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Geomechanical rock properties of the Officer Basin

Adam Bailey
Geoscience Australia

Australian Government
Geoscience Australia

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Geoscience Australia

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Adam H. E. Bailey[1], Liuqi Wang[1], David N. Dewhurst[2], Jade Anderson[1], Amber J. M. Jarrett[1], Lidena K. Carr[1], Paul A. Henson[1]

[1]Geoscience Australia, [2]CSIRO

Introduction

Sample photos pre- and post-test for test 3603. Sandstone from Munta 1, 1983.71 – 1983.81 m depth (GA sample ID 20212578). Core plug is 25.45 x 53 mm.

The Officer Basin spanning South Australia and Western Australia is the focus of a regional stratigraphic study being undertaken as part of the Exploring for the Future (EFTF) program, an Australian Government initiative dedicated to increasing investment in resource exploration in Australia. Despite numerous demonstrated oil and gas shows, the Officer Basin remains a frontier basin for energy exploration with significant uncertainties due to data availability.

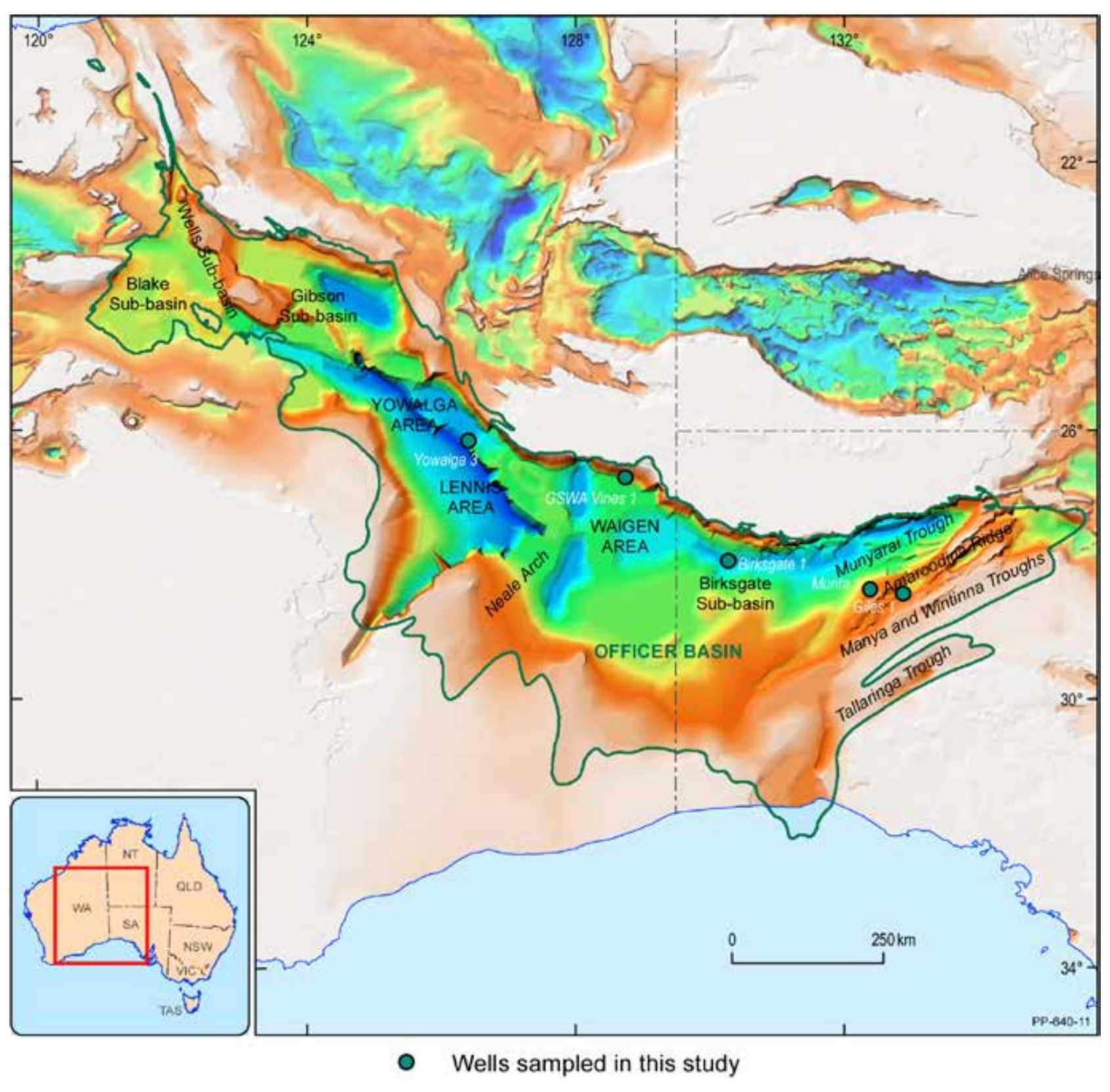
Under the EFTF Officer-Musgrave Project, Geoscience Australia acquired new geomechanical rock property data from forty coresamples in five legacy stratigraphic and petroleum exploration wells that intersected Paleozoic and Neoproterozoic aged intervals. These samples were subjected to unconfined compressive rock strength tests, Brazilian tensile strength tests and laboratory ultrasonic measurements. Petrophysical properties were also characterised via X-ray computerised tomography scanning, grain density and porosity-permeability analysis.

Accurate characterisation of static geomechanical rock properties through laboratory testing is essential. In the modern exploration environment, these datasets are a precompetitive resource that can simplify investment decisions in prospective frontier regions such as the Officer Basin.

Sample photos pre- and post-test for test 3617. Sandstone from Birksgate 1, 1378.91 – 1378.97 m depth (GA sample ID 20212578). Core plug is 25.44 x 52.41 mm

Background and Analyses

- The Neoproterozoic to Paleozoic Officer Basin is an intracratonic sedimentary basin that covers approximately 525,000 km² over South Australia and Western Australia.
- The Officer Basin contains up to 10 km of marine and non-marine siliciclastic and carbonate rocks, with minor volcanics. Sediments were primarily deposited within a series of sub-basins that run parallel to the northern basin margin.
- To date, no hydrocarbon accumulations have been identified, though numerous hydrocarbon shows have been recorded in a range of formations from the Neoproterozoic to the overlying Permian sequences.



Location of wells sampled and analysed in this study. Basin outline after Raymond et al. (2018).

- Forty one samples from Officer Basin wells, from both Western Australia and South Australia, were analysed in this study. Samples were selected from intervals considered to have potential as either conventional or unconventional reservoirs while being representative of lithologies intersected by drillcore throughout the basin.

  Testing was undertaken by the CSIRO Geomechanics and Geophysics Laboratory in Perth, and included:
  - Photographic and 2D X-ray Computerised Tomography (XCT) scan images of whole core and core plugs;
  - 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, Youngs, Bulk and Shear moduli plus Poisson's ratio;
  - Gas porosity and permeability; and
  - Grain Density.
- Background, methods, and results were provided to Geoscience Australia by CSIRO Energy and are summarised in Bailey et al. (2021). Cylindrical core plugs approximately 25 mm in diameter and 50 mm in length were prepared normal to bedding for UCS testing, and where core was unable to yield a plug suitable for UCS testing, an approximately 25 mm by 10-15 mm disc was extracted for Brazilian tensile strength (BRZ) testing.

Acknowledgements

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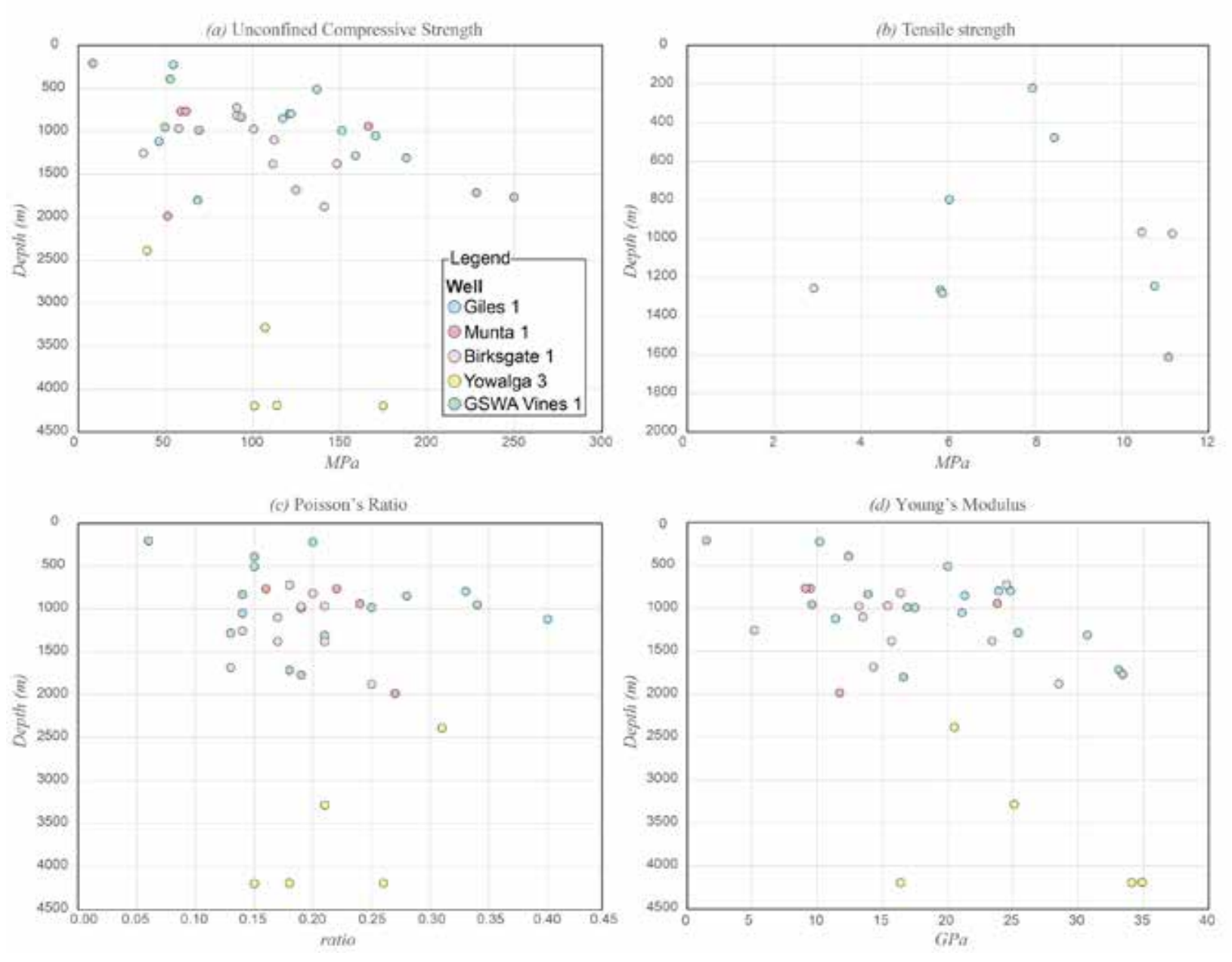
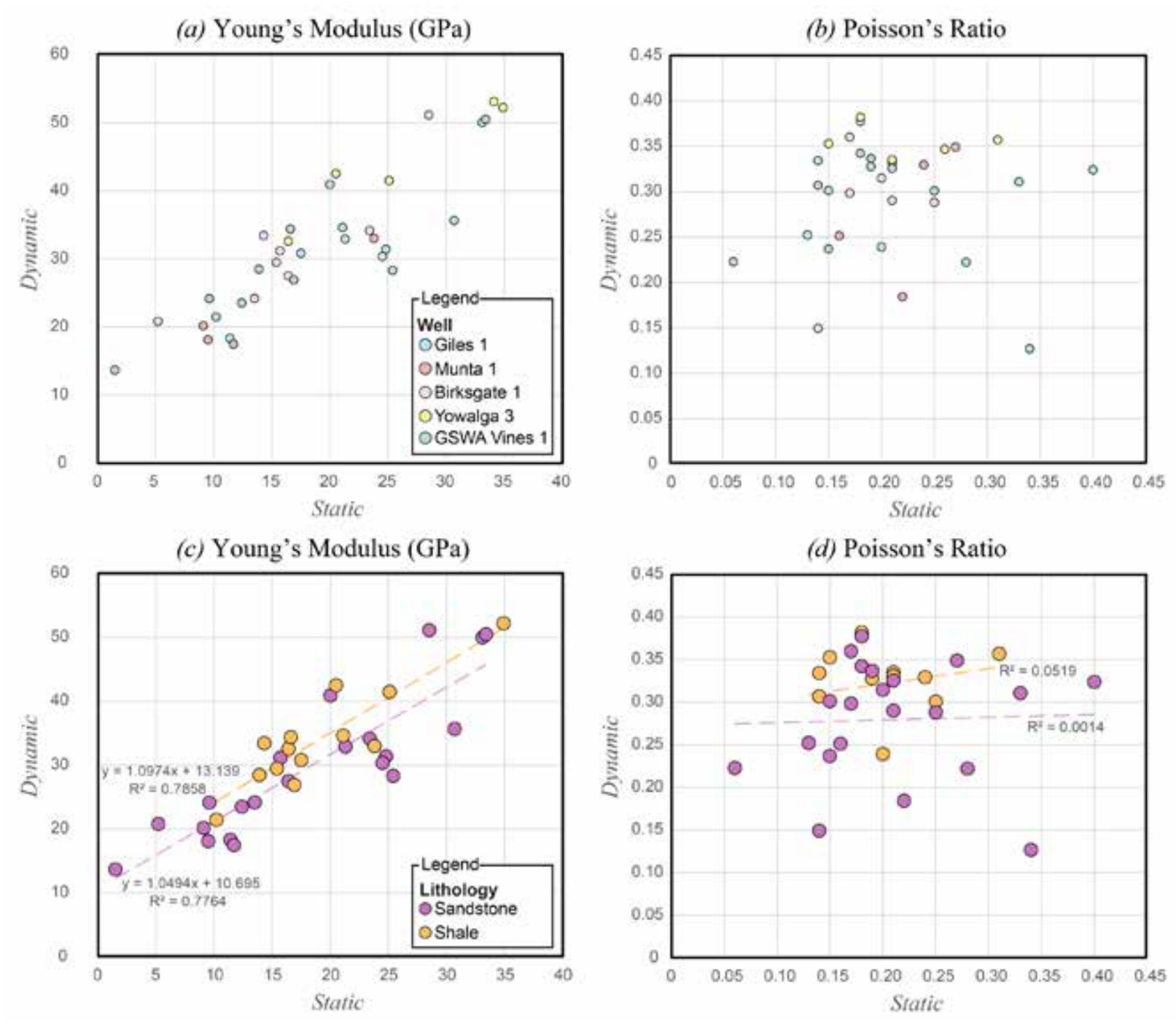
Results and Conclusions

- A total of 47 UCS and BRZ tests were undertaken, including two repeat tests. Static values for UCS, tensile strength, Poisson's ratio, and Young's modulus were acquired.
- Benchtop ultrasonic measurements were also acquired at a single stress point during UCS testing with dynamic rock properties calculated from these data.



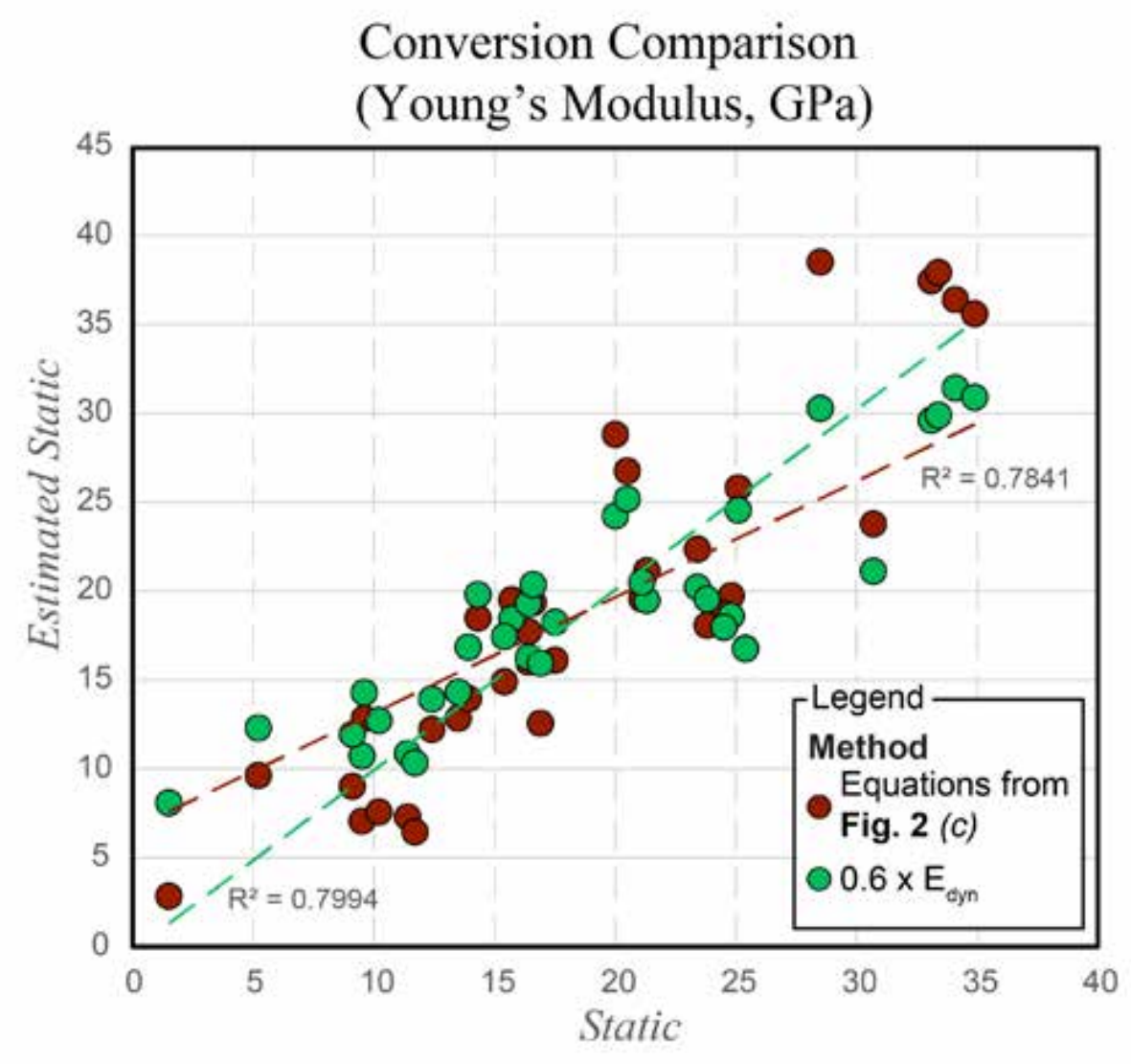
Results of compressive testing for: (a) Unconfined compressive strength (UCS); (b) Tensile rock strength; (c) Poisson's ratio, and; (d) Young's Modulus. Note, Brazilian tensile strength tests were only carried out on a subset of the samples (Table 1). Further details are outlined in Bailey et al. (2021).All plots refer to the legend presented in (a).



Crossplots of laboratory measured (static) and calculated values (dynamic) of Young's modulus and Poisson's ratio. (a) and (b) are displayed by well and (c) and (d) are displayed by simplified lithology. 'Sandstone' includes all sandstones and siltstones and 'Shale' includes all shales, mudstones, and claystones. Dynamic values of Young's modulus and Poisson's ratio are calculated from benchtop ultrasonic measurements. Further detail on testing and results are in Bailey et al. (2021). The legend in (a) applies to (a) and (b); the legend in (c) applies to (c) and (d).

- Crossplots of laboratory measured (static) and ultrasonic derived (dynamic) Young's modulus and Poisson's ratio illustrate the relationships between these parameters in the Officer Basin.
- Static and dynamic Young's modulus measurements from the Officer Basin demonstrate a clear relationship when plotted against one another. Dynamic values are consistently observed to be higher than static values.
- Generally, the difference between static and dynamic Poisson's ratio is very small and so it is often not considered, as there is no direct relationship these values. These data illustrate that there is no systematic relationship between these datasets. Hence, no generalised conversion is attempted herein.

- Linear relationships between static and dynamic Young's modulus for shale and sandstone are presented above. Approximately, static Young's modulus is on average 40% lower than dynamic Young's modulus.
- Conversions between dynamic and static Young's modulus using a) the lithology specific relationships from above, and b) an estimate of $E_{stat} = 0.6 \times E_{dyn}$ demonstrate similar scatter and correlations when crossplotted with the known static values. Hence, both methods likely approximate static Youngs Modulus from dynamic Young's modulus with the same efficiency.
- Accurate characterisation of geomechanical rock properties, such as rock strengths and elastic moduli, through laboratory testing is essential. It allows for the construction of detailed mechanical earth models, enables the designing of drilling programs and placing wells (reducing drilling risk and ensuring wellbore stability), and facilitate the prediction of fracture propagation.



Comparison of two methods of converting dynamic Young's modulus (E_{dyn}) into static Young's modulus (E_{stat}). Firstly, the equations for the lithology specific linear relationships were attempted (in red) and secondly, a quick estimate of $E_{stat} = 0.6 \times E_{dyn}$ (green). Note the very similar correlation coefficients (R2 values) for each method.

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