

MAY 2013

PETROLEUM

IN WESTERN AUSTRALIA

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



Contents



Photos of the first shale oil recovered from a hydraulic fracture stimulation in Western Australia. The hydraulic fracture was carried out on Norwest's Arrowsmith 2 well, which was temporarily shut-in in September when the company discovered oil being produced to surface in the early stages of flowback while testing the Kockatea Shale. In the article by Norwest in the current issue, the company states that "the Kockatea Shale formation holds potential for a 200-metre thick section capable of producing shale oil/wet gas and extends over a large geographic area".

Department of Mines and Petroleum Petroleum Division

Mineral House, 100 Plain Street
East Perth, Western Australia 6004
Tel: +61 8 9222 3622
Fax: +61 8 9222 3799
www.dmp.wa.gov.au

Editor: Karina Jonasson

Email: karina.jonasson@dmp.wa.gov.au

Cover photo: Post hydraulic fracturing flow-back equipment at Arrowsmith 2. In the photo, oil and water comes from the flow tree through the choke manifold into the separator and then into the holding tank. From the holding tank, the underflow goes to the sump and the overflow goes to the oil gauge tank. Insets show oil recovered from the Kockatea Shale after stimulation (see above).

(Photos courtesy of Norwest Energy)

Disclaimer: The information contained in this publication is provided in good faith and believed to be reliable and accurate at the time of publication. However, the information is provided on the basis that a reader will be solely responsible for making their own assessment of the information and its veracity and usefulness.

The State shall in no way be liable, in negligence or howsoever, for any loss sustained or incurred by anyone relying on the information, even if such information is or turns out to be wrong, incomplete, out of date or misleading.

ARTICLES

- 03 Minister's Message
- 04 Executive Director's Message – Hurdles to Overcome to Develop Gas Supplies from Shale Gas and Tight Gas in Onshore Western Australia
- 06 Director's Message – US Gas Industry a Learning Opportunity for Western Australia
- 07 Review of Petroleum Exploration, Production and Development in Western Australia in 2012
- 11 Company Profile – Advent Energy
- 14 Significant Upside for Shale Gas in the Perth Basin
- 16 Awards of Exploration Permits
- 18 State Areas Released for Petroleum Exploration May 2013
- 20 The Petroleum and Geothermal Register (PGR) – New Native Title Module
- 21 Recent Changes to the Environmental Regulation of the Western Australian Petroleum Industry
- 23 The State of Geothermal in Western Australia
- 29 Implications of High Heat Flow and Temperatures for Geothermal Energy in the Southern Carnarvon Basin
- 34 See you at the WA Basins Symposium in August

TABLES

- 38 **Table 1.** 2012 Production by Field and Cumulative Production as at 31 December 2012
- 39 **Table 2a.** Petroleum Reserves Estimates by Basin as at 31 December 2011 (metric units)
- 39 **Table 2b.** Petroleum Reserves Estimates by Basin as at 31 December 2011 (field units)
- 40 **Table 3.** Petroleum Wells in Western Australia – Onshore and State Waters 2012
- 40 **Table 4.** 2012 Surveys in Western Australia – State Onshore, State Waters & Territorial Waters
- 41 **Table 5.** List of Petroleum and Geothermal Titles and Holders as at 3 January 2013
- 48 Trade and Investment Offices

Key Petroleum Contacts



Courtesy Buru Energy

WESTERN AUSTRALIA

Opportunities to Explore

BIDS INVITED FOR ACREAGE

PETROLEUM ACREAGE

Perth Basin

There is one release area in the onshore northern Perth Basin. Area size is 1277 km². This region is noted for its Permian and Jurassic oil and gas production, and significant infrastructure. The release area is broadly within the oil window and potential plays include fault-controlled, small folds and drape over basement highs.

Northern Carnarvon Basin

There are two release areas in the highly prospective offshore Northern Carnarvon Basin. The basin is Australia's leading producer of both liquid hydrocarbons and gas.

A combined release area is 370 km² in size. The other area is 878 km² in size. Targets may include Cretaceous, Jurassic and Triassic sandstones.

Southern Carnarvon Basin

There is one release area in the onshore Southern Carnarvon Basin. Area size is

1265 km². 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 two larger release areas (8095 km² and 9338 km²) in the Neoproterozoic central Officer Basin. 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.

**Bids close on:
Thursday 14 November 2013.**

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.

GEOHERMAL 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

Richard Bruce

Petroleum Division

Department of Mines and Petroleum

Telephone: +61 8 9222 3273

Email: richard.bruce@dmp.wa.gov.au

Web: www.dmp.wa.gov.au/acreage_release



Hon. Bill Marmion

Minister for Mines and Petroleum

Minister's Message

It is with great pleasure that I write my first Minister's Message for *Petroleum in Western Australia* as the newly appointed State Minister for Mines and Petroleum.

I am honoured to have been selected to lead a sector which makes such a significant contribution to the State's economy and energy security.

As former Minister for Environment and Water, I have played an active role in the petroleum industry — providing approvals for significant oil and gas projects including Chevron's Wheatstone LNG project and early work on the proposed Browse LNG project.

This experience has given me a comprehensive understanding of the opportunities and challenges facing Western Australia's petroleum industry.

To ensure the continued viability, growth and international competitiveness of WA's resources sector, the State Government is investing \$20 million towards resource development.

Of this investment, \$2 million will go towards promoting exploration for WA's resources, as well as WA's resources services sector, to overseas markets such as Japan and China — of which the State's LNG sector heavily depends upon.

Investing to secure new and existing international markets is crucial during a time when new innovations, such as the United States' shale gas industry, are revolutionising how the world produces and trades energy.

What sets Western Australia apart from other jurisdictions is the size of our State and huge resource potential, our strong work ethic, and robust and efficient regulatory system.

However, no matter how robust our regulations, the State will continue to feel the impact of national policy shifts that affect our petroleum sector. These changes have caused regulatory uncertainty among some investors, which is a challenge WA must work hard to overcome.

To encourage investment, the State Government has committed \$18 million to track approvals across government and develop a State Environmental Data Library.

Under the Resource Track project, \$10 million of this will be used to expand the Department of Mines and Petroleum's online lodgement and approvals tracking system, to include other approval agencies such as the Environmental Protection Authority, the new Department of Environmental Regulation and the Department of Water.

This will allow proponents to track the progress of their approvals, regardless of which government department is evaluating them.

Additionally, the new State Environmental Data Library will assist industry to access existing biodiversity, water and cultural heritage surveys.

The library will ensure cultural and environmental assessment processes associated with project approvals are more efficient and cost effective.

Through streamlining the approvals process, the State hopes to encourage further investment and exploration in the resources industry.

This goal is solidified by the State Government's commitment to continue the Exploration Incentive Scheme — a scheme which plays a key role in encouraging exploration for minerals and petroleum for the long-term future of the State's resources sector.

The scheme includes the co-funded exploration drilling program, which encourages the discovery of new resources including new oil and gas fields.

To date, the scheme has offered co-funding to seven oil and gas projects — encouraging the discovery of new petroleum fields, which is crucial as domestic gas demand continues to rise.

An emerging resource which could play a key role in meeting this demand is shale and tight gas.

As is often the case with a new industry, there is some community uncertainty about how the shale and tight gas industry could impact Western Australians.

Unfortunately, much of this uncertainty has grown from the public receiving conflicting information from different sources.

The State Government is committed to working with communities to understand their concerns and provide access to factual information about shale and tight gas, including the strict regulations that oil and gas companies must adhere to in order to get a project off the ground.

With so much attention often focused on the perceived impacts of shale gas development, it is easy to forget this emerging industry has the potential to secure WA's domestic energy needs for decades to come. It could also increase job opportunities and training for people living in regional areas, which is part of the State Government's commitment to improve the amount of local skilled workers employed in the resources industry.

I look forward to the exciting challenges that lie ahead as the new Minister for Mines and Petroleum.

**Bill Tinapple**Executive Director
Petroleum Division

Executive Director's Message – Hurdles to Overcome to Develop Gas Supplies from Shale Gas and Tight Gas in Onshore Western Australia

Western Australia is just beginning its journey to develop a shale and tight gas and oil industry. Of the 15 wells drilled targeting unconventional gas since 2005, hydraulic fracture stimulation has only occurred on seven of these. No production or horizontal wells have so far been drilled for unconventional targets. Although good indications have been achieved during exploration, no commercial proof of concept flows have occurred as yet.

Commitments to Explore

Perceptions of prospectivity drive bidding for acreage releases. Existing gas prices in WA are high enough to make shale gas and tight gas production viable. Estimates of gas resources are driving investors to acquiring acreage. The possibility of high liquids gas and shale and tight oil has further increased interest.

Exploration acreage is awarded on the basis of work program bidding. However, bidders have to be convinced that if discoveries are made, commercial development is feasible.

It appears that industry has decided that the WA onshore has sufficient prospectivity to come and explore. Farmouts and recent bidding rounds have indicated high levels of interest, with companies such as Hess, ConocoPhillips and, most recently, Gujarat NRE Oil Ltd entering into the fray.

Current existing work commitments, as shown in Figure 1, are sufficient to move the potential new industry to proof of concept. Over the next four years, there is an average commitment of 22 exploration wells, both in State waters and onshore, per year with expected expenditures of \$72 million per year. Later years will see additional wells and increased expenditure as commitments from upcoming bidding rounds are added to the total.

Availability of Equipment and Services

There is currently a lack of modern drilling rigs capable of deep, horizontal drilling, with only one rig in operation at the time of writing. However, new and renovated rigs are near to being ready to operate. There are no hydraulic fracturing spreads or other service units yet available without mobilisation from the east coast or overseas locations. There is a need for additional facilities, which often include basic infrastructure, such as pipelines, roads, and general services.

With the emergence of one new drilling company and the predicted arrival of a modern AC hydraulic rig later this year, DMP will in future find it hard to accept "force majeure" on the lack of equipment as a valid reason for deferring well commitments.

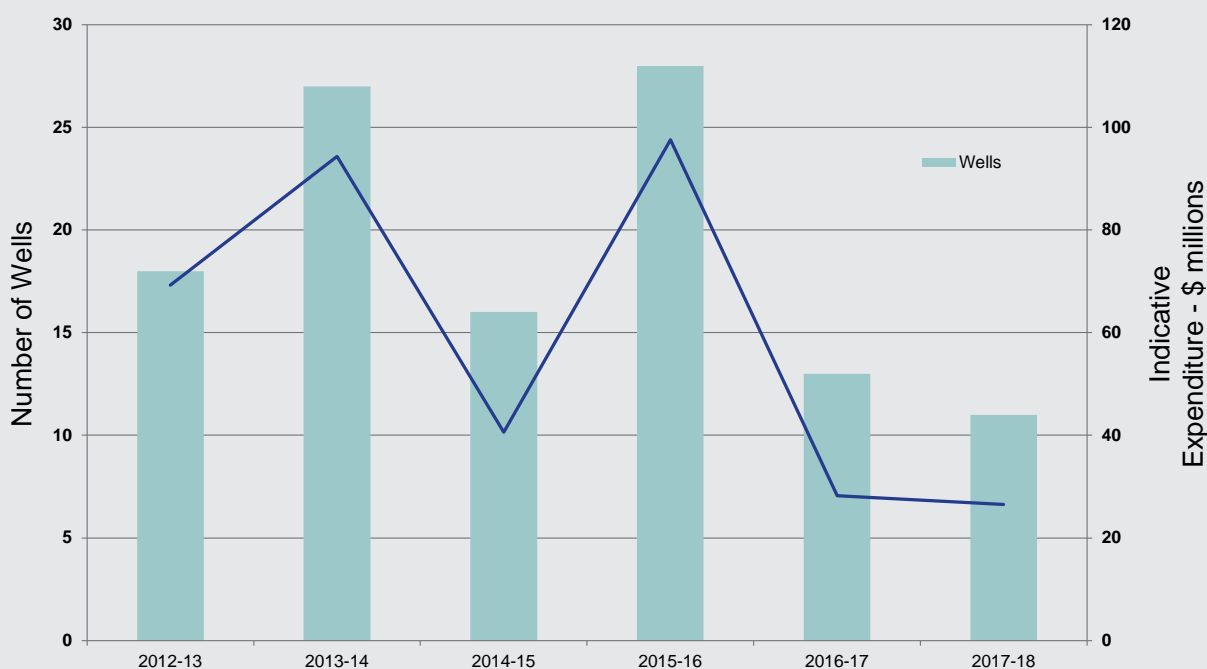


Figure 1 | Commitments to explore for petroleum in Western Australia

Hydraulic fracturing equipment at Arrowsmith 2 in the northern Perth Basin
(Photo courtesy of Norwest Energy)



Community Concerns

There are significant community concerns over hydraulic fracturing and the impact on water supplies, public health, air emissions, seismicity and long term integrity of wells and facilities. DMP, as lead agency for other government agencies, has had an independent review of the regulatory framework and is making continual improvements and providing more information to the public. For example the department's chemical disclosure policy is the most transparent of any jurisdiction in the world.

Approval Processes

Prior to operations, proponents of exploration and drilling activities must have approvals in place for management of risks and land access, including the following: Environment Plan, Safety Case, Work Program, and Access Agreement with landholders. Approvals are only given when proposed operations adhere to international best practice.

Establishment Time

In the US, unconventional gas and oil seems to be growing exponentially. However, even with high levels of supply of equipment, services and infrastructure, it took 25 years to reach the growth levels being seen currently. For example, the Barnett Shale in Texas was known to contain gas for many years prior to attempts to start producing the gas in 1981. It was not until 1995 when hydraulic fracturing technology was available that allowed production at commercial rates in unconventional vertical wells. Soon after this, horizontal drilling technology was applied to extend commercial viability. Now two per cent of the gas consumed in the US is produced from the Barnett Shale.

How soon will there be shale and tight gas and oil production in Western Australia? A reasonable sequence for development would be:

- Proof of concept flows in vertical wells
- Horizontal wells and multi-stage fracturing
- Proof of concept flows in horizontal wells
- Appraisal seismic, drilling, hydraulic fracture stimulation and testing to achieve certified reserves
- Gas marketing and contracting
- Construction of facilities, including pipelines
- Drilling of development wells

DMP has no applications for hydraulic fracture stimulation or horizontal drilling at the time of writing.

Although some extended well testing production could occur in two to three years, it seems reasonable to forecast, given the hurdles outlined above, that it could take eight to ten years to have substantial production.



Jeffrey Haworth

Director Technology,
Petroleum and Geothermal
Petroleum Division

Director's Message – US Gas Industry a Learning Opportunity for Western Australia

As a representative for Western Australia's emerging unconventional gas sector at the North American Prospect Expo (NAPE) in Houston Texas, I recently toured key shale gas sites in the United States with Jason Medd, Principal Policy Officer in the Petroleum Division.

We visited a number of West Texas sites including BHP Billiton and ConocoPhillips — where advanced drilling technologies and hydraulic fracturing is being used to safely and effectively extract shale gas.

Our tour also included visits to rig manufacturers, to inspect firsthand the modern AC hydraulic rigs needed to drill the deep horizontal wells for shale gas and Halliburton's research facility, where new fracturing fluids and cements are developed to improve fracturing efficiency and are environmentally friendly.

The visit was an invaluable opportunity to learn from a country so advanced in shale gas and oil production like the US, as WA's shale and tight gas industry is currently in the early exploration phase and these technologies will be adopted as the industry develops.

With WA's domestic gas supply anticipated to fall below demand by

as early as 2016, it is important we explore alternative gas solutions to ensure WA's energy security for future generations.

If exploration for shale gas proves successful, DMP is committed to ensuring the responsible and safe development of this emerging industry.

I also presented to the 18,000-strong crowd at the 2013 Winter North American Petroleum Expo in Houston, Texas (4-7 February 2013) and attended the Fifth Energy Conference in the same State.

The events allowed me to promote Western Australia's shale gas resources and gain an understanding of the experienced operators that are interested in investing in our petroleum industry.

I was also able to have some discussions with US manufacturers and service providers, to encourage investment.

The US is ranked second in the world for shale gas, with an estimated resource of 24,409 Gm³ (862 Tcf). Australia is ranked sixth in the world, with the majority of shale gas resources, totaling 8155 Gm³ (288 Tcf), found in Western Australia.



Rigs for sale at NOV yard in Houston Texas. More rigs here than in all of Australia

Review of Petroleum Exploration, Production and Development in Western Australia in 2012

Karina Jonasson

Petroleum Resource Geologist
Resources Branch



Nippling up the hydraulic fracturing tree
(Photo courtesy of Norwest Energy)

2012 Overview

In 2012, there were 12 wells drilled and 10 seismic surveys carried out in Western Australian State Waters and onshore. The greatest activity was in the Canning Basin where eight new field wildcats and one appraisal well were drilled. One well, Evandra 2, was drilled in the onshore Perth Basin by AWE Limited, and two development wells, Bambra 10H ST3 and Barrow G84B MB were spudded in the Carnarvon Basin, by Apache and Chevron respectively. The surveys comprised three 3D seismic surveys, two 2D seismic surveys, two geochemical and one each of gravity, aeromagnetic and electronic spin resonance surveys. Details of these activities can be found in the tables (3&4) at the back of this magazine.

Exploration Highlights

Buru Energy was busy this past year with new field wildcat drilling activity in two of its Canning Basin permits in their search for conventional and unconventional gas and oil; three wells were drilled in EP 371 (Valhalla North 1, Paradise 1 Deepening, and Asgard 1) and one well in EP 391 (Ungani North 1).

In January, the Valhalla North 1 well was drilled off structure from the Valhalla 2 well, which discovered wet gas in the Laurel Formation, in order to

confirm Buru's interpretation that the Valhalla area contains a substantial unconventional wet gas accumulation that may extend over a very large area. The Valhalla North 1 well encountered high levels of background gas over 1300 m of section of the Laurel Formation. The immediate Valhalla area could potentially contain 56.5 Gm³ (2 Tcf) recoverable gas plus tens of millions of barrels of associated liquids (petroleumnews.net, 9 March 2012). Buru enlisted the expertise of McDaniel's to assess the potential of the Valhalla accumulation, with the result an independent confirmation of a "multi-Tcf" [gross recoverable volume of 425 Gm³ (15 Tcf) of gas and 68.7 GL (432 MMbbl) of liquids (condensate and LPG) with a high side up to 934 Gm³ (33 Tcf)] wet gas accumulation reported (Buru, 2012 Annual Report).

Further testing of the theory of a "basin centred gas accumulation" was to be accomplished with the deepening of the Paradise 1 well located 21 km to the northeast of Valhalla 2, and drilling Asgard 1, 35 km to the east. (Paradise 1 was not drilled to total depth back in November 2010 due to the onset of wet season). Problems with high gas pressures and gas influxes were experienced at the Paradise 1 Deepening well which was suspended

for future testing. However, Buru believes the well confirms that the Valhalla accumulation extends a further 12 km to the west of the Valhalla wells.

Buru reported gas shows increasing with depth from the top of the Upper Laurel Clastics in Asgard 1, which was drilled to test the presence of the Laurel Formation and determine whether the Valhalla accumulation extended to the east and south of the Valhalla wells.

The primary target at Ungani North 1 was the *Ungani Dolomite*, which is the producing interval at the Ungani oilfield, which was discovered in 2011. An oil column of approximately 40 m was interpreted at the top of the dolomite reservoir section and there were excellent gas shows in the Nullara Limestone deeper down. The well will be tested in the future.

Buru also drilled an appraisal well on the Yulleroo field, with the Yulleroo 3 well targeting the Carboniferous Laurel Formation and secondary targets of Anderson and Upper Laurel Formation clastics. Buru confirmed the well had strong gas shows in over 1000 m of gas charged section. Yulleroo 3 was drilled to a total depth of 3578 m. Buru believes the Yulleroo field may also be part of a larger basin centred gas accumulation similar to Valhalla.

Key Petroleum operated the drilling of Cyrene 1 in EP 438, which spudded mid-December and was still drilling at the end of the year. The Cyrene 1 well has both conventional and unconventional oil targets. Partner Buru plan to comprehensively core the Goldwyer Shale in order to evaluate the formation for its unconventional oil potential.

New Standard Energy (NSE) with partner ConocoPhillips drilled the first two of three wells of its phase 1 program in the Canning Basin, targeting Goldwyer Formation shales with the Century Rig 14. Nicolay 1 was suspended in EP 456 after drilling in the latter half of 2012. NSE's second well, Gibb-Maitland 1 spudded in early December in EP 450. The well was still drilling at the end of 2012.

During September and October 2012, Advent Energy concluded the production testing of Waggon Creek 1 in EP 386 which had originally commenced in 2011, but was suspended as a result of the early onset of the wet season. Four zones were perforated in all over the interval of 378-595 mKB which has an interpreted net pay of 5.5 m to 7.8 m. Gas flows of up to 27,000 m³/d (0.96 MMscf/d) were recorded from the test.

Unconventional Operations

AWE Ltd and Norwest Energy Ltd carried out hydraulic fracture stimulation on three wells in the northern Perth Basin.

Norwest Energy's Arrowsmith 2 well was successfully stimulated in the second half of 2012. Both oil and gas were found to flow back naturally in the Kockatea Shale in this well after proof of concept fracture stimulation took place. Flowback and testing was completed in December 2012 from this well. Gas flows were also achieved from tight sands in the High Cliff Sandstone, from the Irwin River Coal Measures, and from the lower and middle Carynginia Formation shales. The plan is to commence flowback of the Carynginia Formation in February 2013 and a 3D seismic program is proposed. At Arrowsmith 2, 83 per cent of fluids used in the stimulation have already been recovered from the Kockatea Formation.

Two zones in AWE Ltd's Woodada Deep 1 well and one zone in Senecio 2 were also successfully hydraulically fractured and gas flows were recorded from all zones during clean-up in August 2012. The two zones stimulated in Woodada Deep 1 were in middle and upper Carynginia shales at 2370-2425 m and 2283-2314 m. Senecio 2 was stimulated at

2643-2685 m over the Wagina (Permian) and Dongara (Triassic) formations, both tight sandstone reservoirs. Senecio 2 achieved a stabilised flow rate of 38,227 m³/d (1.35 MMscf/d) with a total of 131,673 m³ (4.65 MMscf) of gas and approximately 10.3 kL (65 bbl) of crude oil/condensate produced during testing.

Buru's State Agreement

In November 2012, the Buru-Mitsubishi Joint Venture entered into a State Agreement with the Western Australian government which effectively allows Buru to retain and explore key acreage in the Canning Basin for a number of years in order to facilitate development of a domestic gas project.

The State Agreement specifically covers gas resources in permits EP 371, 391, 428, 431, and 436, which contain the Valhalla and Yulleroo gas accumulations. Provided the Joint Venture meets all of their exploration, appraisal and development obligations under the agreement, they will not be required to relinquish any of the acreage in these permits until 31 January 2024.

Under the State Agreement, the Department of State Development is the lead agency with the role of coordinating and facilitating gas developments in these permits.



Stimulation at Arrowsmith 2
(Photo courtesy of Norwest Energy)



Site preparation works at Ashburton North
(Photo courtesy of Chevron)

Production Highlights

In August, the first load of Buru Energy's Ungani crude was delivered to the BP refinery in Kwinana, south of Perth, after starting an extended production test at the oilfield in EP 391. The Ungani 1 ST1 well began producing at initial test rates of more than 300,000 litres of oil per day (1887 bbl/d) as an extended production test got underway mid-year.

Both Ungani 1 and 2 initially produced oil on clean-up, but while Ungani 1 continued to pump back drilling mud, Buru said that Ungani 2 was producing in excess of 85 per cent clean oil at the end of the year.

Buru reported flows up to 596 kL (3750 bbl) of oil per day from Ungani 1 and of 163 kL (1026 bbl) liquid/emulsion per day with a 55 per cent oil cut at Ungani 2. Ungani 2 has flowed liquid/emulsion at up to 226 kL/d (1425 bbl/d) on open choke. Cumulative production from the Ungani field in 2012 was 12,095 kL of oil and 4,461,000 m³ of gas.

Buru plans to build a 2400 kL/d (15,000 bbl/d) production facility and export terminal on Western Australia's northwest coast to develop the Ungani oilfield and has applied for a location over the Ungani field ahead of submitting an application for a

Production Licence. Buru has submitted their preliminary Field Development Plan to DMP for approval.

Production was increased from several fields in 2012 including Agincourt, Crest, Lee, Little Sandy, Mohave, Redback, Rose, Saladin, Simpson, South Plato and Yammaderry. The Rose field showed a significant increase over the 2011 production. There was no production from Mount Horner in 2012.

In December 2012 the operator Origin elected to shut in the Jingemia plant and expected to restart operations in February 2013, however at the time of writing, the field was still not back online.

Development Highlights

The third domestic gas hub in the State (after Karratha and Varanus Island), Apache's Devil Creek domestic gas plant, was officially opened in February 2012. The two-train plant has a gross capacity of 220 TJ of gas per day and will process gas from the offshore Reindeer field, 105 km off the coast of Karratha. Future gas supplies will include the Macedon project (BHP Billiton).

Construction of the Red Gully gas and condensate plant in EP 389 in the

Perth Basin by Empire Oil and Gas and its partners, ERM Gas and Wharf Resources, commenced in 2012 after gaining all necessary approvals from DMP. The processing facility, located near Gingin, will process gas and condensate from the Gingin West and Red Gully fields. Gingin West 1 flowed 212,376 m³ (7.5 MMcf) of gas and 59.6 kL (375 bbl) of condensate per day during testing, while Red Gully 1 flowed 339,802 m³ (12 MMcf) of gas and 132.2 kL (832 bbl) of condensate during testing and is connected to the Dampier to Bunbury natural gas pipeline. The plant was scheduled for commissioning in March 2013, but at the time of writing was still under construction.

Domestic gas from the Wheatstone Project will be processed onshore at the latest facility being built at Ashburton North, 12 km west of Onslow in the Pilbara region. During the year the focus was on building the accommodation camp to house more than 900 people working at the site and to improve the road access to the facility. The entire village will eventually house 5000 workers. Clearing has commenced for access roads. The LNG hub will have two LNG processing trains with a combined capacity of 8.9 million tonnes per annum (mtpa), a 5.6 Mm³/d

(200 MMcf/d) domestic gas plant and associated offshore infrastructure including a 225 km trunkline to connect the offshore platform to the onshore plant at Ashburton North. Start-up is anticipated in late 2016.

The Gorgon Project, located on Barrow Island, is now in its third year and is about 40 per cent complete. Gorgon LNG will be off loaded via a four km long loading jetty for transport to international markets. The domestic gas will be piped to the Western Australian mainland at a capacity of 7.79 Mm³/d (275 MMscf/d).

Some of the key milestone activities for the year include:

- The construction of the quarantine approved facility was completed;
- dredging for the LNG jetty and Materials Offloading Facility was completed;
- jetty foundation caissons have been installed;
- ten of 12 accommodation clusters were completed, and are now occupied by workers;
- two LNG storage tanks were completed, with internal tank structure construction to commence;
- construction of the LNG plant commenced with the arrival on the island of the first of 51 LNG modules needed to build the plant;
- work is almost complete on the installation of a 12.5 km pipeline that will deliver gas from the west coast of Barrow Island to the LNG processing plant and the domestic gas plant.
- The first of five gas turbine generators on Barrow Island was put in place in December. These will operate as a standalone power plant, generating the electricity required to power the LNG plant and associated facilities.
- Offshore, development drilling at Jansz-lo (10 wells) and Gorgon (eight wells) fields continued; subsea equipment, offshore pipeline and umbilicals were installed.
- On the mainland, construction of the domestic gas meter station's pipeline commenced which will connect into the Dampier to Bunbury natural gas pipeline.

Other News

New rig to WA

Ensign International mobilised the new-build ADR1500 (automated drill rig) Rig 963 from Houston to Perth in

mid-2012 for Chevron's Barrow Island drilling program. The automated drilling rig can drill to nearly 5500 m and has been specifically designed to minimise its environmental footprint on Barrow Island by allowing multiple wells to be drilled from a single location. The rig is drilling infill oil development wells on Barrow Island before commencing drilling activities for the Gorgon CO₂ injection project in 2013.

Abandonment Proceedings

Apache began work in December to plug and abandon the Campbell production wells and this work will continue into 2013. The Campbell gasfield was first discovered in 1979 by West Australian Petroleum Pty Ltd, but the Campbell 1 well, which intersected a 7 m gross hydrocarbon column, was not tested. Campbell 2 was drilled in 1986 and encountered 21 m of net gas pay and 1.5 m of net oil pay. Campbell 2 came on production in 1992. The fifth Campbell well became the second producing well on the field, with a total of seven wells drilled to appraise the field. The field is located in Production Licence TL/5 in the Barrow Sub-basin, approximately 31 km northeast of Varanus Island, and produced a total of 2,400,700 km³ (84.7 Bcf) gas and 297,085 kL (1.9 MMbbl) of condensate before being shut-in in August 2004.



The Ensign Rig 963 on location at the Barrow G48B MB development well on Barrow Island
(Photo courtesy of Chevron)

Company Profile – Advent Energy

Gas flowing during production testing at Advent's Waggon Creek 1 well in EP 386
(Photo courtesy of Advent Energy)



Advent Energy's Bonaparte Basin gas project joins the Australian shale gas revolution

Unlisted oil and gas company Advent Energy is increasingly positive about its strategy to develop its unconventional shale and conventional gas assets in the Bonaparte Basin.

The Bonaparte Basin is a proven producing petroleum basin which previously had been estimated to contain 19 per cent and 17 per cent of Australia's conventional liquids and gas, respectively. Production to date has all been from the offshore.

The basin extends from the Timor Sea through to onshore northern Australia.

Immediately within the southern onshore extension of the basin, which covers adjacent areas of the Western Australian and Northern Territory border, is the Ord-East Kimberley Expansion Project (Figure 1), on which the Australian and Western Australian Governments are spending over \$500 million to develop road works and infrastructure.

This infrastructure development for Advent was the first of three key contributors to making Advent's project a game changer. The second was the changed price for gas in Western Australia, and the third and critical development was the results from Advent's study of 17 wells drilled in the onshore Bonaparte area to determine the potential for a shale gas project.

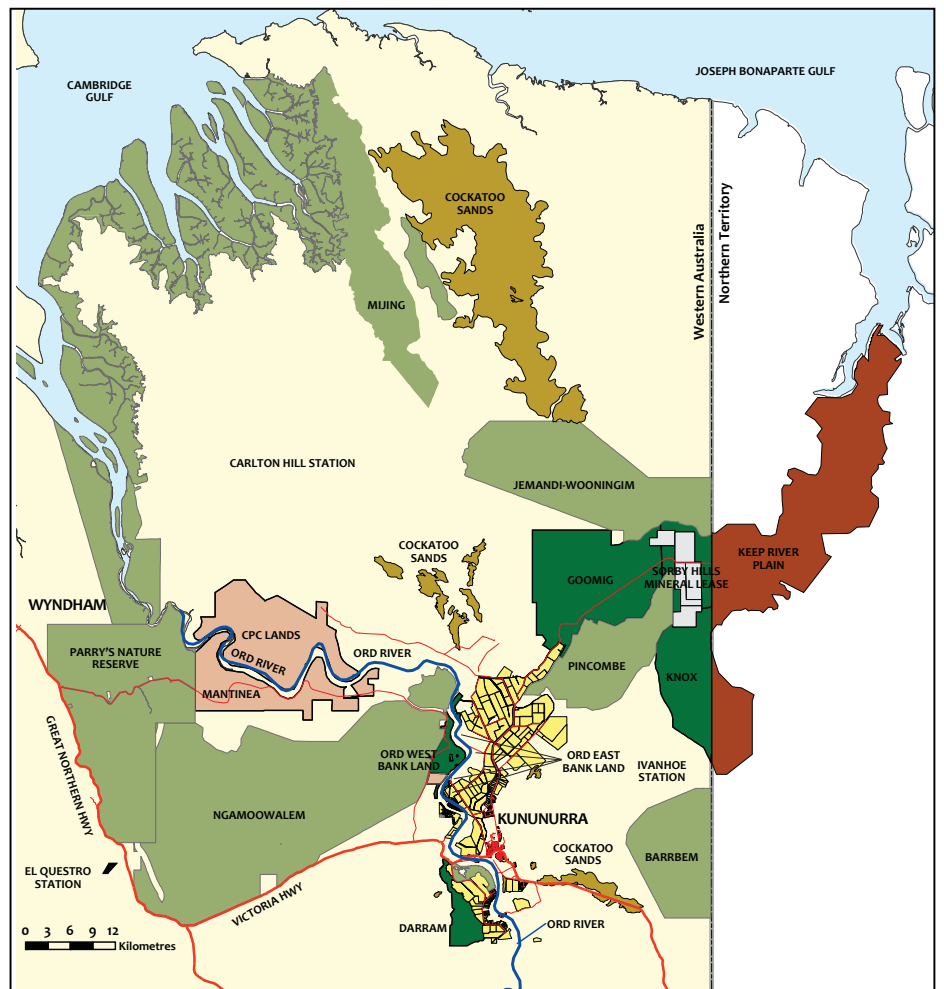


Figure 1 | Location map of the Ord River region in the East Kimberley where over \$500 million is being spent on roads and infrastructure, which can only benefit petroleum projects in the vicinity

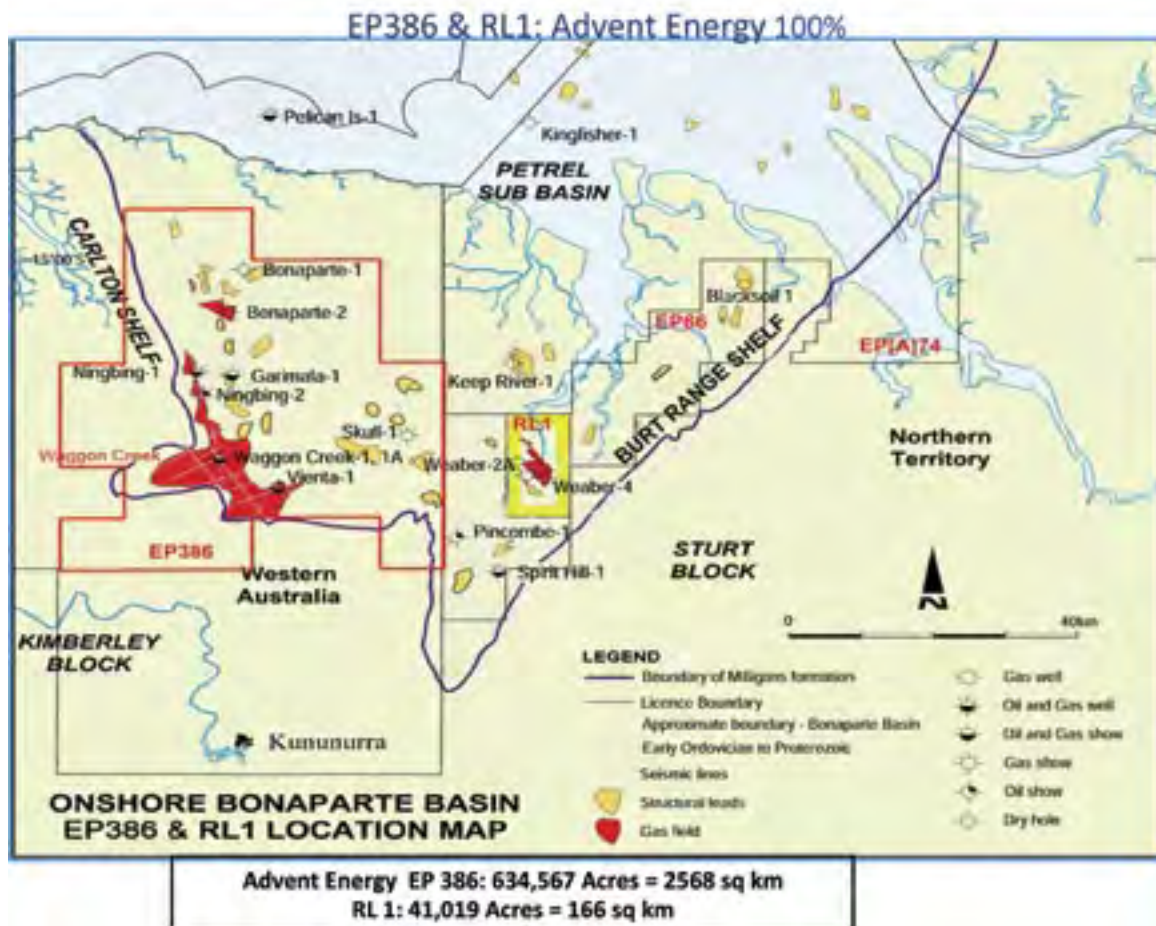


Figure 2 | Location map of Advent's permits — EP 386 (in WA) and RL1 (in NT)

The results of the study released by Advent indicate significant potential upside in prospective shale gas resources, with estimated unrisks original gas in place (OGIP) in the range from 538 Gm³ (19 Tcf) to 3993 Gm³ (141 Tcf) for the 100 per cent Advent owned EP 386 and RL1 (Figure 2). The thickness of the prospective shale gas play varies from 300 m to over 1500 m. Advent has now calculated a risked recoverable prospective shale gas resource estimate of 272 Gm³ (9.6 Tcf) for its Bonaparte permits.

Advent, the major shareholder of which is MEC Resources Ltd (ASX: MMR), has 100 per cent interests in EP 386 and RL1 which cover 2568 km² and 166 km², respectively, in the onshore Bonaparte Basin.

A Geoscience Australia report on the Bonaparte Basin noted the source pod for hydrocarbons as being in the Carlton Sub-basin in the onshore portion of the southern Bonaparte. Analysis of this study by Advent has indicated that the 'postulated higher quality source rocks' contained within

the Carlton Sub-basin lies substantially within Advent's permits. Advent is also collaborating with Geoscience Australia in geochemical analysis of Advent's hydrocarbons produced to surface.

A previous study by the USGS again showed the "pod of active source rocks boundary" largely covers the Advent onshore permit areas. In that study the USGS gave their estimate for the hydrocarbons in the onshore Bonaparte as an undiscovered conventional resource of 13 Gm³ (460 Bcf) of gas and 8.9 GL (56 MMBbl) of oil. This study was released in 2000, prior to the commencement of the United States shale gas production revolution.

Advent executive director David Breeze has stated that what attracted the company most to the acreage was the extremely good technical success rate in the drilling that has occurred to date.

"The Weaber field alone has been reported by Geoscience Australia as having a potential of 706 Mm³ (4.3 MBOE in conventional figures). Virtually every well that has been drilled in the permit areas has demonstrated

gas and even some oil shows have been recorded. Gas flows of up to 121.7 m³/d (4.3 Mscf/d) have been recorded."

Beach Energy Ltd (ASX: BPT) has further reported on the Bonaparte Basin and its shale gas prospectivity. Beach's focus from 2007 has been to find the best shale acreage in Australia, with particular attention given to 'underexplored and highly prospective' areas and 'unconventional areas with infrastructure close to markets'.

Beach has identified key technical contributors to success in shale areas, with shale thickness as a key. The Bonaparte Basin has shale thicknesses of over 1000 m, and Beach is just conducting an Airborne Gravity and Magnetic survey over a large area of the onshore Bonaparte, including over a large area held by Advent. The survey will generate data over RL1, a portion of EP 386 and an intervening space, and an agreement has been entered into for sharing this data.

David Breeze is in no doubt as to the prospectivity of the assets.

“As Beach Energy has noted, the area is highly prospective. What is noted by Beach as one of the key technical contributors is the thickness of the shales along with other characteristics. The Bonaparte has very thick marine shales with thicknesses of between 300 m to over 1500 m, which compare very favourably to the US shale thicknesses”, Mr Breeze said.

“Taking all the characteristics of these shales into account, Advent has calculated a potential unrisksed unconventional gas in place (GIP) for Advent’s EP 386 and RL1 areas’ resource estimate of between 538 Gm³ to 3993 Gm³ (19 Tcf to 141 Tcf) in the Milligans Formation shales, with additional potential in deeper prospective shales.

“The immediate benefit, however, is in the proved conventional gas reservoirs which Advent can now look to put into production as a result of the Government spending nearly \$500 million on road works and infrastructure for the phase two of Ord scheme, which brings the new highway to within 15-20 km of our proven gas wells in EP 386.”

Advent’s conventional gas assets within EP 386 and RL1 include the Weaber

gasfield and the Waggon Creek and Vienta gas discoveries. There have been six conventional gas discovery wells drilled in EP 386 and RL1.

The three main discoveries made in EP 386 so far are Vienta, Waggon Creek and Bonaparte, along with Weaber in RL1 in the Northern Territory. Other wells drilled have been technical successes for both gas and oil. During the testing of wells in EP 386 and RL1, gas flows of up to 127 Mm³/d (4.5 MMscf/d) have been recorded. Advent recently announced an independently assessed contingent resource for the Weaber field of 1.27 Gm³ (45 Bcf) (3C).

First production in Advent’s 100 per cent owned areas is expected to come from the proven conventional areas onshore Bonaparte Basin as a result of the Ord scheme development and a number of mining projects.

Advent recently released the results of an independent market study showing the Waggon Creek and Vienta gas discoveries are the subject of current appraisal activities for the anticipated commercialisation and supply of natural gas to the local market with possible sales of up to 12 TJ/d from a mini LNG facility.

The local market includes the town sites of Kununurra and Wyndham, currently powered by hydroelectricity and diesel. Resources projects such as the proposed Sorby Hills Pb/Zn/Ag mine, the Argyle diamond mine and numerous other minerals projects are within trucking distance for compressed natural gas (or LNG) from Advent’s EP 386 and RL1 conventional gas accumulations.

Should everything go as planned, the path to gas production should be clear.

“The new highway means that we can now evaluate using compressed natural gas equipment or small scale LNG equipment to supply gas from the proven conventional gas areas within our permits to customers who are currently using diesel as an energy source and where there is no clear energy supply alternative”, Mr Breeze said.

“The gas price in Western Australia in remote areas is as high as \$16 per GJ, but even if you make your calculations using this figure the reality is these users pay up to \$26 per GJ for diesel on an energy equivalent basis, so natural gas obviously offers a cost saving as well as being a cleaner energy alternative.”



Production testing at Waggon Creek 1 in the Bonaparte Basin produced flow rates of up to 26,370 m³ (0.96 MMscf) per day without any formation water production
(Photo courtesy of Advent Energy)

Significant Upside for Shale Gas in the Perth Basin

Norwest Energy

Western Australia's energy market could be on the cusp of a major transformation if unconventional shale gas and tight gas discoveries in the onshore Perth Basin prove commercial.

Just as the US shale gas boom has changed the face of its energy sector, so too can WA look forward to a major shift in the way we go about our energy business if progress in the Perth Basin continues to reap rewards.

According to recent APPEA figures, WA's energy demand is expected to increase over the next 20 years by almost 100 per cent, which highlights the need to explore and develop new energy sources such as onshore shale oil and gas.

While the shale petroleum industry is still in its infancy, substantial resources and growing demand have allowed potential onshore gas producers to forge ahead with their exploration and development plans.

The only successful test to date of the shale petroleum concept in Western Australia has been from the Kockatea Formation at Norwest Energy's proof-of-concept Arrowsmith 2 well (testing four separate formations), located within EP 413, 50 km south of Dongara and about 300 km north of Perth.

The 450-metre thick formation had originally been marked by Norwest as a secondary target in its exploration program but became a priority focus when early gas and oil flowed to surface in mid-2012.

Arrowsmith 2 is located in the same field as Arrowsmith 1 (400 m away) which naturally produced gas from the Carynginia Formation in the 1960s at rates as high as 113,000 m³/d (4 million standard cubic feet per day (scf/d)).

Today, the well is the subject of a joint venture between AWE Limited (44.25 per cent), India's Bharat PetroResources (27.80 per cent) and Norwest (27.95 per cent, operator).

The permit is the focal point of Norwest's shale gas exploration strategy, and is a good candidate to become WA's first shale gas producing province given current high gas prices, the basin's developed infrastructure and its proximity to major markets.

Under the EP 413 joint venture, Arrowsmith 2 first flowed gas from the High Cliff Sandstone Formation at a maximum rate of 22,000 m³/d (777,000 scf/d) in July 2012.

The well was temporarily shut-in in September when the company

discovered oil being produced to surface in the early stages of flowback and testing of the Kockatea Shale, and shut-in again in December for pressure build-up monitoring works.



Flowback after stimulation, Arrowsmith 2
(Photo courtesy of Norwest Energy)



Coiled tubing on top of the wellhead
(Photo courtesy of Norwest Energy)

The Kockatea Shale Formation holds potential for a 200-metre thick section capable of producing shale oil/wet gas and extends over a large geographic area, which could have significant upside for Norwest and WA's gas market if the discovery proves economic.

A schedule of activities including continued well testing and flowback will complete the proof-of-concept program.

Certainly there is a clear indication from operations to date that as more fluid used in the hydraulic stimulation is recovered from each interval, gas rates significantly improve, and after a period of pressure-build up in the well, both fluid recovery and gas rates increase.

In the initial period of flowback for example, a gas flow rate of 3400 m³/d (120,000 scf/d) was recorded. However, after 49 days of pressure build-up testing on this interval, that rate increased to 11,700 m³/d (414,000 scf/d), with an average rate of 5700 m³/d (200,000 scf/d).

Following on from the success in the Kockatea Shale interval, Norwest commenced flowback and testing in early 2013 of the primary shale gas target, the Carynginia Formation.

Early results showcasing a maximum gas rate of 9900 m³/d (350,000 scf/d) have been recorded on several occasions since the well started flowback in mid-February, with higher rates anticipated in the future.

The Carynginia had a limited period of flowback during the 2012 hydraulic fracture stimulation program due to tight operational timelines, which resulted in a significant percentage of the injected fluid remaining on the formation.

Despite this, the zone demonstrated a strong early gas rate which Norwest believes to be an encouraging sign of what is in store.

The Carynginia Formation is considered a primary target in the Arrowsmith 2 well as it is the most typical shale formation in the northern Perth Basin,

is demonstrated to be laterally extensive, and is 250 metres thick in the vicinity of the well.

Together, the Carynginia and Kockatea Shale formations are estimated by the US Energy Information Administration to hold around 1671 Gm³ (59 trillion cubic feet – Tcf) of recoverable natural gas — equating to an extremely large gas-in-place resource of 6145 Gm³ (217 Tcf) in the northern Perth Basin.

If the remaining two formations to be tested at Arrowsmith 2 – the High Cliff Sandstone and Irwin River Coal Measures – prove commercial, this estimation could increase significantly.

Combined with the EIA's estimate of a further 6485 Gm³ (229 Tcf) for the Canning Basin, these numbers represent more than twice the amount of gas known from offshore WA — indicating that both basins are rich, active hydrocarbon provinces capable of generating enough energy to meet Perth's needs for the next 3000 years.



Arrowsmith 2
(Photo courtesy of Norwest Energy)

Awards of Exploration Permits

Richard Bruce
Exploration Geologist
Resources Branch

State Award of Petroleum Exploration Permits

To the end of January 2013, Petroleum Exploration Permits awarded in State areas were as follows:

In August 2012, EP 481 in the Southern Carnarvon Basin was awarded to New Standard Onshore Proprietary Limited. The firm two-year period program consists of geotechnical studies and 400 km 2D seismic reprocessing to an estimated value of \$150,000. The remaining program consists of two exploration wells, geotechnical studies and an 80 km 2D seismic survey to an estimated value of \$5,500,000.

In August 2012, EP 482 in the Southern Carnarvon Basin was awarded to New Standard Onshore Proprietary Limited. The firm two-year period program consists of geotechnical studies and 400 km 2D seismic reprocessing to an estimated value of \$150,000. The remaining program consists of two exploration wells, geotechnical studies and an 80 km 2D seismic survey to an estimated value of \$5,500,000.

In January 2013, EP 483 in the offshore Northern Carnarvon Basin was awarded to Finder No. 3 Proprietary Limited. The firm two-year period program consists of 1500 km 2D seismic reprocessing and a 115 km²

3D seismic survey. The remaining program consists of geotechnical studies and an exploration well to an estimated value of \$6,550,000.

In January 2013, EP 484 in the Perth and Southern Carnarvon basins was awarded to Dynasty Metals Australia Limited. The firm two-year period program consists of two stratigraphic wells and 60 km of 2D seismic acquisition to an estimated value of \$660,000. The remaining program consists of five stratigraphic wells, geotechnical studies and 120 km of 2D seismic acquisition to an estimated value of \$1,585,000.

In January 2013, EP 485 in the Perth and Southern Carnarvon basins was awarded to Dynasty Metals Australia Limited. The firm two-year period program consists of two stratigraphic wells and 65 km of 2D seismic acquisition to an estimated value of \$710,000. The remaining program consists of five stratigraphic wells, geotechnical studies and 120 km of 2D seismic acquisition to an estimated value of \$1,585,000.

Commonwealth Award of Petroleum Exploration Permits

These new permits result from the second round of the 2011 Acreage Release that closed on Thursday 12 April 2012.

Near Moogooree WA in the Southern Carnarvon Basin, about 880 km north of Perth
(Photo courtesy of Arthur Mory, GSWA)



Commonwealth award information was sourced from the website of Australia's Department of Resources, Energy and Tourism.

WA-477-P (released as W11-2) north-northwest of Broome, offshore Western Australia mainly within the Scott Plateau has been awarded to Shell Development (Australia) Pty Ltd. The company proposed a guaranteed work program of 2560 km² 3D seismic acquisition and processing; 500 km² 3D seismic reprocessing; 1000 km² 3D pre-stack depth migration processing; 200 km² high definition shallow hazard survey reprocessing; one exploration well; and geological and geophysical studies to an estimated value of \$58.4 million. The secondary work program consists of 1000 km² 3D pre-stack depth migration processing, geotechnical studies, and one exploration well to an estimated value of \$39.8 million. There was one other bid for this area.

WA-479-P (released as W11-4) north-northeast of Port Hedland offshore Western Australia has been awarded to Pathfinder Energy Pty Ltd. The company proposed a guaranteed work program of geological and geophysical studies, and 460 km² 3D seismic survey and processing to an estimated value of \$8.45 million. The secondary work program consists of geological and geophysical studies, and one exploration well to an estimated

value of \$25.4 million. There were no other bids for this area.

WA-480-P (released as W11-8) north of Dampier, Western Australia, across the northeastern parts of the Exmouth Plateau and the Beagle Sub-basin, has been awarded to Repsol Exploration, SA. The company proposed a guaranteed work program of geotechnical studies and 2000 km² of 3D seismic surveying, processing and interpretation; 1800 km of 2D seismic survey, processing and interpretation; and geological and geophysical studies to an estimated value of \$27.55 million. The secondary work program consists of geological and geophysical studies; one exploration well; and acquisition and processing of 500 km² 3D seismic survey to an estimated value of \$110.36 million. There were two other bids for this area.

WA-482-P (released as W11-9) extending across the northeastern Exmouth Plateau and the Beagle Sub-basin (outer Northern Carnarvon Basin) has been awarded to Liberty Petroleum Corporation. The company proposed a guaranteed work program of 2010 km² 3D seismic acquisition and processing; licensing 3800 km² of reprocessed 3D seismic data; 5000 km of reprocessed 2D seismic data; and an exploration well to an estimated value of \$96.5 million. The secondary work program consists of one exploration well, and geological and geophysical studies to an estimated

value of \$80.5 million. There were four other bids for this area.

WA-478-P (released as W11-14) off the coast of Western Australia on the Exmouth Plateau within the Northern Carnarvon Basin has been awarded to Woodside Energy Ltd and Japan Australia LNG (MIMI) Pty Ltd. The companies have proposed a guaranteed work program of 810 km² 3D seismic survey; purchase and reprocessing of 810 km² Aragon 3D seismic data; and geotechnical studies to an estimated value of \$13.48 million. The secondary work program consists of geotechnical studies and one exploration well to an estimated value of \$36.8 million. There was one other bid for this area.

WA-481-P (released as W11-18) over the offshore northern Perth Basin, offshore Western Australia has been awarded to Murphy Australia Oil Pty Ltd, Kufpec Australia Pty Ltd, and Samsung Oil & Gas Australia Pty Ltd. The companies have proposed a guaranteed work program of 4738 km² 2D seismic reprocessing; 550 km² 2D seismic survey; 2550 km² 3D seismic survey; seismic interpretation; three exploration wells; and geotechnical studies to an estimated value of \$70.76 million. The secondary work program consists of geotechnical studies and two exploration wells to an estimated value of \$36.5 million. There were three other bids for this area.



State Areas Released for Petroleum Exploration May 2013

Richard Bruce

Exploration Geologist
Resources Branch



Exploration drilling in the Officer Basin (GWSA well Lancer 1)
(Photo courtesy of Mark K Stevens)

DMP continues to promote the petroleum potential of Western Australia's vast sedimentary basins using a specific area release system in our State Waters and onshore 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 May 2013, DMP released a total of six blocks (Fig. 1). This release comprised two blocks in the offshore Northern Carnarvon Basin, one block in the onshore Southern Carnarvon Basin, two blocks in the Officer Basin, and one block in the onshore northern Perth Basin.

The 872 km² block, L12-1, is located in the Barrow Sub-basin and offshore Peedamullah Shelf of the highly productive offshore Northern Carnarvon Basin. The primary reservoir objective is the Early Cretaceous Birdrong Sandstone, as well as reservoirs within the Permian and Triassic successions of the offshore Peedamullah Shelf.

The combined T13-1/L13-1 block is 370 km² in size and lies in the Barrow Sub-basin, southwest of the giant Barrow Island oilfield. The regional structural trend of Barrow Island passes through T13-1, along which several oil and gasfields have been discovered.

Release area L13-2 is 1265 km² 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.

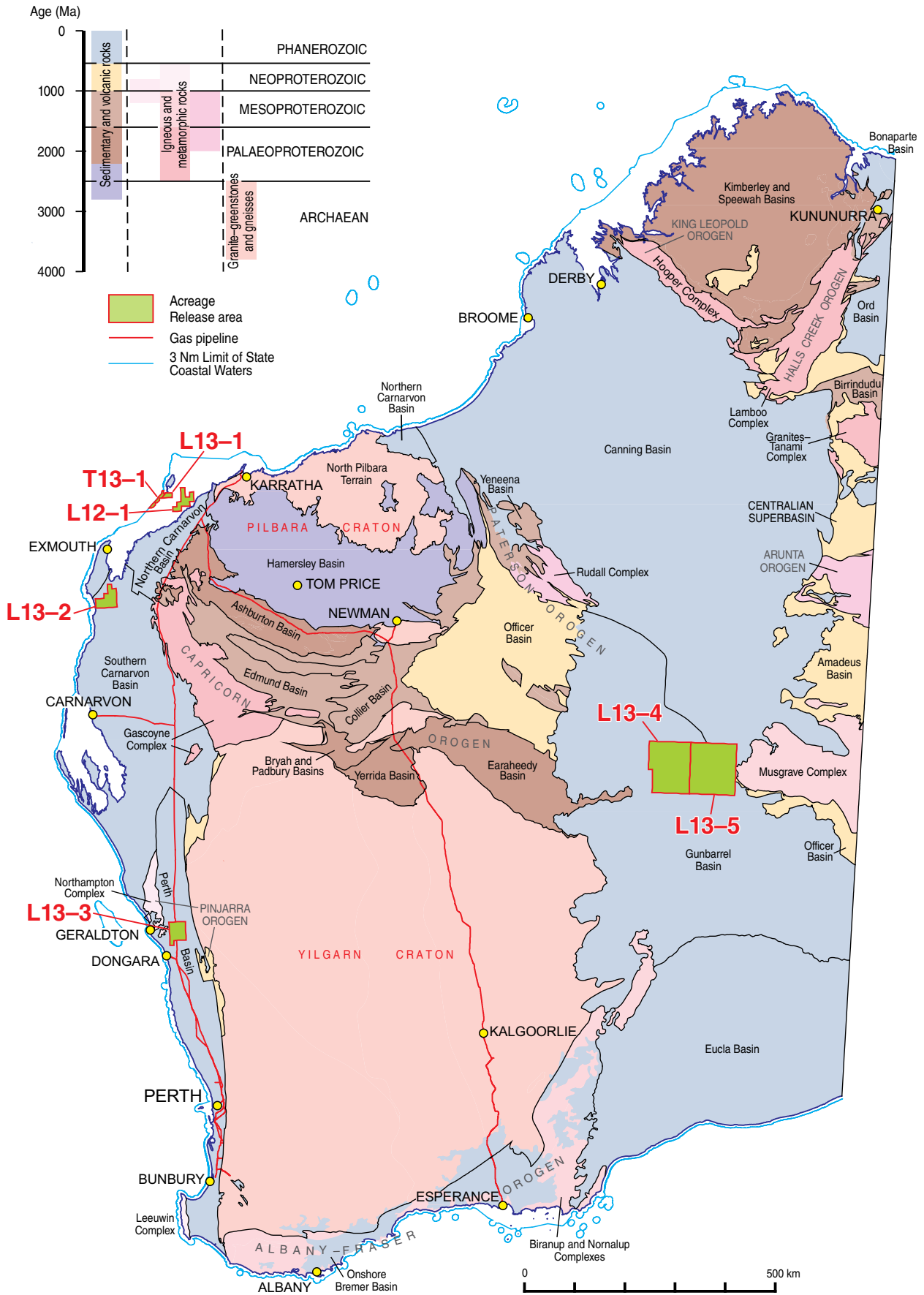
In the Officer Basin release areas L13-4 and L13-5 are respectively 8095 km² and 9338 km² in size. From a global perspective, the Officer Basin resembles Neoproterozoic successions in Oman and Russia that contain commercial hydrocarbon resources. It appears that all the elements of a petroleum system 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 (such as shale gas and oil, or tight sand reservoirs) present.

There is one release area, 1277 km² in size, located in the onshore northern Perth Basin. The region has a thick Lower Triassic source and seal interval, as well as likely source intervals in the Lower Jurassic. Possible plays include fault-controlled, small folds and drape over basement highs. A sealed highway connects to the State capital Perth and the Kwinana oil refinery, and there are significant domestic and industrial markets for gas in the region.

Work program bids for the release areas close at 4pm on Thursday 14 November 2013.

Should you require any further information or assistance, please contact Richard Bruce (08 9222 3314) of DMP's Petroleum Division or Ted Bowen (08 9222 3124) of the Geological Survey of Western Australia. All enquiries will be dealt with in strictest confidence.



RB73

12.02.13

Figure 1 | May 2013 State petroleum release areas

The Petroleum and Geothermal Register (PGR) — New Native Title Module

Hazel Harnwell

Manager Project Coordination and Information Management
Business Development Branch



The PGR Native Title Development Team

In December 2012 PGR released its latest module for management of Native Title cases.

The Native Title module provides internal functionality that allows the business area in Petroleum Division to record and manage Native Title matters relating to State acreage releases and the assessment of an application for a title. Case officers can now store information and manage individual cases within PGR as well as use the data for internal reporting purposes.

The main features of this release are:

- Replacement of an Excel spreadsheet previously used to record and track Native Title cases;
- Ability for Petroleum Division's Land Access staff to easily record, track and monitor each stage of the Native Title process;
- Ability for other Petroleum Division staff to easily view the status of an application and its current progress within the Native Title process;
- Improved processes for referring an application to Land Access staff;
- Improved processes for sending notification to Senior Titles Officers on completion of the Native Title process;
- Mapping functionality to easily identify Determined Areas, Claimed Areas, Representative Bodies, Heritage Sites and Part III Reserves that overlap an application area; and

- Integrated workflows that:
 - Identify Tasks as Key Events
 - Specify Due Dates for Tasks
 - Setup Reminders for when a Task is due for completion

The PGR Native Title Module shares data from the Department's eMiTS and Tengraph systems in relation to Determined Holders, Claimant Groups and Representative Bodies. This ensures that information obtained from the National Native Title Tribunal (NNTT) is not duplicated within the Department.

Other significant recent additions to PGR are:

- Bidding module for online submission of acreage release bids;
- Online lodgement of Exploration Permit or Drilling Reservation applications against Special Prospecting Authorities with Acreage Option;
- Online submission of Field Development Plans (FDP), which allows a FDP to be submitted for comment prior to formal lodgement; and
- Location Management module which has provided industry with the ability to lodge applications online for:
 - Declaration of Location
 - Extension of Location
 - Variation of Location
 - Revocation of Location

Currently under development is a Drilling Management module that will track the complete life cycle of a well via lodgement and processing of

applications for: completion; intervention; suspension; variation; testing; and abandonment.

The data will link to a related title and previously approved Application to Drill. This development is in preparation for the new *Resource Management and Administration Regulations* and will ensure internal users consistently assess, approve and monitor well activities. It will also provide an internal reporting function. It will be the first time that technical data for a drilling activity will be captured and stored in one central location.

PGR went online for the first time in February 2008 with the focus of providing information and services to both industry and the public. Over the last two years the focus has been expanded to include replacing functionality handled by the Electronic Petroleum Register (EPR) system that is more than 14 years old. The remaining EPR modules are scheduled for full migration into PGR by June 2013 at which time EPR will be decommissioned.

Bill Tinapple, Executive Director Petroleum Division, said that the new Native Title module was yet another significant step in the development of PGR. "Once again PGR has expanded to accommodate other business activities within Petroleum Division. It further demonstrates the division's commitment to the transparency of all its processes and streamlining of procedures. It's another job well done by Petroleum Division and Information Services Branch staff," Bill said.

Recent Changes to the Environmental Regulation of the Western Australian Petroleum Industry

Trent Richards
Environmental Officer
Petroleum Environment Branch



Production platforms in WA State Waters
(Photo courtesy of Apache Energy)

The Petroleum Environment Regulations 2012 (the Regulations)

- *Petroleum and Geothermal Energy Resources (Environment) Regulations 2012*
- *Petroleum (Submerged Lands) (Environment) Regulations 2012*
- *Petroleum Pipelines (Environment) Regulations 2012*

Available from the State Law Publisher website: www.slp.wa.gov.au



DMP environmental officers at the Mt Horner oilfield, Perth Basin

On 29 August 2012, three new sets of regulations were gazetted by the Government of Western Australia (WA).

The Regulations represent a milestone in the environmental regulation of the WA petroleum industry, by legislating key aspects of environmental management.

Consequently it is now a regulatory requirement for all current and proposed petroleum activities in Western Australia to have an approved Environment Plan (EP).

Existing operators in WA will already be familiar with the Environment Plan (EP) regime, and former Environmental Management Plan (EMP) requirements.

The EP regime was developed by the Commonwealth Department of Resources, Energy and Tourism (DRET) in conjunction with the Department of Mines and Petroleum (DMP), and has now been adapted for consistent application to petroleum activities in State jurisdiction.

The Department of Mines and Petroleum (DMP) has found the EP regime to be an effective and holistic framework for objective-based and risk-based environmental management. It achieves this by enabling uptake of management practices (standard practice through to world's best practice) to be incorporated into petroleum activities, typically without the need for prescription.

The EP regime achieves this by allowing flexibility to the operator, to decide on the suite of environmental management practices to best deliver acceptable, desired performance outcomes.

Adoption and implementation of acceptable or best practice environmental management is also beneficial to project approvals, so far as minimising the need for condition-based approvals. Excessive conditions may detract from adaptive management, and the principles of continuous improvement such as reducing impacts to As Low As Reasonably Practicable (ALARP).

The Regulations outline DMP's expectations for petroleum activities, including:

- the application of the principles of Ecologically Sustainable Development (ESD);
- continuous improvement processes to reduce impacts to ALARP;
- undertaking adequate stakeholder consultation; and
- transparency by making a public summary of an approved EP publicly available.

It is of utmost importance that all WA petroleum operators note that the Regulations are applicable to all petroleum activities, including those approved prior to 29 August 2012 and which are ongoing.

For these activities, operators will need to submit a revised EP, modifying their existing EMP where appropriate to meet the new regulatory requirements.

To allow for the above revision process to occur, the Regulations provide for

transitional arrangements – a 12 month period ending 29 August 2013 – during which all in-force EMPs approved before 29 August 2012 must be revised to meet the requirements of an EP. Any ongoing petroleum activities which do not have an approved EP as of 29 August 2013 will be considered in breach of the Regulations and may be subject to a penalty of \$10,000.

In view of the potential influx of revised EPs to DMP, it is recommended that all operators with ongoing petroleum activities (with an EMP approved before 29 August 2012), lodge their revised EP for assessment no later than 29 May 2013.

To assist in this process of submitting a revised EP, DMP has developed the *Guidelines for the Preparation and Submission of an Environment Plan* (the Guidelines) (DMP, 2012)¹.

These Guidelines clarify all regulatory requirements expected in the revised EP, including:

- Risk assessment and risk management standards

- Chemical disclosure requirements²
- Performance objective, standard and measurement criteria based reporting (recordable incidents)
- Risk-based incident report (reportable incidents)
- Quarterly emissions and discharge reporting
- Annual Environmental Reports
- EP summaries and publication thereof
- Mandatory five yearly revision of EPs

For further information on the Regulations, please contact an officer in the Petroleum Environment Branch via our web page: www.dmp.wa.gov.au/825.aspx

1 *Guidelines for the Preparation and Submission of an Environment Plan*: www.dmp.wa.gov.au/documents/ENV-PEB-177.pdf

2 *Chemical and other substance disclosure details*: www.dmp.wa.gov.au/documents/ENV-PEB-178.pdf



Varanus Island Processing Hub off the north west coast of WA
(Photo courtesy of Apache Energy)

The State of Geothermal in Western Australia

Kerem Kanadikirk

Petroleum Drilling Engineer
Resources Branch



Geothermal steam flow
(Photo courtesy of Geodynamics Ltd)

Geothermal energy is an environmentally friendly alternative energy source to traditional fossil fuels and enjoys a growing international market. Despite its worldwide use as a clean energy solution for producing electricity, and for heating and cooling, geothermal energy is relatively new to Western Australia.

Geothermal Exploration Permits (GEPs) were initially granted in the Kimberley, Carnarvon, Perth and Esperance regions (Table 1, Figure 1). Since geothermal energy is a significantly lower energy source compared to petroleum, its economic viability depends on maintaining high temperatures and flow rates. Geothermal energy explorers choose their path in the light of this fact. Comparing a temperature map of WA (Figure 2) to the distribution of GEPs (Figure 1) shows initial acreage selection corresponded to high temperature areas close to roads, infrastructure and markets.

The first GEPs in Western Australia were awarded on 30 July 2009. With the first acreage releases, demand for GEPs was high and the number of granted

titles reached 41 in the first year. The last two titles were awarded in the following year, but there haven't been any new GEPs granted since then. In a post-GFC world, this shows the reluctance of financiers to invest in what was seen as high risk due to the infancy of geothermal exploration in Australia. Furthermore, of the 43 titles granted to date, nine titles have already been surrendered, eight titles are pending surrender and one title has been cancelled (Table 1, Figure 1).

Today, the geothermal family consists of eight companies and two research institutions, respectively; AAA Energy Ltd, Granite Power Ltd, Green Power Energy Limited, Green Rock Energy Limited, GT Power Pty Ltd, Kagara Ltd, Mid West Geothermal Power Pty Ltd, New World Energy Ltd, CSIRO and the University of Western Australia.

Geothermal exploration and production is administered under the *Petroleum and Geothermal Energy Resources Act 1967*. Permit holders are expected to fulfil the minimum work commitment for the first two years without variation.

In addition, as part of the gazette notice for the releases, it is required that a minimum of one shallow well (i.e. approximately 400 metres) will need to be drilled during the first two years of the GEP.

Geothermal Exploration Permit applications are required to specify a clear and concise work program and rationale (minimum number of wells to be drilled and their depth, line kilometres of seismic, geophysical surveys, etc.) to be carried out and estimated expenditures for each of the six years of the permit term.

For the existing titles held in WA, the work commitments, estimated expenditures on the geothermal exploration work programs and their current status are shown in Table 2.

While total indicative expenditure declared in work programs is almost \$600 million, the total actual expenditure is just \$2.5 million. Notably, no exploration wells have been drilled so far. Progress on the geothermal exploration front is decidedly underwhelming. When will Western Australia realise the potential of geothermal energy? Will it be five years? Will it be ten years?

GEOTHERMAL TENURE (Current and Historical)

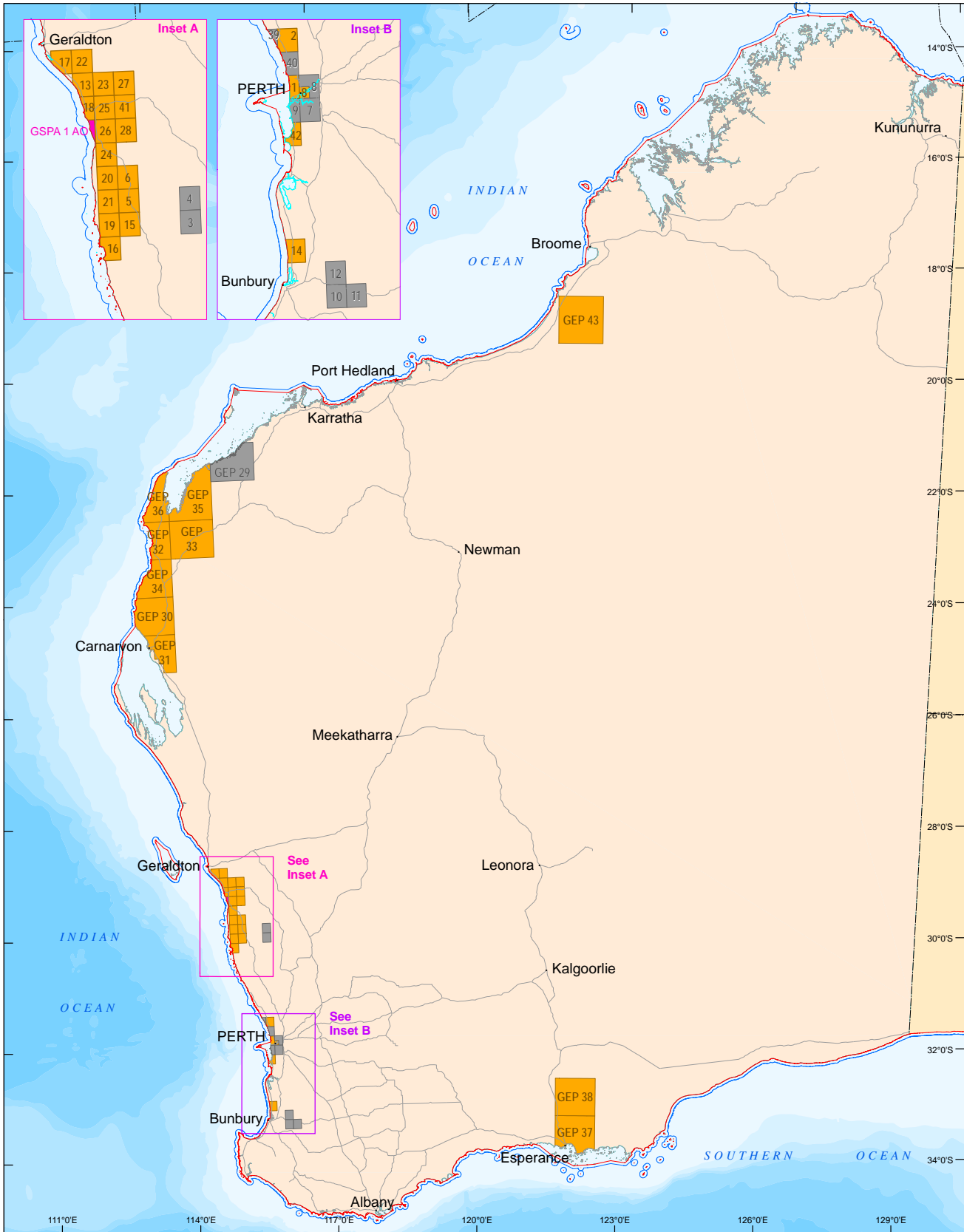
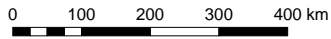
Western Australia

April 2013



Legend

- Current Geothermal title
- Current Geothermal Special Prospecting Authority
- Historical Geothermal title
- Three Nautical Mile limit
- Territorial baseline
- Schedule 2 boundary



I:\MAPPING\GEO_THERMAL\WA_Geothermal_Titles_current-and-historical_A1_Albans.mxd - JB 04/04/2013

Figure 1 | Geothermal exploration permits in Western Australia



Australian Government
Geoscience Australia

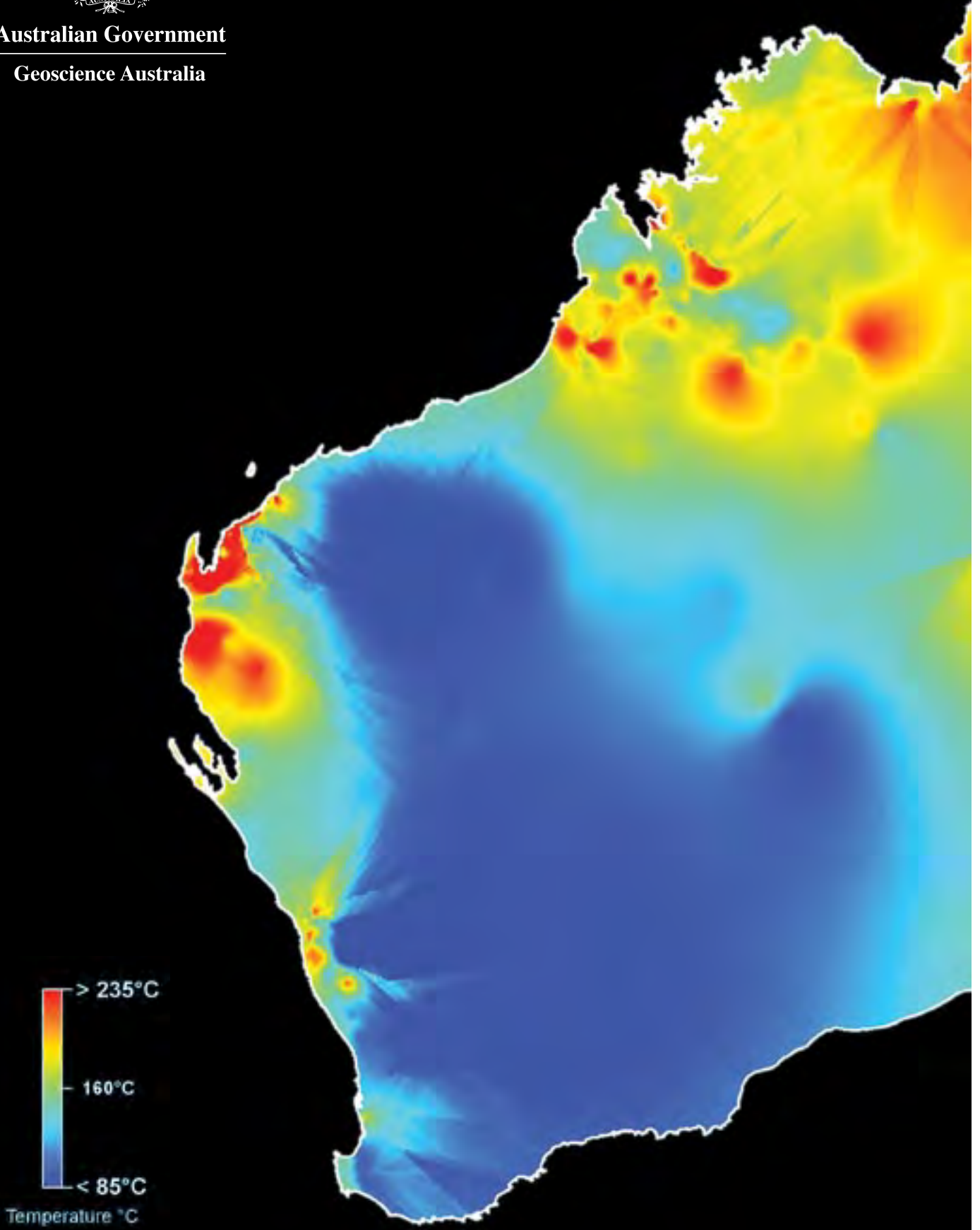


Figure 2 | WA temperatures at 5 km depth

Table 1. Geothermal Exploration Permits (GEPs) in Western Australia regulated under the *Petroleum and Geothermal Energy Resources Act, 1967* as at 10 April 2013

Regions	Title	Title Holders	Issue Date	Expiry Date	Status
Perth	GEP 1	Green Rock Energy Limited; The University of Western Australia	30/07/09	29/07/15	Active
	GEP 2	Green Rock Energy Limited	30/07/09	29/07/15	Active
	GEP 3	Green Rock Energy Limited	30/07/09	29/07/15	Surrendered
	GEP 4	Green Rock Energy Limited	30/07/09	29/07/15	Surrendered
	GEP 5	Granite Power Limited	30/07/09	29/07/18	Term Extended
	GEP 6	Granite Power Limited	30/07/09	29/07/18	Term Extended
	GEP 7	GT Power Pty Ltd	30/07/09	30/06/16	Surrendered
	GEP 8	CSIRO	30/07/09	31/12/16	Active
	GEP 9	GT Power Pty Ltd	30/07/09	29/07/15	Surrendered
	GEP 10	Green Rock Energy Limited; BHP Billiton Worsley Alumina Pty Ltd	11/09/09	10/09/15	Surrendered
	GEP 11	Green Rock Energy Limited; BHP Billiton Worsley Alumina Pty Ltd	11/09/09	10/09/15	Surrendered
	GEP 12	Green Rock Energy Limited; BHP Billiton Worsley Alumina Pty Ltd	11/09/09	10/09/15	Surrendered
	GEP 13	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 14	New World Energy Limited	11/09/09	10/09/16	Pending Surrender
	GEP 15	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 16	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 17	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 18	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 19	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 20	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 21	New World Energy Limited	11/09/09	10/09/16	Active
	GEP 22	AAA Energy Pty Ltd	22/09/09	21/09/15	Active
	GEP 23	Mid West Geothermal Power Pty Ltd	22/09/09	21/09/15	Active
	GEP 24	Mid West Geothermal Power Pty Ltd	22/09/09	21/09/15	Active
	GEP 25	Mid West Geothermal Power Pty Ltd	22/09/09	21/09/15	Active
	GEP 26	Mid West Geothermal Power Pty Ltd	22/09/09	21/09/15	Active
	GEP 27	Mid West Geothermal Power Pty Ltd	22/09/09	21/09/15	Active
	GEP 28	Mid West Geothermal Power Pty Ltd	22/09/09	21/09/15	Active
Carnarvon	GEP 29	Geothermal Energy Pty Ltd	23/02/10	22/02/16	Cancelled
	GEP 30	New World Energy Limited	23/02/10	22/08/17	Pending Surrender
	GEP 31	New World Energy Limited	23/02/10	22/08/17	Pending Surrender
	GEP 32	New World Energy Limited	23/02/10	22/08/17	Pending Surrender
	GEP 33	New World Energy Limited	23/02/10	22/08/17	Pending Surrender
	GEP 34	New World Energy Limited	23/02/10	22/08/17	Pending Surrender
	GEP 35	New World Energy Limited	23/02/10	22/08/17	Pending Surrender
	GEP 36	New World Energy Limited	23/02/10	22/08/17	Pending Surrender
Esperance	GEP 37	Greenpower Energy Limited	24/02/10	23/02/16	Active
	GEP 38	Greenpower Energy Limited	24/02/10	23/02/16	Active
Perth	GEP 39	Green Rock Energy Limited	13/04/10	12/04/16	Surrendered
	GEP 40	Green Rock Energy Limited	13/04/10	12/04/16	Surrendered
	GEP 41	Mid West Geothermal Power Pty Ltd	13/04/10	12/04/16	Active
	GEP 42	GT Power Pty Ltd	4/03/11	3/03/17	Active
Kimberley	GEP 43	Kagara Ltd	6/05/11	5/05/17	Active

Table 2. Geothermal exploration work programs in Western Australian GEPs as at 10 April 2013

Title	Firm Two Year Program includes	Indicative Expenditure	Secondary Program includes	Indicative Expenditure	Work Done	Actual Expenditure
GEP 1	Geoscientific studies, 400 m well	\$375,000	Geotechnical studies, two deep wells, economic studies	\$9,000,000	Geological studies	\$246,519
GEP 2	Geoscientific studies, two 200 m wells, one 400 m well	\$260,000	Geotechnical studies, two deep wells, economic studies	\$17,500,000	Geothermal studies, geoscientific studies	\$136,819
GEP 3	Geoscientific studies, 400 m well	\$150,000	Geotechnical studies, two deep wells, economic studies	\$17,500,000	Geological studies	\$59,801
GEP 4	Geoscientific studies, 400 m well	\$150,000	Geotechnical studies, two deep wells, economic studies	\$17,500,000	Geological studies	\$70,413
GEP 5	Geoscientific studies, 25 km 2D seismic survey, two shallow wells	\$902,000	Two deep wells and pilot plant	\$49,150,000	Geological studies	\$65,475
GEP 6	Geoscientific studies, 25 km 2D seismic survey, two shallow wells	\$902,000	Two deep wells and pilot plant	\$49,150,000	Geological studies	\$65,475
GEP 7	Geoscientific studies, 400 m well	\$217,000	Three deep wells, one shallow well	\$1,300,000	Geoscientific studies	\$161,222
GEP 8	Geoscientific studies, 400 m well	\$217,000	Three deep wells, one shallow well	\$1,300,000	Geoscientific studies	\$262,632
GEP 9	Geoscientific studies, 400 m well	\$217,000	Three deep wells, one shallow well	\$1,300,000	Geoscientific studies	\$157,976
GEP 10	50 km magnetotelluric survey, geoscientific studies, one 400 m well, two 200 m wells	\$375,000	Geotechnical studies, two deep wells, fracture stimulation, economic studies	\$14,000,000	Geoscientific studies	\$80,567
GEP 11	50 km magnetotelluric survey, geoscientific studies, one 400 m well, two 200 m wells	\$375,000	Geotechnical studies, two deep wells, fracture stimulation, economic studies	\$14,000,000	Geoscientific studies	\$73,241
GEP 12	50 km magnetotelluric survey, geoscientific studies, one 400 m well, two 200 m wells	\$460,000	Geotechnical studies, two deep wells, fracture stimulation, economic studies	\$17,500,000	Geoscientific studies	\$81,301
GEP 13	209 km gravity survey, geoscientific studies, three 500 m wells	\$878,500	50 km magnetotelluric survey, geotechnical studies, two deep wells, fracture stimulation	\$12,114,100	Geological studies, geothermal studies	\$50,663
GEP 14	Geoscientific studies, two 500 m wells, one deep well	\$1,939,050	Geotechnical studies, two deep wells, pilot plant	\$16,126,800	Geological studies, geothermal studies	\$17,302
GEP 15	209 km gravity survey, geoscientific studies, three 500 m wells	\$878,500	50 km magnetotelluric survey, geotechnical studies, three deep wells, fracture stimulation	\$8,676,900	Geological studies, geothermal studies	\$44,447
GEP 16	209 km gravity survey, geoscientific studies, two shallow wells	\$717,750	50 km magnetotelluric survey, geotechnical studies, two shallow wells, two deep wells	\$5,590,100	Geological studies, geothermal studies	\$23,063
GEP 17	209 km gravity survey, geoscientific studies, two shallow wells	\$717,750	Geotechnical studies, two shallow wells, two deep wells, fracture stimulation	\$11,020,100	Geological studies, geothermal studies	\$16,583
GEP 18	209 km gravity survey, geoscientific studies, three shallow wells	\$907,950	Three shallow wells, three deep wells, geotechnical studies, geophysical survey, fracture stimulation	\$19,852,900	Geological studies, geothermal studies	\$16,757
GEP 19	209 km gravity survey, geoscientific studies, three 500 m wells	\$878,650	Geotechnical studies, three deep wells	\$8,676,900	Geological studies, geothermal studies	\$32,447
GEP 20	Geoscientific studies, two shallow wells, one deep well	\$1,939,050	Geotechnical studies, two deep wells, pilot plant	\$12,626,800	Geological studies, geothermal studies	\$18,002
GEP 21	Geoscientific studies, two shallow wells, one deep well	\$1,939,050	Geotechnical studies, two deep wells, pilot plant	\$11,626,800	Geological studies, geothermal studies	\$28,498
GEP 22	Geoscientific studies, 60 km 2D seismic survey, one deep well	\$4,375,000	Geotechnical studies, one deep well, fracture connection test, pilot plant	\$10,500,000	Not reported	—

Table 2. Continued

Title	Firm Two Year Program includes	Indicative Expenditure	Secondary Program includes	Indicative Expenditure	Work Done	Actual Expenditure
GEP 23	Geoscientific studies, two 200 m wells, one 400 m well	\$260,000	Geotechnical studies, two deep wells, fracture connection test, economic studies	\$17,500,000	Geoscientific studies	\$150,780
GEP 24	Geoscientific studies, two 200 m wells, one 400 m well	\$260,000	Geotechnical studies, two deep wells, fracture connection test, economic studies	\$17,500,000	Geoscientific studies	\$128,650
GEP 25	Geoscientific studies, two 200 m wells, one 400 m well	\$260,000	Geotechnical studies, two deep wells, fracture connection test, economic studies	\$17,500,000	Geoscientific studies	\$152,800
GEP 26	Geoscientific studies, one shallow well	\$150,000	Geotechnical studies, two deep wells, fracture connection test, economic studies	\$17,500,000	Geoscientific studies	\$46,800
GEP 27	50 km magnetotelluric survey, geoscientific studies, one 400 m well, three 200 m wells	\$460,000	Geotechnical studies, two deep wells, fracture stimulation, economic studies	\$17,500,000	Geoscientific studies	\$36,415
GEP 28	Geoscientific studies, one shallow well	\$150,000	Geotechnical studies, two deep wells, fracture connection test, economic studies	\$17,500,000	Geoscientific studies	\$32,900
GEP 29	Geoscientific studies, two 450 m wells	\$350,000	Geoscientific studies, 20 km 2D seismic survey, magnetotelluric survey, three deep wells reservoir studies	\$15,800,000	Not reported	—
GEP 30	Geotechnical studies, one 800 m well	\$344,250	Four deep wells, geothermal studies	\$1,962,650	Geological studies, geothermal studies	\$17,312
GEP 31	Geotechnical studies, one 800 m well	\$358,750	Four deep wells, geothermal studies	\$1,962,650	Geological studies, geothermal studies	\$13,269
GEP 32	Geotechnical studies, one 800 m well	\$359,250	Four deep wells, field review	\$1,962,600	Geological studies, geothermal studies	\$12,844
GEP 33	Geothermal studies, one 500 m well	\$207,375	Geothermal studies, one 500 m well, three deep wells	\$8,859,825	Geological studies, geothermal studies	\$19,720
GEP 34	Magnetotelluric survey, geoscientific studies, one deep well	\$648,450	Geoscientific studies, two deep wells, economic studies	\$10,846,300	Geological studies, geothermal studies	\$15,053
GEP 35	Seismic interpretation, geoscientific studies, one deep well	\$644,450	Geoscientific studies, two deep wells, economic studies	\$8,903,200	Geological studies, geothermal studies	\$22,880
GEP 36	Geoscientific studies, one 800 m well	\$462,450	Geoscientific studies, three deep wells, economic studies	\$9,246,150	Geological studies, geothermal studies	\$20,596
GEP 37	Geotechnical studies, one shallow well	\$700,000	Engineering studies, two deep wells	\$20,750,000	Not reported	—
GEP 38	Geotechnical studies, one shallow well	\$700,000	Engineering studies, two deep wells	\$20,750,000	Not reported	—
GEP 39	Geoscientific studies, one 400 m well	\$200,000	Geotechnical studies, one deep well, reservoir testing	\$4,410,000	Geoscientific studies	\$8,401
GEP 40	Geoscientific studies, one 400 m well	\$200,000	Geotechnical studies, one deep well, reservoir testing	\$4,410,000	Geoscientific studies	\$6,100
GEP 41	Geoscientific studies, one 400 m well	\$200,000	Geotechnical studies, two deep wells, reservoir testing	\$12,410,000	Geoscientific studies	\$135,118
GEP 42	Geotechnical studies, geochemical studies	\$90,000	Geothermal studies, geotechnical studies, two deep wells	\$2,260,000	Geoscientific studies	\$35,174
GEP 43	Geotechnical studies	\$140,000	Geotechnical studies, three deep wells, two production wells	\$8,240,000	Not reported	—

Note: Shallow well < 1,000 m Deep well >= 1,000 m

Implications of High Heat Flow and Temperatures for Geothermal Energy in the Southern Carnarvon Basin

Mike F. Middleton
 General Manager
 Resources Branch

Introduction

High temperatures have been recognised in the Southern Carnarvon Basin (Figure 1), and have been reported in a study by Ghorri (2008). This basin (Figure 1) is probably the most prospective region in Western Australia for geothermal energy. However, very little geothermal exploration has been carried out, despite seven Geothermal Exploration Permits (GEPs) having been granted for the region. This article briefly reviews the geothermal energy potential of the Southern Carnarvon Basin, and specifically the recognised high-temperature region, and also offers some suggestions for proper exploration and exploitation of these resources.

Geothermal energy can fall within two legislative brackets: (1) those uses that fall under the *Petroleum and Geothermal Resources Act 1967* (PGERA67), and (2) those uses that fall under other State legislation, including legislation for water usage, environmental protection and general safety. The Department of Mines and Petroleum regulates geothermal activities that fall under PGERA67. The PGERA67 was essentially designed to regulate geothermal energy recovered for the purposes of electricity generation, and, in keeping with the thinking of the mid- and late 2000s, to regulate “hot dry rock” geothermal sources, which have been described in previous PWA issues (see PWA April 2008, 2010).

It has been subsequently recognised that geothermal energy in Western Australia seems to be best derived from “hot sedimentary aquifers” (PWA April 2008, 2010). According to current philosophy (see WAGES 2011 and 2012), most prospective sources of

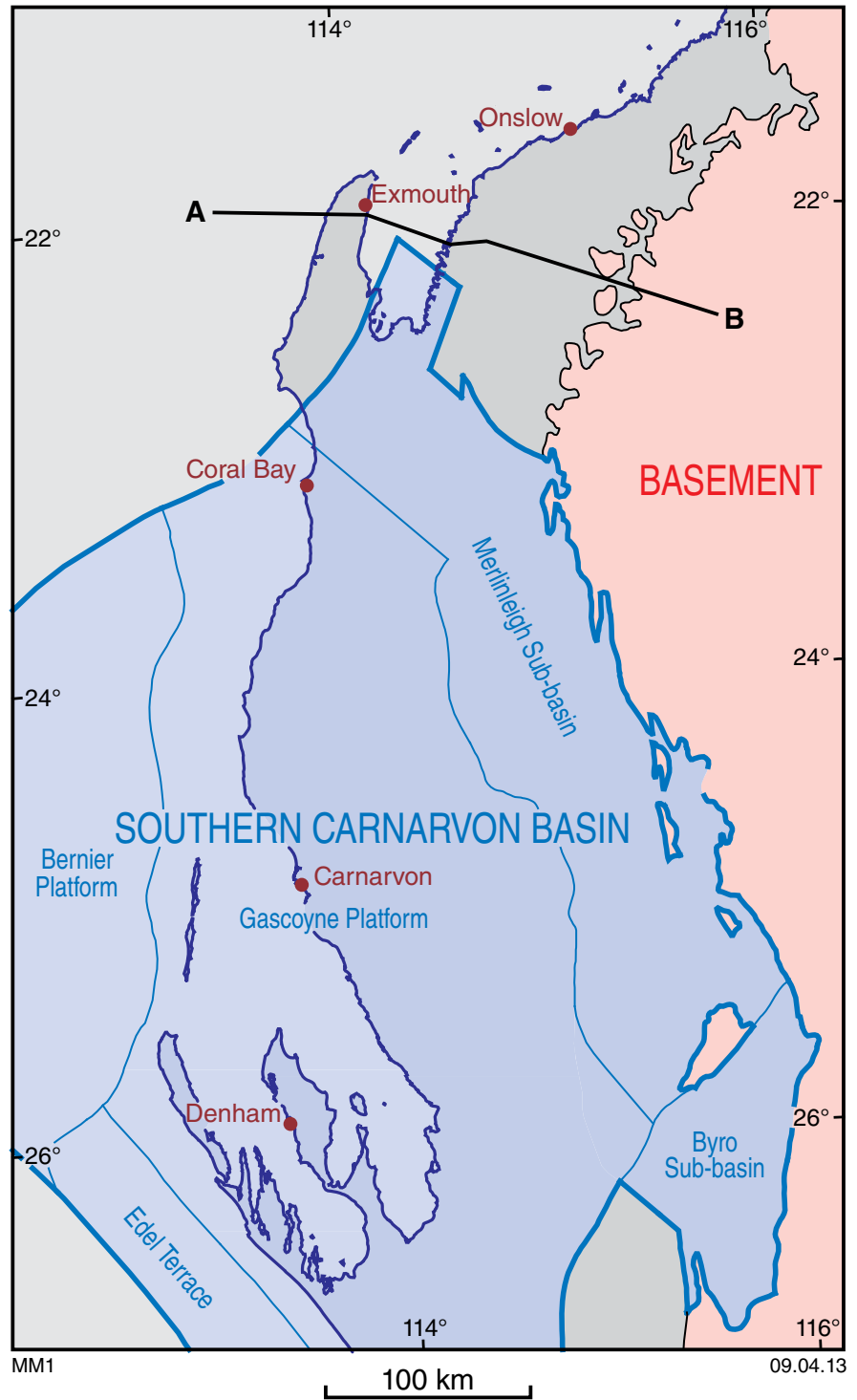


Figure 1 | Location map after GSWA Memoir 3 (Hocking, 1990). Cross-section is shown in Figure 4

geothermal energy, close to Western Australian markets, are in the Perth Basin, and comprise (1) hot sedimentary aquifers (relevant to PGERA67), and (2) shallow sources of warm water for non-commercial use (exempted under PGERA67).

After several initial rounds of geothermal permit releases, the whole State was thrown open to geothermal exploration in April 2012 with application through a Special Geothermal Prospecting Authority with Acreage Option (SPGA/

AO). At this stage 43 GEPs had been granted, and it unfolded, that since then, only one new SPGA/AO had been sought until April 2013. It seemed that the geothermal market had been saturated, and was suffering from a general market disinterest (largely investment driven) in geothermal energy. However, some recent activity has been seen in the northern Perth Basin by a Green Rock Energy and AWE Joint Venture directed towards a geothermal-sourced electricity supply project for the Mid West region of the

State. This project is supported by a \$4 million grant from the Western Australian State Government, which will hopefully also be supported by Commonwealth Government funds, to match the initial industry investment.

The Green Rock Energy-AWE Joint Venture is the only geothermal project with significant large-scale economic impact in this State at the present time; the project entertains substantial medium-grade geothermal resources for electricity generation, which are known to exist at economically drillable depths.

However, apart from the northern Perth Basin, hot sedimentary aquifer geothermal resources have been shown potentially to exist in the Carnarvon and Canning basins (Ghori 2008). Substantial evidence supports the premise that the Southern Carnarvon Basin may be able to supply the Pilbara mining communities with not only (1) long-term geothermal-sourced electricity (looking beyond North West Shelf sourced gas supply, i.e. beyond perhaps 2050), but also (2) intermediate-term nearby resource projects and tourism enterprises. It is of note that Davidson (2012) described the Peninsula Hot Springs Bath House and Spa Centre tourist enterprise in southern Victoria, which entertains an estimated \$75 million per annum regional economic benefit. Such enterprises are potentially available to environmentally sensitive, but tourist intensive, coastal resort sites from Carnarvon north to Exmouth.

The Geothermal Puzzle

The unanswered geothermal puzzle of the Southern Carnarvon Basin is centred on the cause of the elevated geothermal gradients in the Exmouth and Gascoyne sub-basins. Essentially, the puzzle may condense into whether the elevated temperatures reported by Ghori (2008) are caused by underlying radiogenic (“hot”) granites or by the flow of deep hot groundwater into surface sediments. No extensive studies have been carried out to understand this phenomenon. Some preliminary studies on the source of the elevated heat flow by a radiogenic source (“hot” granites) have been carried out within the Resources Branch of the Petroleum Division of the Department of Mines and Petroleum, and these are reported herein.

Geology and Geophysics

The geology of the Southern Carnarvon Basin is well understood, having been described by Hocking *et al.* (1987), Hocking (1990), and the geothermal potential by Ghori (2008). The geology of the North West Cape, which is especially relevant to the current article was studied by Malcolm *et al.* (1991). It has been shown from petroleum drilling data that an unusually hot region exists along the coastal region from Shark Bay to the Exmouth Peninsula, and maybe for some distance inland towards, and perhaps including, the outcropping Pilbara Craton. It is reasonable to expect that the Pilbara Craton underlies a reasonable amount of the onshore Carnarvon Basin between Shark Bay and Exmouth, including the North West Cape. Further, it is expected that the Pilbara Craton may contain some “hot” granites in this region.

There appears to be no detailed scientific study of why the elevated heat flow occurs in this region, despite

it being covered since 2010 by seven GEPs. According to the studies by Ghori (2008), temperatures in excess of 150 °C may exist between drillable depths of 3000 to 4000 m, and these wells have a geothermal gradient in the range of 60 to 100 °C/km (Figure 2, Ghori, 2008).

The source of the observed high heat flow in petroleum wells appears to be generated from high radiogenic (“hot”) granites that underlie the deep sedimentary blanket in the region. However, without sufficient investigation and further studies, convective heat transport should not be ruled out as the cause of these elevated temperatures. Figure 3 shows the surface heat generation (from airborne radiometrics) in the region near the Southern Carnarvon Basin (modified from Middleton, 2011). Comparison to the surface geological units indicates that the sedimentary cover has a surface heat generation in the vicinity of 1 μWm^{-3} , as opposed to up to 5 μWm^{-3} in the adjacent Pilbara Craton. Middleton (2013) has shown that values of 5 μWm^{-3} on surface

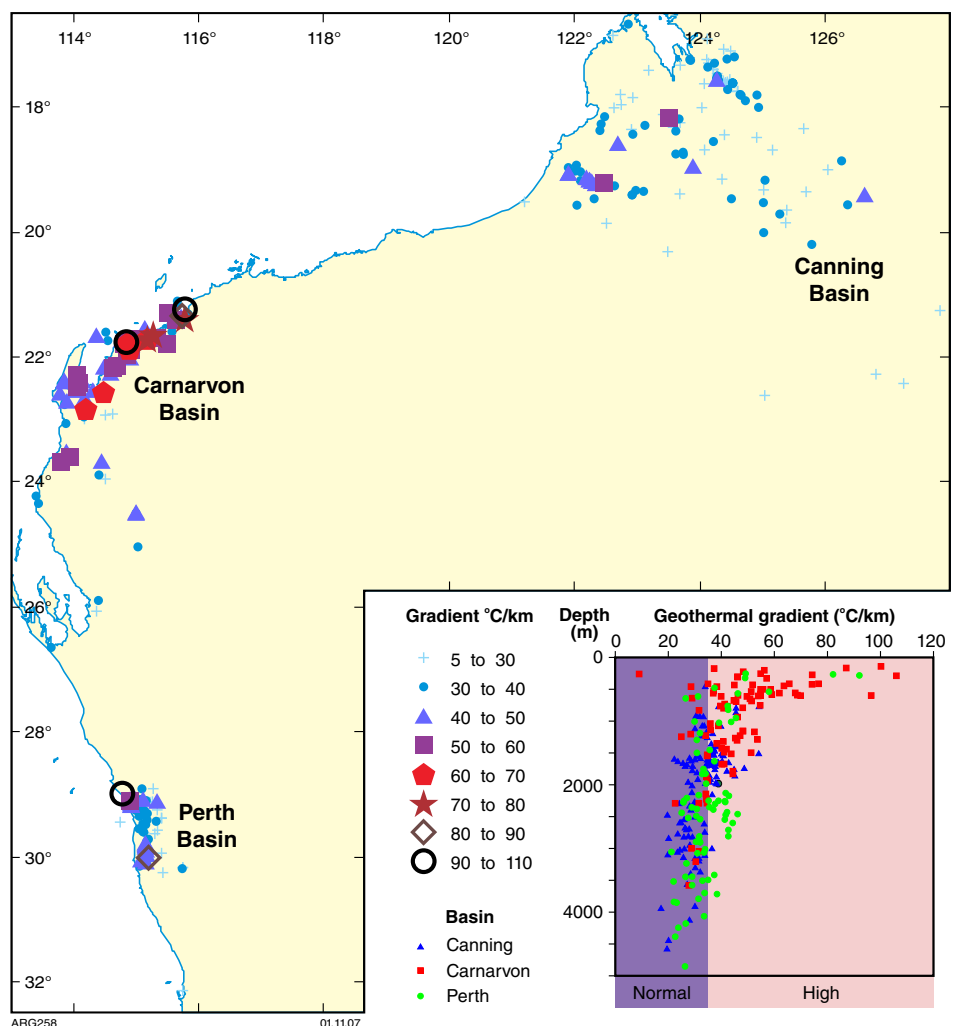


Figure 2 | Geothermal gradients in the Southern Carnarvon Basin (Ghori, 2008)

Table 1. Temperature modelling results

Heat Generation (μWm^{-3})	Geothermal Gradient ($^{\circ}\text{C}/\text{km}$)	Temp @ 2 km ($^{\circ}\text{C}$)	Temp @ 3 km ($^{\circ}\text{C}$)	Temp @ 4 km ($^{\circ}\text{C}$)
3	42	104	146	188
6	60	140	200	260
9	78	176	256	332
12	96	212	308	404

Table 2. Assumed parameters for the models in Table 1

PARAMETER	VALUE (units)	COMMENT
Sediment thickness	4000 (m)	Varies between 2 and 8 km
“Hot” granite thickness	6000 (m)	May vary between 2 and 8 km
Basal heat flow	24 (μWm^{-3})	Assumed from Perth Basin
Surface temperature	20 ($^{\circ}\text{C}$)	Can be higher
Thermal conductivity	3 ($\text{Wm}^{-1}\text{C}^{-1}$)	Variable between 2 and 5 units

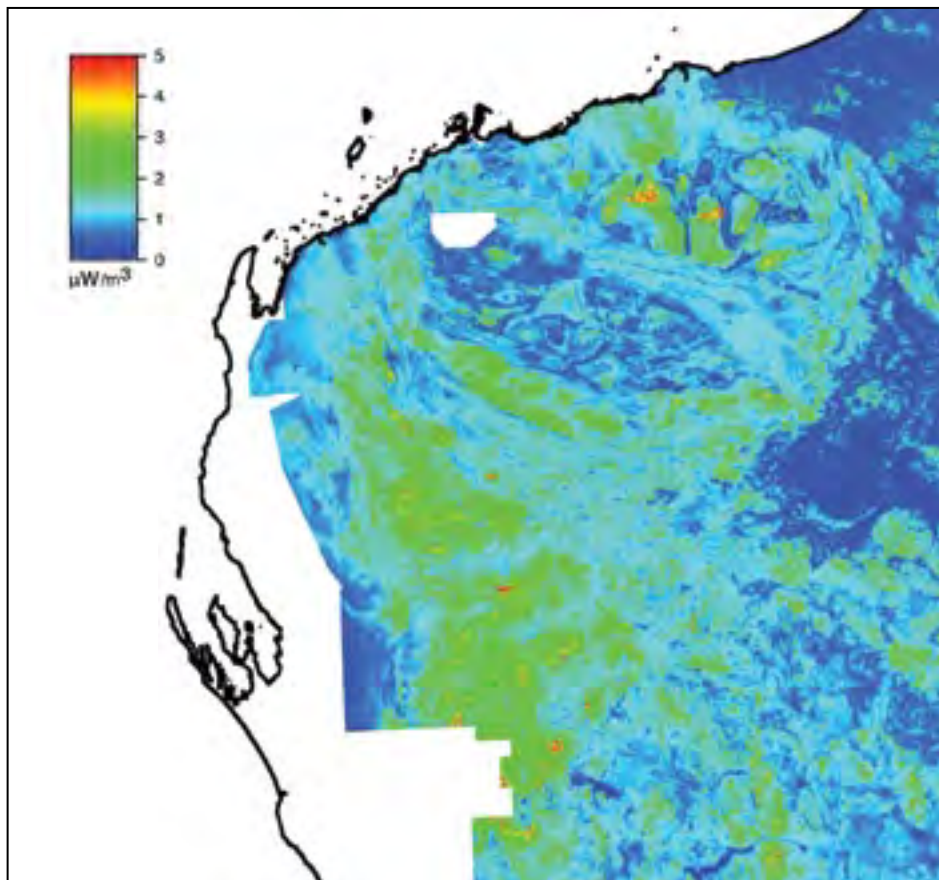


Figure 3 | Surface heat generation map for the Southern Carnarvon Basin region, and geological tectonic units for comparison. The sedimentary regions have a surface heat generation of about $1 \mu\text{Wm}^{-3}$. The Pilbara Craton has surface heat generation up to $5 \mu\text{Wm}^{-3}$, which is typical for airborne radiometrics over “hot” radiogenic granites in Western Australia. Surface “ground-truthing” has shown airborne values of 3-5 μWm^{-3} , may be higher than $12 \mu\text{Wm}^{-3}$

airborne radiometrics can translate to up to $12 \mu\text{Wm}^{-3}$ in specific geologic units on the ground. Therefore, the green regions of the adjacent Pilbara Craton in Figure 3, which are considered likely to underlie the Southern Carnarvon Basin sedimentary section, may possess a heat generation value of up to $12 \mu\text{Wm}^{-3}$ or more. As previously mentioned, this heat generation value is typical of “hot” granites in the Cooper Basin, where geothermal energy is currently being developed.

The WAPET Cape Range petroleum exploration wells are known to encounter bottom-hole temperatures in excess of 140 – 160 $^{\circ}\text{C}$ at depths of between 4300 and 4600 m; these temperatures are probably greater after fluid stabilisation in the drill hole. Figure 4 shows that the total sedimentary blanket over interpreted high heat generating granites may be up to eight kilometres thick (Hocking, 1990; Malcolm *et al.*, 1991).

Temperature Modelling

A schematic model for heat generation in a “hot” granite which is overlain by a sedimentary pile is shown in Figure 5. Several numerical models of the temperature versus depth for various heat generation scenarios are shown in Table 1. These are based on the usual 1D mathematical geothermal models for such situations (Middleton, 2011, 2013). The assumptions used to generate Table 1 are shown in Table 2, and are based on the surface radiogenic heat map in Figure 3, data reported in Middleton (2013), Hocking (1990), Jaeger (1970) and Sass *et al.* (1976). Ghori (2008) has shown from petroleum wells that the temperature gradient in the Southern Carnarvon Basin can range between 30 and 100 $^{\circ}\text{C}/\text{km}$, and these are consistent with temperatures generated in the models in Table 1. Given that convection is not involved, the governing factor appears to be the heat generation of underlying granites.

The models in Table 1 demonstrate that temperatures at depths greater than 3000 m may have temperatures significantly greater than 200 $^{\circ}\text{C}$, depending on the heat generation of underlying granite bodies. In the upper side of the models, one is looking at full steam-type turbines for the generation of electricity, which are the current optimal geothermal energy-producing technology, and is common place in New Zealand, Indonesia and California.

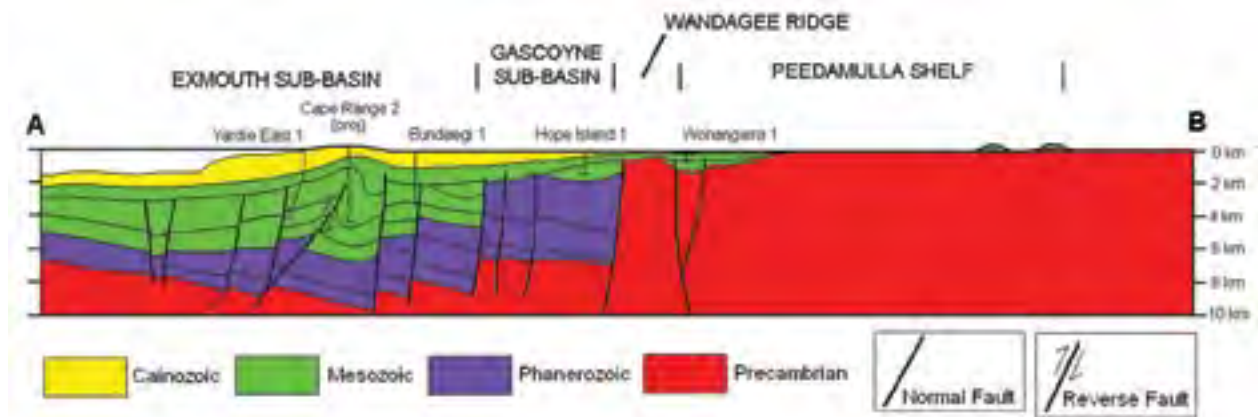


Figure 4 | **Geological cross-section of the Southern Carnarvon Basin from GSWA Memoir 3 (modified after Hocking, 1990; Malcolm *et al.*, 1991)**

Notional Risk and Economics

It is recognised that \$10 million may be needed to achieve a geothermal discovery well. This is spent many times yearly on “dry” petroleum exploration wells. The geothermal resource does not depend on a geological structure, as for a conventional petroleum resource. Near-surface exploration can determine a region of high heat flow, and an extensive heat resource will exist below in a hot sedimentary aquifer. The risks are in the flow characteristics of the hot aquifer. These can be determined from the initial \$10 million well: same risk perhaps as a petroleum well (resource will be there, but the economic recovery to surface is the only risk). If the resource is there, world-wide examples show that economic recovery is achievable.

Perhaps ten times the initial \$10 million is required to achieve an electricity pilot plant, and then more again for an electricity supply of up to 100 MW supporting local industry in the Pilbara mining region. Such costs seem to be a barrier to current geothermal exploration. A sensible risking model for geothermal energy seems to be missing in Western Australia. The geothermal resources are known to exist, and a market also exists in the Perth and Pilbara regions. It is incomprehensible why no action is occurring in this part of the energy sector, and especially this region of Western Australia. Indeed, there seems to be an incomprehensible *FEAR* in the investment market about geothermal energy. Why?

Conclusion — Future Geothermal Releases

This article demonstrates that suitable temperatures to enable economic geothermal energy projects in the Southern Carnarvon Basin most certainly occur. It has shown that cause of such elevated heat flow, and temperatures, can be demonstrated to be due to “hot” radiogenic granites underlying the Carnarvon Basin sediments. While this article suggests that radiogenic heat generation is the cause of the elevated temperatures in the Southern Carnarvon Basin, convective heat transport may also occur. Further studies will be necessary, perhaps along the lines of the study of Swift *et al.* (1988), to establish such an influence.

From this study, temperatures in excess of 200 °C may exist between drillable depths of 3000 to 4000 m, which are similar to temperatures exploited in the Habanero wells drilled by Geodynamics in the Cooper Basin. These temperatures are sufficient to drive new generation organic-cycle electricity turbines (Welch *et al.*, 2010), and can provide an adequate electricity supply for many Pilbara mining projects.

The tourist project potential can be realised at much shallower depths and lower costs. In this respect, one is referred to Davidson (2012). Such an entrepreneurial development along the lines of the Davidson model (start-up

cost in the order of \$5 million; Davidson, personal communication) is very feasible on the tourist coast between Shark Bay and Exmouth. This development in southern Victoria possesses a realisable \$75 million regional economic benefit per annum (Davidson, 2012).

It is anticipated that the Southern Carnarvon Basin will be re-released in a focused program in the latter part of 2013. Eight blocks will be released. These will be advertised in September 2013.



Figure 5 | **Schematic model for models summarised in Table 1**

References

- Davidson, C, 2012, Geothermal beyond power — Opportunities for geothermal resource development, Abstracts, West Australian Geothermal Energy Symposium, Perth, 2012, p. 4, ISBN 981-1-74052-250-2.
- Ghori, K.A.R., 2008, Western Australia's Geothermal Resources, Proceedings of American Association of Petroleum Geologists (AAPG), Annual Convention & Exhibition, April 20 – 23, 2008, San Antonio, Texas.
- Hocking, R.M., 1990, Carnarvon Basin, in *Geology and Mineral Resources of Western Australia: Western Australia Geological Survey, Memoir 3*, p. 457–495.
- Hocking, R.M., Moors, H.T., and van de Graff, W.J.E., 1987, *Geology of the Carnarvon Basin, Western Australia: Geological Survey of Western Australia, Bulletin 133*, 289p.
- Jaeger, J.C., 1970, Heat flow and radioactivity in Australia, *Earth and Planetary Science Letters*, 8, 285–292.
- Malcolm, R.J., Pott, M.C., and Delfos, E., 1991, A new tectono-stratigraphic synthesis of the North West Cape area, *APEA Journal*, 31, 154–176.
- Middleton, M.F., 2011, Temperatures within outcropping, radiogenic granites: Implications for geothermal energy in Western Australia, West Australian Geothermal Energy Symposium 2011, Abstracts, Middleton, M.F. and Gessner, K. (Eds), Perth, April 2011, ISBN 981-1-74052-250-1.
- Middleton, M.F., 2013, Radiogenic heat generation in the Darling Range, Western Australia, *Exploration Geophysics*, in press 2013.
- Sass, J.H., Jaeger, J.C. and Munroe, R.J., 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*.
- Swift, M.G., Stagg, H.M.J., Falvey, D.A., 1988, Heat flow regime and implications for oil maturity and migration in the offshore northern Carnarvon Basin, in Purcell, P.G. and R.R., (Eds), *The North West Shelf, Australia: Proceedings of Petroleum Exploration Society Australia Symposium*, Perth, 1988, 539-551.
- WAGES, 2011: West Australian Geothermal Energy Symposium 2011, Abstracts, Middleton, M.F. and Gessner, K. (Eds), Perth, April 2011, ISBN 981-1-74052-250-1.
- WAGES, 2012: West Australian Geothermal Energy Symposium 2012, Abstracts, Middleton, M.F. and Gessner, K. (Eds), Perth, April 2012, ISBN 981-1-74052-250-2.
- Welch, P., Boyle, P., Sells, M., and Murillo, I., 2010, Performance of new turbines for geothermal power plants, *Geothermal Research Council (GRC) Transactions*, 34, 1091-1096.



Hill top geothermal pool on the Mornington Peninsula in Victoria
(Photo courtesy of Peninsula Hot Springs)

See you at the WA Basins Symposium in August

The foundation for much of the petroleum exploration knowledge of Western Australia, both onshore and offshore, has been the regular conferences on the sedimentary basins of the State and adjacent regions. The Western Australian Branch of the Petroleum Exploration Society of Australia (PESA) held its first conference of this type, the *Canning Basin, WA, Symposium*, during 1984. Similar high quality conferences were held every four years and evolved into PESA's *West Australian Basins Symposium (WABS)*. The last WABS took place during 2006 when the Conference was jointly held with the highly successful American Association of Petroleum Geologists' Perth ICE.

Significant advances in petroleum exploration and development in Western Australia and increased understanding of the region have taken place since the last WABS Conference. The sedimentary basins of Western Australia are experiencing unprecedented activity, and the region has become one of the world's deep water E&P hot spots and a leading global supplier of LNG. Major international companies are again active onshore, exploring for conventional plays and unconventional resources. These developments have created a vibrant industry with a demand for another conference at which geologists, geophysicists, engineers, managers, government representatives, academics and students working on the region can receive and share the latest knowledge.

The WABS 2013 Conference and Exhibition to be held at the Perth Conference and Exhibition Centre from 18-21 August 2013 has been planned to meet this demand. The Conference

will be a "must" for Australian and overseas professionals with an interest in the latest industry developments and research in these basins. The Conference is being promoted both at home and abroad, and a large number of delegates is anticipated.

WABS 2013 will deliver a wide program with addresses by industry leaders, three days of technical sessions, an extensive exhibition, pre- and post-Conference field trips and short courses, and social events. The Call for Papers resulted in over 100 abstracts being submitted, from which around 60 peer-reviewed papers, together with numerous posters, will establish a new landmark in the understanding of the sedimentary basins of the region. At press time the final program was still being finalised. The following list of Technical Papers is preliminary and will be supplemented shortly. Delegates and potential registrants are being asked to check for the latest program details on the Conference Website, www.wabs2013.com.au, through which registrations may also be lodged and sponsorship and exhibition places reserved.

Under the Conference Theme "Expanding Our Horizons", the Conference Program includes daily Plenary Addresses, delivered by international experts and Australian industry leaders. These will be followed by concurrent Technical Sessions focussing on each of the main sedimentary basins and covering topics such as:

- New Oil and Gas Discoveries
- Canning Basin Revival

- The Triassic of the North West Shelf
- Unconventional Petroleum Resources
- The Latest Regional Geology
- New Hydrocarbon Plays
- Reservoir Models

A complimentary DVD containing the written papers and posters will be provided to all delegates at the start of the Conference.

The pre- and post-Conference program of events is expected to attract keen participation from specialists, regional explorationists and students who wish to follow a particular stream of interest. The events have been selected to complement the theme of the Conference and will be led by experts in their field. Events include separate core library workshops on *Technology of the North West Shelf* and *Giant Gas Field Reservoirs of the North West Shelf*. As previous core library workshops have been sell-out events, the organisers are encouraging intending participants to secure their spots early. Field trips are planned to the Canning Basin, Southern Carnarvon Basin and Timor Leste. The latter offers participants the rare opportunity to examine the exposed and deformed outer edge of the North West Shelf of Australia. The pre- and post-Conference short course program includes courses on shale gas evaluation, stratigraphic forward modelling, seismic stratigraphic interpretation, sequence stratigraphy, practical geochemistry and global G-plate interpretation. Places on several short courses have been reserved at concession rates for full-time students.



Plenary Paper Title	Author & Affiliation
An Overview of Unconventional Gas in Western Australia, and Other Recent Industry Developments	Bill Tinapple – Western Australia Department of Mines and Petroleum
Western Australian Basins Overview	Dr Marita Bradshaw – Geoscience Australia
The Prelude Natural Gas Project	Speaker TBA - Shell Development Australia
An Independent's View on Advances in Petroleum Industry Seismic Acquisition Technology	Dr Dave Monk – Apache Corporation
Developments in the Canning Superbasin	Eric Streitberg – Buru Energy
The Last 10 Years in WA Offshore Basins	Mark Thompson – Woodside Energy
4D Evolution of Rifted and Passive Margins — Models for the Development of North West Australia	Professor Ken McClay – Royal Holloway, University of London
Integration of Seismic Sequence Stratigraphy and Seismic Geomorphology for Prediction of Lithology	Dr Henry Posamentier – Chevron Petroleum
Foothills: drilling blind, side-tracking and struggling with seismic	Dr Jean-Claude Ringenbach – TOTAL E&P

Bonaparte Basin Papers	
Early Carboniferous petroleum source rocks of the southeastern Bonaparte Basin, Australia	ENI Australia
Discovery to development: a subsurface case history of Kitan	ENI Australia & ENI Indonesia
Assessing controls on nearshore clastic deposition in the Plover Formation using ichnology: Case studies from the Bonaparte Basin (Timor Sea, Australia and Timor Leste)	Firmground
Sedimentary and structural features of the Plio-Pleistocene Timor Accretionary Wedge, Timor Leste	ENI Australia

Canning Basin	Author & Affiliation
Petroleum Geochemistry of the Canning Basin, Western Australia	Geological Survey of Western Australia
Development of a Regional Stratigraphic Framework for Upper Devonian Reef Complexes Using Integrated Chronostratigraphy: Lennard Shelf, Canning Basin, Western Australia	Chevron & others
New insights into structural patterns of the northern Canning Basin, Western Australia	Geological Survey of Western Australia
Assessment Methodology for Unconventional Resource Estimation in the Canning Basin, Western Australia	Western Australia Department of Mines and Petroleum
Insights from the Automated Extraction of Surfaces from the Bunda 3D Seismic Survey	Total Depth & Buru Energy
The Exploration History of the Laurel Basin Centred Gas System, Canning Superbasin, Western Australia	Buru Energy Limited
Provenance constraints from detrital zircon U-Pb ages for the Paleozoic of the Canning and Officer basins, Western Australia: implications for basin evolution and interbasin connections	Geological Survey of Western Australia

Carnarvon Basin Papers	Author & Affiliation
Petroleum potential of the post-Triassic succession in the central Beagle Sub-basin, Northern Carnarvon Basin, North West Shelf, Australia	Geoscience Australia
Structural architecture of the Gorgon Platform, North West Shelf, Australia	Royal Holloway, University of London
Seismic Stratigraphy and Depositional Model of the Kimmeridgian-Tithonian Dupuy Formation	Chevron
Acme Field Discovery, Carnarvon Basin WA	Chevron
The Gorgon Field: An Overview	Chevron
Submarine slide and slump complexes, Exmouth Plateau, North West Shelf	Royal Holloway, University of London
Seismic Stratigraphic Relationships within a Lowstand Reservoir System: Examples from the Barrow Group, NW Shelf	BHP Billiton Petroleum
Extensional Fault Systems in the Exmouth Sub-basin, North West Shelf Australia	Royal Holloway, University of London

Carnarvon Basin Papers Continued ...	Author & Affiliation
The Vincent Oil Field, Exmouth Sub-Basin: Origin, Impact and Mapping of Reservoir Fluid Property Variation at the Metre-Scale	Woodside & others
What are the Barrow Deltas? Integrated sedimentological interpretation of the Barrow Group at Barrow Island	Chevron
Triassic Mungaroo and Brigadier of the Northern Carnarvon Basin	Woodside
Detailed Stratigraphic Relationships of Turbidite Reservoirs within the Stybarrow Field, NW Australia: Insights from High Resolution 4D Seismic	BHP Billiton Petroleum
The impact of multi-azimuthal seismic over Tidepole	Woodside
Northern Carnarvon Basin hydrocarbon recoveries using WAPIMS	Aardvark Exploration Consultants
Beyond the deltas: Late Triassic isolated carbonate platforms on the Exmouth Plateau, Carnarvon Basin, Western Australia	Woodside
Analysis of Geobody Geometries within the Fluvio-Deltaic Mungaroo Formation, NW Australia	University of Manchester
An Integrated Regional Triassic Stratigraphic Framework for the Carnarvon Basin, NWS, Australia	Chevron & others

North West Shelf Papers	Author & Affiliation
Identification of Fluid Flow Features in the Shallow and Deep Subsurface and their Implications for Prospect and Geohazard Assessment: Examples from the Australian Northwest Shelf	Total Depth & others
Newly recognised continental fragments rifted from the West Australian margin	University of Sydney
Neotectonic evidence for a crustal strain gradient on the central-west Western Australian margin	Geoscience Australia
Identifying and reducing exploration risks associated with igneous systems in sedimentary basins using seismic and thermal history data	University of Adelaide
Use of U-Pb geochronology to further our insights into provenance pathways on the North West Shelf, Australia	Geoscience Australia
A new sequence stratigraphic framework for the North West Shelf, Australia	Woodside

Perth Basin Papers	Author & Affiliation
Northern extension of active petroleum systems in the offshore Perth Basin — an integrated stratigraphic, geochemical, geomechanical and seepage study	Geoscience Australia
Tectonic evolution and continental fragmentation of the southern West Australian margin	University of Sydney
Structural Architecture of Australia's Southwest Continental Margin and Implications for Early Cretaceous Basin Evolution	Geoscience Australia
Analysis of seabed features for signs of seepage: results from the 2012 marine surveys in the southern Perth and Bonaparte basins	Geoscience Australia

Other Basins & General Interest Papers	Author & Affiliation
Impacts of igneous intrusions on source and reservoir potential in prospective sedimentary basins	Australian School of Petroleum
Recent mega-tsunamis in the Shark Bay, Pilbara, and Kimberley areas of Western Australia	Geological Survey of Western Australia
Depositional history of the Early to Middle Jurassic deltaic reservoirs in Calliance and Brecknock fields (Plover Formation), Browse Basin, North West Shelf, Australia	The University of Western Australia
Mobile salt structural controls on the development of the hydrocarbon exploration potential of the Bremer Basin	Bradshaw Geoscience Consultants & others
The influence of exhumation on prospectivity in the sedimentary basins of WA	Geotrack International
Estimating vertical motions of Western and Northern Australia over the past 30 Ma from river profile analysis and geodynamic modelling	University of Sydney
A Paleozoic perspective of west Australia	Geological Survey of Western Australia
Depositional Analogues & Subsurface Uncertainty Management: Implications for Reservoir Characterisation & Modelling	Woodside



Outcropping Dean Quartzite Formation in the Amadeus Basin
(Photo courtesy of Heidi Allen)

Table 1. 2012 Production by Field and Cumulative Production WA Onshore and State Waters as at 31 December 2012

Field	Operator	2012 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	13,414.4	169.9	8296.1	546,298.4	4,219.9	38,979.1	TL/1
Albert	Apache	4084.6	41.4	1516.1	74,205.6	137.4	9557.1	TL/6
Apium	AWE	0.0	6.5	803.3	0.0	391.5	33,744.3	L1
Bambra	Apache	29,958.5	4835.9	77,828.7	383,374.5	158,114.9	1,347,582.7	TL/1
Barrow Island	Chevron	314,576.0	0.0	30,965.4	50,904,050.0	0.0	5,374,374.4	L1H
Blina	Buru Energy	903.0	0.0	0.0	298,698.0	0.0	0.0	L6
Boundary	Buru Energy	217.0	0.0	0.0	21,180.0	0.0	0.0	L6
Corybas	AWE	0.0	16.3	866.1	0.0	232.3	12,443.1	L2
Cowle	Chevron	1311.0	0.0	568.0	537,068.0	0.0	91,871.0	TL/4
Crest	Chevron	254.0	0.0	1099.0	275,465.0	108.0	64,247.0	L12, L13
Dongara	AWE	849.3	0.0	17,649.9	195,070.3	49,681.0	12,927,489.9	L1, L2
Double Island	Apache	2793.6	40.1	2549.3	708,510.6	2943.1	59,149.3	TL/9
Eremia	AWE	23.2	0.0	29.6	244,037.2	0.0	14,629.6	L1
Harriet	Apache	9153.7	140.8	7555.1	8,232,653.7	61,226.8	1,510,682.1	TL/1
Hovea	AWE	1364.8	0.0	993.0	1,170,005.8	251.0	104,830.0	L1
Jingemia	Origin	12,610.0	0.0	1001.9	745,616.0	0.0	36,542.9	L14
Lee	Apache	0.0	1699.3	11,185.8	4.0	110,094.3	726,034.8	TL/1
Little Sandy	Apache	1726.9	24.5	1950.3	95,189.9	491.5	15,906.3	TL/6
Mohave	Apache	5481.1	216.8	8609.5	167,857.1	585.8	39,044.5	TL/6
North Alkimos	Apache	18.9	0.0	17.3	12,652.9	98.0	22,699.3	TL/6
Pedirka	Apache	6680.9	58.6	4739.6	340,076.9	1366.6	45,437.6	TL/6
Redback	Origin	0.0	290.0	186,882.3	0.0	432.0	311,985.3	L11
Roller	Chevron	28,420.0	0.0	11,748.0	7,184,779.0	0.0	781,782.0	TL/7
Rose	Apache	0.0	3751.2	28,566.2	0.0	208,820.2	1,027,695.2	TL/1
Saladin	Chevron	55,517.0	0.0	23,361.0	15,584,814.0	0.0	1,785,246.0	TL/4
Simpson	Apache	10,766.6	2028.5	3137.8	857,264.6	14,299.5	90,199.8	TL/1
Skate	Chevron	0.0	0.0	105.0	266,950.0	8873.0	178,287.0	TL/7
South Plato	Apache	1876.2	0.5	91.8	704,788.2	899.5	51,782.8	TL/6
Sundown	Buru Energy	604.0	0.0	0.0	74,112.0	0.0	0.0	L8
Ungani	Buru Energy	12,095.0	0.0	4461.0	12,095.0	0.0	4461.0	EP 391
Victoria	Apache	3882.0	41.4	1397.0	61,014.0	470.4	11,374.0	TL/6
West Cycad	Apache	2600.8	8.5	777.0	217,393.8	535.5	36,581.0	TL/9
West Terrace	Buru Energy	67.0	0.0	0.0	39,589.0	0.0	0.0	L8
Wonnich	Apache	0.0	10,173.5	142,573.1	0.0	476,894.5	4,828,573.1	TL/8
Yammaderry	Chevron	109.0	0.0	11,016.0	858,332.0	0.0	128,954.0	TL/4
Total		521,358.5	28,606.3	617,242.5	90,813,145.5	1,101,166.7	31,712,166.2	

Table 2a. Petroleum Reserves Estimates by Basin as at 31 December 2011 (metric units)

Basin	Oil		Sales Gas		Condensate	
	GL		Gm ³		GL	
Category 1	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	21.181	9.429	0.356	0.158
Browse	0.000	0.000	63.712	44.174	19.450	13.016
Northern Carnarvon	58.969	24.123	1,152.046	917.330	72.001	57.661
Perth	1.022	0.712	0.20	0.138	0.001	0.001
Total	59.99	24.84	1237.14	971.07	91.81	70.84
Category 2	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	60.698	34.118	1.650	0.957
Browse	0.000	0.000	504.300	504.300	66.300	66.300
Northern Carnarvon	4.329	2.117	720.511	406.398	38.347	19.622
Total	4.33	2.12	1285.51	944.82	106.30	86.88
Category 3	P50	P90	P50	P90	P50	P90
Browse	0.000	0.000	348.207	276.519	74.537	60.408
Northern Carnarvon	8.263	4.975	105.548	67.226	13.829	8.514
Perth	0.000	0.000	1.148	0.454	0.001	0.000
Total	8.26	4.98	454.90	344.20	88.37	68.92
Category 4	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	13.180	0.446	0.074	0.022
Browse	0.000	0.000	34.790	16.175	3.382	1.259
Canning	0.046	0.017	2.737	0.707	0.620	0.151
Carnarvon	50.338	31.756	494.842	308.921	21.808	13.927
Perth	0.000	0.000	5.500	5.500	0.000	0.000
Total	50.38	31.77	551.05	331.75	25.88	15.36
GRAND TOTAL	122.97	63.70	3528.60	2591.84	312.36	242.00

Table 2b. Petroleum Reserves Estimates by Basin as at 31 December 2011 (field units)

Basin	Oil		Sales Gas		Condensate	
	MMbbl		Tcf		MMbbl	
Category 1	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	0.748	0.333	2.243	0.998
Browse	0.000	0.000	2.249	1.559	122.339	81.869
Northern Carnarvon	370.906	151.730	40.684	32.395	452.876	362.677
Perth	6.430	4.481	0.006	0.004	0.006	0.006
Total	377.34	156.21	43.69	34.29	577.46	445.55
Category 2	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	2.143	1.204	10.378	6.025
Browse	0.000	0.000	17.809	17.809	417.014	417.014
Northern Carnarvon	27.232	13.318	25.444	14.351	241.195	123.418
Total	27.23	13.32	45.40	33.36	668.59	546.46
Category 3	P50	P90	P50	P90	P50	P90
Browse	0.000	0.000	12.296	9.765	468.828	379.960
Northern Carnarvon	51.975	31.295	3.727	2.374	86.983	53.553
Perth	0.000	0.000	0.040	0.016	0.011	0.005
Total	23.84	14.78	23.60	17.17	755.02	547.45
Category 4	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	0.465	0.015	0.469	0.143
Browse	0.000	0.000	1.228	0.571	21.277	7.919
Canning	0.289	0.109	0.096	0.024	3.899	0.949
Carnarvon	316.616	199.740	17.475	10.909	137.171	87.601
Perth	0.000	0.000	0.194	0.194	0.000	0.000
Total	316.91	199.85	19.46	11.71	162.82	96.61
GRAND TOTAL	773.45	400.67	124.60	91.52	1964.69	1522.14

NOTES

Canning Basin reserves are too small to measure.

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

Category 2 comprises estimates of recoverable reserves which are held under Retention Leases 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 FFDP 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.

Reserves estimates for 2012 have not yet been submitted by industry to DMP.

Table 3. Petroleum Wells in Western Australia - Onshore and State Waters 2012

Well Name	Class	On Off	Title	Operator	Latitude	Longitude	Gnd Elev/ Water Depth m	RT/ KB m	Spud Date	TD Date	Rig Release Date
Canning Basin											
Asgard 1	NFW	On	EP 371 R1	Buru	125.0142	-18.2470	123.0	128.9	28/08/12	29/09/12	11/10/12
Cyrene 1	NFW	On	EP 438	Gulliver/ Buru	122.4014	18.2763	47.0	53.0	13/12/12		
East Blina 1	NFW	On	L 6 R1	Oil Basin	124.5274	-17.6156	56.0	59.0	17/10/12	29/10/12	1/11/12
Gibb-Maitland 1	NFW	On	EP 450	New Standard	124.6407	-20.9956	296.0	305.3	5/12/12		
Nicolay 1	NFW	On	EP 456	New Standard	123.2586	-20.5700	278.0	287.7	18/08/12	18/10/12	2/11/12
Paradise 1 Deepening	NFW	On	EP 371 R1	Buru	124.5765	-17.9999	63.9	69.0	25/05/12	11/06/12	24/06/12
Ungani North 1	NFW	On	EP 391 R2	Buru	123.1644	-17.9329	62.0	67.4	5/07/12	17/08/12	1/09/12
Valhalla North 1	NFW	On	EP 371 R1	Buru	124.7298	-18.0258	109.0	115.1	16/01/12	22/02/12	18/03/12
Yulleroo 3	EXT	On	EP 391 R2	Buru	122.8916	-17.8498	47.0	53.1	25/05/12	27/07/12	5/08/12
Carnarvon Basin											
Barrow G48B MB	DEV	On	L 1H R2	Chevron	115.3668	20.8408	49.5	53.0	20/12/12		
Bambra 10H ST3	DEV	Off	TL/1 R1	Apache	115.6141	-20.6022	22.8	43.5	30/03/12	12/04/12	31/05/12
Perth Basin											
Evandra 2	NFW	On	L 1 R1	AWE	115.0209	-29.3483	16.6	22.0	9/04/12	16/04/12	19/04/12

Table 4. 2012 Surveys in Western Australia - State Onshore, State Waters & Territorial Waters

Survey Name	Class	On Off	Title	Operator	Commenced	Completed	2D Line km @ 31/12/2012	3D km ² @ 31/12/2012
Browse Basin								
Rosebud 3D M.S.S.	3D	Off	TR/5 R1	Woodside	19/10/12	31/10/12		37
Canning Basin								
Asgard 2D S.S.	2D	On	EP 371 R1	Buru	13/09/12	5/10/12	325	
Bracken/ Hassen 2011 Aerial Gravity and Magnetic Survey	AEROMAG	On	SPA 3 AO, SPA 4 AO	Hess	26/11/12		9036.70	
NSO 2012 Gravity Survey	GRAVITY	On	EP 417 R1	New Standard	22/08/12	5/09/12	4461.00	
Ungani 3D S.S.	3D	On	EP 391 R2, EP 428	Buru	19/10/12	28/10/12		21
Yakka Munga 2D S.S.	2D	On	EP 428, EP 391 R2	Buru	27/08/12	11/09/12	218.74	
Carnarvon Basin								
Byro Geochemical Survey	GEOCHEM	On	SPA 5 AO	Rusa Resources	8/11/12	19/11/12		
North Merlinleigh Geochemical Survey	GEOCHEM	On	SPA 6 AO	Rusa Resources	8/11/12	19/11/12		
Perth Basin								
Irwin 3D S.S.	3D	On	EP 320 R4, EP 368 R3, L1 R1, L2 R1, L7 R1	Origin Energy	16/02/12	10/04/12		273
Perth Basin #6 ESR Survey	ESR	On	SPA 1 AO	Southern Sky Energy	19/03/12	22/03/12	2100.00	

Classification

2D	2D Seismic Survey
3D	3D Seismic Survey
AEROMAG	Aeromagnetic Survey
ESR	Electron Spin Resonance
GEOCHEM	Geochemical Survey
GRAVITY	Gravity Survey

Table 5. List of Petroleum and Geothermal Titles and Holders as at 3 January 2013

PETROLEUM (SUBMERGED LANDS) ACT 1982 Exploration Permit	
Title	Registered Holders (* denotes Nominee)
TP/7 R4	Pan Pacific Petroleum (South Aust) Pty Ltd Santos (Bol) Pty Ltd Tap (Shelfal) Pty Ltd * Apache Oil Australia Pty Ltd
TP/8 R4	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd * Apache Northwest Pty Ltd
TP/15 R2	Westranch Holdings Pty Ltd
TP/23 R1	Apache Northwest Pty Ltd

PETROLEUM (SUBMERGED LANDS) ACT 1982 Pipeline Licence	
Title	Registered Holders (* denotes Nominee)
TPL/1 R1	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd * Apache Northwest Pty Ltd
TPL/2 R1	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd * Apache Northwest Pty Ltd
TPL/3 R1	Apache Oil Australia Pty Ltd Pan Pacific Petroleum (South Aust) Pty Ltd Santos (Bol) Pty Ltd Tap (Shelfal) Pty Ltd
TPL/4 R1	Apache Oil Australia Pty Ltd Pan Pacific Petroleum (South Aust) Pty Ltd Santos (Bol) Pty Ltd Tap (Shelfal) Pty Ltd
TPL/5 R1	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd * Apache Northwest Pty Ltd
TPL/6 R1	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd
TPL/7 R2	Apache Oil Australia Pty Ltd Pan Pacific Petroleum (South Aust) Pty Ltd Santos (Bol) Pty Ltd Tap (Shelfal) Pty Ltd
TPL/8	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd * Apache Northwest Pty Ltd
TPL/9 R1	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd
TPL/10	Inpex Alpha Ltd Mobil Exploration & Producing Australia Pty Ltd

	* Bhp Billiton Petroleum (Australia) Pty Ltd
TPL/11	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd
TPL/12	Apache East Spar Pty Ltd Apache Kersail Pty Ltd Santos (Bol) Pty Ltd * Apache Oil Australia 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	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd * Apache Northwest 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	Arc (Offshore Pb) Limited 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	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 * Chevron (Tapl) Pty Ltd
TPL/22	Chubu Electric Power Gorgon Pty Ltd Mobil Australia Resources Company Pty Limited

Table 5. List of Petroleum and Geothermal Titles and Holders as at 3 January 2013

	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
	* Chevron (Tapl) Pty Ltd
TPL/23	Apache Pvg Pty Ltd
	Bhp Billiton Petroleum (Australia) Pty Ltd
TPL/24	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
	* Chevron (Tapl) Pty Ltd

PETROLEUM (SUBMERGED LANDS) ACT 1982 Production Licence	
Title	Registered Holders (* denotes Nominee)
TL/1 R1	Harriet (Onyx) Pty Ltd
	Kufpec Australia Pty Ltd
	* Apache Northwest Pty Ltd
TL/2 R1	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (Bo) Pty Ltd
	Tap (Shelfal) Pty Ltd
TL/3 R1	Chevron (Tapl) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TL/4 R1	Chevron (Tapl) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TL/5 R1	Harriet (Onyx) Pty Ltd
	Kufpec Australia Pty Ltd
	* Apache Northwest Pty Ltd
TL/6 R1	Harriet (Onyx) Pty Ltd
	Kufpec Australia Pty Ltd
	* Apache Northwest Pty Ltd
TL/7	Chevron (Tapl) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TL/8	Harriet (Onyx) Pty Ltd
	Kufpec Australia Pty Ltd
	* Apache Northwest Pty Ltd
TL/9	Harriet (Onyx) Pty Ltd
	Kufpec Australia Pty Ltd
	* Apache Northwest 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 Holders (* denotes Nominee)
TR/1 R2	Harriet (Onyx) Pty Ltd
	Kufpec Australia Pty Ltd
	* Apache Northwest Pty Ltd
TR/3 R2	Apache Northwest Pty Ltd
TR/4 R1	Chevron (Tapl) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TR/5 R1	Bhp Billiton Petroleum (North West Shelf) Pty Ltd
	Bp Developments Australia Pty Ltd
	Japan Australia Lng (Mimi Browse) 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 AND GEOTHERMAL ENERGY RESOURCES ACT 1967 Access Authority to Deviated Well	
Title	Registered Holders (* denotes Nominee)
ADW 8/90-1	Chevron (Tapl) Pty Ltd
ADW 10/92-3	Harriet (Onyx) Pty Ltd
ADW 12/91-2	Harriet (Onyx) Pty Ltd
ADW 10/92-3	Kufpec Australia Pty Ltd
ADW 12/91-2	Kufpec Australia Pty Ltd
ADW 8/90-1	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
ADW 10/92-3	* Apache Northwest Pty Ltd
ADW 12/91-2	* Apache Northwest Pty Ltd
ADW 8/90-1	* Chevron Australia Pty Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967 Drilling Reservation	
Title	Registered Holders (* denotes Nominee)
DR 11	Titan Energy Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967 Exploration Permit	
Title	Registered Holders (* denotes Nominee)
EP 61 R7	Chevron (Tapl) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
EP 62 R7	Chevron (Tapl) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd

Table 5. List of Petroleum and Geothermal Titles and Holders as at 3 January 2013

EP 104 R5	Arc Energy Limited		* Rough Range Oil Pty Ltd
	Far Ltd	EP 413 R2	Arc Energy Limited
	Gulliver Productions Pty Ltd		Bharat Petroresources Limited
	Indigo Oil Pty Ltd		Norwest Energy NI
	Pancontinental Oil & Gas NI	EP 416 R1	Allied Oil & Gas Plc
	Phoenix Resources Plc		Erm Gas Pty Ltd
EP 110 R5	Pancontinental Oil & Gas NI		* Empire Oil Company (Wa) Limited
	Strike Energy Western Australia Pty Limited	EP 417 R1	Buru Energy Limited
EP 129 R5	Buru Energy Limited		New Standard Onshore Pty Ltd
EP 307 R5	Harriet (Onyx) Pty Ltd	EP 424	Pancontinental Oil & Gas NI
	Kufpec Australia Pty Ltd		Strike Energy Western Australia Pty Limited
	* Apache Northwest Pty Ltd	EP 426	Allied Oil & Gas Plc
EP 320 R4	Arc (Beharra Springs) Pty Ltd		Erm Gas Pty Ltd
	* Origin Energy Developments Pty Limited		Empire Oil Company (Wa) Limited
EP 321 R3	Alcoa Of Australia Limited		Westranch Holdings Pty Ltd
	* Latent Petroleum Pty Ltd	EP 428	Buru Energy Limited
EP 325 R3	Advent Energy Ltd		Diamond Resources (Canning) Pty Ltd
	Bow Energy Ltd	EP 429	Hess Australia (Canning) Pty Limited
	Rough Range Oil Pty Ltd	EP 430	Empire Oil Company (Wa) Limited
	Strike Energy Western Australia Pty Limited	EP 431	Buru Energy Limited
EP 357 R3	Chevron (Tap) Pty Ltd		Diamond Resources (Fitzroy) Pty Ltd
	Mobil Australia Resources Company Pty Limited	EP 432	Allied Oil & Gas Plc
	Santos Offshore Pty Ltd		Erm Gas Pty Ltd
	* Chevron Australia Pty Ltd		* Empire Oil Company (Wa) Limited
EP 358 R3	Harriet (Onyx) Pty Ltd	EP 433 R1	Lansvale Oil & Gas Pty Ltd
	Kufpec Australia Pty Ltd		Pace Petroleum Pty Ltd
	* Apache Northwest Pty Ltd	EP 434 R1	Pace Petroleum Pty Ltd
EP 359 R2	Bounty Oil & Gas NI		Rough Range Oil Pty Ltd
	Lansvale Oil & Gas Pty Ltd		* Lansvale Oil & Gas Pty Ltd
	Pace Petroleum Pty Ltd	EP 435 R1	Australian Oil Company No 3 Pty Limited
	Phoenix Resources Plc		Bounty Oil & Gas NI
	* Rough Range Oil Pty Ltd		Rough Range Oil Pty Ltd
EP 368 R3	Westranch Holdings Pty Ltd	EP 436	Buru Energy Limited
	* Empire Oil Company (Wa) Limited		Diamond Resources (Fitzroy) Pty Ltd
EP 371 R1	Buru Energy Limited	EP 437	Empire Oil Company (Wa) Limited
	Diamond Resources (Canning) Pty Ltd		Key Petroleum (Australia) Pty Ltd
EP 381 R3	Whicher Range Energy Pty Ltd	EP 438	Buru Energy Limited
EP 386 R3	Onshore Energy Pty Ltd		Diamond Resources (Canning) Pty Ltd
EP 389 R2	Erm Gas Pty Ltd		Gulliver Productions Pty Ltd
	Empire Oil Company (Wa) Limited		Indigo Oil Pty Ltd
	Wharf Resources Plc	EP 439	Falcore Pty Ltd
EP 390 R2	Buru Energy Limited		Indigo Oil Pty Ltd
	Diamond Resources (Canning) Pty Ltd		Jurassica Oil & Gas Plc
EP 391 R2	Buru Energy Limited		Longreach Oil Limited
	Diamond Resources (Fitzroy) Pty Ltd		Vigilant Oil Pty Ltd
EP 407 R1	Alcoa Of Australia Limited		* Rough Range Oil Pty Ltd
	* Latent Petroleum Pty Ltd	EP 440	Empire Oil Company (Wa) Limited
EP 408 R2	Whicher Range Energy Pty Ltd	EP 441 R1	Apache Northwest Pty Ltd
	* Calenergy Resources (Australia) Limited	EP 443	Conocophillips (Canning Basin) Pty Ltd
EP 412 R2	Bounty Oil & Gas NI		New Standard Onshore Pty Ltd

Table 5. List of Petroleum and Geothermal Titles and Holders as at 3 January 2013

EP 444	Rough Range Oil Pty Ltd
EP 447	Gcc Methane Pty Ltd
EP 448	Gulliver Productions Pty Ltd
	Indigo Oil Pty Ltd
	United Orogen Limited
EP 449	Hess Australia (Canning) Pty Limited
EP 450	Conocophillips (Canning Basin) Pty Ltd
	New Standard Onshore Pty Ltd
EP 451	Conocophillips (Canning Basin) Pty Ltd
	New Standard Onshore Pty Ltd
EP 453	Budside Pty Limited
	Pobelo Pty Ltd
EP 454	Empire Oil Company (Wa) Limited
EP 455	Titan Energy Ltd
	* Arc Energy Limited
EP 456	Conocophillips (Canning Basin) Pty Ltd
	New Standard Onshore Pty Ltd
EP 457	Rey Resources Ltd
	* Buru Fitzroy Limited
EP 458	Rey Resources Ltd
	* Buru Fitzroy Limited
EP 460	Falcore Pty Ltd
	Indigo Oil Pty Ltd
	Jurassica Oil & Gas Plc
	Longreach Oil Limited
	Vigilant Oil Pty Ltd
	* Rough Range Oil Pty Ltd
EP 461	Falcore Pty Ltd
	Indigo Oil Pty Ltd
	Jurassica Oil & Gas Plc
	Longreach Oil Limited
	Vigilant Oil Pty Ltd
	* Rough Range Oil Pty 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
EP 478	Buru Energy (Acacia) Pty Ltd
	Buru Energy Limited
EP 479	Erm Gas Pty Ltd
	Empire Oil & Gas NI
EP 480	Erm Gas Pty Ltd
	Empire Oil & Gas NI
EP 481	New Standard Onshore Pty Ltd
EP 482	New Standard Onshore Pty Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Geothermal Exploration Permit

Title	Registered Holders (* Denotes Nominee)
GEP 1	The University Of Western Australia
	* Green Rock Energy Limited
GEP 2	Green Rock Energy Limited
GEP 5	Granite Power Limited
GEP 6	Granite Power Limited
GEP 8	Csiro
GEP 13	New World Energy Limited
GEP 14	New World Energy Limited
GEP 15	New World Energy Limited
GEP 16	New World Energy Limited
GEP 17	New World Energy Limited
GEP 18	New World Energy Limited
GEP 19	New World Energy Limited
GEP 20	New World Energy Limited
GEP 21	New World Energy Limited
GEP 22	Aaa Energy Pty Ltd
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 30	New World Energy Limited
GEP 31	New World Energy Limited
GEP 32	New World Energy Limited
GEP 33	New World Energy Limited
GEP 34	New World Energy Limited
GEP 35	New World Energy Limited
GEP 36	New World Energy Limited
GEP 37	Greenpower Energy Limited
GEP 38	Greenpower Energy Limited
GEP 41	Mid West Geothermal Power Pty Ltd
GEP 42	Gt Power Pty Ltd
GEP 43	Kagara Ltd

Table 5. List of Petroleum and Geothermal Titles and Holders as at 3 January 2013

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967 Geothermal Special Prospecting Authority	
Title	Registered Holders (* denotes Nominee)
GSPA 1 AO	Green Rock Energy Limited

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967 Production Licence	
Title	Registered Holders (* Denotes Nominee)
L 1 R1	Apt Parmelia Pty Ltd Arc Energy Limited Origin Energy Developments Pty Limited
L 2 R1	Origin Energy Developments Pty Limited * Arc Energy Limited
L 4 R1	Arc Energy Limited
L 5 R1	Arc Energy Limited
L 6 R1	Buru Energy Limited
L 7 R1	Arc Energy Limited
L 8 R1	Buru Energy Limited
L 9 R1	Dbp Services Co Nominees Pty Limited
L 10 R1	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd
L 11	Arc (Beharra Springs) Pty Ltd * Origin Energy Developments Pty Limited
L 12	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd
L 13	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd
L 14	Arc Energy Limited Geary, John Kevin Norwest Energy NI 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
L 16	Australian Oil Company No 3 Pty Limited Bounty Oil & Gas NI Rough Range Oil Pty Ltd
L 1H R2	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967 Retention Lease	
Title	Registered Holders (* Denotes Nominee)
R 1 R1	Arc Energy Limited Far Ltd Gulliver Productions Pty Ltd Indigo Oil Pty Ltd Pancontinental Oil & Gas NI Phoenix Resources Plc
R 2 R1	Bhp Billiton Petroleum (North West Shelf) Pty Ltd Bp Developments Australia Pty Ltd Japan Australia Lng (Mimi Browse) 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 PIPELINES ACT 1969 Pipeline Licence	
Title	Registered Holders (* Denotes Nominee)
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	Arc Energy Limited
PL 7 R1	Buru Energy Limited
PL 8 R1	Mitsui Iron Ore Development Pty Ltd Nippon Steel Australia Pty Limited North Mining Limited Sumitomo Metal Australia Pty Ltd * Robe River Mining Co Pty Ltd
PL 12 R1	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd * Apache Northwest Pty Ltd
PL 14 R1	Apache Oil Australia Pty Ltd Pan Pacific Petroleum (South Aust) Pty Ltd Santos (Bol) Pty Ltd Tap (Shelfal) Pty Ltd
PL 15 R1	Chevron (Tapl) Pty Ltd Mobil Australia Resources Company Pty Limited Santos Offshore Pty Ltd * Chevron Australia Pty Ltd
PL 16	Dbp Services Co Nominees Pty Limited
PL 17	Harriet (Onyx) Pty Ltd Kufpec Australia Pty Ltd

Table 5. List of Petroleum and Geothermal Titles and Holders as at 3 January 2013

	* Apache Northwest Pty Ltd	PL 47	Dbngp (Wa) Transmission Pty Limited
PL 18	Arc (Beharra Springs) Pty Ltd	PL 48	Energy Generation Pty Ltd
	* Origin Energy Developments Pty Limited	PL 52	Apt Parmelia Pty Ltd
PL 19	Dbp Services Co Nominees Pty Limited	PL 53	Apt Parmelia Pty Ltd
PL 20	Dbp Services Co Nominees Pty Limited	PL 54	Western Power Corporation
PL 21	Chevron (Tapl) Pty Ltd		* Apt Pipelines (Wa) Pty Limited
	Mobil Australia Resources Company Pty Limited	PL 55	Global Advanced Metals Wodgina Pty Ltd
	Santos Offshore Pty Ltd	PL 56	Epic Energy (Wa) One Pty Ltd
	* Chevron Australia Pty Ltd	PL 57	Australian Gold Reagents Pty Ltd
PL 22	Epic Energy (Pilbara Pipeline) Pty Ltd	PL 58	Bhp Billiton Petroleum (North West Shelf) Pty Ltd
PL 23	Apt Parmelia Pty Ltd		Bp Developments Australia Pty Ltd
PL 24	Alinta Dewap Pty Ltd		Chevron Australia Pty Ltd
	Southern Cross Pipelines (Npl) Australia Pty Ltd		Japan Australia Lng (Mimi) Pty Ltd
	* Southern Cross Pipelines Australia Pty Limited		Shell Development (Australia) Proprietary Limited
PL 25	Southern Cross Pipelines Australia Pty Limited		* Woodside Energy Ltd
PL 26	Southern Cross Pipelines Australia Pty Limited	PL 59	Esperance Pipeline Co Pty Limited
PL 27	Southern Cross Pipelines Australia Pty Limited	PL 60	Gas Transmission Services Wa (Operations) Pty Ltd
PL 28	Southern Cross Pipelines (Npl) Australia Pty Ltd	PL 61	Apt Parmelia Pty Ltd
PL 29	Apache East Spar Pty Ltd	PL 62	Harriet (Onyx) Pty Ltd
	Apache Kersail Pty Ltd		Kufpec Australia Pty Ltd
	Santos (Bol) Pty Ltd		* Apache Northwest Pty Ltd
	* Apache Oil Australia Pty Ltd	PL 63	Gas Transmission Services Wa (Operations) Pty Ltd
PL 30	Apache East Spar Pty Ltd	PL 64	Arc Energy Limited
	Apache Kersail Pty Ltd		Origin Energy Developments Pty Limited
	Santos (Bol) Pty Ltd	PL 65	Dalrymple Resources Pty Ltd
	* Apache Oil Australia Pty Ltd		Norilsk Nickel Wildara Pty Ltd
PL 31	Epic Energy (Pilbara Pipeline) Pty Ltd	PL 67	Hamersley Iron Pty Ltd
PL 32	Apt Pipelines (Wa) Pty Limited	PL 68	Gas Transmission Services Wa (Operations) Pty Ltd
PL 33	Apt Pipelines (Wa) Pty Limited	PL 69	Dbngp (Wa) Nominees Pty Limited
PL 34	Newmont Yandal Operations Pty Ltd	PL 70	Arc (Offshore Pb) Limited
PL 35	Plutonic Operations Limited		Awe Oil (Western Australia) Pty Ltd
PL 36	Australian Pipeline Limited		Roc Oil (Wa) Pty Limited
PL 37	Norilsk Nickel Cawse Pty Ltd	PL 72	Edl Ngd (Wa) Pty Ltd
PL 38	Epic Energy (Pilbara Pipeline) Pty Ltd	PL 73	Redback Pipelines Pty Ltd
PL 39	Origin Energy Pipelines Pty Limited	PL 74	Edl Lng (Wa) Pty Ltd
PL 40	Dbngp (Wa) Nominees Pty Limited	PL 75	Eit Neerabup Power Pty Ltd
PL 41	Dbngp (Wa) Transmission Pty Limited		Erm Neerabup Pty Ltd
PL 42	Apache East Spar Pty Ltd	PL 76	Apa Group
	Apache Kersail Pty Ltd	PL 77	Sino Iron Pty Ltd
	Apache Northwest Pty Ltd	PL 78	Hamersley Iron Pty Ltd
	Apache Oil Australia Pty Ltd	PL 80	Latent Petroleum Pty Ltd
	Harriet (Onyx) Pty Ltd	PL 81	Apache Northwest Pty Ltd
	Kufpec Australia Pty Ltd	PL 82	Epic Energy (Pilbara Pipeline) Pty Ltd
	Santos (Bol) Pty Ltd	PL 83	Wa Gas Networks Pty Ltd
PL 43	Western Power Corporation	PL 84	Chubu Electric Power Gorgon Pty Ltd
	* Apt Pipelines (Wa) Pty Limited		Mobil Australia Resources Company Pty Limited
PL 44	Apt Parmelia Pty Ltd		Osaka Gas Gorgon Pty Ltd
PL 45	Apt Parmelia Pty Ltd		Shell Development (Australia) Proprietary Limited
PL 46	Apt Parmelia Pty Ltd		Tokyo Gas Gorgon Pty Ltd

Table 5. List of Petroleum and Geothermal Titles and Holders as at 3 January 2013

	* Chevron (Tapl) Pty Ltd		Mobil Australia Resources Company Pty Limited
PL 85	Chubu Electric Power Gorgon Pty Ltd		Osaka Gas Australia Pty Ltd
	Mobil Australia Resources Company Pty Limited		Shell Development (Australia) Proprietary Limited
	Osaka Gas Gorgon Pty Ltd		Tokyo Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited		* Chevron (Tapl) Pty Ltd
	Tokyo Gas Gorgon Pty Ltd	PL 93	Chubu Electric Power Gorgon Pty Ltd
	* Chevron (Tapl) Pty Ltd		Mobil Australia Resources Company Pty Limited
PL 86	Apache Northwest Pty Ltd		Osaka Gas Gorgon Pty Ltd
	Santos Offshore Pty Ltd		Shell Development (Australia) Proprietary Limited
PL 87	Apache Pvg Pty Ltd		Tokyo Gas Gorgon Pty Ltd
	Bhp Billiton Petroleum (Australia) Pty Ltd		* Chevron (Tapl) Pty Ltd
PL 88	Apache Pvg Pty Ltd	PL 94	Dbngp (Wa) Nominees Pty Limited
	Bhp Billiton Petroleum (Australia) Pty Ltd	PL 95	Dbngp (Wa) Nominees Pty Limited
PL 89	Crosslands Resources Ltd	PL 96	Erm Gas Pty Ltd
PL 90	Apache Pvg Pty Ltd		Empire Oil Company (Wa) Limited
	Bhp Petroleum (Australia) Pty Ltd		Wharf Resources Plc
PL 91	Dbngp (Wa) Nominees Pty Limited	PL 97	Robe River Mining Co Pty Ltd
PL 92	Chubu Electric Power Gorgon Pty Ltd	PL 98	Esperance Pipeline Co Pty Limited

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

DEPARTMENT OF STATE DEVELOPMENT TRADE AND INVESTMENT OFFICES

Perth — Western Australia

Tel: +61 8 9222 0566
Fax: +61 8 9222 0505
Email: invest@dspd.wa.gov.au

Middle East — Dubai

Tel: +971 4 343 3226
Fax: +971 4 343 3238

Europe — London

Tel: +44 20 7240 2881
Fax: +44 20 7240 6637

**People's Republic of China
— Shanghai**

Tel: +86 21 5292 5899
Fax: +86 21 5292 5889

India — Mumbai

Tel: +91 22 6630 3973
Fax: +91 22 6630 3977

**People's Republic of China
— Hangzhou**

Tel: +86 571 8795 0267
Fax: +86 571 8795 0295

Indonesia — Jakarta

Tel: +62 21 5290 2860
Fax: +62 21 5296 2722

Singapore

Tel: +65 6836 5626
Fax: +65 6836 5698

Japan — Tokyo

Tel: +81 3 5157 8281
Fax: +81 3 5157 8286

South Korea — Seoul

Tel: +82 2 722 1217
Fax: +82 2 722 1218

Japan — Kobe

Tel: +81 78 242 7705
Fax: +81 78 242 7707

KEY PETROLEUM CONTACTS

DEPARTMENT OF MINES AND PETROLEUM



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

EXECUTIVE

DIRECTOR GENERAL

Richard Sellers TEL: (08) 9222 3555

DEPUTY DIRECTOR GENERAL APPROVALS

Tim Griffin TEL: (08) 9222 3160

PETROLEUM DIVISION

TEL: (08) 9222 3622

FAX: (08) 9222 3799

EXECUTIVE

EXECUTIVE DIRECTOR

Bill Tinapple TEL: (08) 9222 3291

DIRECTOR TECHNOLOGY, PETROLEUM
AND GEOTHERMAL

Jeffrey Haworth TEL: (08) 9222 3214

RESOURCES

GENERAL MANAGER

Mike Middleton TEL: (08) 9222 3076

PETROLEUM TECHNOLOGIST

Stuart Webster TEL: (08) 9222 3023

SENIOR GEOSCIENTIST

Mark Keith Stevens TEL: (08) 9222 3011

SENIOR GHG STORAGE RESERVOIR ENGINEER

Jianhua Liu TEL: (08) 9222 3261

ACREAGE RELEASE

Richard Bruce TEL: (08) 9222 3314

PETROLEUM RESOURCE GEOLOGIST

Karina Jonasson TEL: (08) 9222 3445

SENIOR TECHNICAL OFFICER

Mark Fletcher TEL: (08) 9222 3652

PETROLEUM TENURE AND LAND ACCESS

GENERAL MANAGER

Beverley Bower TEL: (08) 9222 3133

MANAGER PETROLEUM REGISTER

Stephen Collyer TEL: (08) 9222 3318

MANAGER PETROLEUM AND
GEOTHERMAL INFRASTRUCTURE

Walter Law TEL: (08) 9222 3319

TITLES COORDINATOR

Alyssa Harrison TEL: (08) 9222 6143

BUSINESS DEVELOPMENT

GENERAL MANAGER

Mark Gabrielson TEL: (08) 9222 3010

PRINCIPAL LEGISLATION AND POLICY OFFICER

Colin Harvey TEL: (08) 9222 3315

PRINCIPAL POLICY OFFICER

Jason Medd TEL: (08) 9222 0442

PROJECT COORDINATION AND
INFORMATION MANAGEMENT

Hazel Harnwell TEL: (08) 9222 3490

APPROVALS MONITORING OFFICER

Hayden Samuels TEL: (08) 9222 3362

ENVIRONMENT DIVISION

EXECUTIVE DIRECTOR

Phil Gorey TEL: (08) 9222 3290

DIRECTOR OPERATIONS

Steve Tantala TEL: (08) 9222 3447

GENERAL MANAGER PETROLEUM ENVIRONMENT

Kim Anderson TEL: (08) 9222 3142

RESOURCES SAFETY DIVISION

DIRECTOR PETROLEUM SAFETY

Alan Gooch TEL: (08) 9358 8113

TEAM LEADERS

Vun Pheng Leong TEL: (08) 9222 3485

Kevin Clary TEL: (08) 9222 3409

Bob Temple TEL: (08) 9222 3410

GEOLOGICAL SURVEY DIVISION

TEL: (08) 9222 3222/3168

FAX: (08) 9222 3633

EXECUTIVE

EXECUTIVE DIRECTOR

Rick Rogerson TEL: (08) 9222 3170

CHIEF GEOSCIENTIST

Roger Hocking TEL: (08) 9222 3590

RESOURCES

MANAGER ENERGY GEOSCIENCE

Ted Bowen TEL: (08) 9222 3124

MANAGER PETROLEUM EXPLORATION INFORMATION

Felicia Irimies TEL: (08) 9222 3268

STRATEGIC PLANNING AND ROYALTIES

GENERAL MANAGER

David Norris TEL: (08) 9222 3304

MANAGER SYSTEMS AND ANALYSIS

Vince D'Angelo TEL: (08) 9222 3524

MANAGER PETROLEUM ROYALTIES AND ACCOUNTING

Angelo Duca TEL: (08) 9222 3662
