WESTERN AUSTRALIA'S DIGEST OF PETROLEUM EXPLORATION, DEVELOPMENT AND PRODUCTION

PETROLEUM IN WESTERN AUSTRALIA

SEPTEMBER 2014

Contents

Drilling Senecio 3

ARTICLES

TABLES

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Cover: Loading operations at the Port of Wyndham Photo © Buru Energy

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Government of **Western Australia**
Department of **Mines and Petroleum**

WESTERN AUSTRALIA
Opportunities to Explore
BIDS INVITED FOR ACREAGE

PETROLEUM ACREAGE

Canning Basin

Interest in the Canning Basin has revived significantly in recent years, with the oil discovery at Ungani and large estimates for shale gas. Mitsubishi, ConocoPhillips, Hess, and as of 2013, PetroChina and Apache are participating in Canning Basin exploration. There are four release areas in platform areas (Broome and Crossland Platforms), with one area partly in the Kidson Sub-basin. Area size ranges from 1770 km^2 to 2407 km^2. These release areas became available for gazettal by statutory relinquishment at the end of permit terms from Buru Energy Exploration Permits. The areas may be prospective for sub-salt Ordovician plays.

Southern Carnarvon Basin

There is one release area in the onshore Southern Carnarvon Basin. Area size is 1265 km^2. Although an under-explored basin, geochemical studies indicate that Devonian and Permian oil and gas-prone source intervals are present across the basin. The release area is considered prospective for Permian shale gas or tight gas, as well as pre-Permian oil.

Officer Basin

There are four large release areas (ranging in size from 10,925 km^2 to 15,413 km^2) in the Neoproterozoic central Officer Basin adjacent to the South Australian border. It appears that all the elements of a petroleum system are present. Good source beds and proven reservoirs capped by thick sections of salt or shale have been intersected. There may be sub-salt and unconventional hydrocarbons present. The Officer Basin resembles Neoproterozoic successions in Oman and Russia that contain commercial hydrocarbon resources.

Bids close on Thursday 23 April 2015.

Acreage release disk packages are available from DMP and a web version is also available:
www.dmp.wa.gov.au/acreage_release

Acreage release packages contain relevant information about the release areas, land access and how to make a valid application for an Exploration Permit.

GEOTHERMAL ACREAGE

Acreage is available for the whole of the State not covered by permits or applications. Application is by a Geothermal Special Prospecting Authority (GSPA) with Acreage Option (AO).

Companies are invited to apply for areas each with size up to 160 5'x5' graticular blocks.

Companies interested in geothermal acreage are allowed to bid for multiple areas and are expected to drill at least one well during the first two years of obtaining a geothermal title.

Geothermal acreage information is available from DMP on the web at:
www.dmp.wa.gov.au/acreage_release

FURTHER INFORMATION

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Minister's message

Hon. Bill Marmion
Minister for Mines and Petroleum

The discovery of what we all hope will be a major commercial oilfield near Port Hedland is good news indeed for the oil and gas industry.

Results from the Phoenix South 1 well have yet to be analysed and appraised, but it augurs well for exploration of overlooked areas of the North West Shelf.

Oil exploration in Western Australia started a long way south of our established offshore fields.

Back in 1902, explorers drilled for oil near the Warren and Blackwood Rivers.

But drilling for oil is a risky business and big finds are rare, so it's little surprise this first venture was unsuccessful.

This year is the 120th anniversary of the founding of the Department of Mines and Petroleum and to commemorate it, Petroleum Executive Director Jeff Haworth has taken a timely look back at the development of the State's oil and gas industry.

In his article on page 4, Jeff provides a detailed and fascinating account that includes history-making names and places such as WAPET, Rough Range 1 and Barrow Island.

Did you know that that more than 3200 wells have been drilled in Western Australia since 1903 – with 1772 of them onshore or on nearby islands and a further 1476 offshore?

It's a great read and I recommend it to you.

I'm pleased to see that DMP is again promoting the petroleum potential of Western Australia's vast sedimentary basins by using a specific area release system for areas of our onshore and State waters.

Exploration Geologist Richard Bruce writes that the department released nine onshore blocks this month – four in the Canning Basin, one in the Southern Carnarvon Basin and four in the Officer Basin.

A disk package has been sent out as part of the release to provide information about the prospectivity of release areas, available data listings, land access, and how to make a valid application for an Exploration Permit.

Also in this edition, Senior GHG Storage Reservoir Engineer Jianhua Liu has written a review of ISO 31000 – the family of standards relating to risk management codified by the International Organization for Standardization – and includes a focus on its application to Carbon Capture and Storage (CCS).

While we're on the subject of CCS, Petroleum Engineer Mina Torbatynia has provided an insight into the geomechanical characterisation of CO_2 storage sites.

Geologist Charmaine Thomas was an integral part of the recently completed 700 km, five-week road trip in the Kimberley that we know as the Canning Coastal Seismic Survey.

The deep crustal reflection seismic and gravity survey spanned the Canning Basin and recorded data from as deep as 50 to 60 km into the earth's crust.

Analysts are now poring over information that may answer some big questions about the geological framework of Western Australia.

Meanwhile, the data obtained from shallower depths can also be used by resource companies to identify areas that may be prospective for minerals and petroleum.

On a topical note, DMP graduate officer Joanna Wong and Mohammad Bahar from the Resources Branch have co-authored an article on Shale Gas Resource Assessment in the Merlinleigh Sub-basin, an area under explored for this resource.

We all know that there is considerable community interest in natural gas from shale and tight rocks, so this article certainly merits attention.

Executive Director's message

Jeff Haworth
Executive Director
Petroleum Division

This year is the 120th anniversary of the creation of the Department of Mines and Petroleum, so I thought I would reminisce a little on the development of the petroleum industry in Western Australia and focus on the Department's regulatory role during this time.

The first petroleum exploration wells, drilled in the Blackwood and Warren rivers area in 1902, were unsuccessful and other early exploration of the State was sporadic and also brought little success. The first concerted exploration drilling campaign began in the 1950s with West Australian Petroleum (WAPET) drilling the Rough Range 1 well near North West Cape and finding non-commercial oil in 1955. WAPET continued a statewide exploration campaign drilling wells in the Canning, Perth and Carnarvon Basins, but it wasn't until 1964 that a commercially viable oilfield was discovered on Barrow Island.

The strategic value of oil and gas was recognised by the Commonwealth Government which created the *Petroleum Search Subsidy Act 1957*. This provided incentives to industry for petroleum exploration throughout Australia. The discovery of oil at Barrow Island was a part of this program.

During this period the Western Australian Government regulated the industry under the *Petroleum Act 1936*.

In 1967 the *Petroleum Act 1967* (now the *Petroleum and Geothermal Energy Resources Act 1967* [PGERA67]) together with the Commonwealth *Petroleum (Submerged Lands) Act 1967* were passed to regulate the industry.

Oil and gas was discovered in the Mid West in 1966 at the Dongara field, which came into production in 1971 when the Parmelia gas pipeline was constructed to deliver gas to the metropolitan area. Several other gasfields were also discovered around Dongara, including Mondarra, Woodada, Warro, Yardarino and Gingin; some proved to be commercial while others were not. Further discoveries were made in the 1990s and 2000s, including the Tubridgi and Beharra Springs gasfields, the Eremia, Jingemia and Hovea oilfields and the offshore Cliff Head oil- and gasfield. More than 3200 wells have been drilled in Western Australia since 1903, 1772 of which were onshore or on nearby islands with a further 1476 offshore.

Woodside (then, the Burmah Oil Company of Australia) started exploring, along with others, off the coast in the North West Shelf area in the 1970s. During this time, there were significant gas discoveries made, such as North Rankin, Goodwyn, Gorgon, Scott Reef, and Scarborough to name a few, however these were not commercially viable at the time.

DMP regulated this exploration in the onshore areas and on behalf of the Commonwealth in the offshore as the Designated Authority. Regulation was conducted under a set of Schedules of Requirements for both areas and all activities conducted by companies required assessment and approval by DMP before commencement. All were subject to audit during operations by DMP inspectors.

In the 1980s the State Government underwrote the construction of the Dampier to Bunbury Natural Gas Pipeline which provided domestic gas from the North West Shelf to customers in the South West. The North Rankin and Goodwyn fields started production in 1984 and 1995, respectively, with Liquefied Natural Gas (LNG) export to Japan commencing in 1989.

It was also in the 1980s, 6 July 1988 to be specific, that the Piper Alpha disaster in the North Sea took place, killing 167 people. The subsequent Cullen Inquiry into the disaster recommended that regulation should move from prescriptive legislation to "objective based" regulation with a focus on risk identification and management. The Commonwealth, the States and the Northern Territory agreed to adopt this style of legislation in 1994 and moved towards replacing the existing Schedules with a set of regulations. The Commonwealth started this process first and Western Australia followed, with changes to its legislation starting in 2010. These included the Safety Regulations for the three State Acts, PGERA67, *Petroleum (Submerged Lands) Act 1982* and the *Petroleum Pipelines Act 1969*. The Environment Regulations were introduced in 2012 and the final set of regulations, the Resource Management and Administration Regulations, are due to be introduced in the later part of this year.

The real boom in the offshore occurred from the 1990s onwards with the introduction of floating technology, subsea manifolds, multi-lateral wells and horizontal drilling in the North West Shelf. The introduction of floating production storage and offloading facilities (FPSOs), especially, allowed previously unviable oilfields to be brought into production. Again, DMP was heavily involved in the regulation of these new technologies, including the construction and management of high pressure, high volume gas production wells in deep water, ensuring the legislation and regulatory framework dealt with the safe, environmentally responsible development of the industry.

During this offshore boom time, the onshore gasfields were reaching the end of their commercial life and in recent years only one new commercial gasfield has been brought into production, the Red Gully/Gingin West field. Much has been said about the potential resources of natural gas in shale and tight rocks in Western Australia and this is seen as a potential replacement of the North West Shelf domestic gas supply, which is due to decline in 2020.

This industry is in its infancy in WA with only a few exploration wells drilled specifically for this target and no commercially viable fields discovered as yet. The US industry is harnessing technologies that have advanced from the days they were first used onshore, specifically horizontal drilling and hydraulic fracture stimulation. As mentioned previously, DMP has been regulating horizontal drilling in offshore areas since the 1990s and this type of hydraulic fracturing since early 2000.

As part of DMP's regulatory role, it reviews other jurisdictions' regulation of the industry, both nationally and internationally, and compares this to our own. The shale and tight rocks development has been around since the 1980s in the US and officers of the DMP have watched its development with keen interest, as well as some officers visiting shale gas well sites in the US.

DMP had an independent review of its legislation in 2010, which concluded that the current regulation of the industry was robust. However, some changes were recommended to improve transparency. These recommendations have been implemented by DMP.

This department, along with other agencies in government, treats the shale and tight rock industry with the same due diligence as the rest of the petroleum industry to ensure operations are conducted in a safe, environmentally responsible manner. DMP manages this through a rigorous assessment and approvals system, followed up by compliance auditing of the operations. As the regulator, this department will continue to monitor the development of the onshore and offshore petroleum industry to ensure best practices are adhered to as it has done in the past, now and into the future, on behalf of the people of Western Australia.

Photo © DMP

DMP inspector auditing the Ungani facility

Release of Western Australia's Petroleum and Geothermal Explorer's Guide – 2014 Edition

The 2014 edition of this highly sought after publication has been revised and updated to reflect recent changes to the legislation and regulations governing the petroleum and geothermal industries in Western Australia, in particular the Environment regulations and the Resource Management and Administration regulations.

The Explorer's Guide provides general information to companies interested in exploring and investing in Western Australia's upstream petroleum and geothermal energy industries.

Information in this guide relates to petroleum and geothermal energy resources in the State of Western Australia, its onshore and State Waters areas, including islands which are administered under the *Petroleum and Geothermal Energy Resources Act 1967*, the *Petroleum (Submerged Lands) Act 1982*, the *Petroleum Act 1936* and the *Petroleum Pipelines Act 1969*.

All petroleum and geothermal operations must comply with all the relevant legislation.

This guide assists explorers with information on:

- The role of Government
- The geology and prospectivity of Western Australia's sedimentary basins
- Geothermal energy resources
- Carbon capture and storage projects in Western Australia
- How to access data
- Petroleum and geothermal legislation and administration, resource management and environmental assessment and legislation
- Native title and land access
- Occupational safety and health
- Taxation and commercial aspects relating to petroleum and geothermal production

Copies of this publication are available from:
Public Counter, 1st Floor Mineral House, 100 Plain Street, East Perth.

The Public Counter is open from 8.30 am to 4.30 pm Monday to Friday.

A digital copy of the Explorer's Guide can be accessed via the DMP online 'Publications Systems' link at:
www.dmp.wa.gov.au/8481.aspx

or from the petroleum publications page at:
www.dmp.wa.gov.au/5592.aspx


Photo © AWE Limited

A brief overview of activities in 2013/2014

Karina Jonasson
Petroleum Resource Geologist
Petroleum Division

Seismic line crew

Drilling

It has been quiet on the drilling front during the period from July 2013 to June 2014. Only two new wells were drilled since January, to add to the two others drilled between July and December as reported in the April edition of *Petroleum in Western Australia*. Summary tables for wells, seismic, and the 2013 production and reserves can be found at the back of this magazine.

On Barrow Island, two wells were drilled in July 2013 for the Gorgon Project as water disposal wells for the Gorgon Plant. These are Disposal Wells Z-WI1 and Z-WI2.

Ungani 3 spudded on 14 January 2014 in EP 391 in the Canning Basin. The well is located about 1000 m east of the central Ungani field. It was interpreted from the Ungani 3D seismic data to be a separate structure, targeting the Ungani Dolomite. Early reports indicated poor reservoir development in the main reservoir section. However wireline logs confirmed at least one zone with reservoir potential that will require further testing.

In the Perth Basin, the Drover 1 exploration well was spudded on 29 June 2014 by AWE in EP 455. Drover 1 is located on pastoral land in the Shire of Coorow, approximately 18 km southeast of Green Head and 220 km north of Perth.

The Drover 1 exploration well will be drilled vertically to a planned total depth of 2400 m and is designed to evaluate the unconventional gas potential in the southern area of AWE's Perth Basin acreage.

Drover 1 is targeting the Kockatea and Caryngingia shale formations, the Irwin River Coal Measures and the High Cliff Sandstone. A total of 21.5 m of core samples were collected from the Kockatea Shale and sent for analysis as well as a set of sidewall cores from the target formations. The well is expected to reach the total depth in mid-July.

Enerdrill rig 3 at Drover 1 in the northern Perth Basin

Surveys

Five surveys were carried out in Exploration Permits during the period, all in the Canning Basin: EP 449 Airborne Gradiometry Survey for Hess; the EP 448 Geochemical Survey for Key Petroleum; and the Frome Rocks 2D Seismic Survey, Southern Canning Airborne Gravity Survey, and Ungani 3D Seismic Survey Resumption, all for Buru Energy.

Two surveys were carried out under Special Prospecting Authorities, both in the Perth Basin: the AGG-HRAM 2013 Aeromagnetic Survey for Finder Petroleum; and the Murgoo Gravity Survey for Palatine Energy.

Workover Activity

Workover activities include one or more of a variety of remedial operations on a producing well to try to increase the production, maintain the well integrity or change the purpose of the well. Remedial operations can include setting a plug to isolate a water zone, tubing/packer replacement, squeeze cement and so on.

One recent example involves a plug set to isolate a lower production zone followed by perforation and testing of an upper zone at Red Gully 1. Another example is Whicher Range 4 ST1 where the well was suspended with a loss of tubing integrity. The workover was done to retrieve the existing tubing string and replace it with a new string of tubing.

Production

Thevenard Island is the hub where crude oil from six Chevron-operated offshore petroleum fields – Saladin, Roller, Skate, Yammaderry, Cowle, and Crest – is processed and prepared for shipment by ocean tanker to Australian refineries. The first oil from Thevenard Island operations flowed in 1989, and subsequent fields were brought into production in a staged development.

In December 2013, Chevron applied for abandonment of the Thevenard island fields, and received approval from DMP. Chevron indicated that all the fields ceased production in April 2014.

Two onshore fields continue on extended production tests, the Ungani oilfield in the Canning Basin (EP 391) and the Corybas gasfield in the northern Perth Basin (L 2).

Oil from the Ungani wells is trucked to the Port of Wyndham where it is loaded onto a tanker for shipment to Southeast Asian markets.

Gingin West 1 and Red Gully 1, located 80 km north of Perth, discovered commercial quantities of natural gas and condensate. The wells were drilled in 2010 and 2011.

The processing facility consists of the development of these two wells, which are still in the commissioning phase as the project's performance has been hampered by continuing design and commissioning issues. The onshore gas and condensate facility officially began production in June last year and is now supplying gas to bauxite miner Alcoa.

The Red Gully processing facility is designed to produce 8 TJ/day of natural gas and 64 kL/d (400 bbl/d) of condensate.

Tight Gas Proposal Upheld

In June, WA Environment Minister Albert Jacob upheld the Environmental Protection Authority's (EPA) determination in regard to Buru Energy's tight gas testing proposal in the Canning Basin. The program is known as the Laurel Formation Tight Gas Pilot Exploration Program.

In dismissing the appeals against the EPA decision, the Minister said the EPA had concluded that Buru's "small scale, limited duration 'proof of concept' exploration proposal is unlikely to have a significant effect on the environment".

The proposal is being further evaluated by the Department of Mines and Petroleum and Department of Water to meet the EPA's objectives for the environmental factors identified for the proposal.

Gorgon Project Update

Construction began on Barrow Island, offshore Western Australia, in late 2009, and the Chevron-led Gorgon Project is on track to deliver the first shipment of LNG by mid-2015. The Gorgon Project is 80 per cent complete.

Twenty-two LNG Train 1 and common modules are on their foundations at the plant site and all five gas turbine generator units have been placed on their foundations. Hydro-testing activities are complete on LNG tank 1. On LNG tank 2, the outer concrete wall pours are complete with preparations under way for the roof pour. Work continues on the 2.1 km-long LNG jetty with the LNG loading platform under construction. All pre-assembled racks and roadways have been installed at the materials offloading facility and the LNG jetty.

Wheatstone Project Update

Construction on the Wheatstone Project began in late 2011. The Chevron-led project includes an 8.9 million-metric-tonne-per-year LNG facility with two processing units and a separate domestic gas plant.

The Wheatstone Project commenced its offshore drilling campaign in January (left). In March, the Solitaire pipelay vessel began installation of the 225 km-long trunk line to shore. At the DSME yard in Okpo, Korea, piping and electrical equipment is being installed on the platform topsides. Fabrication of the steel gravity structure continues. In early April, the Material Offloading Facility (MOF) received its first materials shipment. The piling activities for the LNG tank foundations are complete. Piling and foundation work continues on LNG Trains 1 and 2 and at the inlet facilities area. The foundation for LNG Tank 1 is progressing with four concrete pours completed. The main refrigeration compressor foundation for LNG Train 1 continues to progress. All phases of the construction village and supporting power and water utilities are now complete, with approximately 5000 beds onsite.

Photo © Chevron Australia

The LNG jetty for the Gorgon Project nears completion

Company focus — Buru operations update

Buru Energy Limited
14 July 2014

Load out of Ungani crude from the Ungani field

Buru Energy Limited

Buru Energy Limited is pleased to provide the following update on the Company's operations.

Summary

- Ungani EPT progressing very well with fifth oil cargo sold
- Appraisal activity including well tests planned for Ungani 3, Ungani North 1 and Paradise 1
- Four oil focused exploration wells proposed for remainder of 2014
- 2014 seismic program underway with first 2D program acquisition commencing shortly
- TGS (Laurel Formation Tight Gas Pilot Exploration Program) phasing optimised with main program early in 2015 dry season to maximise environmental, operational and cost benefits.

Ungani Extended Production Test (EPT)

Production:

The Ungani 2 well continues to produce strongly with production above 1590 kL/d (1000 bbl/d) at current choke settings, with very low water cut of ~1% in accordance with current modelling predictions. The production from Ungani to date is as follows:

- Production Test Phase 1 – 31 May 2012 to 30 March 2013: 16.1 ML (101,278 bbl)
- Production Test Phase 2 – 9 December 2013 – 30 June 2014: 27.4 ML (172,535 bbl)

The oil produced has been shipped from the Port of Wyndham and sold to Asian refineries under the marketing agreement between Buru Energy and Mitsubishi.

A number of production rate tests have been carried out, and interference tests to investigate the communication between the Ungani 2 and Ungani 3 wells have also been completed, with this data currently being recovered for analysis. The planned workover and production testing of Ungani 1 will provide further production data to calibrate the reservoir prediction models and provide more certainty about long term reservoir performance and oil recoveries.

Facilities:

The upgrade of Ungani facilities for permanent production is being reviewed to ensure the new facilities are "fit for purpose" and completed at lowest possible cost. The actual facility design is dependent on the predictions of reservoir performance that are being calibrated with the results of the EPT.

Negotiations to access the Port of Broome for export of oil are continuing and are a priority for the Joint Venture.

Work program for the second half of 2014

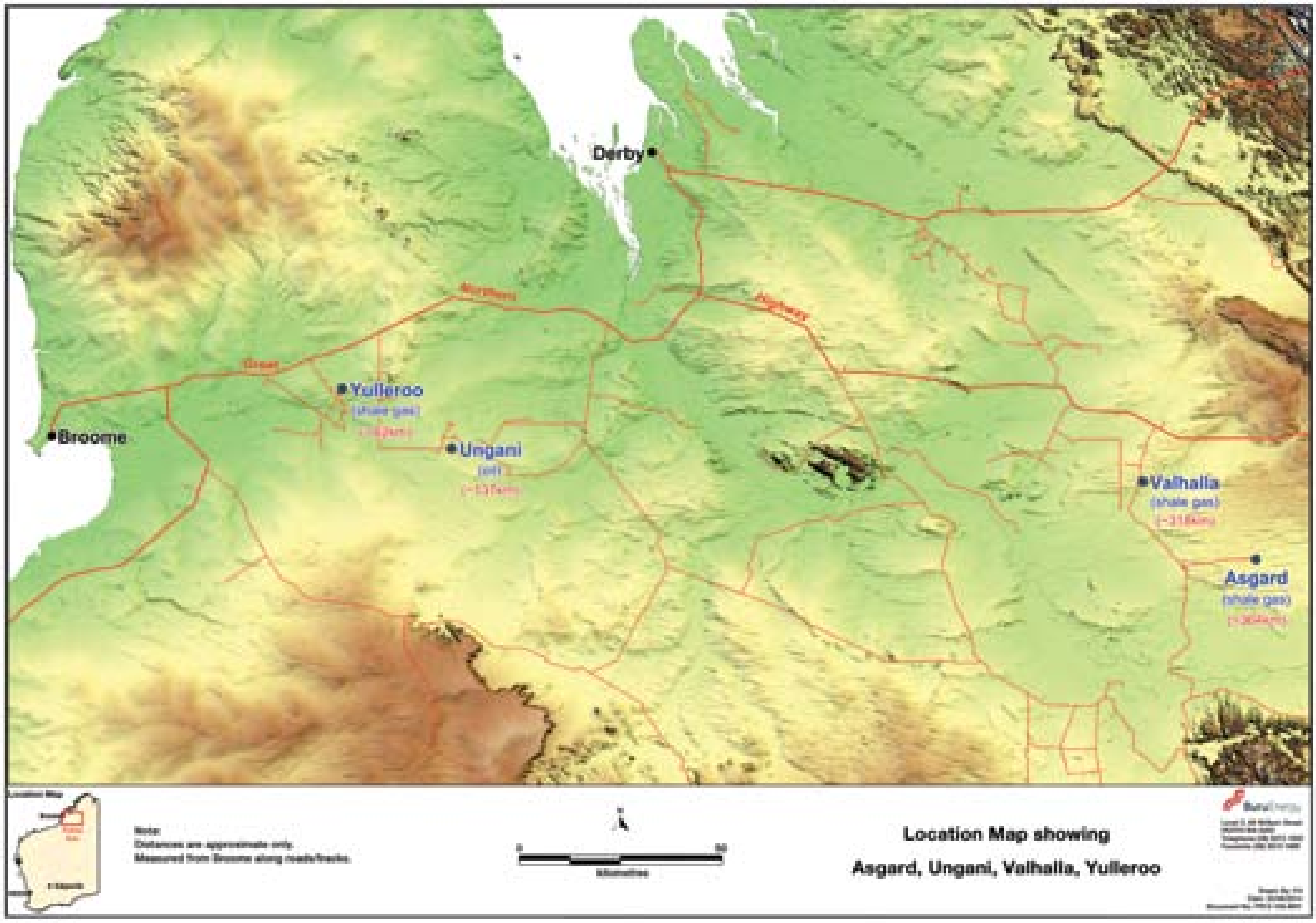
A work program for the second half of 2014 has been prepared and proposed to the various joint ventures. The work program is aimed at high impact low cost activity. A principal component is ensuring that production from Ungani is maintained and increased where possible.

The proposed work program has a substantial component aimed at oil appraisal and exploration, given the high economic value of oil production and the high value add of the identification of further reserves. The proposed program is subject to further approvals from joint venture parties, Traditional Owners and regulatory authorities.

Oil add value

Ungani 1 ST1: The previous attempt to re-complete this well as a dual producer and water injector was not successful. The currently planned workover will be aimed at re-establishing oil production without the option to also inject water. This will allow additional data gathering for the EPT phase and appropriate redundancy in the production system.

Ungani North 1: It is proposed a test of this well will be undertaken using a low cost method to establish the flow potential of the Ungani Dolomite reservoir.



Location map of Buru's operations in the Kimberley region

Ungani 3: A re-completion to fully isolate the water zone will allow a definitive test of the upper zone from which oil was swabbed in the recent test.

Paradise 1: This well has an identified oil zone in the Winifred member of the Grant Formation which was noted in the original drilling of the well in 2010, and from which free oil was recovered in 2012 during well remediation operations. A simple low cost testing operation is planned to verify the oil productivity of this zone which is a significant "play opener".

Exploration drilling

The Company intends to drill up to four exploration wells in the remainder of this year, focused on shallow, high value, oil targets.

Coastal wells:

The Coastal farmout to Apache Corporation included the commitment by Apache to drill two wells at Apache's cost.

These wells have been identified as Olympus and Commodore and are both located in the Kidson Sub-basin and have both conventional and unconventional prospectivity. Both wells are relatively shallow (less than 1500 metres) and will be drilled with a low cost, fit for purpose rig. The joint venture is currently in final negotiations for the supply of the rig from one of a number of rig providers who have submitted bids.

In addition, the Company is in negotiations to use the DCA7 rig which is currently drilling in the Perth Basin for the workover of Ungani 1. This rig would then also be available for the drilling of additional wells in the basin at low cost.

Fitzroy Trough exploration wells:

Ungani trend: The Company has identified a number of shallow oil prospects on the greater Ungani trend that could be drilled with either of the two rigs it intends to contract, and is working with the various joint venture parties and other stakeholders to ensure that at least one of these prospects is drilled this year.

EP129: This permit in the Blina area is currently held 100 per cent by Buru Energy and contains a number of shallow, high value oil targets that could be drilled with either of the two proposed rigs. The Company is currently in preliminary farmout discussions with a number of parties for them to farm in to this permit and participate in this year's drilling program.

Seismic programs

The Company has 2D and 3D seismic programs planned for 2014 to mature drilling targets for 2015 and to meet permit commitments.

2D seismic program: The Terrex seismic crew has commenced line clearing for the 123 km Commodore West Seismic Survey in EP 471, and the data acquisition is expected to commence in approximately 10 days. There are up to a total of 800 km of seismic planned in various permits that are currently subject to the receipt of heritage reports and various other approvals.

Ungani 2 wellhead and Buru Energy field operator

3D seismic program: The planned Jackaroo 3D seismic program is located between Yulleroo and Ungani and will join the two existing 3D grids to give seamless 3D coverage from Yulleroo to Ungani. It covers the currently identified Jackaroo prospect and a number of other oil prospects along trend. All regulatory approvals and heritage clearances have been obtained for this survey and the Terrex 3D seismic crew is available to undertake the survey subject to final joint venture approval.

TGS (Laurel Formation Tight Gas Pilot Exploration Program)

The previous success of the trial low impact reservoir simulation of the Laurel Formation in the Yulleroo 2 well has demonstrated that the Laurel Formation will produce high quality wet gas at potentially economic rates with a relatively minor stimulation program, and this has led to the drilling of a series of exploration wells that have defined a major gas accumulation in the Laurel Formation. The Company is now preparing to undertake a larger scale program known as the TGS or Laurel Formation Tight Gas Pilot Exploration Program, to attempt to quantify the commercial viability of this accumulation by undertaking fracs and flow testing on a number of these wells.

The Company has now received all regulatory approvals required for the TGS program after undertaking a full and transparent consultation process that has included the extensive involvement of independent experts and the sourcing of world class technical expertise. These robust and thorough consultations and approval programs have been in train for nearly two years and have resulted in transparent and fact based approvals for the program.

The extensive and iterative nature of these approvals has also meant that the operational timeframes for undertaking the program have been compressed, as it was not possible to commence initial site and preparatory work until the approvals were received. In light of the fact the approvals have only recently been received, it has been necessary to undertake a full review of the planned execution and timing of the program.

This review has included operational considerations such as the availability of specialised technical equipment, the ability to complete the program prior to the wet season (including completing the flow back and testing program), and the costs of the program (which are affected by timing of the program), and the ability to compete it in a way that maximises efficient equipment utilisation.

The results of this review have led the joint venture to adopt a three-phased program. This phasing will ensure the program is undertaken in the most cost effective way and will also ensure the program meets all regulatory requirements and environmental standards.

Buru Energy's stakeholders, the Kimberley community and the wider WA community can be assured that this phased approach ensures the best environmental outcome from the program with the highest probability of delivering definitive results.

The phased approach will consist of the following steps:

Phase 1: August to October 2014

- Wellsite preparation and civil works including the construction of the water holding and flowback fluid retention ponds, flare pits, and associated civil works. This work is complete at the Asgard site and underway at the Valhalla North site. These are major civil works required to support the currently planned frac configuration.
- Well conditioning to ensure the well bores contain an operationally appropriate brine solution. This work will be undertaken with a coiled tubing unit.
- Cement bond logging to confirm previously obtained data.
- Conducting of "mini-fracs" or Diagnostic Fracture Injection Tests (DFITs). These are routinely conducted as part of frac programs and consist of fracs of a single zone by perforating the zone and injecting brine and observing the resultant pressure responses. This operation does not involve any flow back from the well and is performed with a relatively small crew and equipment package that does not require the mobilisation of the full frac crew. The data from these mini-fracs is used to optimise the design of the main fracs to ensure they provide definitive results at the lowest cost.

Phase 2: August 2014 to March 2015

Phase 2 will take place during the Kimberley wet season. This is a planning, validation and optimisation phase to ensure all operations and logistics are optimised and all contracts are the most cost effective. The design of the fracs will also be reviewed incorporating the results from the DFITs to ensure the highest probability of obtaining definitive results at the lowest cost.

Phase 3: March to August 2015

This phase will include mobilisation of the frac spread, undertaking the fracs, and then a three month flow back period to ensure the data obtained will allow definitive decline curves to be calculated.

The current estimated total cost of the three phase program is in excess of $40 million. Buru Energy's 50 per cent share of this cost will be covered by the previously announced agreement with Alcoa.

Corporate and Administrative

A program of staff and cost reduction and internal re-organisation has been implemented to ensure the company's structure is fit for purpose. These changes will substantially reduce overheads and introduce stringent cost controls into the business. This program is substantially complete and together with the recent Board changes, have positioned Buru Energy to be a cost-competitive and efficient operator.

Loading operations for Ungani crude at the Port of Wyndham

Grant of petroleum titles

Richard Bruce
Exploration Geologist
Petroleum Division

Undertaking seismic work in the Canning Basin

State Awards

From 1 January 2014 to the end of June 2014, the following petroleum titles were awarded in State areas:

Petroleum Exploration Permits

In March 2014, EP 487 in the Canning Basin was awarded to Backreef Oil Proprietary Limited. The firm two-year period includes a 500 km 2D seismic survey and two exploration wells to an estimated value of $5,750,000. The remaining program includes four exploration wells and a 200 km 2D seismic survey to an estimated value of $7,100,000.

In May 2014, EP 488 in the Perth Basin was awarded to UIL Energy Limited. The firm two-year period includes 66 km and 100 km 2D seismic surveys to an estimated value of $1,600,000. The remaining program includes two exploration wells and a 35 km^2 seismic survey to an estimated value of $11,500,000.

In May 2014, EP 489 in the Perth Basin was awarded to UIL Energy Limited.

The firm two-year period includes 35 km and 40 km 2D seismic surveys to an estimated value of $750,000. The remaining program includes one exploration well and a 40 km 2D seismic survey to an estimated value of $5,700,000.

Poole Range, Canning Basin

In May 2014, EP 490 in the offshore Northern Carnarvon Basin was awarded to Carnarvon Petroleum Limited. The firm two-year period includes 500 km^2 of 3D seismic reprocessing to an estimated value of $800,000. The remaining program includes two exploration wells to an estimated value of $14,400,000.

In May 2014, EP 491 in the offshore Northern Carnarvon Basin was awarded to Carnarvon Petroleum Limited. The firm two-year period includes 400 km^2 of 3D seismic reprocessing to an estimated value of $700,000 to an estimated value of $14,400,000.

Special Prospecting Authorities with Acreage Option

In November 2013, SPA 16 AO in the Perth Basin was awarded to Finder No. 5 Proprietary Limited for the acquisition of and analysis of airborne gravity/gradiometry data. The SPA/AO expires on 13 November 2014. From this date the registered holder has six months to apply for an Exploration Permit.

In January 2014, SPA 13 AO in the Canning and Amadeus Basins was awarded to Amadeus Basin Oil & Gas Proprietary Limited for the acquisition of and analysis of airborne gravity and magnetometer data. The SPA/AO expires on 30 December 2014. From this date the registered holder has six months to apply for an Exploration Permit.

In January 2014, SPA 14 AO in the Canning and Officer Basins was awarded to Woolnough Dome Oil & Gas Proprietary Limited for the acquisition of and analysis of gravity and magnetometer data. The SPA/AO expires on 30 December 2014. From this date the registered holder has six months to apply for an Exploration Permit.

In January 2014, SPA 15 AO in the Officer Basin was awarded to CSR Well 13 Oil & Gas Proprietary Limited for the acquisition of and analysis of gravity and magnetometer data. The SPA/AO expires on 30 December 2014. From this date the registered holder has six months to apply for an Exploration Permit.

In March 2014, SPA 17 AO in the Canning Basin was awarded to Admiral Oil No Liability for the acquisition and analysis of airborne gravity gradiometry data. The SPA/AO expires on 23 March 2015. From this date the registered holder has six months to apply for an Exploration Permit.

Commonwealth Awards

WA-497-P (released as W13-18) located offshore Western Australia approximately 75 km west of Onslow, has been awarded to AWE Australia Pty Limited.

WA-498-P (released as W13-10) located offshore Western Australia approximately 163 km north of Karratha has been awarded to Santos Offshore Pty Ltd and JX Nippon Oil and Gas Exploration (Australia) Pty Ltd.

WA-499-P (released as W13-13) located offshore Western Australia approximately 160 km north-northwest of Onslow, has been awarded to Apache Northwest Pty Ltd.

WA-500-P (released as W13-9) located offshore Western Australia approximately 190 km northwest of Dampier, has been awarded to Finder No 7 Pty Limited.

WA-501-P (released as W13-12) located offshore Western Australia approximately 80 km northwest of Dampier has been awarded to Carnarvon Petroleum Limited.

WA-502-P (released as W13-2) located offshore Western Australia has been awarded to Santos Browse Pty Ltd and INPEX Browse E&P Pty Ltd.

WA-503-P (released as W13-11) located offshore Western Australia approximately 90 km north of Dampier in the Northern Carnarvon Basin, has been awarded to Neon Energy Limited.


Photo © DMP

State areas released for petroleum exploration September 2014

Richard Bruce
Exploration Geologist
Petroleum Division

Gastropods, Fitzroy Valley

DMP continues to promote the petroleum potential of Western Australia's vast sedimentary basins using a specific area release system in our onshore and State Waters areas.

A disk package accompanies the acreage release and contains information about the prospectivity of release areas, available data listings, land access, and how to make a valid application for an Exploration Permit.

In September 2014, DMP released a total of nine onshore blocks (Fig. 1). This release comprised four blocks in the Canning Basin, one block in the Southern Carnarvon Basin and four blocks in the Officer Basin.

Canning Basin

Interest in the Canning Basin has revived significantly in recent years, with the oil discovery at Ungani and large estimates for shale gas. Mitsubishi, ConocoPhillips, Hess, and as of 2013, PetroChina and Apache are participating in Canning Basin exploration. There are four release areas in platform areas (Broome Platform and Crossland Platform), with one partly in the Kidson Sub-basin. Release area size ranges from 1770 km^2 to 2407 km^2. These release areas became available for gazettal by statutory relinquishment at the end of permit terms from Buru Energy Exploration Permits. The areas may be prospective for sub-salt Ordovician plays.

Southern Carnarvon Basin

Release area L13-2 is 1265 km^2 in size and is located in the northern Merlinleigh Sub-basin of the onshore Southern Carnarvon Basin. The area is readily accessible and near the North West Shelf facilities. Although an under-explored basin, geochemical studies indicate that Devonian and Permian oil and gas-prone source intervals are present across the basin. The release area is considered prospective for Permian shale gas or tight gas, as well as pre-Permian oil.

Officer Basin

In the Officer Basin there are four large release areas, which range in size from 10,925 km^2 to15,413 km^2. From a global perspective, the Officer Basin resembles Neoproterozoic successions in Oman and Russia that contain commercial hydrocarbon resources. It appears that all the elements of a petroleum system are present. Good source beds and proven reservoirs capped by thick sections of salt or shale have been intersected. There may be sub-salt and unconventional hydrocarbons present.

Work program bids for the release areas close at 4pm on Thursday 23 April 2015.

Should you require any further information or assistance, please contact Richard Bruce (08 9222 3314) of DMP's Petroleum Division or Ameed Ghori (08 9222 3758) of the Geological Survey of Western Australia. All enquiries will be dealt with in strictest confidence.

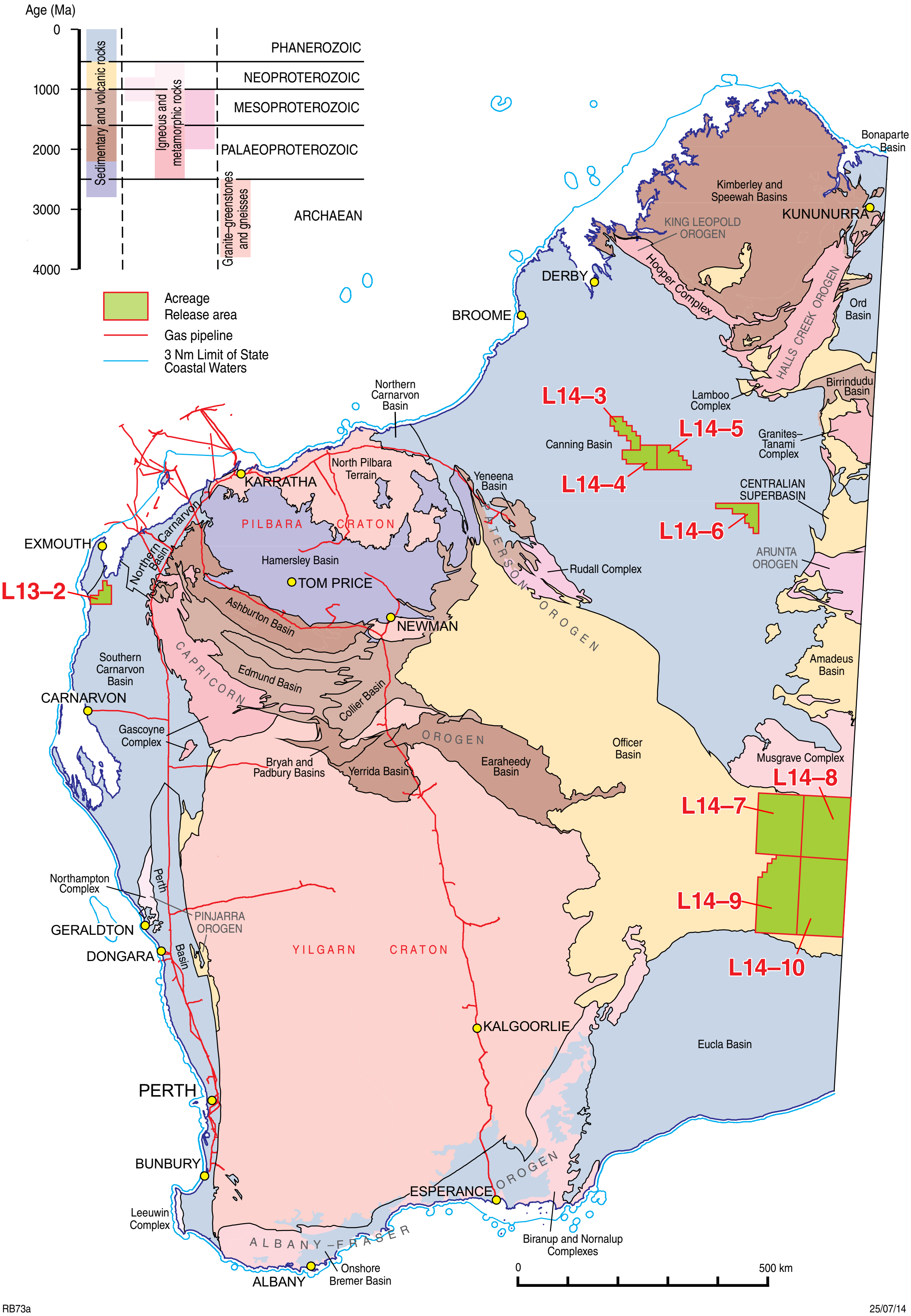


Figure 1 September 2014 State petroleum release areas

Photo © Geoscience Australia

Towards a deeper understanding of the Canning Basin

Above and facing page:
Signs and traffic management for the survey conducted along active road corridors

Charmaine Thomas
Geologist
GSWA

The Geological Survey of Western Australia (GSWA) and Geoscience Australia have just completed the Canning Coastal Seismic Survey, a 700 km-long, deep crustal reflection seismic and gravity survey spanning the entire cross-strike width of the Canning Basin, which will provide clues as to the nature of the basin's boundaries with the Pilbara and Kimberley Cratons, and its structure and basement.

Data acquisition was funded by the Western Australian State Government's Royalties for Regions Exploration Incentive Scheme (EIS), with co-funding for the seismic processing provided by the Australian Government to evaluate the region for CO_2 storage potential.

The reflection seismic survey commenced on 21 May with a period of thorough testing to determine the best acquisition parameters. These parameters differed from those used in other deep crustal surveys acquired by the State and Federal governments, such as the Yilgarn–Officer–Musgrave (YOM) and Albany–Fraser Orogen (AFO) surveys, because of the need to adequately image the younger, shallower basin as well as the deep basement.

150-fold data were recorded on 600 live channels over a 12 km-spread, with a geophone group interval of 20 m in an in-line array. The energy source was an in-line array of three Hemi-50 vibrators that each conducted a single linear sweep of 6 – 96 Hz per Vibroseis source point (VP), which were

Seismic Energy Source: 3 X Hemi 50,000 pound vibrators spaced every 40 m. Once the Vibroseis trucks conducted the 28-second sweeps, the geophones listened for an extra 20 seconds, allowing for reflections from a depth of ~60 km to be measured.

The survey has generated much interest from petroleum and mineral exploration companies, who see it as an opportunity to relate the local geology within their permits or tenements to the regional picture of the basin. Traditional owners and pastoral station lessees also showed an interest in the survey, and came out to see the survey in progress.

Not only will the survey data provide an uninterrupted image of the basin's architecture, it will also be a springboard for interesting future research. A good image of the deeper crust, integrated with basement ages obtained from petroleum wells along the seismic line, will allow for a greater understanding of the Paterson and King Leopold Orogens and Centralian Superbasin, which are thought to underlie the basin, but about which little is known in this region. The structure of the lower crust and upper mantle, combined with an understanding of the basin's boundaries and geometry, will give a greater insight into intracratonic rifting processes, such as the influence of pre-existing lithospheric weaknesses on basin architecture.

In keeping with other GSWA / Geoscience Australia deep crustal surveys, an endeavour was made to keep the survey along existing tracks and roads to minimise heritage and environmental impacts.

GSWA and Geoscience Australia contracted the Perth-based company Terrex Seismic via a competitive quotation process to acquire the seismic data. A final processed dataset is expected to be available in the first quarter of 2015 via the Department of Mines and Petroleum website and the Geoscience Australia website.

For more information, please contact:

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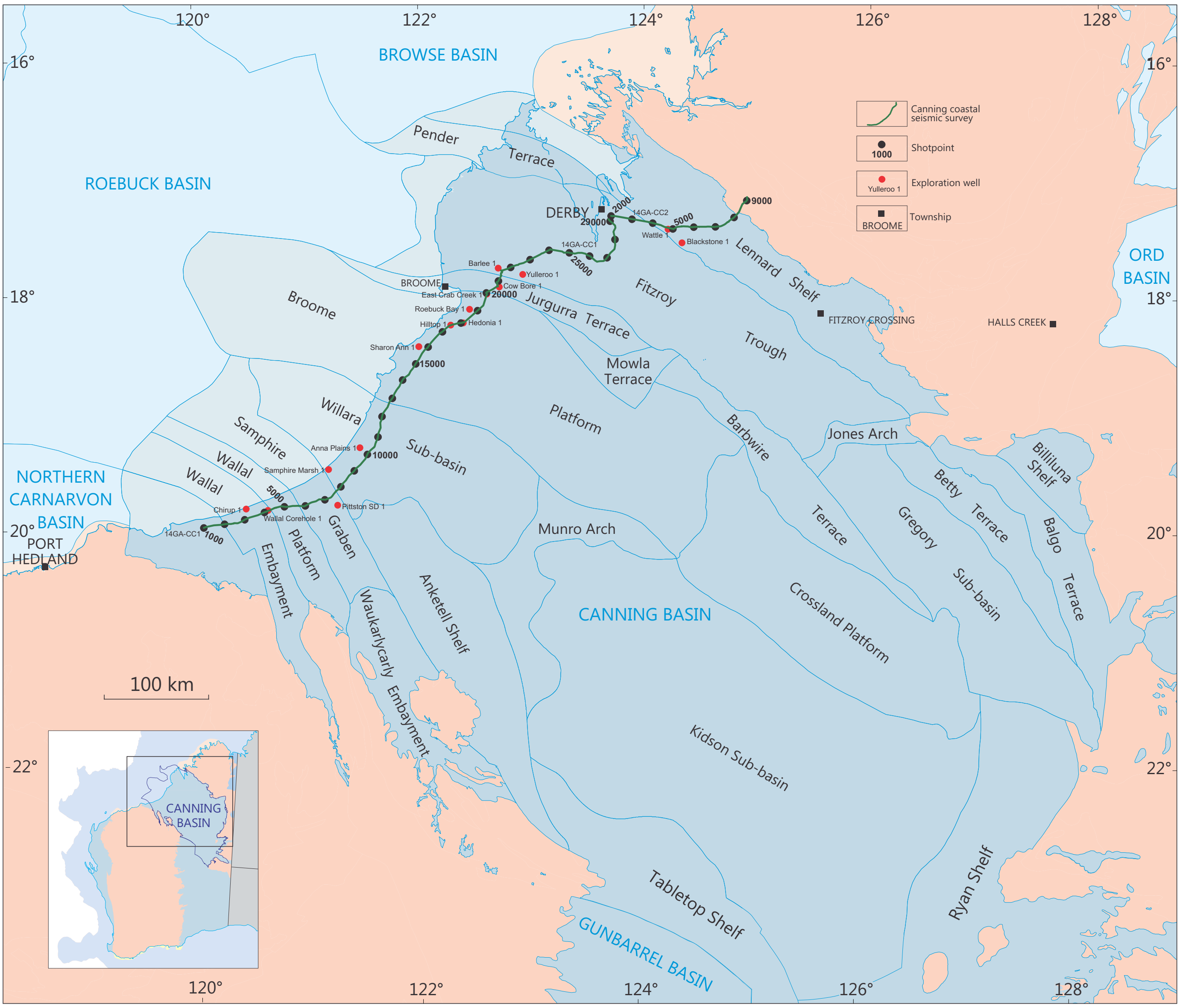

Location of the seismic traverse

Is geothermal energy dead in WA?

Control room for geothermal plant in Perth

Mike F. Middleton
General Manager Resources
Petroleum Division

Introduction

There are currently no geothermal energy exploration permits active in Western Australia. By the end of 2014, all geothermal exploration permits (GEPs) will have been surrendered. From this process, it would appear that the geothermal concept, and the introduction of "geothermal" into the *Petroleum and Geothermal Energy Resources Act 1967* (PGERA67) has not had a successful outcome. However, this may not actually be the case.

From the present experience, there is no commercial appetite for geothermal energy to create electricity in Western Australia. The lack of funding towards geothermal exploration for electricity has led to similar experiences being encountered elsewhere in Australia, for example, in the Paralana Project in South Australia and difficulties with the Innaminka Project in the Cooper Basin. Nevertheless, geothermal energy is being increasingly used to replace electricity for water heating and air conditioning. Some 14 projects of this nature are recognised in the Perth metropolitan area.

Only one geothermal exploration borehole has been drilled in Western Australia under the PGERA67, and this was in GEP 48 near Esperance, on the assumption that low heat conducting granites may provide insulation over higher heat producing granites. Greenpower Energy Limited drilled this first geothermal borehole in 2013.

The company considered the borehole to be a "technical success", but not a commercial success, and has subsequently proposed to relinquish the GEP. Recognising the company's initiative, the Department of Mines and Petroleum (DMP) Resources Branch has re-investigated the findings of this first geothermal well, Mt Ridley 1. This study is being conducted in the light of on-going studies of heat generation of granitoids by DMP in Western Australia, and these studies are being carried out with specific reference to a commitment for geothermal energy in the State.

Heat Generation in Granitoids

Granitoids are granite-like rocks, and capture a large group of igneous rocks with such characteristics. Granitoids underlie many sedimentary rocks in the Perth, Carnarvon and Canning Basins in Western Australia, and contribute to heat flow in these basins.

Previous work by DMP (Middleton and Stevens 2013) has shown that radiogenic heat from granitoids may contribute to possible geothermal energy in the South West of Western Australia. Some of the largest heat-generating granitoids in Australia have been observed in the Vasse region of Western Australia, and may present a unique renewable energy source for that region.

Mt Ridley 1 – Measurements

The future of geothermal energy in Western Australia largely hinges on the outcome of the science from Mt Ridley 1, north of Esperance (Fig. 1). This article looks at the probable temperatures found at Mt Ridley 1 and possible economic implications.

The most direct implications from the drilling of the Mt Ridley 1 geothermal borehole are:

1. An uncorrected geothermal gradient of 14.75 °C/km which supports a temperature of 17.5 °C at the surface and 23.4 °C at the bottomhole depth of 405 m. This thermal is quite low, but is not atypical of thermal gradients in the granitoid region of the southwest of Western Australia (Sass et al. 1976).
2. The Thorium/Uranium ratio is about 10, which has implications for heat generation from the granitoids of the region.
3. Geochemical and petrophysical measurements were made on cores, and some direct correlations can be seen between borehole-gamma-log and core gamma-log measurements (Fig. 2). The absolute measurement values of the core-based measurements versus the borehole measurements are uncertain.

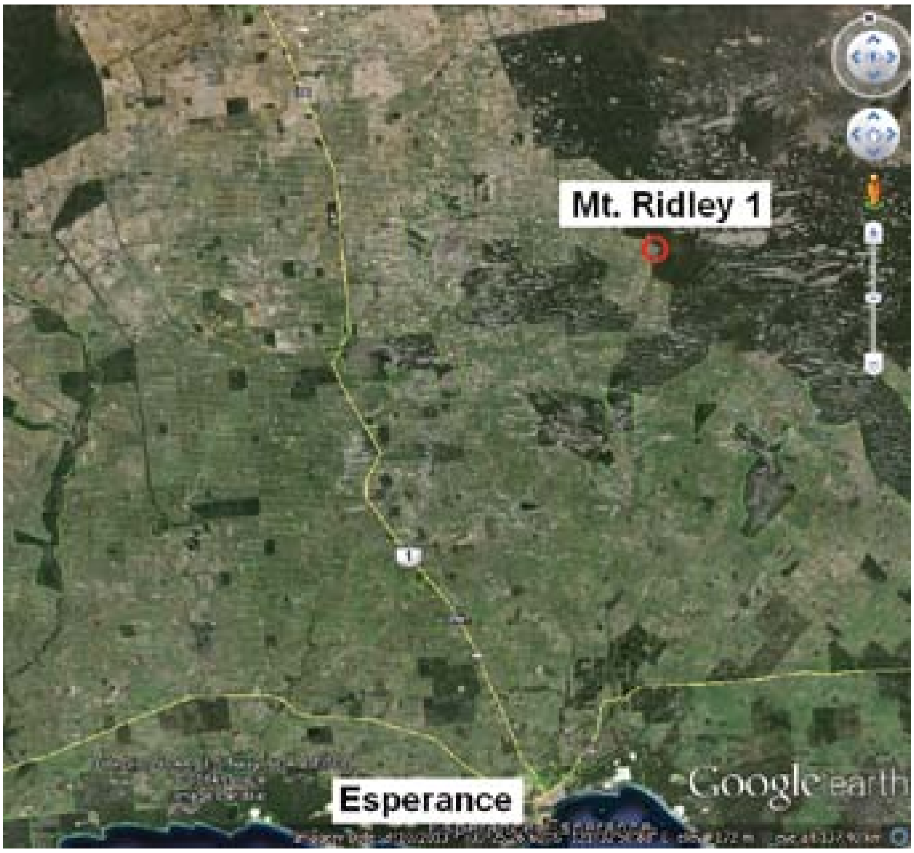

Figure 1. Location of Mt Ridley 1

4. Uncertainty exists between the field-scillintometer Potassium (K), Uranium (U) and Thorium (Th) elemental concentrations reported by the company and the actual values. This is because the measurements were made on a core field-scillintometer, but without a known reference (i.e. laboratory or other field calibration). Nevertheless, the core-measurement-based Potassium (K) concentrations appear to be consistent with independent laboratory measurements. It is assumed that real (i.e. real rock volume) Uranium and Thorium concentrations are similar to those quoted in the report. Independent corroboration with core analyses will be made, when core is made available to DMP.

Mt Ridley 1 – Technical implications

Figure 2 shows the gamma-log and core-gamma measurements versus depth. There is a reasonable correlation, although the magnitude of the counts-per-second (cps) is significantly different. The difference is due to the difference of volume being sampled by the core instrument (core samples) as opposed to the actual rock-volume being sampled by the down-hole-gamma probe, and also the different types of instrumentation.

This difference in the magnitude in the down-hole gamma tool versus the core measurement device (an FS hand-held scintillometer) does pose some scientific questions about the comparison of the numerical results. Such questions still need to be resolved for this dataset. Nevertheless, some general observations and calculations can be made (Table 1).

The derived heat generation in the Mt Ridley borehole is 1.77 mWm^{-3}. This is considerably lower than other granitoid regions in Western Australia. By comparison, heat generation in the Darling Range can be as high as 10.2 mWm^{-3}, and 15.7 mWm^{-3} in the Leeuwin Complex (Middleton et al. 2014). This lower heat generation in Mt Ridley 1 is the principal reason why temperatures and geothermal gradients are low in the Esperance region.

Scientific Implications: Radiogenic Crustal Thickness in Western Australia

On the basis of geothermal and heat flow measurements, Jaeger (1970) proposed that the thickness of the radiogenic crust to be approximately 4.5 km. The present information from Mt Ridley 1 allows us to test this proposal.

Radiogenic crustal thickness (RCT) is given by the formula:

RCT = (Surface Heat Flow – Mantle Heat Flow) / Heat Generation

From the Mt Ridley 1 borehole, one can calculate a surface heat flow from the equation above to be 44.74 μWm^2, where the mantle heat flow is generally accepted to be 25.6 μWm^2 (Jaeger, 1970; Middleton 2013). The heat generation is assumed to be 1.77 mWm^{-3}, which is based on Mt Ridley 1 data (Table 1).

Table 1. Mt Ridley 1 – preliminary evaluation by DMP

Observed geothermal gradient	14.75 °C/km
Surface temperature	17.5 °C
Approximate temperature @ 3 km	59 °C
Potassium concentration (upper 400 m)	2 per cent
Thorium/Uranium ratio	8
Surface Thorium (GA map)	7.2 ppm
Mean Uranium content over 400 m	2 ppm
Mean Thorium content over 400 m	15 ppm
Maximum core Thorium	28.3 ppm @ 375 m
Minimum core Thorium	4.7 ppm @ 272.1 m
Mean heat generation	1.77 mWm^{-3}

From these data and the equation above, the RCT is found to be 10.5 km. This is considerably deeper than the 4.5 km suggested by Jaeger (1970) and subsequent studies by Middleton and Stevens (2013). Further work is required to understand why this is the case.

Conclusions

This study supports the relinquishment of GEP 38 as not being suitable for geothermal exploitation.

This supports a Department of Mines and Petroleum recommendation that geothermal energy is not suitable in the Esperance region because of unsuitable rock characteristics. These rock characteristics indicate that temperatures at economically drillable depths are insufficient to support geothermal energy at commercial rates.

Nevertheless, the exploration activity has provided some valuable scientific information. Interestingly, it seems that the possibility exists of a deeper than recognised radiogenic-rich crust in the Albany-Fraser geological Province.

Indeed, not all exploration activity is commercially productive, but can be of value from a scientific or engineering perspective, as well as for future planning.

References

Jaeger, JC, 1970, Heat flow and radioactivity in Australia, *Earth and Planetary Science Letters*, 8, 285-292.

Middleton, MF, 2013, Radiogenic heat generation in the Darling Range, Western Australia, *Exploration Geophysics*, 44, 206-214.

Middleton, MF, Brett, J. and Flint, D., 2014, Thorium occurrence: Geological and geophysical implications for Western Australia, In: Thorium Chemical Properties, Uses and Environmental Effects, Renae Jamison (Ed.), Nova Science Publishers, Inc., ISBN 978-1-63321-309-8.

Middleton, MF and Stevens, MK, 2013, Heat generationin the Vasse Shelf Region: Implications for geothermal exploration, *Petroleum in Western Australia* September 2013, www.dmp.wa.gov.au

Sass, JH, Jaeger, JC and Munroe, RJ, 1976, Heat flow and near-surface radioactivity in the Australian continental crust, *United States Department of the Interior, Geological Survey*, Open-File Report 76-250.

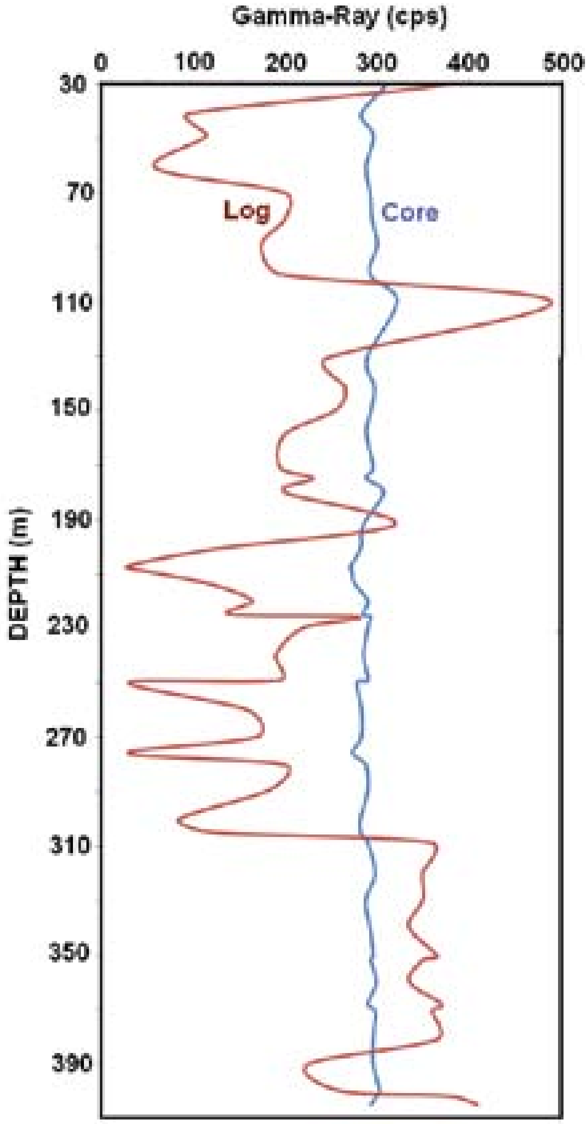

Figure 2. Geochemical and petrophysical measurements were made on cores, and some direct correlations can be seen between borehole-gamma-log and core gamma-log measurements

Shale gas resource assessment in the Merlinleigh Sub-basin, Carnarvon Basin

A Buru Energy gas site development

Joanna Wong
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Petroleum Division

Introduction

The rapid progression of shale gas developments and the rise of improved technologies in the US have encouraged Western Australia to explore our own potentially massive shale gas resources.

Unlike conventional petroleum systems, shale gas plays consist of source rock and are commonly independent of structural and stratigraphic traps and can cover extremely large areas. These source rocks are thermally mature and have retained substantial amounts of hydrocarbons. The key to unlocking these residual hydrocarbons is a comprehensive understanding of the geochemical, geomechanical and petrophysical properties of the source rocks, in order to employ directional drilling and hydraulic fracturing activities (Ghori 2013).

Geology of the Carnarvon Basin

Situated on the northwest coast of Western Australia, the Carnarvon Basin covers an onshore area of approximately 115,000 km^2 and an offshore area of about 535,000 km^2. The Carnarvon Basin is split into the mostly offshore Northern Carnarvon Basin and mostly onshore Southern Carnarvon Basin; the onshore Carnarvon Basin consists of four sub-basins: the Peedamullah Shelf, Gascoyne Platform, Byro Sub-basin and Merlinleigh Sub-basin (Fig. 1).

The Gascoyne Platform is the largest sub-basin in the Southern Carnarvon Basin and contains a mainly Silurian-Devonian succession unconformably overlain by thin Cretaceous and Cenozoic cover. In the Merlinleigh Sub-basin, the Silurian-Devonian succession is overlain by a thick Permian-Carboniferous succession, except along its eastern margin (Fig. 2, Ghori 2013). According to previous geological and geochemical studies, the Merlinleigh Sub-basin contains the best gaseous source rocks in the Carnarvon Basin, in the Byro and Wooramel Groups. Other source intervals are present in the Gneudna Formation and the Dirk Hartog Group. In this study, geochemical and petrophysical data from four wells were analysed to determine source rock quality: Quail 1, Burna 1, Kennedy Range 1 and Gascoyne 1.

Geochemistry parameters

Petroleum geochemistry is the most effective technique used to evaluate the hydrocarbon-generating capacity of source rocks, by identifying and determining the amount, type and maturation level of the organic matter. It is a highly important method for the shale gas industry in that the target source rocks can be better characterised to reduce the inherent uncertainty in exploration and production of these generally poorly-known plays. Geochemical testing can be performed on outcrop samples, formation cuttings, sidewall cores and conventional cores. Some geochemical techniques include kerogen typing, vitrinite reflectance analysis, gas chromatography and laboratory pyrolysis (McCarthy et al. 2011).

In order to identify the source potential of each shale layer in the Merlinleigh Sub-basin, geochemical data obtained from each well was analysed for four main parameters:

- Type of kerogen
- Total organic carbon
- Generation potential
- Thermal maturity/vitrinite reflectance.

Kerogen is a naturally occurring organic matter found in source rocks and is capable of expelling hydrocarbons when heated. There are three types of kerogen: Type I, which consists of mainly algal material that is likely to produce oil; Type 2, which is a mix of terrestrial and marine organic matter that can generate waxy oil; and Type 3, a woody, terrestrial source material that is highly prone to generating gas. By identifying the type of kerogen in a source rock, we can anticipate what kinds of hydrocarbons are most likely to be produced by that source rock.

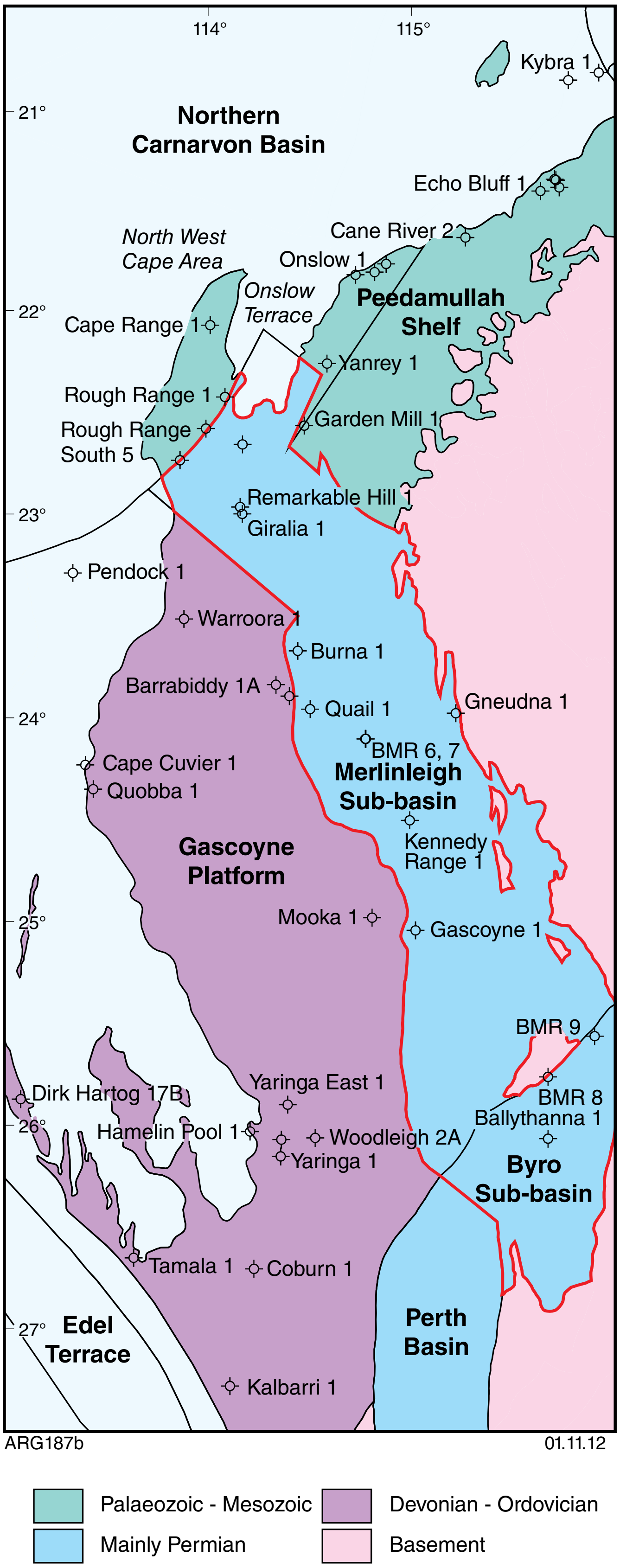

Figure 1. Map showing tectonic units of the Carnarvon Basin, WA (Ghori 2013)

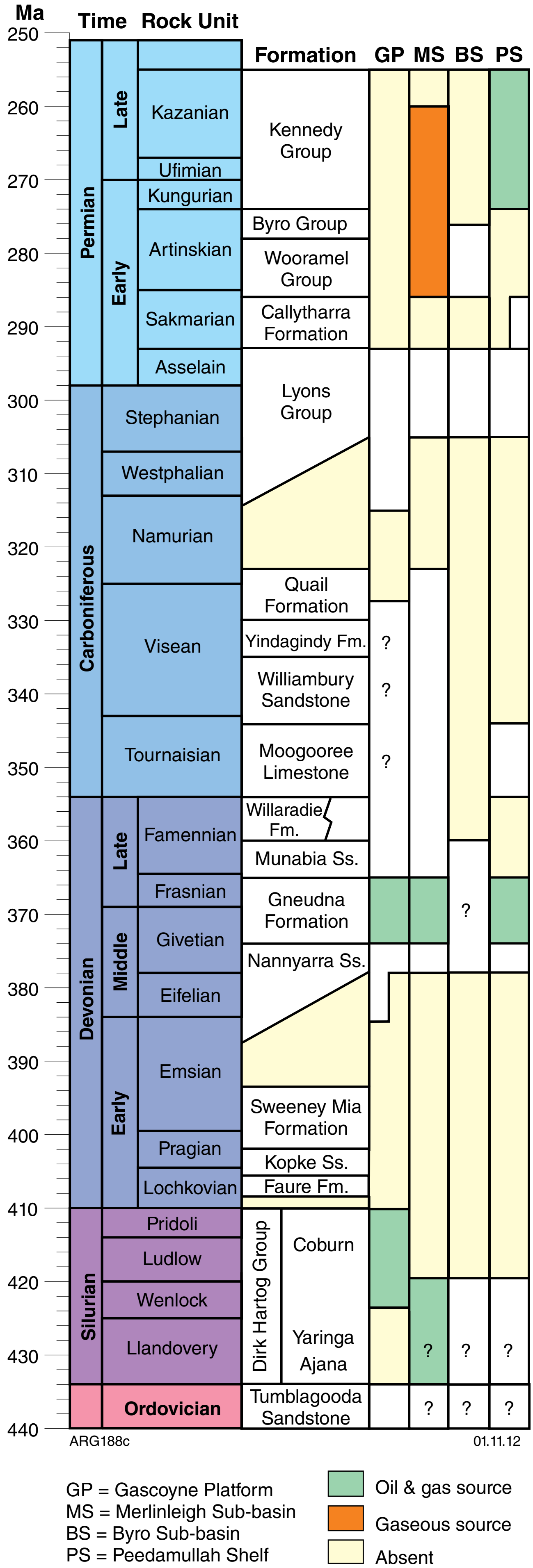

Figure 2. Generalised stratigraphy and source rock locations of the onshore Carnarvon Basin (Ghori 2013)

Total organic carbon (TOC) indicates the quantity of organic material in a source rock. Measured by percentage weight (wt%), a source rock that contains greater than 2% TOC is considered to have excellent kerogen quantity and therefore would favour the presence of shale gas.

The generation potential of a source rock is the amount of hydrocarbon that can be generated per gram of rock (mg hydrocarbon/g rock). It is determined by rock pyrolysis: a geochemical analysis in which a rock sample is subject to controlled heating until hydrocarbons are generated. This enables the quality of the source rock to be assessed and is instrumental in evaluating shale gas plays. During the controlled heating event, the rock sample emits various gases that are detected by specialised sensors and are shown as peaks on a pyrogram. Typically, five emission peaks are formed that are denoted S1, S2, S3, S4 and S5. The S1 and S2 peaks represent the free hydrocarbons generated by the rock prior to kerogen cracking and the hydrocarbons generated by kerogen cracking, respectively. The S3, S4 and S5 peaks represent the CO_2 emitted during pyrolysis, oxidation and carbon decomposition, respectively. The generation potential is then equivalent to the sum of the S1 and S2 peaks (McCarthy et al. 2011). A generation potential of 10 mg/g is considered very good in terms of source rock quality.

Lastly, the thermal maturity of a source rock is classified according to the quality of vitrinite reflectance. Vitrinite is a coal maceral formed through the thermal alteration of lignin and cellulose in plant cell walls, which responds optically to increasing levels of thermal maturity. For a source rock to be gas-prone, vitrinite reflectance levels would ideally lie between 1 and 1.5%, corresponding to a thermal maturity of mature to over-mature.

Source potential of the Merlinleigh Sub-basin

The Lower Permian section in the Merlinleigh Sub-basin contains the best gas-prone source beds in the Carnarvon Basin, and their maturity ranges from immature along the margins of the sub-basin to over-mature towards the centre (Ghori et al. 2005).

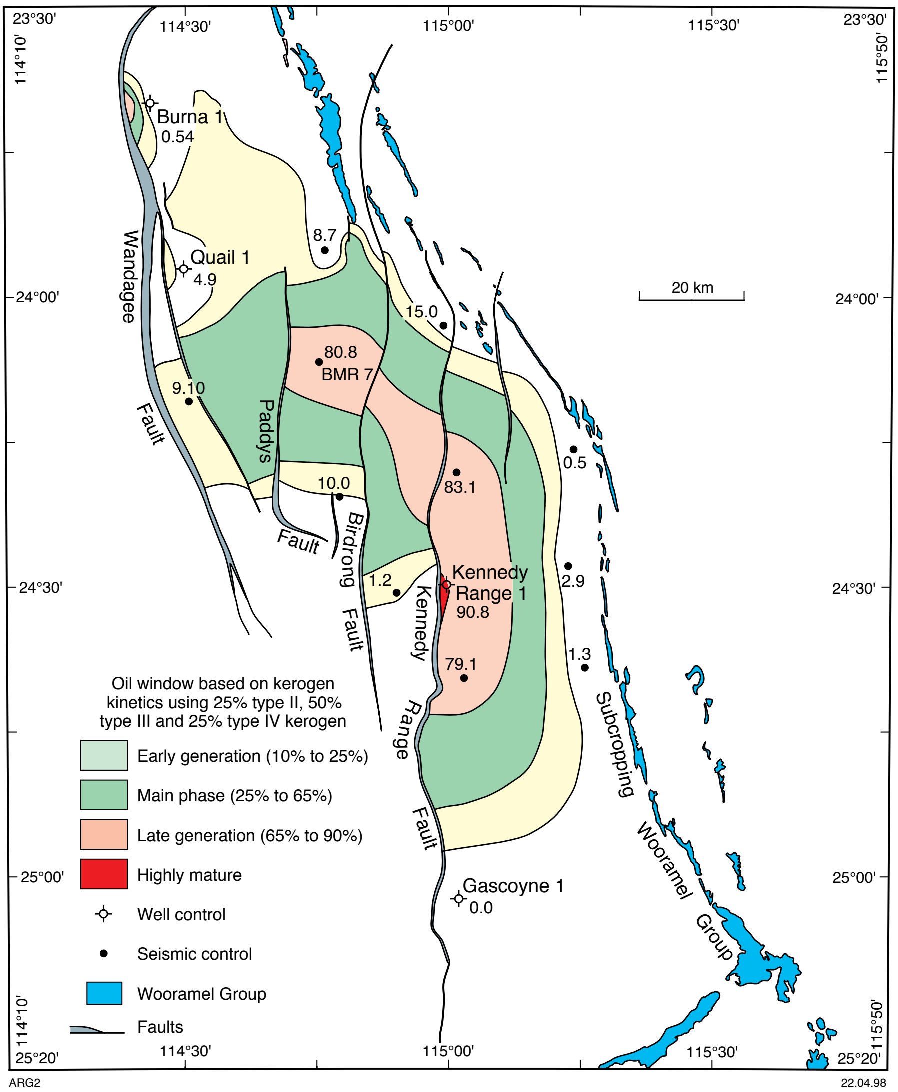

Figure 3. Maturity map of the top Wooramel Group (Iasky et al. 2005)

The widespread Artinskian Wooramel Group of the Merlinleigh Sub-basin is up to 380 m thick and contains interbedded organic-rich shales with good to fair source potential that are predominantly gas-prone (Fig. 3). TOC values are up to 16%, with an average of 7%, and their maximum potential yield is 12 mg/g, with an average of 6 mg/g. The formation is 250 m thick in Wandagee 1 and the adjacent Quail 1, and 115 m thick in Burna 1. The Wooramel Group is found to be over-mature in Kennedy Range 1, which is understood to be the result of a local intrusion rather than a regional heating event (Ghori 2013).

The next best quality source rocks is the Byro Group, where good to fair gas-prone source rock intervals are present through a 700 m thick interval in Kennedy Range 1. The Byro Group is immature and missing section in the studied wells, except in Kennedy Range 1, where it ranges from immature to over-mature (Ghori 2013). Thin source rock intervals have also been identified in the Gneudna Formation, with good to fair organic richness and generating potential. This information is summarised in Table 1.

Table 1. Summary of potential source rock layers (Ghori 1996)

Formation	Organic Richness	Generating Potential	Kerogen Type
Gneudna Formation	Good to Fair	Good to Fair	Oil and gas
Wooramel Group	Very good to Fair	Very good to Fair	Mainly gas
Byro Group	Very good to Fair	Good to Fair	Mainly gas

Surfer® maps

Formation maps of the Merlinleigh Sub-basin subsurface were created using Didger® 4 and Surfer® 11 software. The depth map of the Moogooloo Sandstone, which is a part of the Permian Wooramel Group, is shown in Figure 4 with the location of the intersecting wells and geological faults. A 3D compilation of three formation layers (top and bottom of the Lyons Group and Moogooloo Sandstone) was also created for enhanced visual representation (Fig. 5).

The depth of the Moogooloo Sandstone ranges from the surface down to approximately 700 m close to Kennedy Range 1, where maturity levels are also the highest, owing to a combination of temperature increase with depth and a local intrusion.

The top and bottom contours of the Lyons Group in the 3D map can be seen extending into the Peedamullah Shelf in the Northern Carnarvon Basin and plunging significantly to approximately 2745 m in the North West Exmouth region. The Moogooloo Sandstone effectively covers the entire Merlinleigh Sub-basin with concentric dip towards the centre.

TOC calculation from logs

Source rocks such as shales and lime-mudstones are known for their significant organic matter content. An alternative method to geochemical analysis utilises the responses of common well logging tools to identify organic matter in a formation. This enables geochemical data to be validated against calculated values from log data.

Observations from Passey et al. (1990) suggest that resistivity increases dramatically in mature source rocks, presumably in response to the generation of non-conductive hydrocarbons. Data with relatively high resistivity and either relatively high transit time or low bulk density represent a probable source rock; otherwise, the rock is probably barren of organic matter.

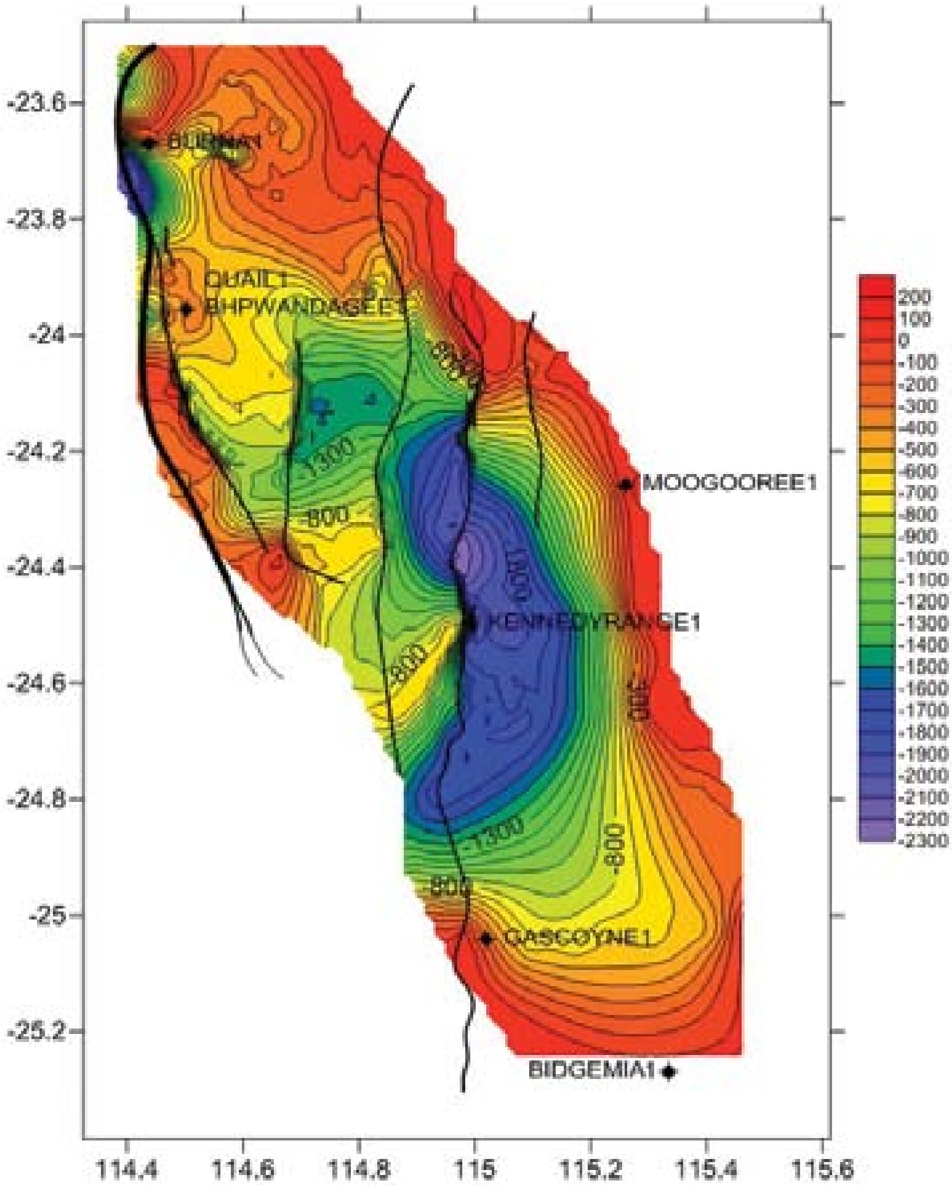

Figure 4. Moogooloo Sandstone base contour map

This highly successful technique is called the 'ΔlogR' method, where organic-rich intervals can be identified by the separation between the resistivity and porosity logs. GS Software was used to overlay the Resistivity and Sonic Porosity logs from four wells in the Merlinleigh Sub-basin for comparison with geochemical and log-calculated TOC values. Both the geochemical data and the calculated TOC values were found to produce a good match, thereby validating both sets of data.

Resource estimations

Resource estimations of shale gas volumes in three formations were performed using both a deterministic and probabilistic approach. From the calculations involved in the deterministic approach, the resource estimations for the Gneudna Formation, Wooramel Group and Byro Group were found to be 40.5 Gm^3 (1.43 Tcf), 1167 Gm^3 (41.21 Tcf) and 1476 Gm^3 (52.14 Tcf), respectively. A Monte Carlo method in Crystal Ball used probabilistic estimates to obtain P50 values that were very similar to the deterministic method, providing increased confidence in our volumetric assessment (Table 2).

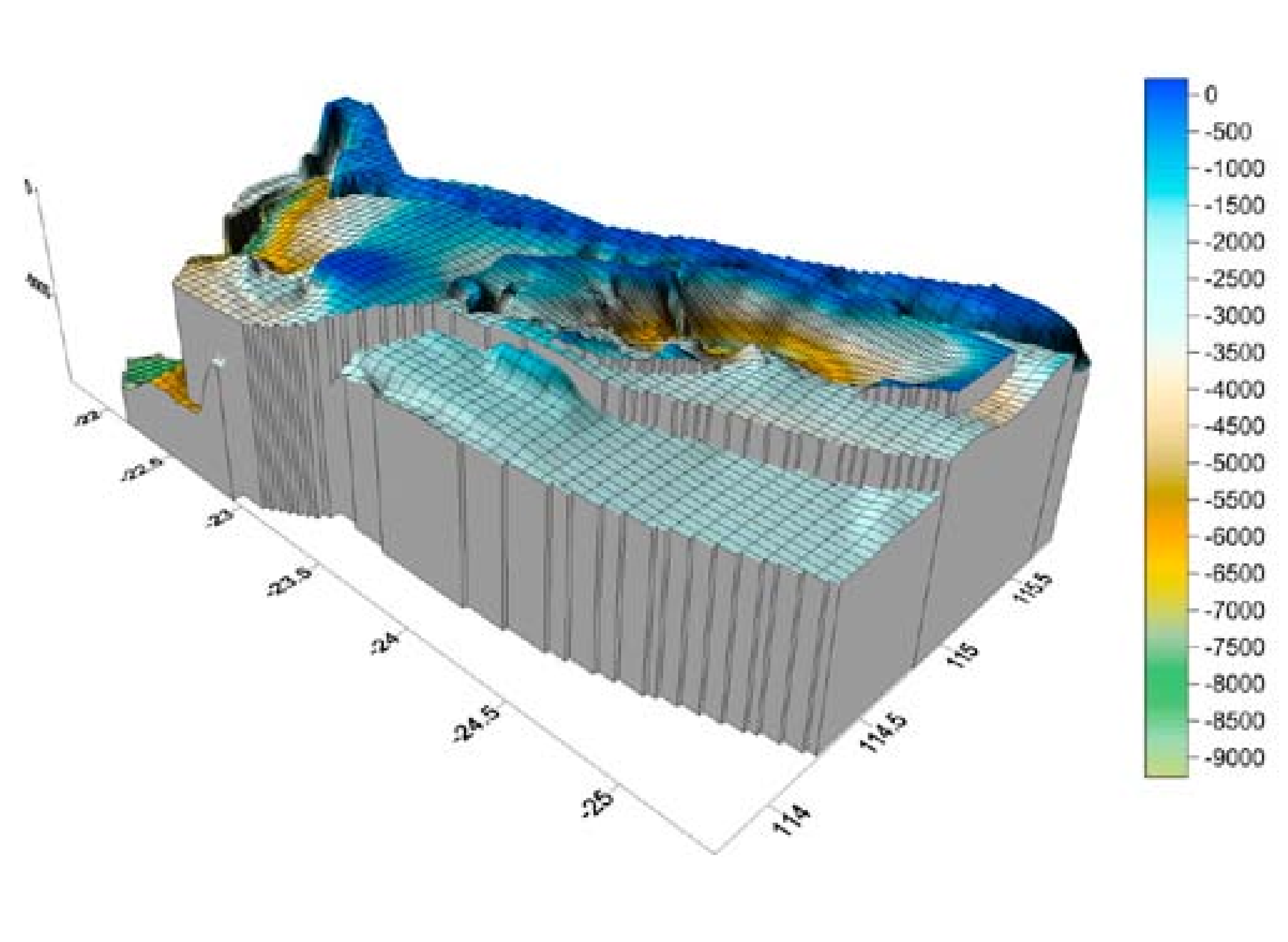

Figure 5. 3D representation of the Lyons Group (top and bottom) and Moogooloo Sandstone

Table 2. Total Gas-Initially-in-Place (GIIP) and risked recoverable resource estimates in Gm³ (Tcf in brackets) for the Merlinleigh Sub-basin shale gas formations

	Gneudna Formation	Wooramel Group	Byro Group
GIIP	40.5 (1.43)	1167 (41.21)	1476 (52.14)
Recoverable Resource	6.3 (0.22)	175.0 (6.18)	221.4 (7.82)
Risked GIIP (30%)	12.2 (0.43)	350.0 (12.36)	442.9 (15.64)
RRR (15% ReF)	1.7 (0.06)	52.4 (1.85)	66.5 (2.35)
RRR (20% ReF)	2.5 (0.09)	70.0 (2.47)	88.6 (3.13)
RRR (30% ReF)	3.7 (0.13)	105.0 (3.71)	132.8 (4.69)
Crystal Ball Prediction			
P90	32.5 (1.15)	902.2 (31.86)	1182.5 (41.76)
P50	40.2 (1.42)	1152.5 (40.70)	1460.2 (51.57)
P10	49.0 (1.73)	1449.2 (51.18)	1786.2 (63.08)

ReF: Recovery Factor

RRR: Risked Recoverable Resource

Shale gas potential of other sub-basins in the Carnarvon Basin

Shale gas exploration within the onshore Carnarvon Basin is still very limited and highly uncertain, however, the available data shows great potential for large shale plays. On the Peedamullah Shelf, good hydrocarbon generating potential has been identified in the Middle–Upper Devonian Gneudna Formation, Lower Carboniferous Moogooree Limestone, Upper Permian Kennedy Group, and Lower–Middle Triassic Locker Shale (Crostella et al. 2000). These source beds have also been found to be both oil- and gas-prone.

Although the Merlinleigh Sub-basin shows some signs of source potential in the Silurian Coburn Formation and the Devonian Gneudna Formation, these beds are conventionally considered to contain much higher potential in the Gascoyne Platform. Oil-prone source rock intervals were identified in Yaringa East 1 (southern part of the platform) and Barrabiddy 1A (northern part) consisting of thin, organic rich, laminated mudstone within carbonate facies. The Silurian source beds have an organic richness of up to 7.43% TOC, generation potential of up to 38.1 mg/g rock, and a hydrogen index of up to 505. Devonian source beds have an organic richness of up to 13.56% TOC, potential yield of up to 40.09 mg/g rock, and a hydrogen index of up to 267 (Iasky et al. 2003).

The potential for shale gas in the onshore Carnarvon Basin is in need of investigation by industry in order for exploration and data acquisition to increase. Large resource estimates have been established for shale gas plays in the Canning and Perth Basins. The resources of the Carnarvon Basin potential predict an even more exciting future for shale gas exploration and development in Western Australia.

Acknowledgements

The authors would like to acknowledge the Executive Director Petroleum, Jeff Haworth, and DMP's Innovation Group for their support of this project.

References

Crostella, A, Iasky, RP, Blundell, KA, Yasin, AR and Ghori, KAR, 2000, Petroleum Geology of the Peedamullah Shelf and Onslow Terrace, Northern Carnarvon Basin, Western Australia: Western Australia Geological Survey, Report 73, 119p.

Ghori, KAR, 1996, Petroleum Source Rocks Merlinleigh and Byro Sub-basins, Carnarvon Basin, Western Australia: Western Australia Geological Survey, Record 1995/5, 108p.

Ghori, KAR, 2013, Emerging Unconventional Shale Plays in Western Australia. APPEA Journal (1): 313-336.

Ghori, KAR, Mory, AJ, Iasky, RP, 2005, Modelling petroleum generation in the Paleozoic of the Carnarvon Basin Western Australia: Implications for prospectivity. AAPG Bulletin (89): 27-40.

Iasky, RP, D'Ercole, C, Ghori, KAR, Mory, AJ, and Lockwood, AM, 2003, Structure and Petroleum Prospectivity of the Gascoyne Platform, Western Australia: Western Australia Geological Survey, Report 87, 56p.

Iasky, RP, Mory, AJ, Ghori, KAR, and Shevchenko, SI, 2005, Structure and petroleum potential of the Southern Merlinleigh Sub-basin Carnarvon Basin Western Australia: Western Australia Geological Survey, Report 61, 63p.

McCarthy, K, Rojas, K, Niemann, M, Palmowski, D, Peters, K and Stankiewicz, A, 2011, Basic Petroleum Geochemistry for Source Rock Evaluation. Schlumberger. http://www.slb.com/~/media/Files/resources/oilfield_review/ors11/sum11/basic_petroleum.pdf.

Passey, QR, Creaney, S, Kulla, JB, Moretti, FJ, and Stroud, JD, 1990, A Practical Model for Organic Richness from Porosity and Resistivity Logs. The American Association of Petroleum Geologists Bulletin 72 (12): 1777-1794.

Flat-lying outcrop of the Kennedy Group on the eastern side of Kennedy Range

A review of AS/NZS ISO 31000:2009 Risk Management – principles and guidelines

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Introduction

ISO 31000 is the ISO standard for risk management. It is intended to be a family of standards relating to risk management codified by the International Organization for Standardization. ISO 31000:2009 provides principles and guidelines on the implementation of risk management. It is understood that in 2009 the Australian and New Zealand Standards Committee approved the adoption of this new standard as AS/NZS ISO 31000:2009.

AS/NZS ISO 31000:2009 can be applied throughout the life of an organisation, and to a wide range of activities, including strategies and decisions, operations, processes, functions, projects, products, services and assets. It can be used by the public, private and industry sectors. It can be applied to any type of risk, whatever its nature, whether having positive or negative impacts. However, it is not intended to promote uniformity of risk management nor is it intended for certification purposes.

This report briefly reviews the contents of AS/NZS ISO 31000:2009.

What are risk and risk management?

In AS/NZS ISO 31000:2009, risk is defined as the "effect of uncertainty on objectives". Note that an effect may be positive, negative, or a deviation from the expected; an objective may be financial, related to health and safety, or defined in other terms. Risk is often referred to potential events or consequences, or a combination of these. It is often expressed in terms of a combination of the consequences of an event, including changes in circumstances, and associated likelihood of occurrence. Uncertainty is the state, even partial, of deficiency of information related to understanding or knowledge of an event, its consequences, or likelihood.

Risk management refers to the architecture of managing risks effectively, which includes the principles, framework and process of risk management.

The components of AS/NZS ISO 31000:2009

The relationship between the risk management framework, principles and process is shown in Figure 1.

For a risk management plan to be effective, there are 11 explicitly stated **principles** that an organisation should comply with (see the left column of Fig. 1).

The success of the risk management will depend on the effectiveness of management framework, as described by clause 4 shown in the middle column of the above figure. It focuses on Plan, Do, Check and Act. In the Plan stage, framework has to be designed; in the Do stage, risk management will be implemented; in the Check stage, the framework is monitored and reviewed; and in the Act stage, the framework will be improved continually.

The risk management **process** in the AS/NZS ISO 31000:2009 comprises five key elements.

- Communication and consultation – throughout the risk management process, various forms of communications (written or verbal) between risk manager, risk owner, and stakeholders will continue to occur.
- Establishing context – setting boundaries or parameters about risk appetite and risk management activities, considering internal factors (strategy, resources and capabilities), and external factors (social, cultural, political and economic).
- Risk assessment – identifying, analysing and evaluating risks. This is at the centre of risk management process, and comprises of three distinct steps of risk identification, risk analysis and risk evaluation.
- Risk treatment – when the level of risk is intolerable, risk should be treated by avoiding risk, treating risk sources, modifying likelihood, changing consequences, or sharing elements of risks until the risk level is acceptable.

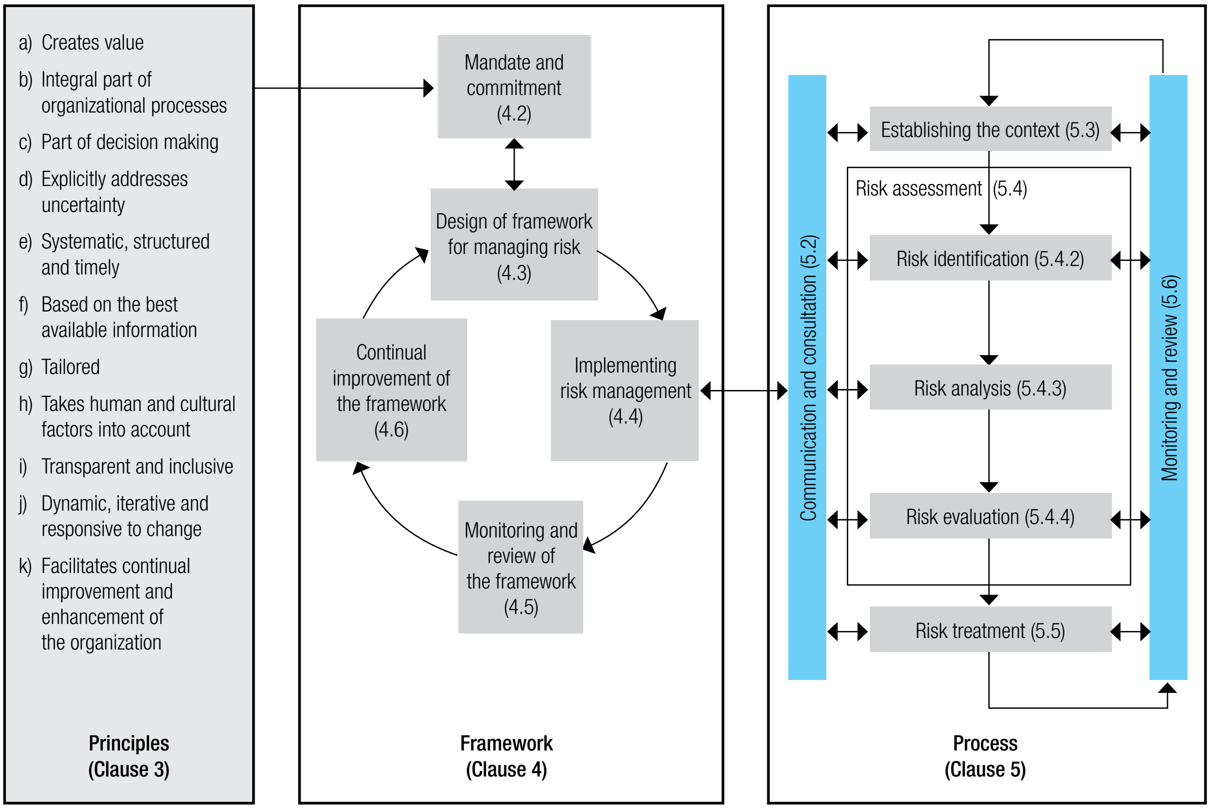

Figure 1 Relationship between the risk management framework, principles and process (source: AS/NZS ISO 31000:2009)

- Monitoring and review – planned, regular monitoring of risks and the risk management framework and process is critically important for successful risk management. The results should be recorded accordingly.

Strategies for enhanced risk management

The five attributes listed in the Annex of the AS/NZS ISO 31000:2009 as attributes for enhanced risk management are:

- Continual improvement
- Full accountability of risks
- Application of risk management in all decision making
- Continual communications
- Full integration in the organisations' governance structure

Application to Carbon Capture and Storage (CCS) projects

CCS projects, especially CO_2 storage projects, involve the injection of CO_2 into subsurface reservoirs via wells drilled into the storage formation. From cradle to grave – conceptual design to final implementation of CO_2 storage operations and site closure – there are many risks and uncertainties.

In an assessment of a CO_2 storage project, the following factors need to be considered:

- Does the reservoir formation have enough storage capacity to accommodate the injected CO_2?
- Can CO_2 be injected into the target reservoir?
- Will CO_2 stay in the reservoir formation as expected after injection?
- How does CO_2 plume move underground within the reservoir?
- Are there any conduits such as faults or fractures that may provide pathways for CO_2 to migrate out of the injection target zone?
- How is the CO_2 storage operation managed?
- Is the monitoring program adequate?

The answer to each of the above mentioned questions depends on information which involves a range of uncertainty and therefore introduces risk; hence risk management is essential for a successful CCS project. Also requiring consideration are the recurrent themes of monitoring and review, and risk management occurring in every decision. AS/NZS ISO 31000:2009 clearly states the risk management principles, framework and processes. These features fit well with a CCS project assessment and approval.

AS/NZS ISO 31000:2009 can be applied to all aspects of a CCS project, including site assessment, well drilling, injection operation, monitoring and verification, and site closure. DMP can provide such guidelines for companies involved in the application for CCS projects.

Recommendation

AS/NZS ISO 31000:2009 provides generic guidelines and explicit principles for risk management. It should be integrated in all decision making processes of a CCS project. The recurrent features of framework and process review are well suited for the risk management of CCS projects and can be implemented in Western Australia.

It is recommended that all CCS applications clearly set the risk management context. Its scope should include risk identification, risk assessment and risk treatment. Monitoring and review processes should also be included for effective implementation of a risk management plan.

Geomechanical characterisation of CO_2 storage sites

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Carbon dioxide compression module, Gorgon Project

Introduction

One of the more efficient methods for reducing the amount of carbon dioxide (CO_2) being emitted into the atmosphere is geological sequestration, which has been successfully undertaken in many places around the globe. Here in Western Australia, the Gorgon CO_2 injection project on Barrow Island and at the South West Hub near Harvey are two major CO_2 storage projects in the pipeline.

CO_2 extracted from natural gas before it is converted to liquefied natural gas (LNG) can be stored underground in a suitable reservoir such as a deep brine-filled sandstone or a depleted oil and/or gasfield. CO_2 can also be stored in coal seams, and can be used for enhanced oil and gas recovery (Fig. 1).

The best candidate reservoirs for CO_2 storage are the ones with good porosity to provide sufficient storage space and good permeability to allow fluid flow and injection. Most importantly a good storage site must have an impervious cap rock and a suitable geological structure to trap the CO_2. Potential damage to the reservoir must be avoided.

Consideration of the geomechanical properties of the reservoir rock and seal layers is essential for quantifying the risks associated with CO_2 sequestration. Geomechanical analysis predicts the evolution of effective stresses in the reservoir and seal rocks during injection, as CO_2 could possibly breach the containment of the storage reservoir. The critical outcome of establishing a geomechanical model is to determine the maximum sustainable fluid pressure of the reservoir rock and seal layer. Increased pore pressure and consequent stress changes can decrease rock strength and lead to brittle failure. Fault and fracture stability and maximum sustainable pore pressure are the main parameters that are dealt with in geomechanical analysis. Repeated measurement of horizontal stresses during CO_2 injection can indicate effective stress changes. Micro-seismic monitoring is also a useful tool to survey the migration pathways and to detect unexpected seismic events in the area, which may be triggered by fault slippage or the creation of fractures.

A geomechanical model is built based on the detailed geological and geomechanical characterisation of the site. In-situ stresses, fault strength data, formation pore pressure and mechanical rock properties are the main inputs for any geomechanical modelling, with detailed attention paid to plausible failure mechanisms in the rocks and to existing discontinuities such as faults and fractures.

This article discusses the various aspects of geomechanical modelling for CO_2 sequestration.

In-situ stresses

A common assumption in most geomechanical analyses is that one of the principal stress directions is always vertical and the other two are horizontal. This hypothesis is only valid in stable tectonic areas where all the stresses have been relaxed following an earlier tectonic event (Fjaer 2008); therefore, expecting such a stress regime in an active tectonic area is not a persuasive assumption. However, as CO_2 storage sites are purposefully chosen in tectonically stable areas, this assumption is considered valid.

Maximum and minimum horizontal stresses – orientation and magnitude

In the absence of a Diagnostic Fracture Injection Test (DFIT) in a borehole, borehole breakout and drilling-induced tensile fracture are the main indicators of the orientation of in-situ horizontal stresses at the injection site. To detect the compressive and tensile failures along the borehole walls, the bore-hole logs (calliper or image logs) must be taken after drilling. Compressive (or shear) failures occur in a direction parallel to the minimum horizontal stress, causing so-called breakouts and the ellipticity of the borehole as a result (Fig. 2).

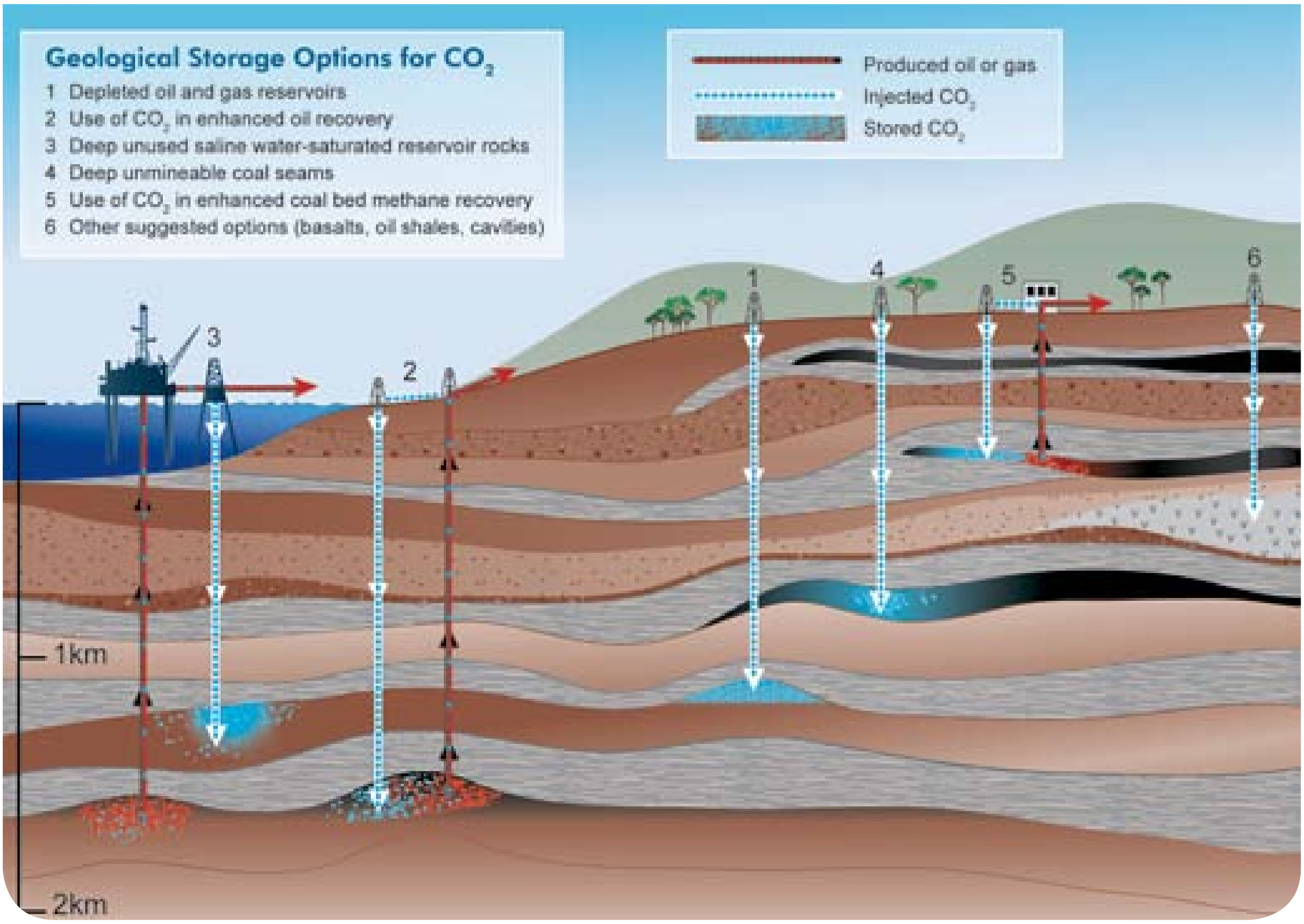
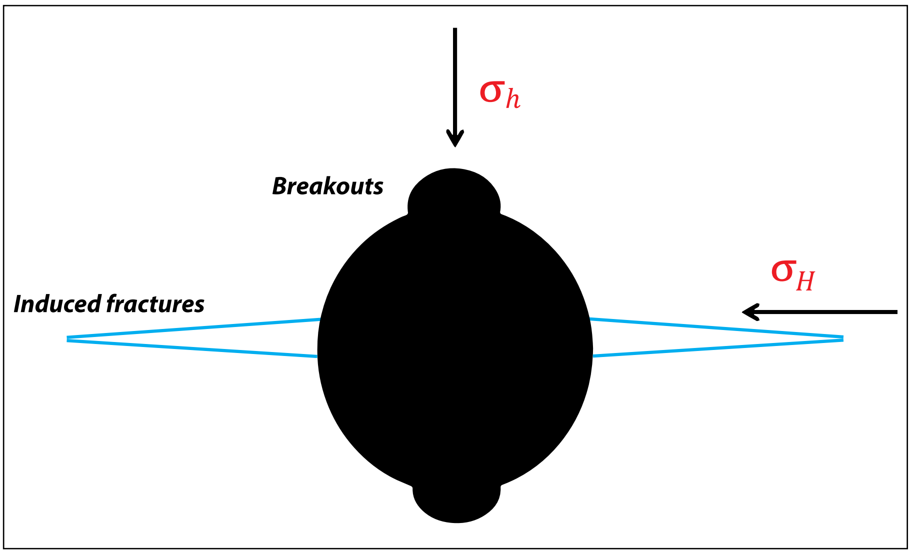


Figure 1. Schematic diagram of the various geological storage mechanisms for CO_2 (CO2CRC)

Figure 2. Illustration of breakouts, induced tensile fractures and maximum and minimum horizontal stress direction when a well is drilled along the vertical stress pathway (Fjaer 2008)



The tensile failures occur parallel to the maximum horizontal stress if the well mud pressure is high enough to induce such fractures.

Minimum horizontal stress (σ_h) magnitude is estimated from leak-off tests and mini-frac test data. If the tests are not carried out in a vertical well, the impact of the well bore trajectory on the measured stress needs to be considered. Low confidence information can also be obtained from Formation Integrity tests (FIT). Quality control is necessary, since inaccuracies can lead to an erroneous estimation of σ_h and consequently an inaccurate stress profile in the geomechanical model.

The magnitude of maximum horizontal stress cannot simply be measured at site, though it is possible to constrain the value of σ_H by applying frictional faulting theory with respect to faulting regime in the area (Sibson 1974). The frictional limit to the stresses is given by:

$$\frac{\sigma_1 - P_P}{\sigma_3 - P_P} \leq \left\{\sqrt{\mu^2 + 1} + \mu\right\}^2$$

where σ_1 and σ_3 are the maximum and minimum principal stresses, P_P is the pore pressure and μ is the coefficient of sliding friction on the fault plane.

Vertical Stress

Vertical stress (σ_v) at any point is caused by the weight of overlying rocks and fluid. Vertical stress is calculated by integrating the bulk density of the overburden rocks and fluid respective to the depth of the measurement. A wireline density log is used to estimate the bulk density of rocks:

$$\sigma_v = \int_z^0 \rho(z) g \, dz$$

where g is the gravitational acceleration, z is the depth and ρ is the density of the rocks and fluids.

Stress regime

Understanding the current stress field at a CO_2 injection site is crucial to deriving the orientation and magnitude of the principal stresses. According to Anderson's classification (Zoback 2007), three different faulting regimes can be identified: a normal faulting regime, ($\sigma_v > \sigma_H > \sigma_h$) a strike slip faulting regime ($\sigma_H > \sigma_v > \sigma_h$), and a reverse faulting regime ($\sigma_H > \sigma_h > \sigma_v$). By diagnosing the current stress field in the area, the orientation and magnitude of the principal stresses and also the evolution of the stresses in the reservoir can be studied (Fig. 3).

Stress changes during CO_2 injection

The effective stress concept first introduced by Karl von Terzaghi in 1925 with applicability to soil mechanics defines the portion of the total stress that causes deformation in soil or rock. It implies that increasing the external hydrostatic pressure produces the same volume change in the materials as reducing the pore pressure. It also indicates that shear strength of a material only depends on the differences between normal stress and pore pressure (Fjaer 2008). Thus Terzaghi's effective stress law is:

$$\sigma_e = \sigma - \alpha Pp$$

The value of Biot's constant (α) can vary for different rocks, with a maximum value of 1 for soils.

The Terzaghi equation implies that rocks fail owing to effective stress, not total stress. The poro-mechanical effect that accompanies CO_2 injection also causes stress changes and rock deformation.

By coupling the reservoir and geomechanical simulation and applying poroelastic theory, the evolution of effective stresses in three dimensions owing to increasing pore pressure in the CO_2 storage system are: (Rutqvist et al. 2008)

$$\Delta\sigma'_z = \Delta\sigma_z - \alpha \Delta P_P$$
$$\Delta\sigma'_y = \Delta\sigma_y - \alpha \Delta P_P$$
$$\Delta\sigma'_x = \Delta\sigma_x - \alpha \Delta P_P$$

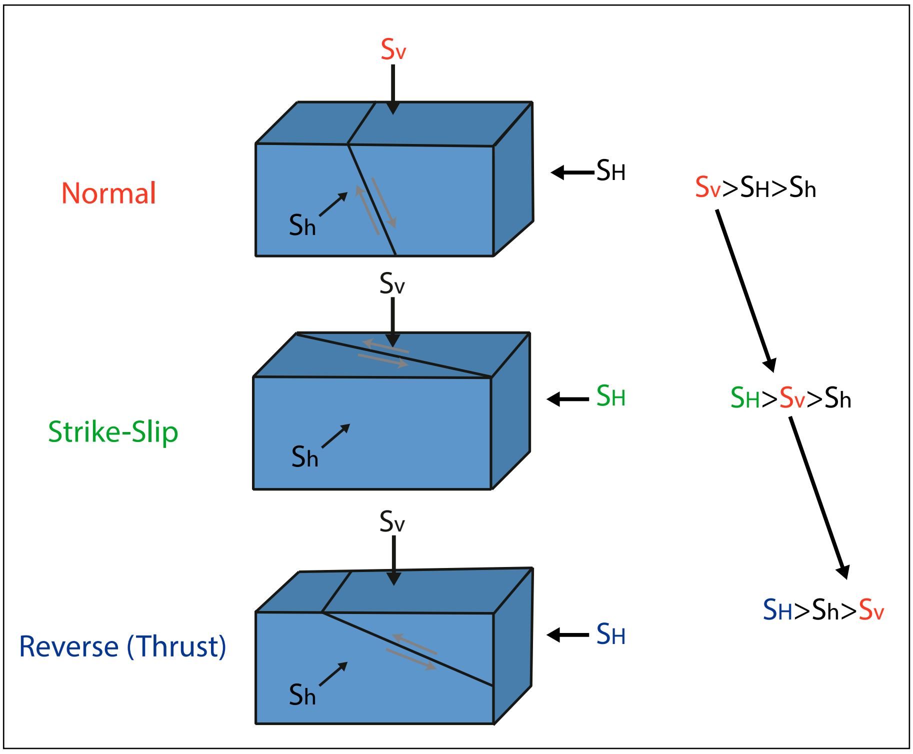


Figure 3. Schematic of Anderson's faulting classification system (Zoback 2007)

Rock mechanical properties

Rock mechanical testing on cores obtained from appraisal wells provides reliable information about intact rock strength. There are also empirical correlations for extracting intact rock geomechanical and strength properties from wireline logs however, log-derived properties must always be calibrated with core-derived data. The strength of the regional seal layer is very important to consider while investigating CO_2 containment. In addition, evaluation of the strength properties of existing faults and fractures is required for the geomechanical analysis of the injection site.

Pore pressure

A pore pressure gradient is usually determined by formation tests in offset or injection wells, bearing in mind that, in addition to the hydrostatic gradient, over-pressured zones could be present and their contribution must be considered with caution in geomechanical analysis. Any abnormal departure (increase) from the normal pore pressure gradient can decrease the injectivity of the CO_2 into those zones or cause brittle failure of the formation.

Intact rock failure

Discontinuities such as new faults and fractures can form in intact rock as a result of an increase in the pore pressure owing to CO_2 injection, when intact rock cannot sustain the extra pressure. Geomechanical analysis enables the estimation of the sustainable change in pressure of the reservoirs and seal layers. The lower the change, the earlier and more easily the rock will undergo failure.

Fault reactivation

Fault reactivation has a significant impact on the success of any CO_2 sequestration project.

Brittle deformation can increase fault and fracture permeability and cause fluid to migrate to an undesired area. At some points, fault slippage can intersect the seal layer and connect the reservoir rock to a permeable layer overlying the seal. This can provide a potential flow conduit for the CO_2 through the seal layer, which may reach the surface and atmosphere. Therefore, it is important to define multiple faulting scenarios in a geological model, such as cohesionless faults, very low sliding friction along faults or faults with different orientations and dips, and to examine the impacts of all these on CO_2 containment.

Sometimes the formation of small-scale faults can provide an easy pathway for CO_2 to migrate out of the reservoir. A fault integrity assessment depends significantly on the regional stress field exerted on the fault plane. By applying specific techniques like FAST (Fault Analysis Seal Technology), we are able to relate the increase of pore pressure to these failures (Mildren et al. 2002) (Fig. 4).

Conclusion

Geomechanical models can aid in understanding the integrity of the reservoirs, seals, faults and fractures both during the injection period and over the long term. To obtain better insights into such behaviour, various coupled models that simultaneously investigate fluid flow, mechanical, thermal and chemical effects of CO_2 injection are recommended. In addition to detailed geological and geomechanical characterisation of the potential sites, real-time monitoring of the reservoir pressure is required to refine the models and operational plans and, in the long run, to decrease the uncertainties that accompany CO_2 sequestration projects.

References

CO2CRC, www.co2crc.com.au/publications/posters.html

Fjaer, E, 2008, Petroleum related rock mechanics. 1st ed. Amsterdam: Elsevier.

Mildren, SD, Hillis, RR and Kaldi, J, 2002, Calibrating predictions of fault seal reactivation in the Timor Sea: APPEA Journal, 42, 187-202.

Rutqvist, J, Birkholzer, J and Tsang, C, 2008, Coupled reservoir–geomechanical analysis of the potential for tensile and shear failure associated with CO_2 injection in multilayered reservoir–caprock systems: International Journal of Rock Mechanics and Mining Sciences, 45(2): 132-143.

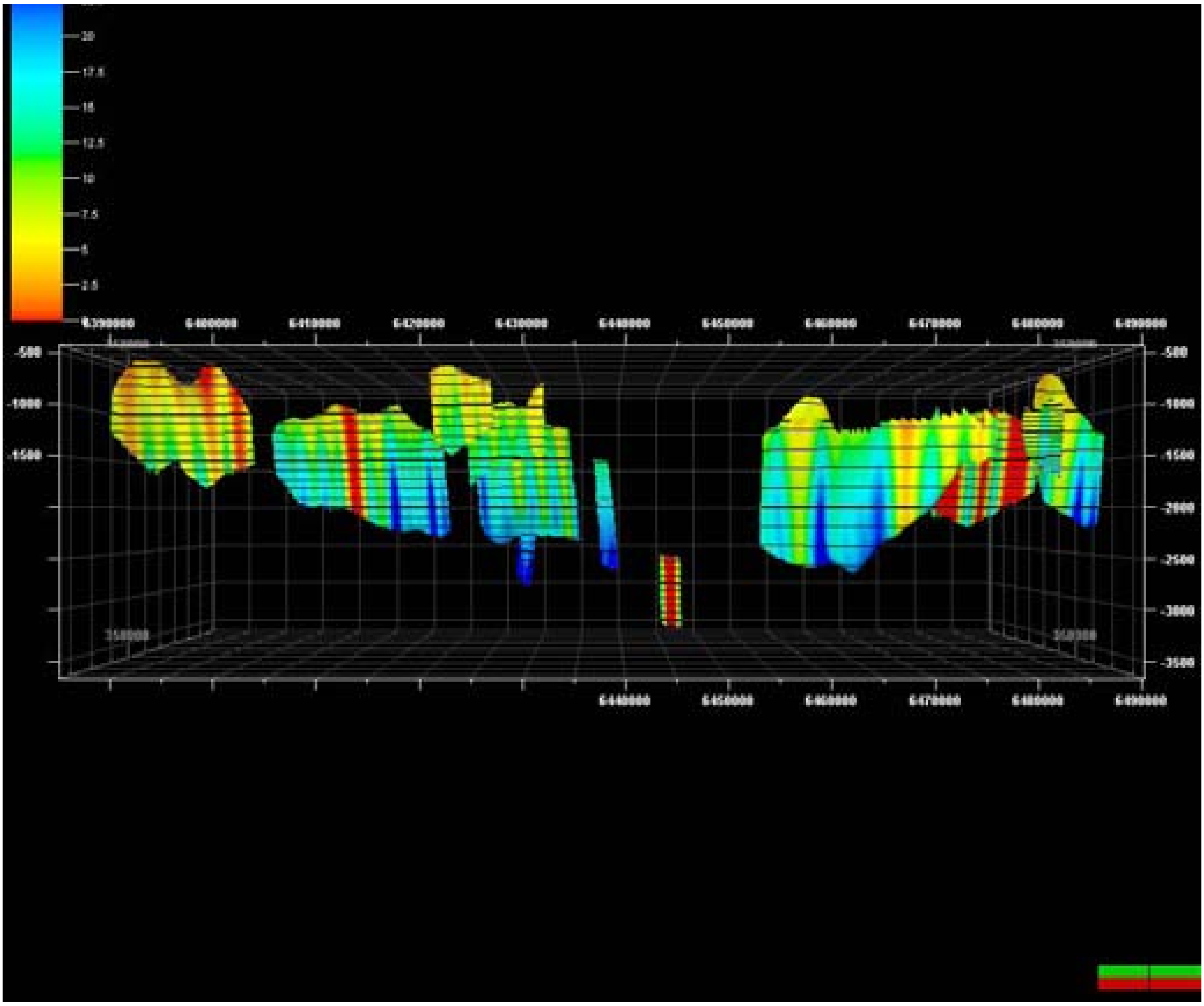


Figure 4. Fault reactivation risk in terms of Delta P. Low Delta P values (warm colours) indicate high reactivation risk and high Delta P values (cool colours) show low risk of reactivation (CO2CRC)

Sibson, RH, 1974, Frictional constraints on thrust, wrench and normal faults: Nature, 249, 542-544.

Zoback, M, 2007, Reservoir geomechanics, 1st ed. Cambridge: Cambridge University Press.

Bibliography

Gidley, J, 1989, Recent advances in hydraulic fracturing. 1st ed. Richardson, TX: Henry L. Doherty Memorial Fund of AIME, Society of Petroleum Engineers.

Langhi, L, Zhang, Y, Nicholson, C, Bernardel, G, Rollet, N, Schaubs, P, Kempton, R and Kennard, J, 2012, Geomechanical modelling of trap integrity in the northern offshore Perth Basin. CSIRO Open File Report EP12425, CSIRO Australia.

Streit, J and Siggins, A, 2005, Predicting, monitoring and controlling geomechanical effects of CO_2 injection, in ES Rubin, DW Keith, and CF Kilboy, Conference on Greenhouse Gas Control Technologies: Oxford, Elsevier, v. 1:643-651.

Tenthorey, E and van Ruth, P, 2007. Geomechanical assessment of CO_2 storage in the southern Browse Basin (Barcoo Sub-basin): Cooperative Research Centre for Greenhouse Gas Technologies, Canberra, Australia, CO2CRC Publication Number RPT07-0949. 19p.

Van Ruth, P, Nelson, E and Hill, R, 2006, Fault reactivation potential during CO_2 injection in the Gippsland Basin, Australia. Exploration Geophysics, 37(1): 50-59.

Van Ruth, P, 2006, Geomechanics: Vlaming Sub-basin, Western Australia: CO2CRC Report number RPT06-0043.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TESCO

Canning Coastal Seismic Survey

Photo © Geoscience Australia

TABLE 1. 2013 PRODUCTION BY FIELD AND CUMULATIVE PRODUCTION WA ONSHORE AND STATE WATERS AS AT 31 DECEMBER 2013

Field	Operator	2013 Production by Field			Cumulative Production			Permit
		Oil	Condensate	Gas	Oil	Condensate	Gas	
		kL	kL	10^3 m^3	kL	kL	10^3 m^3	
Agincourt	Apache	13,304.8	50.1	2,894.2	559,603.42	4,269.61	41,873.22	TL/1
Albert	Apache	3,214.4	242.1	7,117.3	77,419.80	379.80	16,674.10	TL/6
Bambra	Apache	19,648.4	186.2	15,026.8	403,023.10	158,301.20	1,362,609.30	TL/1
Barrow Island	Chevron	300,609.0	0.0	32,994.3	51,204,658.93	0.00	5,407,368.71	L1H
Beharra Springs	Origin	0.0	146.4	13,937.9	0.00	24,357.53	2,293,909.30	L11
Beharra Springs N	Origin	0.0	44.1	4,168.3	0.00	2,056.34	210,398.26	L11
Blina	Buru Energy	27.0	0.0	0.0	298,725.15	0.00	0.00	L6
Boundary	Buru Energy	32.0	0.0	0.0	21,212.14	0.00	0.00	L6
Corybas	AWE	0.0	109.7	6,103.3	0.00	342.40	18,546.33	L2
Crest	Chevron	343.0	0.0	1,526.0	275,808.00	108.00	65,773.00	L12, L13
Dongara	AWE	542.8	0.0	15,971.9	195,612.78	49,681.21	12,943,461.67	L1, L2
Double Island	Apache	2.0	0.0	1.1	708,512.10	2,943.10	59,150.70	TL/9
Gingin West	Empire	0.0	1,010.8	52,339.1	0.00	1,010.79	52,339.06	EP 389
Harriet	Apache	41.6	0.0	79.8	8,232,695.10	61,226.35	1,510,761.58	TL/1
Hovea	AWE	0.0	0.0	25.2	1,170,005.35	251.09	104,855.44	L1
Lee	Apache	309.1	9,118.4	62,325.3	313.50	119,212.30	788,360.20	TL/1
Linda	Apache	0.0	6,120.0	42,185.8	0.00	301,453.80	1,205,096.00	TL/1
Little Sandy	Apache	163.2	0.5	83.3	95,352.90	491.64	15,989.80	TL/6
Mohave	Apache	6,654.2	62.7	1,743.5	174,510.90	648.50	40,788.10	TL/6
Pedirka	Apache	1,173.1	6.2	486.8	341,249.50	1,373.10	45,924.50	TL/6
Red Gully	Empire	0.0	6,576.8	21,147.9	0.00	6,576.80	21,147.87	EP 389
Redback	Origin	0.0	259.3	138,106.5	0.00	691.74	450,091.91	L11
Roller	Chevron	26,611.0	0.0	11,433.0	7,211,390.00	0.00	793,215.00	TL/7
Rose	Apache	3,342.4	1,239.7	14,318.1	6,383.50	210,146.40	1,052,087.90	TL/1
Saladin	Chevron	60,523.0	0.0	26,407.0	15,645,337.00	0.00	1,811,653.00	TL/4
Simpson	Apache	649.9	271.5	325.1	857,914.57	14,570.99	90,524.45	TL/1
South Plato	Apache	12,757.6	9.0	503.9	717,546.10	908.60	52,287.00	TL/6
Sundown	Buru Energy	95.0	0.0	0.0	74,207.18	0.00	0.00	L8
Tarantula	Origin	0.0	175.7	15,850.7	0.00	4,102.83	331,300.40	L11
Ungani	Buru Energy	6,442.0	0.0	11.4	18,537.00	0.00	15.81	EP 391
Victoria	Apache	1,573.5	10.9	416.6	62,587.50	481.20	11,790.70	TL/6
West Cycad	Apache	1,281.9	10.9	409.5	218,676.00	546.80	36,990.60	TL/9
West Terrace	Buru Energy	13.0	0.0	0.0	39,602.35	0.00	0.00	L8
Wonnich	Apache	0.0	2,556.1	27,898.1	0.00	479,450.13	4,856,471.08	TL/8
Yammaderry	Chevron	0.0	0.0	13,442.0	858,332.0	0.0	142,396.0	TL/4
Total		**459,353.9**	**28,207.1**	**529,279.5**	**89,469,215.9**	**1,445,582.3**	**35,833,851.0**	

TABLE 2A. PETROLEUM RESERVES ESTIMATES BY BASIN FOR WA ONSHORE, STATE WATERS AND TERRITORIAL WATERS, AS AT 31 DECEMBER 2013 (METRIC UNITS)

Basin	Oil GL		Sales Gas Gm^3		Condensate GL	
CATEGORY 1	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**
Canning	–	–	–	–	–	-
Carnarvon	0.99	6.00	18.63	19.35	0.08	0.12
Perth	0.00	0.01	18.59	19.47	0.07	0.10
Total	**0.99**	**6.01**	**37.22**	**38.82**	**0.15**	**0.22**
CATEGORY 2	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**
Carnarvon	0.52	0.93	0.38	0.50	–	–
Total	**0.52**	**0.93**	**0.38**	**0.50**	**–**	**–**
CATEGORY 4	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**
Canning	0.02	0.05	1.76	5.41	0.16	0.45
Carnarvon	1.27	6.07	4.39	9.49	–	–
Total	**1.29**	**6.12**	**6.15**	**14.90**	**0.16**	**0.45**
GRAND TOTAL	**2.80**	**13.06**	**43.75**	**54.22**	**0.31**	**0.67**

TABLE 2B. PETROLEUM RESERVES ESTIMATES BY BASIN FOR WA ONSHORE, STATE WATERS AND TERRITORIAL WATERS, AS AT 31 DECEMBER 2013 (FIELD UNITS)

Basin	Oil MMbbl		Sales Gas Bcf		Condensate MMbbl	
CATEGORY 1	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**
Canning	–	–	–	–	–	–
Carnarvon	6.22	37.75	20.26	43.14	0.47	0.78
Perth	0.02	0.08	16.44	46.75	0.45	0.66
Total	**6.24**	**37.83**	**36.70**	**89.59**	**0.92**	**1.44**
CATEGORY 2	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**
Carnarvon	3.25	5.85	13.57	17.57	–	–
Total	**3.25**	**5.85**	**13.57**	**17.57**	**–**	**–**
CATEGORY 4	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**
Canning	0.11	0.29	62.01	191.02	1.01	2.81
Carnarvon	7.99	38.17	154.85	335.03	–	–
Total	**8.10**	**38.46**	**216.86**	**526.05**	**1.01**	**2.80**
GRAND TOTAL	**17.59**	**82.14**	**267.14**	**633.51**	**1.94**	**4.26**

NOTES

Canning Basin reserves are too small to measure.

There are no fields currently under category 3.

Category 1 comprises current reserves of those fields which are producing hydrocarbons or have been declared commercial (with FID)

Category 2 comprises estimates of recoverable reserves which are held under Retention Lease and have not yet been declared commercially viable.

Category 3 comprises estimates of contingent resources which are held in other licences and have been declared commercially viable but may or may not have a FMP and have not yet reached FID.

Category 4 comprises estimates of contingent resources which are held in other licences and have not yet been declared commercially viable and are not held under a Retention Lease.

TABLE 3. PETROLEUM WELLS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS 2013/2014

Well name	Class	On Off	Title	Operator	Latitude	Longitude	Gnd Elev (m)	RT/ KB (m)	Rig	Spud date	TD Date	Rig Release Date
CANNING BASIN												
Ungani 3	EXT	On	EP 391	Buru Energy	123.174	-17.989	77	8	Crusader	1/14/2014	2/22/2014	3/11/2014
CARNARVON BASIN												
Gorgon Plant Disposal Well Z-WI1	WDW	On	L 1H R2	Chevron	115.450	-20.799	15	7.14	Ensign 963	7/12/2013	8/12/2013	9/16/2013
Gorgon Plant Disposal Well Z-WI2	WDW	On	L 1H R2	Chevron	115.450	-20.800	15	7.14	Ensign 963	7/10/2013	8/23/2013	9/16/2013
PERTH BASIN												
Drover 1	NFW	On	EP 455	AWE	115.147	-30.077	176	6.6	Enerdrill 3	6/29/2014		

TABLE 4. SURVEYS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS 2013/2014

Survey Name	Class	On Off	Title	Operator	Commenced	Completed	2D/ Line km @ 31/12/2013	3D km² @ 31/12/2013
CANNING BASIN								
2013 EP 449 Airborne Gradiometry Survey	GRAVITY	On	EP 449	Hess Exploration	26/08/13	4/09/13	3250	
EP 448 Geochemical Survey	GEOCHEM	On	EP 448	Key Petroleum	23/10/13	29/10/13		
Frome Rocks 2D S.S.	2D	On	EP 457, 391 R2, 428	Buru Energy	27/10/13	21/11/13	360	
Southern Canning Airborne Gravity Survey	GRAVITY	On	EP 428,457, 458, 472, 474,477, 478	Buru Energy	28/09/13	30/11/13	45797	
Ungani 3D S.S. Resumption	3D	On	EP 391 R2, 428	Buru Energy	6/09/13	24/10/13		241
PERTH BASIN								
AGG-HRAM 2013 Survey	AEROMAG	On	SPA 16 AO	Finder Exploration	2/12/13	9/12/13	1773	
Murgoo Gravity Survey	GRAVITY	On	SPA 9 AO	Palatine Energy	16/07/13	16/07/13		

Classification

2D	*2D Seismic Survey*
3D	*3D Seismic Survey*
AEROMAG	*Aeromagnetic Survey*
GEOCHEM	*Geochemical Survey*
GRAVITY	*Gravity Survey*

TABLE 5. LIST OF PETROLEUM AND GEOTHERMAL TITLES AND HOLDERS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS AS AT 4 AUGUST 2014

*Denotes nominee

PETROLEUM (SUBMERGED LANDS) ACT 1982
Access Authority

Title	Registered Holder(s)
AA 1 T	TGS-NOPEC GEOPHYSICAL COMPANY PTY LTD

PETROLEUM (SUBMERGED LANDS) ACT 1982
Exploration Permit

Title	Registered Holder(s)
TP/7 R4	APACHE OIL AUSTRALIA PTY LTD* HYDRA ENERGY (WA) PTY LTD SANTOS (BOL) PTY LTD TAP (SHELFAL) PTY LTD
TP/8 R4	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TP/15 R2	WESTRANCH HOLDINGS PTY LTD
TP/23 R1	APACHE NORTHWEST PTY LTD
TP/25	FINDER NO 3 PTY LIMITED
TP/26	PERSEVERANCE ENERGY PTY LTD*
TP/27	CARNARVON PETROLEUM LIMITED

PETROLEUM (SUBMERGED LANDS) ACT 1982
Pipeline Licence

Title	Registered Holder(s)
TPL/1 R1	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TPL/2 R1	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TPL/4 R1	APACHE OIL AUSTRALIA PTY LTD HYDRA ENERGY (WA) PTY LTD SANTOS (BOL) PTY LTD TAP (SHELFAL) PTY LTD
TPL/5 R1	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TPL/6 R1	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
TPL/7 R2	APACHE OIL AUSTRALIA PTY LTD* HYDRA ENERGY (WA) PTY LTD SANTOS (BOL) PTY LTD TAP (SHELFAL) PTY LTD
TPL/8	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TPL/9 R1	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
TPL/10	BHP BILLITON PETROLEUM (AUSTRALIA) PTY LTD* INPEX ALPHA LTD MOBIL EXPLORATION & PRODUCING AUSTRALIA PTY LTD
TPL/11	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
TPL/12	APACHE EAST SPAR PTY LTD APACHE KERSAIL PTY LTD APACHE OIL AUSTRALIA PTY LTD* SANTOS (BOL) PTY LTD
TPL/13	APACHE EAST SPAR PTY LTD APACHE KERSAIL PTY LTD APACHE NORTHWEST PTY LTD APACHE OIL AUSTRALIA PTY LTD HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD SANTOS (BOL) PTY LTD
TPL/14	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TPL/15	BHP BILLITON PETROLEUM (NORTH WEST SHELF) PTY LTD BP DEVELOPMENTS AUSTRALIA PTY LTD CHEVRON AUSTRALIA PTY LTD JAPAN AUSTRALIA LNG (MIMI) PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED WOODSIDE ENERGY LTD*
TPL/16	BHP BILLITON PETROLEUM (NORTH WEST SHELF) PTY LTD BP DEVELOPMENTS AUSTRALIA PTY LTD CHEVRON AUSTRALIA PTY LTD JAPAN AUSTRALIA LNG (MIMI) PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED WOODSIDE ENERGY LTD*
TPL/17	APACHE NORTHWEST PTY LTD SANTOS (BOL) PTY LTD
TPL/18	AWE (OFFSHORE PB) PTY LTD AWE OIL (WESTERN AUSTRALIA) PTY LTD ROC OIL (WA) PTY LIMITED
TPL/19	KANSAI ELECTRIC POWER AUSTRALIA PTY LTD TOKYO GAS PLUTO PTY LTD WOODSIDE BURRUP PTY LTD
TPL/20	APACHE NORTHWEST PTY LTD SANTOS OFFSHORE PTY LTD
TPL/21	CHEVRON (TAPL) PTY LTD* CHUBU ELECTRIC POWER GORGON PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED OSAKA GAS GORGON PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED TOKYO GAS GORGON PTY LTD
TPL/22	CHEVRON (TAPL) PTY LTD* CHUBU ELECTRIC POWER GORGON PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED OSAKA GAS GORGON PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED TOKYO GAS GORGON PTY LTD
TPL/23	APACHE PVG PTY LTD BHP BILLITON PETROLEUM (AUSTRALIA) PTY LTD
TPL/24	CHEVRON (TAPL) PTY LTD* CHUBU ELECTRIC POWER GORGON PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED OSAKA GAS GORGON PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED TOKYO GAS GORGON PTY LTD
TPL/25	APACHE JULIMAR PTY LTD CHEVRON (TAPL) PTY LTD* KUFPEC AUSTRALIA (JULIMAR) PTY LTD KYUSHU ELECTRIC WHEATSTONE PTY LTD PE WHEATSTONE PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED

TABLE 5. LIST OF PETROLEUM AND GEOTHERMAL TITLES AND HOLDERS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS AS AT 4 AUGUST 2014

PETROLEUM (SUBMERGED LANDS) ACT 1982
Production Licence

Title	Registered Holder(s)
TL/1 R1	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TL/2 R1	APACHE OIL AUSTRALIA PTY LTD* HYDRA ENERGY (WA) PTY LTD SANTOS (BOL) PTY LTD TAP (SHELFAL) PTY LTD
TL/3 R1	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
TL/4 R1	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
TL/5 R1	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TL/6 R1	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TL/7	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
TL/8	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TL/9	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TL/10	APACHE NORTHWEST PTY LTD HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD

PETROLEUM (SUBMERGED LANDS) ACT 1982
Retention Lease

Title	Registered Holder(s)
TR/1 R2	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
TR/3 R2	APACHE NORTHWEST PTY LTD
TR/4 R1	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
TR/5 R1	BP DEVELOPMENTS AUSTRALIA PTY LTD JAPAN AUSTRALIA LNG (MIMI BROWSE) PTY LTD PETROCHINA INTERNATIONAL INVESTMENT (AUSTRALIA) PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED WOODSIDE BROWSE PTY. LTD.
TR/6	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD

PETROLEUM (SUBMERGED LANDS) ACT 1982
Special Prospecting Authority

Title	Registered Holder(s)
SPA 1 T	TGS-NOPEC GEOPHYSICAL COMPANY PTY LTD

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Access Authority

Title	Registered Holder(s)
AA 5	
AA 6	TGS-NOPEC GEOPHYSICAL COMPANY PTY LTD

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Drilling Reservation

Title	Registered Holder(s)
DR 11	TITAN ENERGY LTD

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Exploration Permit

Title	Registered Holder(s)
EP 61 R7	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
EP 62 R7	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
EP 104 R5	ARC ENERGY PTY LIMITED FAR LTD GULLIVER PRODUCTIONS PTY LTD INDIGO OIL PTY LTD PANCONTINENTAL OIL & GAS NL PHOENIX RESOURCES PLC
EP 110 R5	PANCONTINENTAL OIL & GAS NL STRIKE ENERGY WESTERN AUSTRALIA PTY LIMITED
EP 129 R5	BURU ENERGY LIMITED
EP 307 R5	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
EP 320 R4	AWE (BEHARRA SPRINGS) PTY LTD ORIGIN ENERGY DEVELOPMENTS PTY LIMITED*
EP 321 R3	ALCOA OF AUSTRALIA LIMITED LATENT PETROLEUM PTY LTD*
EP 325 R3	ADVENT ENERGY LTD BOW ENERGY PTY LTD ROUGH RANGE OIL PTY LTD STRIKE ENERGY WESTERN AUSTRALIA PTY LIMITED
EP 357 R3	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
EP 358 R3	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
EP 359 R3	BOUNTY OIL & GAS NL LANSVALE OIL & GAS PTY LTD PACE PETROLEUM PTY LTD PHOENIX RESOURCES PLC ROUGH RANGE OIL PTY LTD

TABLE 5. LIST OF PETROLEUM AND GEOTHERMAL TITLES AND HOLDERS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS AS AT 4 AUGUST 2014

EP 368 R3	EMPIRE OIL COMPANY (WA) LIMITED* WESTRANCH HOLDINGS PTY LTD
EP 371 R2	BURU ENERGY LIMITED DIAMOND RESOURCES (CANNING) PTY LTD
EP 381 R3	WHICHER RANGE ENERGY PTY LTD
EP 386 R3	ONSHORE ENERGY PTY LTD
EP 389 R2	EMPIRE OIL COMPANY (WA) LIMITED ERM GAS PTY LTD
EP 390 R2	BURU ENERGY LIMITED* DIAMOND RESOURCES (CANNING) PTY LTD
EP 391 R2	BURU ENERGY LIMITED* DIAMOND RESOURCES (FITZROY) PTY LTD
EP 407 R1	ALCOA OF AUSTRALIA LIMITED LATENT PETROLEUM PTY LTD*
EP 408 R2	CALENERGY RESOURCES (AUSTRALIA) LIMITED* WHICHER RANGE ENERGY PTY LTD
EP 412 R2	BOUNTY OIL & GAS NL ROUGH RANGE OIL PTY LTD*
EP 413 R3	AWE PERTH PTY LTD BHARAT PETRORESOURCES LIMITED NORWEST ENERGY NL*
EP 416 R1	ALLIED OIL & GAS PLC EMPIRE OIL COMPANY (WA) LIMITED* ERM GAS PTY LTD
EP 417 R1	BURU ENERGY LIMITED NEW STANDARD ONSHORE PTY LTD
EP 424	PANCONTINENTAL OIL & GAS NL STRIKE ENERGY WESTERN AUSTRALIA PTY LIMITED
EP 426	ALLIED OIL & GAS PLC EMPIRE OIL COMPANY (WA) LIMITED ERM GAS PTY LTD WESTRANCH HOLDINGS PTY LTD
EP 428 R1	BURU ENERGY LIMITED DIAMOND RESOURCES (CANNING) PTY LTD
EP 430	EMPIRE OIL COMPANY (WA) LIMITED
EP 431 R1	BURU ENERGY LIMITED DIAMOND RESOURCES (FITZROY) PTY LTD
EP 432	ALLIED OIL & GAS PLC EMPIRE OIL COMPANY (WA) LIMITED* ERM GAS PTY LTD
EP 433 R1	LANSVALE OIL & GAS PTY LTD PACE PETROLEUM PTY LTD
EP 434 R1	LANSVALE OIL & GAS PTY LTD* PACE PETROLEUM PTY LTD ROUGH RANGE OIL PTY LTD
EP 435 R1	AUSTRALIAN OIL COMPANY NO 3 PTY LIMITED BOUNTY OIL & GAS NL ROUGH RANGE OIL PTY LTD
EP 436 R1	BURU ENERGY LIMITED DIAMOND RESOURCES (FITZROY) PTY LTD
EP 437	CARACAL EXPLORATION PTY LTD EMPIRE OIL COMPANY (WA) LIMITED KEY PETROLEUM (AUSTRALIA) PTY LTD*
EP 438 R1	BURU ENERGY LIMITED DIAMOND RESOURCES (CANNING) PTY LTD GULLIVER PRODUCTIONS PTY LTD* INDIGO OIL PTY LTD
EP 439	FALCORE PTY LTD INDIGO OIL PTY LTD JURASSICA OIL & GAS PLC LONGREACH OIL LIMITED ROUGH RANGE OIL PTY LTD* VIGILANT OIL PTY LTD
EP 440 R1	EMPIRE OIL COMPANY (WA) LIMITED
EP 441 R1	APACHE NORTHWEST PTY LTD
EP 443	CONOCOPHILLIPS (CANNING BASIN) PTY LTD NEW STANDARD ONSHORE PTY LTD* PETROCHINA INTERNATIONAL INVESTMENT (AUSTRALIA) PTY LTD
EP 444 R1	ROUGH RANGE OIL PTY LTD
EP 447 R1	GCC METHANE PTY LTD* UIL ENERGY LTD
EP 448	GULLIVER PRODUCTIONS PTY LTD* INDIGO OIL PTY LTD
EP 449	HESS AUSTRALIA (CANNING) PTY LIMITED
EP 450	CONOCOPHILLIPS (CANNING BASIN) PTY LTD NEW STANDARD ONSHORE PTY LTD* PETROCHINA INTERNATIONAL INVESTMENT (AUSTRALIA) PTY LTD
EP 451	CONOCOPHILLIPS (CANNING BASIN) PTY LTD NEW STANDARD ONSHORE PTY LTD* PETROCHINA INTERNATIONAL INVESTMENT (AUSTRALIA) PTY LTD
EP 453 R1	GOSHAWK ENERGY (LENNARD SHELF) PTY LTD
EP 455	AWE PERTH PTY LTD* TITAN ENERGY LTD
EP 456	CONOCOPHILLIPS (CANNING BASIN) PTY LTD NEW STANDARD ONSHORE PTY LTD* PETROCHINA INTERNATIONAL INVESTMENT (AUSTRALIA) PTY LTD
EP 457	BURU FITZROY PTY LTD* DIAMOND RESOURCES (FITZROY) PTY LTD REY RESOURCES LTD
EP 458	BURU FITZROY PTY LTD* DIAMOND RESOURCES (FITZROY) PTY LTD REY RESOURCES LTD
EP 464	EXCEED ENERGY (AUSTRALIA) PTY LTD
EP 465	AUSTRALIA ZHONGFU OIL GAS RESOURCES PTY LTD
EP 466	ROUGH RANGE OIL PTY LTD
EP 467	ERM GAS PTY LTD
EP 468	OFFICER PETROLEUM PTY LTD
EP 469	WARREGO ENERGY PTY LTD
EP 470	ENERGETICA RESOURCES PTY LTD
EP 471	BURU ENERGY LIMITED* DIAMOND RESOURCES (CANNING) PTY LTD
EP 472	BURU ENERGY LIMITED* DIAMOND RESOURCES (CANNING) PTY LTD
EP 473	BURU ENERGY LIMITED* DIAMOND RESOURCES (CANNING) PTY LTD
EP 474	BURU ENERGY LIMITED
EP 475	ENERGETICA RESOURCES PTY LTD
EP 476	BURU ENERGY LIMITED* DIAMOND RESOURCES (CANNING) PTY LTD
EP 477	BURU ENERGY (ACACIA) PTY LTD* DIAMOND RESOURCES (CANNING) PTY LTD

TABLE 5. LIST OF PETROLEUM AND GEOTHERMAL TITLES AND HOLDERS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS AS AT 4 AUGUST 2014

EP 478	BURU ENERGY (ACACIA) PTY LTD BURU ENERGY LIMITED*
EP 479	EMPIRE OIL COMPANY (WA) LIMITED
EP 480	EMPIRE OIL COMPANY (WA) LIMITED ERM GAS PTY LTD
EP 481	NEW STANDARD ONSHORE PTY LTD
EP 482	NEW STANDARD ONSHORE PTY LTD
EP 483	FINDER NO 3 PTY LIMITED
EP 484	DYNASTY METALS AUSTRALIA LTD
EP 485	DYNASTY METALS AUSTRALIA LTD
EP 486	EXCEED ENERGY (AUSTRALIA) PTY LTD
EP 487	BACKREEF OIL PTY LIMITED OIL BASINS LIMITED
EP 488	UIL ENERGY LTD*
EP 489	UIL ENERGY LTD*
EP 490	CARNARVON PETROLEUM LIMITED
EP 491	CARNARVON PETROLEUM LIMITED

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Geothermal Exploration Permit

Title	Registered Holder(s)
GEP 5	GRANITE POWER LIMITED
GEP 6	GRANITE POWER LIMITED
GEP 23	MID WEST GEOTHERMAL POWER PTY LTD
GEP 24	MID WEST GEOTHERMAL POWER PTY LTD
GEP 25	MID WEST GEOTHERMAL POWER PTY LTD
GEP 26	MID WEST GEOTHERMAL POWER PTY LTD
GEP 27	MID WEST GEOTHERMAL POWER PTY LTD
GEP 28	MID WEST GEOTHERMAL POWER PTY LTD
GEP 37	GREENPOWER ENERGY LIMITED
GEP 38	GREENPOWER ENERGY LIMITED
GEP 41	MID WEST GEOTHERMAL POWER PTY LTD

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Petroleum Lease

Title	Registered Holder(s)
L 1H R2	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Production Licence

Title	Registered Holder(s)
L 1 R1	APT PARMELIA PTY LTD AWE PERTH PTY LTD ORIGIN ENERGY DEVELOPMENTS PTY LIMITED
L 2 R1	AWE PERTH PTY LTD* ORIGIN ENERGY DEVELOPMENTS PTY LIMITED
L 4 R1	AWE PERTH PTY LTD
L 5 R1	AWE PERTH PTY LTD
L 6 R1	BURU ENERGY LIMITED
L 7 R1	AWE PERTH PTY LTD
L 8 R1	BURU ENERGY LIMITED
L 9 R1	DBP DEVELOPMENT GROUP NOMINEES PTY LIMITED
L 10 R1	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
L 11	AWE (BEHARRA SPRINGS) PTY LTD ORIGIN ENERGY DEVELOPMENTS PTY LIMITED*
L 12	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
L 13	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
L 14	AWE PERTH PTY LTD GEARY, JOHN KEVIN NORWEST ENERGY NL ORIGIN ENERGY DEVELOPMENTS PTY LIMITED ROC OIL (WA) PTY LIMITED
L 15	BURU ENERGY LIMITED FAR LTD GULLIVER PRODUCTIONS PTY LTD INDIGO OIL PTY LTD PANCONTINENTAL OIL & GAS NL
L 16	AUSTRALIAN OIL COMPANY NO 3 PTY LIMITED BOUNTY OIL & GAS NL ROUGH RANGE OIL PTY LTD
L 17	BURU ENERGY LIMITED

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Retention Lease

Title	Registered Holder(s)
R 1 R1	ARC ENERGY LIMITED FAR LTD GULLIVER PRODUCTIONS PTY LTD INDIGO OIL PTY LTD PANCONTINENTAL OIL & GAS NL PHOENIX RESOURCES PLC
R 2 R1	BP DEVELOPMENTS AUSTRALIA PTY LTD JAPAN AUSTRALIA LNG (MIMI BROWSE) PTY LTD PETROCHINA INTERNATIONAL INVESTMENT (AUSTRALIA) PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED WOODSIDE BROWSE PTY. LTD.
R 3 R1	OIL BASINS LIMITED
R 4	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
R 5	APACHE OIL AUSTRALIA PTY LTD OMV AUSTRALIA PTY LTD

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Special Prospecting Authority

Title	Registered Holder(s)
SPA 17 AO	ADMIRAL OIL NL

TABLE 5. LIST OF PETROLEUM AND GEOTHERMAL TITLES AND HOLDERS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS AS AT 4 AUGUST 2014

PETROLEUM PIPELINE ACT 1969

Pipeline Licence

Title	Registered Holder(s)
PL 1 R1	APT PARMELIA PTY LTD
PL 2 R1	APT PARMELIA PTY LTD
PL 3 R1	APT PARMELIA PTY LTD
PL 5 R1	APT PARMELIA PTY LTD
PL 6 R3	AWE PERTH PTY LTD
PL 7 R1	BURU ENERGY LIMITED
PL 8 R1	MITSUI IRON ORE DEVELOPMENT PTY LTD NIPPON STEEL & SUMIKIN RESOURCES AUSTRALIA PTY. LTD. NIPPON STEEL & SUMITOMO METAL AUSTRALIA PTY LTD NORTH MINING LIMITED ROBE RIVER MINING CO PTY LTD*
PL 12 R1	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
PL 14 R1	APACHE OIL AUSTRALIA PTY LTD* HYDRA ENERGY (WA) PTY LTD SANTOS (BOL) PTY LTD TAP (SHELFAL) PTY LTD
PL 15 R1	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
PL 16	DBP DEVELOPMENT GROUP NOMINEES PTY LIMITED
PL 17	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
PL 18	AWE (BEHARRA SPRINGS) PTY LTD ORIGIN ENERGY DEVELOPMENTS PTY LIMITED*
PL 19	DBP DEVELOPMENT GROUP NOMINEES PTY LIMITED
PL 20	DBP DEVELOPMENT GROUP NOMINEES PTY LIMITED
PL 21	CHEVRON (TAPL) PTY LTD CHEVRON AUSTRALIA PTY LTD* MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED SANTOS OFFSHORE PTY LTD
PL 22	APA (PILBARA PIPELINE) PTY LTD
PL 23	APT PARMELIA PTY LTD
PL 24	ALINTA DEWAP PTY LTD SOUTHERN CROSS PIPELINES (NPL) AUSTRALIA PTY LTD SOUTHERN CROSS PIPELINES AUSTRALIA PTY LIMITED*
PL 25	SOUTHERN CROSS PIPELINES AUSTRALIA PTY LIMITED
PL 26	SOUTHERN CROSS PIPELINES AUSTRALIA PTY LIMITED
PL 27	SOUTHERN CROSS PIPELINES AUSTRALIA PTY LIMITED
PL 28	SOUTHERN CROSS PIPELINES (NPL) AUSTRALIA PTY LTD
PL 29	APACHE EAST SPAR PTY LTD APACHE KERSAIL PTY LTD APACHE OIL AUSTRALIA PTY LTD* SANTOS (BOL) PTY LTD
PL 30	APACHE EAST SPAR PTY LTD APACHE KERSAIL PTY LTD APACHE OIL AUSTRALIA PTY LTD* SANTOS (BOL) PTY LTD
PL 31	APA (PILBARA PIPELINE) PTY LTD
PL 32	APT PIPELINES (WA) PTY LIMITED
PL 33	APT PIPELINES (WA) PTY LIMITED
PL 34	NEWMONT YANDAL OPERATIONS PTY LTD
PL 35	NORTHERN STAR RESOURCES LTD
PL 36	AUSTRALIAN PIPELINE LIMITED
PL 37	NORILSK NICKEL CAWSE PTY LTD
PL 38	APA (PILBARA PIPELINE) PTY LTD
PL 39	ORIGIN ENERGY PIPELINES PTY LIMITED
PL 40	DBNGP (WA) NOMINEES PTY LIMITED
PL 41	DBNGP (WA) TRANSMISSION PTY LIMITED
PL 42	APACHE EAST SPAR PTY LTD APACHE KERSAIL PTY LTD APACHE NORTHWEST PTY LTD APACHE OIL AUSTRALIA PTY LTD HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD SANTOS (BOL) PTY LTD
PL 43	APT PIPELINES (WA) PTY LIMITED* REGIONAL POWER CORPORATION
PL 44	APT PARMELIA PTY LTD
PL 45	APT PARMELIA PTY LTD
PL 46	APT PARMELIA PTY LTD
PL 47	DBNGP (WA) TRANSMISSION PTY LIMITED
PL 48	ENERGY GENERATION PTY LTD
PL 52	APT PARMELIA PTY LTD
PL 53	APT PARMELIA PTY LTD
PL 54	APT PIPELINES (WA) PTY LIMITED* REGIONAL POWER CORPORATION
PL 55	GLOBAL ADVANCED METALS WODGINA PTY LTD
PL 56	APA (WA) ONE PTY LIMITED
PL 57	AUSTRALIAN GOLD REAGENTS PTY LTD
PL 58	BHP BILLITON PETROLEUM (NORTH WEST SHELF) PTY LTD BP DEVELOPMENTS AUSTRALIA PTY LTD CHEVRON AUSTRALIA PTY LTD JAPAN AUSTRALIA LNG (MIMI) PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED WOODSIDE ENERGY LTD*
PL 59	ESPERANCE PIPELINE CO. PTY LIMITED
PL 60	EII GAS TRANSMISSION SERVICES WA (OPERATIONS) PTY LIMITED
PL 61	APT PARMELIA PTY LTD
PL 62	APACHE NORTHWEST PTY LTD* HARRIET (ONYX) PTY LTD KUFPEC AUSTRALIA PTY LTD
PL 63	EII GAS TRANSMISSION SERVICES WA (OPERATIONS) PTY LIMITED
PL 64	AWE PERTH PTY LTD ORIGIN ENERGY DEVELOPMENTS PTY LIMITED
PL 65	DALRYMPLE RESOURCES PTY LTD NORILSK NICKEL WILDARA PTY LTD
PL 67	HAMERSLEY IRON PTY LIMITED
PL 68	EII GAS TRANSMISSION SERVICES WA (OPERATIONS) PTY LIMITED
PL 69	DBNGP (WA) NOMINEES PTY LIMITED
PL 70	AWE (OFFSHORE PB) PTY LTD AWE OIL (WESTERN AUSTRALIA) PTY LTD ROC OIL (WA) PTY LIMITED
PL 72	EDL NGD (WA) PTY LTD

TABLE 5. LIST OF PETROLEUM AND GEOTHERMAL TITLES AND HOLDERS IN WESTERN AUSTRALIA – ONSHORE AND STATE WATERS AS AT 4 AUGUST 2014

PL 73	REDBACK PIPELINES PTY LTD
PL 74	EDL LNG (WA) PTY LTD
PL 75	EIT NEERABUP POWER PTY LTD ERM NEERABUP PTY LTD*
PL 76	SOUTHERN CROSS PIPELINES AUSTRALIA PTY LIMITED
PL 77	SINO IRON PTY LTD
PL 78	HAMERSLEY IRON PTY LIMITED
PL 80	ALCOA OF AUSTRALIA LIMITED LATENT PETROLEUM PTY LTD
PL 81	APACHE NORTHWEST PTY LTD
PL 82	APA (PILBARA PIPELINE) PTY LTD
PL 83	ATCO GAS AUSTRALIA PTY LTD
PL 84	CHEVRON (TAPL) PTY LTD* CHUBU ELECTRIC POWER GORGON PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED OSAKA GAS GORGON PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED TOKYO GAS GORGON PTY LTD
PL 85	CHEVRON (TAPL) PTY LTD* CHUBU ELECTRIC POWER GORGON PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED OSAKA GAS GORGON PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED TOKYO GAS GORGON PTY LTD
PL 86	APACHE NORTHWEST PTY LTD SANTOS OFFSHORE PTY LTD
PL 87	APACHE PVG PTY LTD BHP BILLITON PETROLEUM (AUSTRALIA) PTY LTD
PL 88	APACHE PVG PTY LTD BHP BILLITON PETROLEUM (AUSTRALIA) PTY LTD
PL 89	CROSSLANDS RESOURCES LTD
PL 90	APACHE PVG PTY LTD BHP BILLITON PETROLEUM (AUSTRALIA) PTY LTD
PL 91	DBNGP (WA) NOMINEES PTY LIMITED
PL 92	CHEVRON (TAPL) PTY LTD* CHUBU ELECTRIC POWER GORGON PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED OSAKA GAS AUSTRALIA PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED TOKYO GAS GORGON PTY LTD
PL 93	CHEVRON (TAPL) PTY LTD* CHUBU ELECTRIC POWER GORGON PTY LTD MOBIL AUSTRALIA RESOURCES COMPANY PTY LIMITED OSAKA GAS GORGON PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED TOKYO GAS GORGON PTY LTD
PL 94	DBNGP (WA) NOMINEES PTY LIMITED
PL 95	DBNGP (WA) NOMINEES PTY LIMITED
PL 96	EMPIRE OIL COMPANY (WA) LIMITED ERM GAS PTY LTD
PL 97	MITSUI IRON ORE DEVELOPMENT PTY LTD NIPPON STEEL & SUMIKIN RESOURCES AUSTRALIA PTY. LTD. NIPPON STEEL & SUMITOMO METAL AUSTRALIA PTY LTD RIO TINTO LIMITED
PL 98	ESPERANCE PIPELINE CO. PTY LIMITED
PL 99	APACHE JULIMAR PTY LTD CHEVRON (TAPL) PTY LTD* KUFPEC AUSTRALIA (JULIMAR) PTY LTD KYUSHU ELECTRIC WHEATSTONE PTY LTD SHELL DEVELOPMENT (AUSTRALIA) PROPRIETARY LIMITED
PL 100	DBNGP (WA) NOMINEES PTY LIMITED
PL 101	DBNGP (WA) NOMINEES PTY LIMITED
PL 102	SUB161 PTY. LTD.
PL 103	DBP DEVELOPMENT GROUP NOMINEES PTY LIMITED
PL 104	APA (PILBARA PIPELINE) PTY LTD
PL 105	DDG FORTESCUE RIVER PTY LTD TEC PILBARA PTY LTD
PL 106	MITSUI IRON ORE DEVELOPMENT PTY LTD NIPPON STEEL & SUMIKIN RESOURCES AUSTRALIA PTY. LTD. NIPPON STEEL & SUMITOMO METAL AUSTRALIA PTY LTD NORTH MINING LIMITED ROBE RIVER MINING CO PTY LTD*

Please consult DMP's online Petroleum and Geothermal Register for the most current information on Titles and Holdings.

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