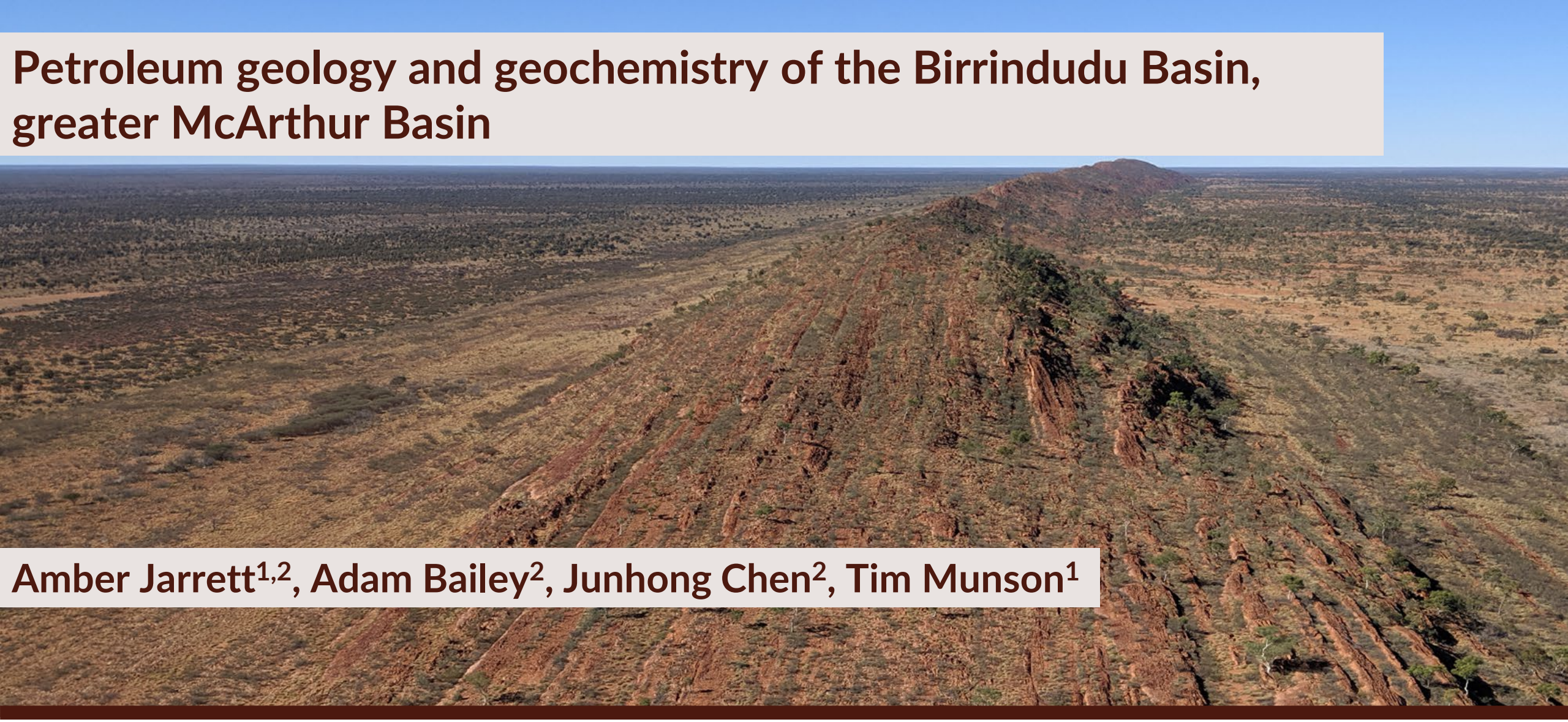
Petroleum geology and geochemistry of the Birrindudu Basin, greater McArthur Basin



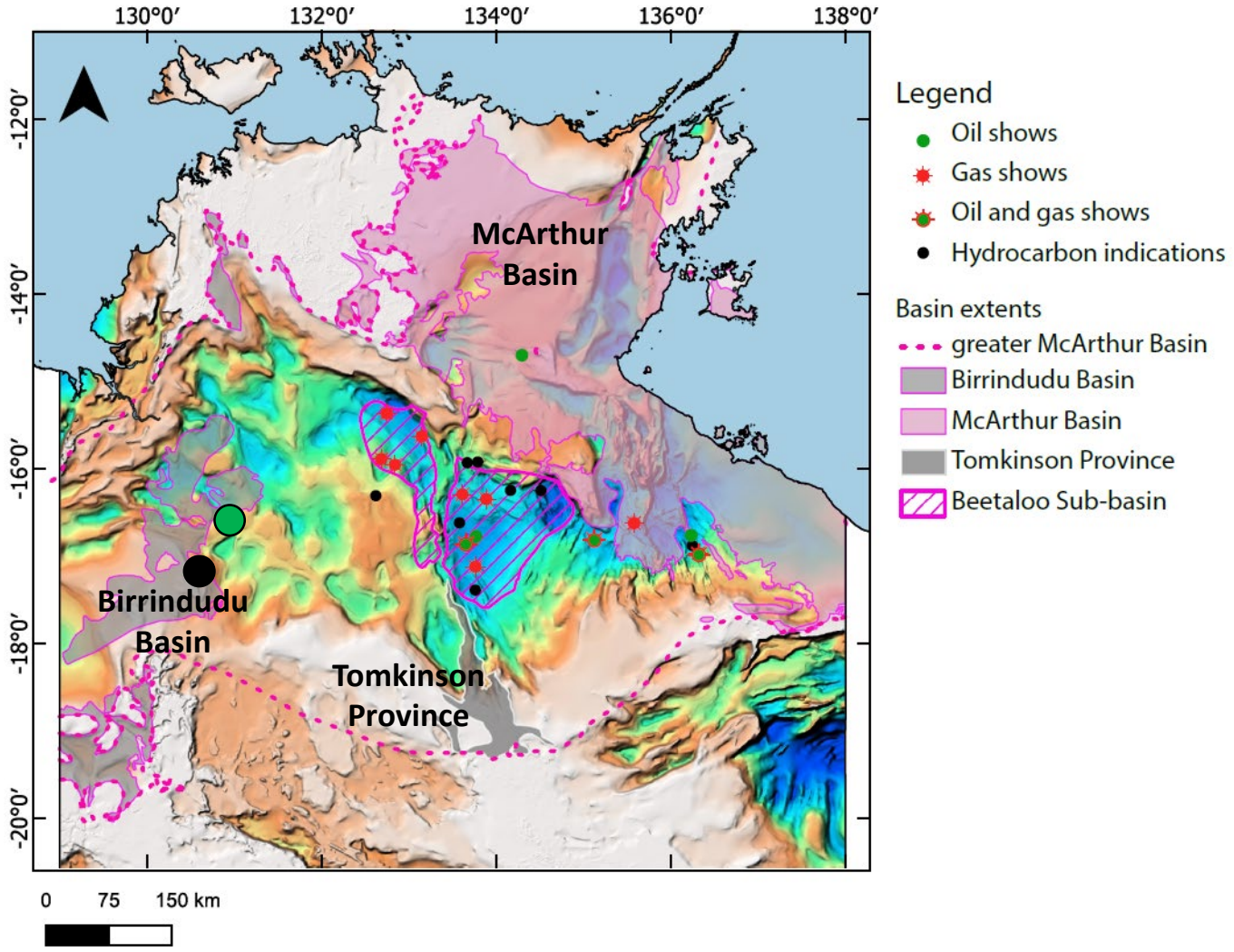
Amber Jarrett[1,2], Adam Bailey[2], Junhong Chen[2], Tim Munson[1]

NORTHERN TERRITORY GOVERNMENT

Australian Government
Geoscience Australia

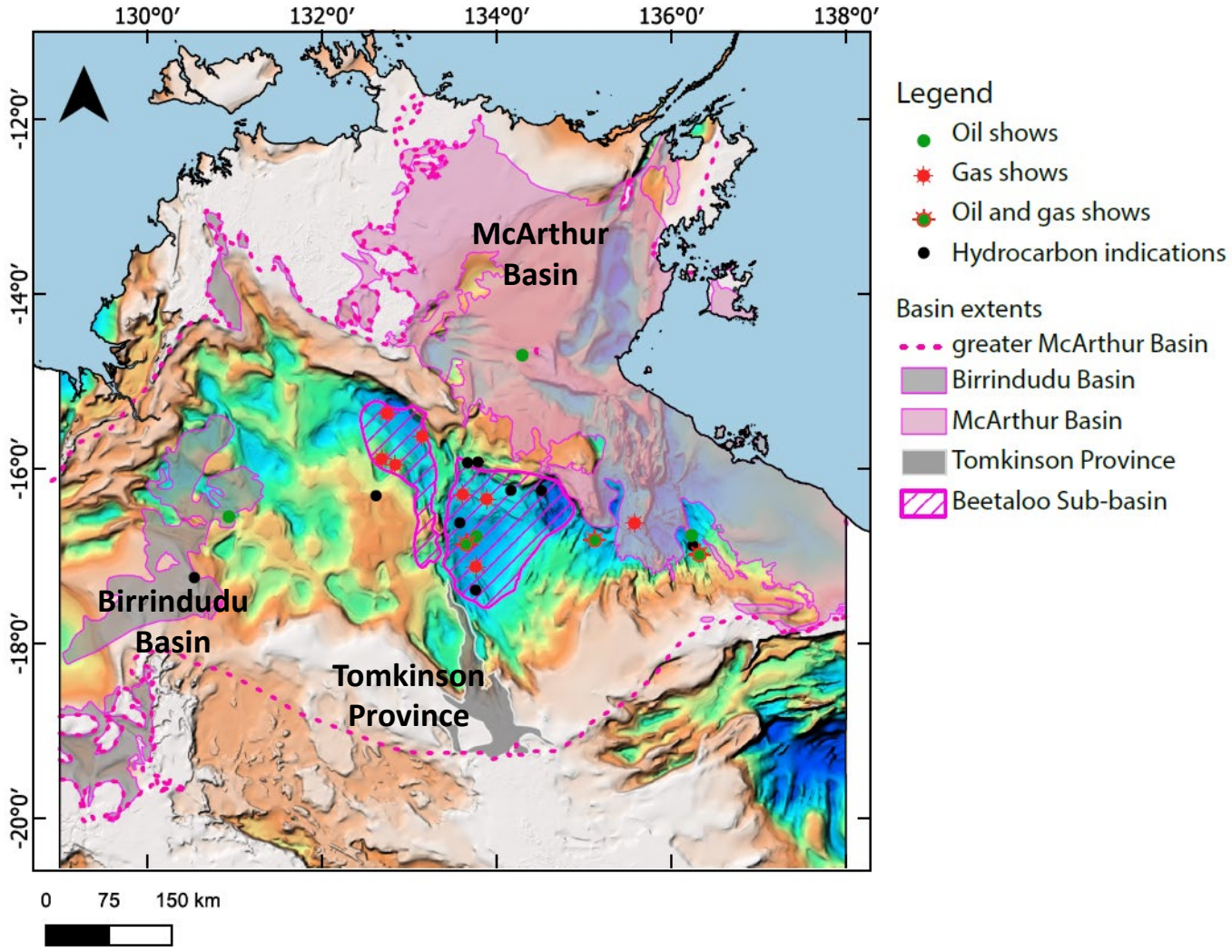
NORTHERN TERRITORY GEOLOGICAL SURVEY
AGES2021
ANNUAL GEOSCIENCE EXPLORATION SEMINAR
20–21 April 2021, Alice Springs, Northern Territory

Resourcing the Territory Initiative



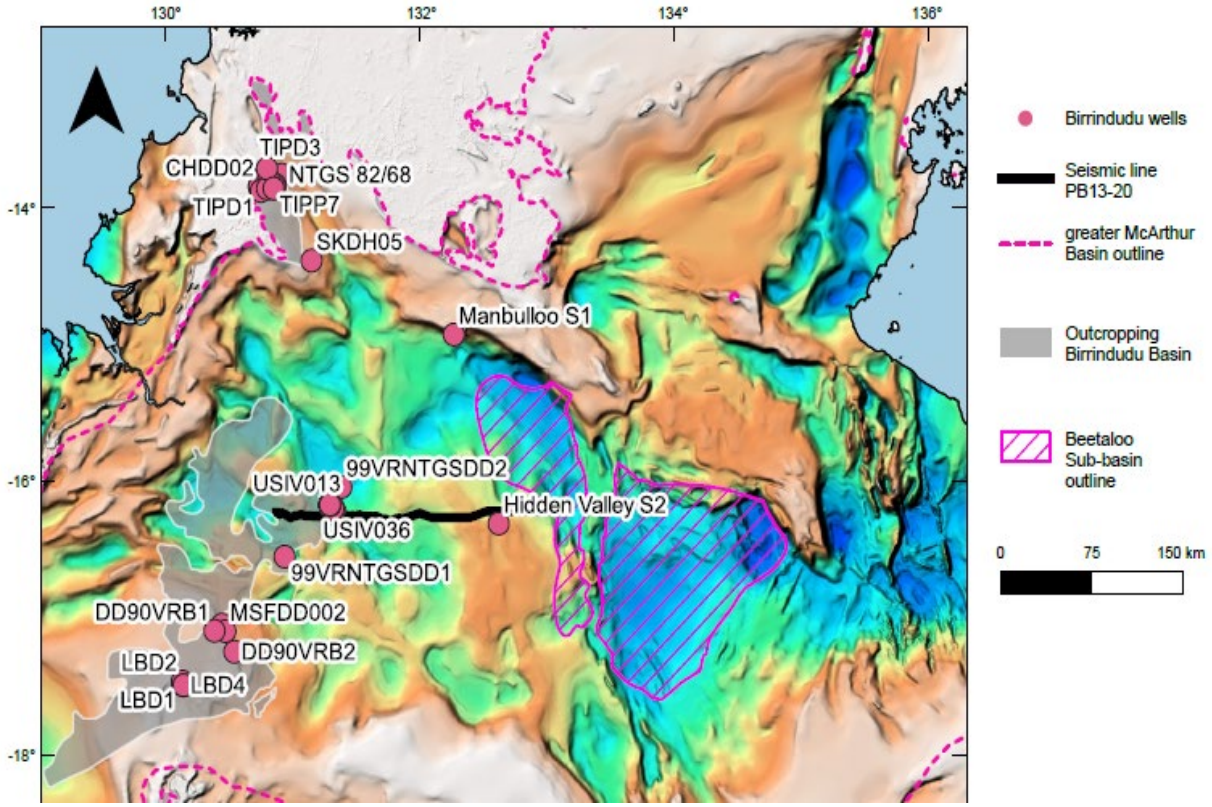
- Supporting exploration in the NT and unlocking new areas for exploration
- This study focuses on the Birrindudu Basin in the greater McArthur Basin
- Comparison to the resource rich McArthur Basin/ Beetaloo Sub-basin
- Collaborative study between Northern Territory Geological Survey and Geoscience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

Aims of this study

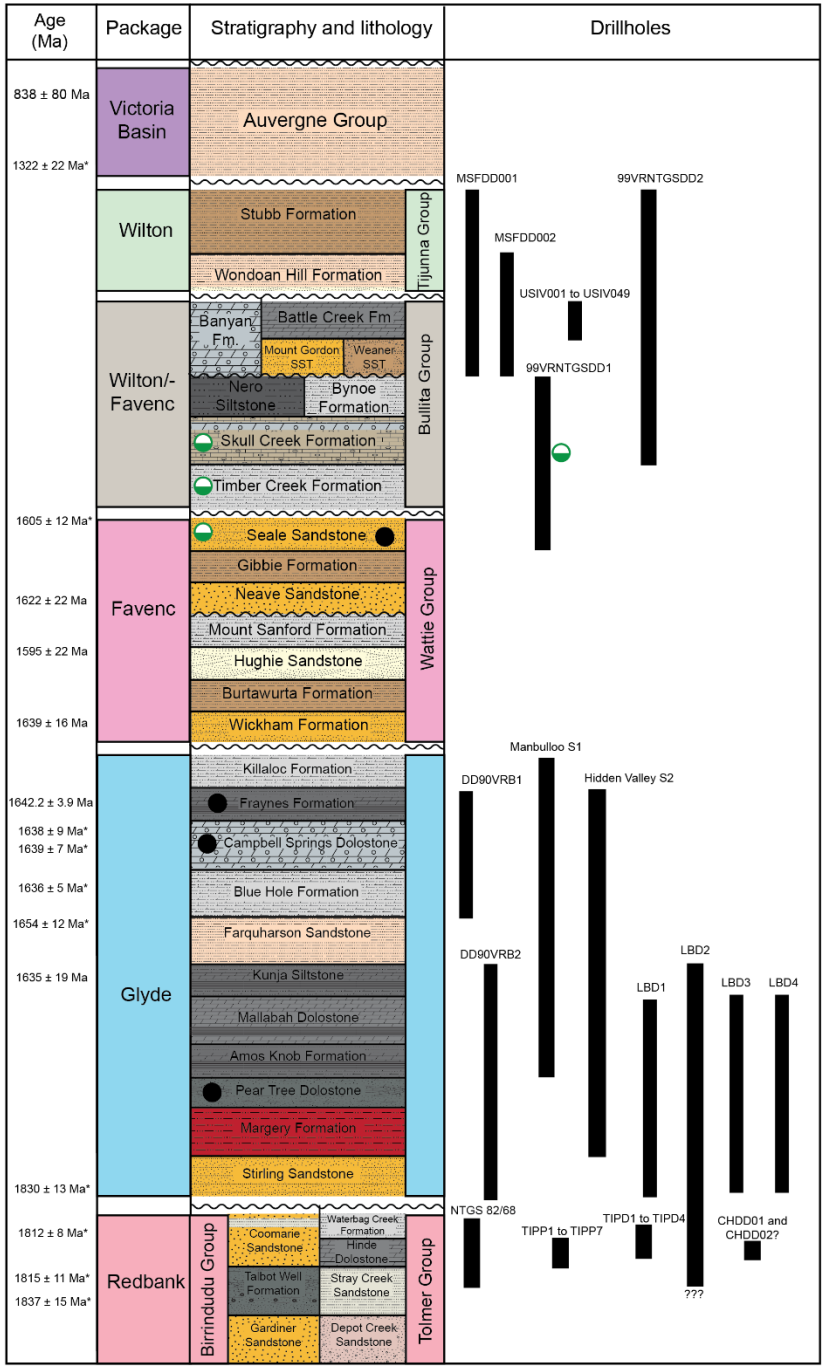


1. Define petroleum systems within the Birrindudu Basin, and reassess regional Petroleum Supersystems
2. Collate new and existing data (DIP-014 update)
3. Assess conventional and unconventional petroleum potential
4. Conduct gap analysis and define areas for future work

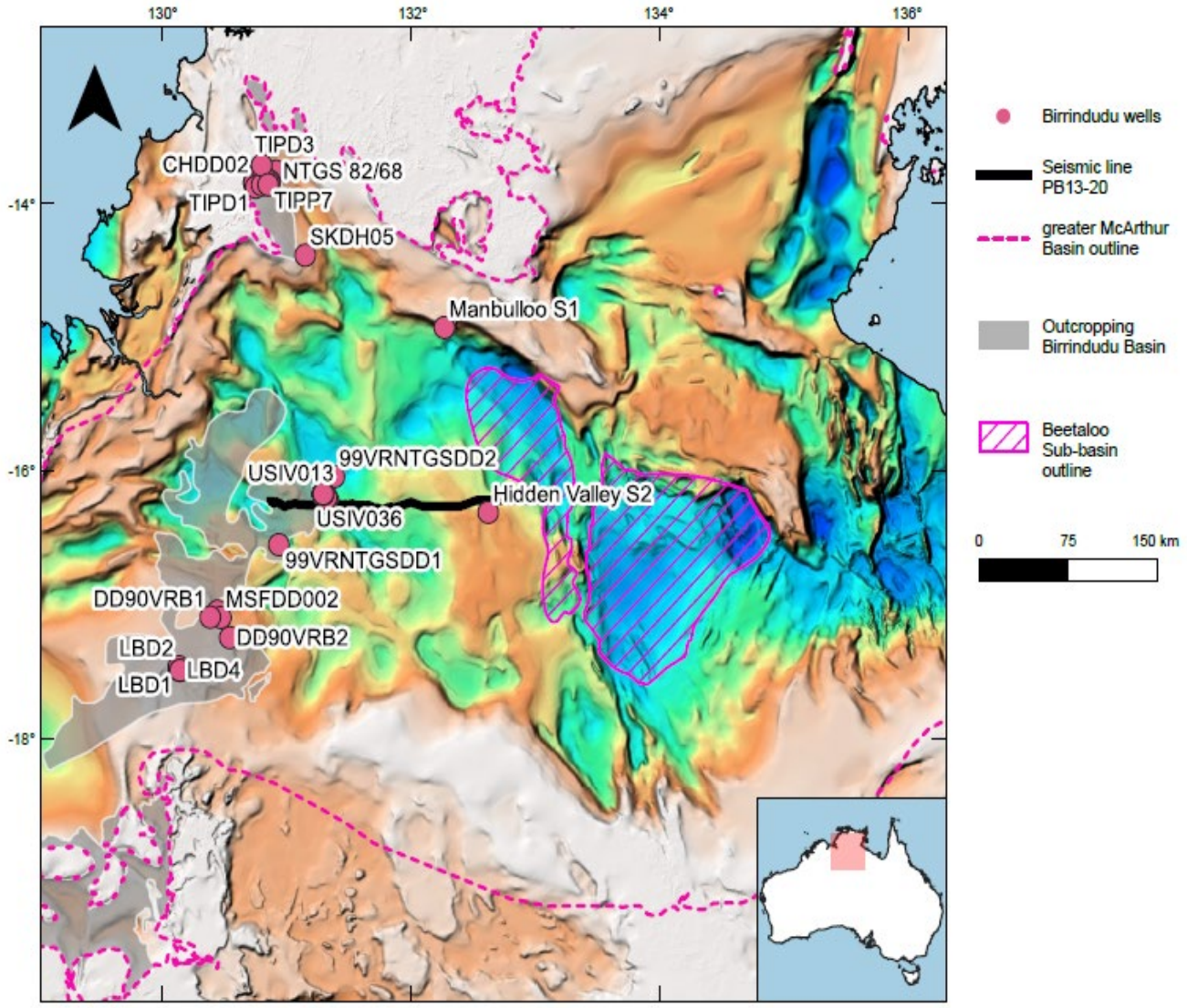
Birrindudu Basin



- Outcrops over 35,000km^2
- 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

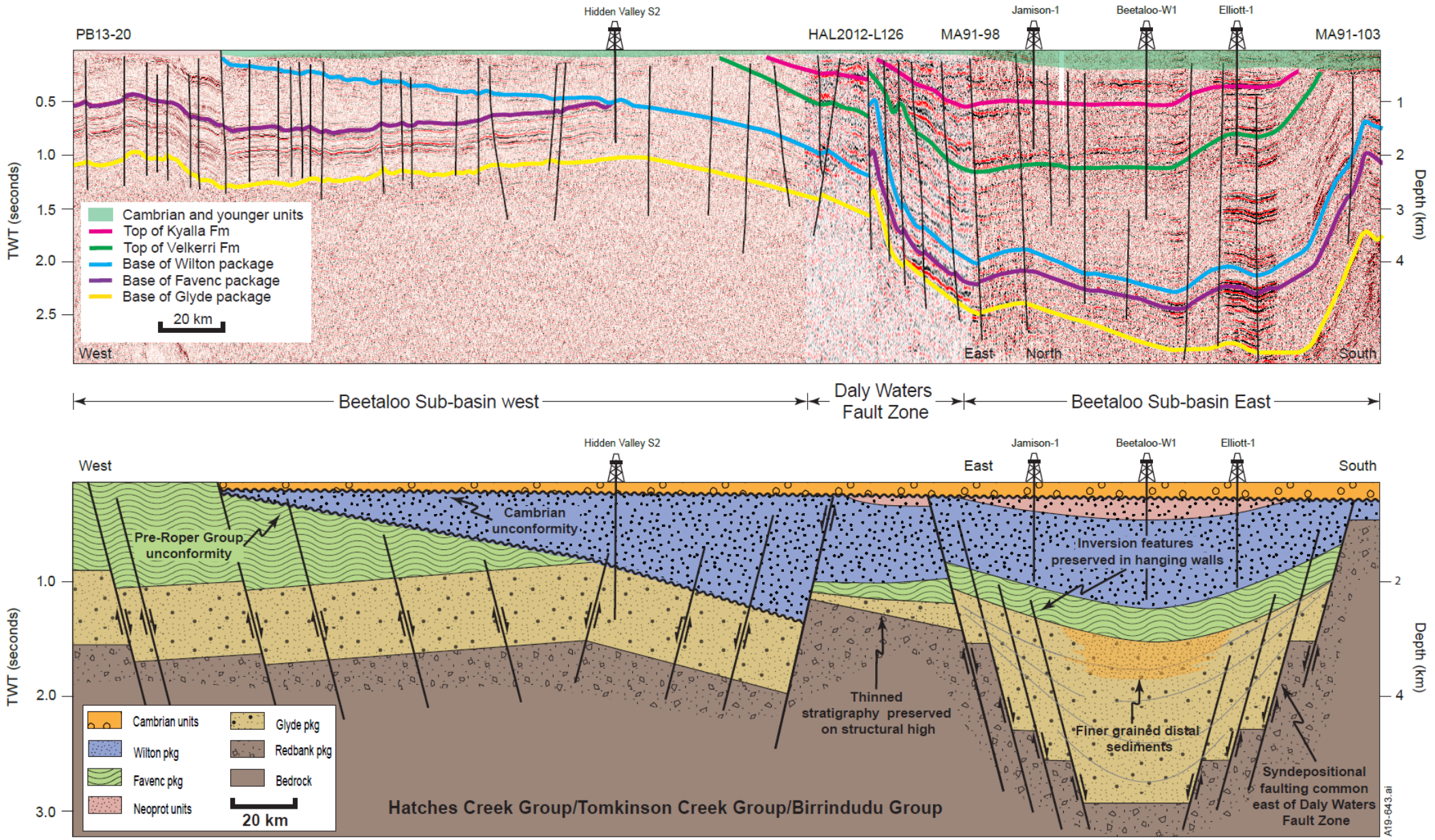


Linking the Birrindudu to the Beetaloo



- 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

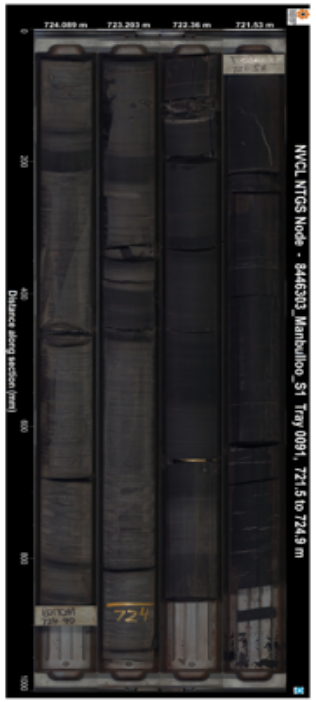


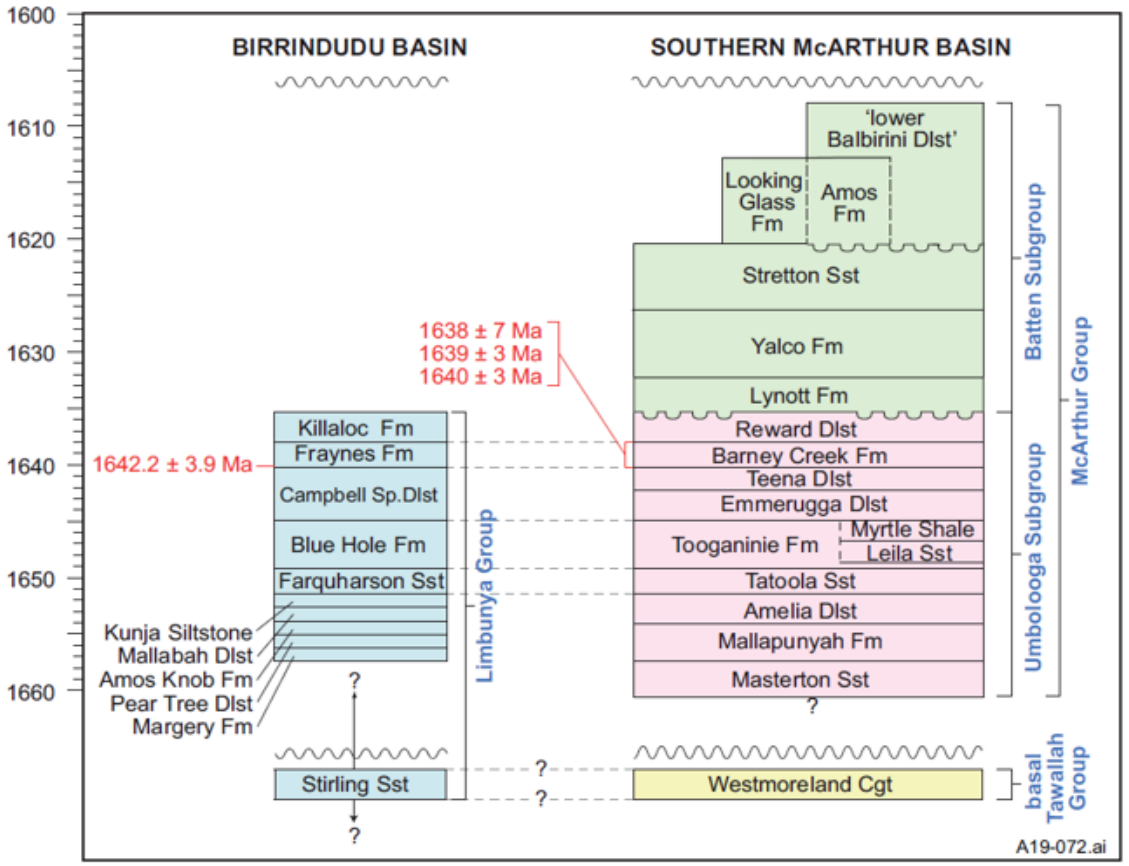
Williams (2019)

https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/89822

Chronostratigraphic links

Fraynes Formation

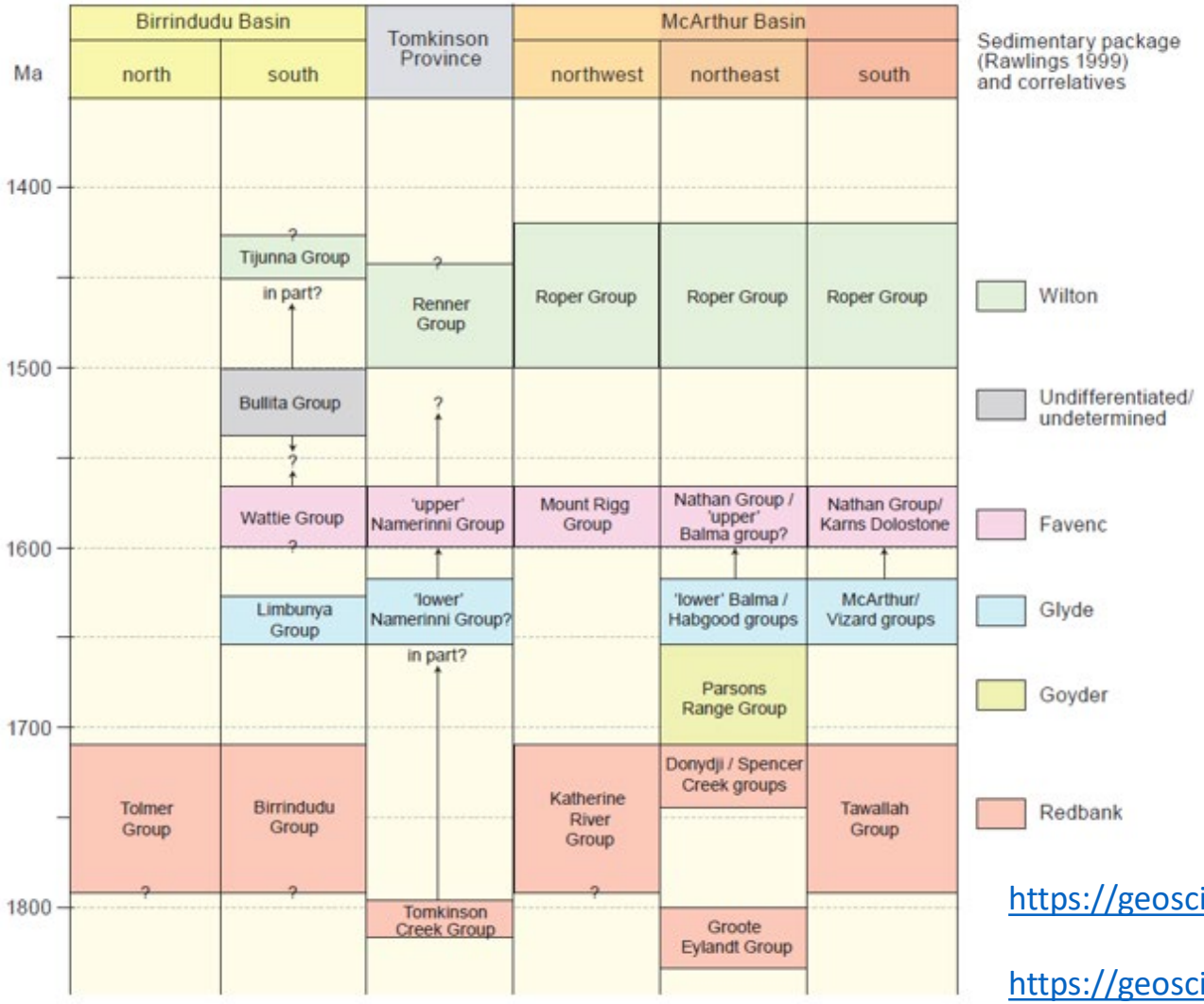




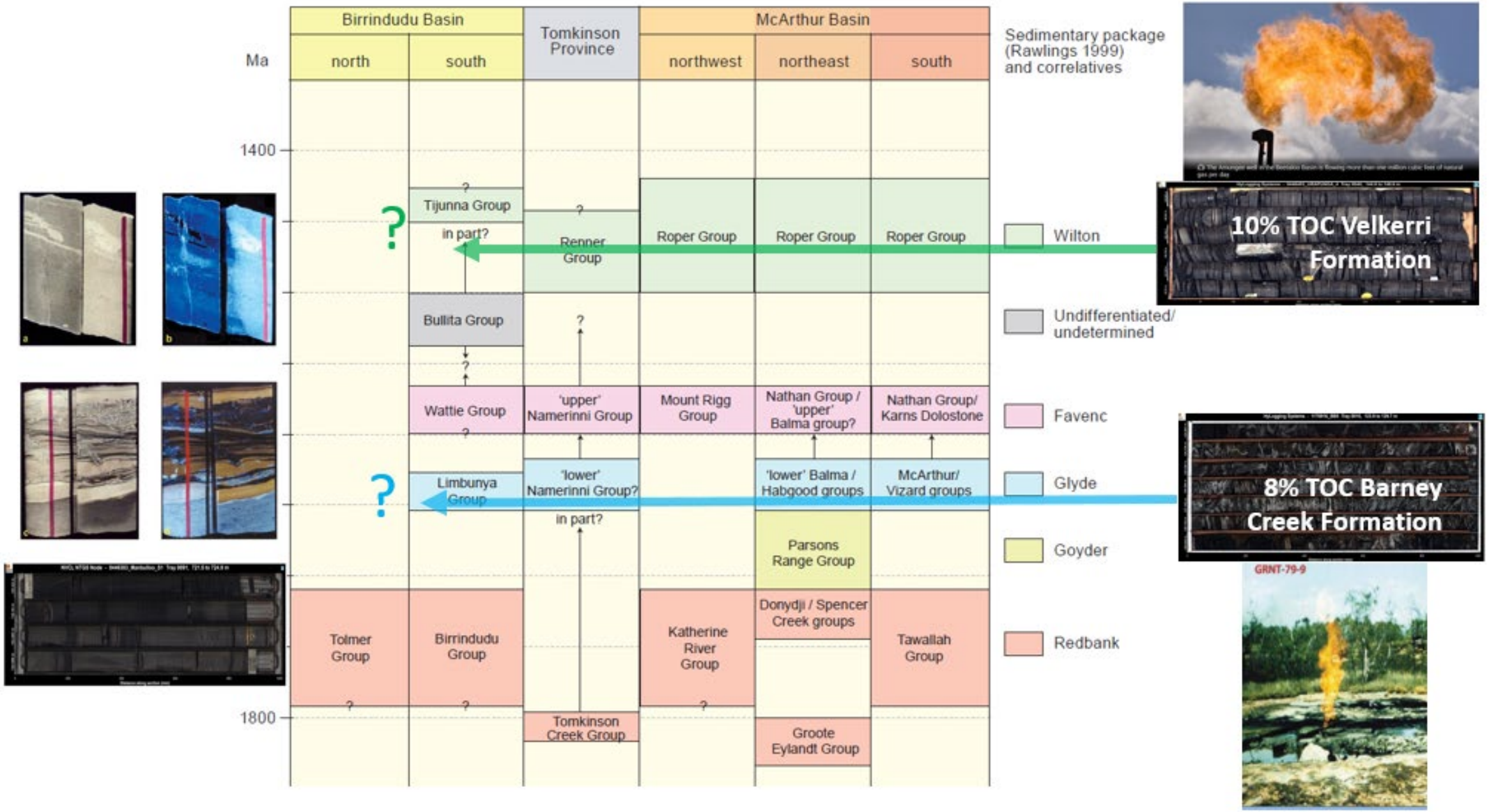
Barney Creek Formation

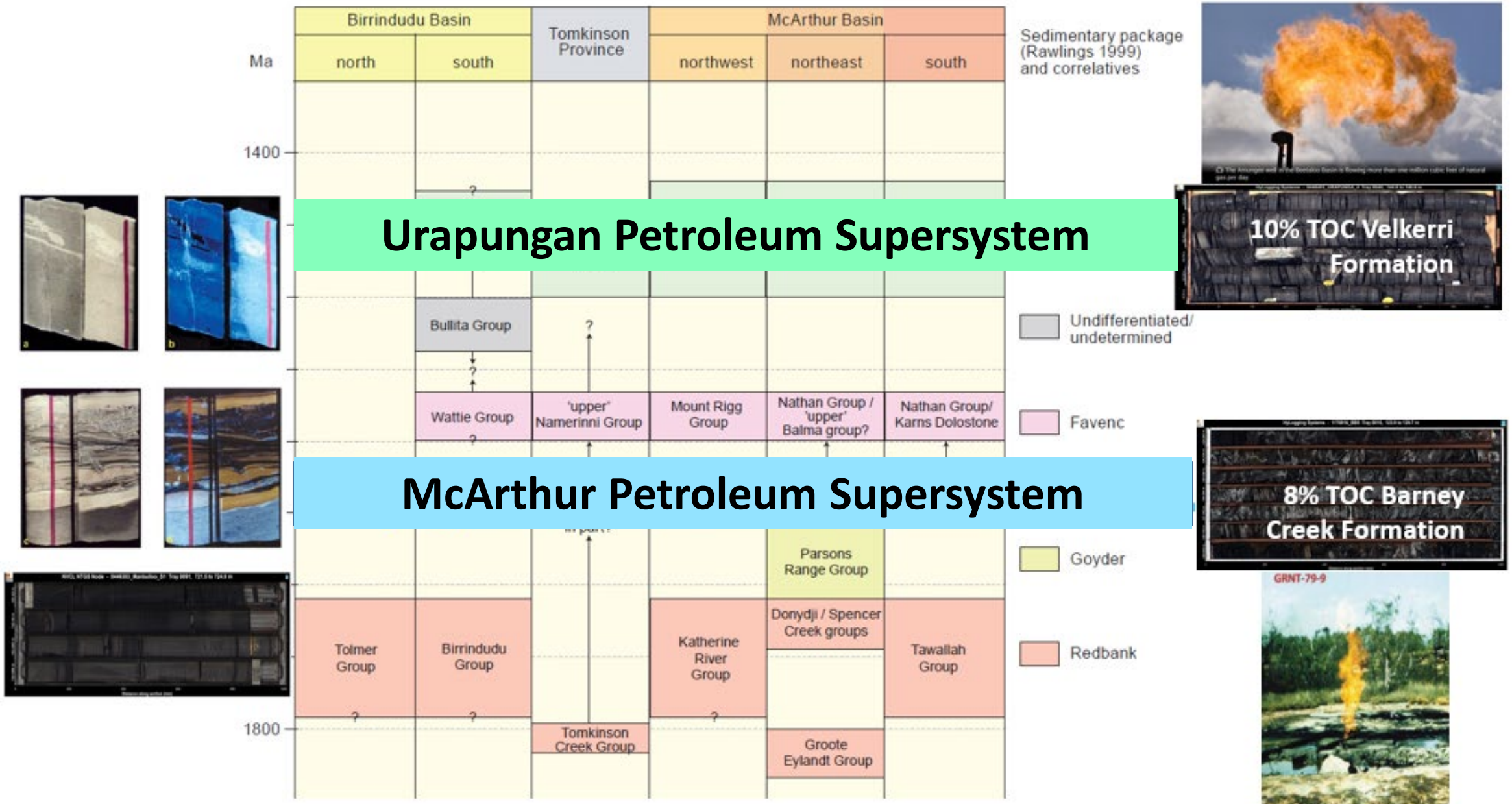
Munson *et al.* (2019)
https://www.tandfonline.com/doi/abs/10.1080/08120099.2020.1669708

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


Birrindudu Basin
north
south
Tomkinson Province
McArthur Basin
northwest
northeast
south
Ma
1400
1800
Tijunna Group
in part?
Renner Group
Roper Group
Roper Group
Roper Group
Bullita Group
Wattie Group
'upper' Namerinni Group
Mount Rigg Group
Nathan Group / 'upper' Balma group?
Nathan Group/ Karns Dolostone
Limbunya Group
'lower' Namerinni Group?
'lower' Balma / Habgood groups
McArthur/ Vizard groups
in part?
Parsons Range Group
Tolmer Group
Birrindudu Group
Katherine River Group
Donydji / Spencer Creek groups
Tawallah Group
Tomkinson Creek Group
Groote Eylandt Group
Sedimentary package (Rawlings 1999) and correlatives
Wilton
Undifferentiated/ undetermined
Favenc
Glyde
Goyder
Redbank
10% TOC Velkerri Formation
8% TOC Barney Creek Formation
GRNT-79-9


Birrindudu Basin
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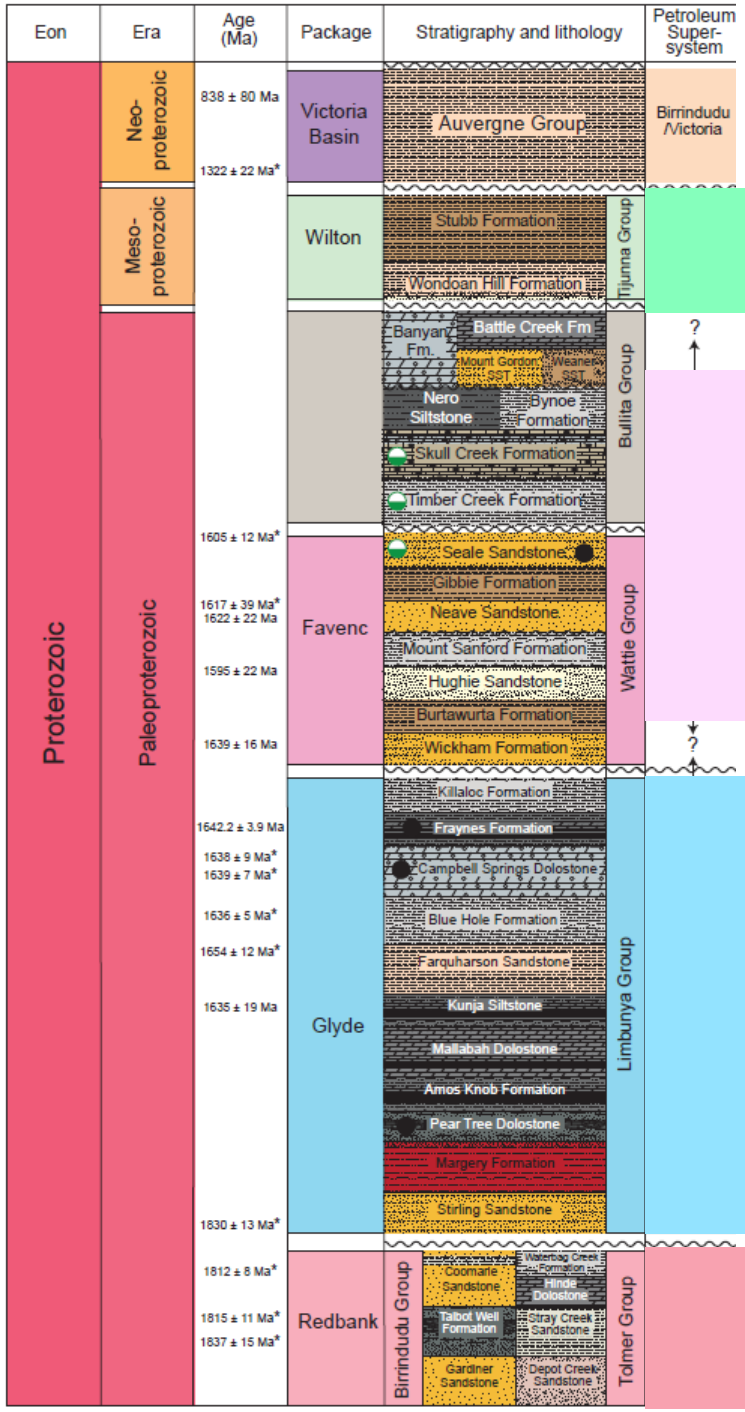
Tolmer Group
Birrindudu Group
Tomkinson Creek Group
Groote Eylandt Group
Urapungan Petroleum Supersystem
McArthur Petroleum Supersystem
10% TOC Velkerri Formation
8% TOC Barney Creek Formation
GRNT-79-9

Petroleum Supersystems in the Birrindudu



Urapungan Petroleum Supersystem

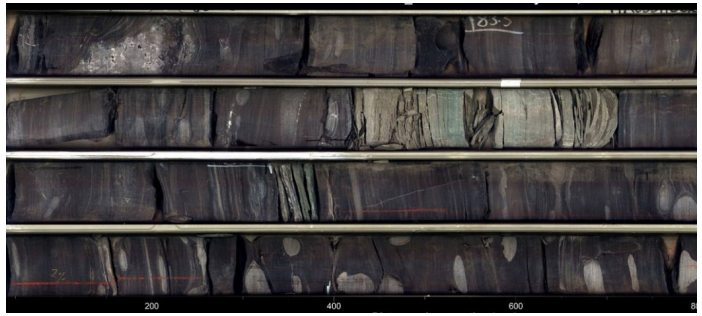
Lawn Petroleum Supersystem

McArthur Petroleum Supersystem

Redbank Petroleum Supersystem

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

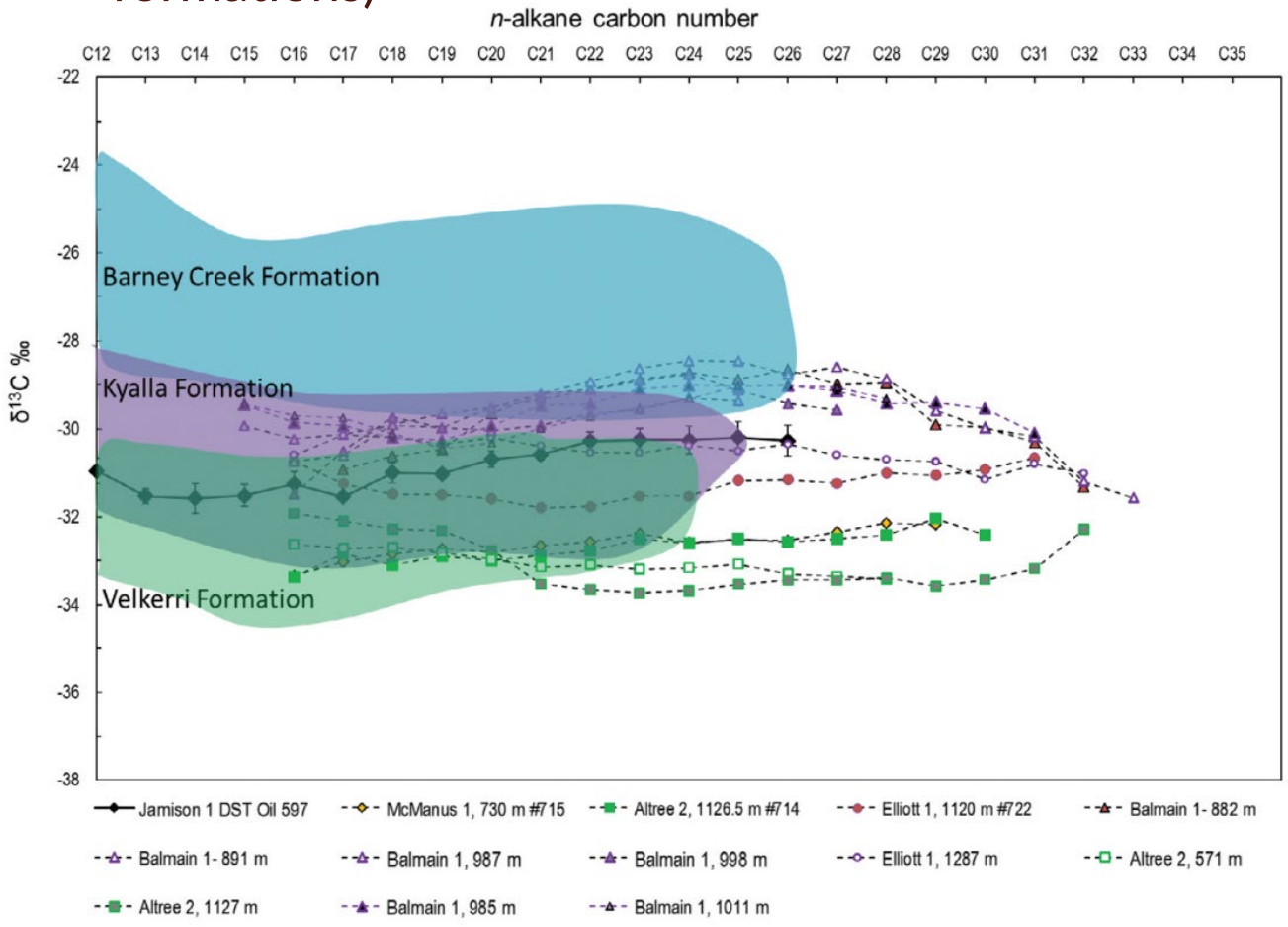
Wollogorang Formation
Redbank Petroleum Supersystem

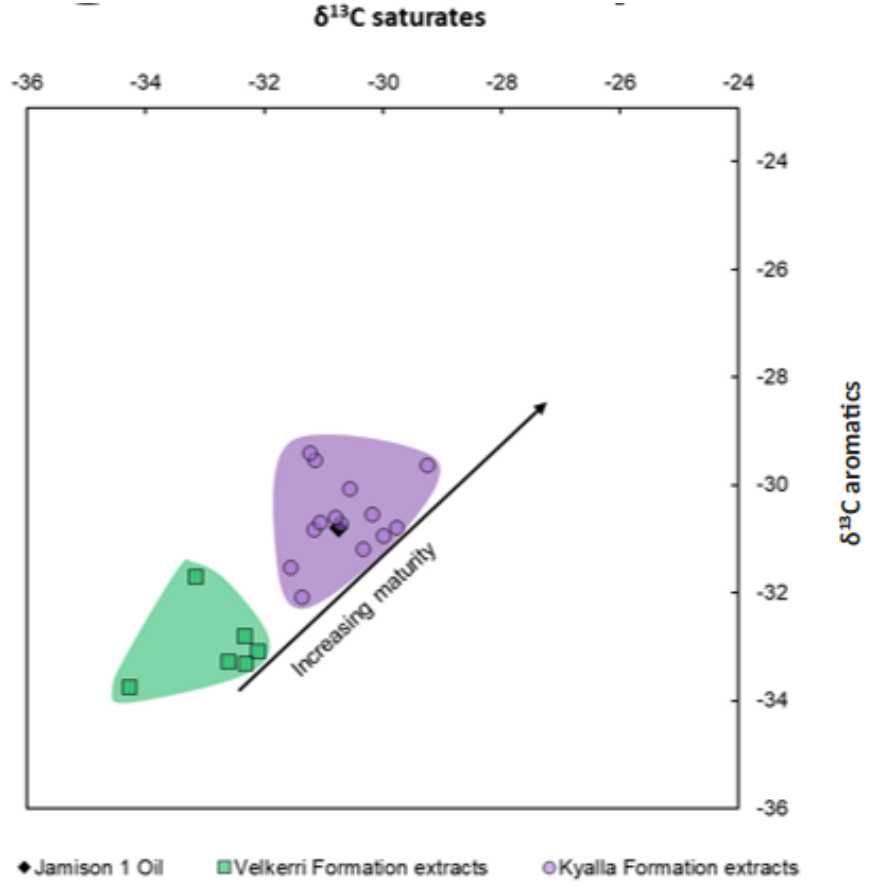


AGES2021

Petroleum Supersystems

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

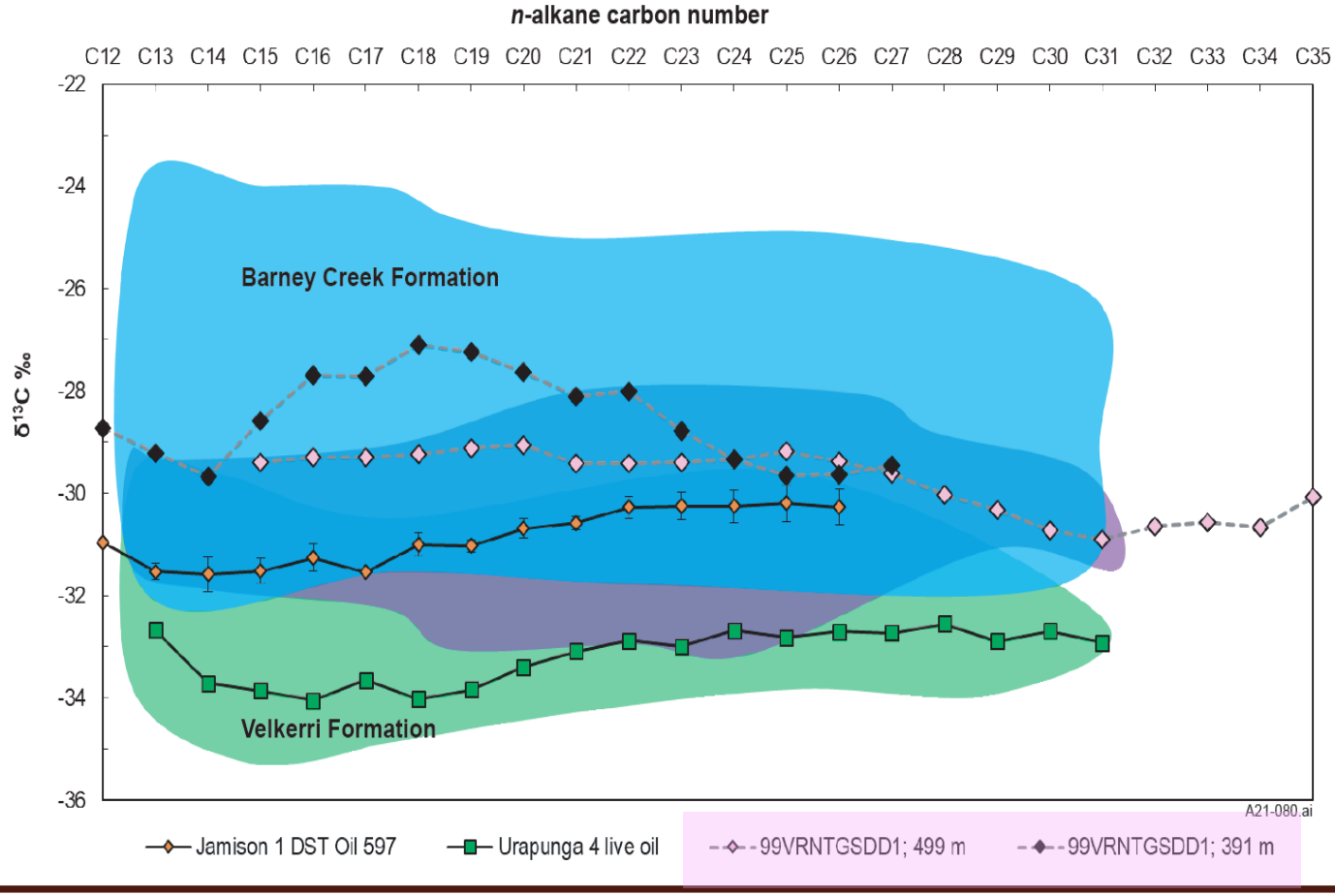


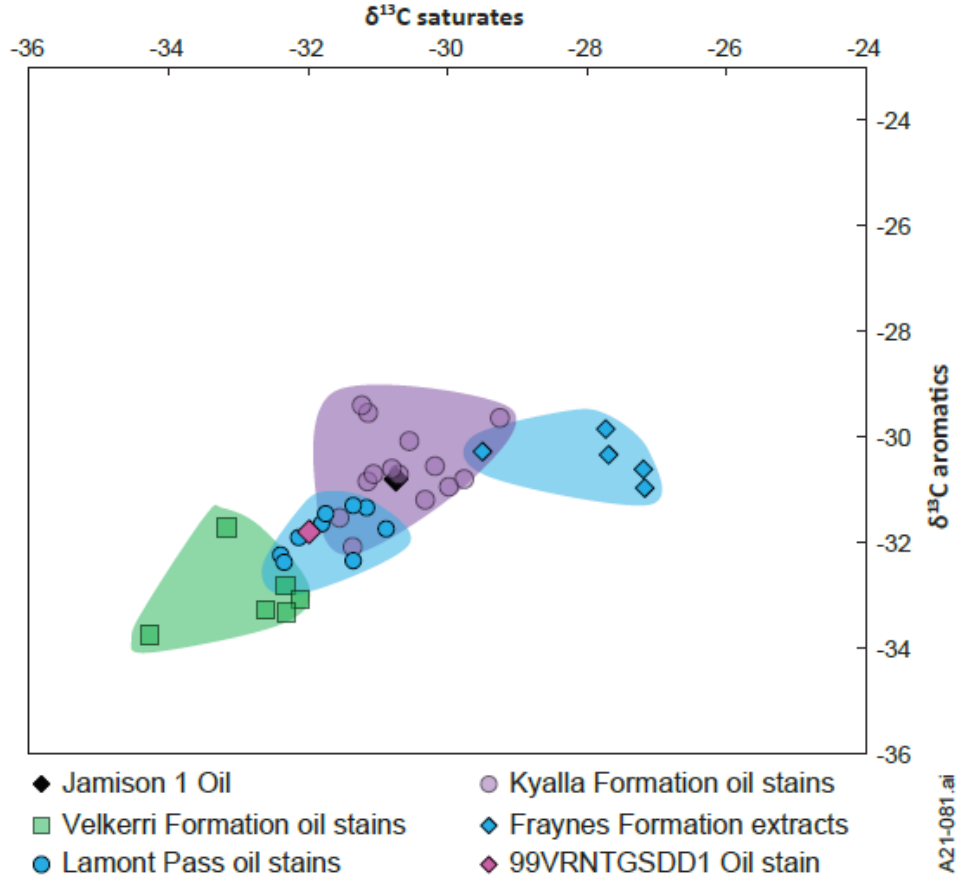


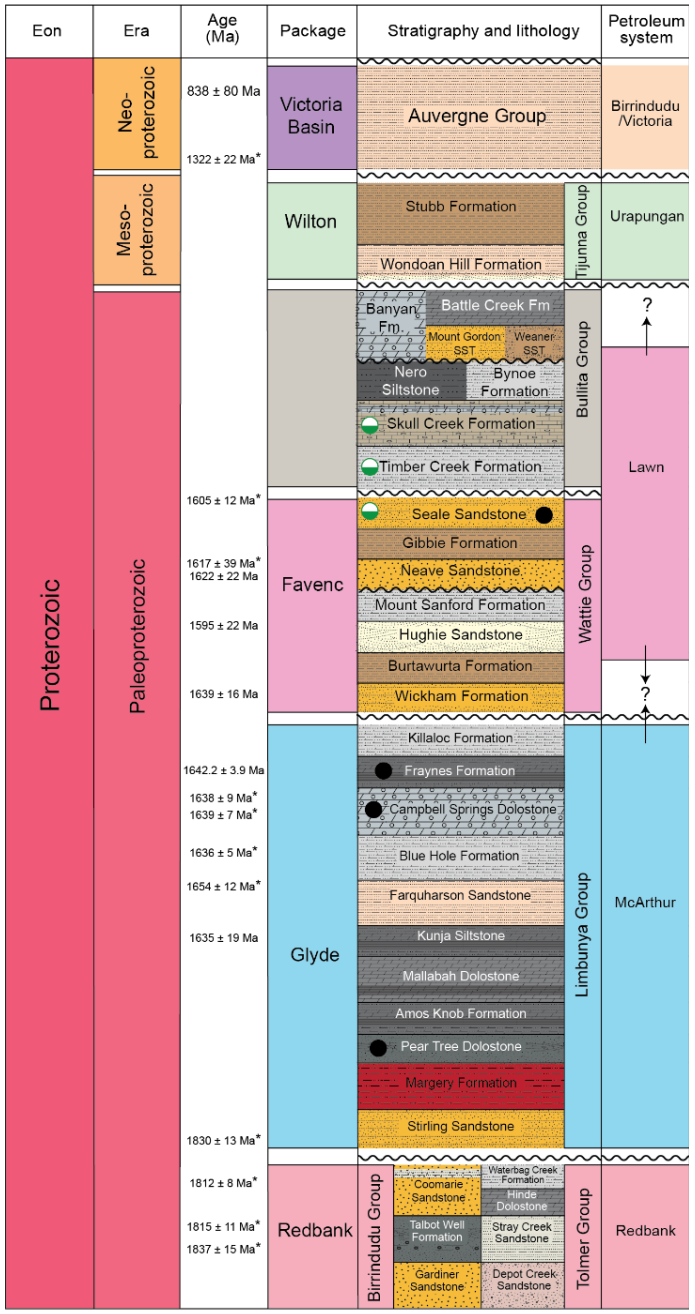
Jarrett *et al.* (2019)
https://geoscience.nt.gov.au/gemis/ntgsjspui/handle/1/88381

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

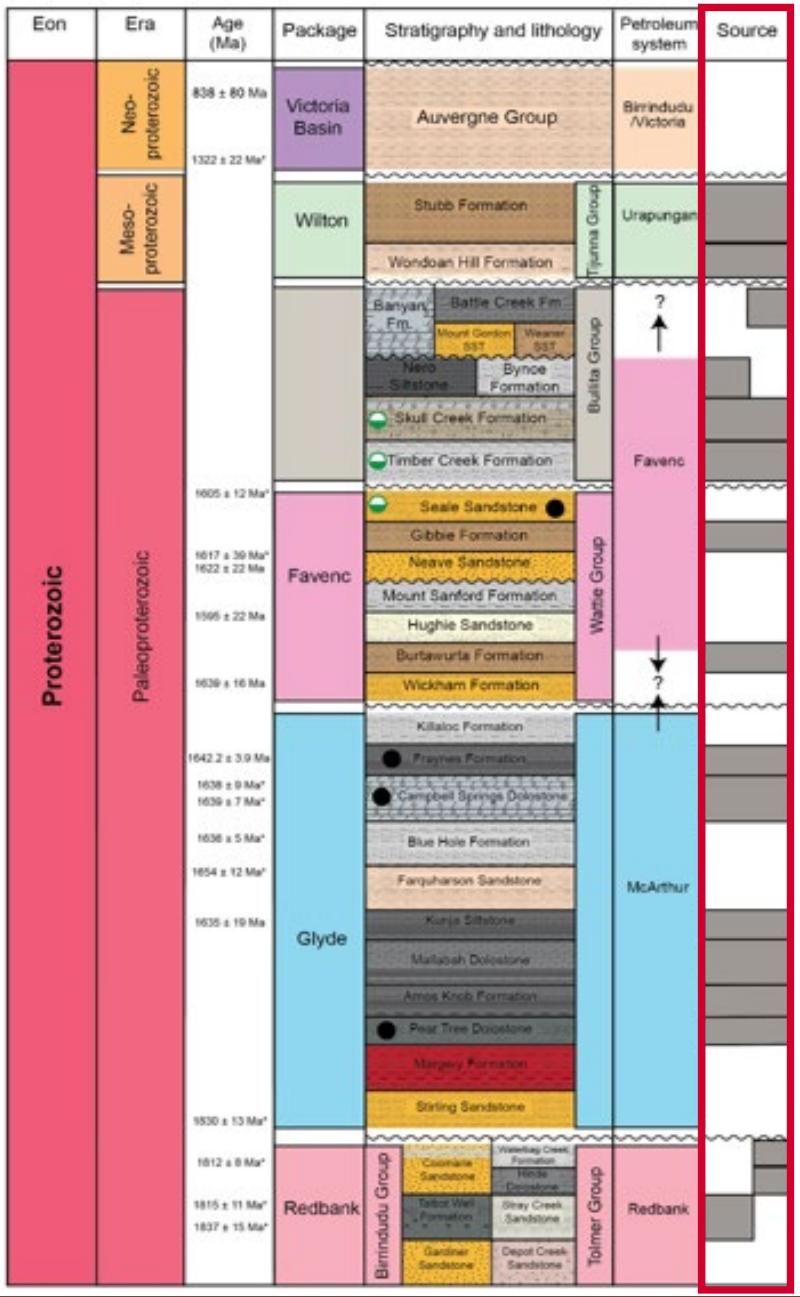






Basin-scale petroleum system elements

- Hypothetical conventional and unconventional petroleum system elements defined based on lithology
  - Source
  - Reservoir
  - Seal
  - Unconventional (shale oil or shale gas)

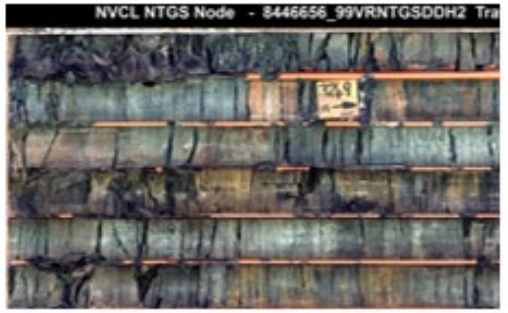


Sources

- 17 potential source rocks
- Limited TOC and pyrolysis data

Skull Creek Formation

Battle Creek Formation



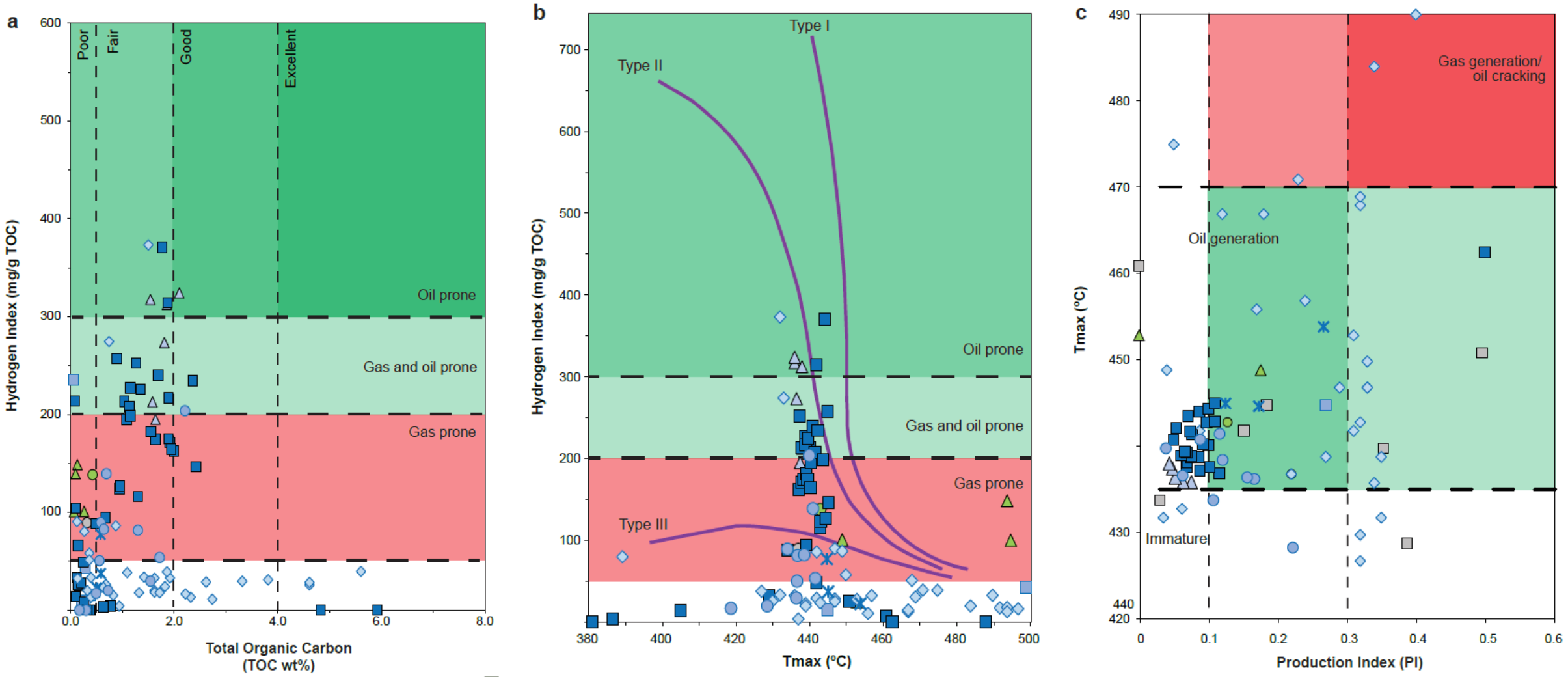
Fraynes Formation

Kunja Siltstone

Stubb Formation

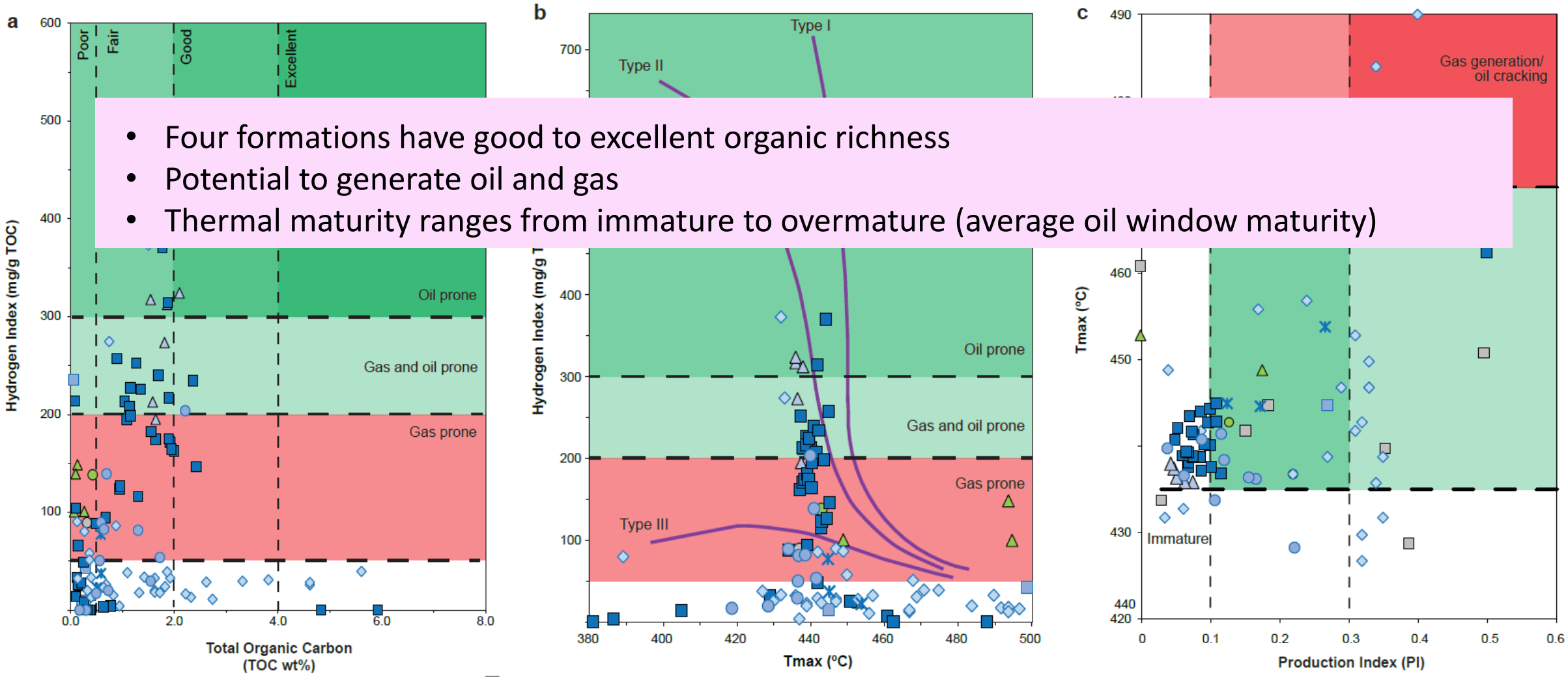
Mallabah Dolostone

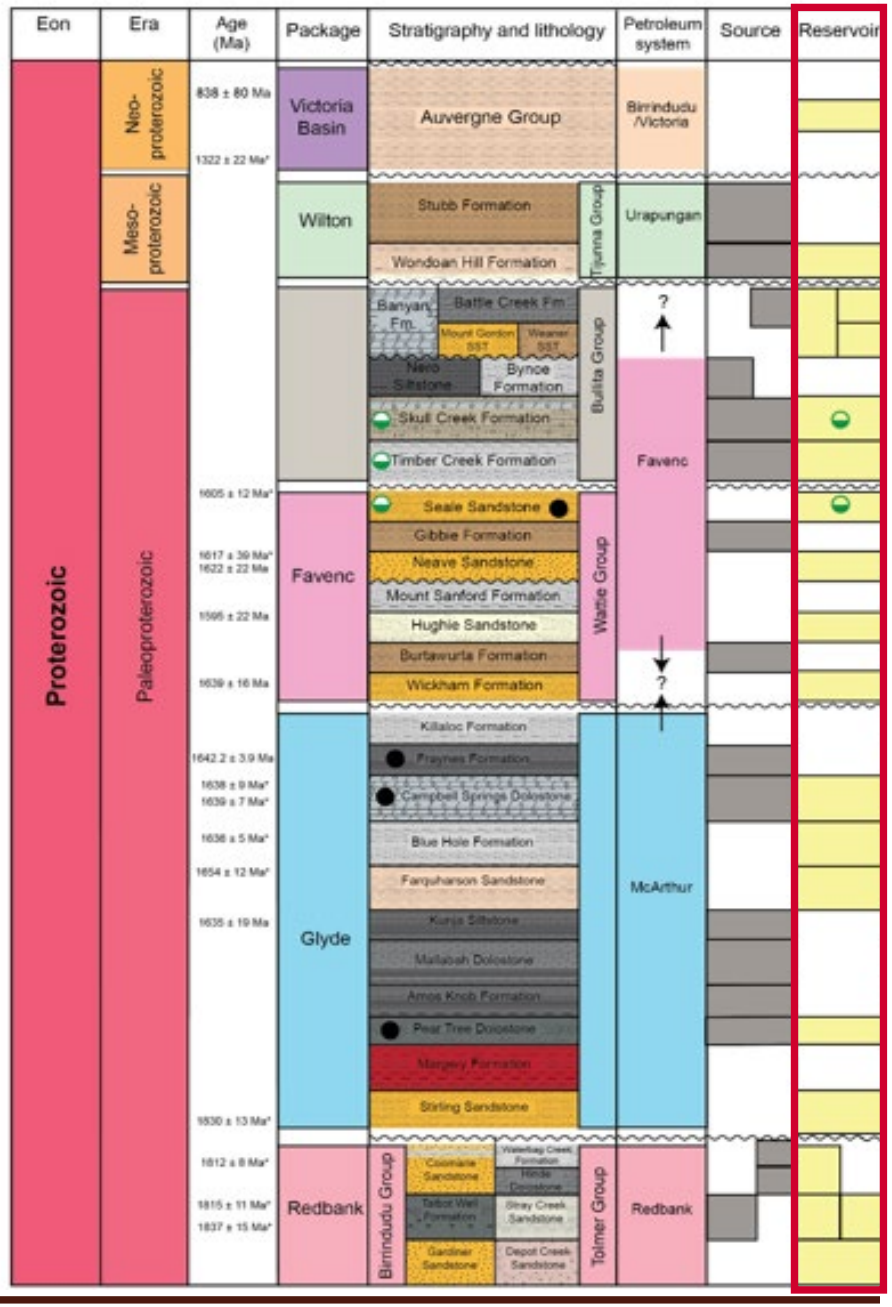
Source rock geochemistry



Source rock geochemistry

- Four formations have good to excellent organic richness
- Potential to generate oil and gas
- Thermal maturity ranges from immature to overmature (average oil window maturity)





Reservoirs

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

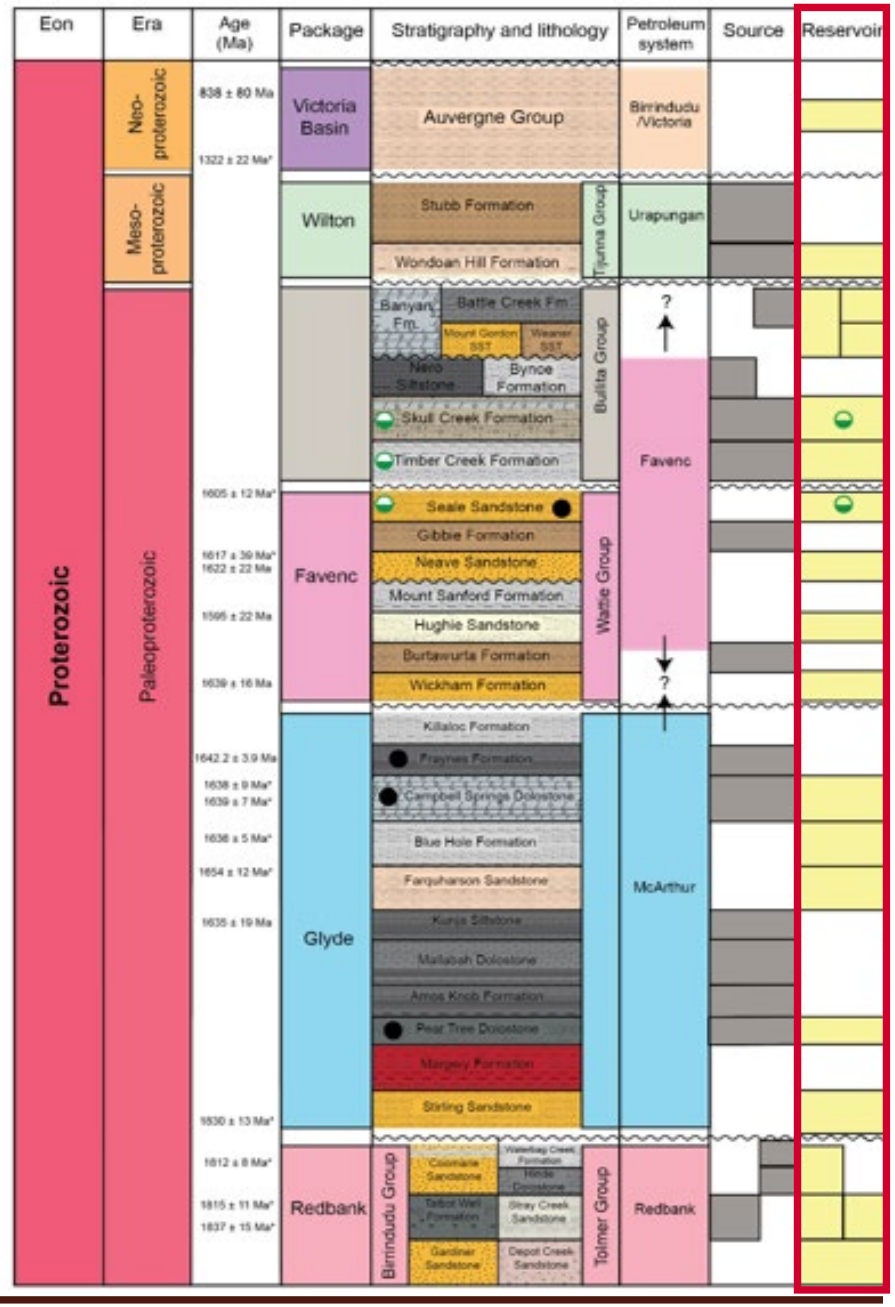
Sandstones

Stirling Sandstone

Carbonates

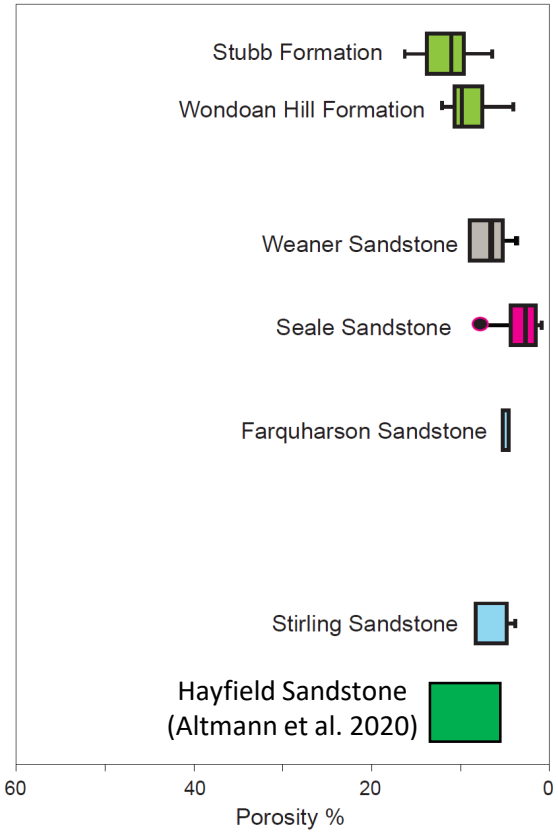
Timber Creek Formation

Reservoirs



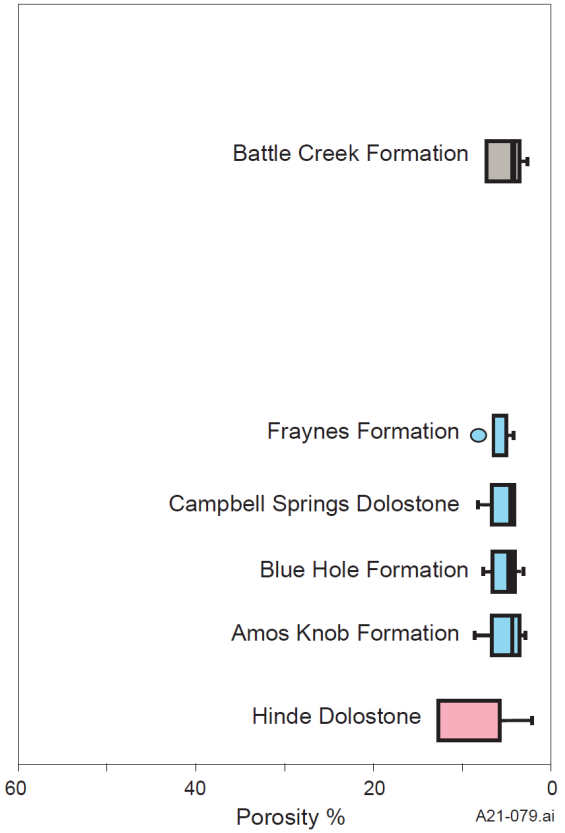
Sandstones

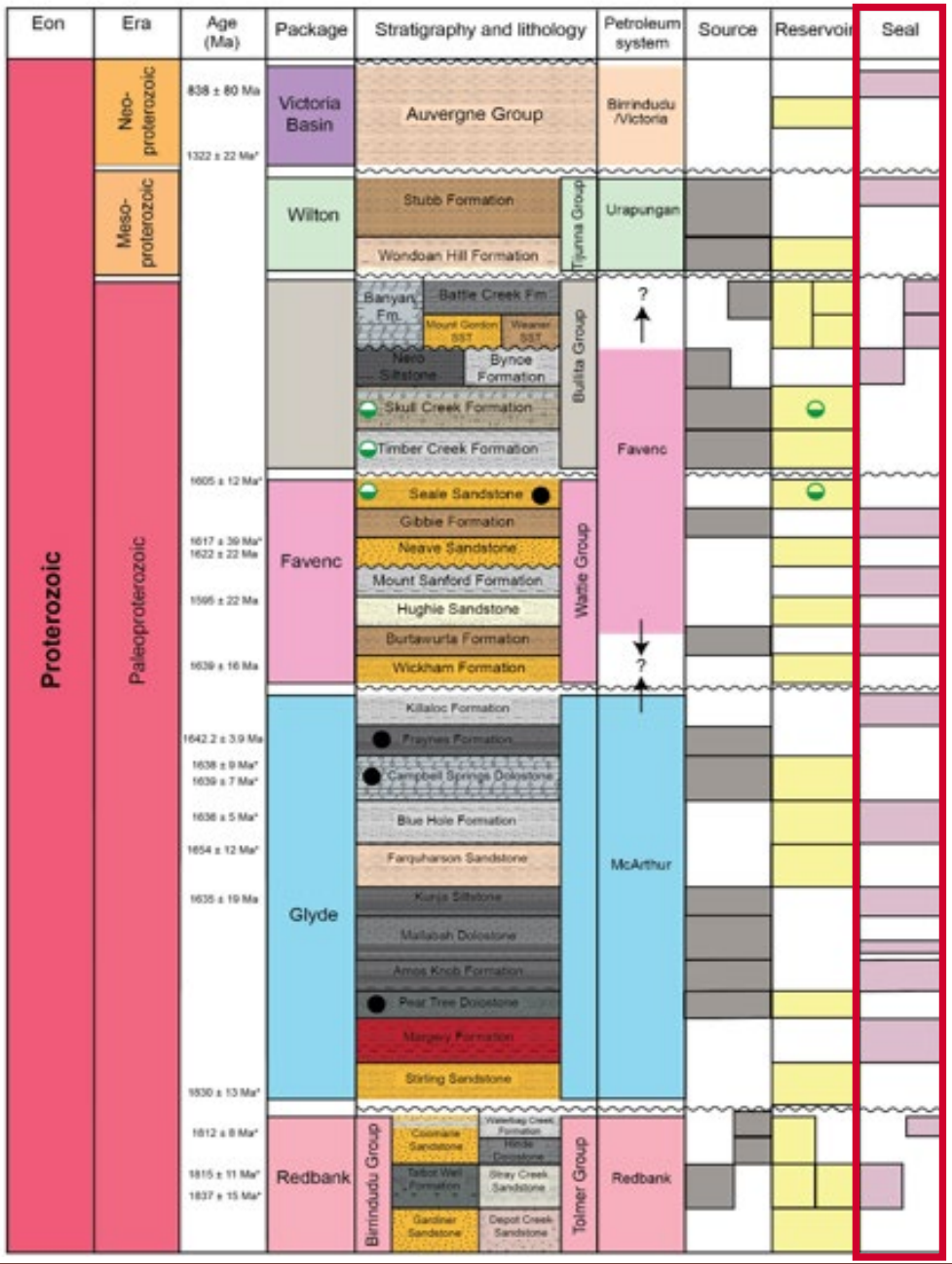
Stirling Sandstone



Carbonates

Timber Creek Formation





Seals

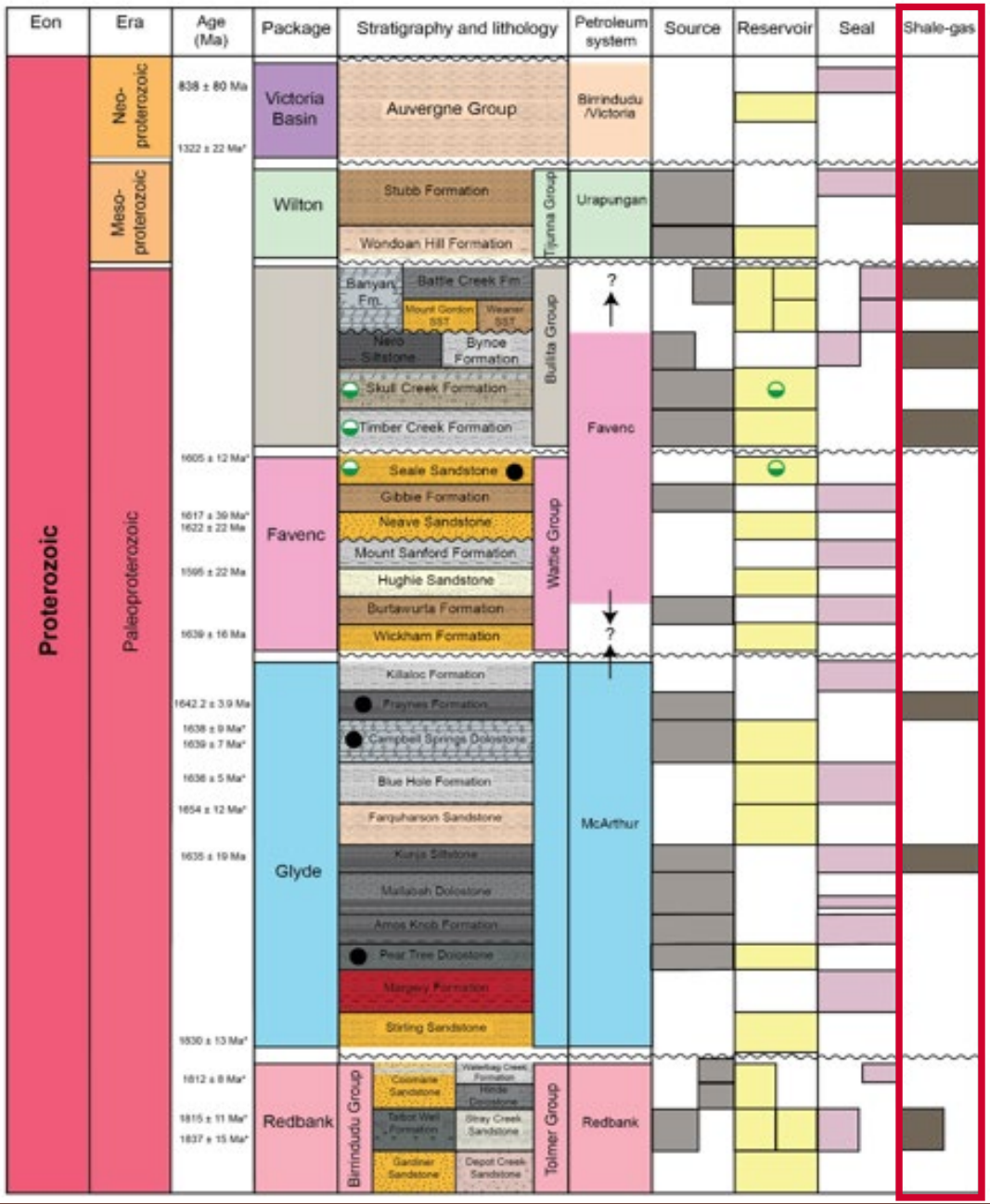
- 16 potential seal rocks
- No data available- all hypothetical

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

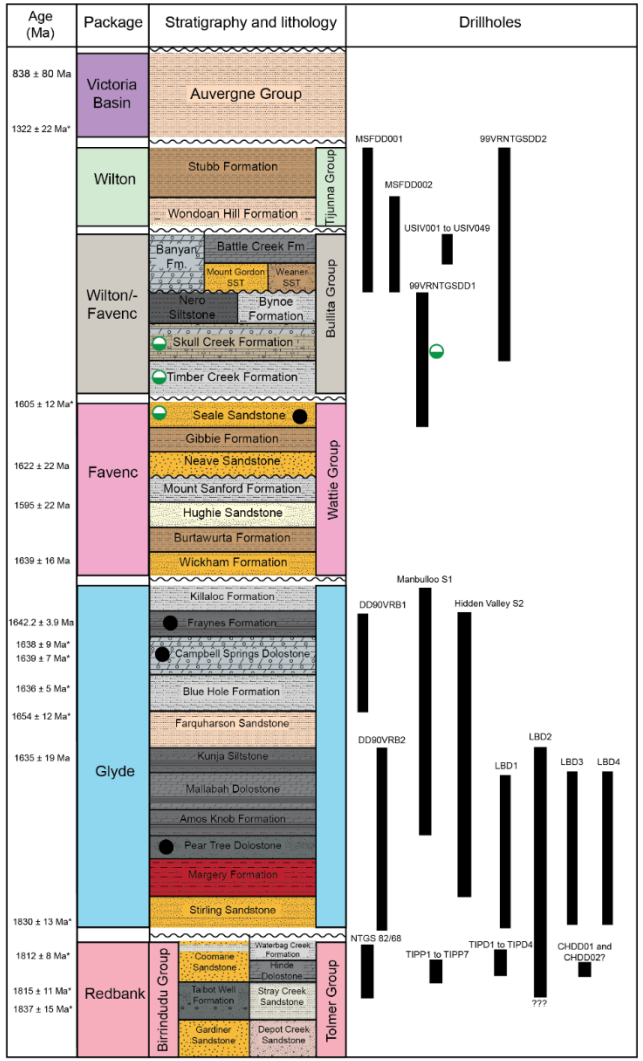
Traffic light Assessment

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

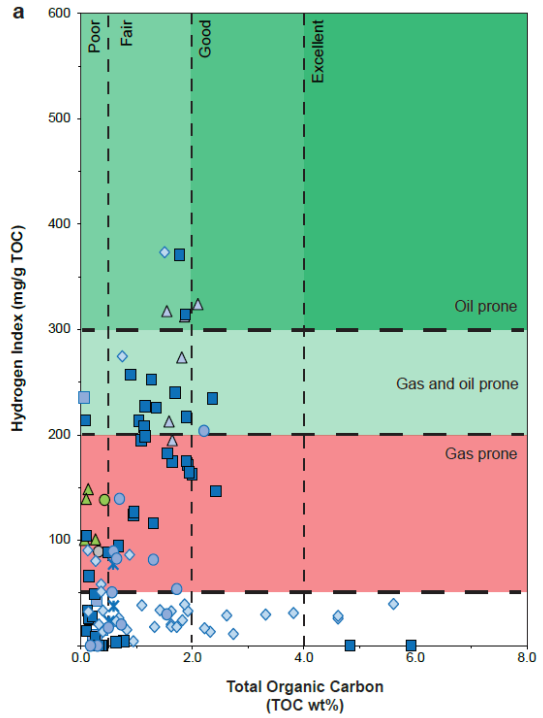
Well and field geology used



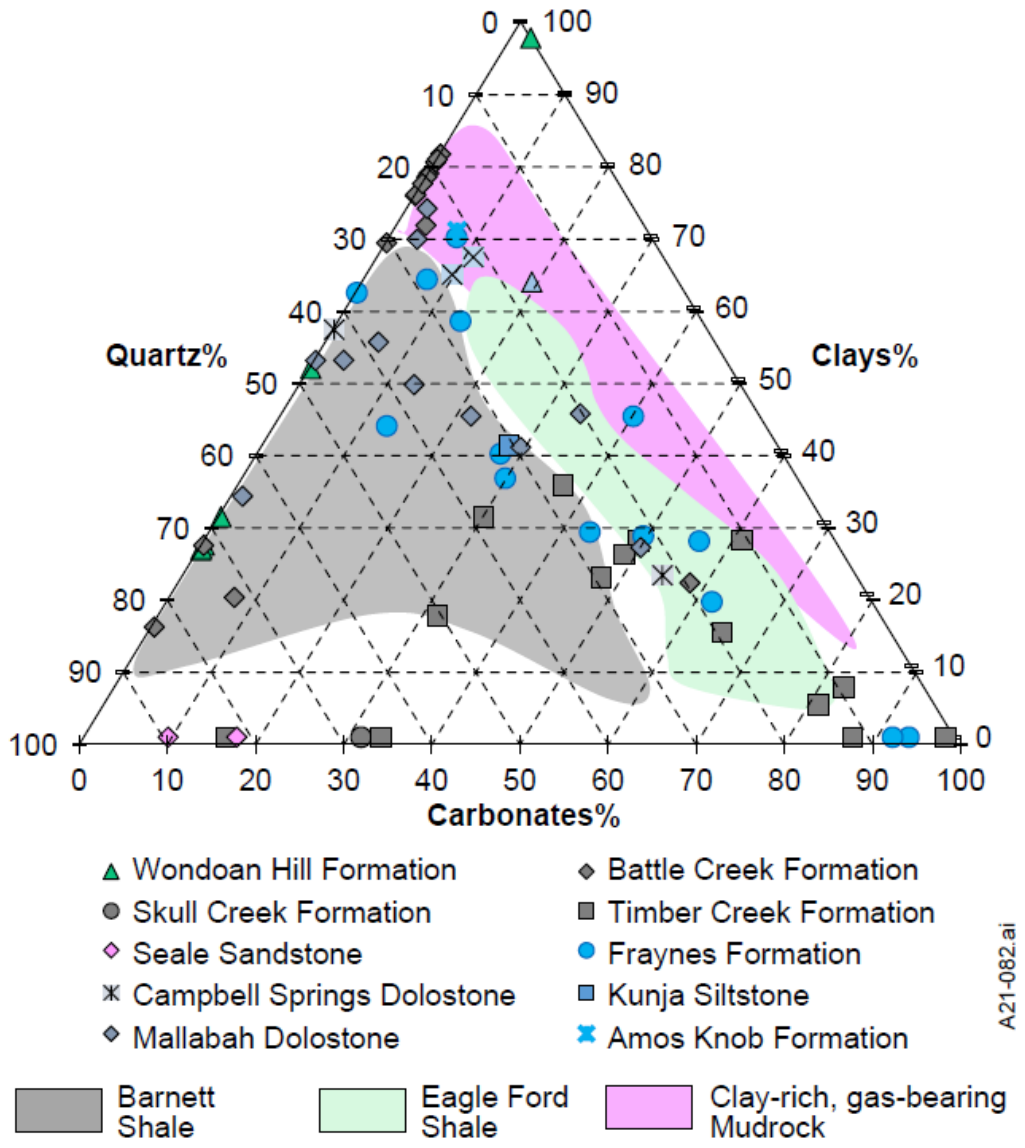
Potential unconventional plays in the Birrindudu

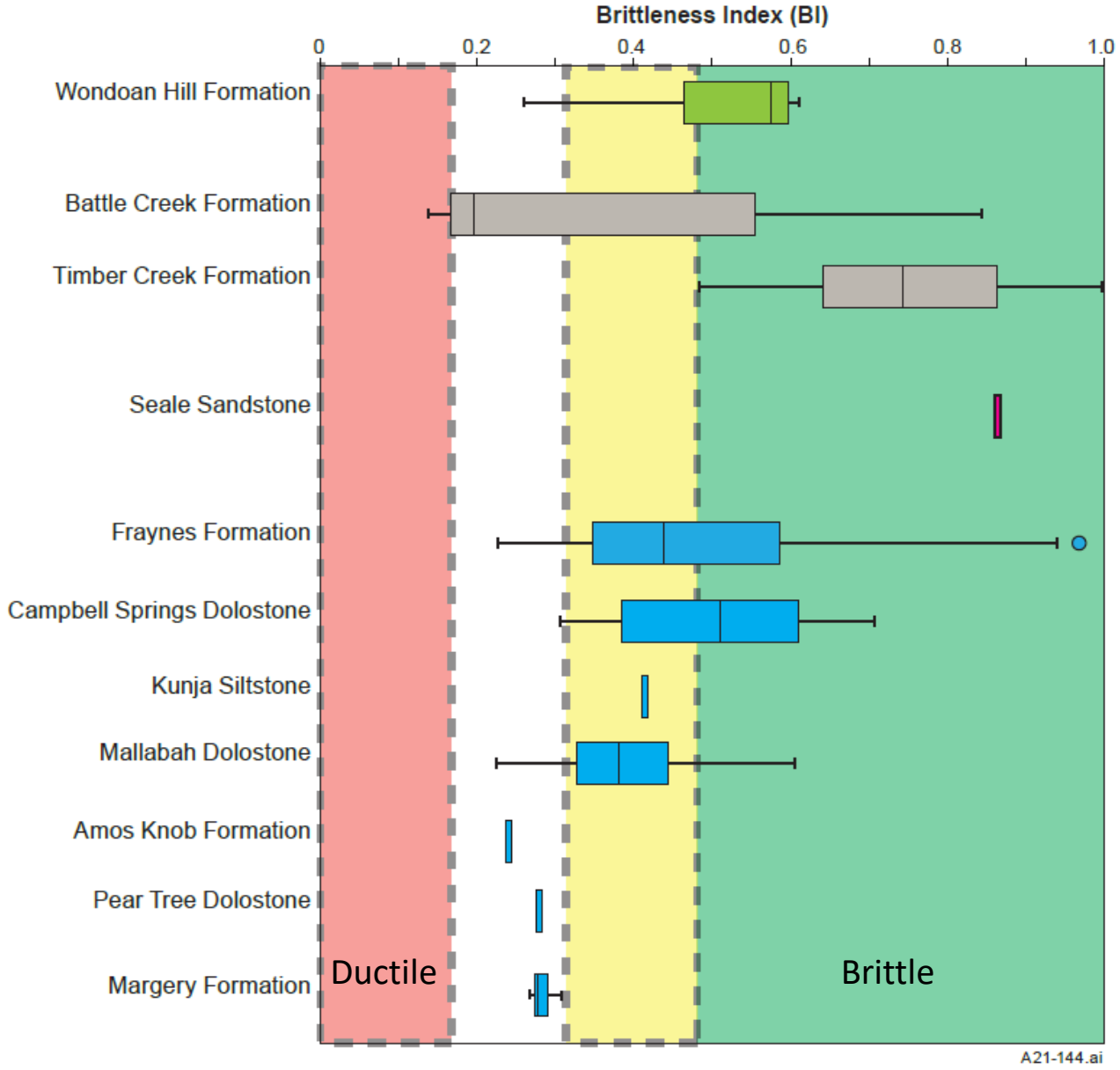
	Geology		Geochemistry	
Basin-scale petroleum system Magoon & Dow (1994)	Shale thickness (m)*	Depth below surface (m)	Total Organic Carbon (TOC wt %)	Thermal maturity
Stubb-Stubb(?)	210	0 to 170	0.4% (n = 1)	Mature 443°C (n = 1)
Nero-Nero(?)	80	No data	No data	No data
Timber-Timber(?)	>300	245 to 552	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



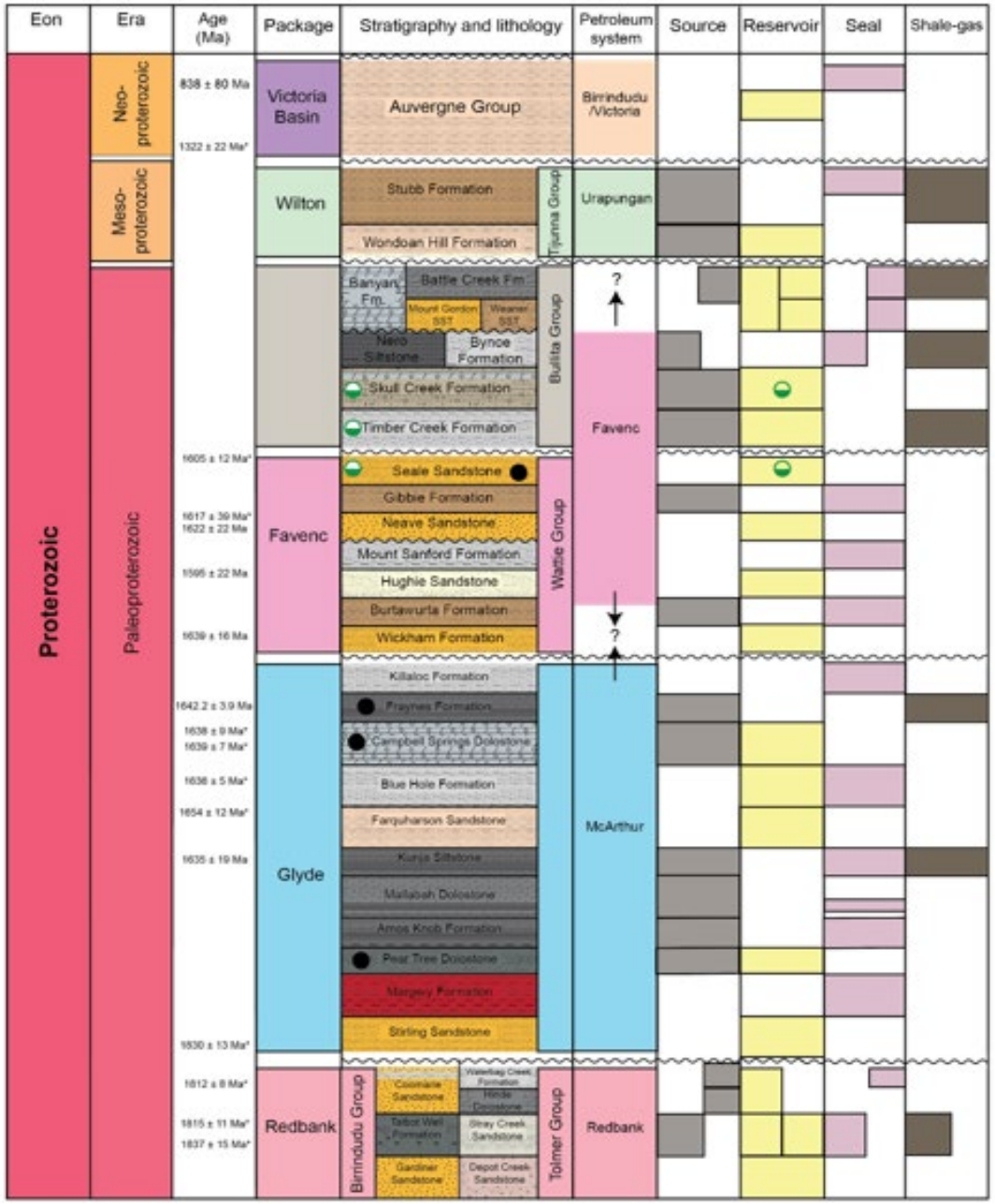
Mineralogy and brittleness





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



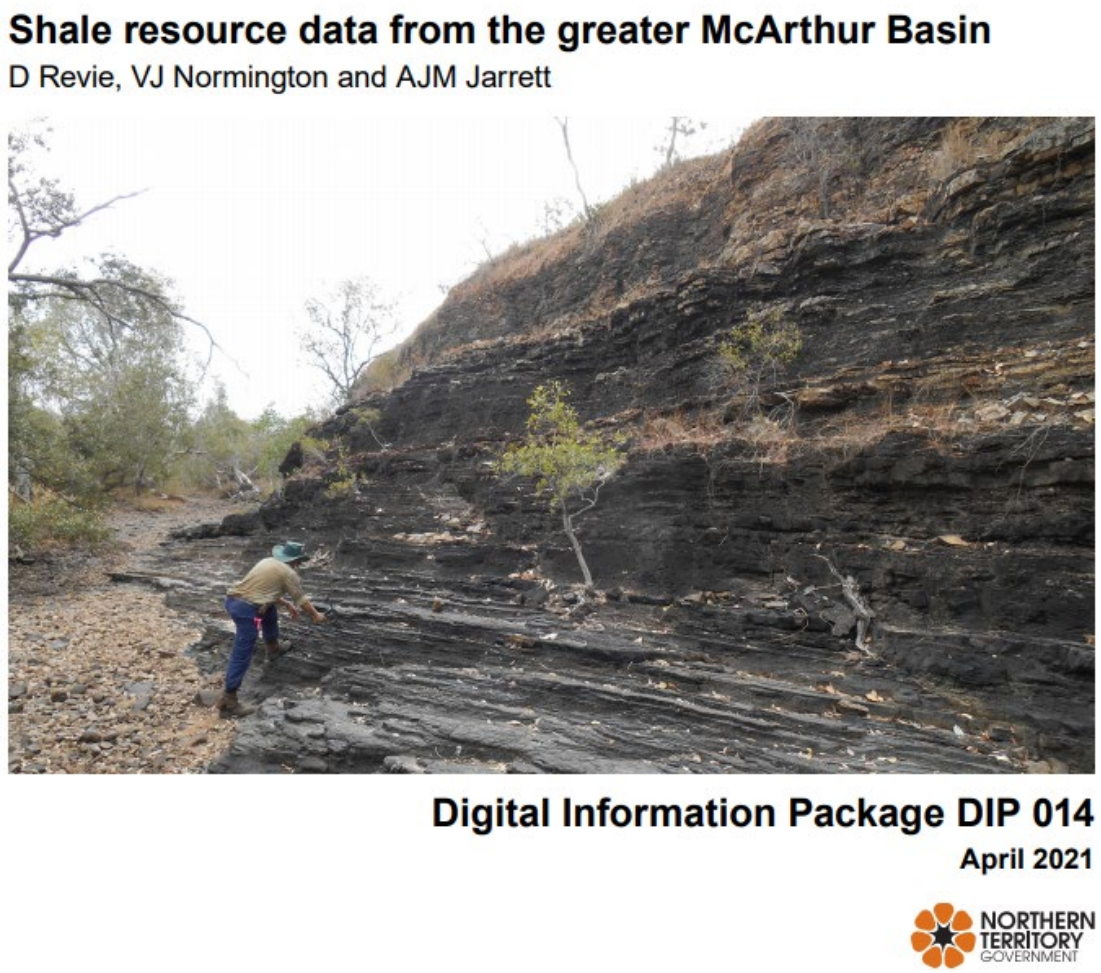
Summary

- 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



- 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

Amber.Jarrett@nt.gov.au