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The potential for residual oil zones to maximize CO_2 storage capacity in Australian petroleum provinces

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Abstract

Saline reservoirs are widely considered to be the ideal targets for large-scale geological storage of CO_2. Evidence from industry and operating and proposed CCS projects worldwide, however, suggests that depleted hydrocarbon fields currently provide the majority of early-mover, rapid-to-develop and low cost options for geological storage of CO_2. In Australia, most of the CO_2 storage projects currently in development plan to make use of depleted fields, at least initially (Fig 1). Reasons for this include excellent existing geological data; the potential to repurpose infrastructure; and the ability to accelerate regulatory approval processes by converting existing petroleum production licences to CO_2 injection and storage licences. One of the recognized disadvantages of utilizing depleted fields for storage is their total storage capacity, which is often considerably less than that of saline reservoirs. This consideration led us to investigate the CO_2 storage potential of residual oil zones (ROZs) as a means of potentially increasing the storage capacity associated with some in brownfields regions – effectively achieving a scale of storage that is more akin to that of saline aquifers, while capitalizing on the benefits of using depleted fields.

Geological residual oil zones can occur in association with oil fields and in greenfields areas with no main pay zone. These naturally water-flooded reservoirs can retain oil saturations of around 10-30% and are fairly recently recognized targets for commercial-scale oil production in some parts of the world (e.g. the Permian Basin, USA), where oil is produced via CO_2 enhanced oil recovery (CO_2-EOR). Storage-optimized CO_2-EOR applied to ROZs can achieve net-neutral or even net-negative oil, helping to provide liquid hydrocarbon resources for the manufacturing of a range of materials as well as for energy security (Tenthorey et al., 2021; Kalinowski et al., 2022; Tenthorey et al., 2022b). Additionally, residual oil zones present a compelling opportunity for CO_2 storage without oil production in well characterized, mature basins. While Tenthorey et al. (2021) have previously described the potential

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for accelerated deployment of CO_2 storage via CO_2-EOR in depleted fields and ROZs, this study investigates the potential for ROZs to augment the CO_2 storage capacity of depleted fields.

To our knowledge, there have been no detailed studies exploring the potential of ROZs in Australia for either additional oil production or CO_2 storage. Under the Australian Government's Exploring for the Future program, we have developed a comprehensive methodology to identify and characterise ROZs, using several onshore, central-eastern Australian hydrocarbon-producing basins as case studies, including the Cooper-Eromanga, Bowen-Surat, Simpson-Pedirka and Amadeus basins (Fig 2) (Tenthorey et al., 2022a; Clennell et al., *in press*). We identified prospective ROZ regions by targeting areas possessing significant light oil accumulations suitable for CO_2-EOR, in productive reservoirs located at depths suitable for CO_2 storage. Once prospective areas were identified, quantification of the ROZs was conducted using well-log analysis in which high resistivity zones were used to infer the presence of residual oil. Hydrocarbon shows and formation tests were also used to complement the resistivity-based interpretation. Approximately 110 oil fields were initially screened for ROZ related storage, with about 15-20 indicating a strong possibility of ROZ presence, most of which occur in association with oil fields in the Cooper-Eromanga basins in central Australia (Figs 2 & 3).

Based on the petrophysical analysis, we constructed a generic static model and conducted multiphase compositional flow modelling to estimate the CO_2 storage efficiency of ROZs. Correct initialization of the model is essential for achieving a realistic distribution and quantity of residual oil in place. To achieve this, we developed a novel modelling methodology that captures the oil migration events leading to the formation of ROZs. The resulting model was used to simulate CO_2 storage over a 20-year injection period. Our modelling demonstrates that CO_2-oil interactions increase the density and viscosity of CO_2, which impacts the plume migration path and sweep efficiency, and enhances lateral CO_2 flow, thereby improving CO_2 storage efficiency. The extent of these effects depends on the quantity and spatial distribution of residual oil in place and whether CO_2 at reservoir conditions is miscible with residual oil.

In this paper, we present the novel methodologies developed and employed to identify and characterise ROZs in key Australian hydrocarbon-bearing basins; the modelling approach developed to better understand the CO_2 storage potential of these reservoirs; and the results of our study, including recommendations for future research to address some of the remaining knowledge gaps.

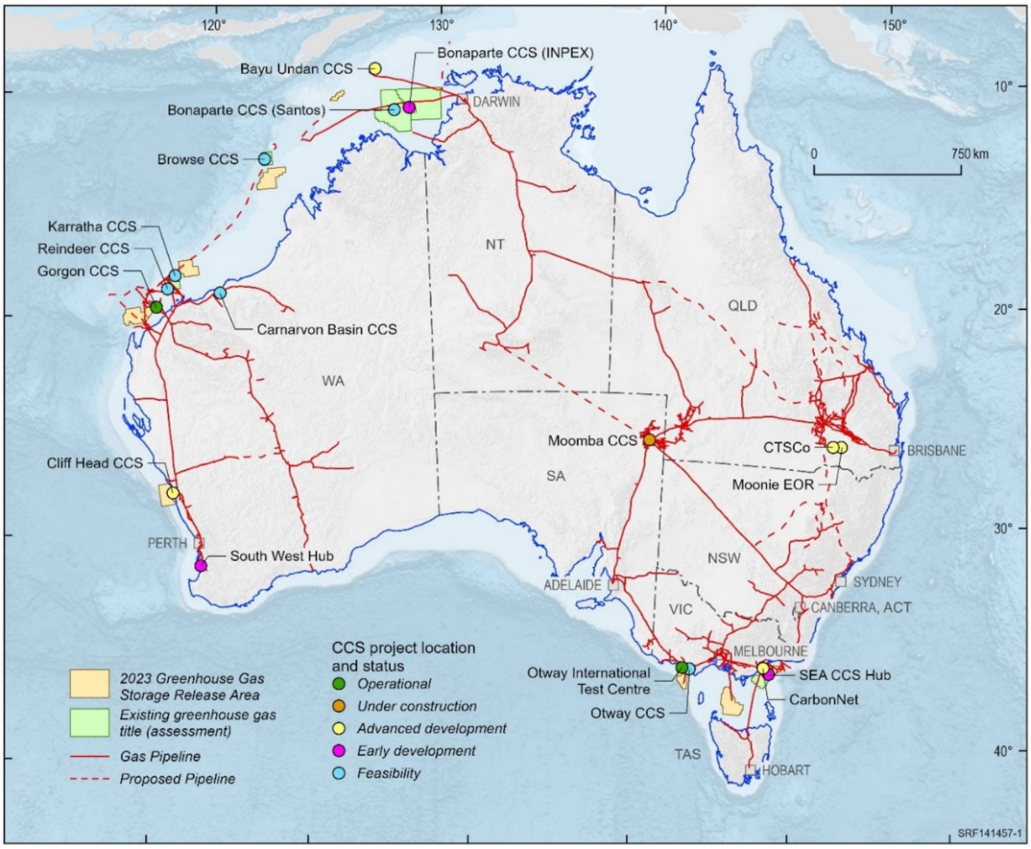

Figure 1. Onshore and offshore CO_2 geological storage projects in various stages of development across Australia (updated from Geoscience Australia, 2023).

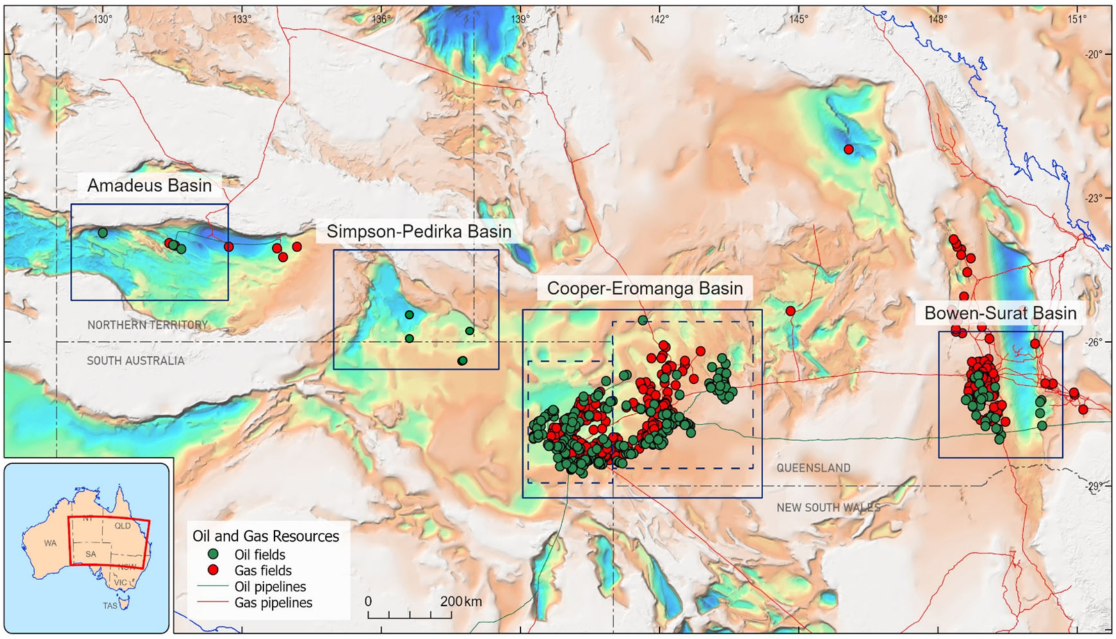

Figure 2. Oil fields in the Cooper-Eromanga, Bowen-Surat, Simpson-Pedirka and Amadeus basins of central-eastern Australia were investigated for indications of residual oil zones, using geological and petrophysical methods (from Clennell et al., 2022).

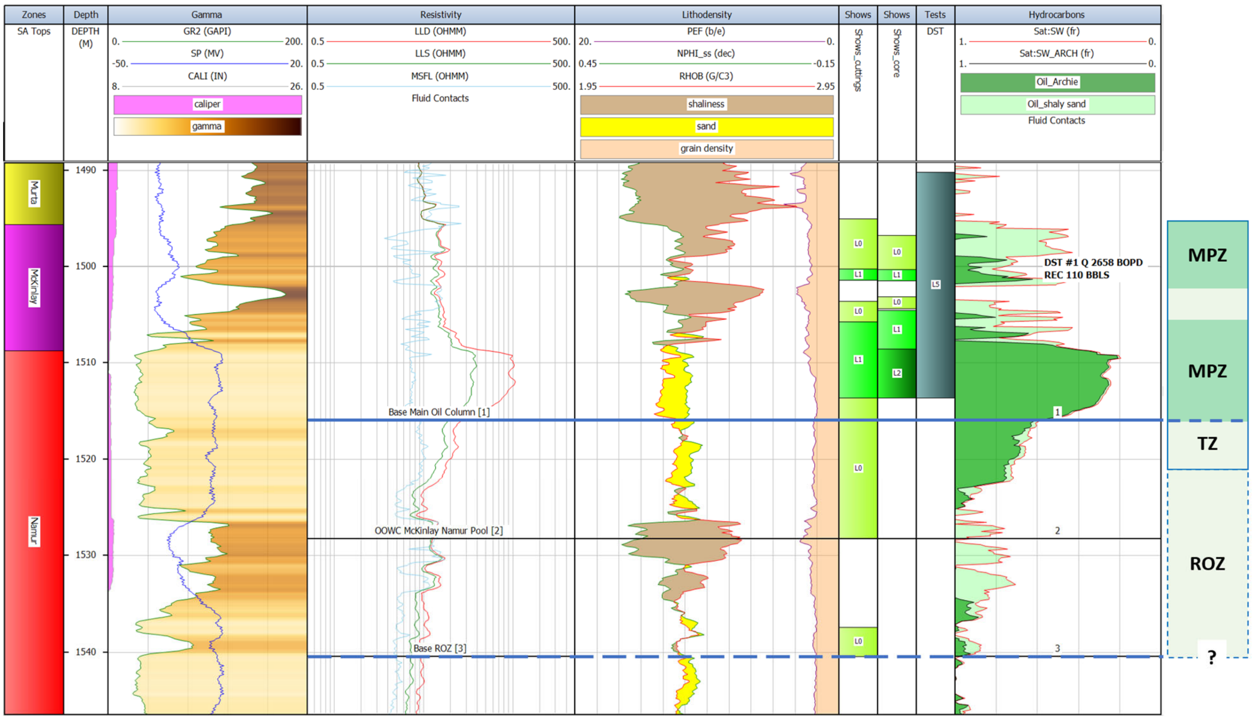

Figure 3. An example interpretation: a summary plot of petrophysics, shows and well tests for Dullingari 29 well, Cooper-Eromanga Basin, with interpreted main pay zones (MPZ), transition zone (TZ) and residual oil zone (ROZ) shown to the right, while the oil-water contacts (OWC) are shown on the plot. The well was drilled prior to any production, but high oil saturation does not extend to the depth of the field spill point. Residual oil with saturation generally 10-20% extends below the field-wide oil water contact (modified from Clennell et al., 2022).

Keywords: residual oil zone; CO_2 storage; capacity; storage efficiency; Australia; Exploring for the Future

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