The 'Australia's Future Energy Resources' project: Investigating the energy resources potential in central Australia

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Introduction

As part of the Australian Government funded *Exploring for the Future* (EFTF) program, the 'Australia's Future Energy Resources' (AFER) project is a four-year multidisciplinary undertaking to investigate the potential of energy resource commodities in selected onshore Mesozoic and Paleozoic sedimentary basins. In the context of Australia's path towards a low-carbon economy, the project is focused on energy resources that will support this transition, including natural gas and hydrogen. It also assesses the presence of residual oil zones that could be produced via carbon dioxide (CO_2) injection and represent a potentially new underground CO_2 storage resource.

The initial phase of the AFER project is focused on the central Australian region encompassing the western and central parts of the Eromanga Basin and the underlying Triassic and Paleozoic basin successions (**Figure 1**). Work is being undertaken primarily in collaboration with the South Australian Department of Energy and Mining (SA DEM) and the Northern Territory Geological Survey (NTGS).

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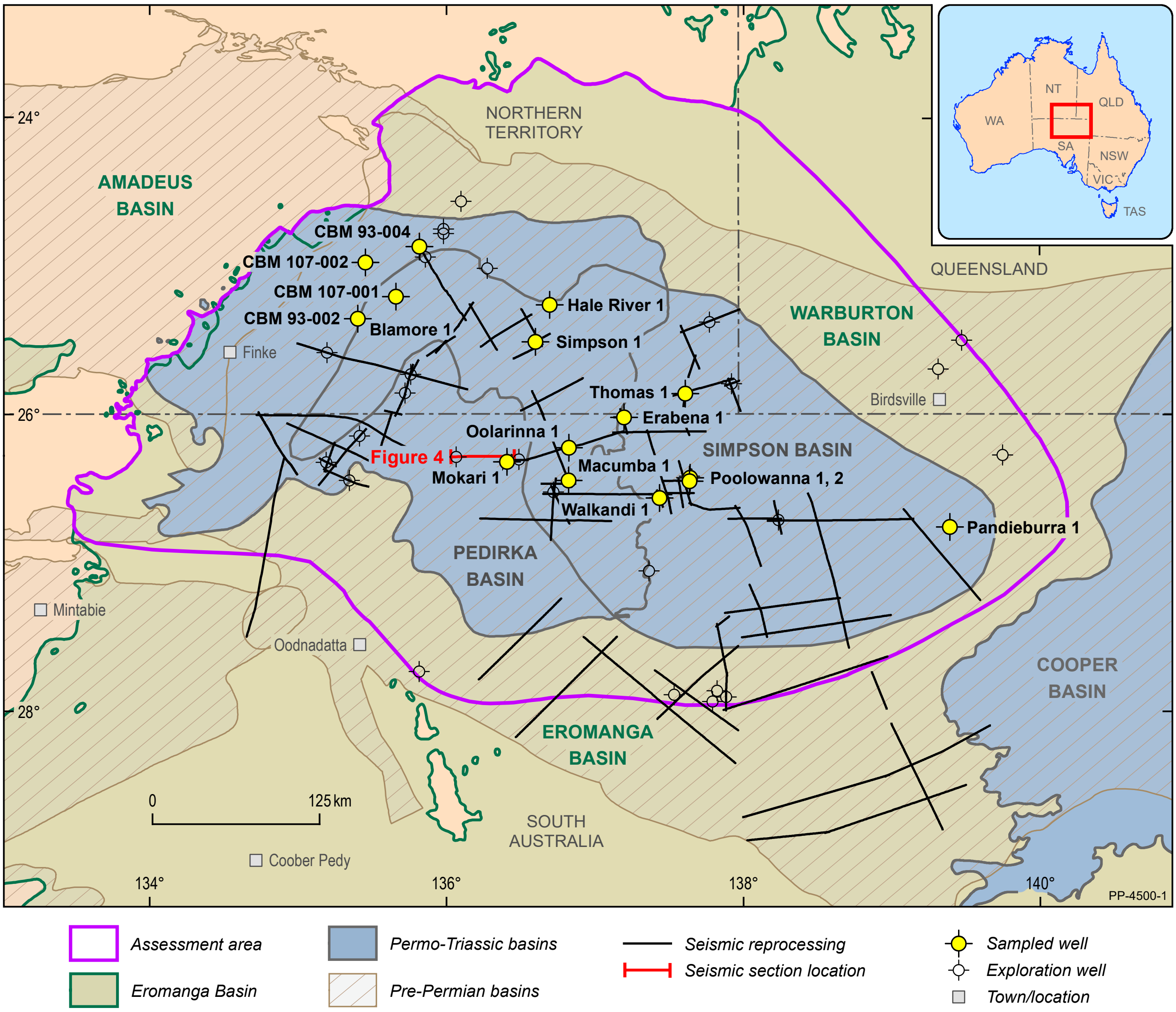


Figure 1. Western Eromanga focus area showing the western boundary of the Eromanga Basin and the extents of older Triassic, Permian and pre-Permian basins. Also shown: the outline of the energy resource assessment area, locations of wells that have been sampled for infill palynological analysis, and seismic lines that are being reprocessed.

Project activities

The AFER project comprises four modules, each of which has a distinct low-carbon energy resource focus:

Module 1: Energy resource assessment

- This component of the AFER project is undertaking basin-scale assessments of hydrocarbon resources, as well as evaluating greenhouse gas storage opportunities in the western Eromanga Basin and underlying Triassic and Permian basin successions. A workflow, based on exploration play-types, is being used to systematically evaluate the key risk elements for each resource type through the analysis of spatial data and drilling results to map target areas for exploration. The resource assessments will improve understanding of the region's 'yet-to-find' hydrocarbon resource potential, map the areas that are likely to have favourable geological conditions for carbon dioxide storage projects, and identify other potential subsurface gas-storage opportunities. Common-risk segment maps are being produced to highlight the fairways for effective reservoir and seal intervals and fluid flow pathways. This will also provide a framework for future assessments of other sediment-hosted resources (eg deep unallocated groundwater, sediment-hosted minerals).

Module 2: Hydrogen studies

- AFER will play an important role in supporting the establishment of the Australian hydrogen industry. Part of the hydrogen module includes an assessment of the potential for hydrogen production via electrolysis through the use of geothermal energy generated from deep-seated hot sedimentary aquifers. Natural gas linked with carbon capture and storage is also a consideration, and can also be used for clean hydrogen production. Another area of focus is the identification of suitable underground storage sites, such as subsurface salt accumulations, that will be able to store the produced hydrogen until it is required for domestic use or for export. This will be accomplished by mapping the nationwide distribution of thick subsurface salt accumulations; the results will assist with better infrastructure planning for the Australian hydrogen industry. Finally, natural (geologic) hydrogen has been reported in the NT's Amadeus Basin in addition to other locations across Australia. Further studies undertaken in this module aim to investigate what constitutes a hydrogen system and produce guidelines for geologic hydrogen exploration.

Module 3: CO_2-enhanced oil recovery (CO2-EOR) in residual oil zones (ROZ)

- In collaboration with CSIRO, the potential application of CO2-EOR to unlocking new oil and CO_2 geological storage resources in residual oil zones is being investigated. Residual oil zones are geological reservoirs that contain potentially economically producible oil resources and offer opportunities for large-scale geological storage of CO_2, but their occurrence and potentially accessible oil resources are not well understood in Australia. Development of ROZ could be economically beneficial, help to address greenhouse gas emissions, and provide increased energy security through the new production of domestic oil resources.

Module 4: Onshore basin inventories

- This module aims to encourage exploration by describing the current status of knowledge of the geology, petroleum systems, and exploration history in selected underexplored basins. A major component of the module revolves around a 'gap analysis' leading to recommendations for future work to improve the understanding of energy resources prospectivity. Depending on data availability, petroleum system modelling will be carried out to highlight the oil and gas potential in underexplored provinces.

Focus areas in the Northern Territory

While the scope of the AFER project is a nation-wide evaluation of the occurrence of low-emission energy resources, especially in the context of hydrogen and carbon capture utilisation and storage (CCUS), the initial focus lies on the eastern-most border region between South Australia and the Northern Territory (**Figure 1**). Geologically, this is a region in the Simpson Desert that encompasses several superimposed intracratonic sedimentary basins that are separated by regional unconformities. Basin successions range in age from early Paleozoic to Quaternary. The tectonostratigraphic understanding of these basin successions varies depending on the degree of subaerial exposure and subsurface data coverage, with many data and knowledge gaps remaining as far as the evolution of the mainly concealed and underexplored Paleozoic and Triassic basins are concerned.

Early Paleozoic rocks from the western part of the Warburton Basin represent the oldest basin succession in the region. Our current understanding of the geology of the western Warburton Basin is constrained by the lack of surface exposures, the small number of well penetrations, limited biostratigraphic age control, and the relatively sparse seismic data coverage with often limited resolution of the Early Paleozoic section. Previous interpretations from the limited well penetrations suggest that the western Warburton Basin includes Cambrian shelf and platform carbonate and mudstone sequences, red-beds of inferred Ordovician age, and siliciclastics of inferred Late Ordovician to Devonian and possibly early Carboniferous age (Munson 2014). Seismic interpretations by Central Petroleum suggest a potential thick Devonian carbonate-rimmed platform and reef complex in the Northern Territory part of the western Warburton Basin (Ambrose *et al* 2012). Metasedimentary rocks of unknown age have also been penetrated in several drillholes (Munson 2014). The chronostratigraphy of the Warburton Basin is still not well understood and will be the focus of future studies by the NTGS and SA DEM.

Permian and Triassic sediments beneath the western Eromanga Basin include several siliciclastic and coal-bearing sequences, which have been the focus of multiple petroleum and coal exploration programs. Consequently, there is greater certainty in the geological knowledge of these successions compared to the underlying western Warburton Basin. However, many data and knowledge gaps remain regarding the tectonostratigraphic history, petroleum systems, groundwater systems, and exploration potential for low carbon energy commodities. Until recently, the Permo–Triassic strata were incorporated into the early Permian Pedirka Basin and the Triassic Simpson Basin (Questa 1990, Hibburt and Gravestock 1995, Radke 2009). This differentiation of Permian and Triassic basins is in contrast to the Cooper Basin, and is based largely on the presence of a regional late Permian to Early Triassic unconformity that removed much of the Permian succession prior to deposition of Triassic strata. However, data acquired during Central Petroleum's NT petroleum drilling program from 2008–2013 has shown evidence for late Permian strata in several wells, and only a limited time break between Permian and Triassic strata in the Blamore-1 well. Consequently, the stratigraphic framework has been revised to show strata extending through most of the early and late Permian, and the basin successions have been redefined in the NT into a single Permo–Triassic Pedirka Basin (Ambrose and Heugh 2012, Ahmad and Munson 2013, Doig 2022; **Figure 2**). The AFER project is working with the NTGS and SA DEM to improve our understanding of the Permian and Triassic geological frameworks through sampling of well cores and cuttings to further constrain ages and depositional environments of these sedimentary rocks.

The large Jurassic to Cretaceous intracratonic Eromanga Basin extends over an area of more than 1 000 000 km^2 across central and eastern Australia. Geoscience Australia's AFER project area incorporates the western part of the Eromanga Basin, which includes the main basin depocentre in the Poolowanna Trough where up to 3000 m of fluvial, lacustrine and marine sediments are preserved (Passmore 1989, Gallagher *et al* 2008). The western Eromanga Basin forms part of the Great Artesian Basin and hosts important groundwater resources for remote communities in central Australia (Wohling *et al* 2013, Miles *et al* 2015). Geoscience Australia is assessing the status of groundwater in the Great Artesian Basin through the Great Artesian Basin Groundwater (GABG) project and the EFTF National Groundwater Systems project. These studies have provided an updated understanding of the chronostratigraphic framework of the Eromanga Basin and regional correlations of key chronostratigraphic surfaces (Hannaford *et al* 2022, Norton and Rollet 2022)

Exploration history

The western Eromanga Basin and underlying Paleozoic and Triassic basins are considered to be underexplored with only 42 petroleum wells and 5 stratigraphic wells drilled since exploration began in the 1950s. However, the broader central Australia region has a long history of exploration for hydrocarbons. Lower Palaeozoic units in the Warburton Basin were the initial target for petroleum exploration in the northeast of South Australia and yielded the first shows in carbonates, which were intersected in the Gidgealpa 1 well in 1963. The wells Gidgealpa 3, 16 and 23 all encountered small gas shows in pre-Carboniferous sediments.

The exploration history of the western Eromanga region dates back to the early 1960s when the emphasis was on targeting the early to middle Paleozoic Amadeus Basin succession (McDills 1, Hale River 1). In 1963, the discovery of Permian gas to the south in the Cooper Basin turned attention to successions of similar age in the Pedirka Basin (eg Colson 1). The presence of an active petroleum system in the Poolowanna Trough was demonstrated in 1977 with uneconomic flows of oil and condensate from Triassic and Jurassic reservoirs in well Poolowanna 1. Exploration activities intensified in the western Eromanga region following the Poolowanna discoveries. However, the quick succession of commercial oil and gas discoveries in the Cooper and central Eromanga basins shifted the exploration focus away from the western Eromanga region (Ambrose *et al* 2007, Ambrose *et al* 2006). Consequently, no wells have been drilled in the South Australian part of the western Eromanga region since the 1980s.

Exploration was rejuvenated in the NT area during Central Petroleum's conventional and unconventional exploration program between 2008 and 2010. Central Petroleum initially focused on conventional hydrocarbons, with the drilling of wells Blamore 1 and Simpson 1 in 2008. Although no hydrocarbons were recovered, evidence for oil generation and migration was found with residual oil zones in Jurassic reservoirs at Blamore 1, and Triassic reservoirs at Simpson 1 (Ambrose *et al* 2007, Central Petroleum 2008). Blamore 1 also intersected thicker than expected interval of early–late Permian coal-bearing strata (Purni Formation), which was identified as a potential target for unconventional gas (coal seam gas; Ambrose and Heugh 2012). Exploration subsequently shifted to western areas of Eromanga Basin to explore the potential for biogenic coal seam gas, but the coal seam intervals tested lacked significant gas content (Central Petroleum 2008).

Several exploration companies, including Central Petroleum, Santos, TriStar and BR Simpson, have recently obtained exploration acreage in the western Eromanga region. Coal-bearing sequences around the shallower basin margins continue to be explored for extractable coal resources and underground coal gasification or coal to liquid resources (Ahmad and Munson 2013). Several conventional hydrocarbon plays have been identified and mapped by SA DEM in Permian, Triassic and Jurassic intervals. Residual oil zones may also provide new conventional plays, particularly within Jurassic and Early Cretaceous reservoirs. Unconventional plays may also occur, including deep-seated coal seam gas plays and tight oil plays in the main Permian and Triassic depocentres.

Energy resource assessment work flow

The energy resource assessment module for the AFER project is evaluating and mapping the presence, effectiveness, and interconnectivity of key geological elements that control the distribution of conventional and unconventional petroleum

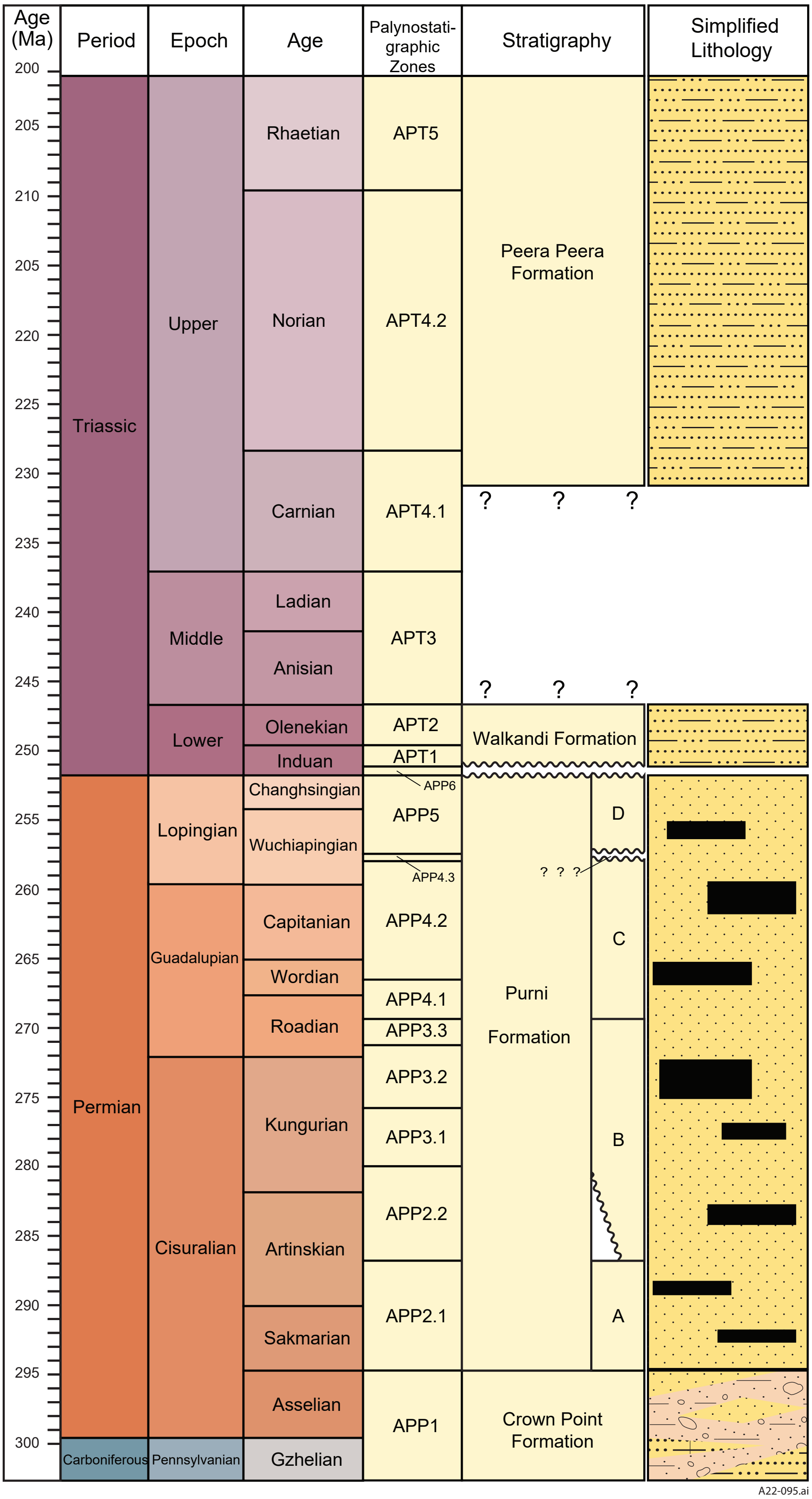


Figure 2. Stratigraphic column of the Pedirka Basin modified from Munson and Ahmad (2013). Timescale is from Ogg *et al* (2016). Palynostratigraphy is after Price (1997) as modified by Hall *et al* (2015), Bodorkos *et al* (2016) and Laurie *et al* (2016). From Doig (2022).

resources. Mapping these play elements will also enable the evaluation of potential geological storage intervals for CO_2 and hydrogen, as well as deep unallocated groundwater resources for potential 'green' hydrogen fuel production.

The resource assessment approach is based on exploration play-types and has been developed over several decades by the petroleum industry (eg Longley and Brown 2016). The Player™ software created by GIS-Pax provides a systematic play-based exploration workflow in an ArcGIS platform, and is being used to evaluate the presence and effectiveness of the main conventional petroleum systems' play elements of reservoir, seal, trap and charge. This play-based workflow will provide key insights into the geological controls on hydrocarbon occurrences and will identify the failure mechanisms of each play using a data driven approach. The play-based exploration workflows to assess conventional hydrocarbons are also being modified to assess the geological elements and criteria that are essential to evaluate unconventional petroleum resources and geological storage potential for CO_2 and hydrogen within the study area. Time-slice based reservoir and seal fairway maps, together with petroleum systems models for fluid flow history, will also provide guidance for the identification of deep-seated aquifers and their potential to provide feedstock for hydrogen production, with possible associated geothermal energy production from hot sedimentary aquifers. Understanding crustal fluid flow and migration pathways of brines through reservoirs and locations of palaeo oil columns may also assists with future assessments of sediment-hosted mineral resources.

The first step in the energy resource assessment workflow has been taken through defining the chronostratigraphy for the play intervals in the western Eromanga Basin and the underlying Permian and Triassic strata. The western Eromanga Basin play scheme has been developed in conjunction with Geoscience Australia's GABG project to ensure that the energy resource play intervals are calibrated to the recently published chronostratigraphic scheme for groundwater resources in the Great Artesian Basin (Hanniford *et al* 2022; **Figure 3**). Play interval schemes are also being developed in collaboration with the NTGS and SA DEM and will incorporate new palynological data from the AFER project as well as new core analysis results from the NTGS.

Post-drill analysis forms a key component of evaluating the resource potential of a region by ensuring that a consistent, systematic approach is used to evaluate the presence and effectiveness of reservoirs, seals, trapping mechanisms, and hydrocarbon charge within each play interval. The AFER project has recently commenced a post-drill analysis of all exploration wells in the assessment area.

Using well data and interpretations from newly reprocessed seismic data and results from a petroleum systems study by SA DEM, the next step in the resource assessment workflow will be to produce gross depositional environment, hydrocarbon charge, depth-structure and isopach maps. These maps will be integrated with post-drill analysis results to create play maps for each risk element and then 'stacked' (spatially analysed) in the Player Software to create common-risk segment maps, which will highlight potential exploration targets for each Permian, Triassic, Jurassic and Cretaceous play interval.

CO_2 geological storage resources in residual oil zones (ROZ)

Carbon dioxide enhanced oil recovery (CO2-EOR) is a technology that can produce residual or difficult-to-move oil while simultaneously geologically storing CO_2; it typically is used as a tertiary production method in conventional oil fields (**Figure 4**). Generally, the aim of CO2-EOR is to recover the maximum amount of oil for the minimum amount of injected CO_2 due to the availability and high cost of CO_2. It is possible, however, to find examples where the amount of CO_2 used for EOR is equal to or larger than the CO_2 produced through the life-cycle of the resulting oil (referred to as CO2-EOR+; Tenthorey *et al* 2021a). The AFER project is investigating the potential application of this technology to residual oil zones in Australia with a view to maximising CO_2 geological storage while growing our hydrocarbon portfolio through as yet poorly characterised and untapped but potentially producible oil resources.

While Australia currently does not have an established CO2-EOR industry, at least in part (and somewhat ironically), due to the difficulty in obtaining sufficient CO_2 for such operations, several carbon capture and storage (CCUS) projects due to come online within the next few years could potentially provide a continuous supply of anthropogenic CO_2 for EOR utilisation and, ultimately, geological storage. It should be noted that the majority of the currently operating or planned CCS projects are seeking to store CO_2 in depleted fields or near existing oil/gas operations, which would provide infrastructure and other resources that could be used for EOR.

Residual oil zones are naturally water-flooded reservoirs that contain a moderate saturation of immobile oil (up to ~30%); this oil can be produced through CO2-EOR – much like a conventional oil field that has undergone earlier stages of production. ROZ can be found beneath the oil–water contact associated with a conventional oil field, or they can be found with no associated main pay zone. Production of oil from these reservoirs is currently limited to the USA where the CO2-EOR industry is well-established and where geological conditions, especially in the San Andres Formation of the Permian Basin, are particularly favourable. Examples include the Seminole oil field, where an additional 225 MMbbl of oil is forecast to be produced from its ROZ alone; and the Kinder Morgan's Tall Cotton field, which has no main pay zone and was producing some 3000 barrels of oil per day by the end of 2018 after four years of development (Trentham *et al* 2015, Allison and Melzer 2017, Trentham and Melzer 2019, Kinder Morgan 2018, 2020).

Through this project, and in collaboration with CSIRO, we aim to determine whether technically accessible and potentially commercially viable oil resources can be found in ROZ within Australia's hydrocarbon basins that could be produced through CO2-EOR and, in turn, provide additional CO_2 storage resources. The 'search' component of the workflow combines petroleum systems knowledge, petrophysical analysis, and other evidence such as shows and fluid inclusions. These are needed to locate possible ROZ and quantify the potential oil resource, initially in brownfields areas where conventional oil production has taken place and data is plentiful, then in greenfields areas and under-explored basins that are also within the scope. The 'production' component of the workflow includes core-flooding/fluid flow experiments that seek to quantify potential oil recovery and CO_2 storage potential in typical Australian ROZ, and to inform reservoir models and potential recovery/storage engineering approaches.

Previous high-level studies of CO2-EOR and ROZ potential in Australia (eg Pepicelli 2018, Rendoulis 2018,

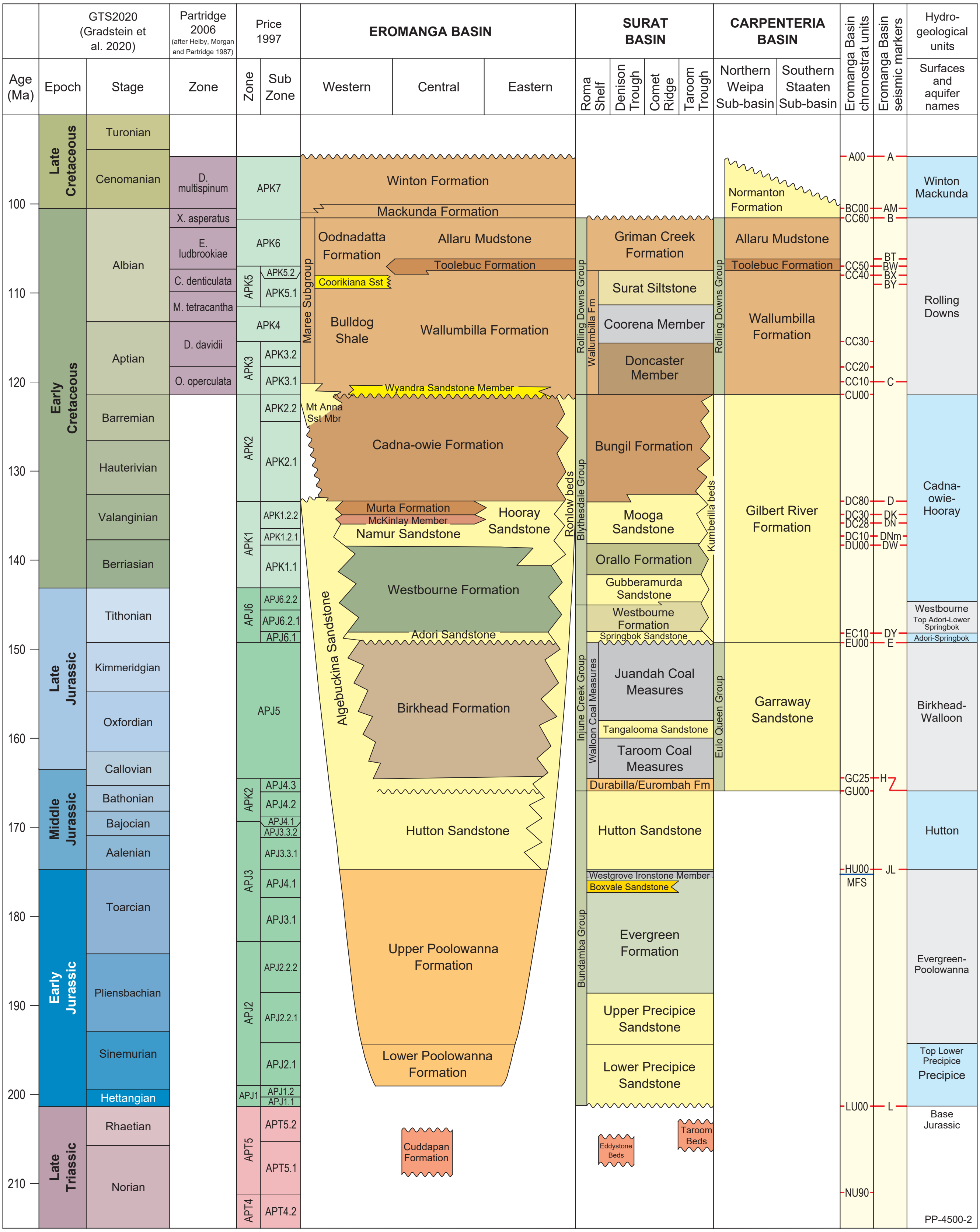


Figure 3. Chronostratigraphic chart for the Eromanga Basin modified from the recently published Geoscience Australia and MGPalaeo Great Artesian Basin chronostratigraphic chart (Hannaford *et al* 2022) to show the nine regional play intervals defined for resource assessments in the Eromanga Basin. Also included are the North West Shelf dinocyst zones of Partridge (2006), the central Australian palynological zones of Price (1997), the Santos Eromanga Basin chronostratigraphic surfaces (Gallagher *et al* 2008), and the North West regional play intervals and sequence stratigraphic surfaces of Marshall and Lang (2013).

Tenthorey *et al* 2021b and Kalinowski *et al* 2022) found considerable promise in several of Australia's mature hydrocarbon provinces, with significant estimated remaining oil in place; the studies speculated that ROZ could be found in these and in several under-explored regions (possibly as greenfields-style fields). The Amadeus and Pedirka basins, for example, show evidence of oil migration and some residual oil examples, although further characterisation is required to determine whether substantial residual oil volumes are present (Tenthorey *et al* 2021b, Kalinowski *et al* 2022). Another example is the offshore Bonaparte Basin, which hosts some of the largest documented residual oil columns in Australia, some over 40 m thick (Newell 1999, Brincat 2001, Kalinowski *et al* 2022).

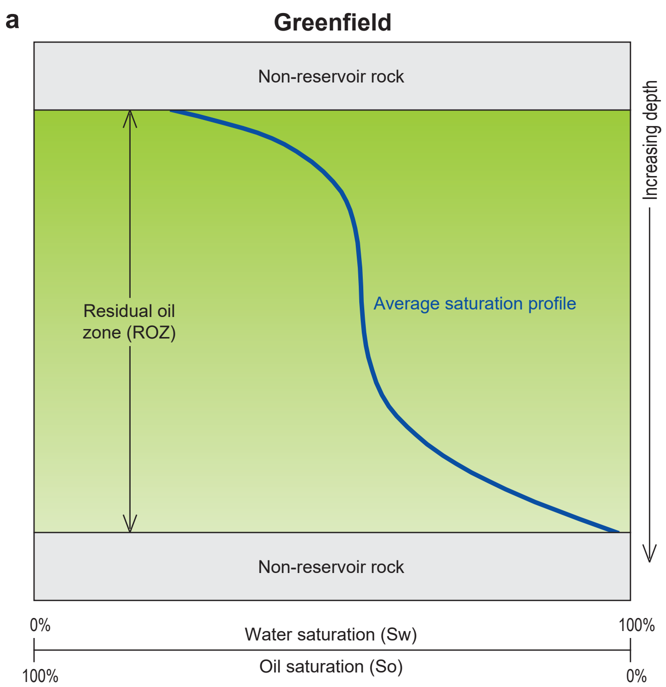
The study is currently focused on the mature Cooper-Eromanga hydrocarbon province where oil production has been ongoing since the 1980s, and where some of the rare Australian examples of EOR have been conducted, such as at the Tirrawarra and Fly Lake oil fields (Brown and Barley 1986, Frears 1998, Gravestock *et al* 1998, Pedler 2009, Radke 2009, Harley 2021). Conditions there are generally favourable for CO2-EOR (eg Rendoulis 2018, Tenthorey *et al* 2021b). Screening of a substantial number of oil fields in the South Australian portion of the basin has identified several fields and formations that will now undergo further detailed petrophysical analysis in combination with the study of other evidence from shows, fluid inclusions, and core analysis (where available) in order to confirm the presence of ROZ and define and quantify potential oil and CO_2 storage resources.

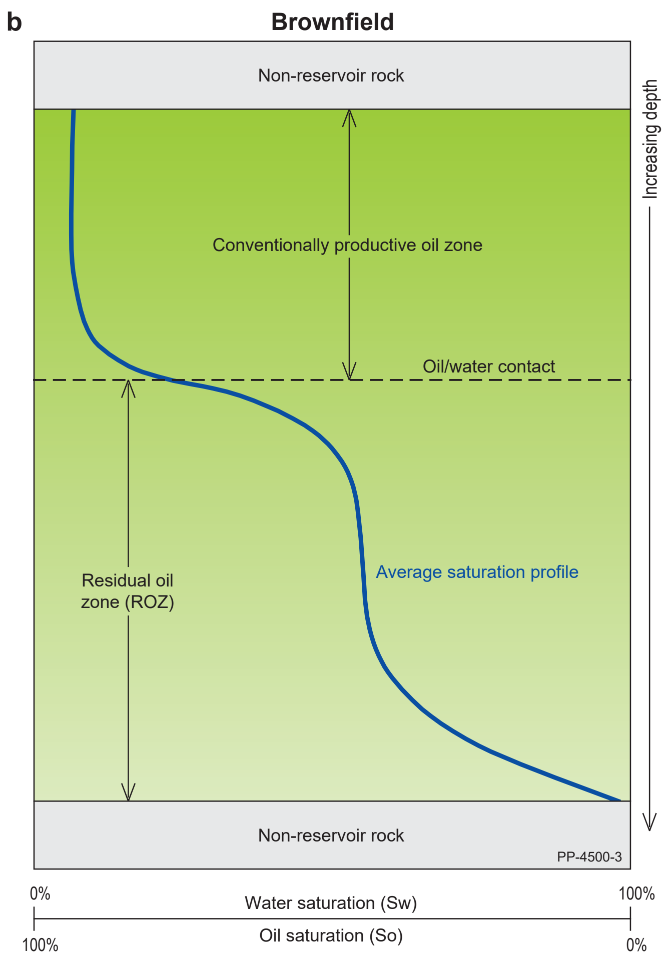
Western Eromanga seismic reprocessing

Seismic data coverage over the western Eromanga Basin is relatively sparse with about 15 000 line km of 2D seismic data acquired across an area of 190 000 km^2. No 3D seismic surveys have been acquired outside the Cooper Basin. The coverage and quality of seismic data varies across the region: the earliest data is of late 1950s vintage and the most recent 2D seismic surveys were acquired by Central Petroleum in 2013. Much of the NT area is covered by relatively vintage seismic data compared to the SA area of the basin, with regional seismic data mainly consisting of single-fold lines acquired during the 1960s and 1970s, infilled by multi-fold data acquired in the 1980s. A key uncertainty for conventional hydrocarbon exploration has been understanding the structural integrity of traps before drilling as most prospects were defined on sparse, relatively low quality seismic data; moreover, several previously drilled traps appear to have been breached during a Cenozoic phase of fault reactivation (Ambrose *et al* 2002, 2007).

The AFER project is helping to reduce the uncertainty in identifying valid traps for exploration by reprocessing about 3750 line km of legacy seismic data across both SA and NT (**Figure 1**). Modern processing techniques are being used to improve the resolution of 1980s' and 1990s' vintage seismic data. Reprocessing has initially focused on seismic data in SA where about 2000 km of 1974 to 1994 vintage data has been reprocessed. This first phase of seismic reprocessing is now completed and will soon be available through Geoscience Australia's EFTF portal.

Figure 4. Diagram illustrating the residual oil zone concept, showing oil and water saturation variations across reservoirs in (**a**) greenfield (no main pay zone) and (**b**) brownfield (associated with a main pay zone) scenarios (from Sanguinito *et al* 2020).





Initial results are highly encouraging with a significant uplift in resolution. Previously, the legacy seismic data showed poor resolution of structures and only allowed confident regional mapping of a few high amplitude seismic horizons (**Figure 5**). The reprocessed seismic data provides greater resolution of structures allowing fault planes to be confidently interpreted to assess their timing and potential to either breach traps or provide valid structural traps. Greater stratigraphic resolution is also provided allowing confident interpretation and mapping of play intervals in the western Eromanga Basin and underlying Permian and Triassic basins. Also, the greater resolution of the pre-Permian section provided will deliver an improved understanding of the western Warburton Basin and underlying basement.

In addition, a further 1750 line km of seismic data is being reprocessed, which includes ~650 km of data from the NT. This second phase of seismic reprocessing supplies additional infill and ties to wells, which will enable improved regional mapping of play intervals and post-drill assessments of previous prospect failures due to the drilling of invalid or breached structural traps. The phase 2 seismic reprocessing is scheduled for release early in the 2022/23 financial year.

Permian and Triassic palynological infill sampling

A key requirement for undertaking reliable play-based resource assessments is to have confident interpretations

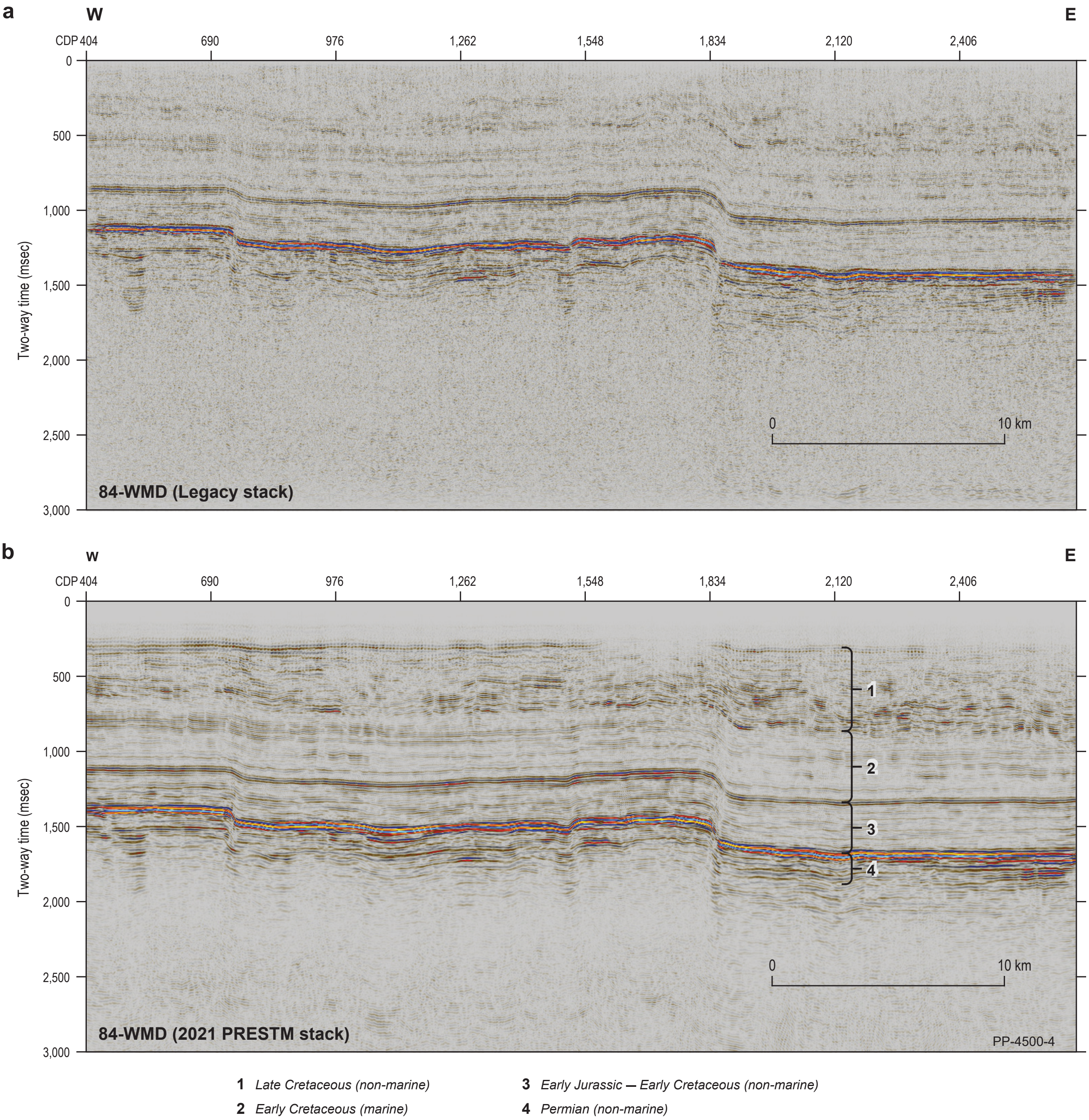


Figure 5. Comparison between (**a**) legacy and (**b**) reprocessed seismic data from line 84-WMD over the western flank of the Poolowanna Trough. The reprocessed seismic data shows a significant uplift in the structural and stratigraphic resolution of the seismic data.

and correlations of regional play intervals in wells. The most recent phase of exploration drilling by Central Petroleum has highlighted the many gaps in our knowledge of the age and regional correlations of stratigraphic units within the Permian and Triassic basin successions. An improved understanding of Late Permian and Early Triassic intervals is particularly important to effectively determine the depositional history leading up to the Permo–Triassic boundary, the hiatus represented by the associated unconformity, and the implications for basin definitions. The AFER project, in collaboration with NTGS and SA DEM, are addressing this geological uncertainty through infill sampling and palynological analysis of Permian and Triassic stratigraphic units in key wells. MGPalaeo have been engaged to undertake palynological analysis of samples that contain suitably preserved palynomorphs.

Eights wells from the SA DEM Adelaide core shed were sampled in December 2021, with a total of 60 samples collected. These samples are currently being analysed and results are planned for release in April 2022. In addition, a total of 68 samples were collected from eight wells in the NTGS Alice Springs core shed in February 2022. Much of the NT sampling has targeted fully cored Permian sections from four of the Central Petroleum coal seam gas exploration wells (CBM93-002, CBM93-004, CBM107-001, CBM107-002). Several samples have been collected immediately above and below tuff intervals recently identified and sampled by NTGS; these samples will potentially enable some spore-pollen zones in the Purni Formation to be calibrated against isotopic ages derived from these tuffs. Results from the NT palynological sampling and analysis are planned to be released in June 2022.

Outlook

Geoscience Australia's AFER project will continue over the next two years under the Commonwealth Government EFTF Program and in collaboration with related studies by NTGS and SA DEM. The AFER project is providing pre-competitive reports and integrated spatial datasets to support exploration for low-carbon energy resources in the central Australian region. A diverse range of national-scale studies are being undertaken to identify: 'yet-to-find' hydrocarbon resources; areas with potential hydrogen resources (naturally occurring, green and blue); residual oil zones that can be produced while utilising and storing CO_2; and areas with high potential for underground storage of hydrogen and CO_2. Products from the AFER project will assist government with the formulation of future energy strategies, including Australia's path to a low carbon economy. Publications, interpretations and new data collected during the project will be made publicly available at regular intervals through the EFTF website and the GA data portal.

The project will contribute to the expansion of Australia's energy commodity resource base. The development of untapped energy resource accumulations will require an expansion of existing infrastructure and/or the creation of new networks. Such undertakings will translate to the creation of new jobs, many of which will require specialist skills, and could be an important driver for increasing Australia's resource wealth. It is anticipated that the results of this project will high-grade the energy resources prospectivity of the eastern boundary region between the Northern Territory and South Australia. Given the area's proximity to the Cooper Basin, the existing infrastructure has potential to be expanded westwards for resource development and production.

Acknowledgements

The authors wish to thank Andrew Feitz and Adam Bailey for their constructive reviews, and Chris Evenden for figure drafting. We also wish to acknowledge the contributions of the Northern Territory Geological Survey and South Australian Department of Energy and Mining to the Australia's Future Energy Resource Project. This extended abstract is published with the permission of the Chief Executive Officer, Geoscience Australia.

References

Ahmad M and Munson, TJ, 2013. Geology and mineral resources of the Northern Territory. *Northern Territory Geological Survey, Special Publication* 5.

Allison J and Melzer S, 2017. *Tall Cotton CO_2 EOR ROZ Greenfield Flood. Presentation*. CO2 ROZ 2017 Conference. https://www.co2conference.net/wp-content/uploads/2017/12/10-Allison-Melzer-Tall-Cotton-Greenfield-ROZ-CO2-EOR-Project-Update-12-6-17.pdf.

Ambrose GJ, 2006. Pedirka/Simpson Desert/Eromanga basins: in Northern Territory of Australia, onshore hydrocarbon potential, 2006. *Northern Territory Geological Survey, Record* 2006-003.

Ambrose GJ and Heugh J, 2012. The Geology of the Pedirka Basin Coal Measures: in '*The Purni Formation, Simpson Desert Area. Proceedings Central Australian Basin Symposium III, Special Publication 2. Alice Springs, 16-17 July, 2012*'. Petroleum Exploration Society of Australia.

Ambrose GJ, Heugh J, Askin H and Alamiyo B, 2012. A Devonian rimmed carbonate platform complex and barrier reef complex offers new exploration opportunities in the Simpson Desert: in Ambrose GJ and Scott J (editors). '*Central Australian Basins Symposium (CABS) III'*. Petroleum Exploration Society of Australia, Special Publication.

Ambrose GJ, Scardigno M and Hill AJ, 2007. Petroleum Geology of Middle-Late Triassic and Early Jurassic sequences in the Simpson Basin and northern Eromanga Basin of central Australia. *The APPEA Journal* 47(1), 127–143.

Ambrose GJ, Liu K, Deighton I, Eadington PJ and Boreham CJ, 2002. New petroleum models in the Pedirka Basin, Northern Territory, Australia. *The APPEA Journal* 42 (1), 259–286.

Brincat MP, Obrien GW, Lisk M, De Ruid M and George SC, 2001. Hydrocarbon Charge History of the Northern Londonderry High: Implications for Trap Integrity and Future Prospectivity. *The APPEA Journal* 41(1), 483–496.

Brown DJ and Barley M, 1986. Tirrawarra and Moorari enhanced oil recovery projects – 'getting more oil out from down under'. *The APPEA Journal* 26(1), 389–396.

Central Petroleum Limited, 2008. CBM 107-002 well completion report. Interpretive data. EP 107, Northern Territory. Central Petroleum Limited. *Northern Territory Geological Survey, Open File Petroleum* PR2011-0125.

Frears RA, 1998. Chapter 11: Recovery technology: in Gravestock DI, Hibburt J and Drexel JF (editors). '*Petroleum Geology of South Australia, Volume 4: Cooper Basin*'. Primary Industries and Resources, South Australia.

Gallagher SM, Wood GR and Lemon NL, 2008. Birkhead Formation chronostratigraphy on the Murteree Horst, South Australia: identifying and correlating reservoirs and seals: in Blevin JE, Bradshaw BE, and Uruski C (editors). '*Eastern Australasian Basins Symposium III, 14–17 September 2008*'. Proceedings of the Petroleum Exploration Society of Australia Symposium: Sydney, 169–190.

Gravestock DI, Jensen-Schmidt B and Sansome A, 1998. Chapter 12: Field summaries: Gravestock DI, Hibburt J and Drexel JF (editors). '*Petroleum Geology of South Australia, Volume 4: Cooper Basin*'. Primary Industries and Resources, South Australia.

Hannaford C, Young M, Watts C, Charles A, Cooling J, and Rollet N, 2022. Palynological review of selected wells and new sampling results in the Great Artesian Basin. Data package and supplementary reports. *Geoscience Australia, Record* 2022/01.

Hibburt JE and Gravestock DI, 1995. Pedirka Basin: in Drexel JF and Preiss WV (editors). '*The geology of South Australia. Volume 2, the Phanerozoic, Chapter 8 Late Palaeozoic*'. *Geological Survey of South Australia, Bulletin* 54, 88–90.

Kalinowski A, Tenthorey E, Taggart I and McKenna J, in press. Residual oil zones: review of current practice and experience. Geoscience Australia, Canberra. *Geoscience Australia, Record*.

Kinder Morgan, 2018. *Tall Cotton (San Andres) Field*. Presentation at Midland CO2 Conference, 5 December 2018, Midland, Texas. https://co2conference.net/presentation/tall-cotton-san-andres-field/.

Kinder Morgan, 2020. *CO_2 Overview*. https://www.kindermorgan.com/Operations/CO2/Index (last accessed 2 March 2022).

Longley IM and Brown J, 2016. Why bother? (with play based exploration): The five reasons why play based exploration is worthwhile in a modern busy understaffed and overworked exploration company environment. *Search and Discovery Article* 110227. https://www.searchanddiscovery.com/documents/2016/110227longley/ndx_longley.pdf.

Marshall NG and Lang S, 2013. *A New Sequence Stratigraphic Framework for the North West Shelf, Australia, West Australian Basins Symposium*. The Petroleum Exploration Society of Australia.

Miles C, Keppel M, Fulton S, Osti A and Foulkes J, 2015. *Context statement for the Pedirka subregion. Product 1.1 for the Pedirka subregion from the Lake Eyre Basin Bioregional Assessment*. Department of the Environment, Bureau of Meteorology, CSIRO, Geoscience Australia and Government of South Australia.

Munson TJ, 2014. Petroleum geology and potential of the onshore Northern Territory, 2014. *Northern Territory Geological Survey, Report* 22.

Newell NA, 1999. Water Washing in the Northern Bonaparte Basin. *The APPEA Journal* 39(1) 227–247.

Norton CJ and Rollet N, 2022. Regional structural correlation transects across the Great Artesian Basin – Eromanga and Surat basin focus study. *Geoscience Australia, Record* 2022/02.

Partridge AD, 2006. Jurassic–Early Cretaceous spore-pollen and dinocyst zonations for Australia: in Monteil E (co-ordinator). *'Australian Mesozoic and Cenozoic Palynology Zonations–updated to the 2004 Geologic Time Scale'*. *Geoscience Australia, Record* 2006/23.

Passmore VL, 1989. Petroleum accumulations of the Eromanga Basin: a comparison with other Australian Mesozoic accumulations: in O'Neil BL (editor). '*The Cooper and Eromanga Basins, Australia*'. Proceedings of the Petroleum Exploration Society of Australia, 371–389.

Questa Australia Pty Ltd, 1990. Eromanga Basin. Northern Territory Geological Survey, Petroleum Basin Study. *Questa Australia Pty Ltd. Report* No. GS90/008.

Pedler I, 2009. *Enhanced oil recovery studies in the Tirrawarra Oil Field, Cooper Basin, South Australia*. Presentation (Santos). https://slideplayer.com/slide/7057514/ (last accessed 2 March 2022).

Pepicelli D, 2018. *Enhanced oil recovery: status and potential in Australia*. IEA EOR TCP, Copenhagen, Denmark, 6 September 2019. Government of South Australia. https://www.petroleum.sa.gov.au/__data/assets/pdf_file/0011/274385/Pepicelli_-_IEA,_6Sep2018.pdf (last accessed 2 March 2022).

Price PL, 1997. Permian to Jurassic palynostratigraphic nomenclature of the Bowen and Surat basins: in Green P, (editor). '*The Surat and Bowen Basins, Southeast Queensland*'. Queensland Department of Mines and Energy, Brisbane, 137–178.

Radke B, 2009. Hydrocarbon and geothermal prospectivity of sedimentary basins in Central Australia; Warburton, Cooper, Pedirka, Galilee, Simpson and Eromanga basins. *Geoscience Australia, Record* 2009/25.

Rendoulis N, 2018. *Potential for carbon dioxide EOR in the Cooper and Eromanga Basins*. Department for Energy and Mining, South Australia.

Sanguinito S, Singh H, Myshakin EM, Goodman AL, Dilmore RM, Grant TC, Morgan D, Bromhal G, Warwick PD, Brennan ST, Freeman PA, Ozgen Karacan C, Gorecki C, Peck W, Burton-Kelly M, Dotzenrod N, Frailey S and Pawar R, 2020. Methodology for estimating the prospective CO2 storage resource of residual oil zones at the national and regional scale. *International Journal of Greenhouse Gas Control* 96, May 2020, 103006 https://doi.org/10.1016/j.ijggc.2020.103006.

Tenthorey E, Taggart I, Kalinowski A and McKenna J, 2021a. CO2-EOR+ in Australia: achieving low-emissions oil and unlocking residual oil resources. *The APPEA Journal* 61, 118–131.

Tenthorey E, Kalinowski A, Wintle E, Easton L, Mathews E, McKenna J and Taggart I, 2021b. *Screening Australia's basins for CO_2-Enhanced Oil Recovery.* CO2CRC Report, CO2CRC Ltd, Carlton Victoria Australia.

Trentham R and Melzer LS, 2019. A 'cookbook' approach to evaluating residual oil zones completed as horizontal depressurizing (DUROZ) wells in the San Andres Formation. Adapted from oral presentation given at 2019 AAPG Southwest Section Annual Convention, Dallas, Tx, April 6–9 2019. *Search and Discovery Article* 51570. http://www.searchanddiscovery.com/documents/2019/51570trentham/ndx_trentham.pdf.

Trentham R, Melzer S, Vance D, Kuuskraa V and Petrusak R, 2015. *Identifying and developing technology for enabling small producers to pursue the residual oil zone (ROZ) fairways in the Permian Basin San Andres. Final Report*. US Department of Energy.

Wohling D, Keppel M, Fulton S, Costar A, Sampson L and Berens V, 2013. Australian Government initiative on coal seam gas and large coal mining — Arckaringa Basin and Pedirka Basin Groundwater Assessment Projects. *Government of South Australia, Department of Environment, Water and Natural Resources*, *Technical Report* 2013/11.