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Exploring for the Future geomechanics: Breaking down barriers to exploration

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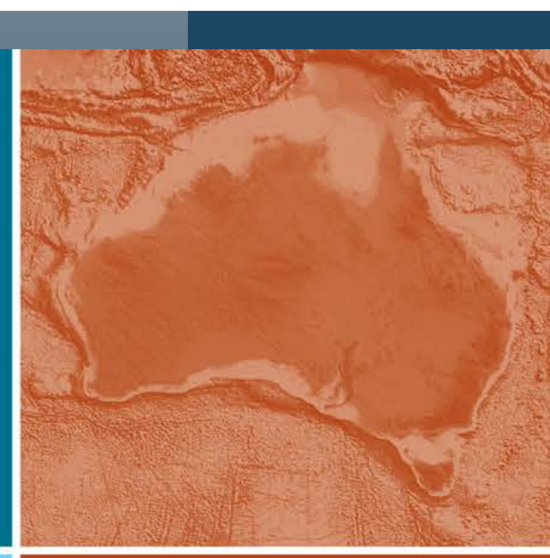
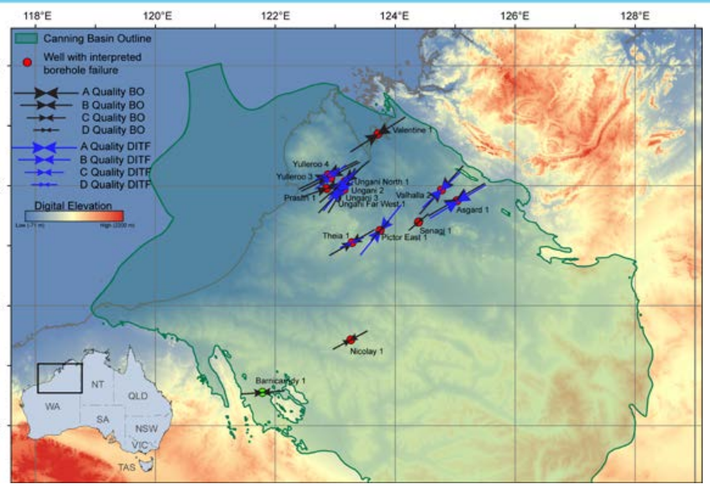


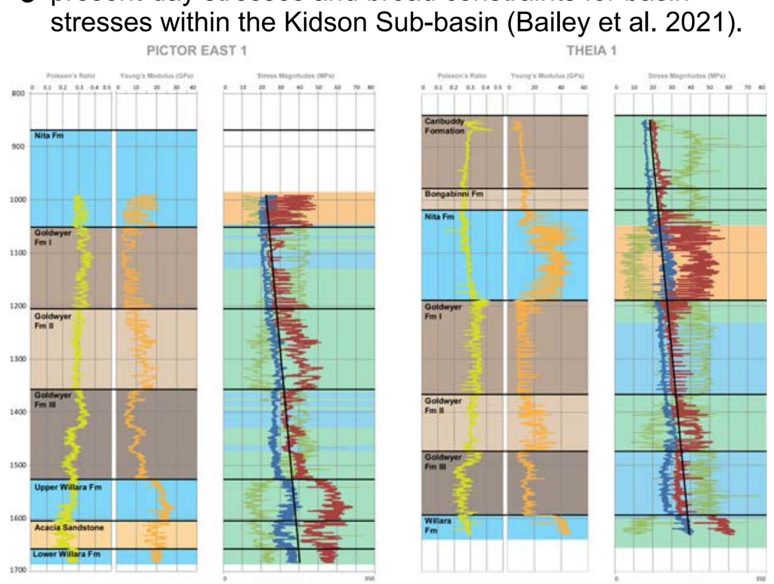
Adam H. E. Bailey, Amber J. M. Jarrett, Liuqi Wang, David N. Dewhurst, Lionel Esteban, Shane Kager, Ludwig Monmusson, Lidena K. Carr, Paul A. Henson



Interpreted stress orientations from image log data in the Canning Basin of Western Australia (Bailey et al., 2021). Borehole breakout (BO) derived orientations are presented in black and drilling-induced tensile fracture derived orientations are presented in blue. Basin outline after Raymond et al. (2018).

Canning Basin (Kidson Sub-basin):

- The Kidson Sub-basin is a large, underexplored depocentre that possibly hosts a continuation of proven Canning Basin petroleum systems (Carr et al. 2020; Southby et al. 2020).
- Canning Basin data have been used to provide detail on present-day stresses and broad constraints for basin stresses within the Kidson Sub-basin (Bailey et al. 2021).



Mechanical earth models for the wells Pictor East 1 and Theia 1, showing both calculated Poisson's Ratio and Young's Modulus, as well as interpreted stress regime (as per legend Figure 10). Of particular interest is the Goldwyer Formation, which is intersected in both wells.

Canning Basin present-day stresses

- A NE-SW regional present-day maximum horizontal stress orientation is interpreted; is in broad agreement with the Australian Stress Map and previously published earthquake focal mechanism data (Bailey et al. 2021).
- In the Barnicarndy Graben, maximum horizontal stress orientation is interpreted as ~E-W (Wilson and Thrane 2020) supporting predictions of continent-scale stresses (Rajabi et al. 2017).
- An overall strike-slip faulting stress regime is interpreted through the basin from mechanical earth models, however, three distinct stress zones are identified through the studied interval:

  1) reverse to strike-slip faulting stress regime at < ~1.0 km depth,
  2) strike-slip faulting stress regime from ~1.0 km to ~3.0 km depth,
  3) strike-slip to normal faulting regime at > ~3.0 km depth.

- Significant stress changes are interpreted, defining discrete mechanical units that form inter- and intra-formational stress boundaries likely act as natural barriers to fracture propagation, particularly within those currently targeted for their unconventional resource potential (Bailey et al. 2021).

Rock testing program

- Rock testing for geomechanical and petrophysical properties was undertaken on samples from the well Barnicarndy 1 (Kidson Sub-basin) and on legacy South Nicholson region core samples.

  a) Barnicarndy 1: Six samples were selected as potential reservoir-seal pairs and subjected to unconfined compressive stress (UCS) tests, ultrasonic testing under load (at ~50% peak strength), mercury injection capillary pressure (MICP), broad-ion-beam milling and scanning electron microscopy (BIB-SEM), and gas porosity and permeability tests (CSIRO 2020; Jarrett et al. 2020c).

  b) South Nicholson region: Fourteen potential unconventional or conventional reservoir samples were analysed through unconfined compressive stress (UCS) tests and ultrasonic testing under load (at ~50% peak strength).

Acknowledgements

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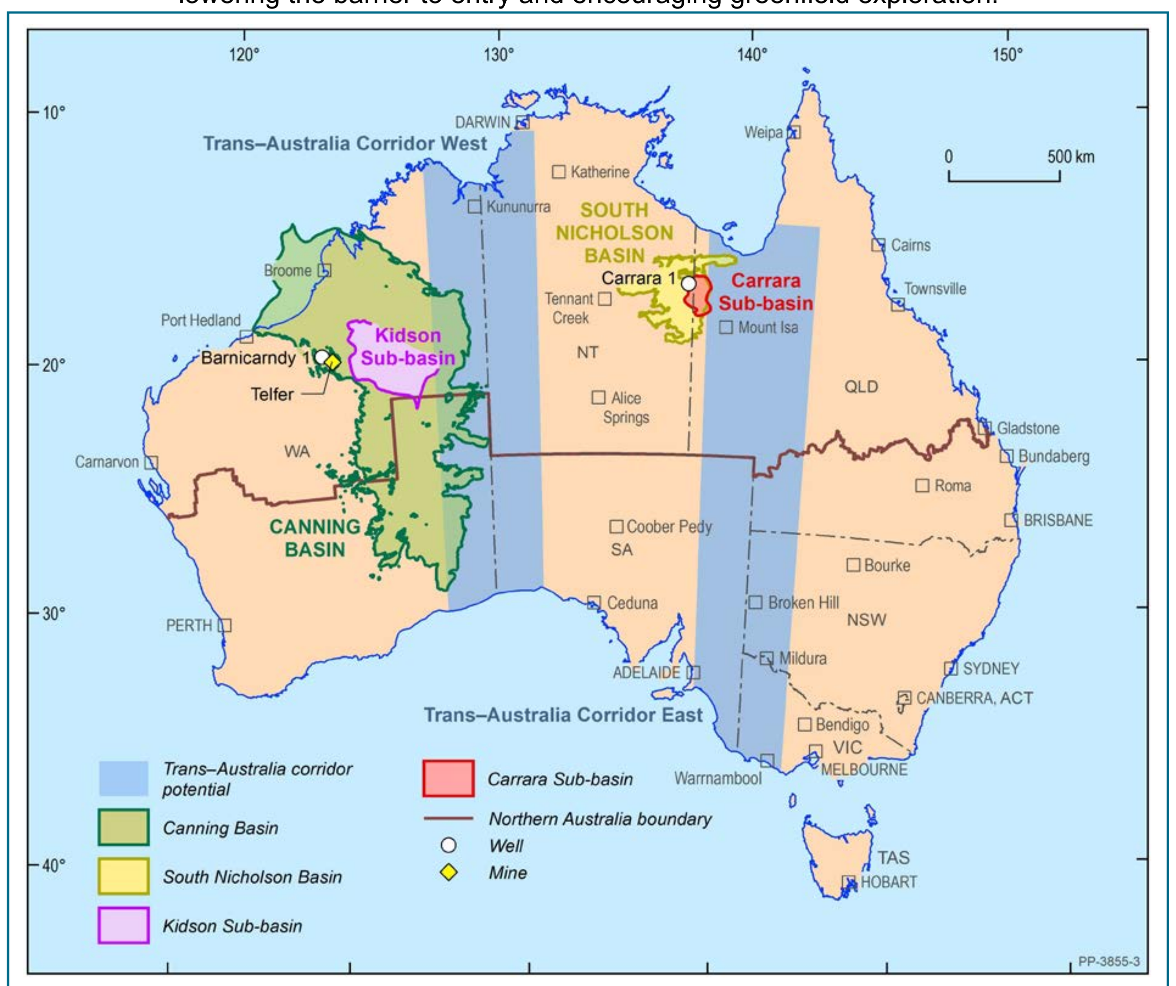
Introduction

Exploring for the Future (EFTF) is an Australian Government initiative focused on gathering new data and information about potential mineral, energy and groundwater resources across Australia. The energy component of EFTF, initially focussed on northern Australia, aims to improve our understanding of the petroleum potential of frontier Australian basins. Building an understanding of geomechanical rock properties is key to understanding both conventional and unconventional petroleum systems as well as carbon storage and sedimentary geothermal systems. Under EFTF, Geoscience Australia has undertaken geomechanical workincluding stress modelling, shale brittleness studies, and the acquisition of new rock property data through extensive testing on samples from the Paleo- to Mesoproterozoic South Nicholson region of Queensland and the Northern Territory, and the Paleozoic Kidson Sub-basin of Western Australia.

Work in these regions demonstrates regional stress orientations in broad agreement with previously modelled, continent-scale stress orientations and stress magnitudes that vary through the basin with depth and by lithology. Rock testing highlights potentially brittle shales and demonstrates variable rock properties in line with lithology. These analyses are summarised herein.

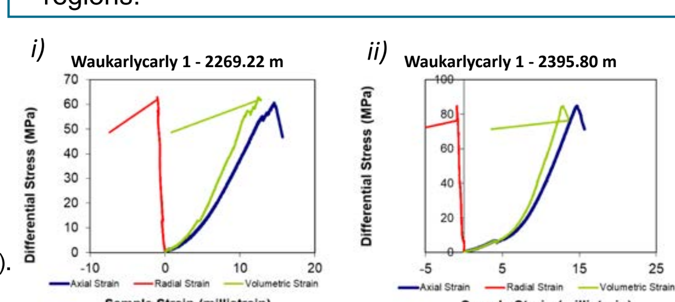
Providing baseline geomechanical data in frontier basins is essential as legacy data coverage can often be inadequate for making investment decisions, particularly where unconventional plays are a primary exploration target. As EFTF increases in scope, Geoscience Australia anticipates expanding these studies to encompass further underexplored regions throughout Australia, lowering the barrier to entry and encouraging greenfield exploration.



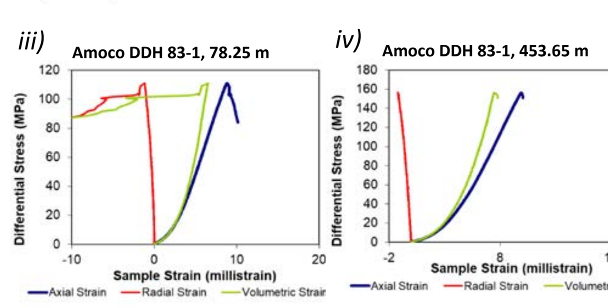
Exploring for the Future energy program study areas: geomechanics work to date has been focussed on the Canning Basin (green) to help understand the frontier Kidson Sub-basin (purple), as well as the South Nicholson Basin (yellow) region. The Carrara Sub-Basin, discovered and described by the Exploring for the Future energy program, is displayed in red. The Trans-Australia corridors of potential (blue) will guide Exploring for the future energy program studies for 2020-2024.

Conclusions

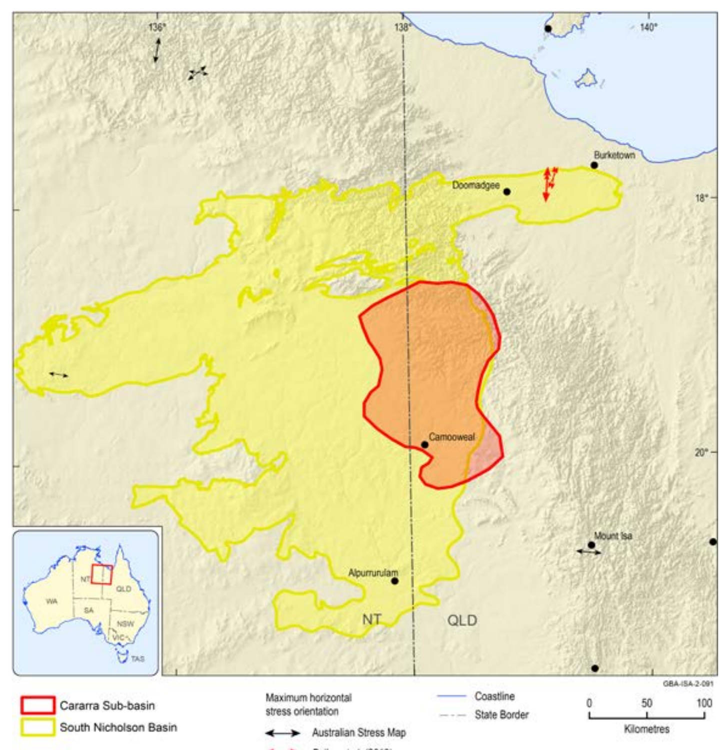
- Geoscience Australia has released new geomechanical and petrophysical data within two prospective frontier regions, de-risking exploration through the provision of additional pre-competitive datasets.
- Analysis and modelling of present-day stresses, shale brittleness studies, and newly acquired rock property data from the Proterozoic South Nicholson region and the Paleozoic Canning Basin are presented and provide geomechanical and petrophysical insights into intervals with identified or potential hydrocarbon prospectivity and allow for extrapolation of rock properties.
- Exploring for the Future is expanding in scope to cover more of the Australian continent and Geoscience Australia is expanding these studies to encompass further frontier geological provinces.
- The delivery of pre-competitive geomechanical data contributes to understanding large-scale variations in crustal stresses and local and regional changes in rock properties, lowering barriers to entry and encouraging greenfield exploration in remote, under-explored regions.



Resultant stress-strain curves from unconfined compressive strength tests on shales from Barnicarndy 1 in the Kidson Sub-basin (Canning Basin). Results from the tested samples in Barnicarndy 1 imply low Poisson's ratios with tested shales demonstrating brittle behaviour (stress-strain curves demonstrate a pronounced peak strength, followed by fracturing and a resultant load bearing capacity of zero). Measured UCS values are typical for lithology and porosity, although some may be slightly over-estimated due to axial splitting mode of failure.



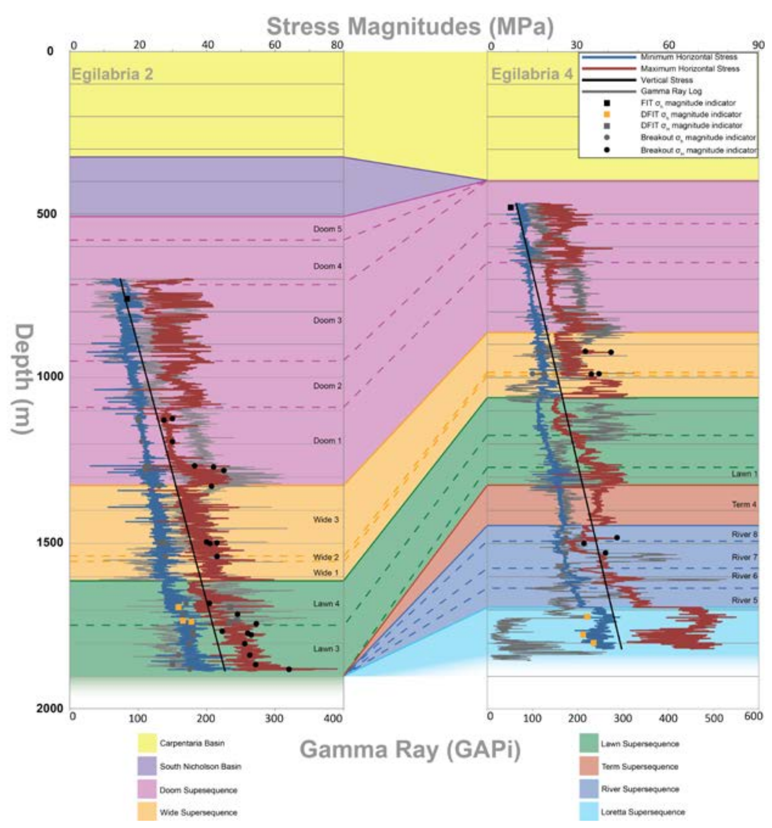
Resultant stress-strain curves from unconfined compressive strength tests on shales from Amoco DDH 83-1 in the South Nicholson region. Results from the tested South Nicholson region samples imply samples high Young's moduli, high unconfined compressive strength, and low Poisson's ratios. Shales are potentially brittle due to their low Poisson's ratio and zero load bearing ability after failure.



Interpreted stress orientations in the South Nicholson region of Jarrett et al (2020). Stress azimuths in red are from Bailey et al. (2019) and in blaack are from the Australian Stress Map (Rajabi et al., 2016). Note the lack of regional stress data.

South Nicholson region:

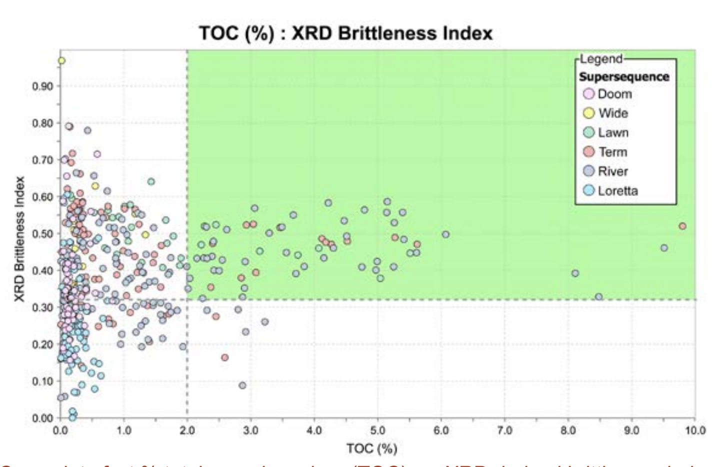
- Interpretation of wellbore failure in image logs acquired in Egilabria 2 and Egilabria 4 reveals an approximately N–S to NNE–SSW maximum horizontal stress orientation.
- Mechanical earth models for Egilabria 2 and Egilabria 4 define a strike-slip faulting regime in the Egilabria wells.
- Sandstone and carbonate intervals exhibit significantly higher stress magnitudes than shale and siltstone intervals, resulting in localised stress variations.



Mechanical earth models constructed for wells Egilabria 2 and Egilabria 4, displayed alongside correlated Isa Superbasin sequences and younger overlying basins. σ_H = maximum horizontal stress. σ_h = minimum horizontal stress. FIT = formation integrity test. DFIT = diagnostic fracture injection test.

Shale brittleness

- Shale brittleness in the South Nicholson region was analysed in two EFTF studies: Bailey et al. (2019) and Jarrett et al. (2019); brittle shales are demonstrated to likely be present within each supersequence.
- Notably, shales in the River and Lawn supersequences are interpreted as having brittle zones potentially favourable for fracture stimulation



Crossplot of wt % total organic carbon (TOC) vs. XRD derived brittleness index (BI) for analysed samples from Isa Superbasin supersequences. The green area represents TOC ≥ 2 wt % and BI ≥ 0.32 (less brittle to brittle); this demonstrates the supersequences which host rocks with potential as shale gas reservoirs (after Jarrett et al., 2019).

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