Australian Government
Geoscience Australia

Cooper Basin Unconventional Gas Prospectivity

Lisa Hall [1], Tony Hill [2], Liuqi Wang[1], Tehani Kuske[1], Dianne Edwards[1], Alison Troup [3], Chris Boreham[1]

[1] Geoscience Australia, ACT

[2] Department of State Development, SA

[3] Geological Survey Queensland, QLD

Acknowledgements:

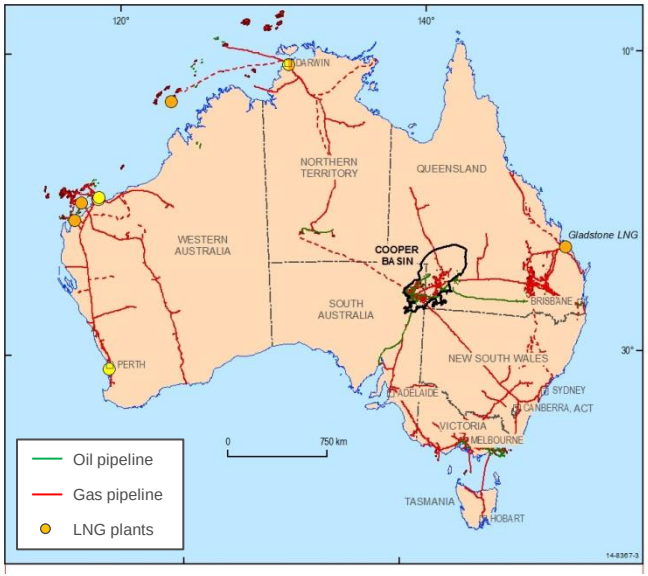
3D Geo, Andrew Murray, Andrew Stacey, Bruce Radke, Jim Preston, Russell Korsch, Sandy Menpes, Steve le Poidevin and many more…

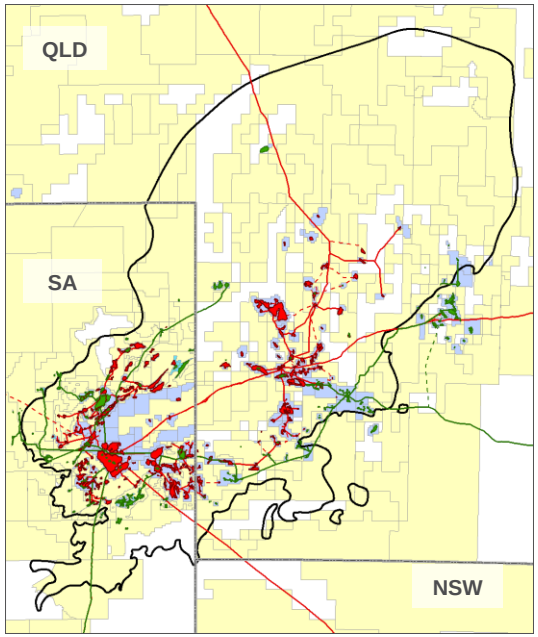
Queensland Government
Department of Natural Resources and Mines

SOUTH AUSTRALIA
Government of South Australia
Department of State Development

Cooper Basin

- Australia's largest onshore conventional gas and oil producer (Queensland, South Australia)
- Infrastructure: pipelines to East Coast gas market/ Gladstone LNG





- Increase in unconventional hydrocarbon exploration over the last 5 years
- Permian targets: shale gas, basin centred gas, deep coal seam gas plays
- Unconventional gas resources potential across all basin remains poorly defined

Project Aims

Review of basin geology and petroleum systems elements, focusing on unconventional gas plays in the Permian

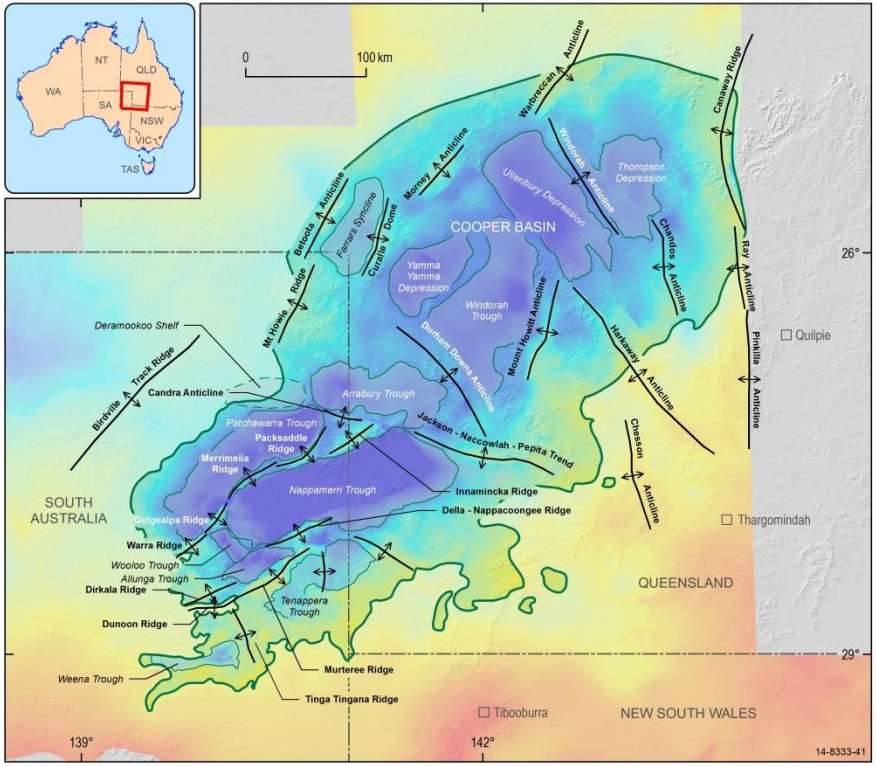
1. Review of regional basin architecture:
    - Structure surfaces, isopachs, lithofacies
2. Evaluation of Permian source rocks:
    - Source distribution, type, quality, maturity
3. Predict the possible extent of Permian unconventional gas plays:
    - Play fairway / chance of success maps

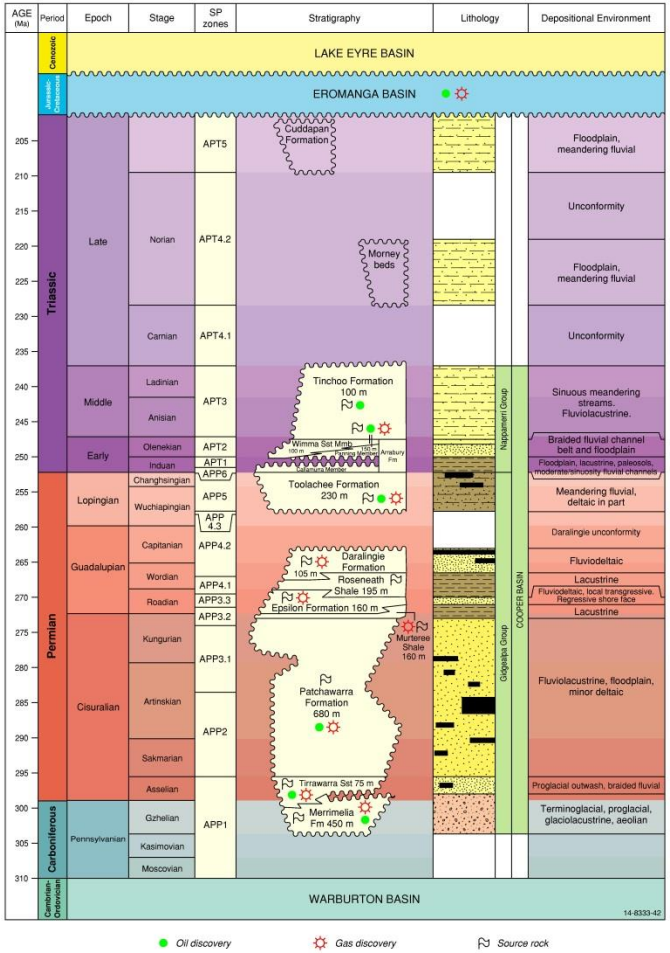
➢ **Improve understanding of basin scale prospectivity**

➢ **Australia petroleum source rock mapping study**

➢ **Underpin future resource assessment studies**

Structural Elements & Tectono-stratigraphy





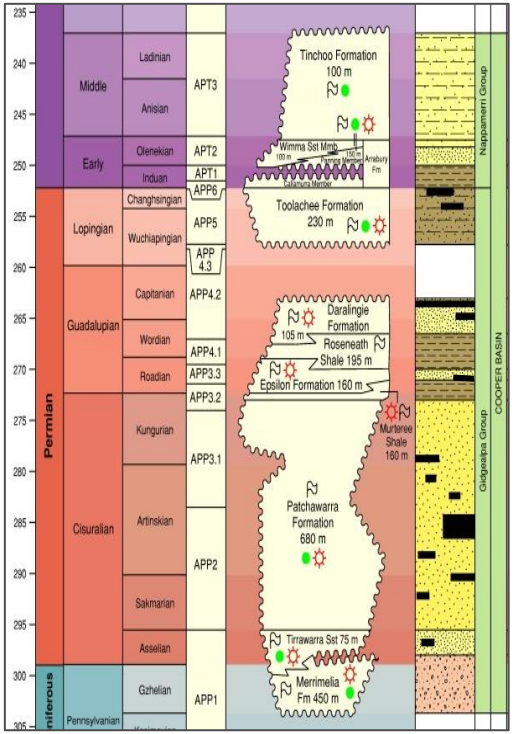
Cooper Basin Unconventional Gas Plays

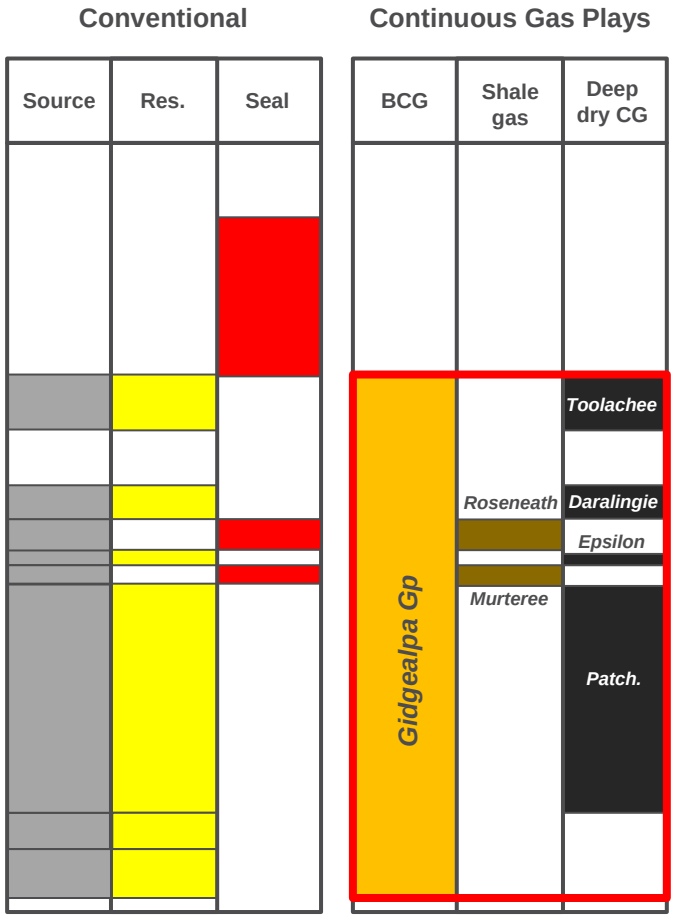
Continuous Gas Play types:

- Basin centred gas
- Shale gas
- Deep coal seam gas

➢ **Gidgealpa Gp composite resource play**

Basin centred gas accumulation +/- shale +/- deep coal seam gas +/- natural fracture play (Menpes et al., URTec, 2013)





Selection Criteria for Defining Continuous Gas Plays

Typical US Shale Gas Play

- TOC > 2 %; Type II marine kerogen
- Net shale thickness > 15-20 m
- Maturity: vitrinite reflectance > 1.1 %; < 3.5 %
- Gas in matrix/organic storage
- Overpressured (>0.45 psi/ft)
- Relatively low water saturation

Typical US Tight Gas Play

- Source rock
- Net reservoir thickness >100 m
- Maturity: vitrinite reflectance > 0.8%
- Low permeability matrix (< 0.1 mD)
- Abnormal pressure (mostly overpressure)
- Relatively low water saturation

Typical Deep Coal Gas Play

- Coal thickness?
- Maturity?
- Other factors (e.g. permeability)?

➢ **Remains poorly defined!**

Selection Criteria for Defining Continuous Gas Plays

Typical US Shale Gas Play

- TOC > 2 %; Type II/ IIs marine kerogen ?
- Net shale thickness > 15-20 m ?
- Maturity: vitrinite reflectance > 1.1 %; < 3.5 % ?
- Gas in matrix/organic storage ☑
- Overpressured (>0.45 psi/ft) ☑
- Relatively low water saturation ☑

Typical US Tight Gas Play

- Source rock ?
- Net reservoir thickness >100 m ?
- Maturity: vitrinite reflectance > 0.8% ?
- Low permeability matrix (< 0.1 mD) ☑
- Abnormal pressure (mostly overpressure) ☑
- Relatively low water saturation ☑

Typical Deep Coal Gas Play

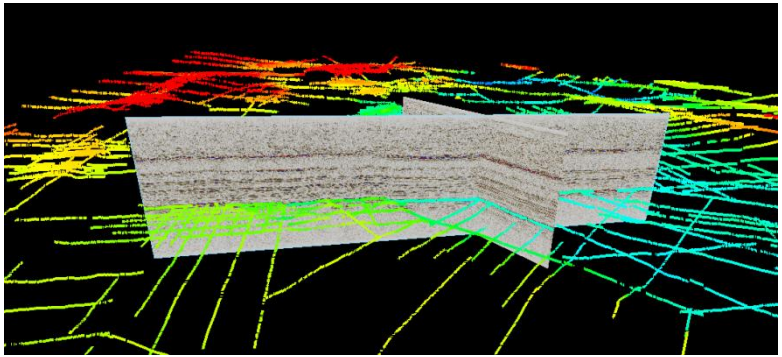
- Coal thickness ?
- Maturity ?
- Other factors (e.g. permeability)?

➢ **Remains poorly defined!**

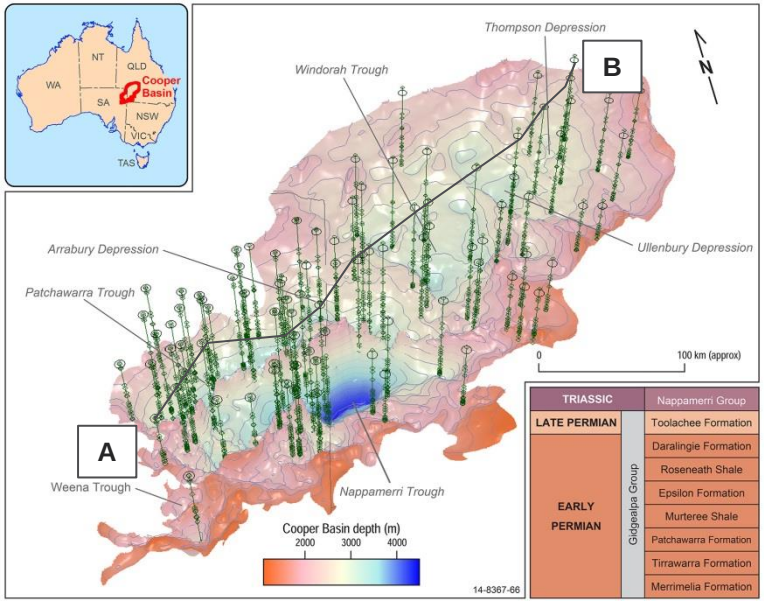
➢ **What screening criteria should be applied to the Cooper Basin?**

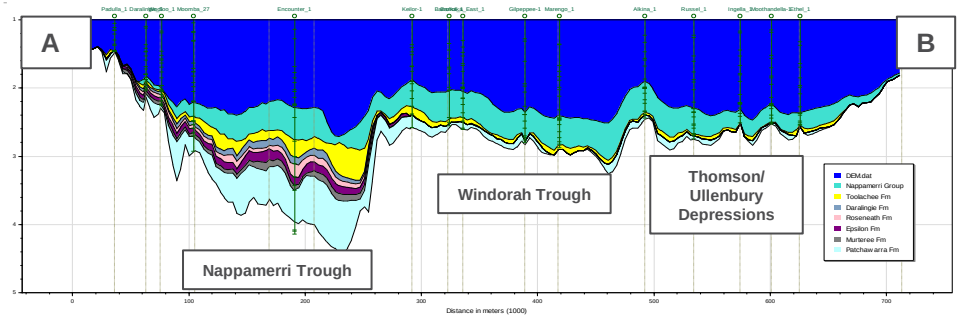
Basin Architecture

- Regional update of key structure surfaces and isopachs
- Better integration of datasets across the state border
- Update to incorporate new public domain well picks (April, 2015) and seismic interpretation



3D perspective view from Cooper Petrel project
Initial data package supplied by 3D Geo





Formation Isopachs

- Further strat review of Weena Trough underway (SA)

➢ **Toolachee/ Patchawarra Fms thickest and most extensive units.**

➢ **Wider extent than previously mapped in QLD**

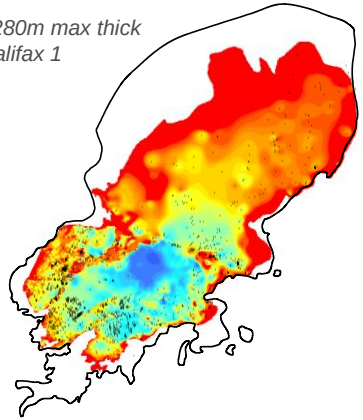
Formation Thickness (m)

< 10	75	200
25	100	300
50	150	>500

Well Tops – black dots

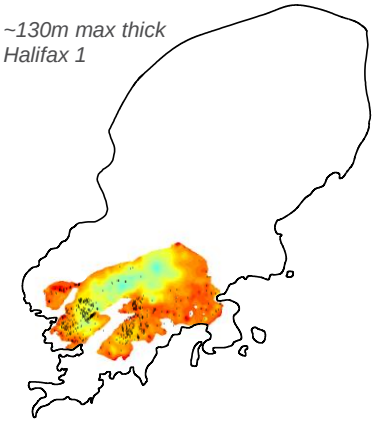
Toolachee Fm

~280m max thick
Halifax 1



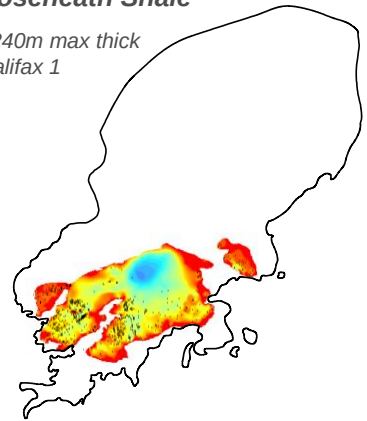
Daralingie Fm

~130m max thick
Halifax 1



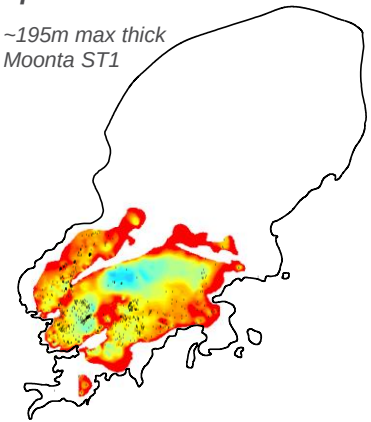
Roseneath Shale

~240m max thick
Halifax 1



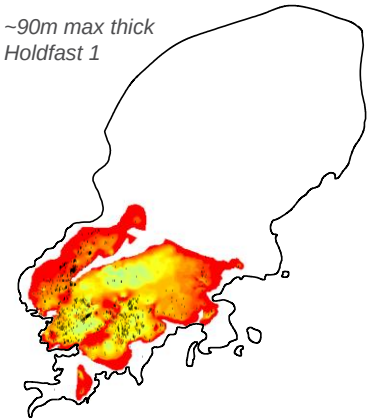
Epsilon Fm

~195m max thick
Moonta ST1



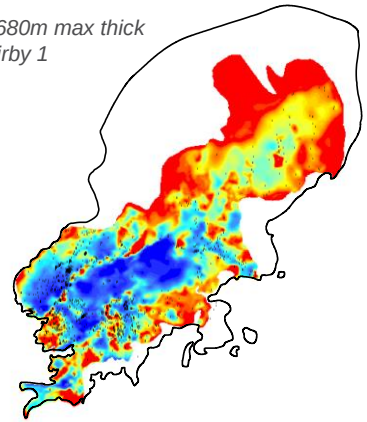
Murteree Shale

~90m max thick
Holdfast 1



Patchawarra Fm

>680m max thick
Kirby 1



Lithofacies

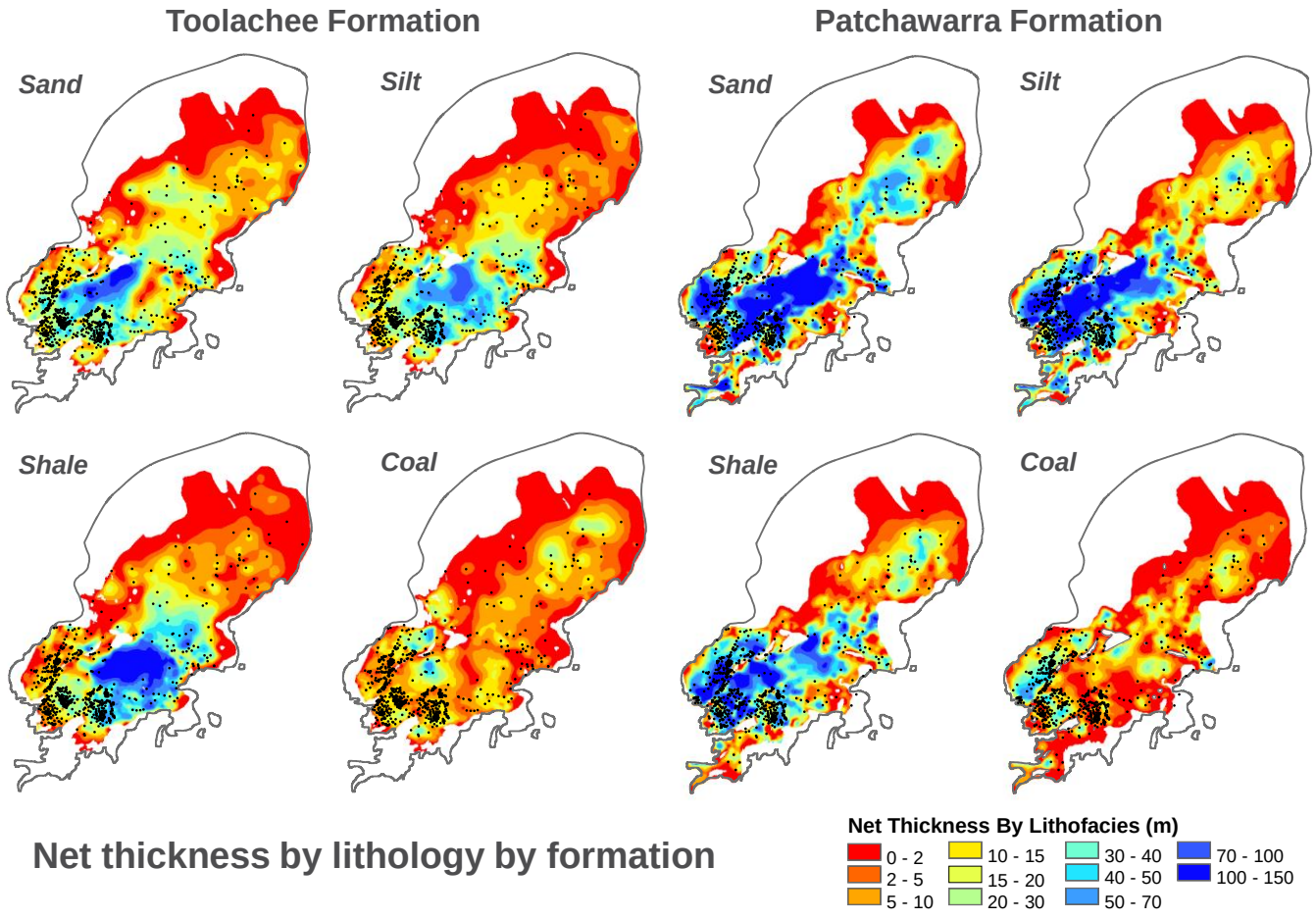
Inputs:

- SA: Sun and Camac (2004) electrofacies mapping, with updated coal thicknesses
- QLD: new electrofacies maps consistent SA methodology

Results

- Sand, silt, shale, coal isoliths & isopachs
- Toolachee, Daralingie, Epsilon & Patchawarra Fms

- **Net source thickness (coal/ shale)**
- **Net reservoir thickness**



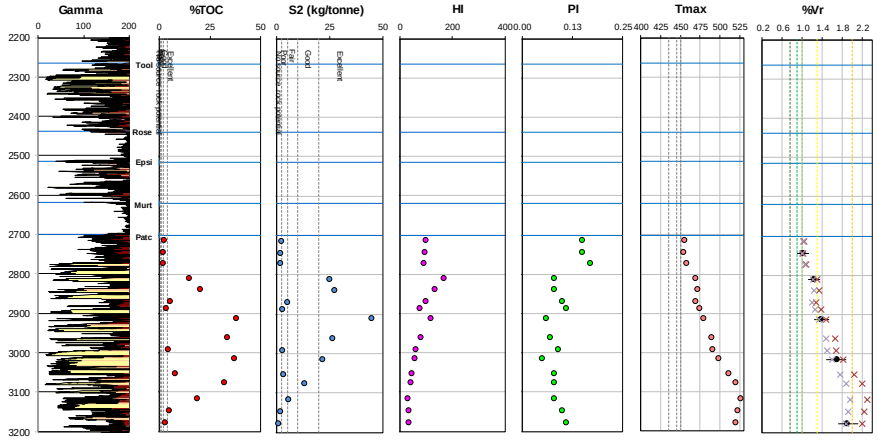
Net thickness by lithology by formation

Source Rock Analysis

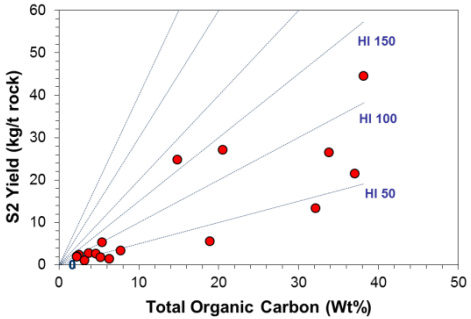
- Geochemical data analysis:
  - Source amount and distribution (TOC maps by formation)
  - Source quality and oil vs gas potential (HI, kerogen type)
- Compilation/ QC of source rock geochemistry data (TOC, Rock Eval, vitrinite reflectance).
- New sampling – changes in source rock characteristics with maturity

➢ **Australia petroleum source rock mapping study**

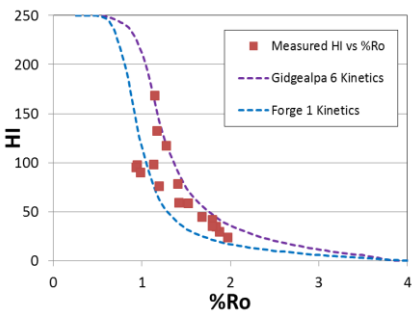
Down well geochemical and maturity profile



Source kerogen type



Natural maturity sequence

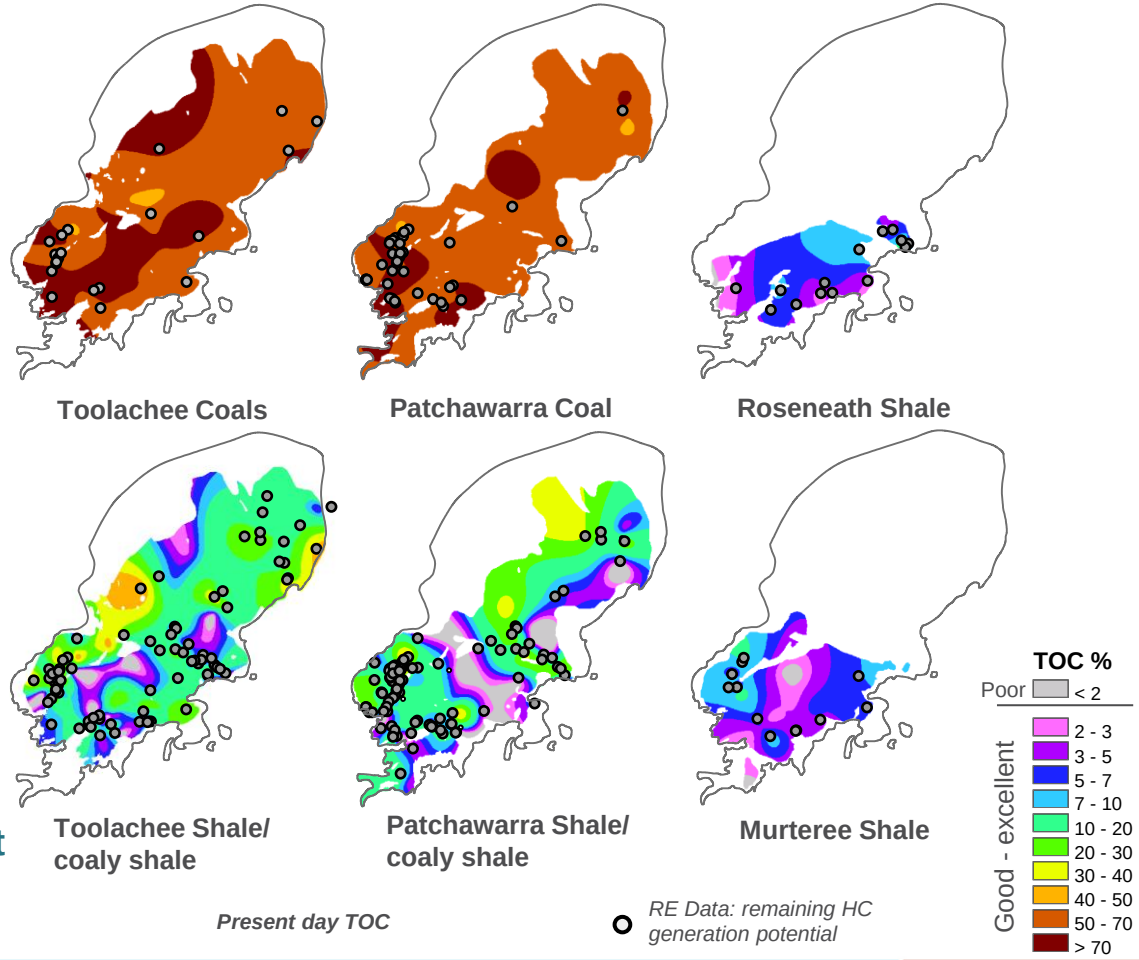


Example Analysis By Well: Allunga Trough 1 (SA)

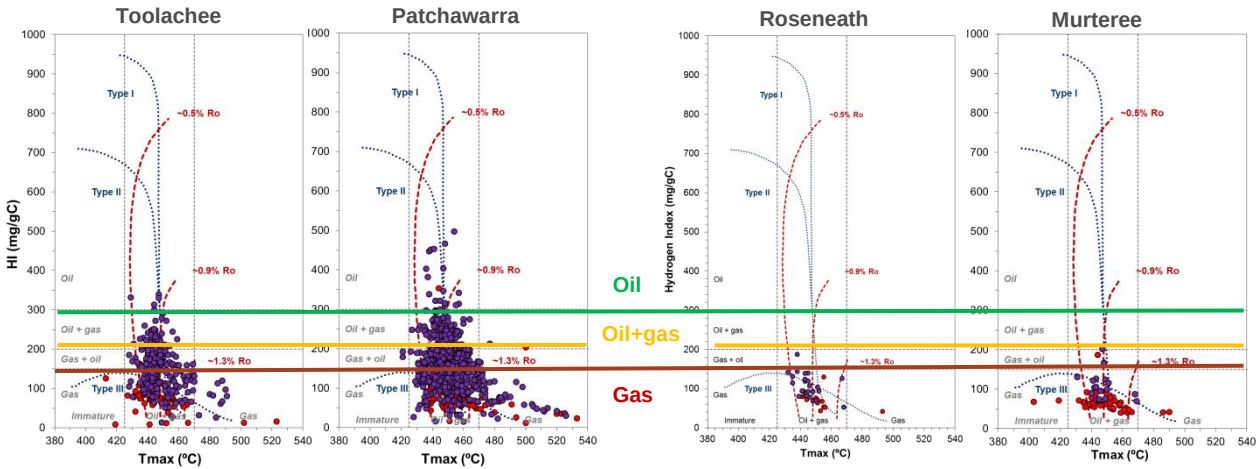
Source Rock Distribution

- TOC maps by formation and lithology: good – excellent source potential (TOC> 2%)
- Highest TOCs associated with the Toolachee and Patchawarra coals and coaly shales
- Source rock with remaining generation potential (TOC > 2%; S1+S2 > 3 mg/gRock)

➢ **Source rocks with remaining generation potential are abundant at multiple intervals across the basin**



Source Rock Characterisation



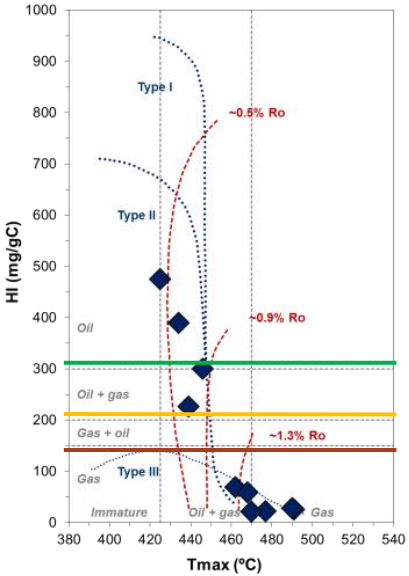
- Coals - shales
- TOCs: 2 – 80%; HI > 250 mg/gC
- Kerogen type II/III (non-marine) - Good gas to oil + gas source potential

- "Shales"
- TOC: 2 - 12 %; HI's < 200 mg/gC
- Kerogen type III/IV (non-marine) - Gas prone

➢ **Toolachee/ Patchawarra coals and shales are the best quality source rocks, not the Roseneath/ Murteree 'shales'**

COMPARISON WITH BARNETT SHALE

(Javie et al., 2005)



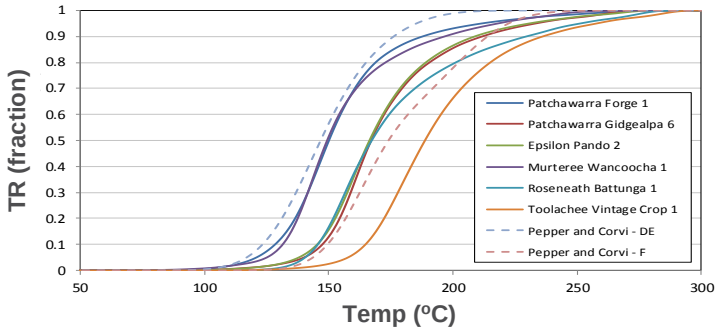
- Shales
- TOC: 2-12 %; HI > 300-500 mg/gC
- Kerogen type II, and some Type I (marine)

Kinetics for Petroleum Generation & Oil/ Gas Windows

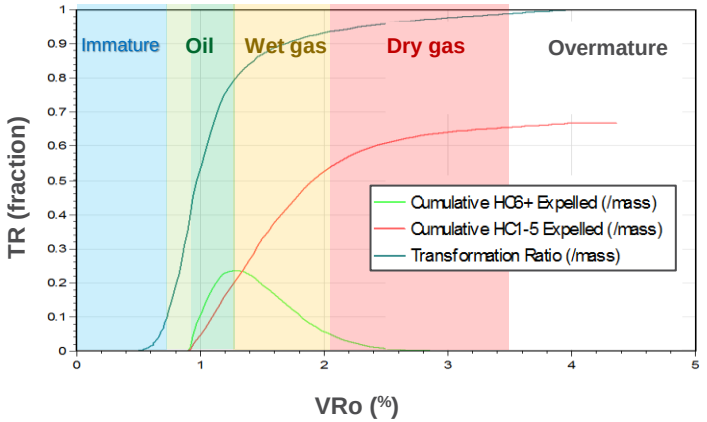
- Cooper basin kinetics (Malhstedt et al., in press).
  - Consistent with Pepper and Corvi DE – F (Type II/III - IV)
  - Potential for late primary gas generation
- Adsorption exerts a major control on ratio of oil vs gas expelled
- Cooper specific maturity windows

	Cooper Basin		Barnett Shale (Jarvie et al.,2005)
	Vr	Tmax	Vr
Early oil	0.75 - 0.9	435 - 445	0.55 – 0.9
Peak oil	0.9 - 1	445 - 455	0.9 – 1.15
Late oil	1 – 1.3	455 - 475	
Wet gas	1.3 - 2	475 - 530	1.15 - 1.4
Dry gas	2 – 3.5	530 - 650	>1.4
Over-mature	> 3.5	> 650	

Cooper specific kinetics: Transformation Ratio (TR) vs Temp



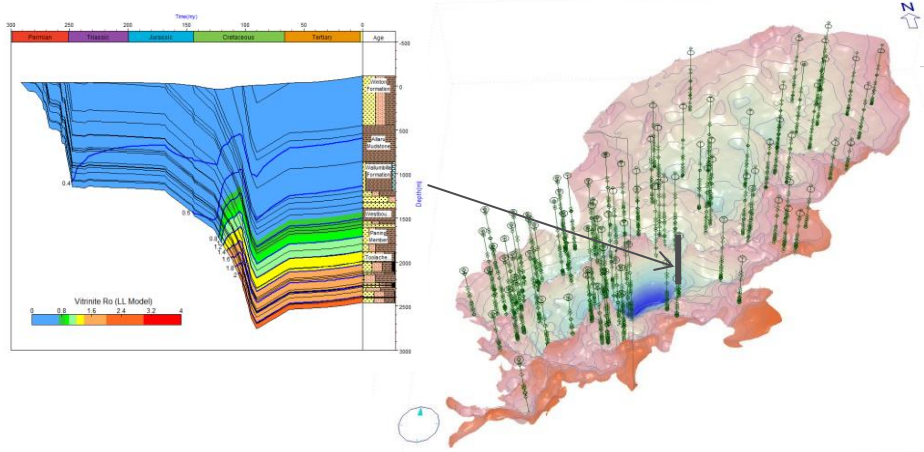
Cooper specific kinetics: Oil/ gas expelled vs maturity

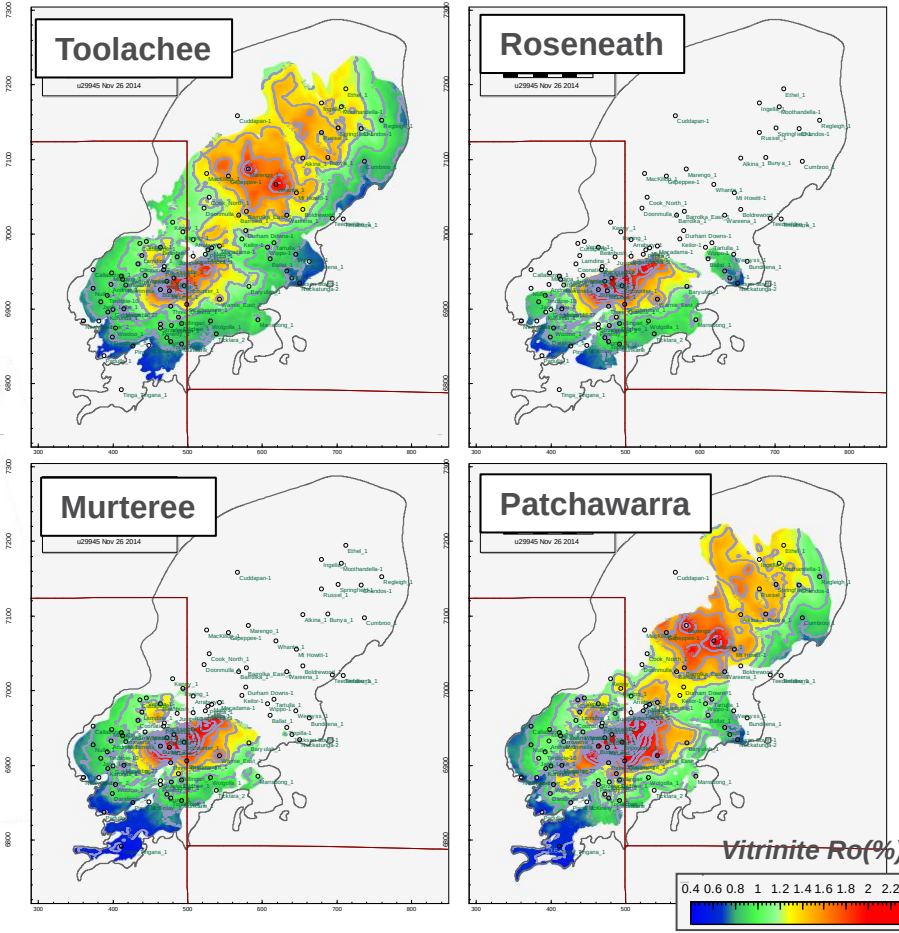


➢ **Later onset of oil and gas generation compared with US shales**

Maturity Modelling

- Multi-1D basin modelling study in progress
- 91 1D models. Calibration: corrected temperatures, vitrinite reflectance etc.
- Source characteristics based on lithofacies, geochem evaluation (original TOC and HI)

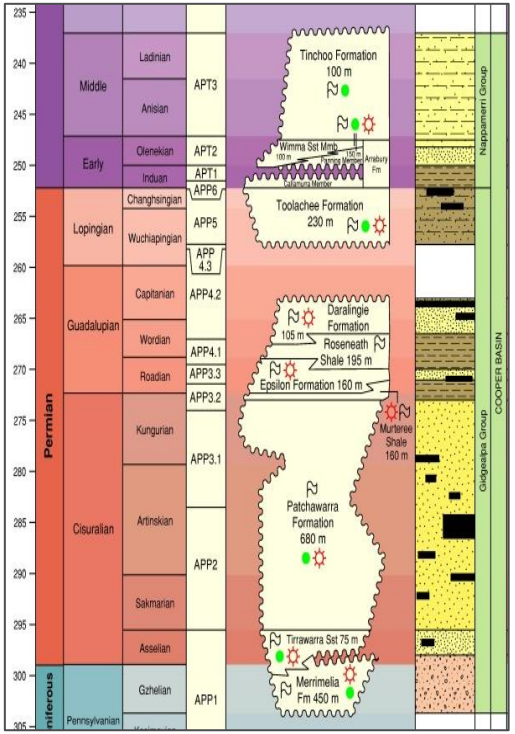


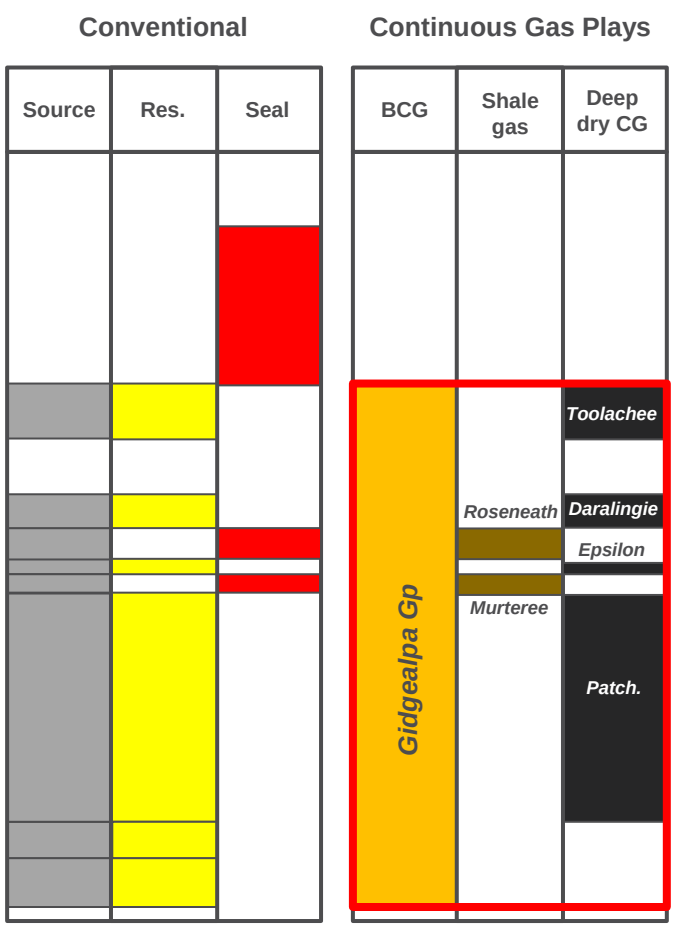


➢ **Large areas of the key source rock intervals are gas mature**

Cooper Basin Unconventional Gas Plays

- Tight gas/ deep coal gas plays are more important than the shale gas plays:
  - thicker, more extensive intervals
  - contain larger amounts of better quality source rocks
- For quick screening, we will apply the composite resource gas play model (Menpes et al., 2013).





Selection Criteria for Defining Continuous Gas Plays

Typical US Shale Gas Play

- TOC > 2 %; Type II/ IIs marine kerogen ?
- Net shale thickness > 15-20 m ?
- Maturity: vitrinite reflectance > 1.1 %; < 3.5 % ?
- Gas in matrix/organic storage ☑
- Overpressured (>0.45 psi/ft) ☑
- Relatively low water saturation ☑

Typical US Tight Gas Play

- Source rock ?
- Net reservoir thickness >100 m ?
- Maturity: vitrinite reflectance > 0.8% ?
- Low permeability matrix (< 0.1 mD) ☑
- Abnormal pressure (mostly overpressure) ☑
- Relatively low water saturation ☑

Typical Deep Coal Gas Play

- Coal thickness ?
- Maturity ?
- Other factors ?

➢ **Remains poorly defined!**

➢ **What screening criteria should be applied to the Cooper Basin?**

Selection Criteria for Defining Continuous Gas Plays

Cooper Shale Gas Play

- TOC > 2 %; ☑ **Type III non-marine kerogen** ☑
- Net shale thickness > 15-20 m ☑
- Maturity: vitrinite reflectance > **1.3 %; < 3.5 %** ☑
- Gas in matrix/organic storage ☑
- Overpressured (>0.45 psi/ft) ☑
- Relatively low water saturation ☑

Cooper Tight Gas Play

- Source rock ☑
- Net reservoir thickness >100 m ☑
- Maturity: vitrinite reflectance > 0.8% ☑
- Low permeability matrix (< 0.1 mD) ☑
- Abnormal pressure (mostly overpressure) ☑
- Relatively low water saturation ☑

Cooper Deep Coal Gas Play

- Coal thickness **> 5m** ☑
- Maturity vitrinite reflectance > **1.3 %; < 3.5 %** ☑
- Other factors ***– still to be considered***

➢ **Most criteria are met BUT**

- ➢ **Adjustments to the shale gas selection criteria required to account for differences in kerogen type.**
- ➢ **Selection criteria for deep dry coal gas need to be defined.**

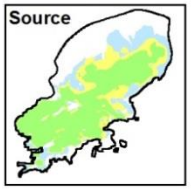
Gidgealpa Gp Composite Resource Play (Gas)

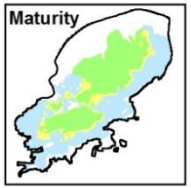
- GIS based common risk segment mapping approach to play fairway definition

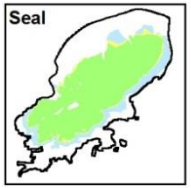
- *Play elements missing:*
  - *Reservoir permeability*
  - *Seal quality*
  - *Migration distance*
  - *Overpressure*

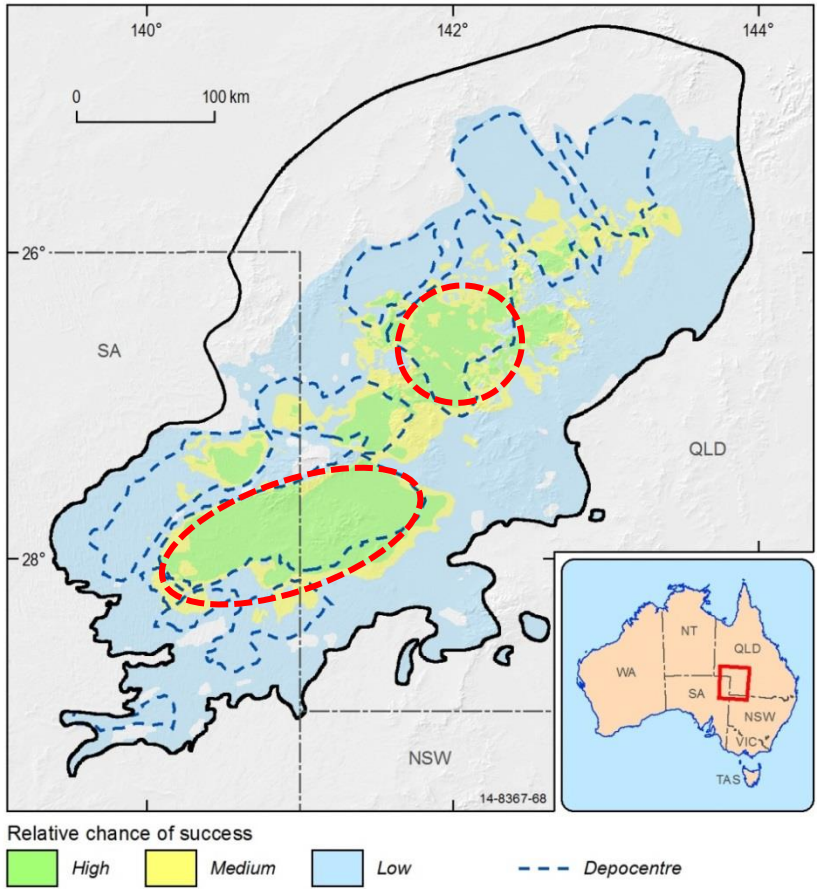
  + uncertainty due to variable data quality/ level of knowledge across the basin

Regional Chance of Success (COS) Map



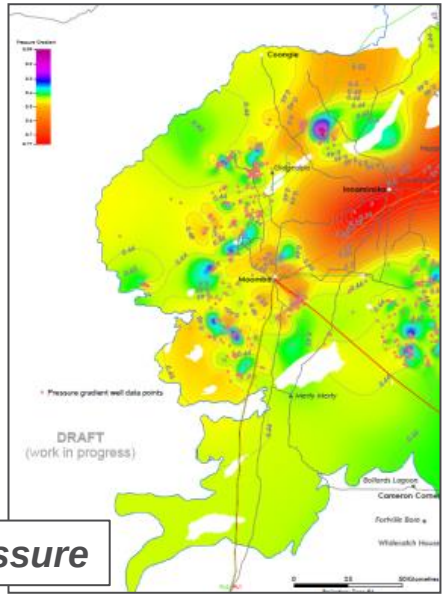






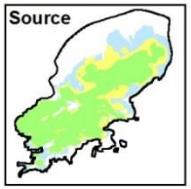
Gidgealpa Gp Composite Resource Play (Gas)

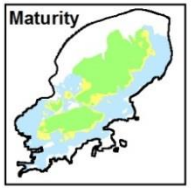
- GIS based common risk segment mapping approach to play fairway definition

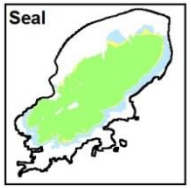


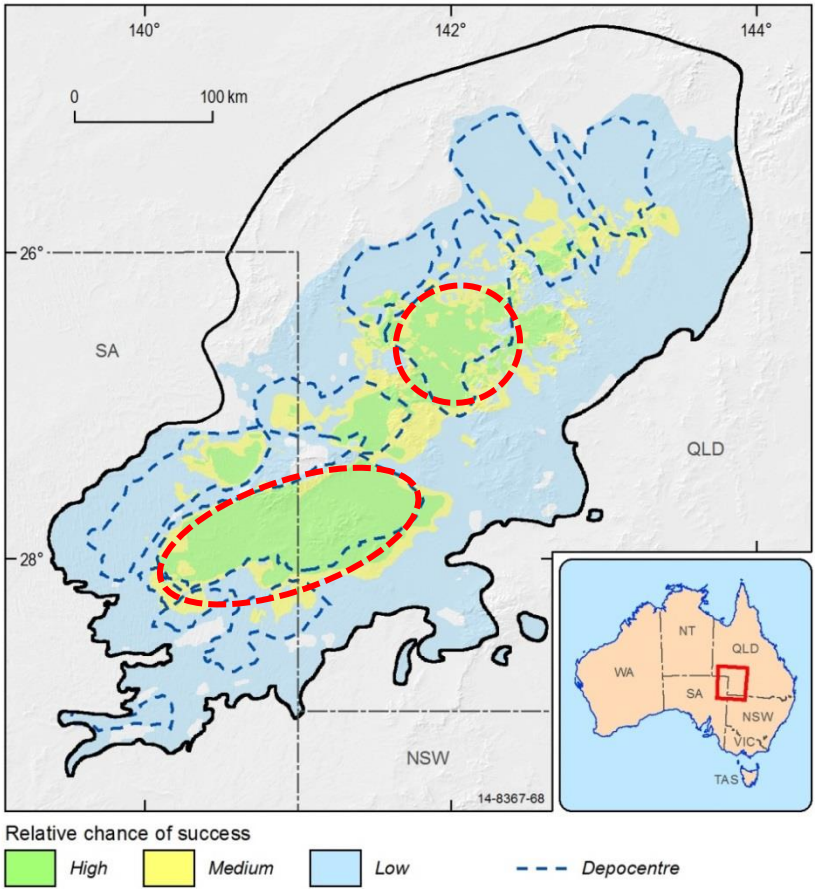
Overpressure

Regional Chance of Success (COS) Map





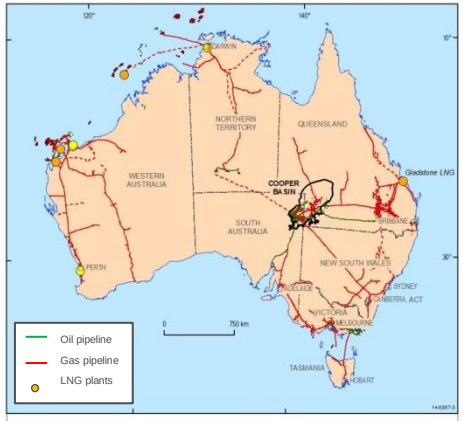


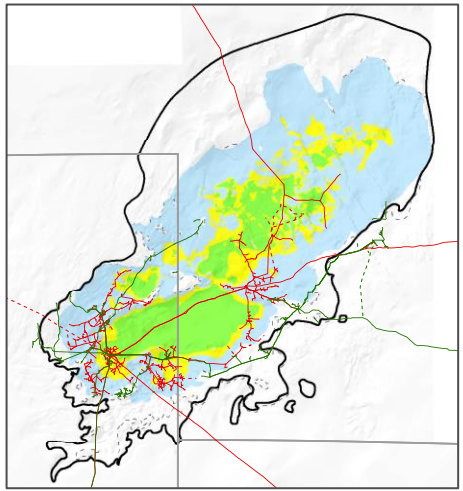


Conclusions

- Plenty of good quality, mature source rock across the basin.
- The most significant source rocks are the Toolachee and Patchawarra coals and coaly shales: not the Roseneath and Murteree shales.
- The composite gas resource play fairway shows there is potential for significant unconventional accumulations in the Permian across the basin.
- Cooper shales are different from typical US examples so application of US analogues requires more careful consideration
- Next steps: move away from COS maps by play type, towards a modelling approach which maps the distribution and amounts of hydrocarbons generated/ expelled.

➢ **Highlights the significance of the Cooper Basin as a world class unconventional gas province.**





Australian Government
Geoscience Australia

For further information contact:

lisa.hall@ga.gov.au

Queensland Government
Department of Natural Resources and Mines

SOUTH AUSTRALIA
Government of South Australia
Department of State Development

Phone: +61 2 6249 9111

Web: www.ga.gov.au

Email: feedback@ga.gov.au

Address: Cnr Jerrabomberra Avenue and Hindmarsh Drive, Symonston ACT 2609

Postal Address: GPO Box 378, Canberra ACT 2601