Unconventional Gas Reservoir Productivity in Australian Proterozoic Rocks – Studies from the McArthur, Beetaloo, Mount Isa, and Amadeus*

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Abstract

A large amount of available exploration data is readily available for many Proterozoic areas in Australia. The data ranges from seismic and conventional well data to cored and mineral bores not specifically focused on the search for hydrocarbons. Both Commonwealth- and State-based programs have also been focused on these rocks. Many Proterozoic basins occur in Australia; however, the Paleo-MesoProterozoic sequences of the McArthur and Mount Isa areas have been an important focus over the past few years. In the McArthur Basin the key organic-rich sequences comprise the Barney Creek and the Velkerri formations. At Mount Isa the Riversleigh and Lawn Hill formations have been the main targets assessed. Despite this activity, several units in the Proterozoic remain little tested, particularly the Wollogorang Formation of the Tawallah Group in the McArthur Basin with known vuggy oil and the organic-rich units of the Bowthorn Siltstone of the Mount Isa area. In the Amadeus Basin, Upper Proterozoic sequences containing organic-rich rocks are interpreted conventional source rocks for gas fields, such as Dingo. These source rocks are interpreted to have unconventional gas potential, and efforts are progressing to better understand the key focus criteria to recognise potential sweet spots to enable exploration focus. The key reservoir shales are commonly carbonate-rich with good fracture stimulation potential. The nature of unconventional reservoirs varies according to the contained gas characteristics and the reservoir conditions. Many situations can combine to provide higher gas production potential and increased wet gas components that can improve the financial returns for individual field areas. In the Proterozoic, one key factor is to target lower maturity rocks as all reservoirs leak, and older rocks have less chance of maintaining preservation conditions and higher formation pressures. Organic content and saturation plus structural controls are additional important factors that can influence hydrocarbon volumes accessible from an individual well bore. From a financial perspective, the main criterion for

good economic returns is the liquids content in the form of associated oil or condensate. As many Proterozoic basins in Australia contain organic-rich shaly rocks produced by Type I kerogens and have relatively low maturities, the setting offers significant potential to derive high-value liquids from such reservoirs.

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SRK Consulting

Egilabria 2
Lawn Hill Formation, northern Mount Isa Basin (Isa Superbasin)
Contingent Gas Resource Estimation, ATP 1087

Unconventional Natural Gas Reservoirs

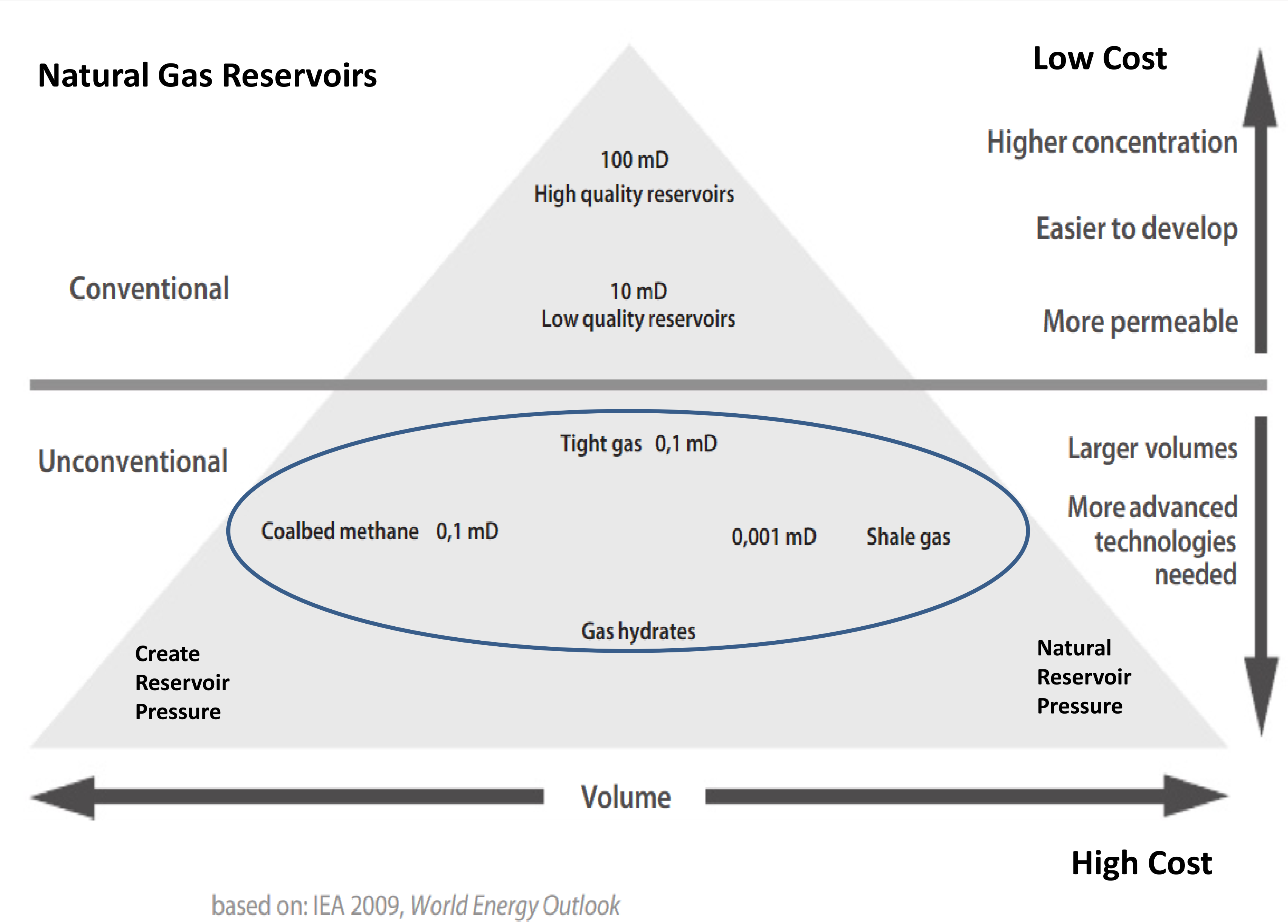
The talk will cover be an appraisal of hydrocarbon frontiers principally Unconventional Natural Gas Reservoirs.

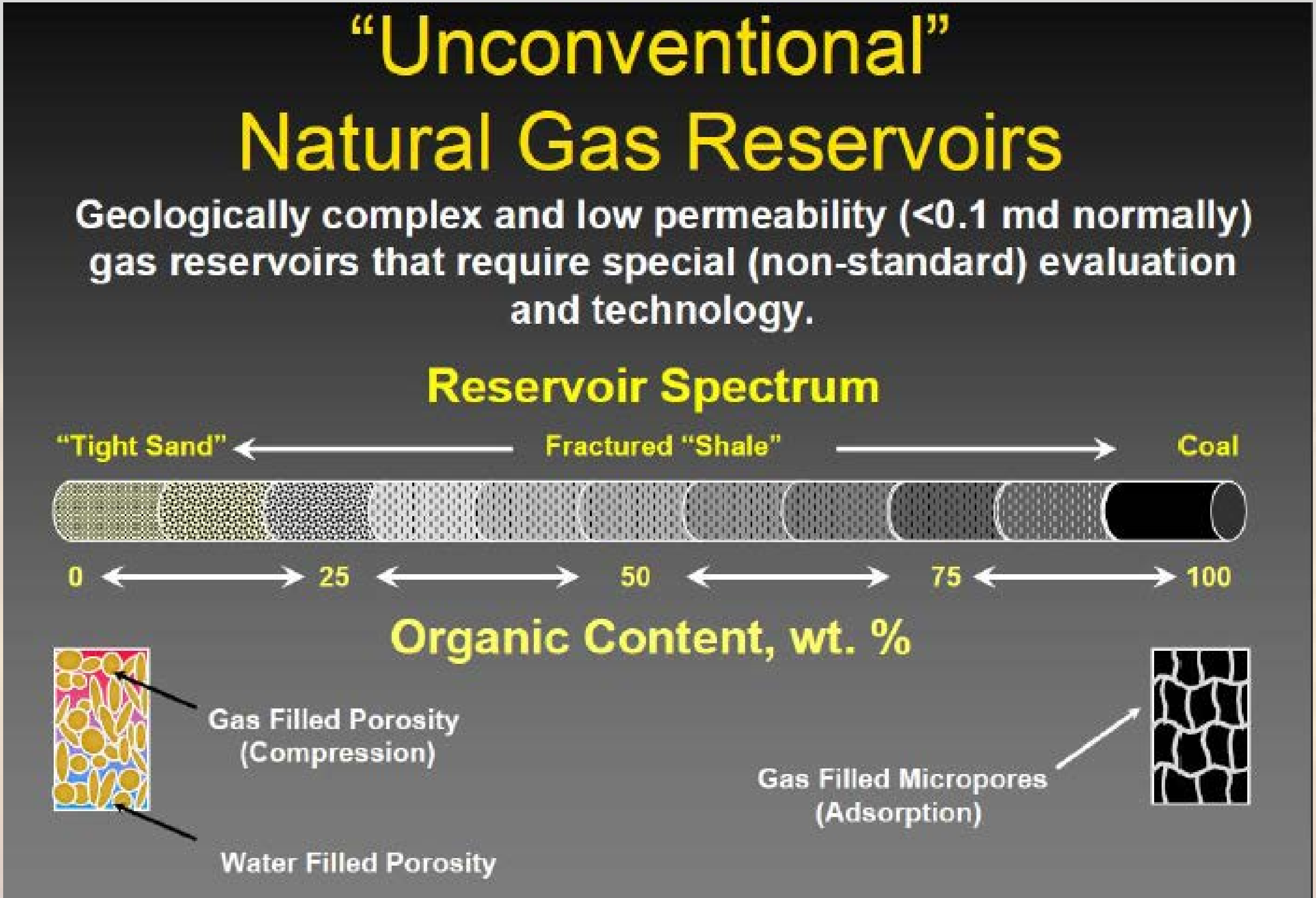
The basis is Proterozoic unconventional reservoir spectrum as seen in the many examples of PaleoProterozoic and MesoProterozoic sequences in Australian basins.

Issues like measuring gas volumes, production phases and production criteria will be addressed. Shale gas sweet spots, shale gas metrics, shale gas production and shale oil potential will be covered.

- **The reservoir spectrum**
- **Estimating gas volumes**
- **The basins reviewed**
- **Shale gas sweet spots in Proterozoic Rocks**
- **McArthur, Beetaloo, Mount Isa, Amadeus**
- **Conclusions**

Marita Bradshaw
Geoscience Australia

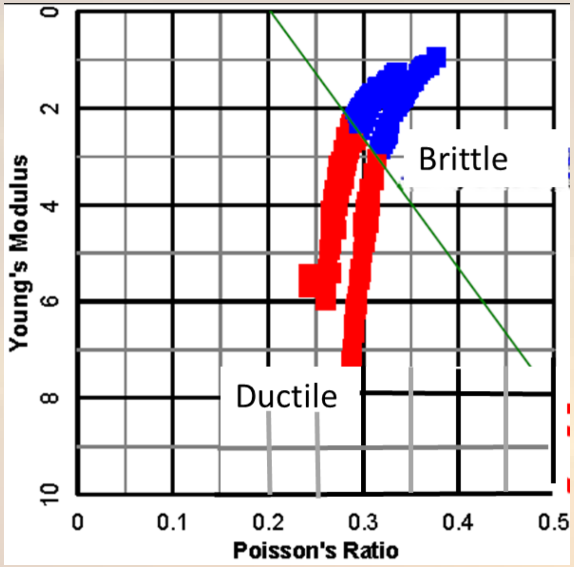

Natural Gas Reservoirs
Low Cost
Higher concentration
Easier to develop
More permeable
100 mD
High quality reservoirs
10 mD
Low quality reservoirs
Conventional
Unconventional
Tight gas 0,1 mD
Coalbed methane 0,1 mD
0,001 mD
Shale gas
Gas hydrates
Larger volumes
More advanced technologies needed
Create Reservoir Pressure
Natural Reservoir Pressure
Volume
High Cost
based on: IEA 2009, World Energy Outlook

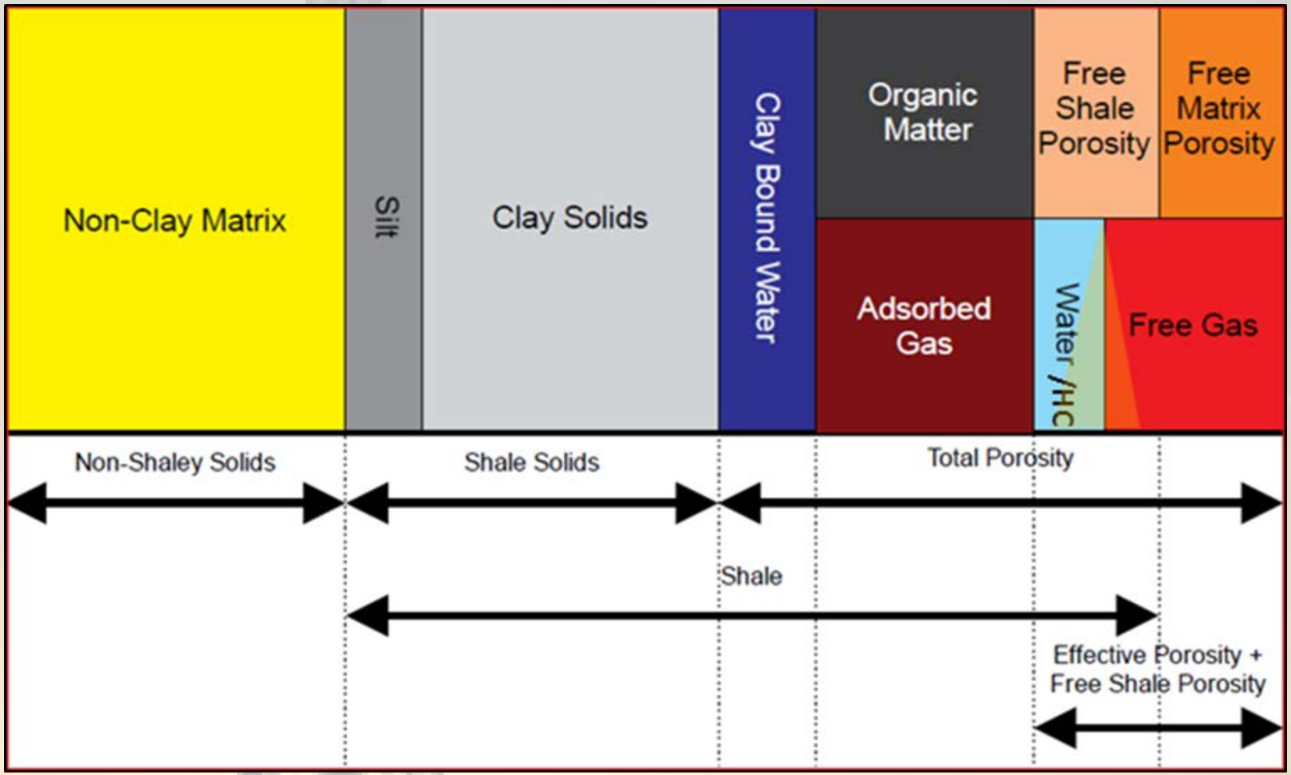


Organic Content

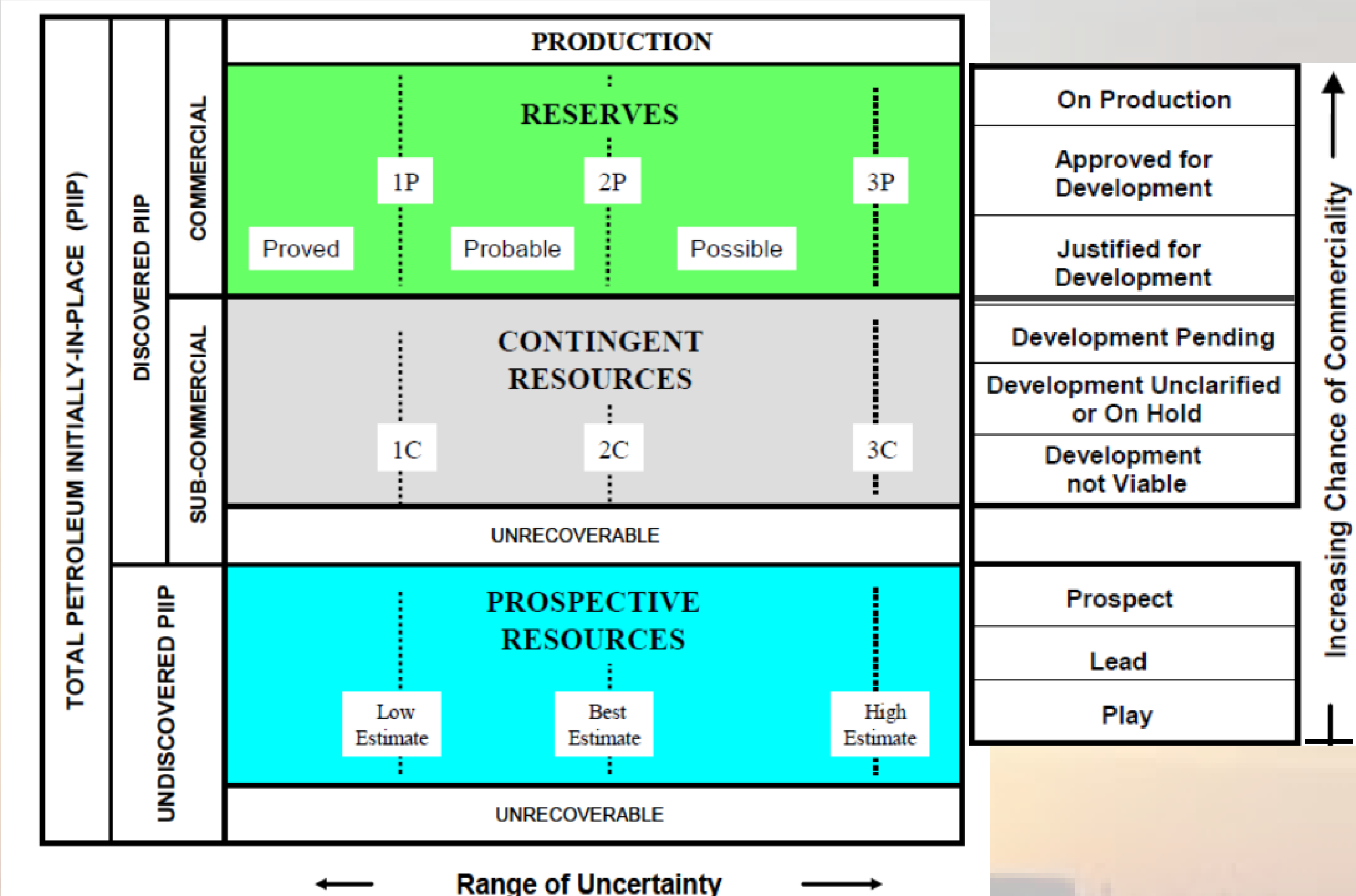
NSAI (2012)

Gas containment in Shale Gas Plays

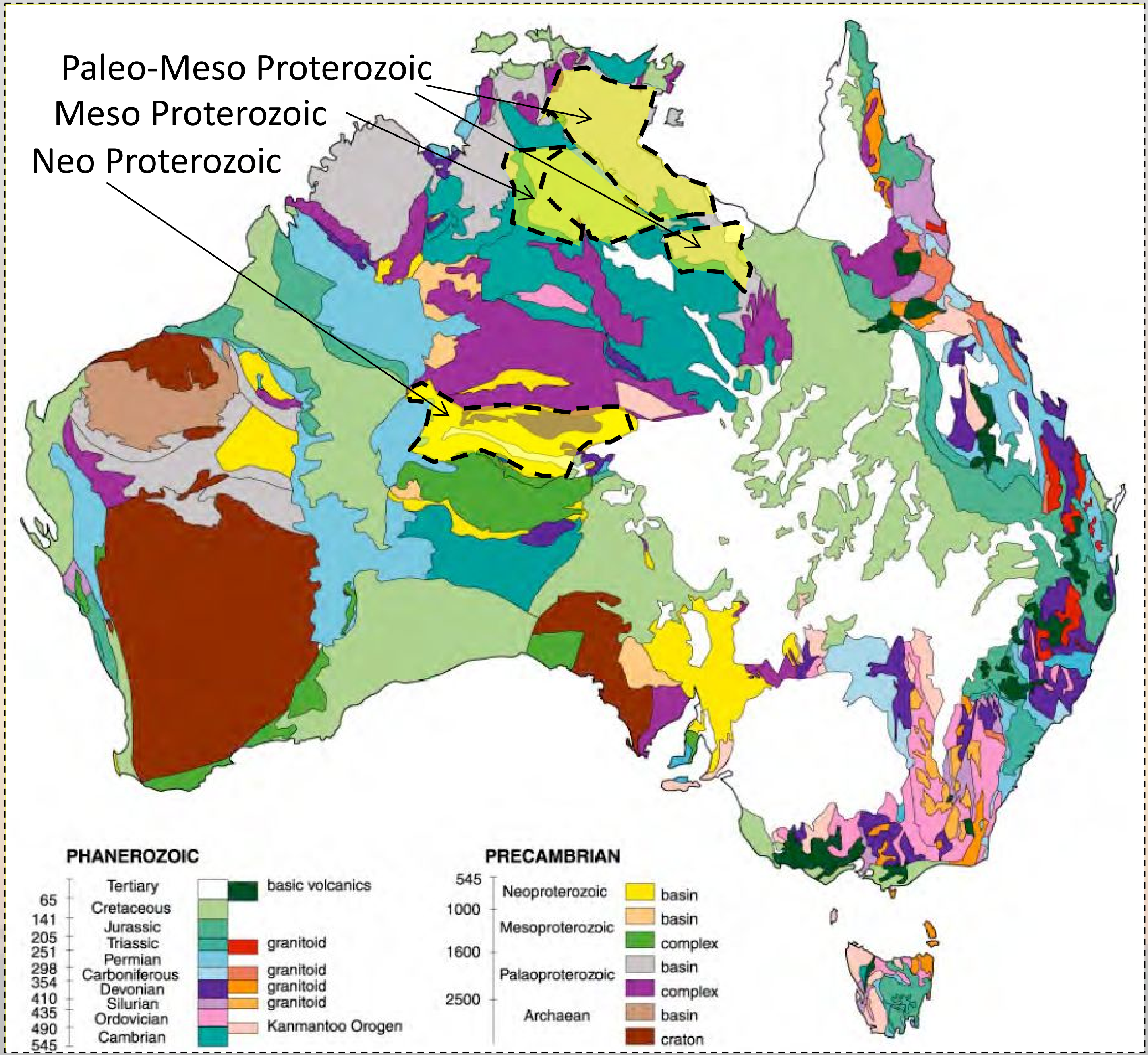




Petrophysical Model to Estimate Free Gas in Organic Shales
Michael Holmes, Dominic Holmes and Antony Holmes



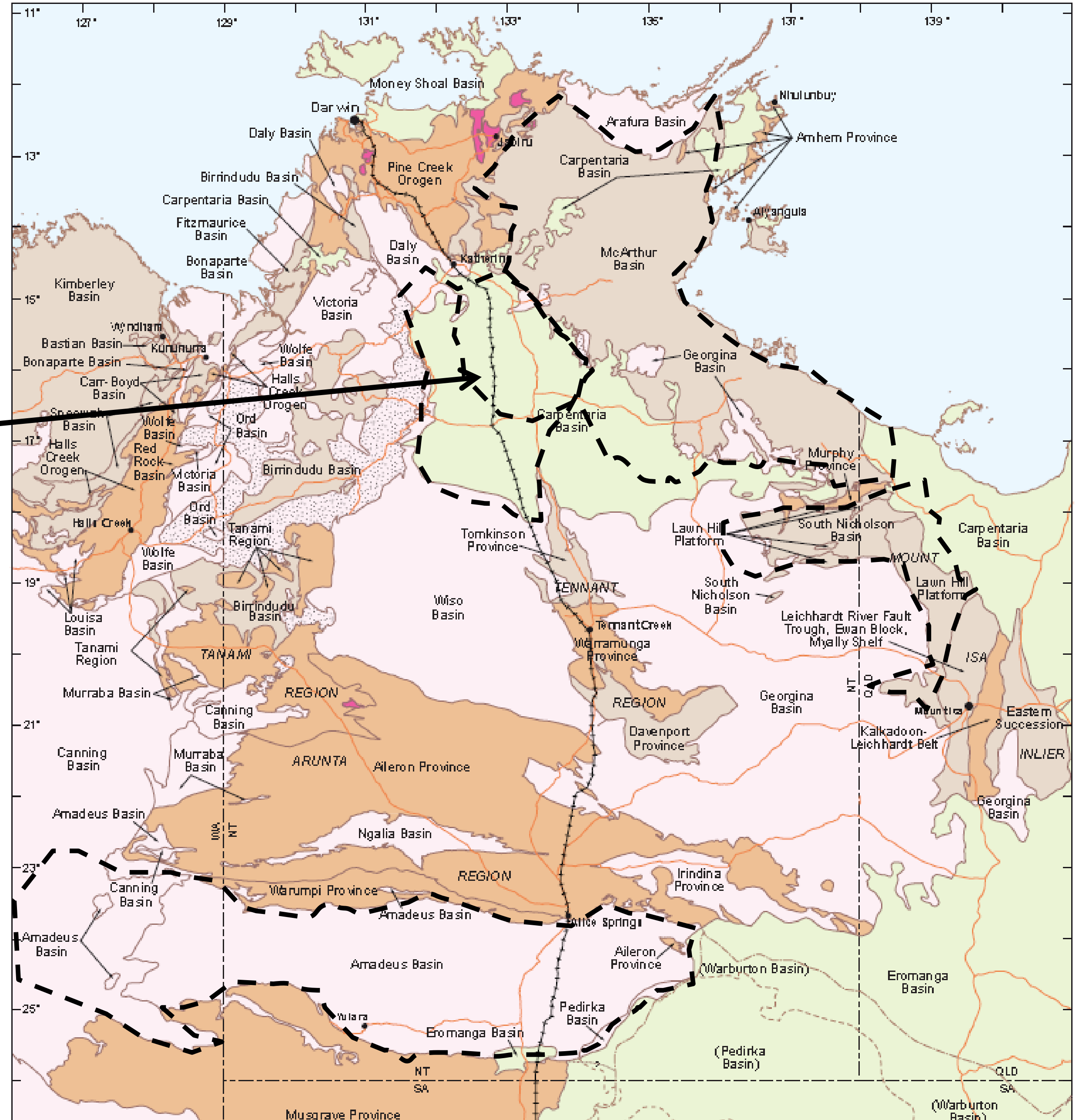
Reserves and Resources as classified by PRMS (not to scale)

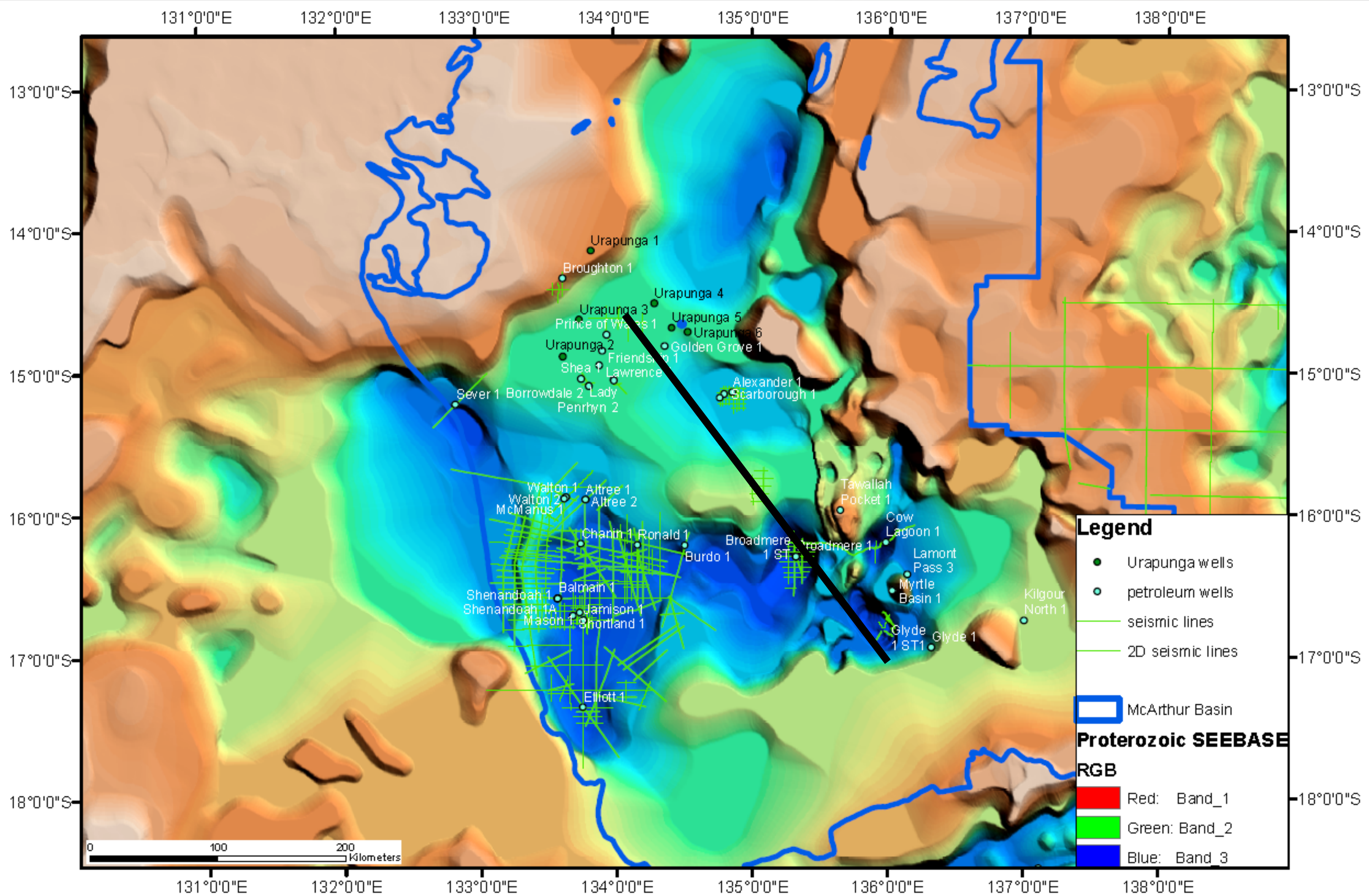


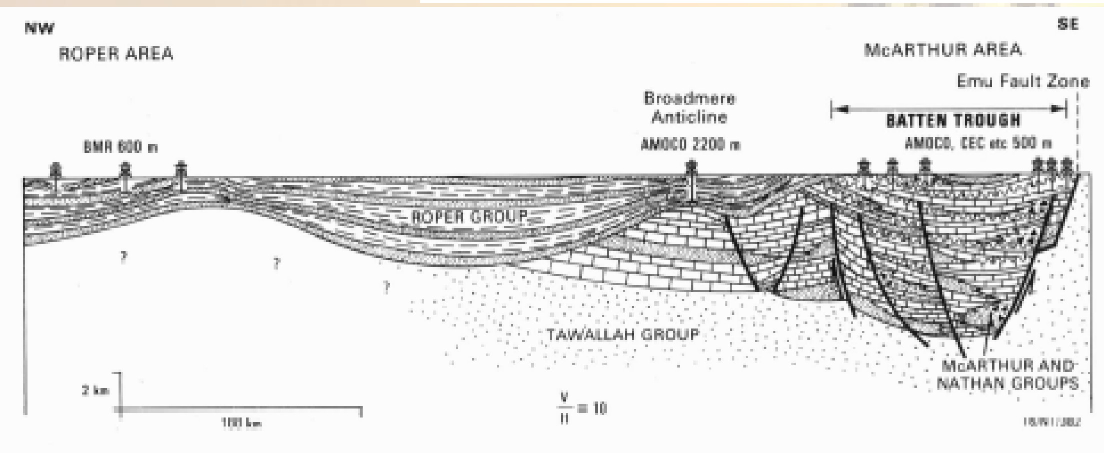
Paleo-Meso Proterozoic
Meso Proterozoic
Neo Proterozoic
PHANEROZOIC
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Cambrian
65
141
205
251
298
354
410
435
490
545
basic volcanics
granitoid
granitoid
granitoid
granitoid
Kanmantoo Orogen
PRECAMBRIAN
545
1000
1600
2500
Neoproterozoic
Mesoproterozoic
Palaoproterozoic
Archaean
basin
basin
complex
basin
complex
basin
craton

Beetaloo Sub-basin/ McArthur Basin

Each area has proven hydrocarbons from pilot production Testing plus very large Prospective Resources

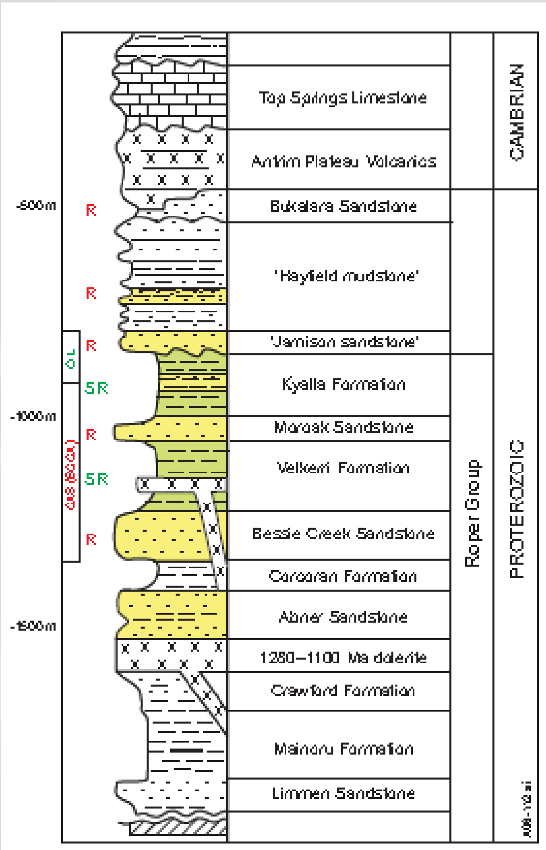


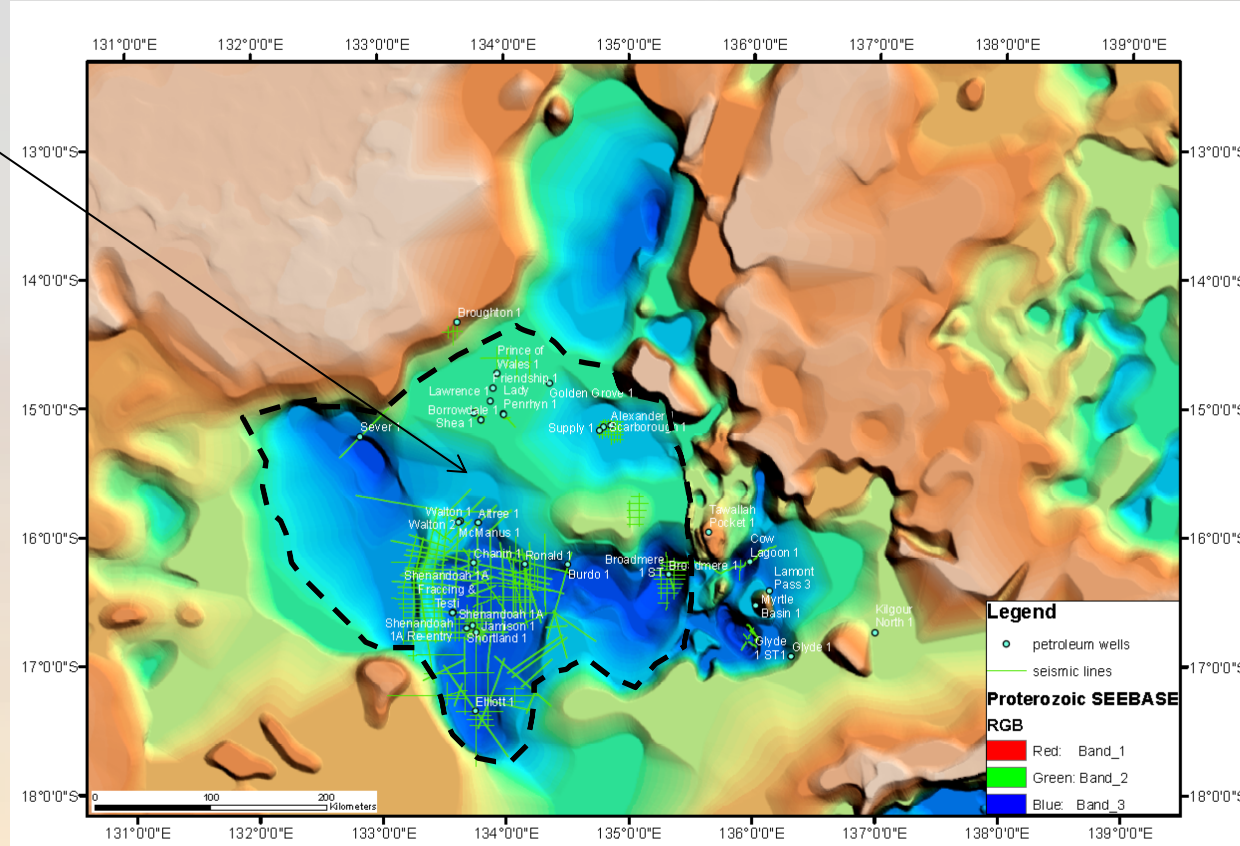




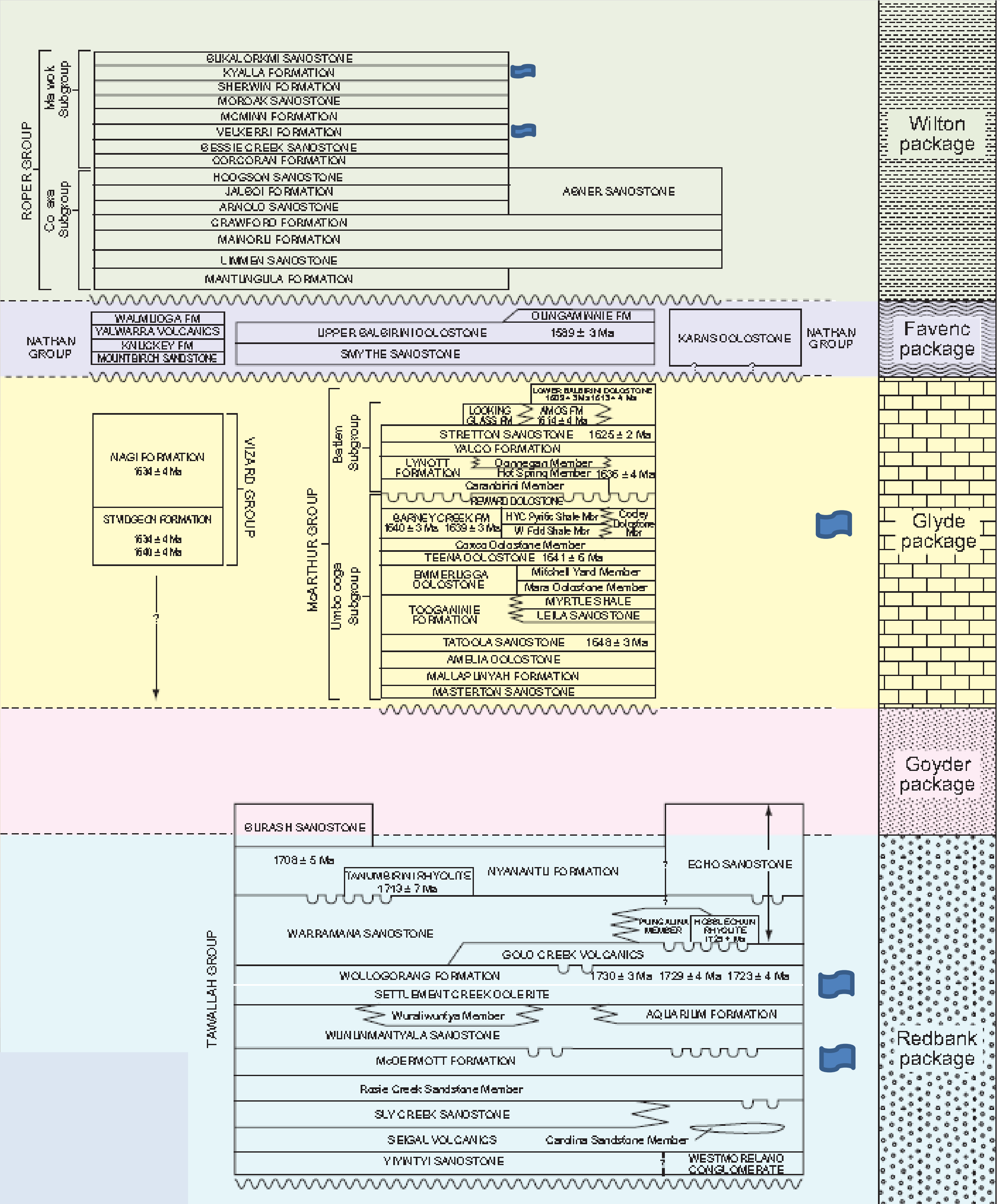
Relationship between the McArthur and Roper Groups

Main Roper Group deposition





(after Silverman *et al* 2007, Falcon 2009)



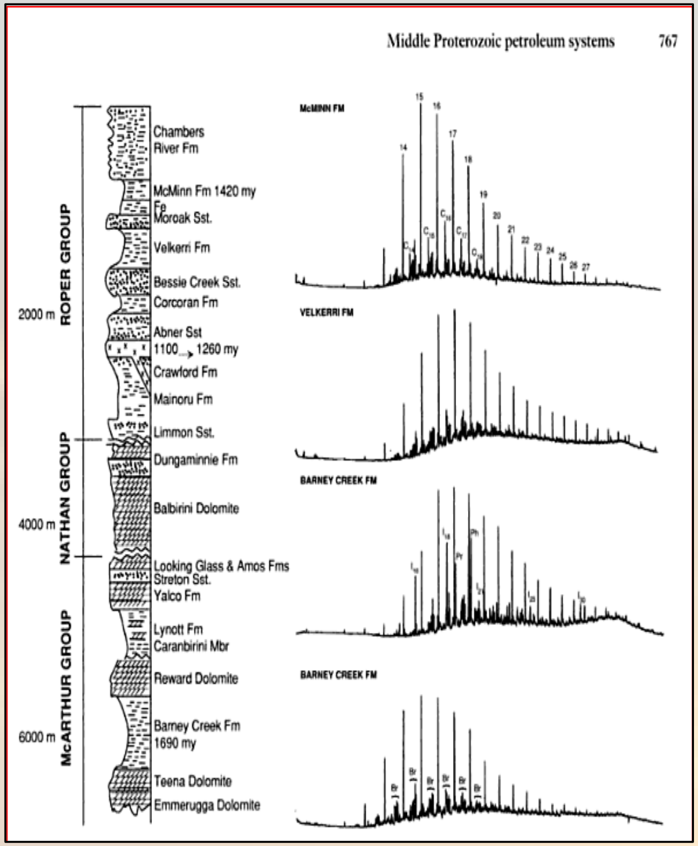
Beetaloo

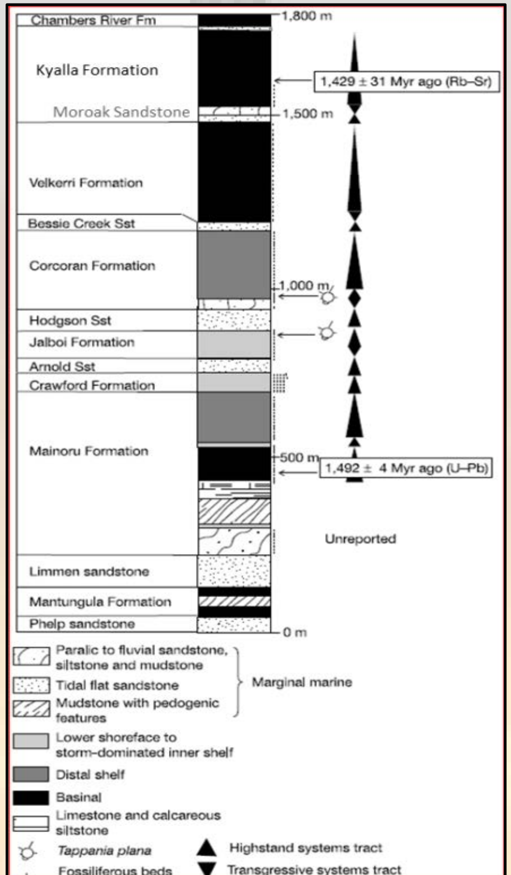
High TOC shale

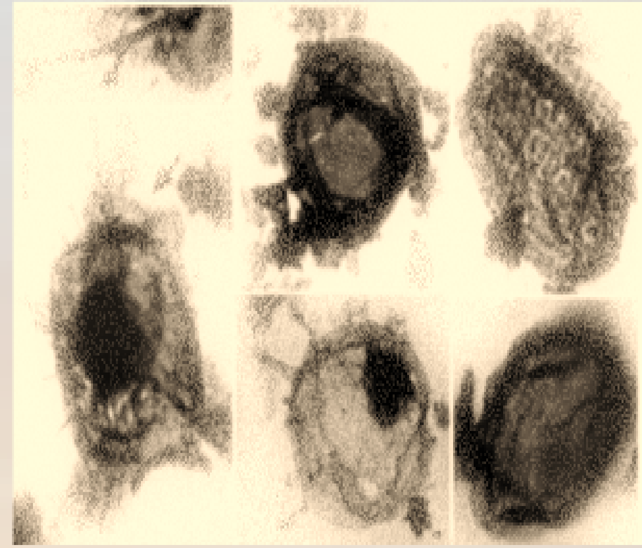
Main unconventional potential

McArthur

Tawallah

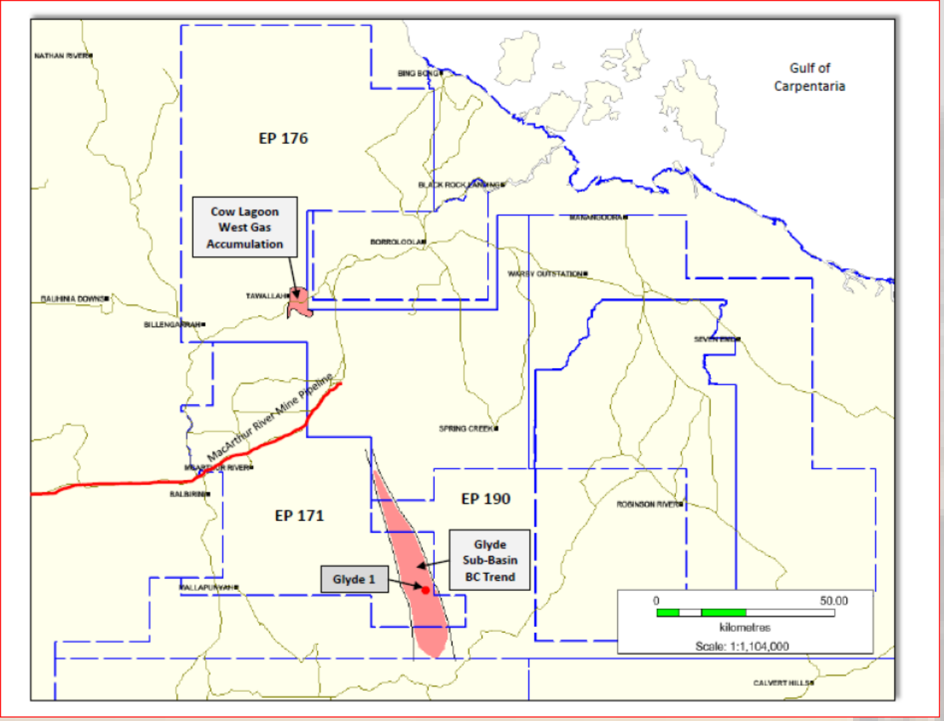






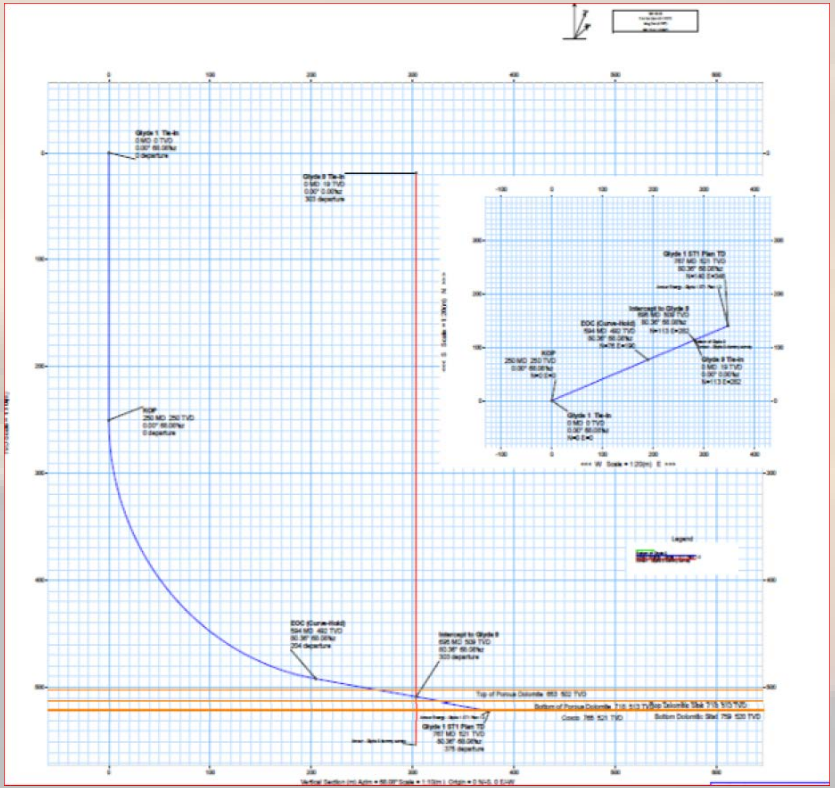

Velkerri Oil Shale and early Roper Group

Eukaryotes (oil prone green algae) Summons et al. (1988)



Gas Flare during Testing at Glyde #1 Lateral Well Measured Well Depth of circa 670m

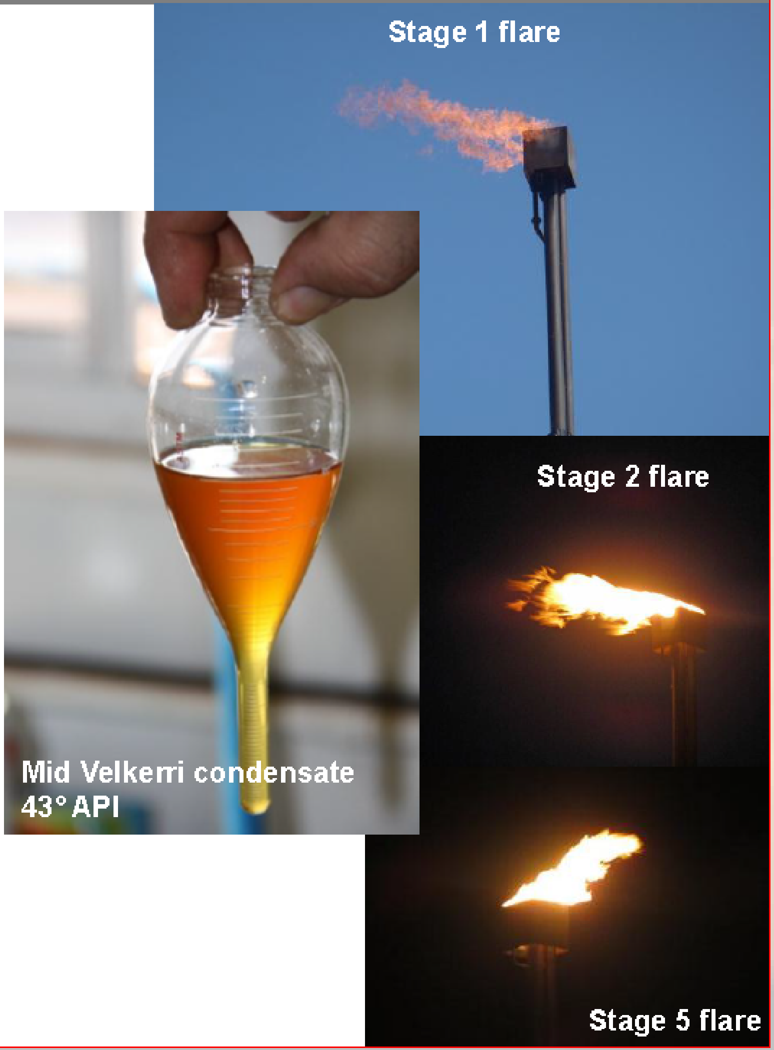
McArthur Basin



Completion Summary – Shenandoah-1A

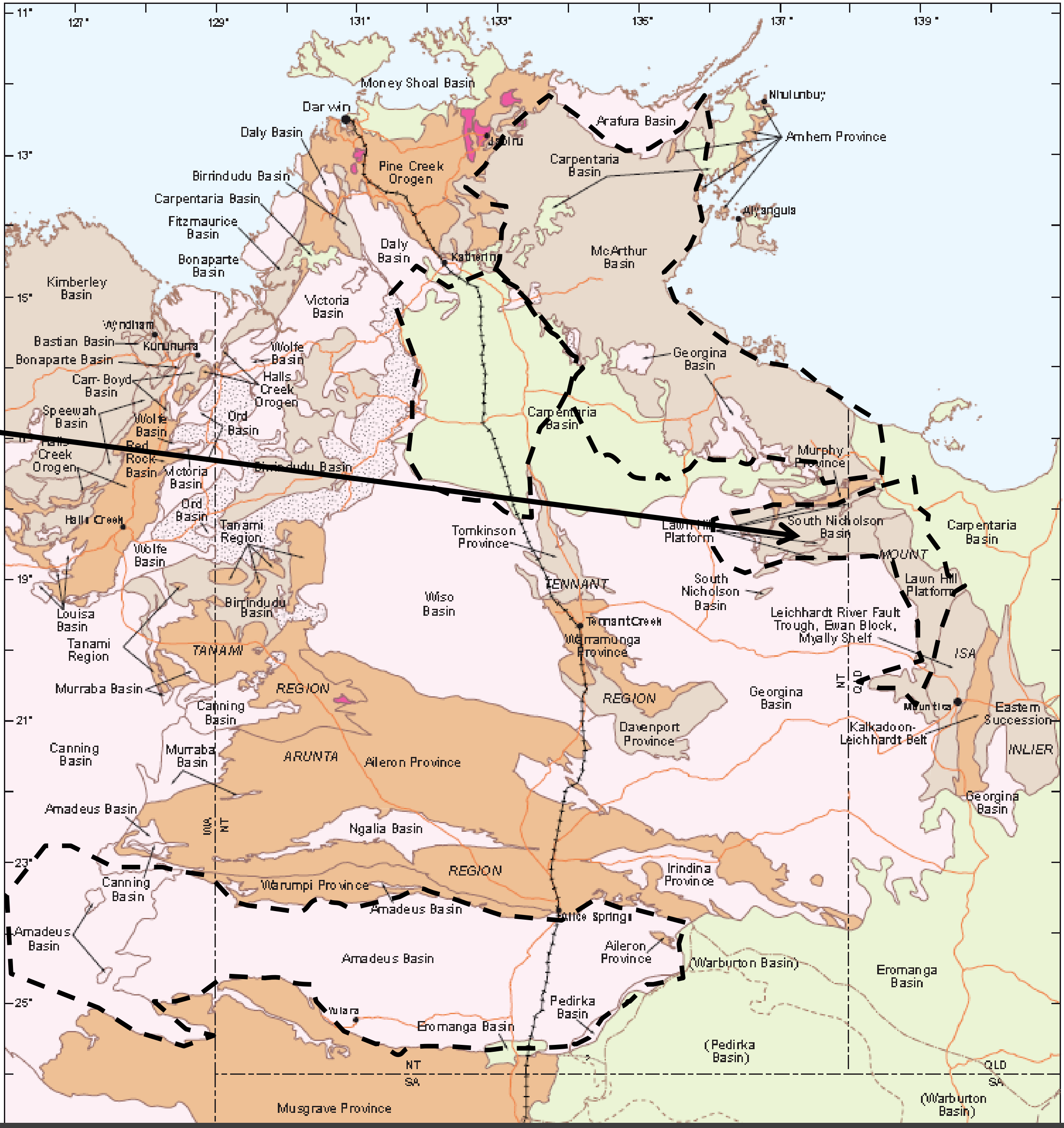
Beetaloo Sub-basin

- Stage 1-Middle Velkerri Lower "B" Zone
  - 2529m to 2548m; carbonate-rich shale
  - Fracture stimulation-37% of load recovered
  - Fracture half length approx. 50 meters
  - **Reservoir pressure of 0.662 psi/ft to 0.567 psi/ft**
  - **Flow back tested ~50 mscfpd, w/ 43° API condensate**
- Stage 2-Middle Velkerri Upper "B" Zone
  - 2481m to 2498.5m ; low porosity gas sand
  - Fracture stimulation-50% of load recovered
  - Fracture half length approx. 46 meters
  - **Reservoir pressure of 0.653 psi/ft to 0.556 psi/ft**
  - **Flow back flared sustained, unassisted ~80 mscfpd**
- Stages 3 and 4-Moroak sandstone
  - Various intervals 1,728m – 1,910m
  - Conventional perforation tests
  - Little to no commercial hydrocarbons present at this location
- Stage 5-Lower Kyalla
  - 1631m-1649m; silica-rich shale
  - Fracture stimulation-30% of load recovered
  - Fracture half length approx. 39 meters
  - **Reservoir pressure of 0.653 psi/ft to 0.556 psi/ft**
  - **Produced burnable gas**



Isa Superbasin

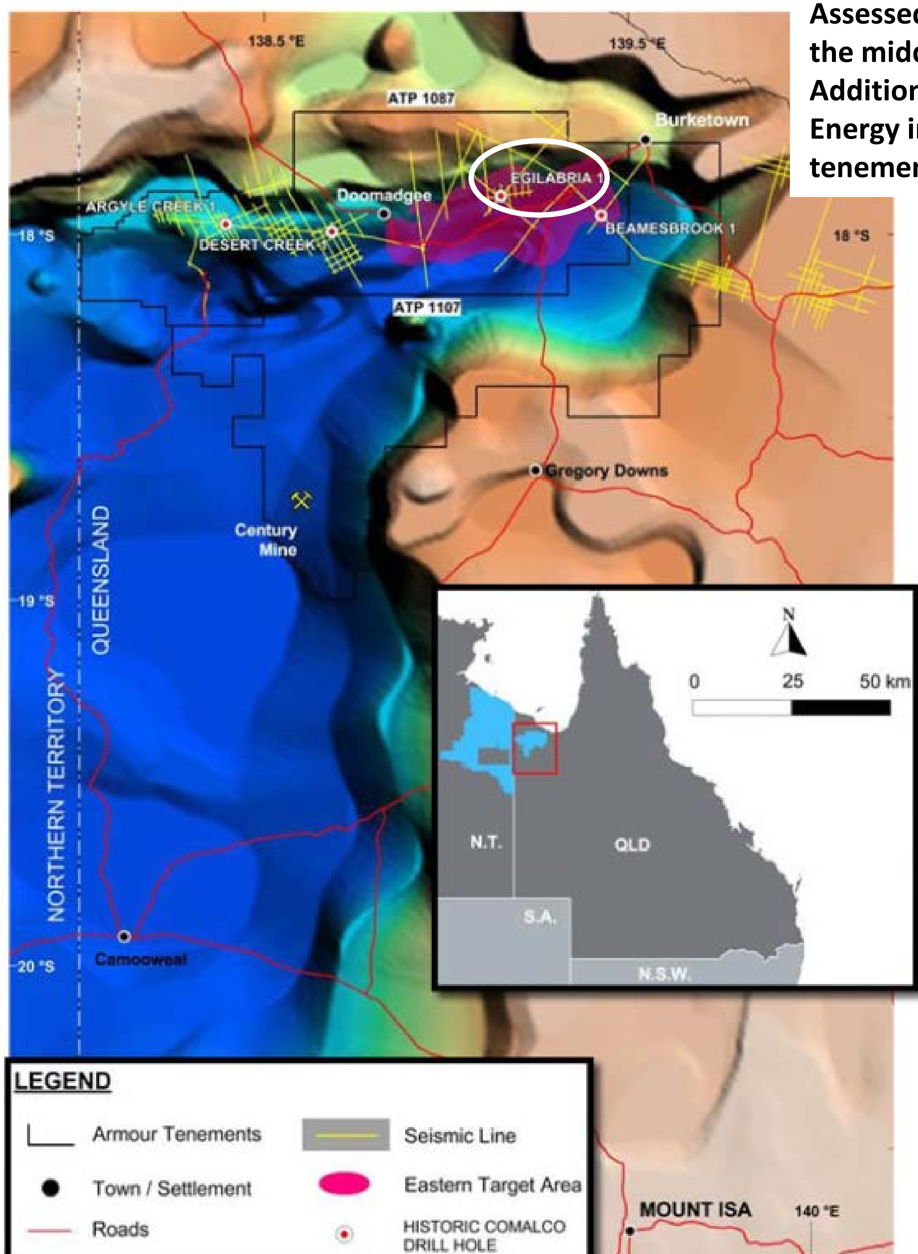
Low to high thermal maturity area

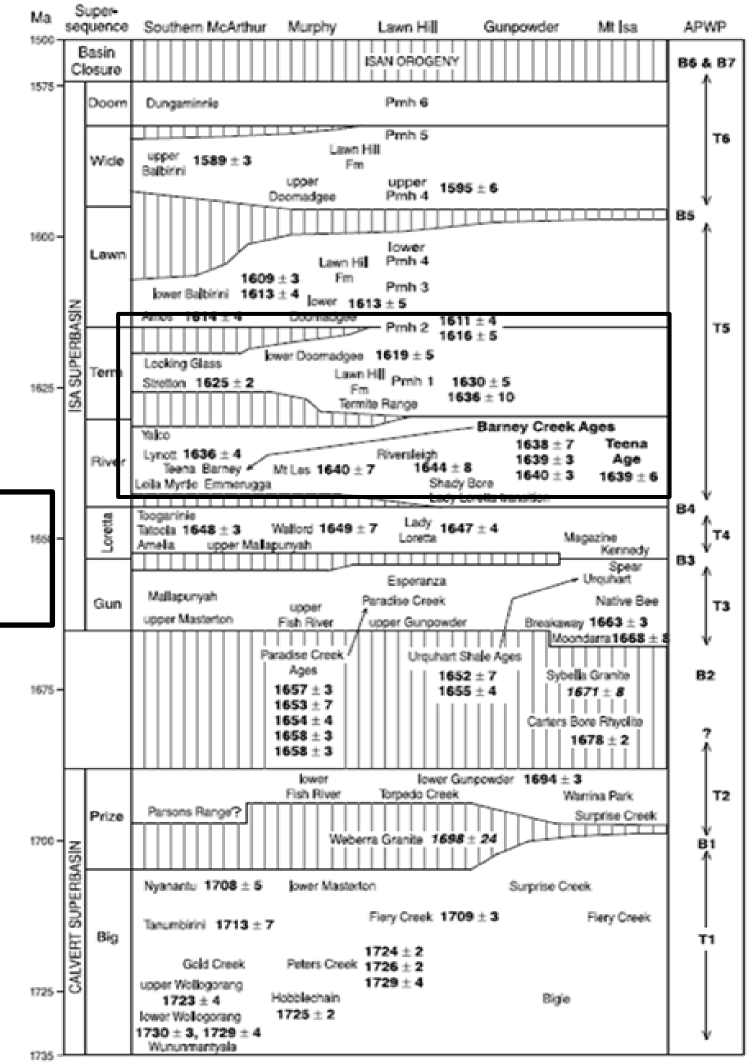


Shale Gas Production

Pilot testing Egilabria-2DW1

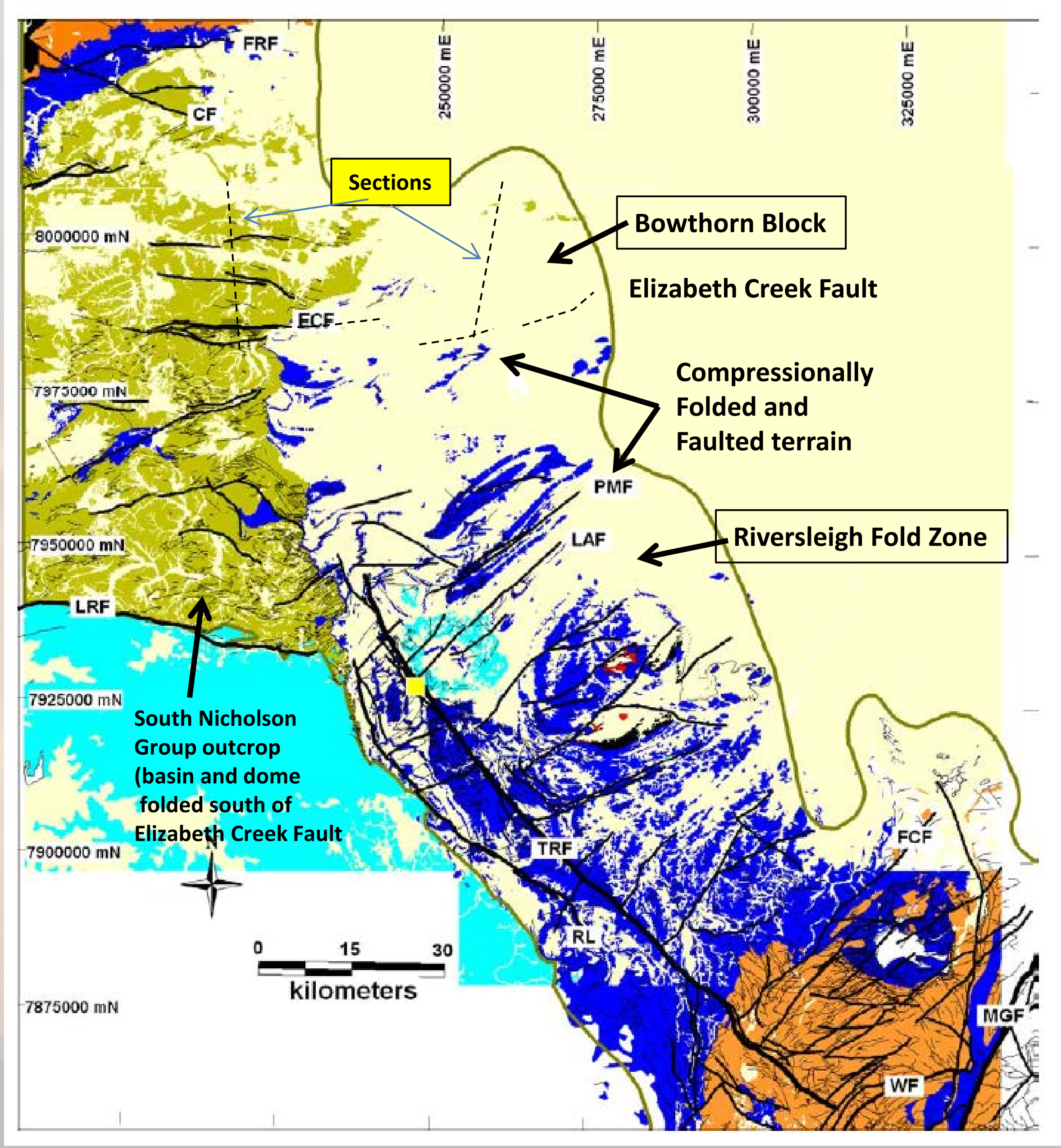
Assessed 22.5 trillion cubic feet (Tcf) of Mean Prospective Resource (gas) in the middle Proterozoic aged Lawn Hill Shale in ATP1087 (MBA Consultants). Additional gas prospectivity has now also been identified by Armour Energy in the underlying Riversleigh Shale that extends across the entire tenement.





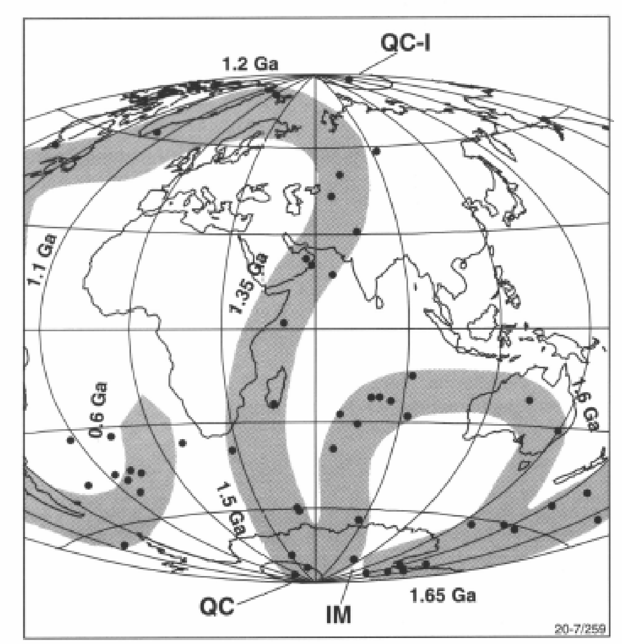
Chronostratigraphic basin framework for Palaeoproterozoic rocks (1730–1575 Ma) in northern Australia and implications for base-metal mineralisation. P. N. SOUTHGATE,1 B. E. BRADSHAW,1 J. DOMAGALA,2 M. J. JACKSON,1 M. IDNURM,1* A. A. KRASSAY,1 R. W. PAGE,1 T. T. SAMI,3† D. L. SCOTT,1 J. F. LINDSAY,1 B. A. McCONACHIE1§ AND C. TARLOWSKI1

Simplified geological map showing distributions of the major rock units by Group



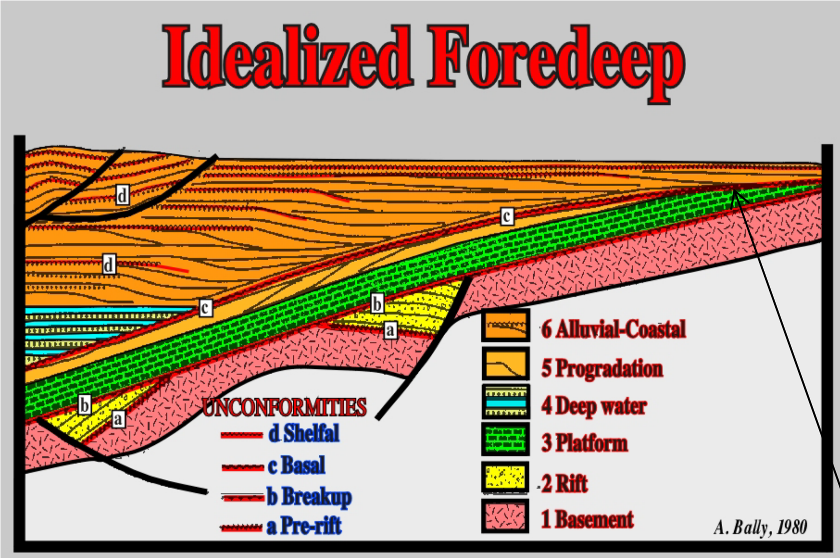
Map From: Structural architecture, 3D modelling and target generation in the Lawn Hill Platform, Queensland

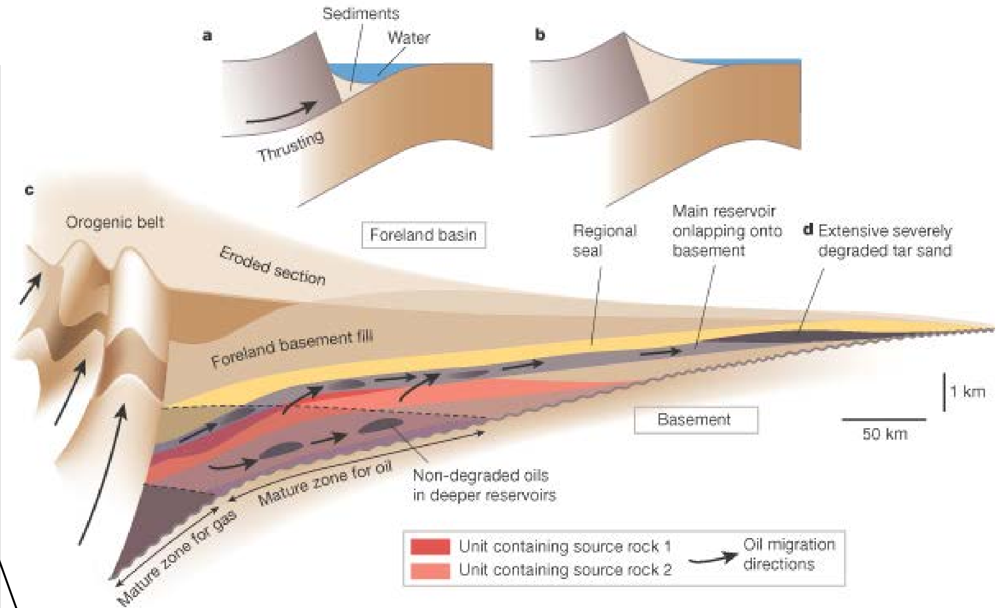
Barry Murphy, Laurent Ailleres, Ben Jupp, Lawrence Leader, Terry Lees and Indrajit Roy



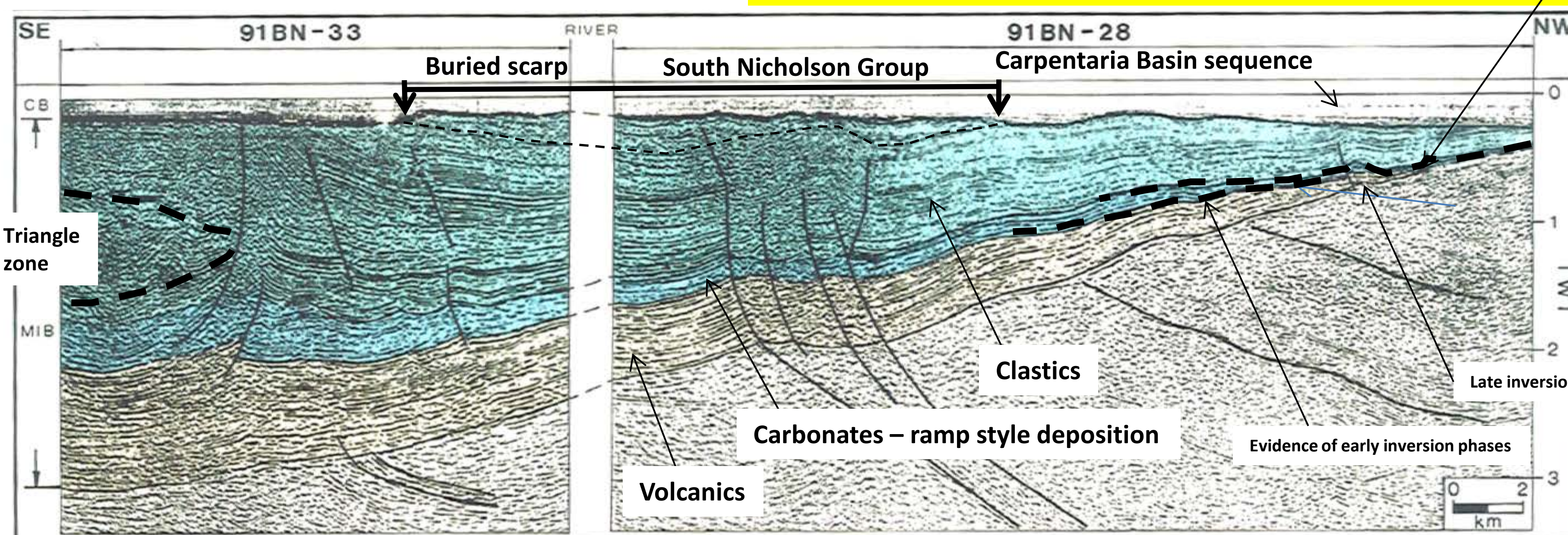
Palaeomagnetism and mineral exploration related studies in Australia: a brief overview of Proterozoic applications

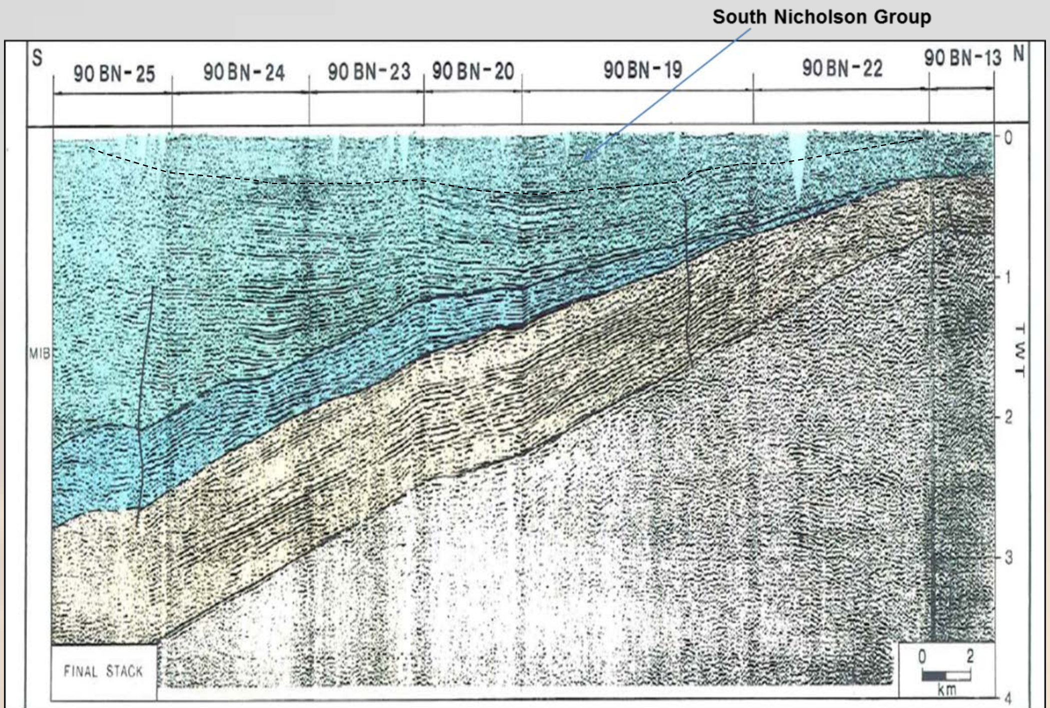
Mart Idnurm & Lesley Wyborn





Penecontemporaneous basin erosion/uplift orogenesis (flexural inversion)
1650-1670Ma About the same time as Broken Hill/Cannington/Mount Isa



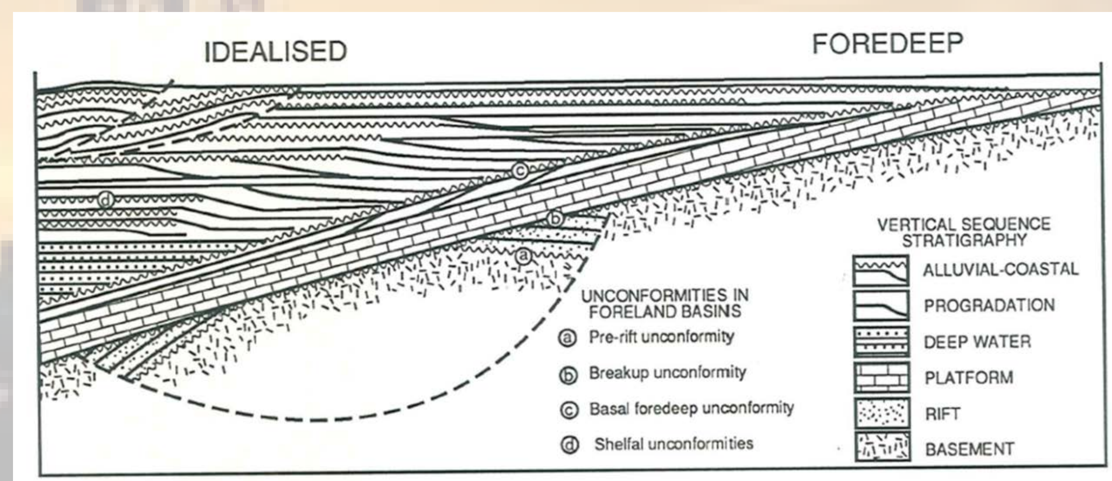


Isa Superbasin (1670–1590 Ma)

The Isa Superbasin is best represented on the Lawn Hill Platform where it comprises 8km of rhythmically-bedded turbidites, carbonaceous shales and stromatolitic dolostone deposited in a shallow to deep water marine environment (Hutton and Sweet, 1982; Krassay et al., 2000).

George M. Gibson1, Paul A. Henson1, Narelle L. Neumann1, Peter N. Southgate1 and Laurie J. Hutton2
Paleoproterozoic–earliest Mesoproterozoic basin evolution in the Mount Isa region, northern Australia and implications for reconstructions of the Nuna and Rodinia supercontinents

McConachie BA, Barlow MG, Dunster JN, Meaney RA and Schaap AD, 1993. The Mount Isa Basin – definition, structure and petroleum geology. *The APEA Journal* 33, 237–257.



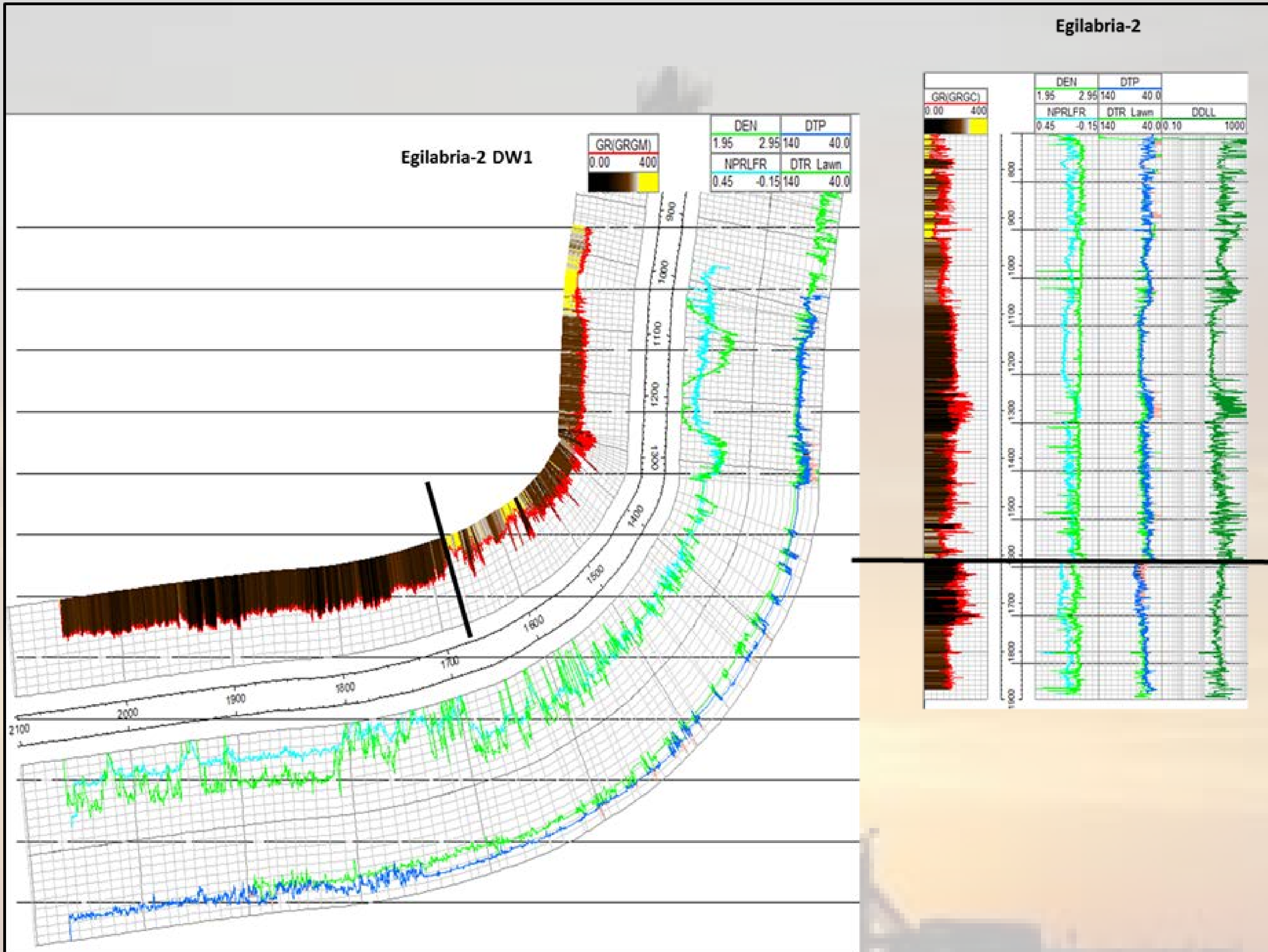
Outcrop scarp

Base of South Nicholson Group in outcrop

West of the seismic line

Isa Superbasin

(mainly unconformable contact but conformable on most seismic lines)

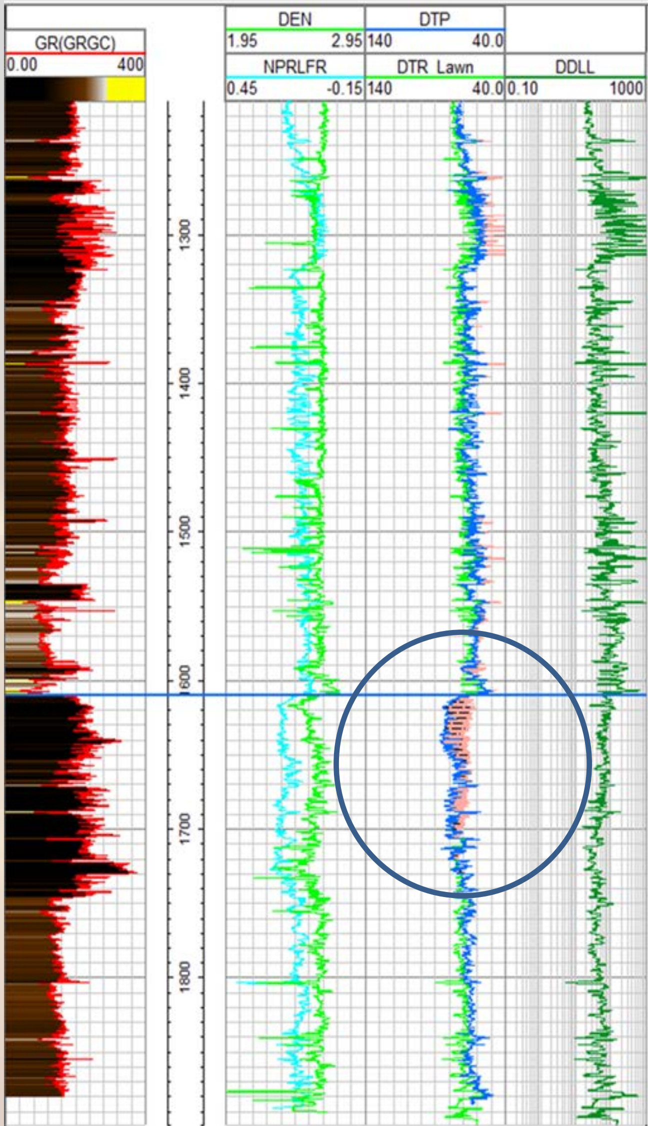


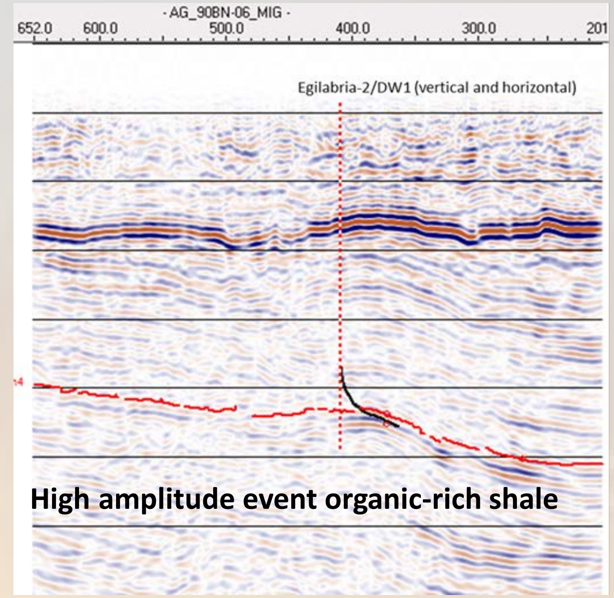
Well path section showing Egilabria 2 hydraulically stimulated DW 1 lateral and Egilabria 2 vertical intersecting Top Lawn Formation

Egilabria 2

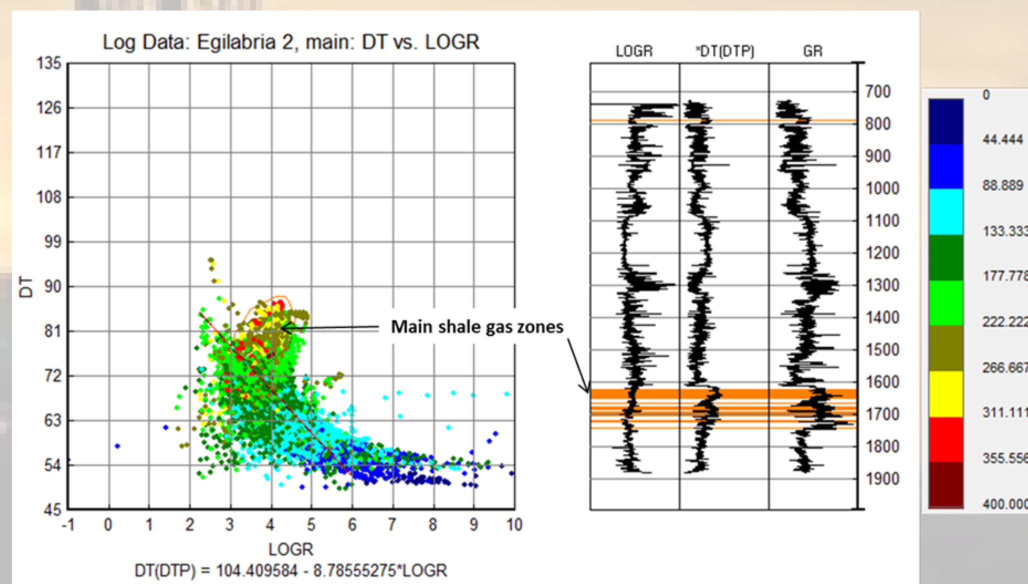
Modified ΔLogR technique

To identify potential hydrocarbon bearing shale intervals





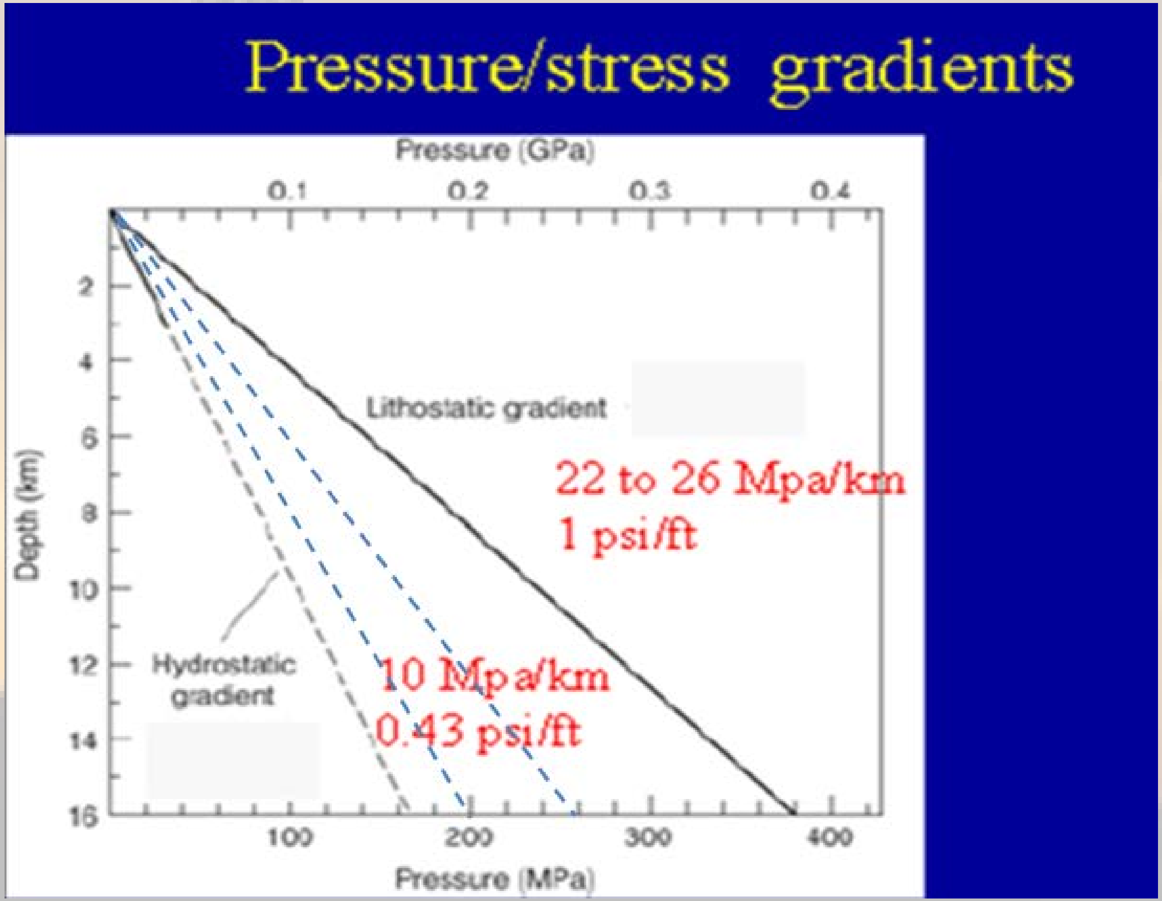
Top Lawn 1610.1m MD



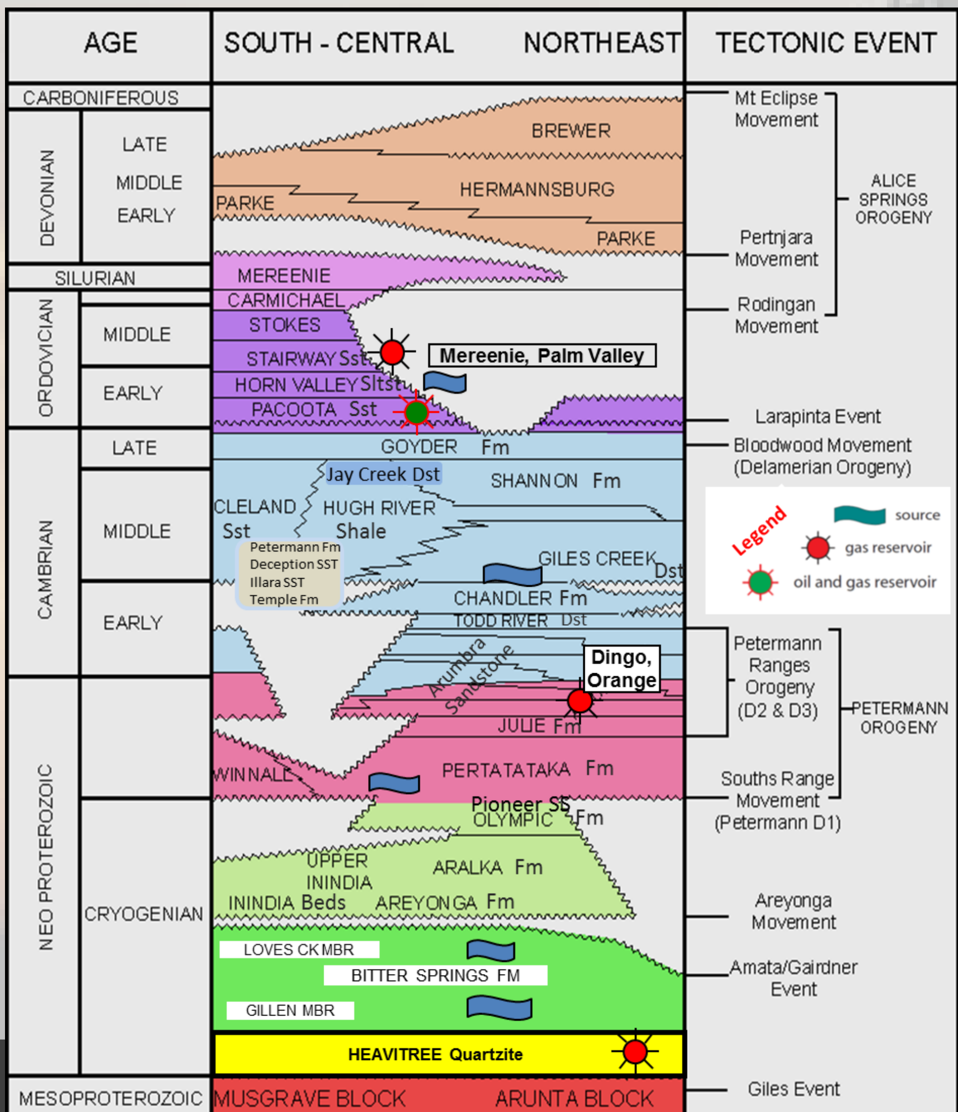
SRK Consulting analysis

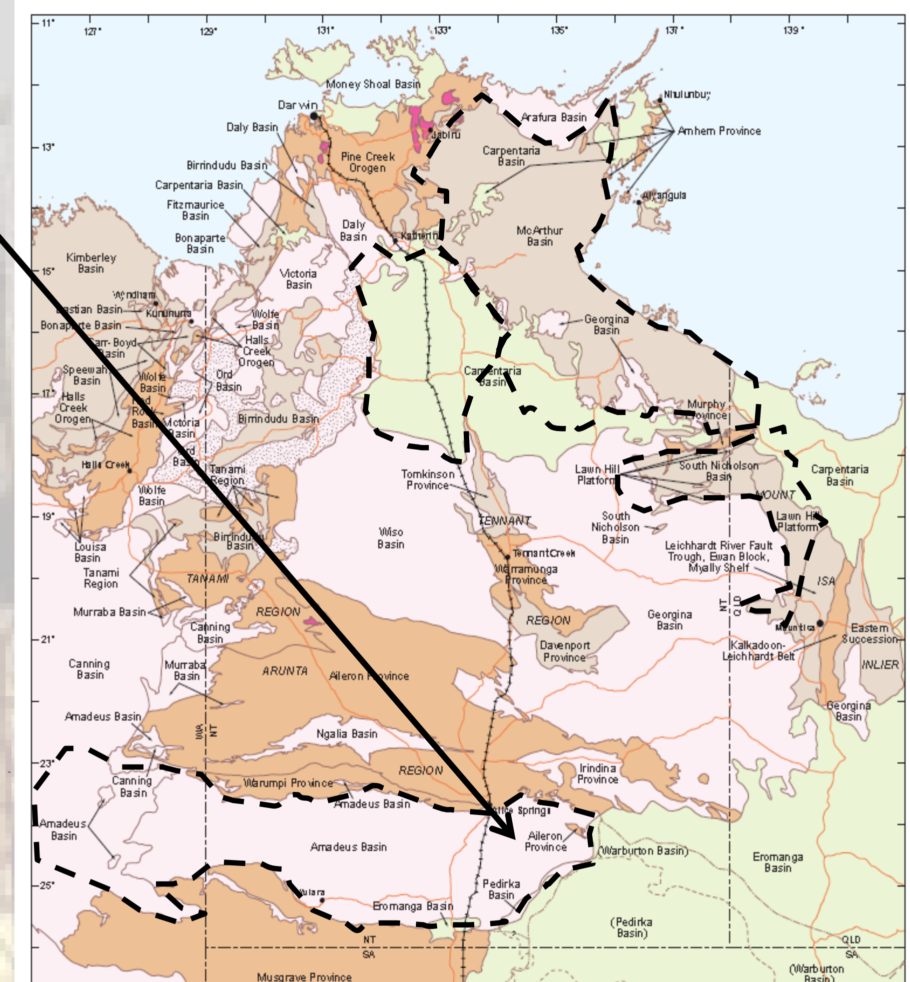
Hydrocarbon containment can occur via pore space and pressure plus via adsorption.

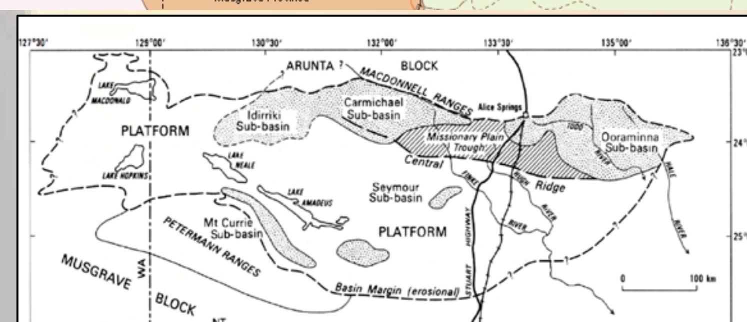
High TOC rocks form Proterozoic basins tend to be brittle suggesting extensive clay dewatering. Pressure gradients are commonly close to hydrostatic.

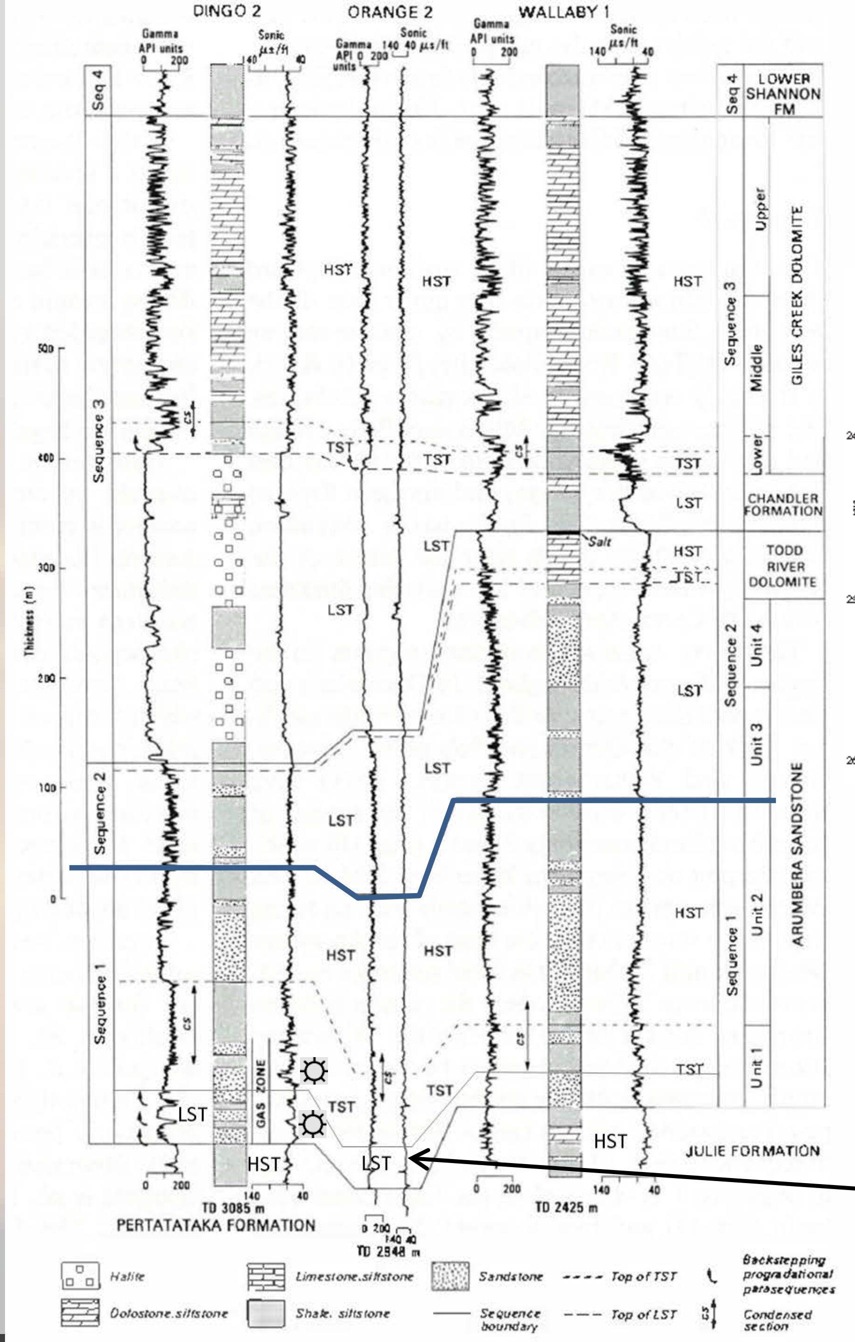


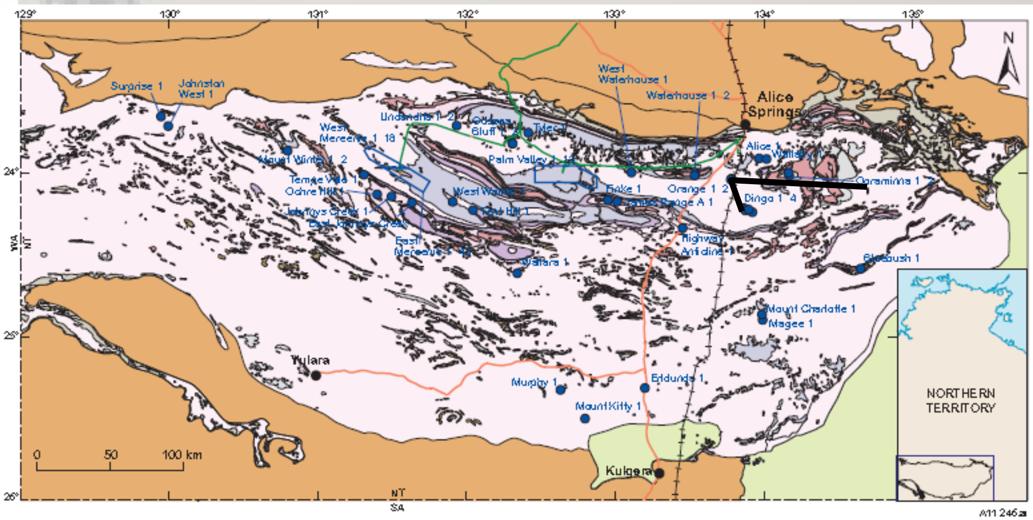
Amadeus Basin



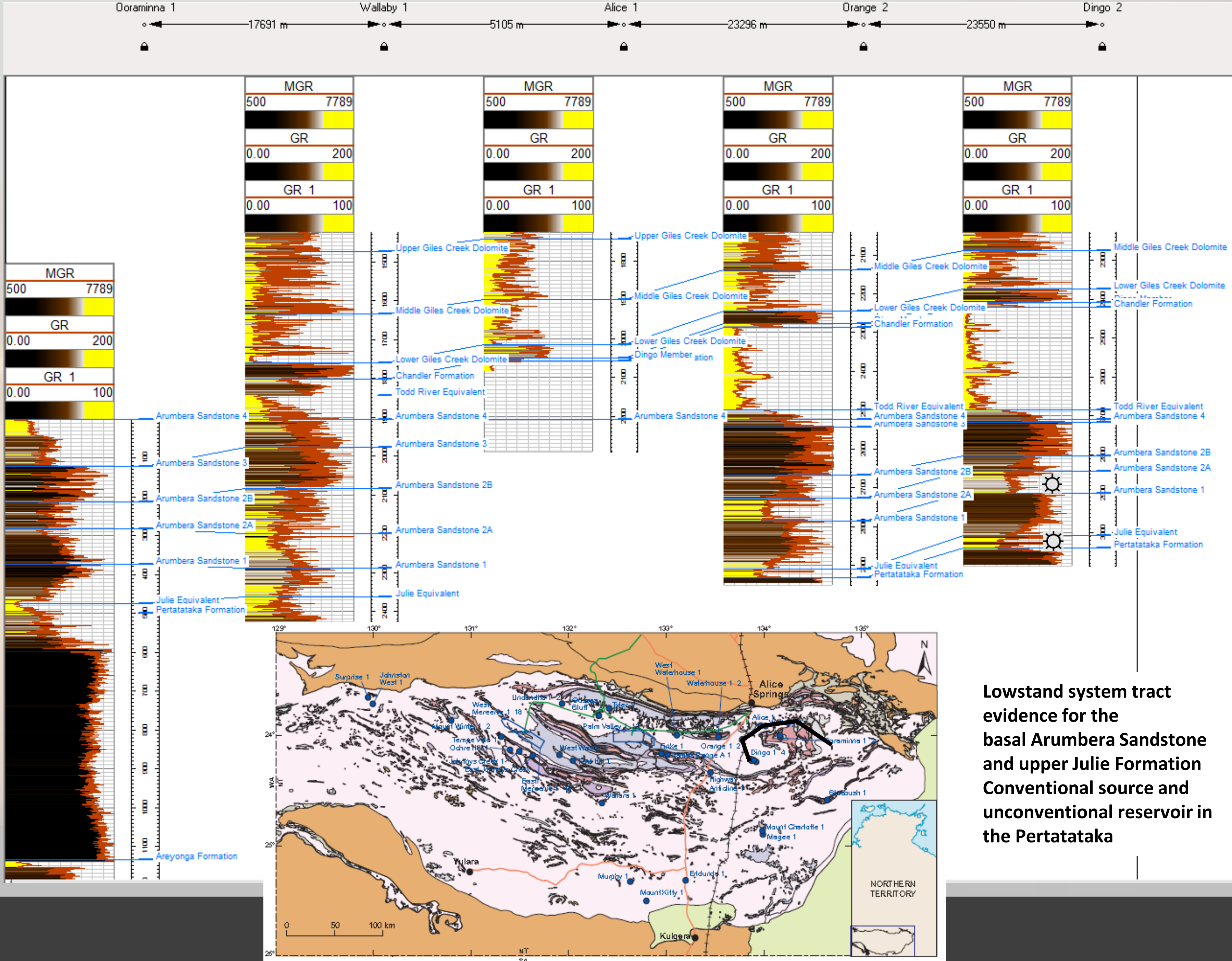




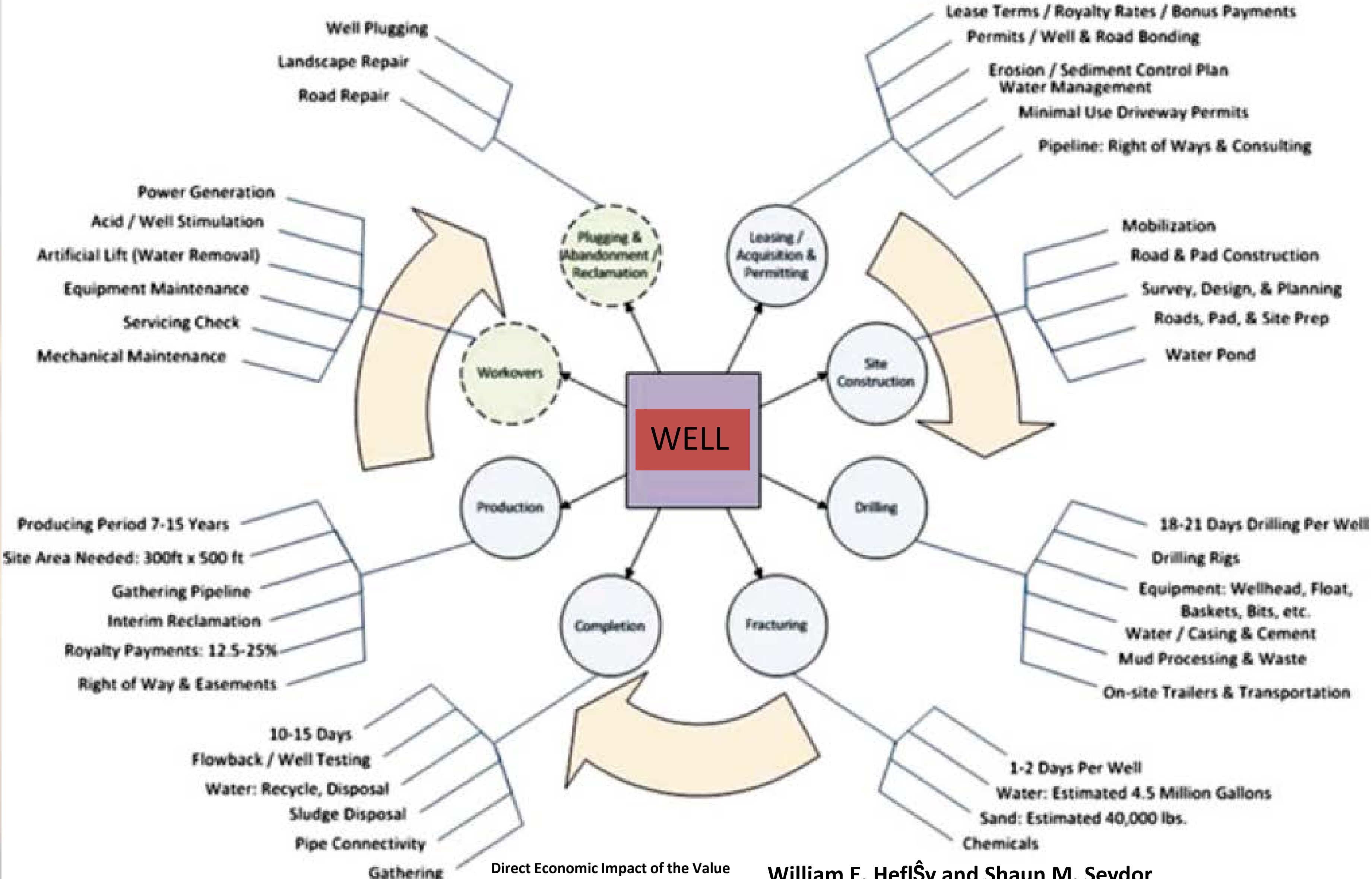




Lowstand system tract evidence - basal Arumbera Sandstone



Lowstand system tract evidence for the basal Arumbera Sandstone and upper Julie Formation Conventional source and unconventional reservoir in the Pertatataka



Direct Economic Impact of the Value Chain of a Marcellus Shale Gas Well

William E. HeflŜy and Shaun M. Seydor

Conclusions

- Vast volumes of organic-rich rocks are known in many Proterozoic basins in Australia
- Hydrocarbons occur today in the form of oil and gas shows and pilot tests/DSTs have demonstrated hydrocarbon production from both conventional and unconventional systems
- Most older basins have pressure regimes close to hydrostatic and the largest volumes of hydrocarbons discovered to date occur mainly as adsorbed gases
- Australia's old rocks can prove their worth – but they will do it based on their unique characteristics

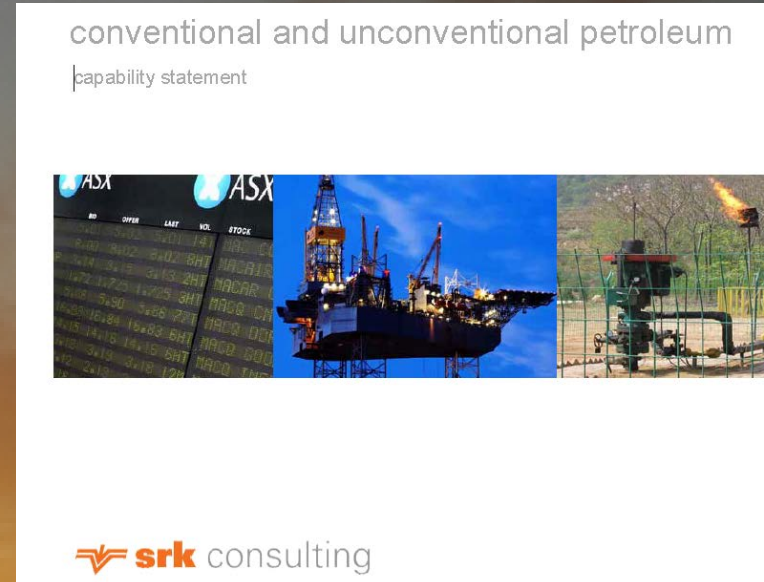
Pilot testing Egilabria-2DW1 Isa Superbasin

Unconventional hydrocarbons
- Australia's old rocks prove their worth

Acknowledgements

Armour Energy Ltd

SRK Consulting Australia



SRK Recent <u>Unconventional Project</u> experience in Shale Gas, Coal Seam Gas and Tight Gas

Australia >16 projects
China 3 projects
USA 1 project
Canada 1 project
Botswana 1 project
South Africa 1 project

Thankyou for your attention