

# Petroleum geology and geochemistry of the Birrindudu Basin, greater McArthur Basin

Amber Jarrett<sup>1,2</sup>, Adam Bailey<sup>2</sup>, Junhong Chen<sup>2</sup>, Tim Munson<sup>1</sup>

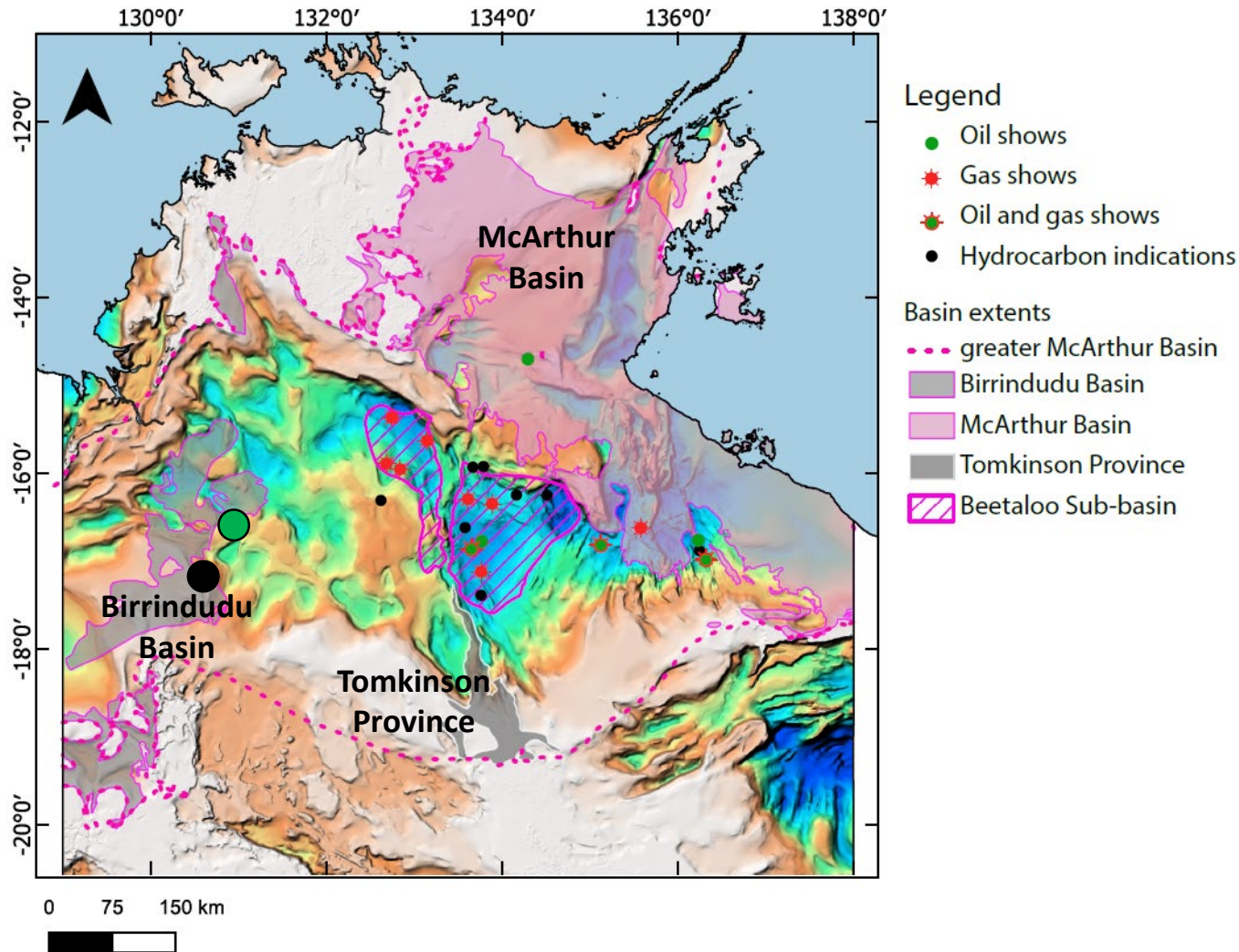


Australian Government  
Geoscience Australia

NORTHERN TERRITORY GEOLOGICAL SURVEY  
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ANNUAL GEOSCIENCE EXPLORATION SEMINAR  
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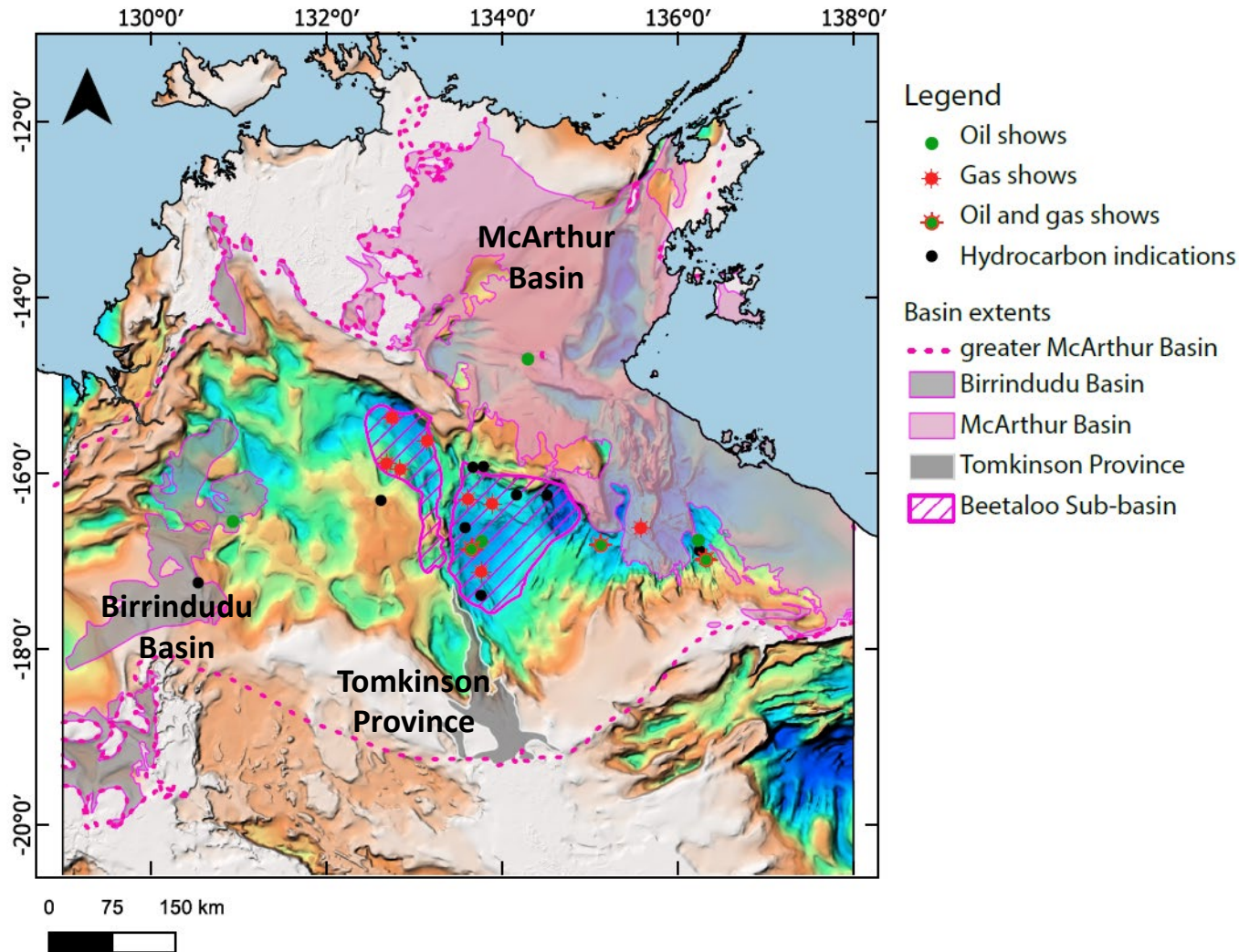


# Resourcing the Territory Initiative



- Supporting exploration in the NT and unlocking new areas for exploration
- This study focuses on the Birrindudu Basin in the greater McArthur Basin
- Comparison to the resource rich McArthur Basin/ Beetaloo Sub-basin
- Collaborative study between Northern Territory Geological Survey and Geoscience Australia

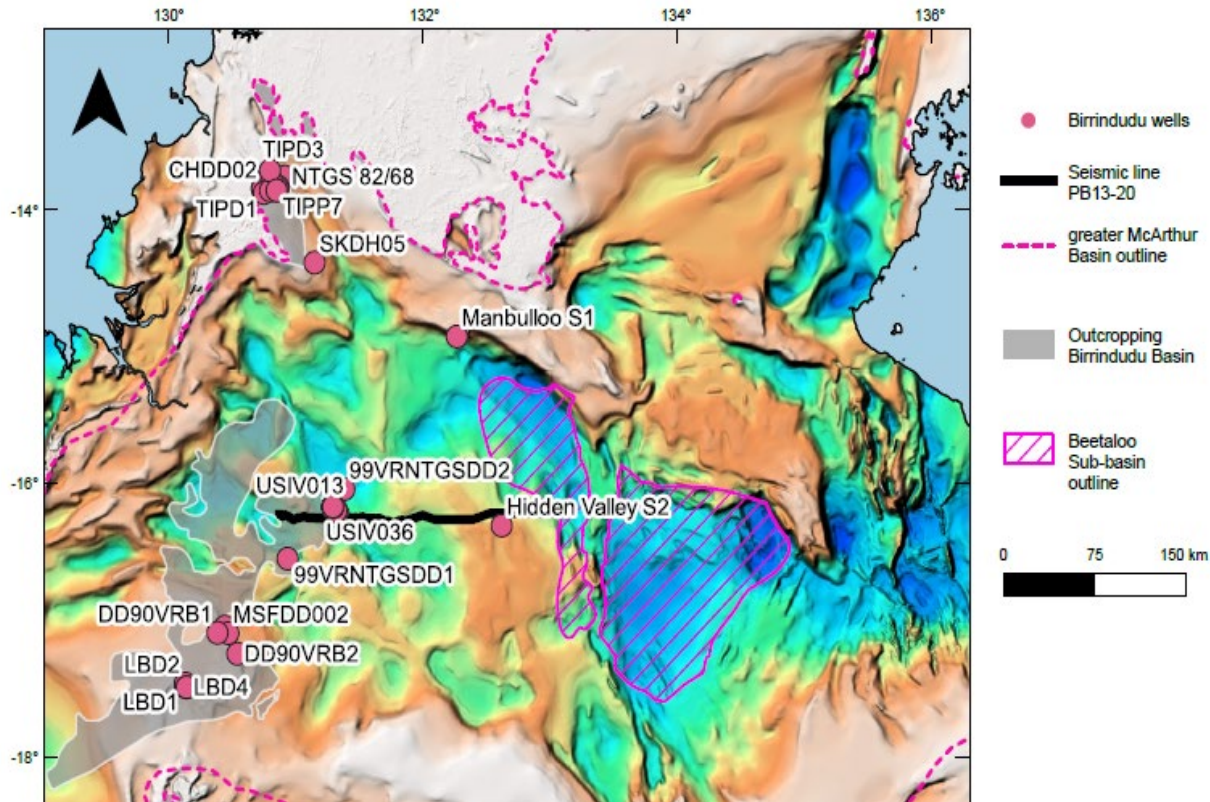
# Aims of this study



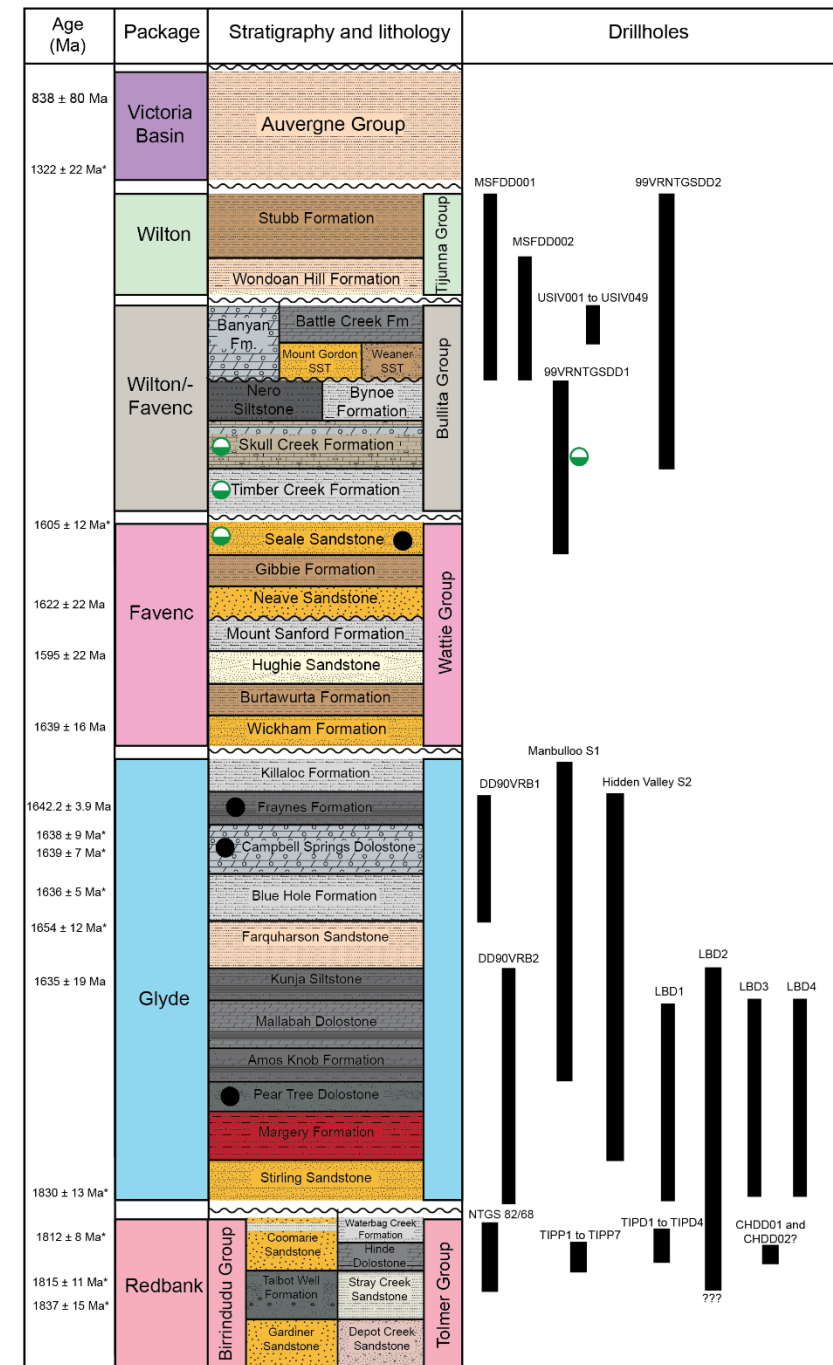
1. Define petroleum systems within the Birrindudu Basin, and reassess regional Petroleum Supersystems
2. Collate new and existing data (DIP-014 update)
3. Assess conventional and unconventional petroleum potential
4. Conduct gap analysis and define areas for future work



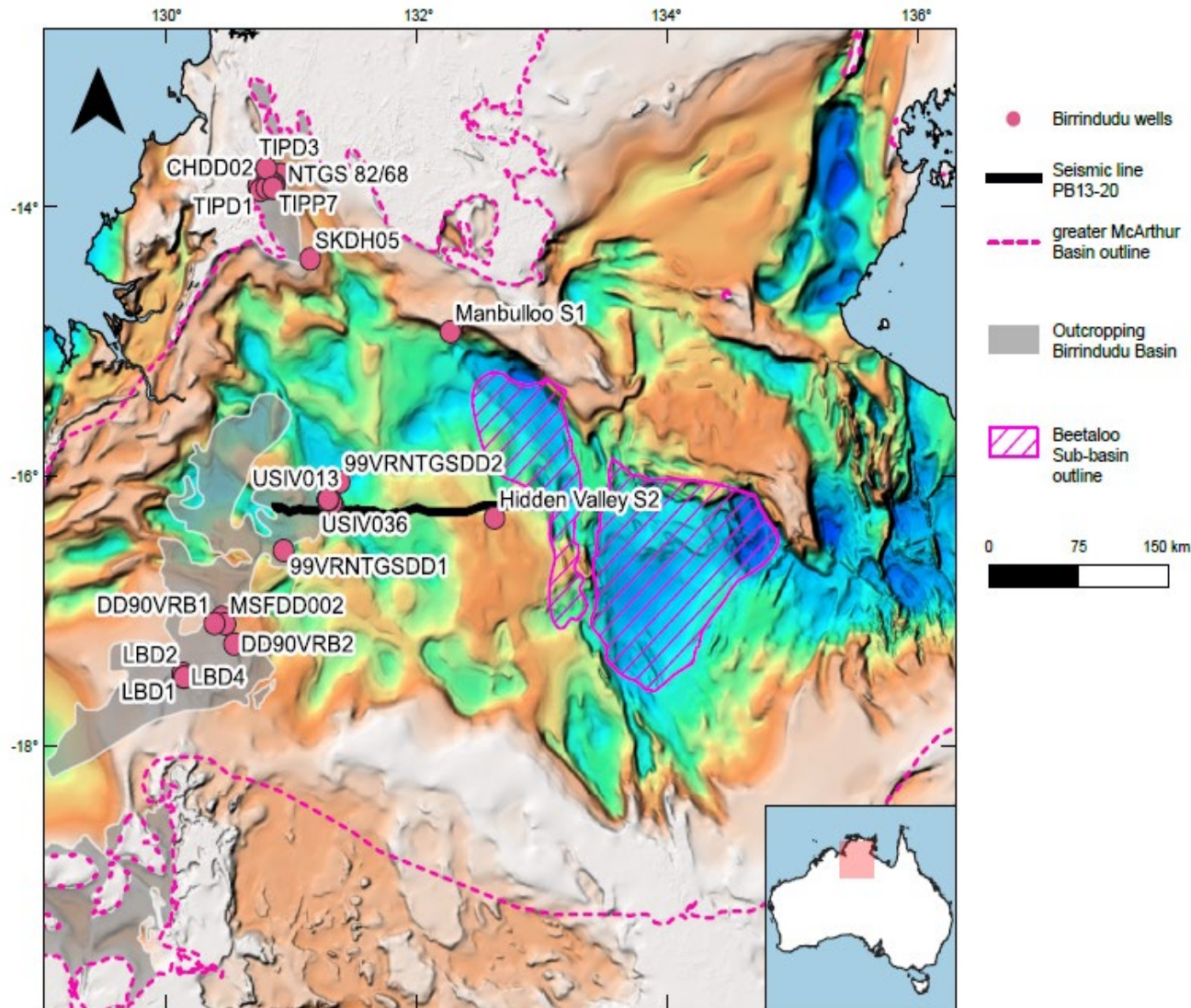
# Birrindudu Basin



- Outcrops over 35,000km<sup>2</sup>
- Six Paleoproterozoic to Mesoproterozoic aged groups
- Very limited exploration- low well and seismic coverage
- Oil shows, fluorescence, hydrocarbon indications
- Minor hints of base-metal mineralisation



# Linking the Birrindudu to the Beetaloo

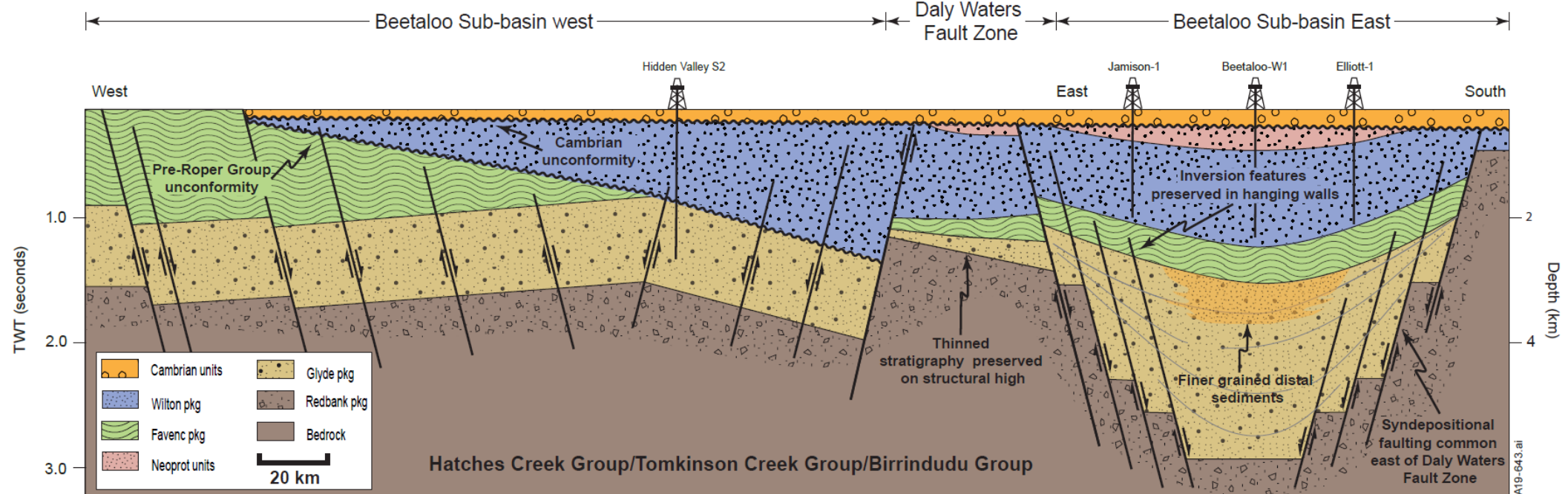
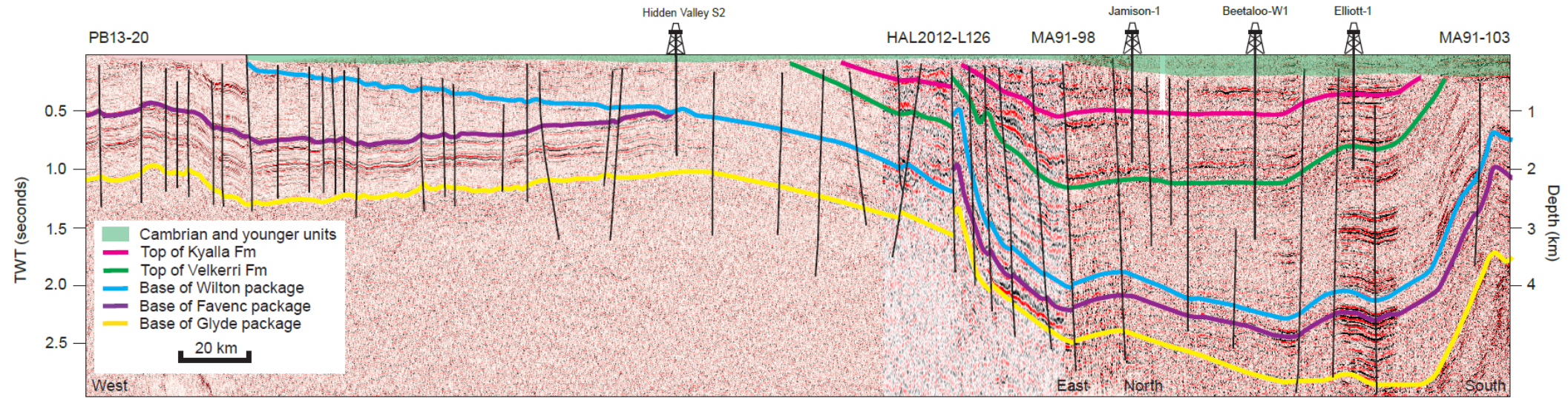


- Seismic reflectors from the Beetaloo traced ~200 km west to outcropping rocks of the Birrindudu Basin

Hoffman (2014)

<https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/82359>



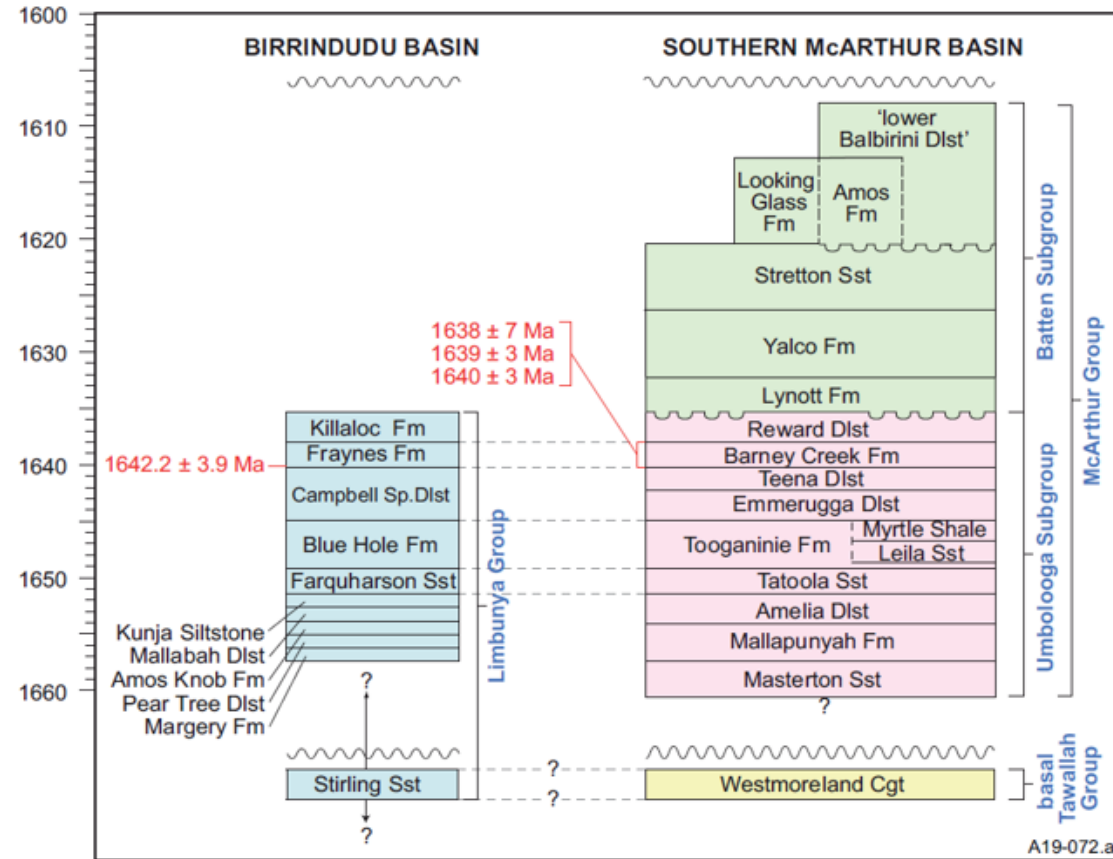


Williams (2019)

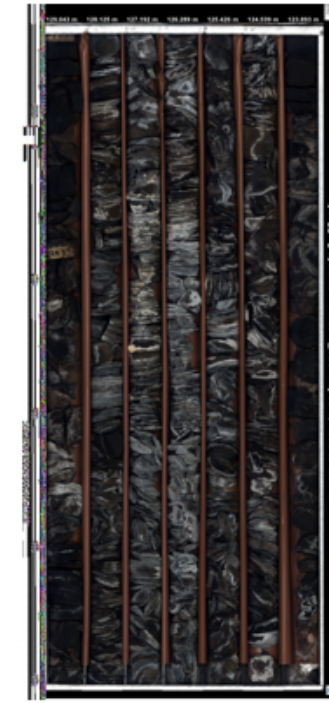
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# Chronostratigraphic links

Fraynes Formation



Barney Creek Formation

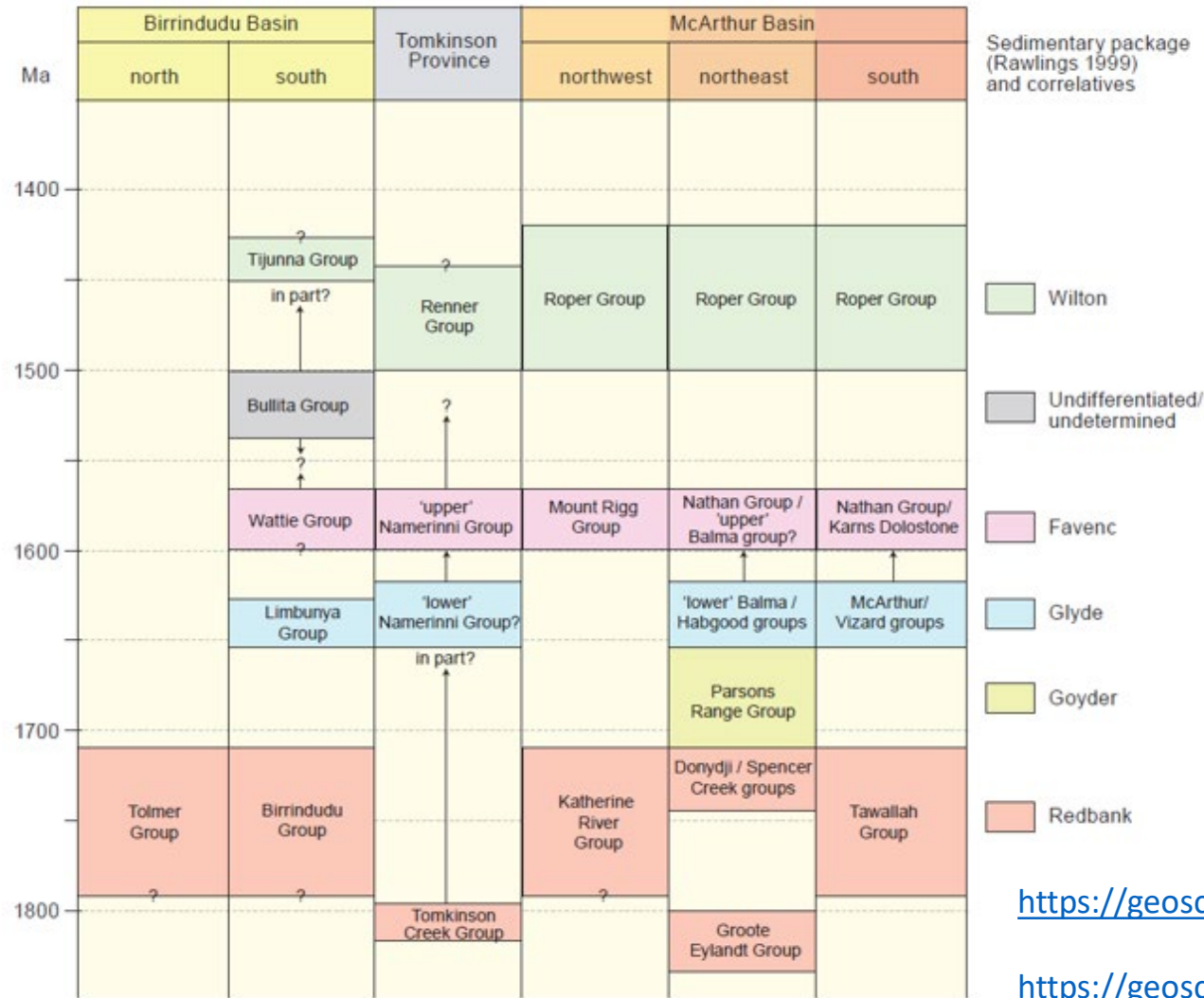


Munson *et al.* (2019)

<https://www.tandfonline.com/doi/abs/10.1080/08120099.2020.1669708>



# Sedimentary packages of the greater McArthur Basin



Munson (2016)

<https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/83806>

Munson (2019)

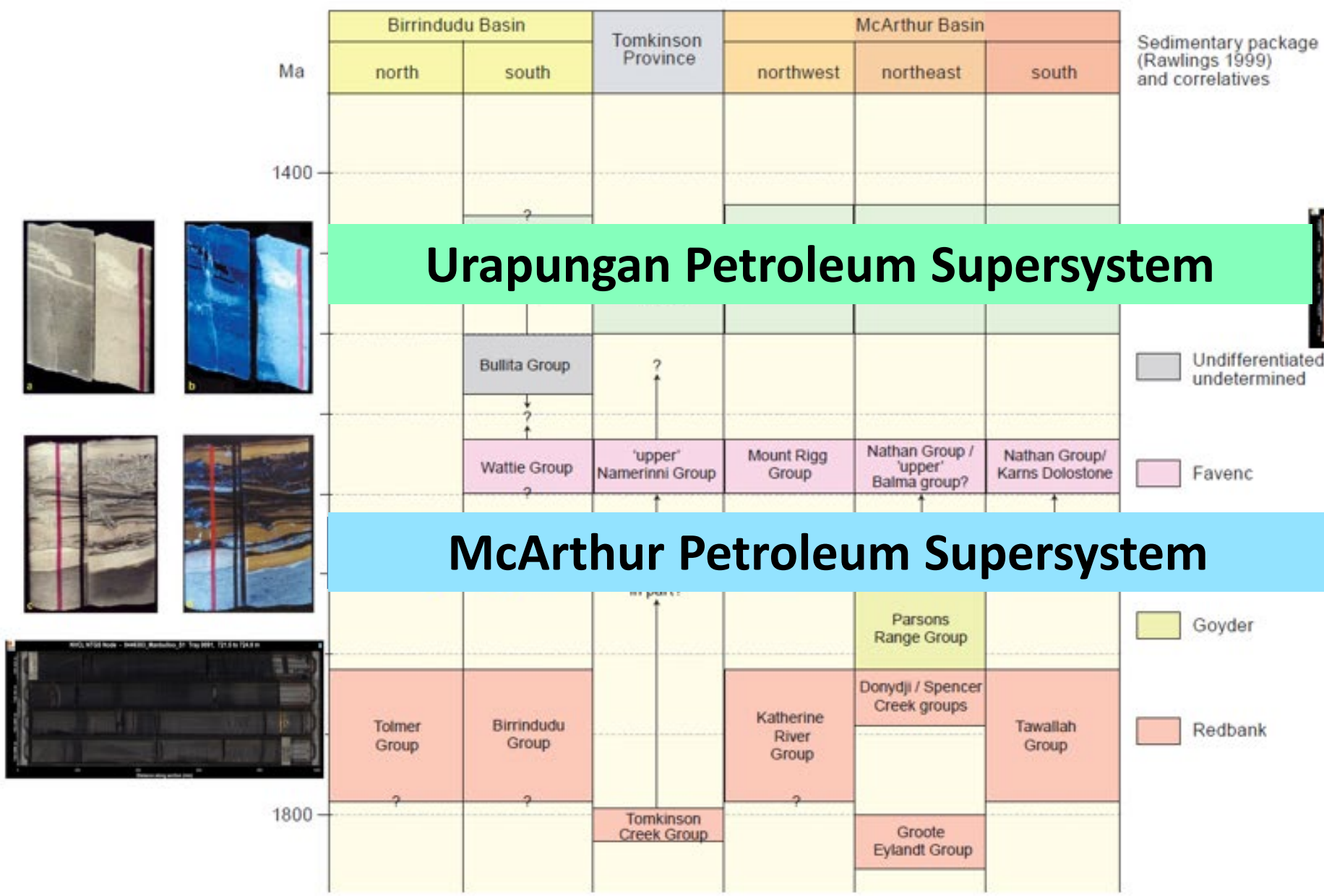
<https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/88373>

Munson *et al.* (2019)

<https://www.tandfonline.com/doi/abs/10.1080/08120099.2020.1669708>









# Petroleum Supersystems in the Birrindudu

Eon	Era	Age (Ma)	Package	Stratigraphy and lithology	Petroleum Super-system
Proterozoic	Neo-proterozoic	838 ± 80 Ma	Victoria Basin	Auvergne Group	Birrindudu /Victoria
	Meso-proterozoic	1322 ± 22 Ma*	Wilton	Stubb Formation	Tijuna Group
				Wondan Hill Formation	
				Battle Creek Fm	Bulita Group
				Banyan Fm	
				Mount Gordon	
				Nero Siltstone	Bynoe Formation
				Skull Creek Formation	
				Timber Creek Formation	
				Seale Sandstone	
Paleoproterozoic		1605 ± 12 Ma*		Gibbie Formation	
		1617 ± 39 Ma*		Neave Sandstone	
		1622 ± 22 Ma		Mount Sanford Formation	
		1595 ± 22 Ma		Hughie Sandstone	
				Burtawurta Formation	
		1639 ± 16 Ma		Wickham Formation	
				Killaloe Formation	
		1642.2 ± 3.9 Ma		Fraynes Formation	
		1638 ± 9 Ma*		Campbell Springs Dolostone	
		1639 ± 7 Ma*		Blue Hole Formation	
		1636 ± 5 Ma*		Farquharson Sandstone	
		1654 ± 12 Ma*		Kunja Siltstone	
		1635 ± 19 Ma		Mallabah Dolostone	
				Amos Knob Formation	
				Pear Tree Dolostone	
				Margery Formation	
		1830 ± 13 Ma*		Stirling Sandstone	
		1812 ± 8 Ma*		Coomalie Sandstone	
		1815 ± 11 Ma*		Talbot Well Formation	
		1837 ± 15 Ma*		Gardiner Sandstone	

## Urapungan Petroleum Supersystem

## Lawn Petroleum Supersystem

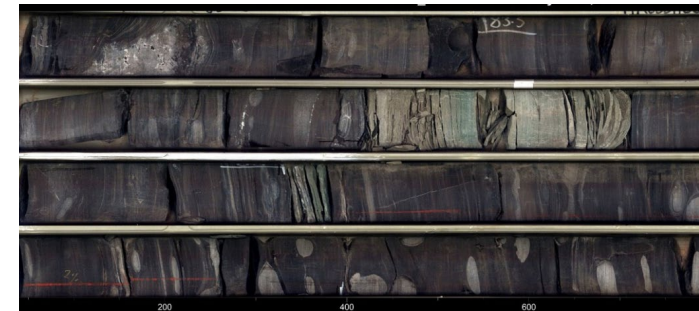
## McArthur Petroleum Supersystem

## Redbank Petroleum Supersystem

Gas flare in Egilabria 2 (Qld)  
Lawn Hill Fm, Lawn Hill Platform

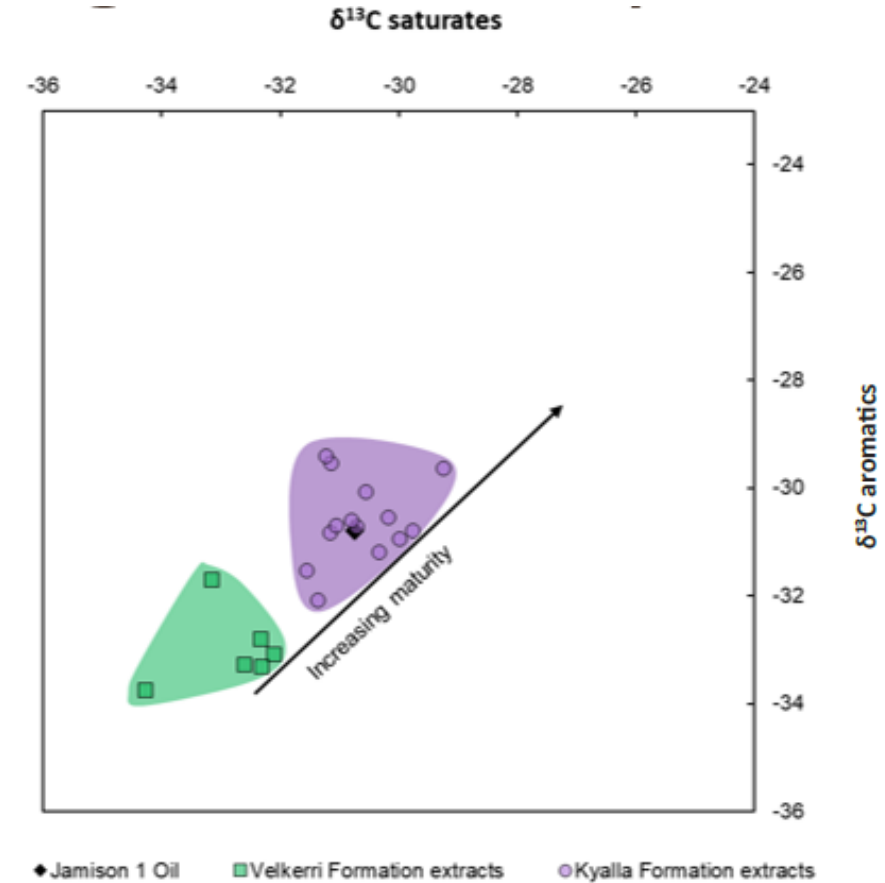
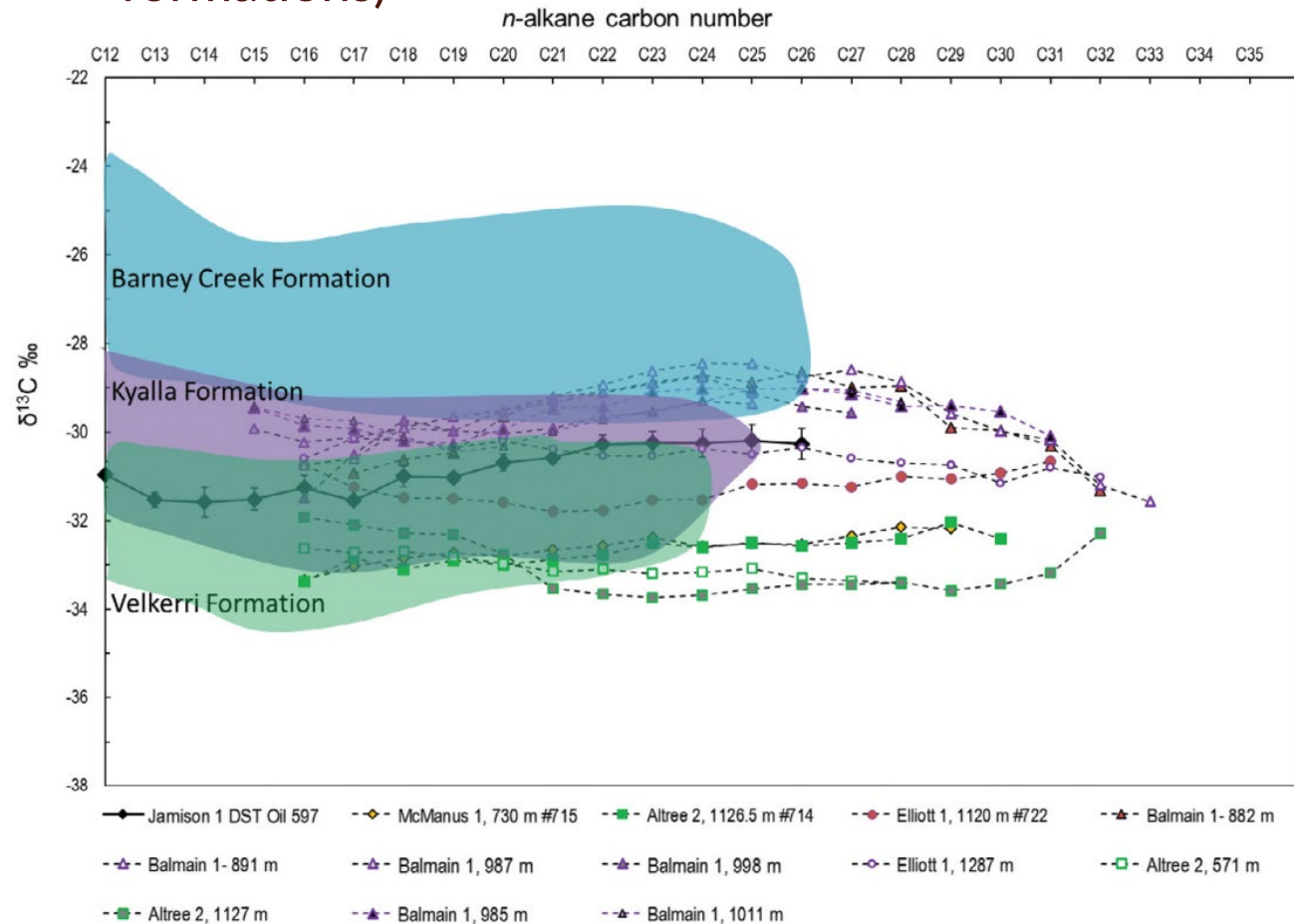


Wollogorang Formation  
Redbank Petroleum Supersystem



# Petroleum Supersystems

- Differentiation between McArthur and Urapunga Petroleum Supersystems
- Differentiation within Urapungan Supersystem reflecting different source rocks (Kyalla and Velkerri formations)



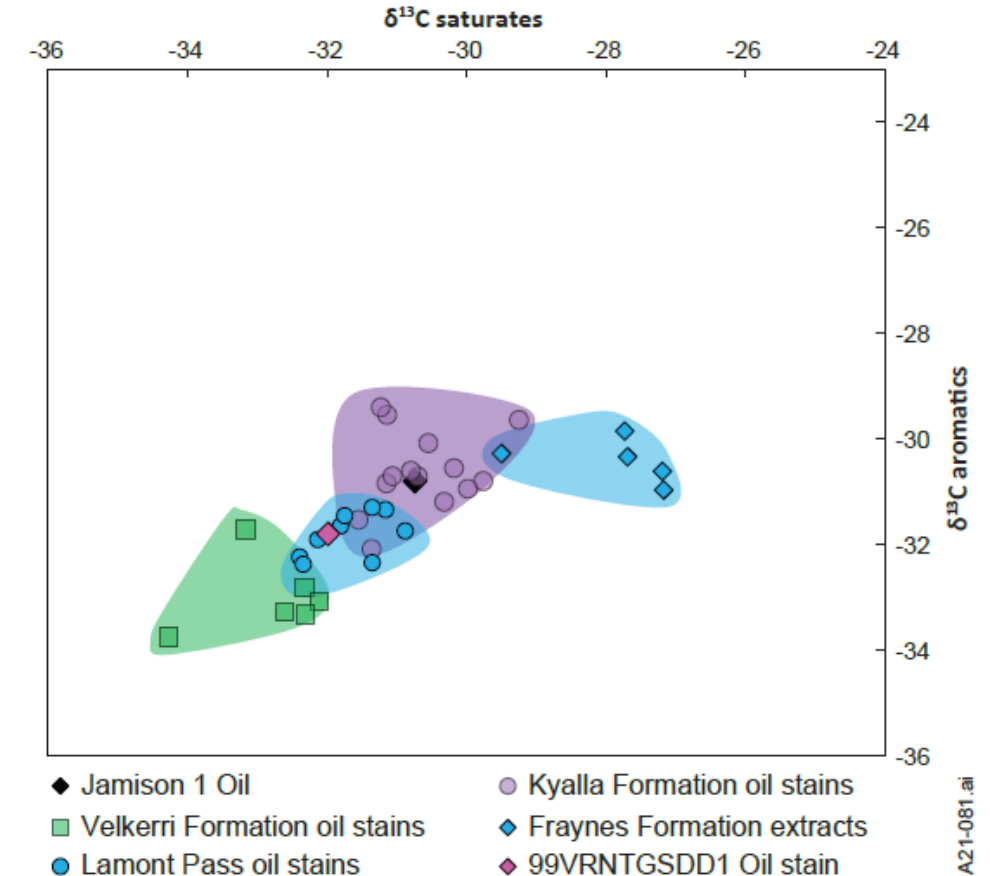
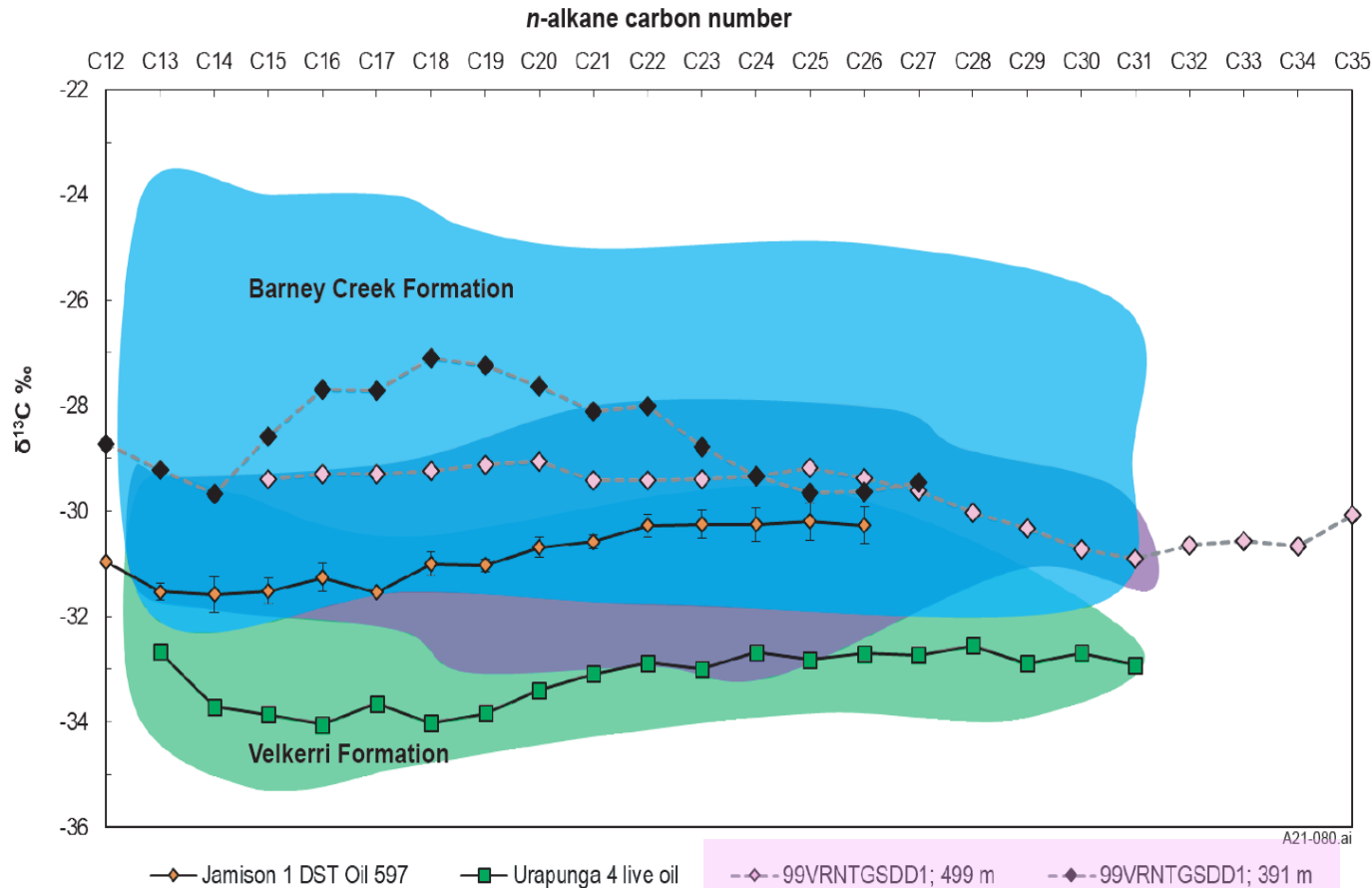
Jarrett *et al.* (2019)

<https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/88381>



# Petroleum Supersystems

- New data suggests higher overlap between McArthur and Urapungan Petroleum Supersystems
- Birrindudu oil stains sits within the zone of mixing
- Birrindudu Basin specific source rock geochemistry needed



# Basin-scale petroleum system elements

- Hypothetical conventional and unconventional petroleum system elements defined based on lithology

- Source
- Reservoir
- Seal
- Unconventional (shale oil or shale gas)

Eon	Era	Age (Ma)	Package	Stratigraphy and lithology	Petroleum system				
Proterozoic	Neo-proterozoic	838 ± 80 Ma	Victoria Basin	Auvergne Group	Birrindudu /Victoria				
		1322 ± 22 Ma*							
	Meso-proterozoic		Wilton	Stubb Formation	Tjunna Group	Urapungan			
				Wondoan Hill Formation					
	Paleoproterozoic			Banyan Fm	Battle Creek Fm	Bullita Group	?		
				Mount Gordon Sst	Weaner Sst				
				Nero Siltstone	Bynoe Formation				
				Skull Creek Formation					
				Timber Creek Formation					
			1605 ± 12 Ma*		Seale Sandstone			Wattie Group	Lawn
				Gibbie Formation					
			1617 ± 39 Ma* 1622 ± 22 Ma	Neave Sandstone					
				Mount Sanford Formation					
			1595 ± 22 Ma	Hughie Sandstone					
				Burtawurta Formation					
			1639 ± 16 Ma	Wickham Formation		?			
					Killaloc Formation	Limbunya Group	McArthur		
					Fraynes Formation				
			1642.2 ± 3.9 Ma		Campbell Springs Dolostone				
			1638 ± 9 Ma* 1639 ± 7 Ma*		Blue Hole Formation				
			1636 ± 5 Ma*		Farquharson Sandstone				
			1654 ± 12 Ma*		Kunja Siltstone				
					Mallabah Dolostone				
					Amos Knob Formation				
			1635 ± 19 Ma		Pear Tree Dolostone				
					Margery Formation				
				Stirling Sandstone					
		1830 ± 13 Ma*							
	1812 ± 8 Ma*		Redbank	Birrindudu Group		Redbank			
				Coomarie Sandstone	Waterbag Creek Formation				
				Hinde Dolostone					
	1815 ± 11 Ma* 1837 ± 15 Ma*			Talbot Well Formation	Stray Creek Sandstone				
				Gardiner Sandstone	Depot Creek Sandstone	Toimer Group			

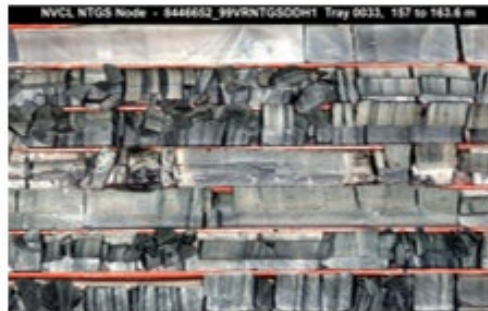


Eon	Era	Age (Ma)	Package	Stratigraphy and lithology	Petroleum system	Source
Proterozoic	Neo-proterozoic	838 ± 80 Ma	Victoria Basin	Auvergne Group	Birimindudu /Victoria	
		1322 ± 22 Ma*				
	Meso-proterozoic		Wilton	Stubbs Formation	Tjanna Group	Urapungan
				Wondan Hill Formation		
	Paleoproterozoic		Bulimba Group	Banyan Fm.		
				Battle Creek Fm.		
				Mount Gordon Sst		
				Wimmer Sst		
				Nero Siltstone		
				Bynoe Formation		
				Skull Creek Formation		
				Timber Creek Formation		
		1605 ± 12 Ma*		Seale Sandstone		
		1617 ± 36 Ma*		Gibbie Formation		
		1622 ± 22 Ma		Neave Sandstone		
		1596 ± 22 Ma		Mount Sanford Formation		
		1639 ± 16 Ma		Hughie Sandstone		
				Burburua Formation		
				Wickham Formation		
		1642.2 ± 3.9 Ma	Glyde	Killar Formation		
		1638 ± 9 Ma*		Fraines Formation		
		1639 ± 7 Ma*		Campbell Springs Dolostone		
		1636 ± 5 Ma*		Blue Hole Formation		
		1654 ± 12 Ma*		Farguherson Sandstone		
		1635 ± 19 Ma		Kunja Siltstone		
				Mallabah Dolostone		
				Amos Knob Formation		
				Pear Tree Dolostone		
				Margery Formation		
		1530 ± 13 Ma*		Stirling Sandstone		
		1812 ± 8 Ma*	Redbank	Coonamble Sandstone		
		1815 ± 11 Ma*		Tabor Well Formation		
		1837 ± 15 Ma*		Stray Creek Sandstone		
				Gardiner Sandstone		
			Birimindudu Group	Woolagong Creek Formation		
				Nicola Dolostone		
				Stray Creek Sandstone		
				Depot Creek Sandstone		
			Tolmer Group			

# Sources

- 17 potential source rocks
- Limited TOC and pyrolysis data

Skull Creek Formation



Battle Creek Formation



Fraines Formation



Kunja Siltstone



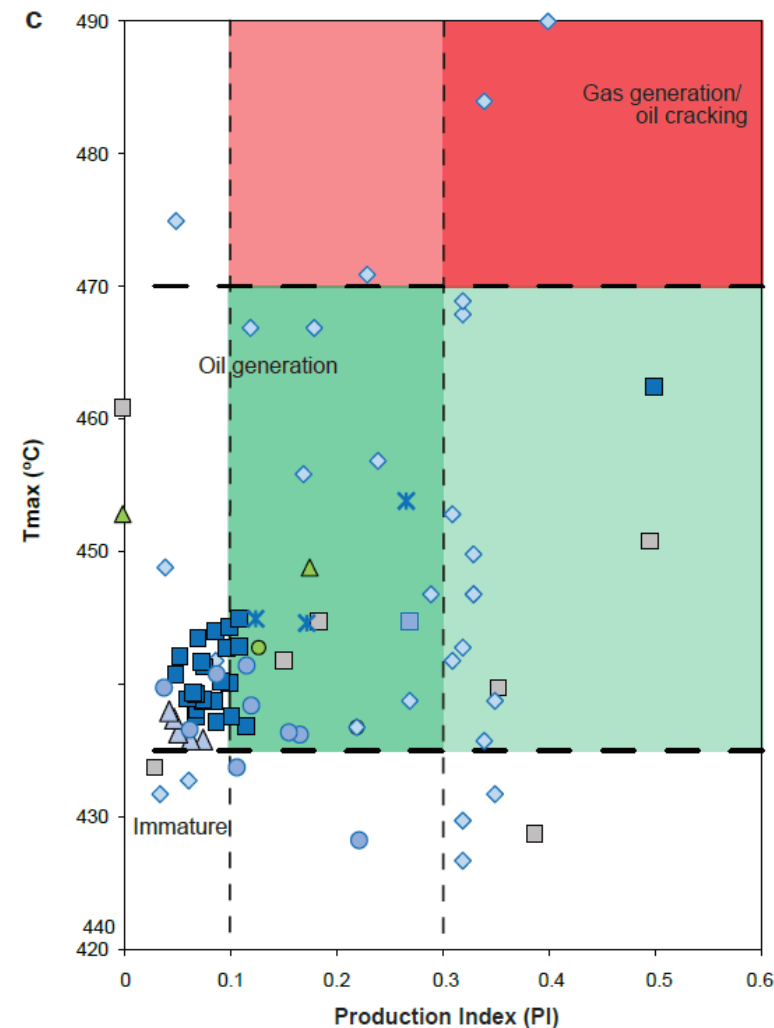
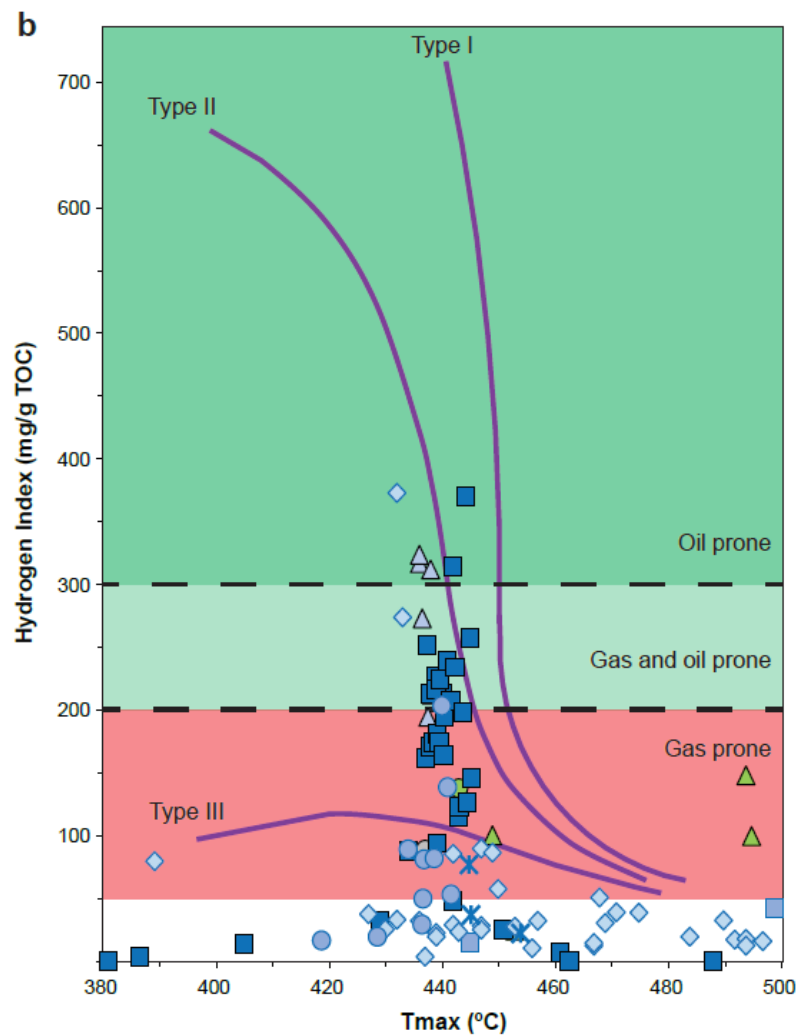
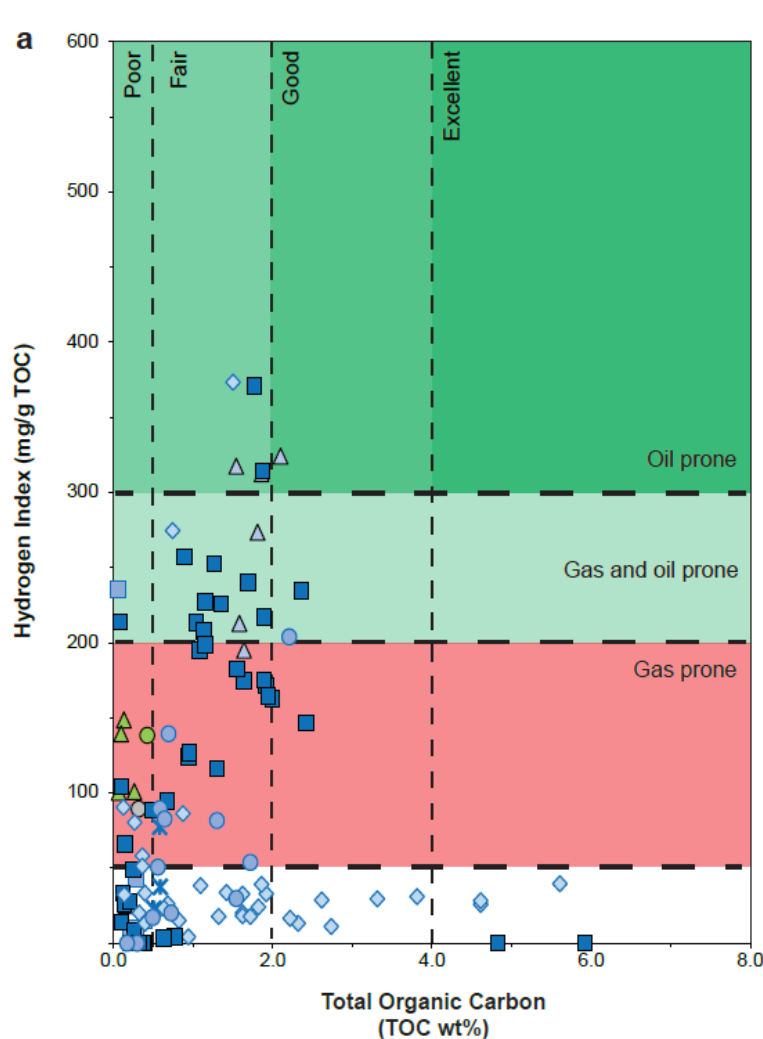
Stubbs Formation



Mallabah Dolostone

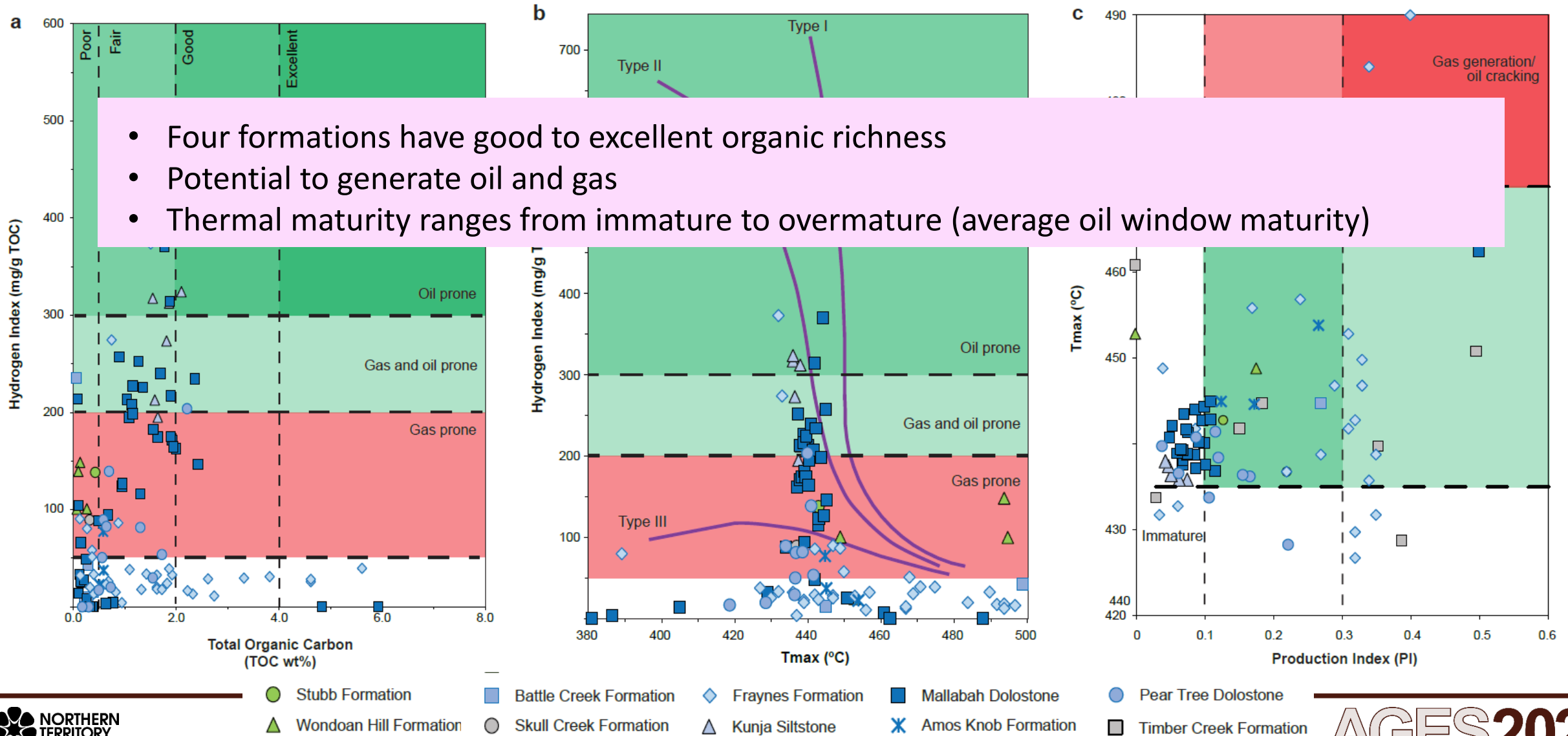


# Source rock geochemistry





# Source rock geochemistry



Eon	Era	Age (Ma)	Package	Stratigraphy and lithology	Petroleum system	Source	Reservoir
Proterozoic	Neo-proterozoic	838 ± 80 Ma	Victoria Basin	Auvergne Group	Bimindudu /Victoria		
		1322 ± 22 Ma*					
	Meso-proterozoic		Wilton	Stubbs Formation	Urapungan		
				Wondwan Hill Formation			
	Paleoproterozoic		Bulimba Group	Banyan Fm.	?		
				Battle Creek Fm.			
				Mount Gordon SSF			
				Wesley SSF			
				Nero Sandstone			
				Bynoe Formation			
			Favenc	Skull Creek Formation			
				Timber Creek Formation			
		1605 ± 12 Ma*		Seale Sandstone			
				Gobbie Formation			
		1617 ± 39 Ma*		Neave Sandstone			
		1622 ± 22 Ma*		Mount Sanford Formation			
		1596 ± 22 Ma	Waste Group	Hughie Sandstone			
				Burtawurta Formation			
		1639 ± 16 Ma		Wickham Formation			
				Killatoc Formation			
		1642.2 ± 3.9 Ma		Praynes Formation			
		1638 ± 9 Ma*	Glyde	Campbell Springs Dolomite			
		1639 ± 7 Ma*		Blue Hole Formation			
		1636 ± 5 Ma*		Farquharson Sandstone			
		1654 ± 12 Ma*		Kurja Silstone			
		1635 ± 19 Ma		Mallabah Dolomite			
			McArthur	Amos Knob Formation			
				Pear Tree Dolomite			
				Margery Formation			
				Stirling Sandstone			
		1530 ± 13 Ma*					
		1812 ± 8 Ma*	Redbank	Coonamble Sandstone			
				Stirling Creek Formation			
				Hicks Dolomite			
		1815 ± 11 Ma*		Tabor Well Formation			
		1837 ± 15 Ma*	Bimindudu Group	Stray Creek Sandstone			
				Gardiner Sandstone			
			Tolmer Group	Depot Creek Sandstone			

# Reservoirs

- 20 potential reservoir rocks
- Sandstones and carbonates
- Limited porosity and permeability data

Sandstones



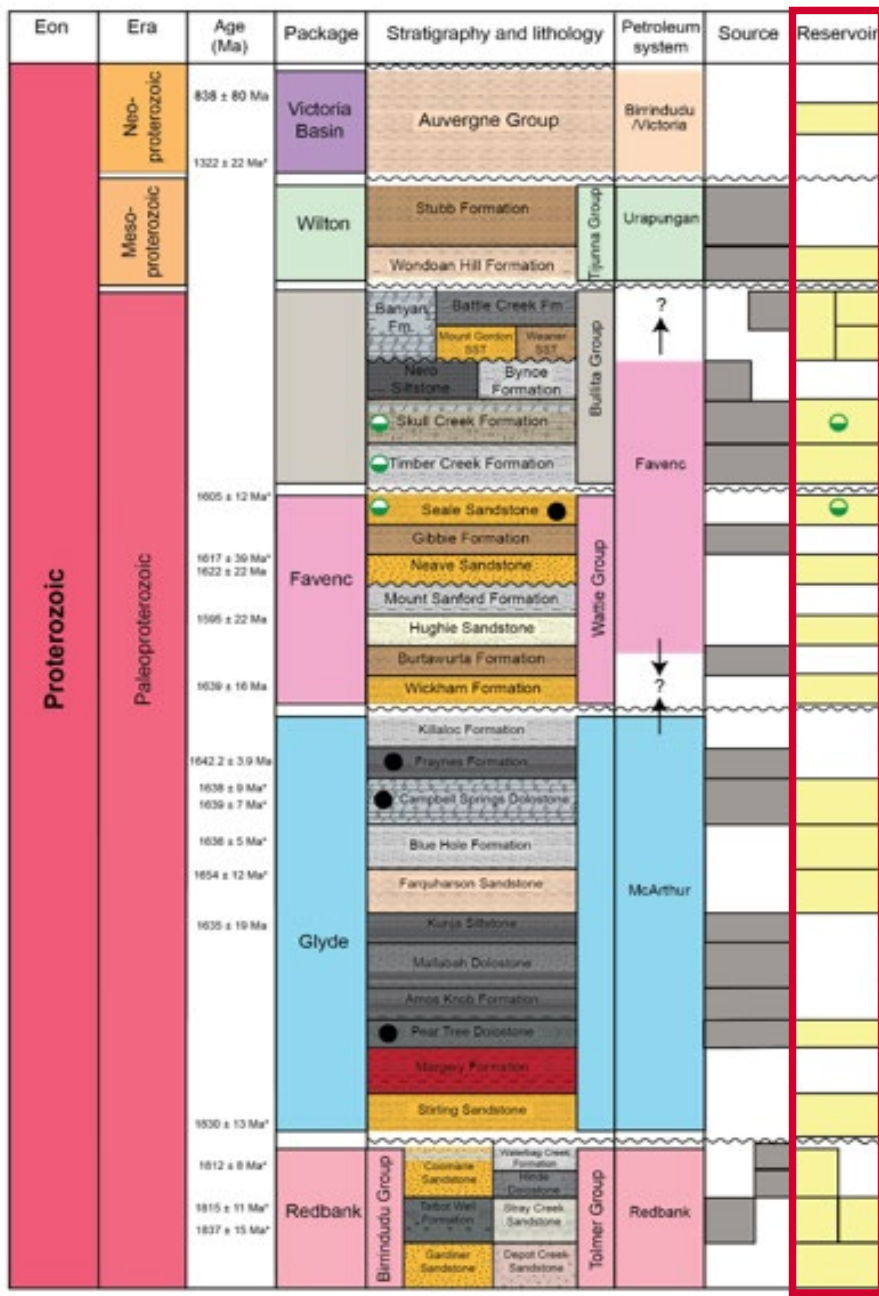
Stirling Sandstone

Carbonates



Timber Creek Formation





# Reservoirs

## Sandstones

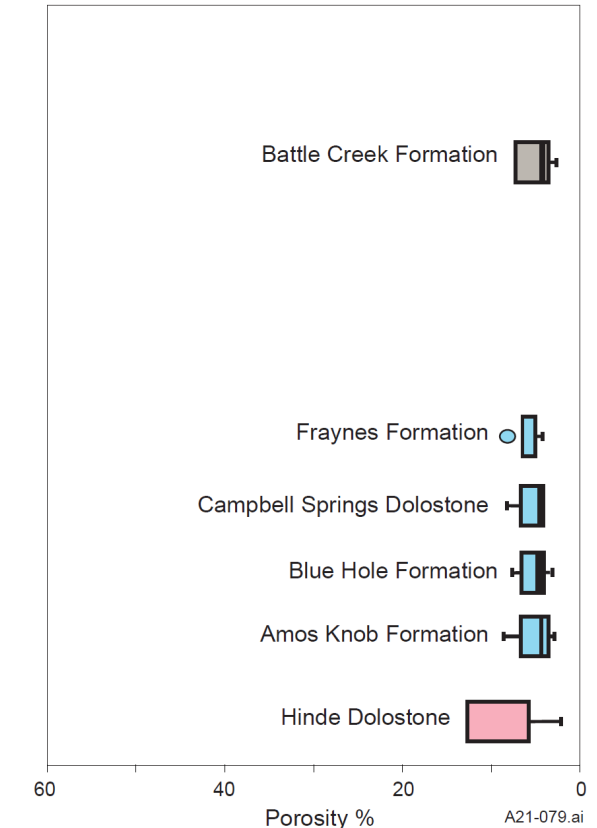
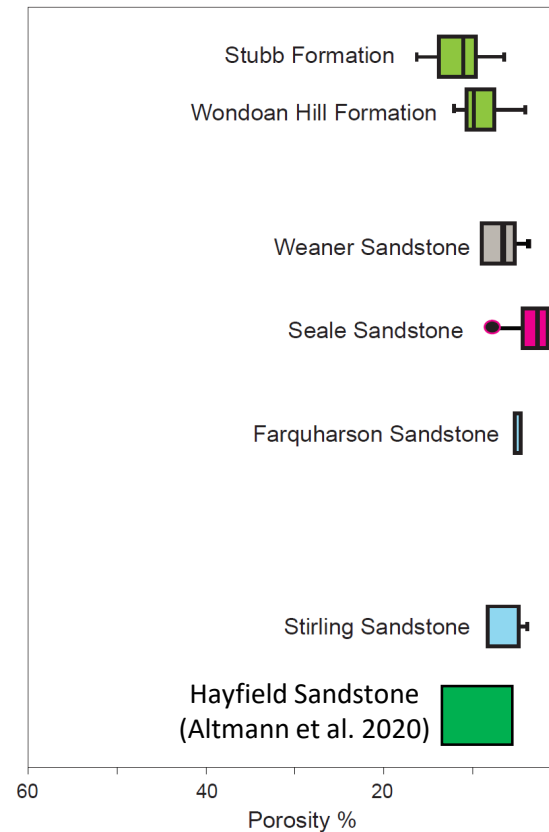


Stirling Sandstone

## Carbonates



Timber Creek Formation



Eon	Era	Age (Ma)	Package	Stratigraphy and lithology	Petroleum system	Source	Reservoir	Seal
Proterozoic	Neo-proterozoic	838 ± 80 Ma	Victoria Basin	Auvergne Group	Birindudu /Victoria			
		1322 ± 22 Ma*						
	Meso-proterozoic		Wilton	Stubb Formation	Tjanna Group	Urapungan		
				Wondan Hill Formation				
	Paleoproterozoic			Banyan Fm.	Bullita Group	?		
				Battle Creek Fm.				
				Mount Gordon 557				
				Wessan 557				
				Nero Siltstone				
				Bynoe Formation				
				Skull Creek Formation				
				Timber Creek Formation				
		1605 ± 12 Ma*		Seale Sandstone				
		1617 ± 39 Ma*		Gibbie Formation				
		1622 ± 22 Ma		Neave Sandstone				
		1596 ± 22 Ma		Mount Sanford Formation				
		1639 ± 16 Ma		Hughie Sandstone				
				Burtawurta Formation				
				Wickham Formation				
		1642.2 ± 3.9 Ma		Killaroc Formation				
		1638 ± 9 Ma*		Fraines Formation				
		1639 ± 7 Ma*		Campbell Springs Dolostone				
		1636 ± 5 Ma*		Blue Hole Formation				
		1654 ± 12 Ma*		Farguherson Sandstone				
		1636 ± 19 Ma		Kunja Siltstone				
		1630 ± 13 Ma*		Mallabah Dolostone				
		1812 ± 8 Ma*		Amos Knob Formation				
		1815 ± 11 Ma*		Pear Tree Dolostone				
		1837 ± 15 Ma*		Margery Formation				
				Stirling Sandstone				
				Stirling Creek Formation				
				Nicola Dolostone				
				Stirling Creek Sandstone				
				Gardiner Sandstone				
				Depot Creek Sandstone				
				Redbank				
				Birindudu Group				
				Tolmer Group				
				Redbank				

# Seals

- 16 potential seal rocks
- No data available- all hypothetical

Stubb Formation



Margery Formation



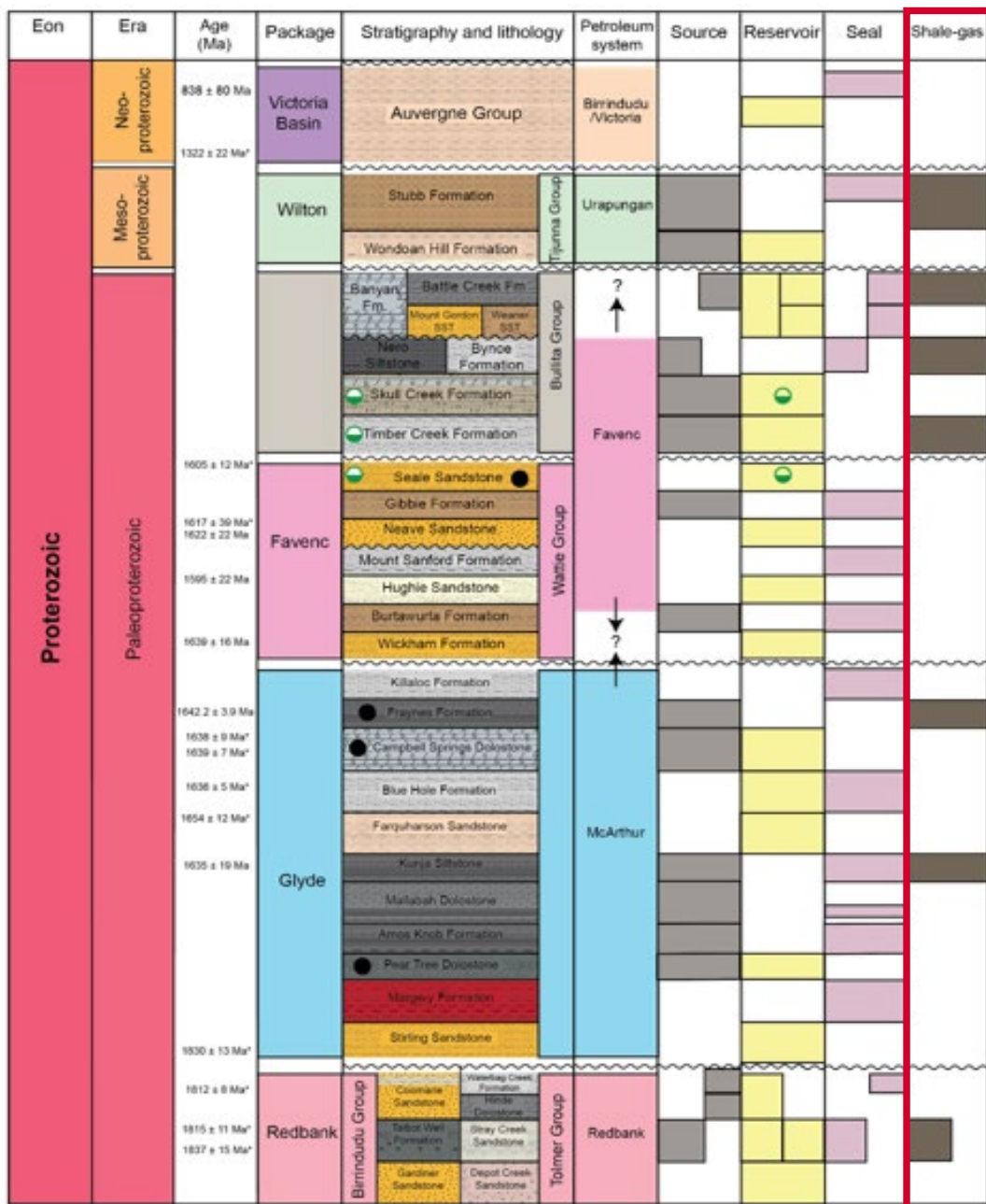
Blue Hole Formation



Kunja Siltstone







# Unconventional shale-oil and -gas

- Nine potential unconventional plays
- Five factors to assess unconventional systems:
  - 1- Geology
  - 2- Organic geochemistry
  - 3- Mineralogy and brittleness
  - 4- *Stress fields and pressure*
  - 5- *Gas composition*

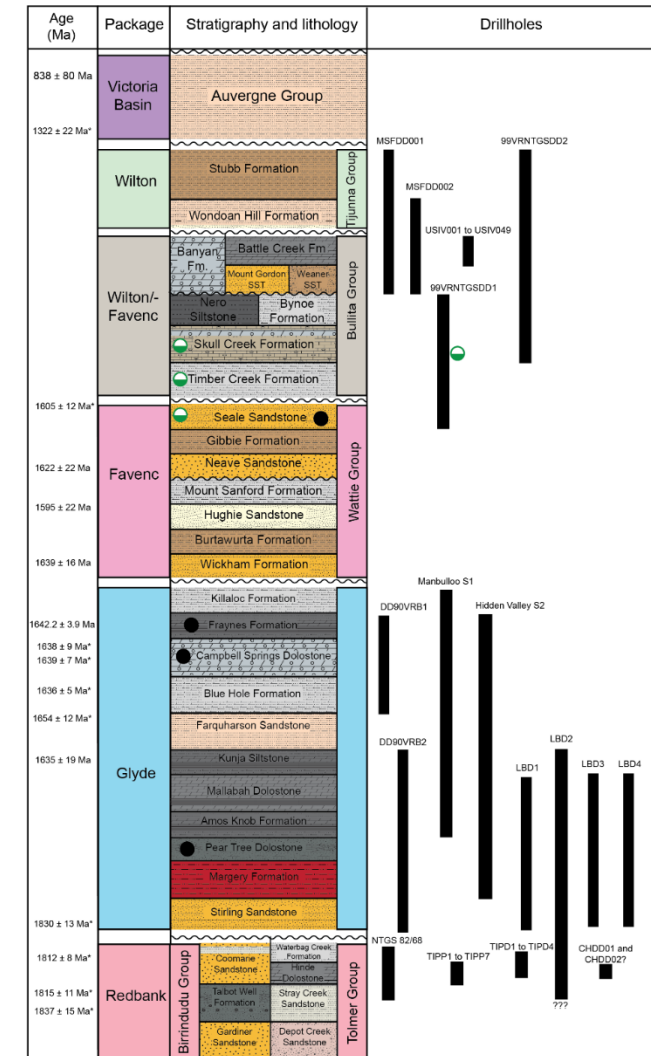
# Potential unconventional plays in the Birrindudu

## Traffic light Assessment

Green = Favourable  
Yellow = Potentially  
Red = Unfavourable  
Grey = No data

Geology		
Basin-scale petroleum system Magoon & Dow (1994)	Shale thickness (m)*	Depth below surface (m)
Stubb-Stubb(?)	210	0 to 170
Nero-Nero(?)	80	No data
Timber-Timber(?)	>300	245 to 552
Fraynes-Fraynes(?)	<100	29 to 992
Kunja-Kunja(?)	60	0 to 1538
Mallabah-Mallabah(?)	20	0 to 1554
Amos Knob-Amos Knob(?)	50	47 to 1609
Hinde-Hinde(?)	55	0 to 465
Undifferentiated Birrindudu	No data	No data

Well and field geology used



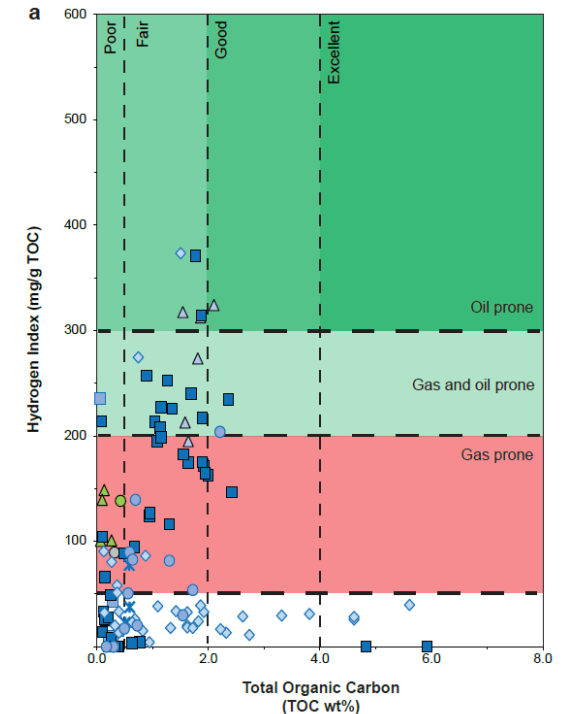


# Potential unconventional plays in the Birrindudu

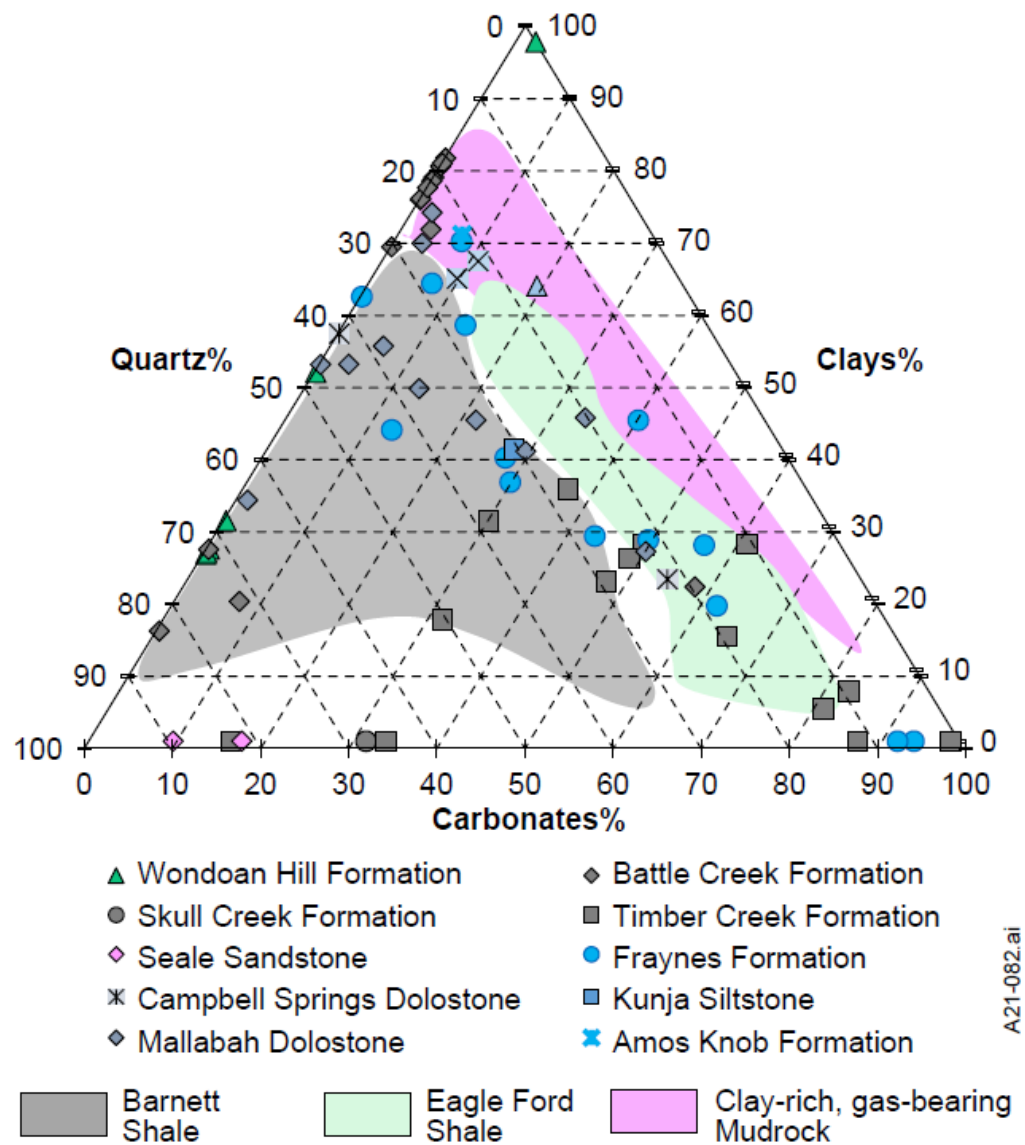
	Geology		Geochemistry	
Basin-scale petroleum system Magoon & Dow (1994)	Shale thickness (m)*	Depth below surface (m)	Total Organic Carbon (TOC wt %)	Thermal maturity
Stubb-Stubb(?)	210	0 to 170	0.4% (n = 1)	Mature 443°C (n = 1)
Nero-Nero(?)	80	No data	No data	No data
Timber-Timber(?)	>300	245 to 552	Max. 0.87% (average 0.2%, stdev 0.2%, n = 16)	Immature to Overmature (Average 466°C, stdev 50°C, n = 11)
Fraynes-Fraynes(?)	<100	29 to 992	Max. 8.1% (average 1.5%, stdev 1.7%, n = 43)	Immature to Overmature (Average 457°C, stdev 27°C, n = 35)
Kunja-Kunja(?)	60	0 to 1538	Max. 2.1 wt% (average 1.5%, stdev 0.2%, n = 7)	Early oil generation (Average 437°C, stdev 1°C, n = 6)
Mallabah-Mallabah(?)	20	0 to 1554	Max. 11.3% (average 2.3%, stdev 2.2%, n = 56)	Immature to Overmature (Average 444°C, stdev 31°C, n = 28)
Amos Knob-Amos Knob(?)	50	47 to 1609	Max. 0.60% (average 0.3%, stdev 0.2%, n = 8)	Peak oil mature (average 448°C, stdev 5°C, n = 3)
Hinde-Hinde(?)	55	0 to 465	No data	No data
Undifferentiated Birrindudu	No data	No data	No data	No data



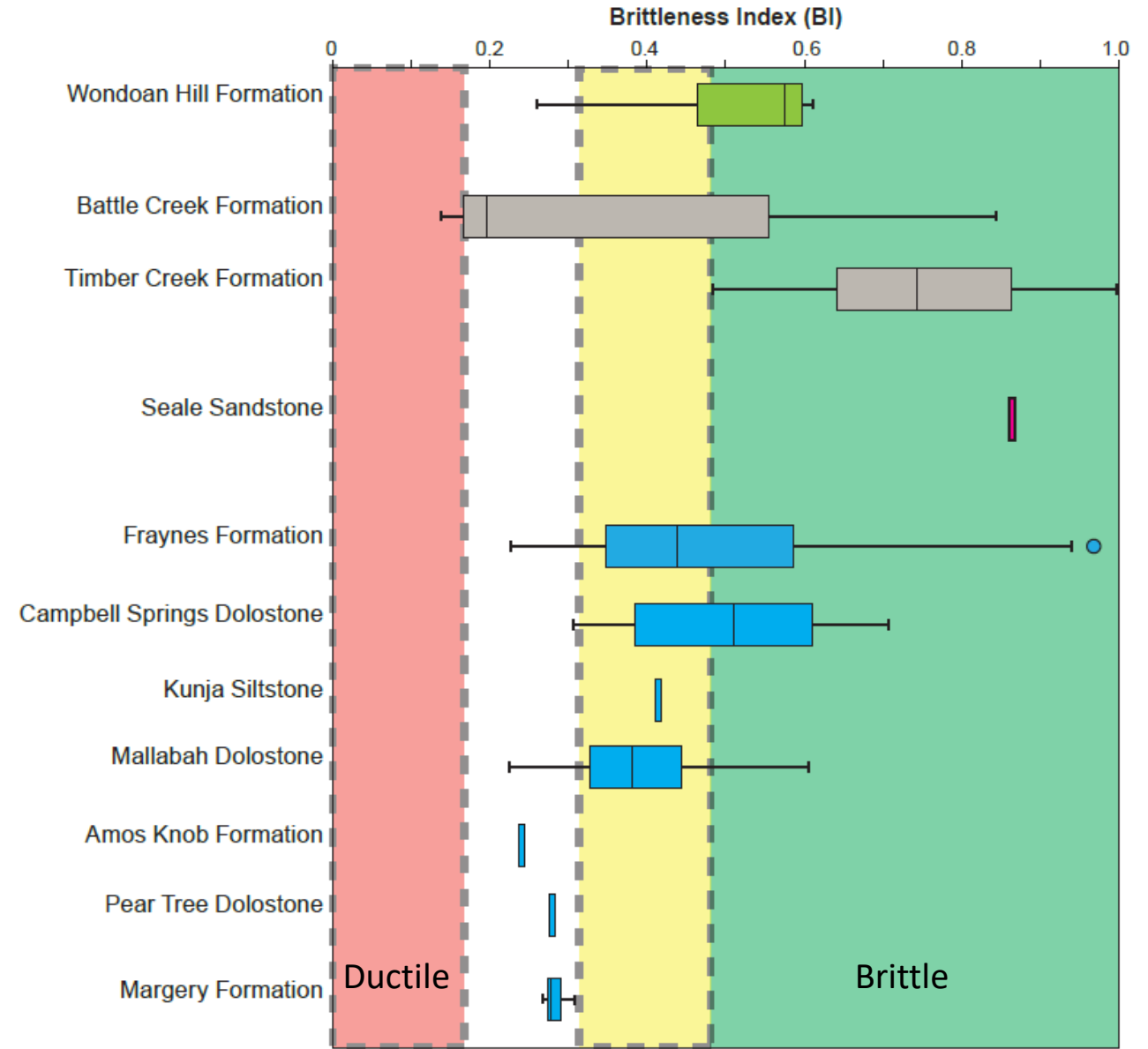
TOC and pyrolysis data used



# Mineralogy and brittleness



A21-082.ai



A21-144.ai



# Potential unconventional plays in the Birrindudu

	Geology		Geochemistry		Mineralogy	
Basin-scale petroleum system Magoon & Dow (1994)	Shale thickness (m)*	Depth below surface (m)	Total Organic Carbon (TOC wt %)	Thermal maturity	Mineralogy	Brittleness
Stubb-Stubb(?)	210	0 to 170	0.4% (n = 1)	Mature 443°C (n = 1)	No data	No data
Nero-Nero(?)	80	No data	No data	No data	No data	No data
Timber-Timber(?)	>300	245 to 552	Max. 0.87% (average 0.2%, stdev 0.2%, n = 16)	Immature to Overmature (Average 466°C, stdev 50°C, n = 11)	Average brittle minerals 75%, average clays 13%	Brittle
Fraynes-Fraynes(?)	<100	29 to 992	Max. 8.1% (average 1.5%, stdev 1.7%, n = 43)	Immature to Overmature (Average 457°C, stdev 27°C, n = 35)	Average brittle minerals 50%, average clays 28%	Less brittle to brittle
Kunja-Kunja(?)	60	0 to 1538	Max. 2.1 wt% (average 1.5%, stdev 0.2%, n = 7)	Early oil generation (Average 437°C, stdev 1°C, n = 6)	Brittle minerals 42%, clays 29%	Less brittle
Mallabah-Mallabah(?)	20	0 to 1554	Max. 11.3% (average 2.3%, stdev 2.2%, n = 56)	Immature to Overmature (Average 444°C, stdev 31°C, n = 28)	Average brittle minerals 40%, average clays 40%	Less brittle to brittle
Amos Knob-Amos Knob(?)	50	47 to 1609	Max. 0.60% (average 0.3%, stdev 0.2%, n = 8)	Peak oil mature (average 448°C, stdev 5°C, n = 3)	Average brittle minerals 22%, average clays 77% (n = 1)	Less ductile (n = 1)
Hinde-Hinde(?)	55	0 to 465	No data	No data	No data	No data
Undifferentiated Birrindudu	No data	No data	No data	No data	No data	No data

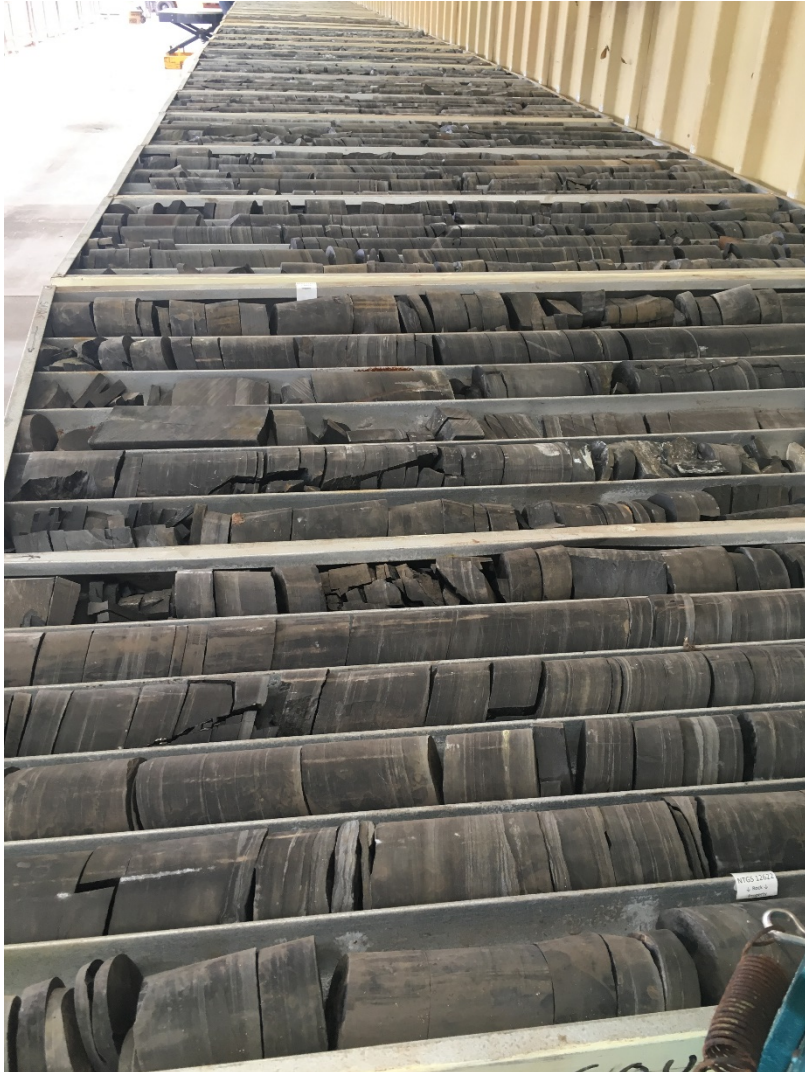
Eon	Era	Age (Ma)	Package	Stratigraphy and lithology	Petroleum system	Source	Reservoir	Seal	Shale-gas
Proterozoic	Neo-proterozoic	838 ± 80 Ma	Victoria Basin	Auvergne Group	Birimindudu /Victoria				
		1322 ± 22 Ma*							
	Meso-proterozoic		Wilton	Stubbs Formation	Urapungan				
				Wondoon Hill Formation					
	Paleoproterozoic			Banyan Fm.	Battle Creek Fm.				
				Mount Gordon SSF	Wessels SSF				
				Nero Siltstone	Bynoe Formation				
				Skull Creek Formation					
				Timber Creek Formation					
		1605 ± 12 Ma*							
		1617 ± 39 Ma*	Favenc	Seale Sandstone					
		1622 ± 22 Ma		Gibbie Formation					
		1596 ± 22 Ma		Neave Sandstone					
				Mount Sanford Formation					
		1639 ± 16 Ma		Hughie Sandstone					
				Burtawurta Formation					
				Wickham Formation					
		1642.2 ± 3.9 Ma		Killatoc Formation					
		1638 ± 9 Ma*		Phaynes Formation					
		1639 ± 7 Ma*		Campbell Springs Dolomite					
		1636 ± 5 Ma*		Blue Hole Formation					
		1654 ± 12 Ma*		Farguherson Sandstone					
		1635 ± 19 Ma	Glyde	Kurja Siltstone					
				Mallabah Dolomite					
				Amos Knob Formation					
				Pear Tree Dolomite					
				Margery Formation					
		1530 ± 13 Ma*		Stirling Sandstone					
		1812 ± 8 Ma*							
		1815 ± 11 Ma*	Redbank	Birimindudu Group					
		1837 ± 15 Ma*		Coonamble Sandstone					
				Tabor Well Formation					
				Gardiner Sandstone					
				Depot Creek Sandstone					
				Tolmer Group					

## Summary

- Numerous hypothetical conventional and unconventional petroleum system elements defined
- Source rock data demonstrates organic rich intervals with potential to generate oil and gas
- Limited porosity and permeability data suggesting some good reservoir rocks
- No data for seal rocks
- Several units are favourable unconventional targets
- Limitations with low amounts of data



# Future work

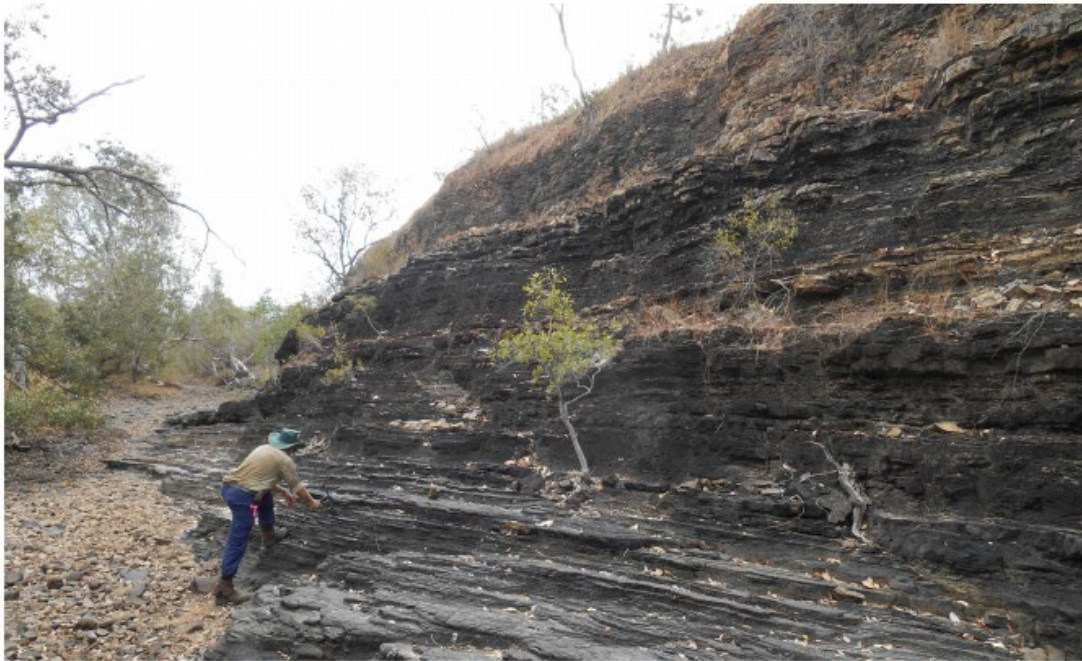


- Data acquisition on legacy core
  - TOC and programmed pyrolysis
  - Porosity and permeability
  - Organic reflectance
  - XRD
  - Organic geochemistry of Birrindudu Basin source rocks
  - Isotopes of kerogen and fluids across the greater McArthur Basin
  - Gas in fluid inclusion analysis
  - Geochronology on wells with unknown formations
  - Correlating to the greater McArthur Basin
- Enhanced understanding of the Birrindudu Basin and greater McArthur Basin

# New updates to Digital Information Package DIP-014

## Shale resource data from the greater McArthur Basin

D Revie, VJ Normington and AJM Jarrett



**Digital Information Package DIP 014**

April 2021



- April update- Version 12
- Over 100,000 samples
- Data has been streamlined into one spreadsheet
- New Rock-Eval, Rock Mechanics, XRD and Inorganic Geochemistry
- Newly updated data dictionary
- Download via GEMIS

Revie, Normington & Jarrett (2021)

<https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/82595>



# Thanks

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