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Unlocking the secrets of unconventional shale: A multi-scale approach to understanding fluid transport and resource recovery

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Understanding the intricate pore structure of shale rocks across scales, from nanometres to micrometres, is crucial for optimizing the recovery of natural gas, geothermal energy, and potentially enabling future CO2 sequestration and subsurface hydrogen storage. This study leverages Small Angle Neutron Scattering (SANS), a non-destructive technique, to precisely characterize pore properties in Australian shale samples. By employing contrast matching experiments, we probe the accessibility of these pores to deuterated methane (CD4).
Our in-situ SANS experiments, conducted on carefully chosen shale samples with diverse thermal maturities and organic carbon contents, reveal how stress and fluid pressure influence the overall pore structure. Notably, we observed that:
• Nanopore gas confinement exhibits sample-specific behaviour.
• Applying pressure to methane (CD4) at 500 bar induces condensation within accessible nanopores (diameter < 10 nm), resulting in the scattering length density (SLD) of confined methane exceeding that of the shale matrix by more than twice.
• Uniaxial stress, mimicking hydraulic fracturing pressure, enlarges some smaller pores and potentially even forms larger ones through coalescence, while expelling confined methane.
These findings provide valuable input for advanced modelling and simulations, enabling us to bridge the gap between submillimeter-scale laboratory data and reservoir-scale behaviours. This paves the way for optimizing resource extraction and developing novel strategies for geological storage of critical elements.

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Primary author: JI, Yeping (CSIRO)

Co-authors: Prof. RADLINSKI, Andrzej P. (UNSW); Dr XIAO, Chen (CSIRO); Dr DELLE PIANE, Claudio (CSIRO); Prof. REGENAUER-LIEB, Klaus (Curtin University); Dr GRIGORE, Mihaela (CSIRO); Mr VU, Phung (UNSW); Dr BLACH, Tomasz (UNSW)

Presenter: JI, Yeping (CSIRO)

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