosional land surface shaped by the Gondwana glaciation



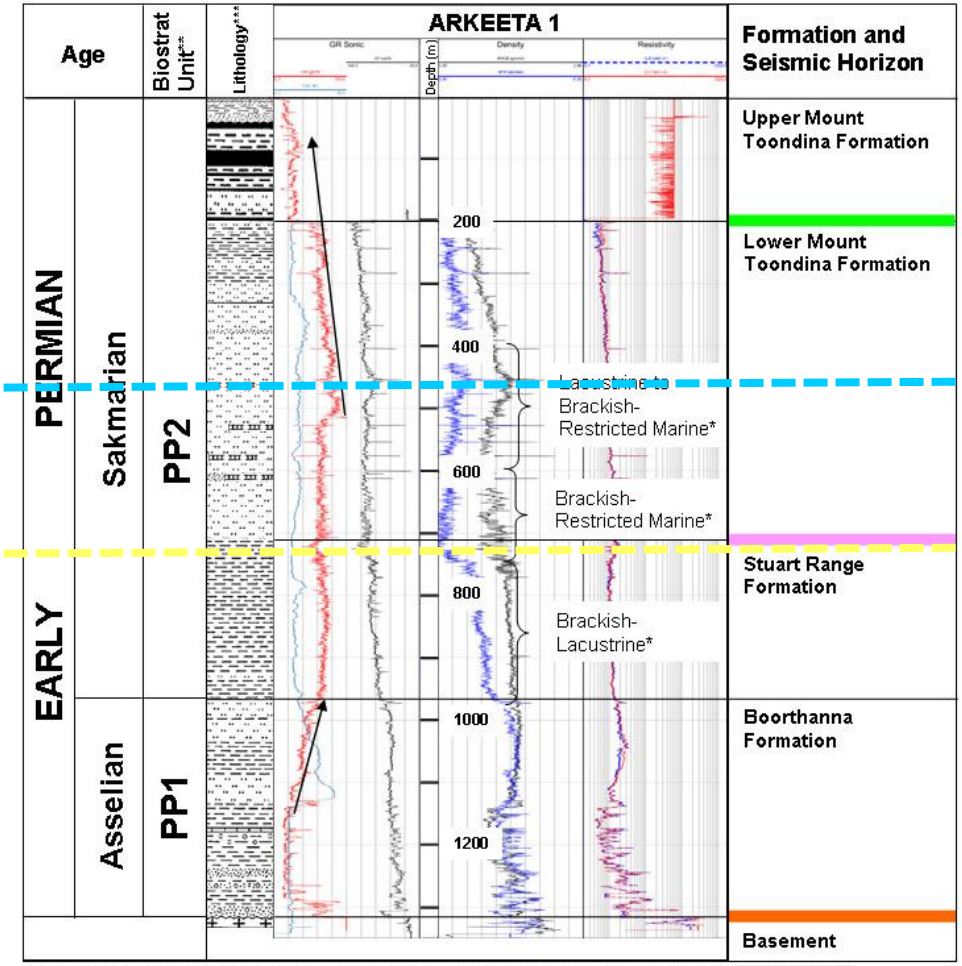


Seismic dip line across West Trough and Phillipson Trough (3 x vertical exaggeration)



Composite seismic line along Boorthanna Trough (10 x vertical exaggeration)

Stratigraphic Column – Southern Arckaringa Basin (modified from Menpes 2010)



* Depositional environment interpreted from Arkeeta 1 palynological study (McBain, 1987)
** Palynological zones from Arkeeta 1 palynological study (McBain, 1987) converted to biostratigraphic units defined by Price et al, 1985
*** Lithology modified from Lake Phillipson Bore (after Hibburt, 1984, Figure 12)

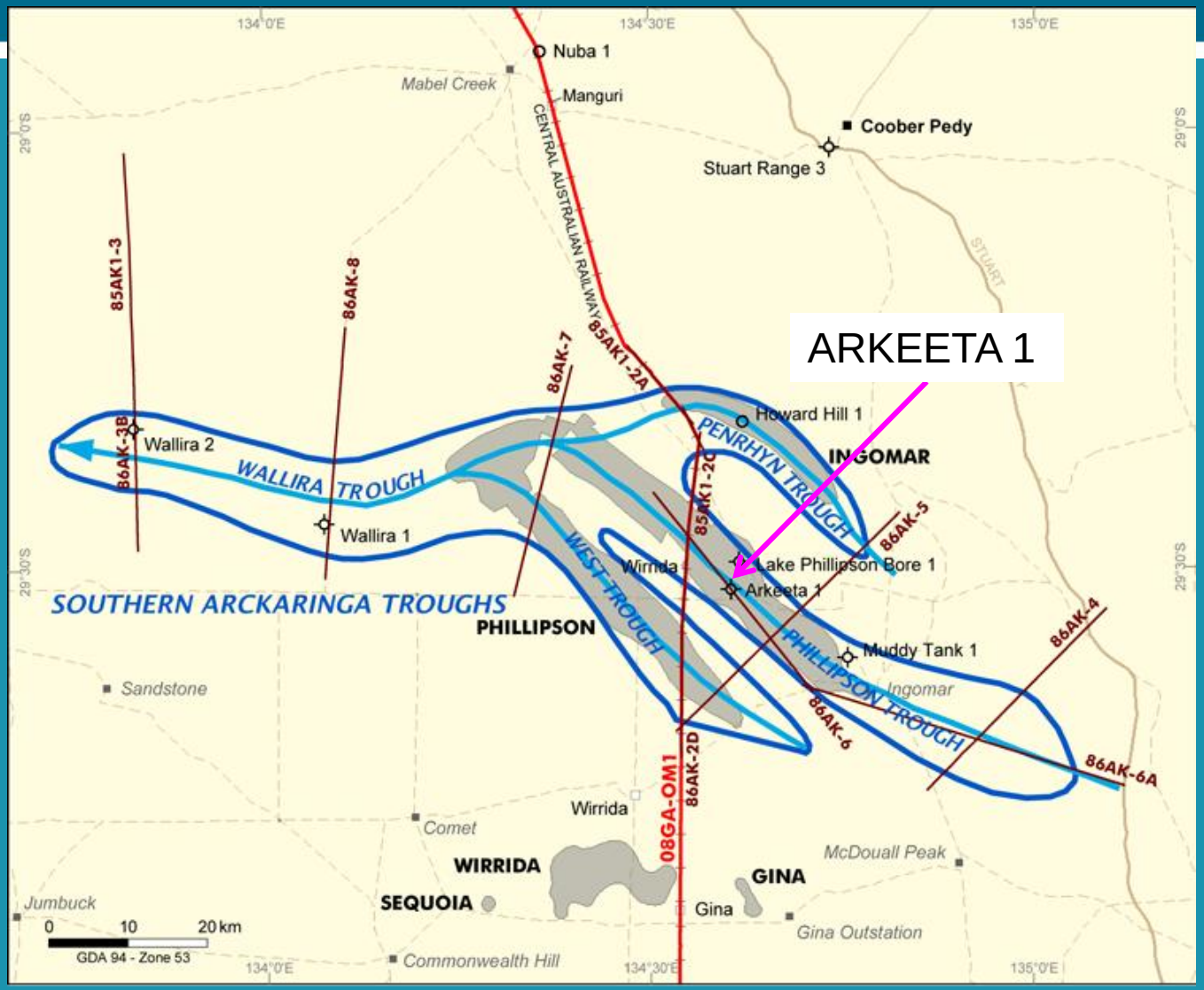
mfs ?

Organic rich marine shales

S B

70m thick black shale in Arck-1, depth 854m - prelim. analysis indicates potential oil yields of between 25 to 45 litres per tonne.

Southern Arckaringa Troughs



Glacier flow

Coalfields

Seismic lines

GOAMA seismic line

Seismic lines – 1980 to 1989

Petroleum wells

Dry hole

Pending

Arkeeta 1
Rock Eval Data

DEPTH	T MAX	S1	S2	S3	S1+S2	PI	S2/S3	PC	TOC	HI	OI
84-87	421	2.00	160.80	7.90	162.80	0.01	20.35	13.56	62.70	256	13
123-126	427	3.05	190.55	6.01	193.60	0.02	31.70	16.13	52.60	362	11
134-137	421	1.81	31.43	6.36	33.24	0.05	4.94	2.77	11.40	276	56
150-153	425	0.50	79.10	4.70	79.60	0.01	16.82	6.63	26.10	303	18
198-201	427	0.55	118.61	4.72	119.16	0.00	25.12	9.93	33.10	358	14
279-282	428	0.44	10.22	3.28	10.66	0.04	3.11	0.88	4.05	252	81
[illegible]	[illegible]	[illegible]	[illegible]	1.99	13.16	0.05	6.28	1.09	4.95	253	40
[illegible]	[illegible]	[illegible]	[illegible]	2.69	5.65	0.09	1.90	0.47	2.45	209	110
[illegible]	[illegible]	[illegible]	[illegible]	1.70	4.04	0.08	2.19	0.33	1.93	193	88
[illegible]	[illegible]	[illegible]	[illegible]	2.35	2.61	0.04	1.06	0.21	1.88	133	125
[illegible]	[illegible]	[illegible]	[illegible]	2.51	5.06	0.16	1.69	0.42	2.20	194	114
423-426	426	0.42	5.13	5.89	5.55	0.08	0.87	0.46	2.70	190	218
447-450	431	0.07	3.93	3.38	4.00	0.02	1.16	0.33	2.50	157	135
477-480	431	0.28	2.76	2.05	3.04	0.09	1.34	0.25	1.60	173	128
501-504	433	0.24	3.37	1.54	3.61	0.07	2.18	0.30	2.05	164	75
519-522	425	0.42	9.17	0.58	9.59	0.04	15.81	0.79	3.25	282	18
540-543	424	0.40	9.31	0.49	9.71	0.04	19.00	0.80	2.90	321	17
561-564	427	0.51	15.23	0.47	15.74	0.03	32.40	1.31	4.10	371	11
585-588	429	0.61	18.07	0.64	18.68	0.03	28.23	1.55	4.40	411	[illegible]
594-597	433	0.65	22.27	0.78	22.92	0.03	28.55	1.91	5.10	437	15
606-609	432	0.57	17.86	0.76	18.43	0.03	23.50	1.53	4.15	430	18
618-621	435	0.71	25.00	1.02	25.71	0.03	24.50	2.14	5.45	459	19
642-645	432	0.67	19.46	0.79	20.13	0.03	24.63	1.67	4.50	432	18
663-666	435	0.73	24.40	0.92	25.13	0.03	26.52	2.09	5.05	483	18
684-687	436	0.84	28.62	0.90	29.46	0.03	31.80	2.45	5.30	540	17
702-705	434	1.50	36.77	1.12	38.27	0.04	32.83	3.18	6.20	593	18
723-726	436	1.70	48.41	1.44	50.13	0.03	33.61	4.17	7.40	654	19
744-747	435	0.83	21.89	0.99	22.72	0.04	22.11	1.89	4.10	533	24
765-768	434	0.37	11.12	0.96	11.49	0.03	11.58	0.95	2.55	436	37
786-789	436	0.44	10.13	0.78	10.57	0.04	12.98	0.88	2.35	431	[illegible]
810-813	436	0.25	5.95	0.78	6.20	0.04	7.62	0.51	2.05	231	38
837-840	435	0.15	3.49	0.57	3.64	0.04	6.12	0.30	1.34	260	42
858-861	436	0.04	0.87	0.35	0.91	0.04	2.48	0.07	0.62	140	56
882-885	437	0.05	0.88	0.32	0.93	0.05	2.75	0.07	0.64	137	50
903-906	437	0.13	0.98	0.41	1.11	0.12	2.39	0.09	0.59	166	69
924-927	436	0.21	6.64	0.59	6.85	0.03	11.25	0.57	1.91	347	30
945-948	439	0.06	1.02	0.35	1.08	0.06	2.91	0.09	0.66	154	53
966-969	438	0.07	1.37	0.30	1.44	0.05	4.56	0.12	0.66	207	45
987-990	435	0.03	0.49	0.16	0.52	0.06	3.06	0.04	0.46	106	34
1014-1017	425	0.08	1.38	0.24	1.46	0.05	5.75	0.12	0.49	281	48
1035-1038									0.15		
1059-1062									0.22		
1080-1083	432	0.10	2.23	0.11	2.33	0.04	20.27	0.19	0.75	297	14
1101-1104									0.16		
1113-1116									0.05		
1131-1134									0.24		
1152-1155									0.10		
1173-1176	432	0.17	4.14	1.01	4.31	0.04	4.09	0.35	1.36	304	74
1191-1194									0.02		
1209-1212									0.07		
1230-1233									0.04		
1251-1254									0.25		
1272-1275									0.25		
1287-1290									0.10		
1311-1314	436	0.14	2.32	1.00	2.46	0.06	2.32	0.20	1.02	227	98

50mg/g of rock
= ~57 litres /tonne of rock
= ~0.36 bbls /tonne of rock

Lower Mount Toondina Formation (Early Permian)

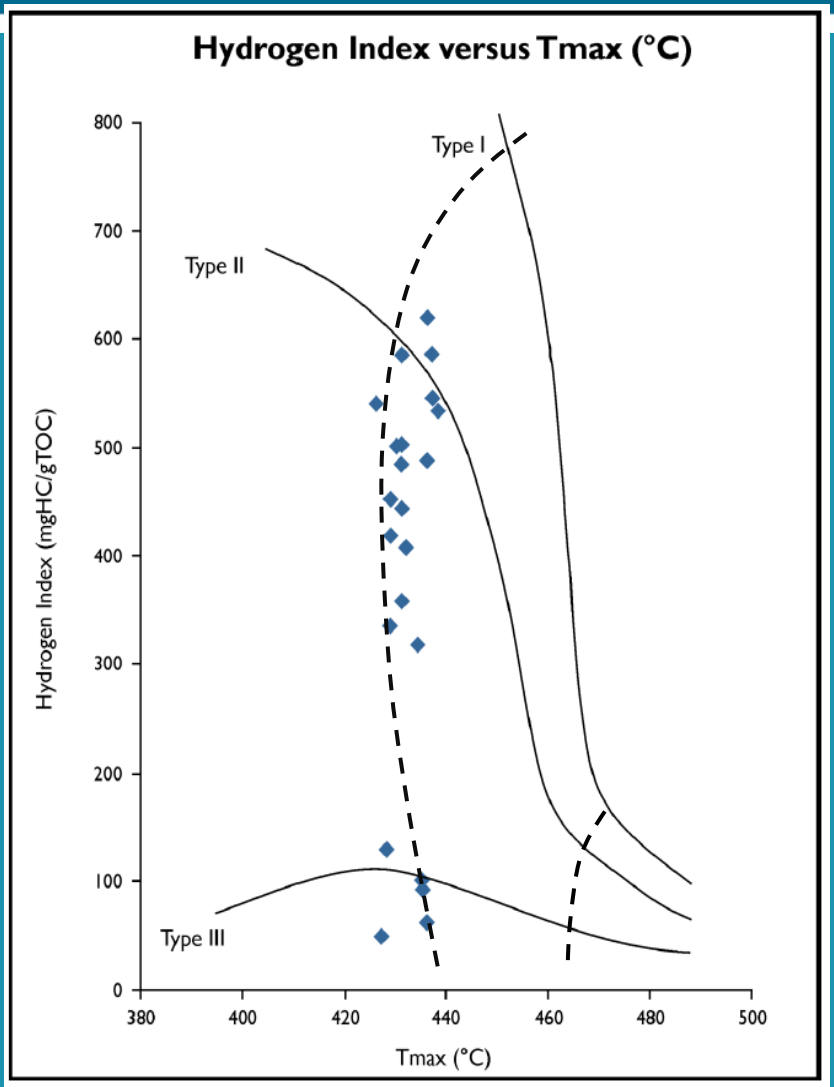
TOC > 2%, HI >400

Stuart Range Formation (Early Permian)

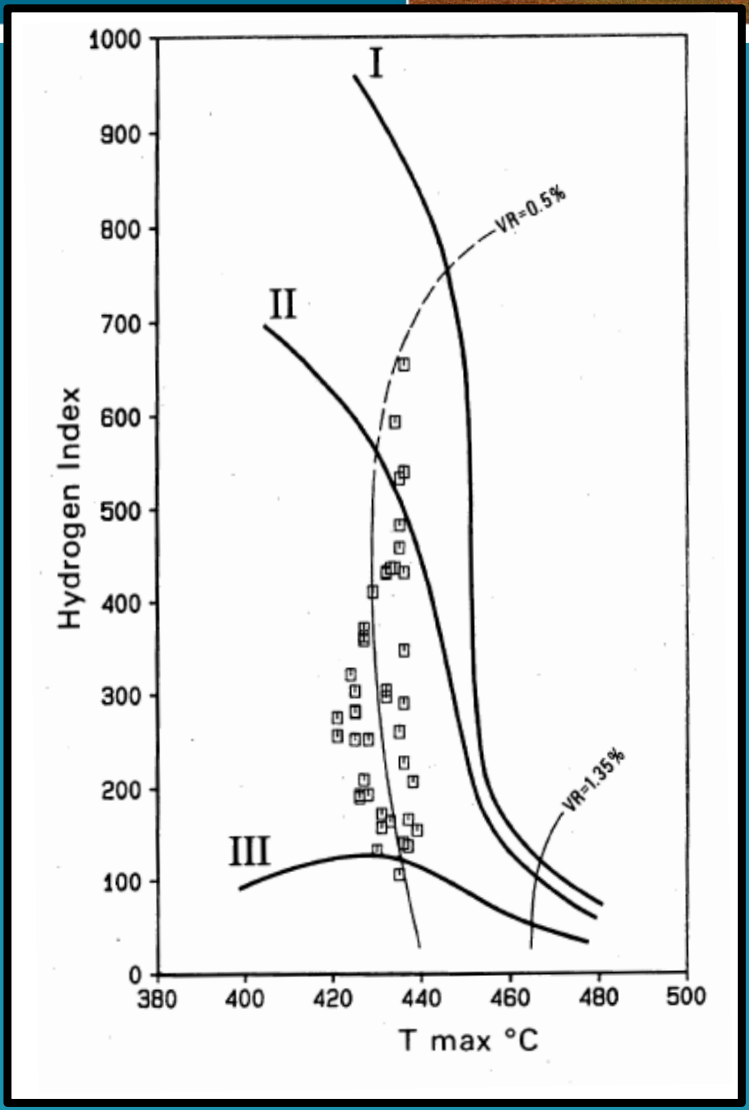
Upper Boorthanna Formation (Late Carb – Early Perm)

Lower Boorthanna Formation (Late Carb – Early Perm)

Arckaringa Basin – organic rich shales



Tmax vs HI - Arck 1, Boorthanna Trough



Tmax vs HI - Arkeeta 1, Phillipson Trough

Boorthanna Trough

Flattened on Blue Horizon (8X Vertical)

W E

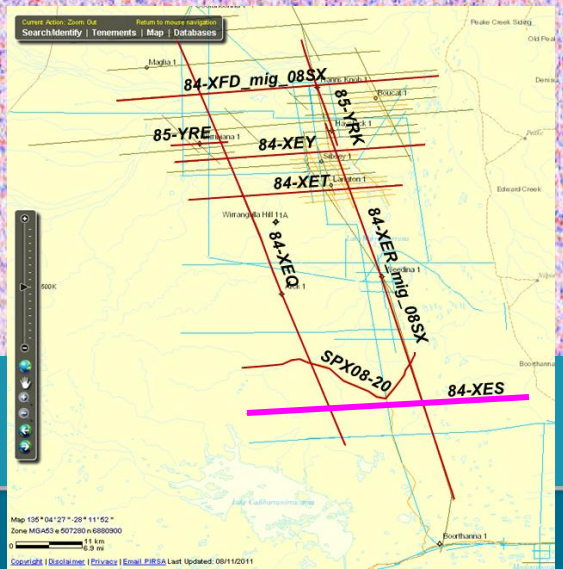
HST

mfs

SB

Pre-Permian basement

Organic rich shales?



Big fish bite if you've got good bait

For more information, visit APPEX booth 134