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Exploring for the Future:

new geomechanical data in frontier Australian basins

Adam Bailey*, David Dewhurst, Liuqi Wang, Chris Carson, Jade Anderson, Grace Butcher and Paul Henson

EFTF: New geomechanical data in frontier basins

- Background
- New data
- Regions of Interest
  - The Paleo-Mesoproterozoic **South Nicholson region**
  - The Paleozoic **Canning Basin**
  - The Neoproterozoic-Paleozoic **Officer Basin**
  - The Paleo-Mesoproterozoic **Birrindudu Basin**
- Key learnings
- Summary and wrap-up

Background – what?

- New geomechanical work under EFTF
  - Stress modelling
  - Shale brittleness studies
  - **Laboratory analysis:**
    - **Newly acquired samples**
    - **Legacy rock samples**

These data form a foundational dataset in a modern exploration setting, as progress is made towards a net zero energy future.

Background – why?

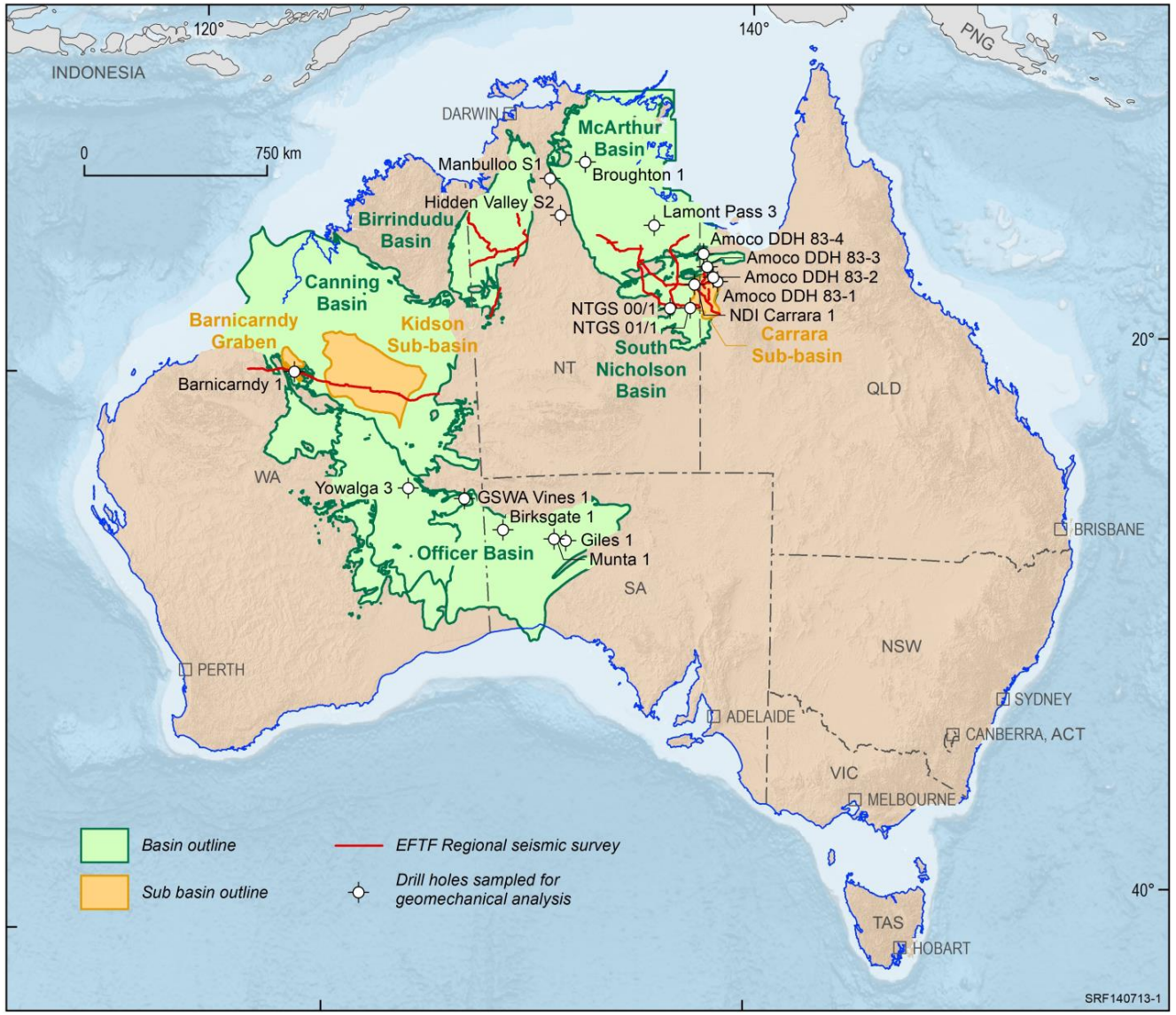
- Understanding rock properties and in-situ stresses is essential in low permeability systems.
- These factors have a primary control over fluid flow pathways.
  - *Encouraging* or *limiting* creation of hydraulic fractures, dependent on requirement.
- Also have implications for borehole stability, enhanced oil recovery and fault reactivation.
- Fundamentally, a detailed understanding of geomechanical rock properties allows for interpretations of hydrocarbon prospectivity as well as suitability assessments for geological storage.

New data – Rock properties

- Elastic rock properties (e.g. Poisson's ratio, Young's modulus) are required for modelling stress, strain and deformation.
- Measured two main ways:
  - *Static method* – laboratory testing through application of force.
  - *Dynamic method* – ultrasonic velocities are measured, and property calculated.
- Differences in the two measurements due to inelastic effects.
- Static moduli are generally slightly lower than dynamic moduli. However, variations of up to an order of magnitude are not uncommon.
- Typically, there is no direct relationship between static and dynamic Poisson's ratio.

Regions of Interest - Analyses

- Analyses undertaken vary by region, primarily due to factors such as
  - Availability of suitable sample material and
  - Sample accessibility.
- E.g: The drillholes NDI Carrara 1 and Barnicarndy 1 were sampled remotely due to COVID-19 related travel restrictions.
- Birrindudu Basin sampling restricted due to most available samples being from small-gauge, shallow drill cores.
- Sampling in all locations was affected by core condition, particularly for older cores that have been in storage for significant lengths of time.



Regions of Interest - Analyses

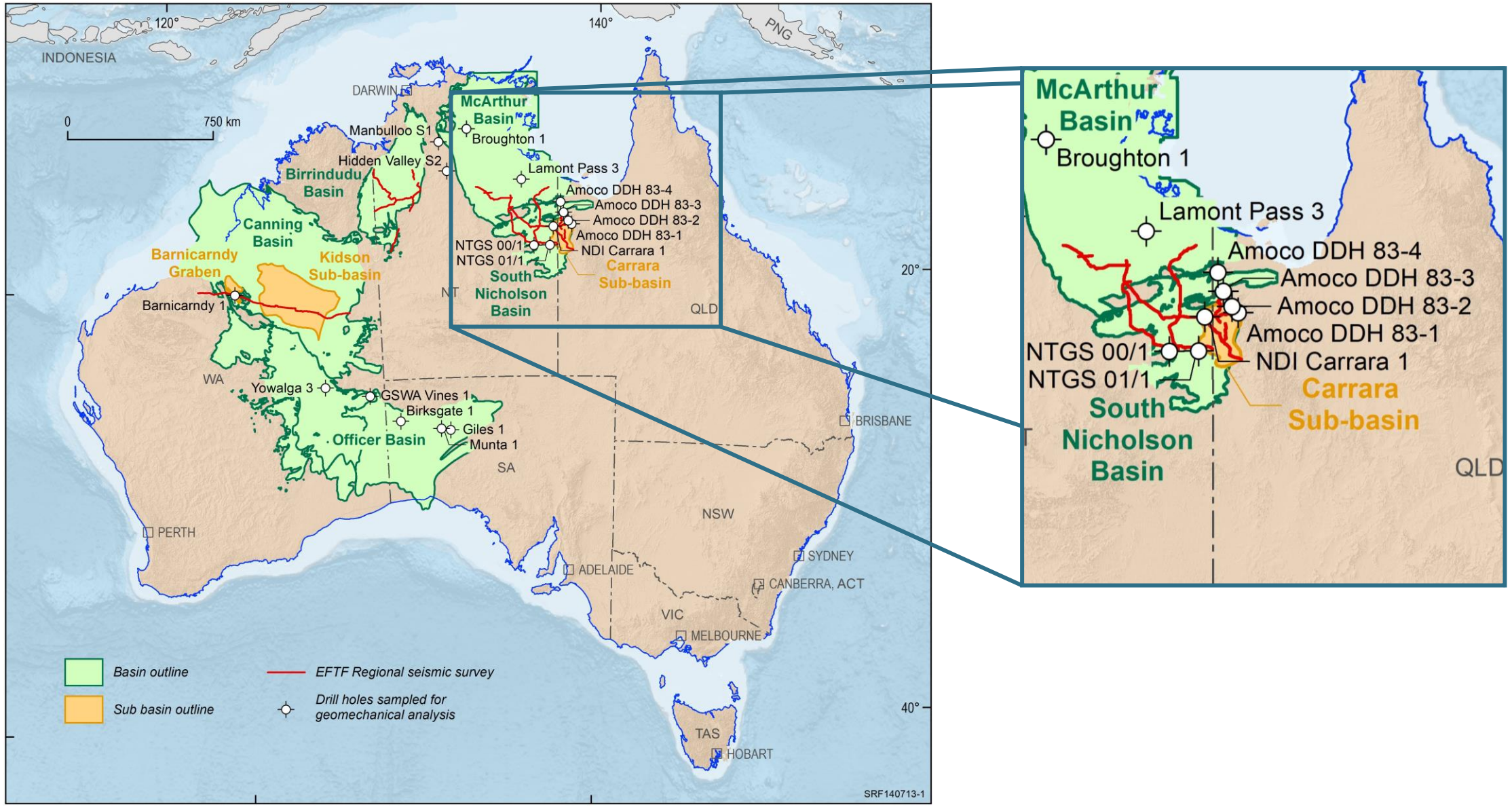
Analysis targeted reservoir-seal pairs as much as practical, to acquire the following data:

- Unconfined compressive strength (UCS) parameters;
- Stress–strain–time curves for UCS experiments;
- Tensile strength characteristics;
- Static elastic properties, Young's modulus (E) and Poisson's ratio (v);
- Dynamic elastic properties, velocity, Vp/Vs ratio, Young's, bulk and shear moduli plus Poisson's ratio.

Where further data were desired (and material was available) multi-stage triaxial tests were undertaken.

Where sample material was limited, attempts were made to acquire discs suitable for Brazilian tensile strength tests.

Regions of Interest – South Nicholson region



Regions of Interest – South Nicholson region

A key EFTF study area:

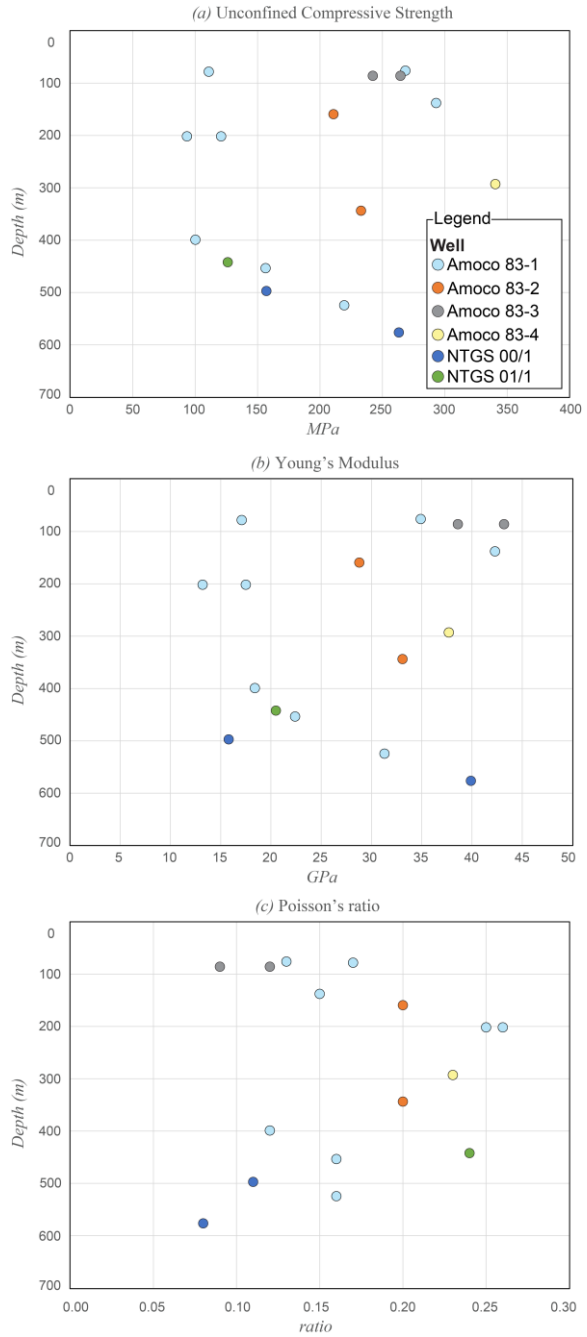
- Extensive legacy analyses
- Two new regional deep-crustal seismic surveys
- A deep stratigraphic drillhole

Geomechanical rock property data from 14 core samples (Paleo- to Mesoproterozoic section) from five legacy stratigraphic drill holes.

Samples were subjected to:

- Unconfined compressive rock strength tests,
- laboratory ultrasonic measurement
- X-ray computerised tomography scanning.

Background, methods and results are summarised in Jarret et al. (2020).



Regions of Interest – South Nicholson (NDI Carrara 1)

Drilled in 2020 in partnership with NTGS and MinEx CRC

- Total depth = 1751 m
- Proterozoic from ~630 m depth
- Dated equivalent to Lawn Hill Formation, Northern Lawn Platform

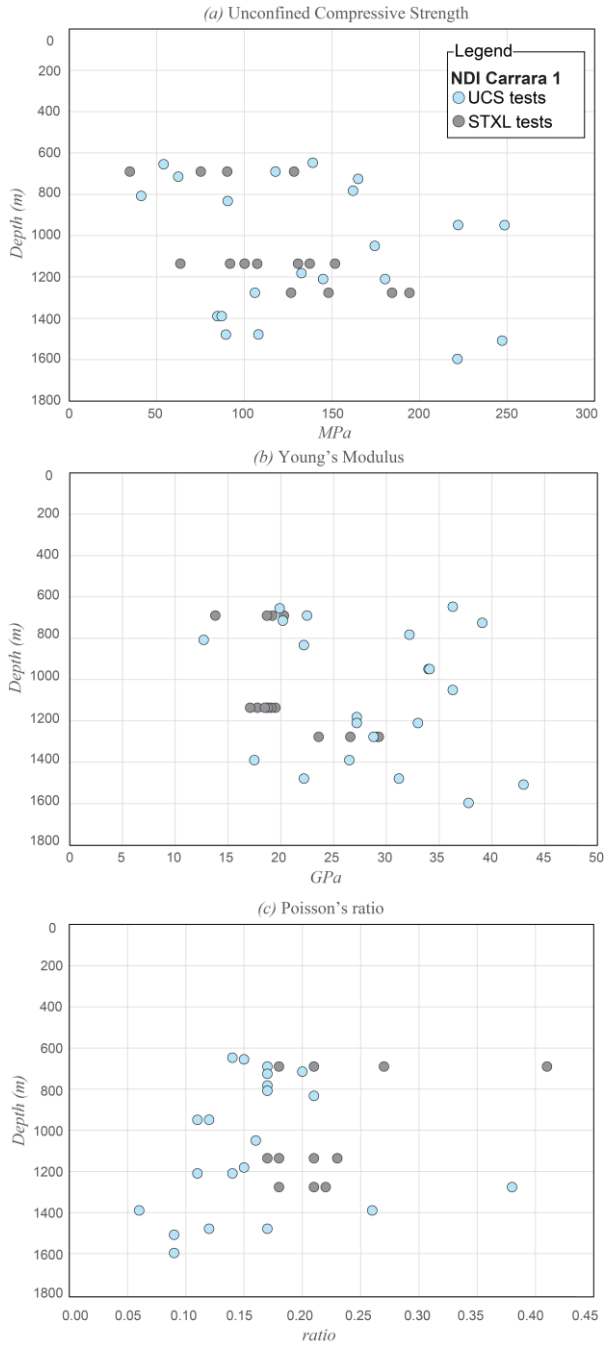
Eighteen samples selected for geomechanical testing, from which 36 plugs were extracted for analysis

Samples were subjected to:

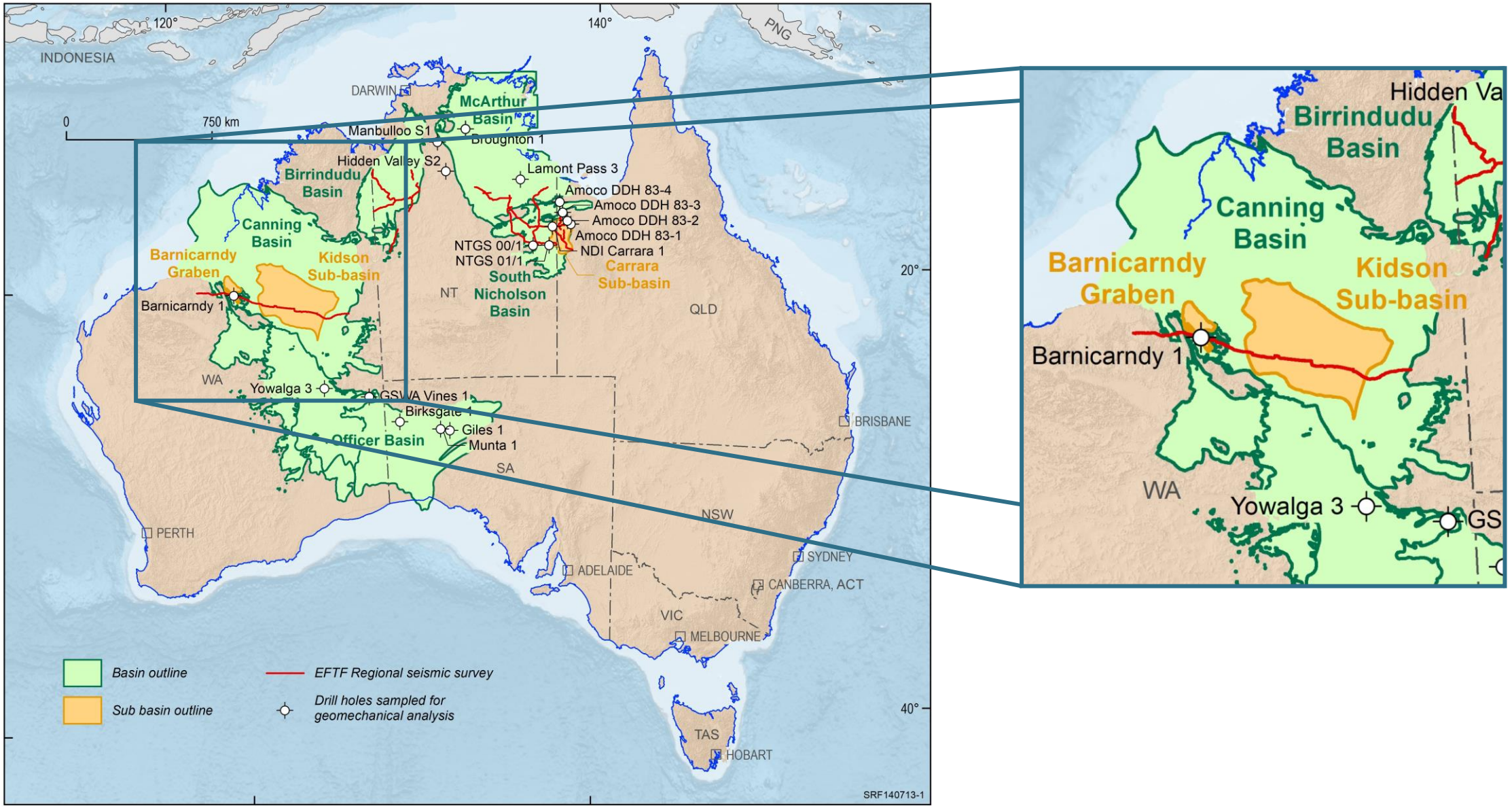
- Unconfined compressive rock strength tests,
- Repeat single-stage triaxial testing
- laboratory ultrasonic measurement

Petrophysical properties were characterised and overlap with the geomechanical samples

Background, methods and results are summarised in Bailey et al (2021).



Regions of Interest – Canning Basin



Regions of Interest – Canning Basin

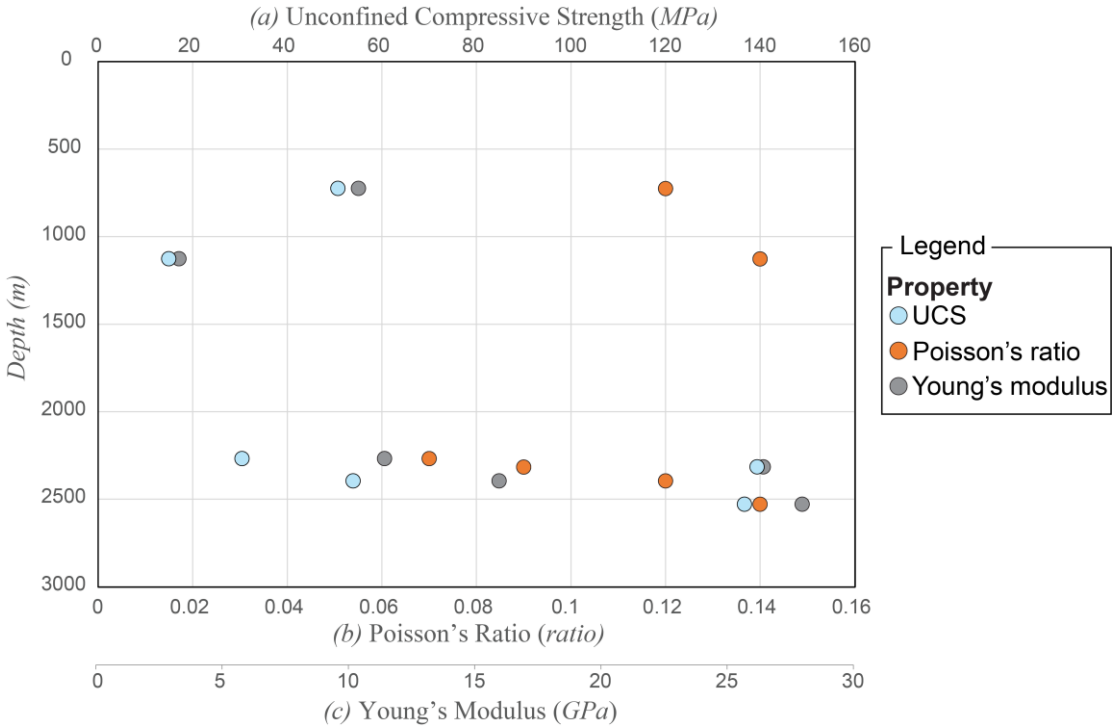
Analyses focussed entirely on Barnicarndy 1

- Deep stratigraphic drillhole funded by EFTF and GSWA
- Located in Barnicarndy Graben
- Total depth = 2681 m

Three potential reservoir-seal pairs were sampled for analysis

Samples were subjected to:

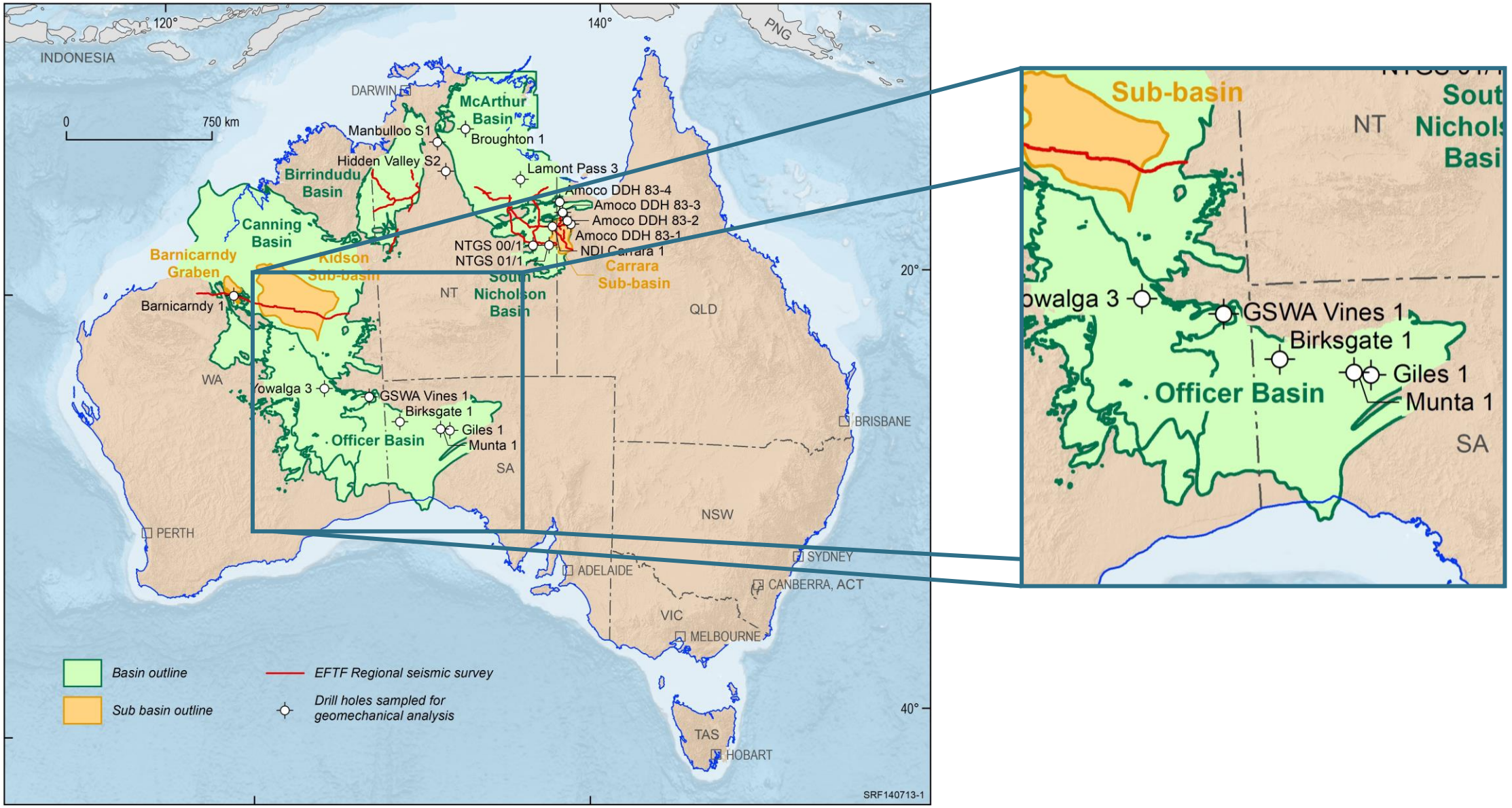
- Unconfined compressive rock strength tests,
- Laboratory ultrasonic measurement



Petrophysical properties were characterised and overlap with the geomechanical samples

Background, methods and results are summarised in Jarrett et al (2020).

Regions of Interest – Officer Basin



Regions of Interest – Officer Basin

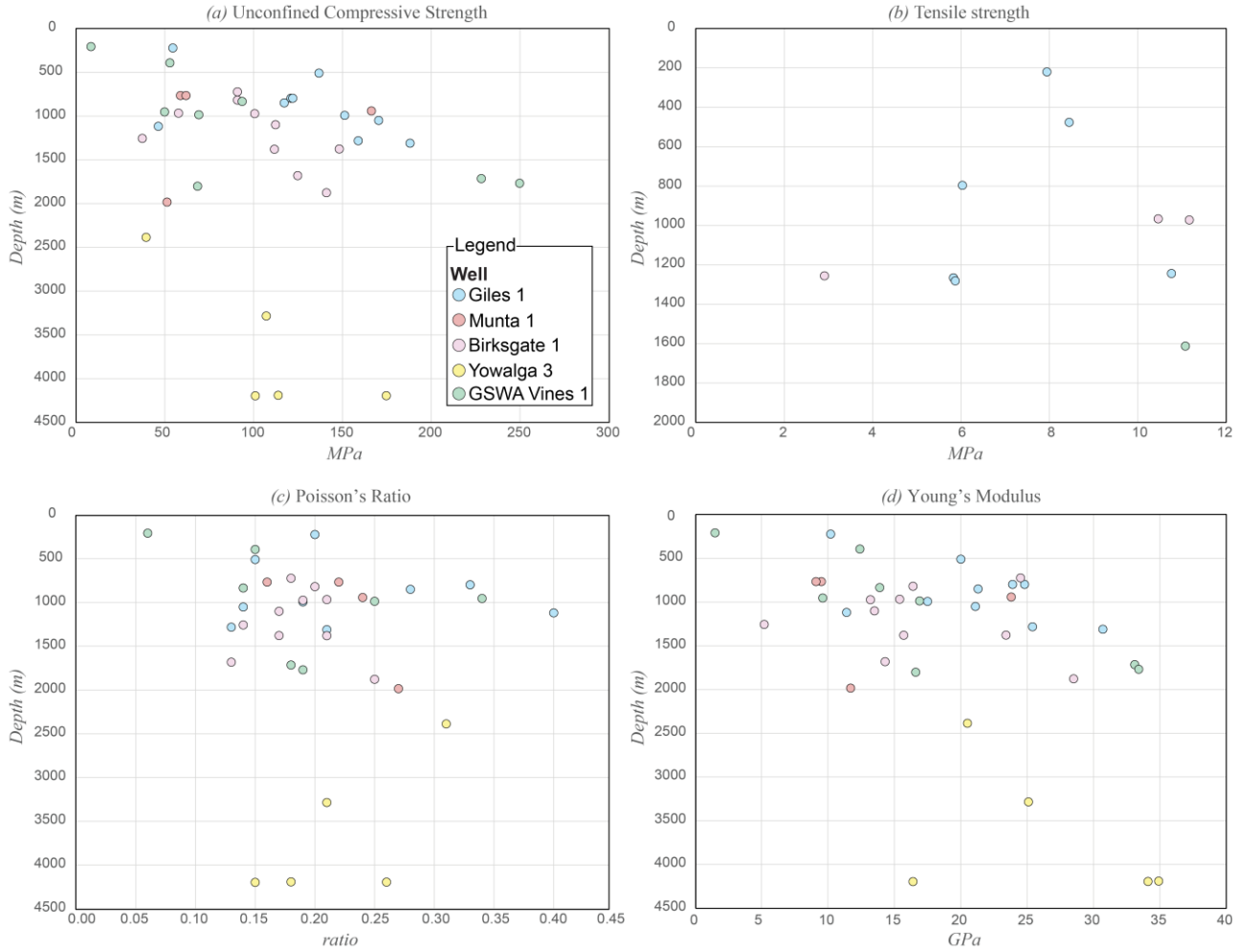
EFTF Officer-Musgrave-Birrindudu program

- Numerous hydrocarbon shows
- Neoproterozoic- Paleozoic
- Frontier basin due to significant undertainties and data quality issues.

Forty core samples from five legacy drillholes were subjected to:

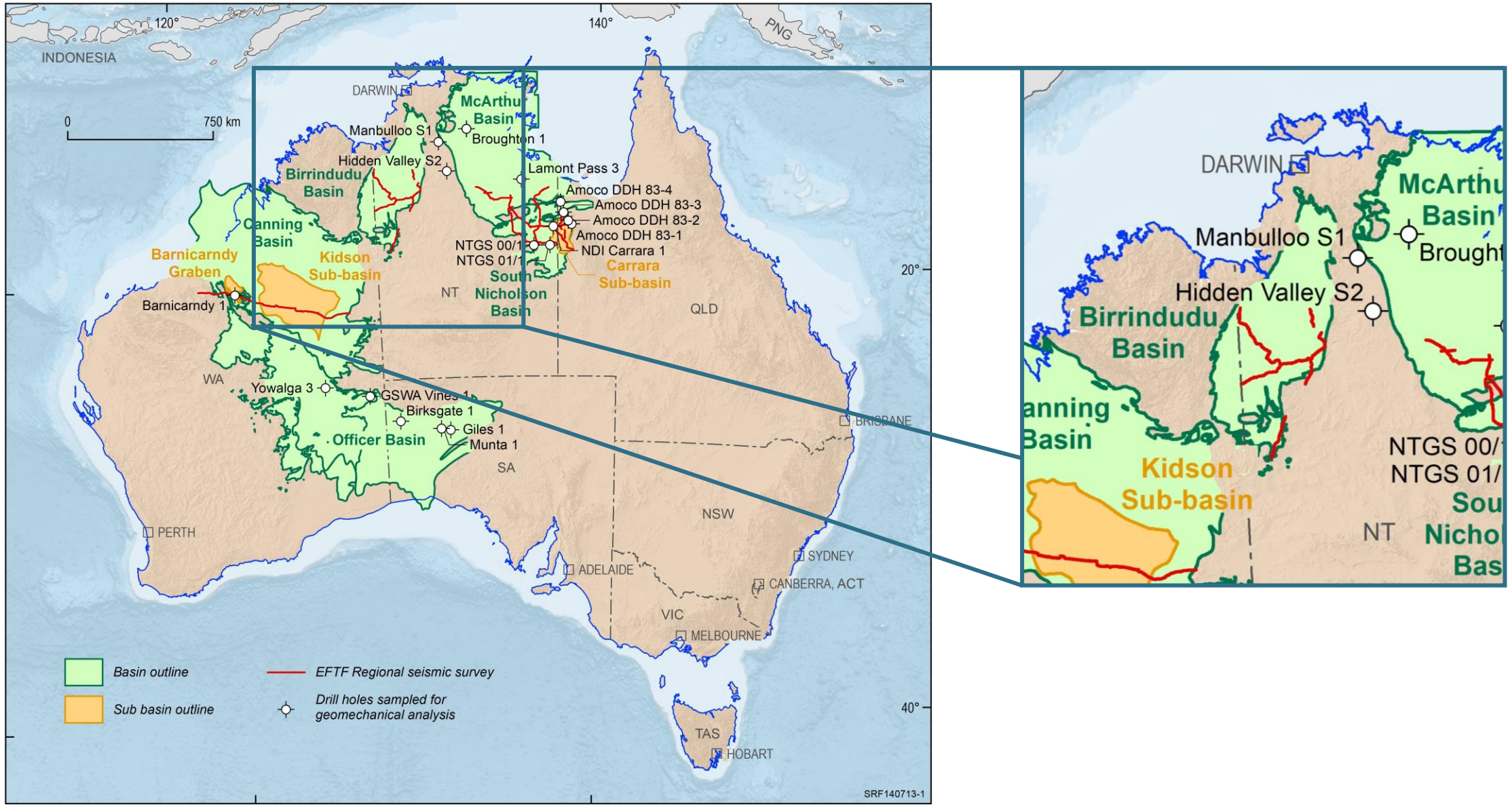
- Unconfined compressive rock strength tests,
- Brazilian tensile strength tests
- laboratory ultrasonic measurement

Petrophysical properties were also characterised and overlap with the geomechanical samples



Background, methods and results are summarised in Bailey et al (2021).

Regions of Interest – Birrindudu Basin



Regions of Interest – Birrindudu Basin

Underexplored, frontier basin studied under EFTF

- Hosts strata of similar age to the McArthur Basin, South Nicholson region and Mount Isa Province – continuous on seismic.
- EFTF and NTGS collaborated to acquire the Northwest Northern Territory Seismic Survey in 2023

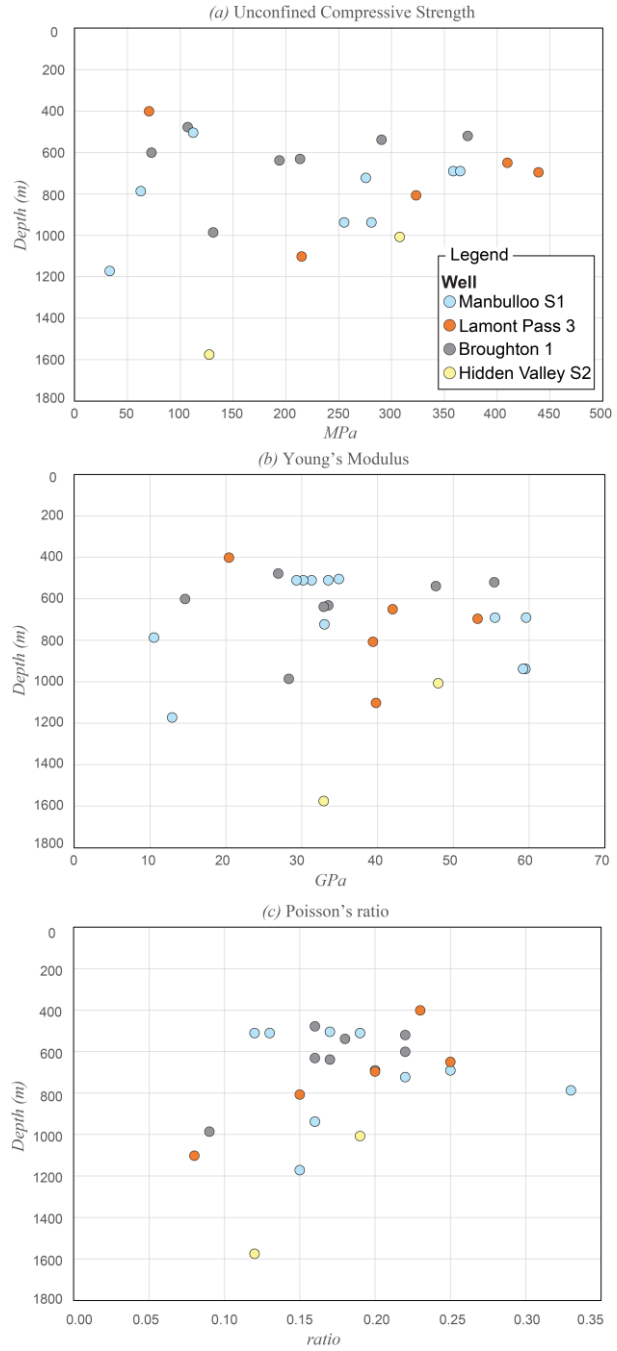
22 samples from four legacy drill holes in the Birrindudu Basin and surrounding regions.

Samples were subjected to:

- Unconfined compressive rock strength tests,
- Repeat single-stage triaxial testing

Petrophysical properties were characterised and overlap with the geomechanical samples

Background, methods and results are summarised in Anderson et al (2024).



Key Learnings – Correlating static and dynamic data

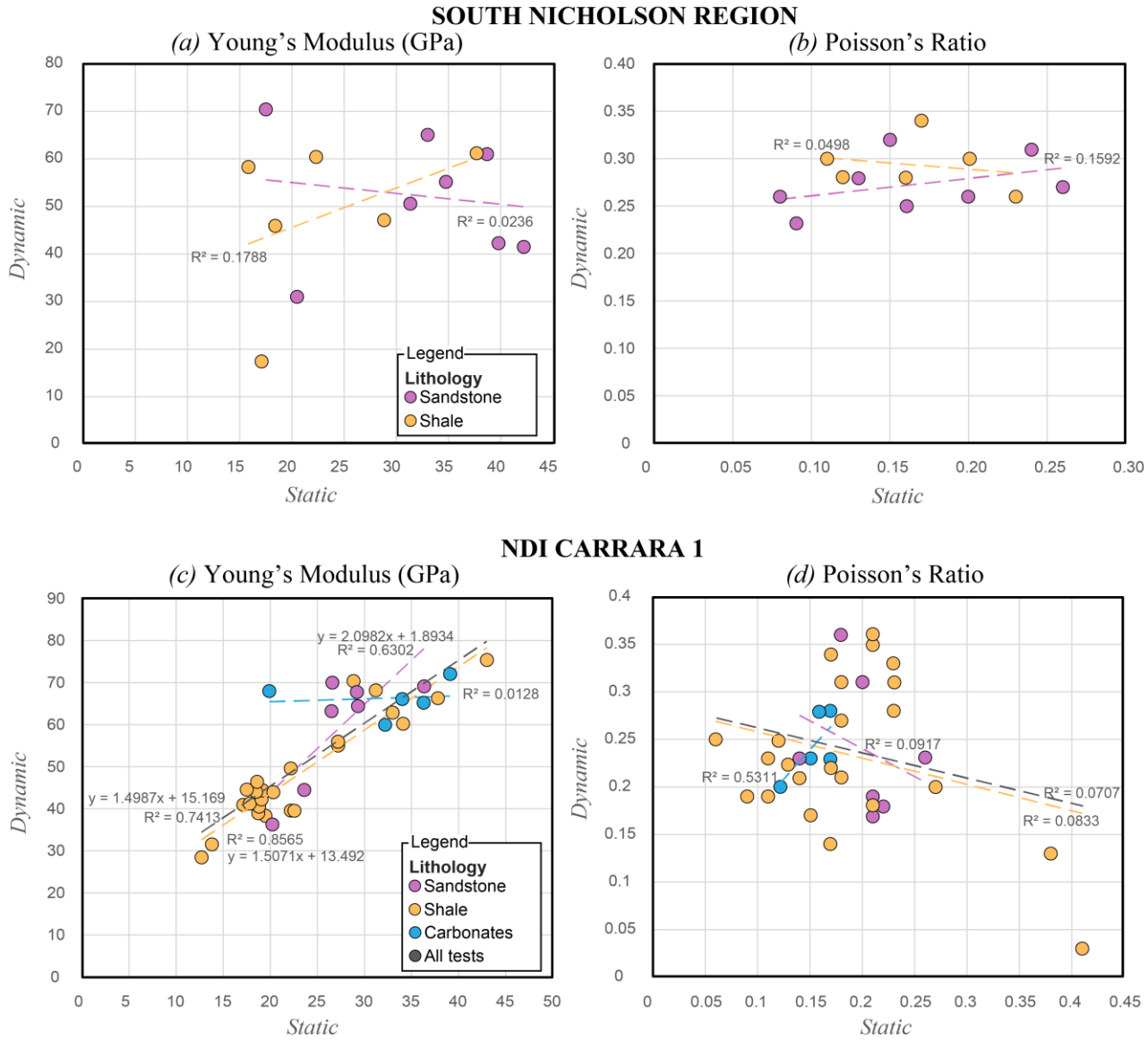
Static data are expensive and so often rarely acquired, particularly in frontier areas. Wireline sonic is common.

- Cross-plots can illustrate the relationships between these parameters.
- Appropriate data was acquired in three of the four regions in this study.
- Relationships vary from poor to good (for Young's Modulus).
- No meaningful relationships are established for Poisson's Ratio.
- Stronger relationships are observed where there are larger sample sizes.
- Stronger relationships are observed within well-defined datasets.

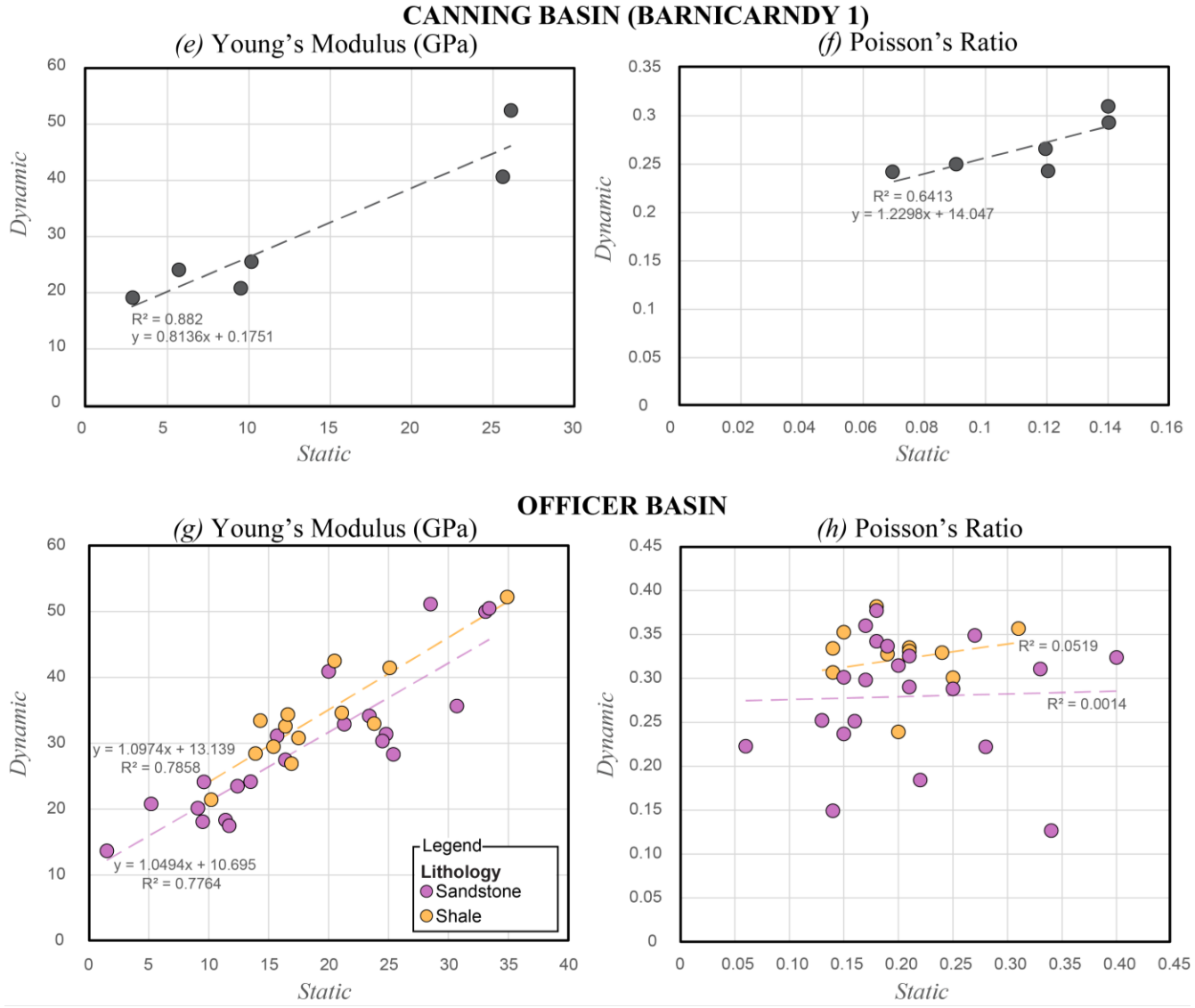
Lithology-specific conversions from dynamic to static Young's modulus are provided for each basin/area.

These are available in the associated publication now available in this year's AEP Journal.

Key Learnings – Correlating static and dynamic data



Key Learnings – Correlating static and dynamic data



Key Learnings – Shales, sands, and failure

Elastic and strength properties separate the study areas into two zones:

- Regions where results are typical for lithology, porosity, and depth (Younger basins - Canning and Officer), and;
- Regions with elevated strength and stiffness (Proterozoic basins – Birrindudu and South Nicholson region).

Where we see high Young's modulus, high UCS, and low Poisson's ratio…

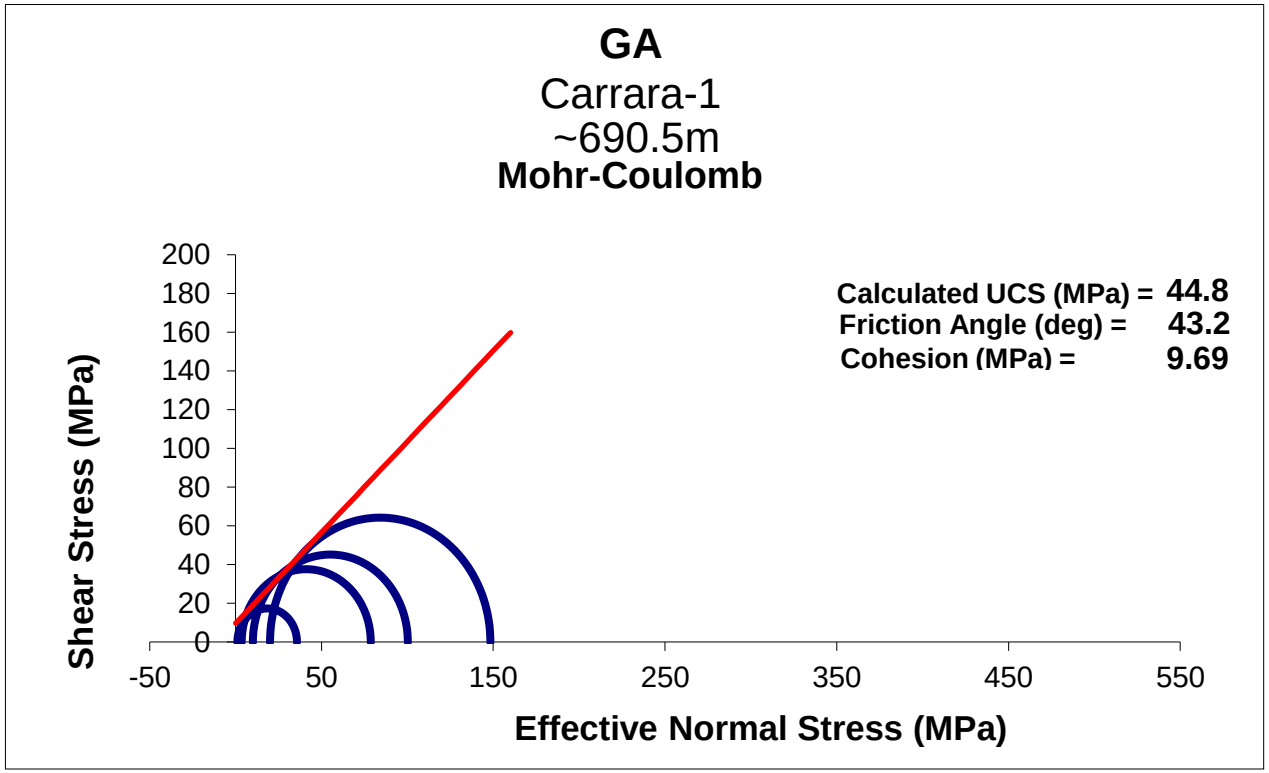
- Testing results imply these intervals are strong but brittle.
- Shales in particular display brittle behaviour
- Stress–strain curves highlight pronounced peak strengths, followed by fracturing and zero load-bearing capacity

Triaxial tests allow construction of failure envelopes (NDI Carrara 1)

- NDI Carrara 1 – demonstrate significant changes in effective stress required to cause failure
- Consistent with high UCS and Youngs Modulus.

Birrindudu triaxial tests did not yield reliable results

- Variability in failure strength due to heterogeneities.
- UCS testing results demonstrate high Young's modulus and low Poisson's ratios.



Summary and wrap-up

- The EFTF program has delivered significant volumes of new precompetitive geomechanical data.
  - Laboratory analysis of both legacy and new samples.
  - Four regions were analysed.
  - Sampling focussed on units with potential as reservoirs and/or seals within postulated un/conventional systems.
  - Primarily focussed on UCS testing to acquire static elastic and strength properties, and where possible, dynamic measurements also.
  - This allowed for the establishment of empirical relationships between static and dynamic values of key parameters such as Young's modulus and Poisson's ratio.
- Test results split into two categories:
  - regions where results are typical for the lithology, and;
  - regions with elevated strength and stiffness.
- Majority of samples display brittle characteristics during failure and, while strong, ***may react brittlely to significant changes in effective stress.***

Summary and wrap-up

- Static data are expensive to acquire and so often sparse, **especially in frontier regions**.
- The data from EFTF forms a precompetitive resource that can:
  - Facilitate investment decisions in frontier regions,
  - Help to identify elements of conventional and unconventional hydrocarbon systems,
  - Enable modelling of in-situ stresses and rock failure, and;
  - provide essential data to assess geological storage opportunities.

Massive thanks to **Vincent Crombez** and **Claudio Delle Piane** for their efforts sampling on our behalf

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Thank you

Particularly to our state and territory partners, CSIRO, and key collaborators.

Further information

www.ecat.ga.gov.au
www.portal.ga.gov.au
www.eftf.ga.gov.au

adam.bailey@ga.gov.au