Department of State Development

South Australia
OTWAY BASIN
Acreage Release
OT2017-A

BIDS CLOSE 4.00 pm ACST
Friday 29 September 2017

Energy Resources Division
March 2017

SOUTH AUSTRALIA

Government of South Australia

CONTENTS

South Australia
OTWAY BASIN
Acreage Release Block OT2017-A

Energy Resources Division, Department of State Development[1]

BIDS CLOSE 4.00 pm Australian Central Standard Time, Friday 29 September 2017

THE OFFER

A new petroleum exploration licence (PEL) in the Otway Basin is being offered by the South Australian Government on the basis of work program bidding (Fig. 1). Block OT2017-A covers 1734 sq. km. comprising partial relinquishments from PEL 494 and full relinquishment from PEL 186. Fourteen petroleum wells have been drilled in the OT2017-A area. A total of 2294.2 line kilometres of 2D and 86.9 km^2 of 3D seismic data have been acquired within the block (Figs 2, 3). The block offers a diversity of play types and the opportunity to build a portfolio of prospects and leads across the Otway Basin. Royalties that may eventuate from the OT2017-A acreage release block will be subject to the recent policy announcement to share a part of the government's take of royalties through the *PACE* Royalty Return initiative.

Applicants should also note:

- in the event that additional Parks or Reserves are proclaimed under the *National Parks and Wildlife Act 1972* prior to the grant of a PEL, and where such Parks or Reserves prohibit the exploration for and production of petroleum, then the area of any such Parks or Reserves shall be excised from the area to be granted as a PEL.
- the *Petroleum and Geothermal Energy Act 2000* (PGE Act) requires licence holders to prepare
  - an Environmental Impact Report (EIR) in consultation with all potentially affected people, enterprises and organisations as a precedent to co-regulatory consideration of activity approval. EIRs document potential impacts on the social, natural and economic environments (which includes public health), and outline the extent to which these impacts are likely and manageable;
  - a Statement of Environmental Objectives (SEO), informed by an EIR, that must state the environmental objectives to be achieved in carrying out the specified activities, as well as the assessment criteria and conditions that must be met to ensure the objectives have been achieved by the licensee; and
  - in the case of any specific areas which may have unique values or importance, area- and activity-specific EIRs and SEOs can manage local to regional social, natural environment and economic risks. Control zones can be specified to protect areas of unique values and importance. Area- and activity-specific SEOs may incorporate control zone(s) and will be informed with targeted consultation focused on potentially affected people, enterprises, organisations and co-regulators. This will ensure that relevant risks to unique values are managed to an acceptable level through appropriate design, location, construction and operation, including monitoring of any proposed activities.

  If a proposed activity regulated pursuant to the PGE Act cannot demonstrate compliance with the objectives for the protection of social, natural and economic environments, then approval for the activity will not be granted.

  The value of contemporaneous, multiple land-use is a key factor in developing all EIRs and SEOs for upstream petroleum operations anywhere in the State, including the south east of South Australia.

1 The Energy Resource Division is scheduled to move from DSD to become a part of the Department of the Premier and Cabinet (DPC) in April 2017. The web-based version of this Acreage Release document will be updated in due course for any changes to web-links, etc.

In this regard – as stated above – defined control zones with special conditions to protect pre-existing land use and values are expected be a factor in EIRs and SEOs for regulated activities in the OT2017-A areas.

SUMMARY OF THE ONSHORE OTWAY BASIN

Age	Jurassic – Late Cretaceous
Area in South Australia	9650 km^2 (3730 sq. miles)
Exploration well density	1 well per 121 km^2 (1 well per 47 sq. miles)
Onshore commercial success rate	12%
Onshore technical success rate	19%
Depth to target zones	1000–4000+ m
Sedimentary thickness	>9 km
Hydrocarbon shows	Commercial gas from the Pretty Hill Formation and the Eumeralla Formation's Windermere Sandstone Member. Associated gas and 2000 bbl oil has been recovered on test from the Sawpit Sandstone Member of the Pretty Hill Formation.
First commercial discovery	1987 gas (Katnook 1), 1967 CO_2 (Caroline 1)
Identified initial reserves	128 PJ (121 x 10^{12} Btu) sales gas (in 8 fields)
Onshore undiscovered resources in conventional reservoirs (50% probability) **Onshore undiscovered resources in unconventional reservoirs (50% probability)**	870 PJ (825 bcf) sales methane gas (DSD[2] estimate, Morton and Boult 2001). 3123 PJ (2960 bcf) sales methane gas (Geoscience Australia estimate, 2017).
Production history	71.46 PJ (67.39 bcf) sales gas; 65,840 kL (414.166 x 10^3 bbl) condensate (Katnook, Ladbroke Grove, Redman, Haselgrove, Haselgrove South) to end October 2011 when production ceased. 795,000 tons (14.2 bcf at standard conditions) saleable CO_2 (Caroline) to end June 2016. Caroline ceased production in mid-January 2017.
Basin type	Rift
Depositional setting	Fluvial–lacustrine – marginal marine – deep water marine
Conventional reservoir types	Braided and meandering fluvial, deltaic and slope fan sandstones.
Unconventional reservoir types	To be established but possibly shale and low permeability sandstones.
Regional structure	Early half graben, late shelf collapse.
Top and lateral (across-fault) seals	Marine and lacustrine shales.
Source rocks	Widely preserved Jurassic – Early Cretaceous restricted lacustrine and Early Cretaceous marginal marine to possibly marine shales. Eumeralla coals are considered as the primary source-rock of: oil/condensate recovered from the Late Cretaceous in Caroline 1; and gas in the Windermere Sandstone Member in Katnook 1.
Depth to oil/gas window	2800–4000+ m (oil); 2600–4000+ m (gas)
Onshore Otway Basin petroleum wells (to February 2017)	101 (comprising 75 exploration, 8 development, 1 appraisal and 17 structural wells).
Geothermal wells (to February 2017)	6
Reflection seismic surveys	Onshore: 10,495 line-km 2D and 782 km^2 3D; Offshore: 25,842 line-km 2D and 373 km^2 3D.

LINKS

- Information Sheet P1 *Holders of petroleum and geothermal tenements in South Australia*
- OT2017-A acreage release web page

PREVIOUS ACREAGE RELEASES

- DSD previous onshore releases web page

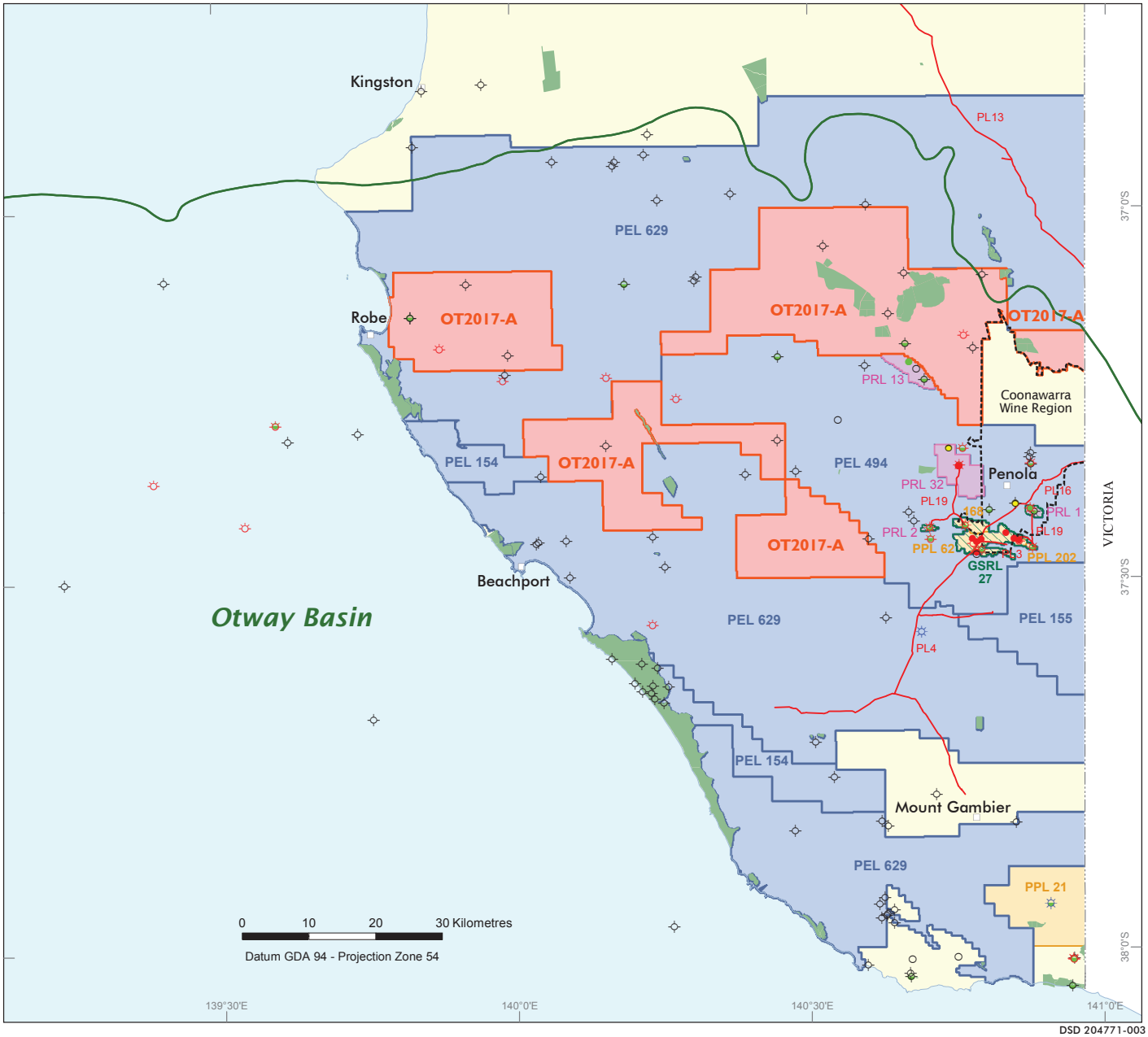
REPORTS

- The petroleum geology of South Australia, Volume 1: Otway Basin, 2nd edition (Boult and Hibburt, 2002)
- DSD Otway publications web page

2 The Energy Resource Division of the Department of State Development (DSD) will become a part of the Department of Premier and Cabinet (DPC) from 1 April 2017.

Otway Basin, South Australia

PETROLEUM LICENCES



Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas

- Otway Basin outline
- Park or reserve – no petroleum exploration access
- Coonawarra Wine Region

Petroleum wells

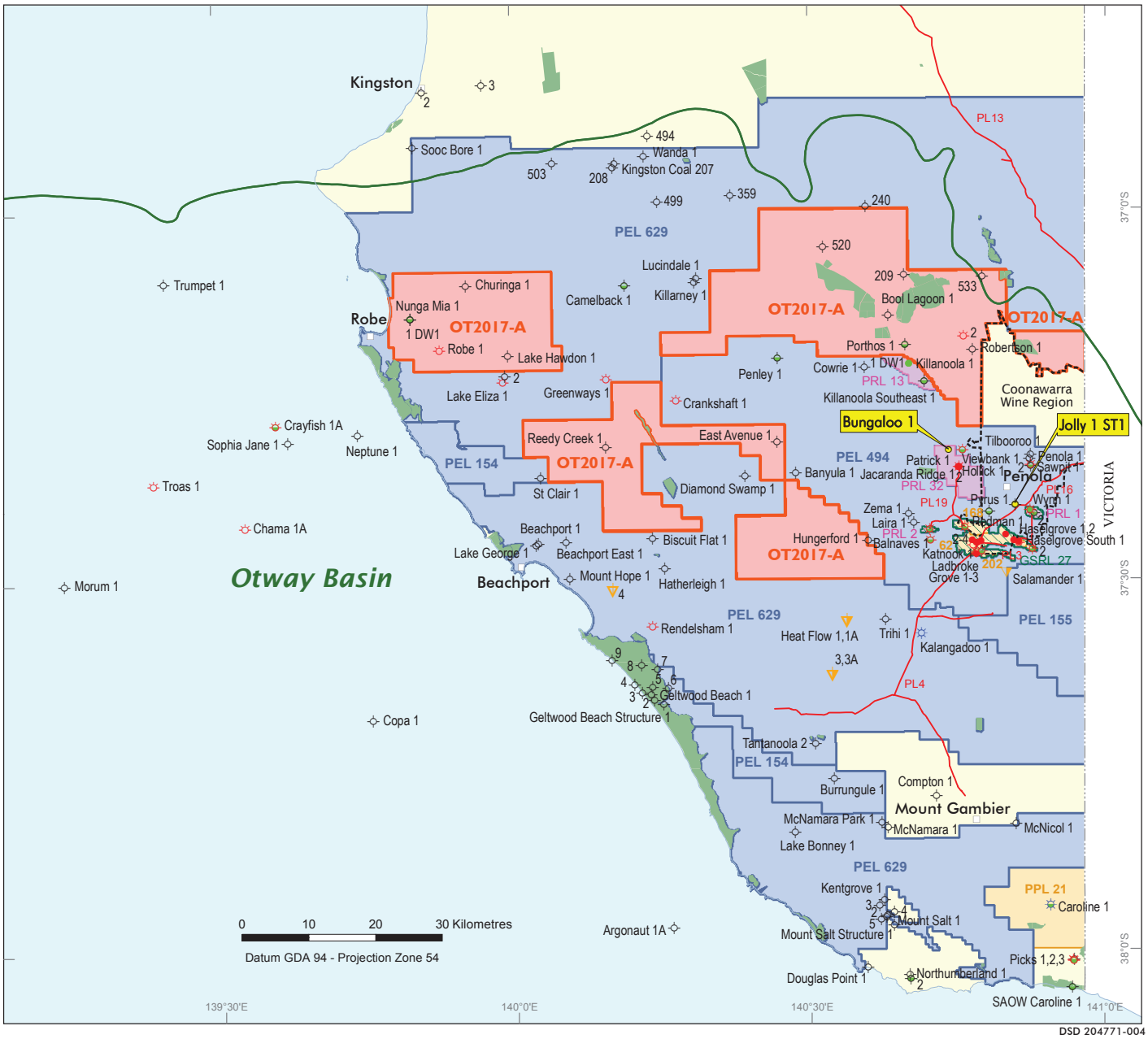
- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

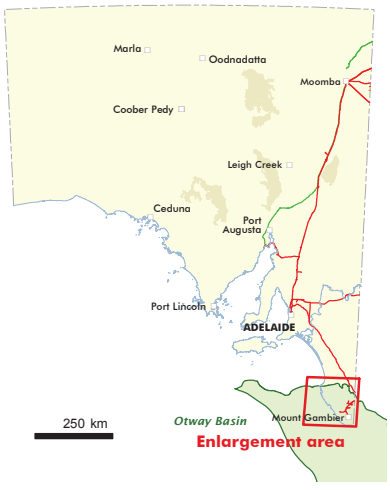
Government of South Australia
Department of State Development

Figure 1 Otway Basin petroleum licences and OT2017-A acreage release areas

Otway Basin, South Australia

PETROLEUM and GEOTHERMAL WELLS





Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas
- Otway Basin outline
- Park or reserve – no petroleum exploration access
- Coonawarra Wine Region

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Resource play well

Geothermal wells

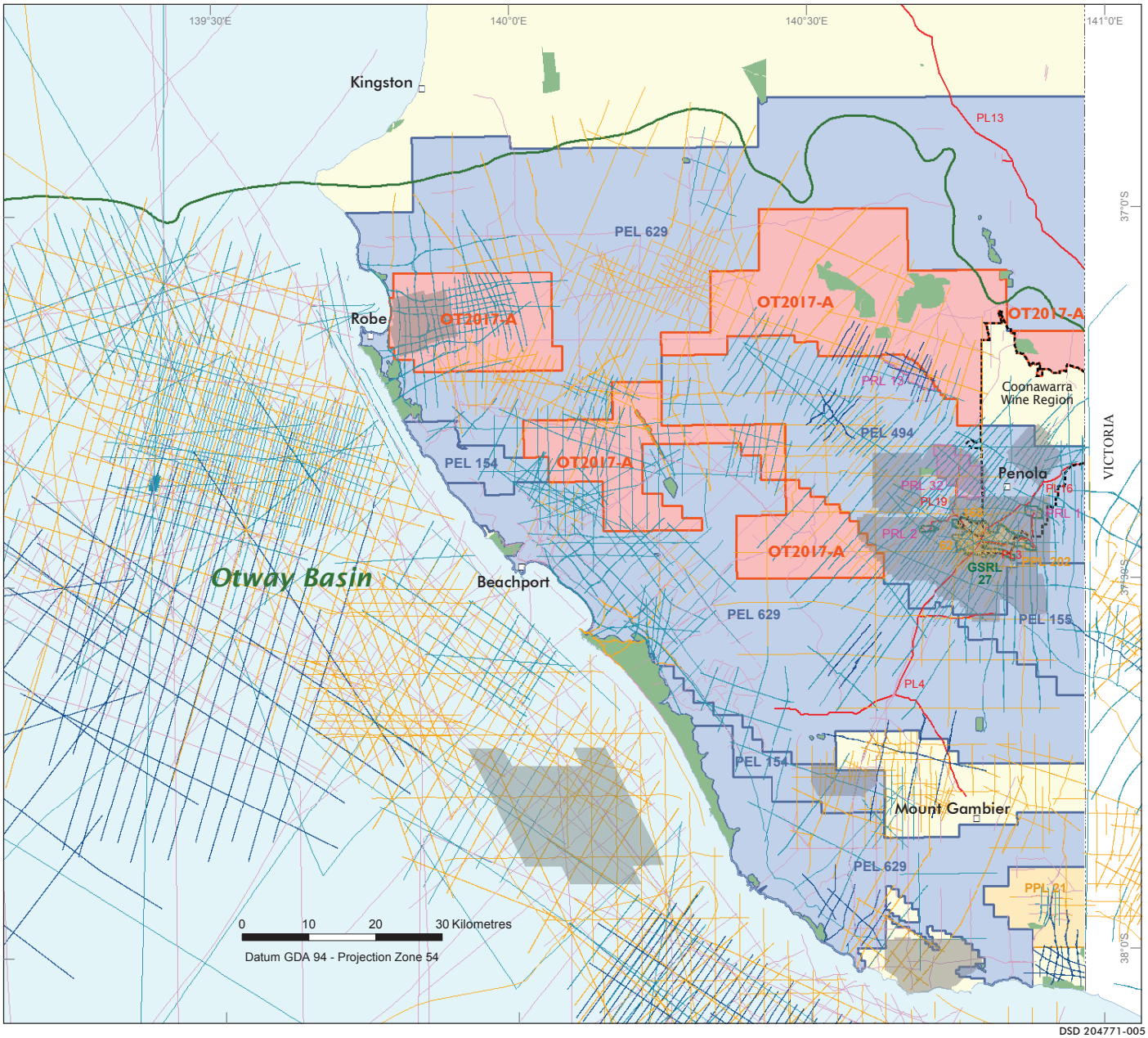
- Abandoned well
- Suspended well

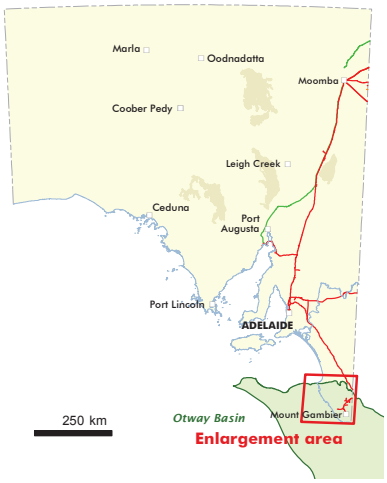
Government of South Australia
Department of State Development

Figure 2 Otway Basin petroleum and geothermal wells

Otway Basin, South Australia

SEISMIC SURVEYS





Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas

- Otway Basin outline
- Park or reserve – no petroleum exploration access
- Coonawarra Wine Region

Seismic surveys

2D Seismic survey lines

- Pre 1980
- 1980 to 1989
- 1990 to 1999
- Post 2000

- 3D Seismic survey areas

Government of South Australia
Department of State Development

Figure 3 Otway Basin seismic surveys

INTRODUCTION

The Otway Basin is one of the best known and most actively explored of the series of Mesozoic rift basins that span the southern coastline of Australia, and which were formed as a result of rifting between the Antarctic and Australian plates (Fig. 4).

Seismic studies have shown that its structural evolution is analogous to basins such as the Tucano–Reconcauo Basin of Brazil and the Gabon and Cabinda basins of the west coast of Africa. Each of these basins contains at least one giant oil field.

The main below-ground, technical risk factors are structural integrity and relatively small targets. Regional 3D seismic surveys have been used to mitigate these below-ground technical risks e.g. explorers are better able to accurately map potentially economic prospects. Additionally, now routine fault leakage analysis of prospects has been used by some operators to rank prospects prior to drilling.

The economic viability of small gas discoveries is improved by the proximity to markets. Modest-in-size gas discoveries can fuel both gas and electricity generation opportunities. One example of modest gas reserves underpinning profitable peak power generation opportunities was demonstrated by the 80 MW Ladbroke Grove Power Station.

In 2002–03, the SEA Gas pipeline was constructed to transport gas to Adelaide from offshore Otway gas fields and the Iona gas storage facility in Victoria (Fig. 1). Origin Energy Retail Ltd constructed and commissioned the SESA Pipeline in 2005. This 45 km pipeline connects the SEA Gas Pipeline in Victoria to Epic Energy's South East Pipeline System and the Ladbroke Grove Power Station.

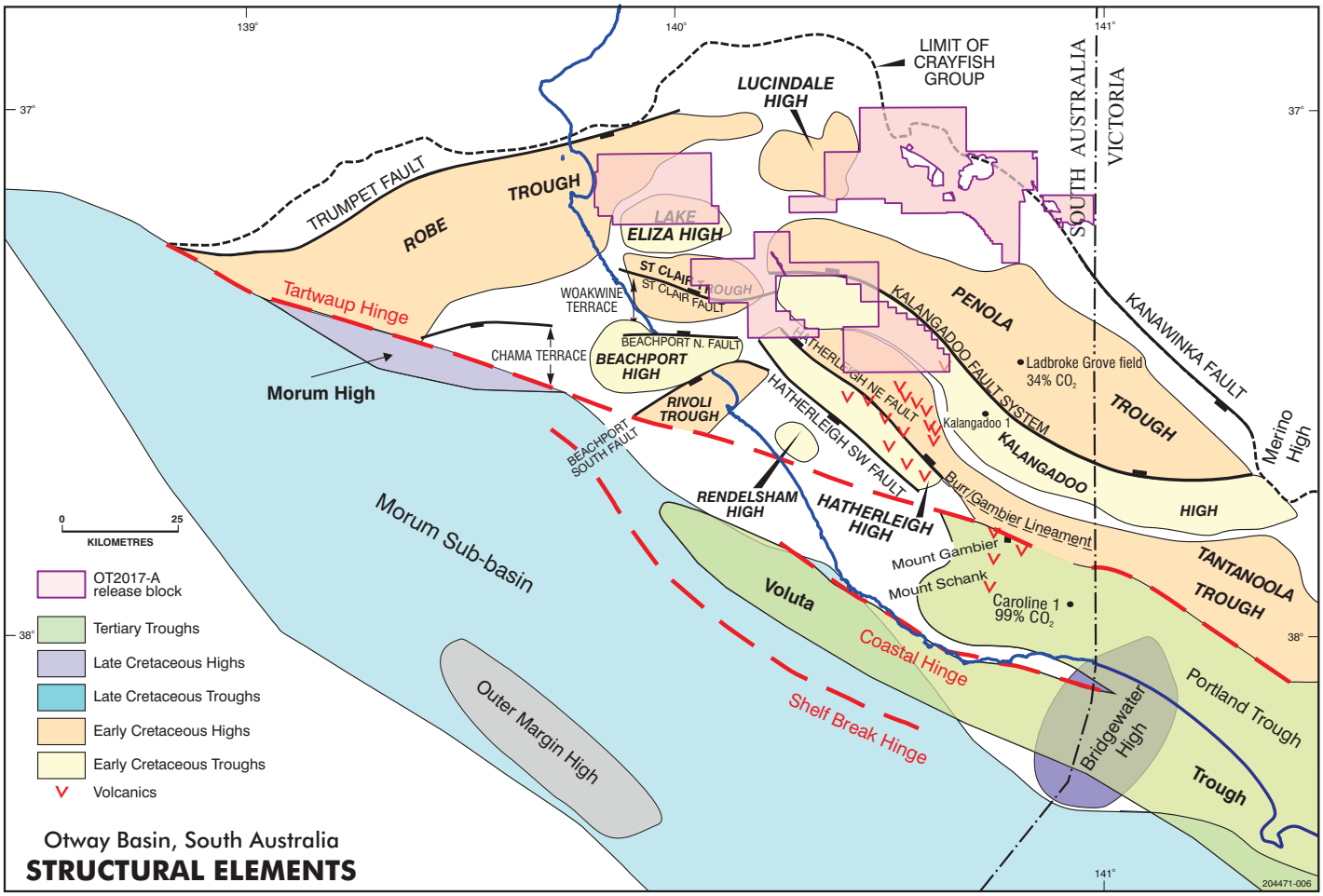


Figure 4 Otway Basin structural elements

PETROLEUM GEOLOGY

Structural setting

The northern limit is defined by outcropping early Palaeozoic metamorphic and igneous rocks (the Padthaway Ridge) and Otway Basin sedimentary deposits occur up to 125 km offshore. Approximately 70% of the basin is offshore. To the west, the basin passes into the offshore Duntroon Sub-basin of the Bight Basin, and in the east the Otway Basin continues, both onshore and offshore Victoria. Offshore, the Otway Basin is locally bound by a Palaeozoic outer-margin high.

Discrete grabens and half-grabens are interpreted over much of the Otway Basin. These grabens and half-grabens have been drilled onshore, and are filled with Jurassic to Early Cretaceous (in age) rift sequence strata. These Mesozoic depocentres are interpreted to exist across most of the basin (Figs 4, 6, and 7) but have not yet been penetrated offshore in the Otway Basin. The rate of Cretaceous rifting slowed during the Barremian to Albian (Early Cretaceous) but rapidly increased before the end of the Albian in the northern part of the basin. Over 4 km of late Albian to Late Cretaceous sediments occur within the offshore Morum Sub-basin.

At least four major sedimentary sequences are targets for petroleum exploration in the onshore Otway Basin in South Australia:

(i) The Late Jurassic Tithonian sequence (Casterton Formation, synrift and a deeper unnamed unit) is known in the deeper portions and northern flank of the Penola Trough and comprises volcanic and algal rich lacustrine shale that grade from oil shale to shale oil with depth (and increasing organic thermal maturity) that are yet to be fully tested (Figs 5 and 9);

(ii) The Early Cretaceous Berriasian to Hauterivian (Early Cretaceous) sequence (Crayfish Group, early rift) is known only from the northern area, where E–W and NW–SE trending half-grabens (Robe, Penola, St Clair and Tantanoola Troughs; Figs 5, 9,10) contain fluvial to lacustrine sediments that are proven gas reservoirs;

(iii) The Early Cretaceous Barremian to Albian sequence (Eumeralla Formation, onshore sag phase) containing lacustrine, back-swamp facies and proven gas reservoirs hosted in meandering fluvial Windermere Sandstone Member and unnamed younger sandstones (Fig. 5); and

(iv) The Late Cretaceous Cenomanian to Maastrictian sequence (Sherbrook Group) occurs as a deltaic to deep-water wedge south of the Tartwaup Hinge (Figs 5, 8 and 11).

Stratigraphy of the Otway Basin

The oldest unit is the Casterton Formation, a volcanic and lacustrine shale unit that occurs in some wells on the northern flank of the Penola Trough in South Australia and to the east in Victoria. The Casterton Formation may occur in the undrilled deeper parts of the Robe and Penola Troughs in South Australia (Figs 4 and 5).

The Crayfish Group fills half-grabens identified in Figure 7. The earliest (basal) unit in the Crayfish Group is the Pretty Hill Formation, a braided fluvial sandstone that occurs in the deepest parts of the troughs. This is overlain with fluvio-lacustrine shales and siltstones of the Laira Formation, which in turn is overlain by the braided fluvial lithologies of the Katnook Sandstone. The Katnook Sandstone thickens to the northwest, and is in part a time-equivalent sandy facies of the Laira Formation. On the extreme northern margin both the Katnook Sandstone and Windermere Sandstone Member pinch out, the Pretty Hill Formation is absent and the Crayfish Group is only represented by the shaly Laira Formation (Fig. 5).

The Crayfish Group is unconformably overlain by the Eumeralla Formation and form the Otway Supergroup. The Eumeralla Formation is a fluvial siltstone – shale sequence with some minor coal and meandering fluvial sandstone units. The Windermere Sandstone is a basal equivalent to the Eumeralla Formation and a regionally extensive transgressive sandstone unit which overlays the unconformity above the Crayfish Group. The Eumeralla Formation generally thickens to the southwest within the Early Cretaceous troughs (such as the Penola Trough). The Eumeralla Formation (Fig. 5) comprises extensive fluvio-lacustrine and volcanogenic facies deposited during the sag phase of the basin.

The Late Cretaceous Sherbrook Group (Fig. 5) overlies the Otway Supergroup as a deltaic

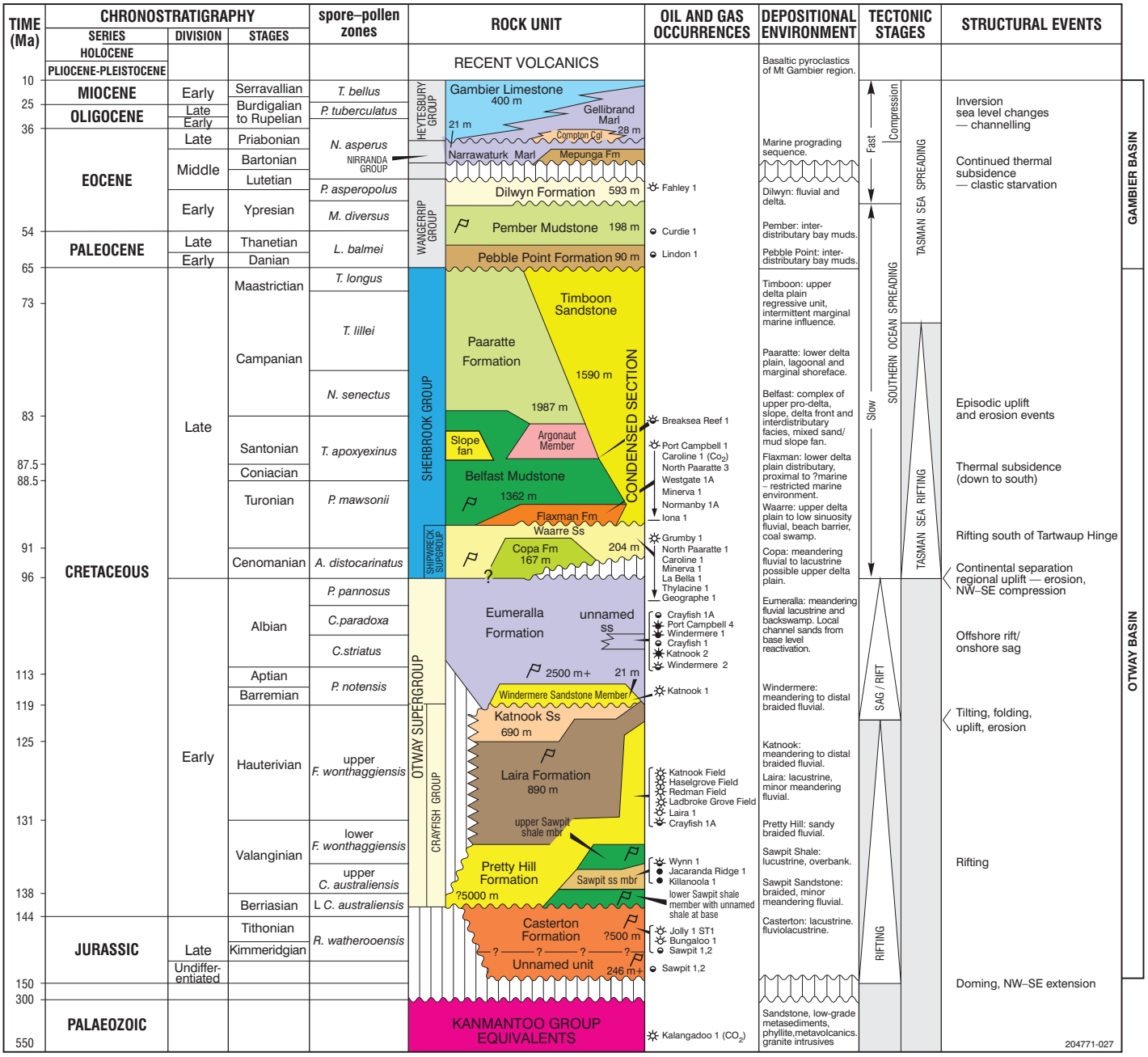


Figure 5 Otway Basin stratigraphy

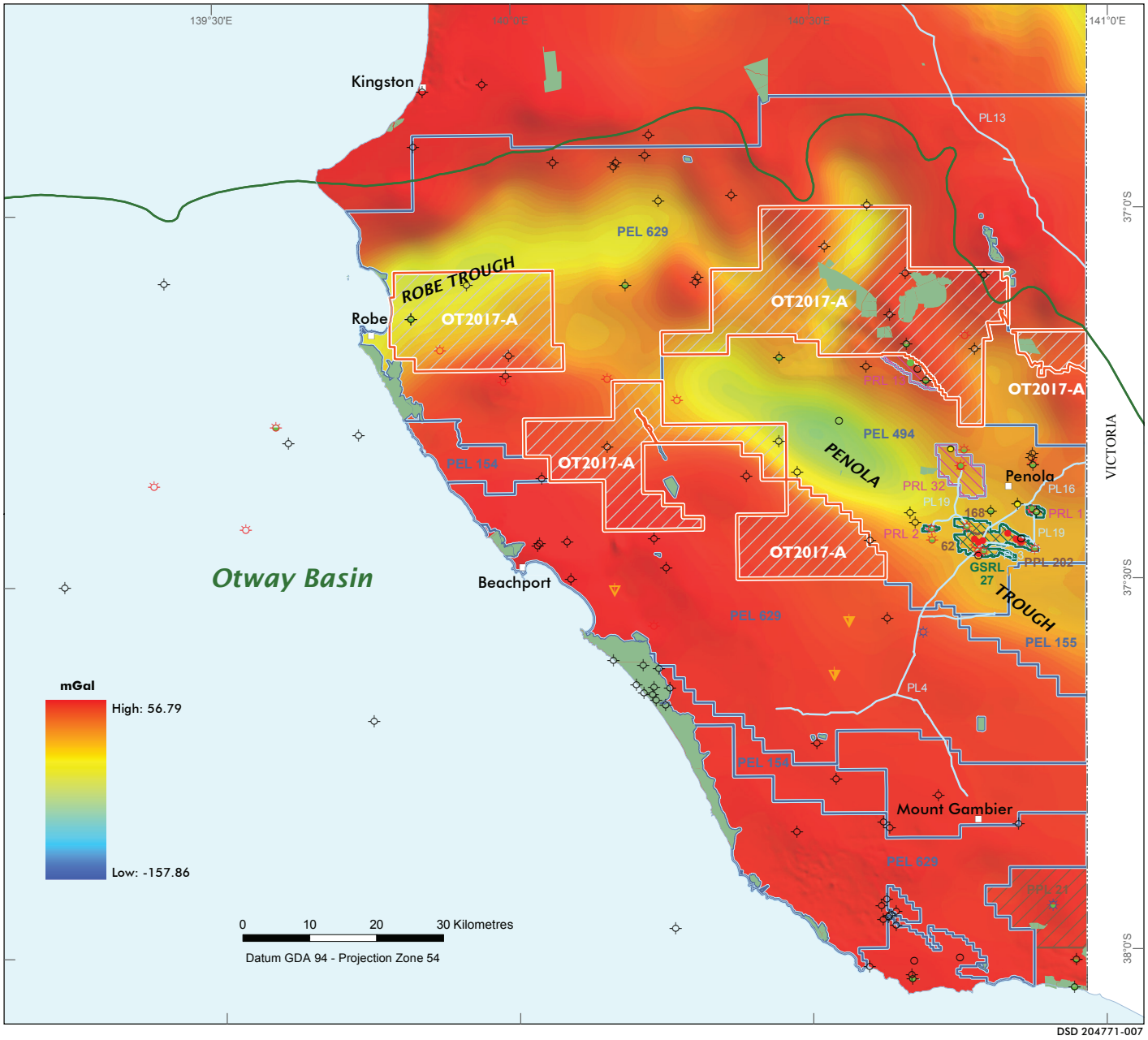
wedge that rapidly thickens to the south accounting for most of the sediment in the Morum Sub-basin. In the northern part of the Otway Basin, the Sherbrook Group is thin and comprised of a coarse grained sandstone that is a condensed equivalent of the Copa, Waarre, Flaxman, Belfast, Paaratte and Timboon units found to the south. Offshore, beyond the present day shelf, thick packages of high-amplitude reflectors indicate the possible presence of paralic oil-prone coals or marine oil shale. The Belfast Mudstone to Timboon Sandstone sequence represents a prograding delta with early marine influence and deep-water submarine slope-fans along the outer margin. Thickening of Cainozoic strata south of the Tartwaup Hinge provide adequate depth of burial to generate hydrocarbons from the Late Cretaceous sequence (Fig. 8). Regional cross-sections across the Otway Basin are shown in Figures 9, 10 and 11.

Source rock distribution and maturity modelling

Source rocks are capable of producing both gas and oil and the present day temperature gradient is moderate, averaging approximately 2.7° C – 3.6° C per 100 m depth. There are numerous rocks with significant organic richness throughout the Late Jurassic to Tertiary section of the western Otway Basin (Fig. 4). For the northern portion of the acreage release

Otway Basin, South Australia

GRAVITY IMAGE MAP



Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas
- Otway Basin outline
- Park or reserve – no petroleum exploration access

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Geothermal wells

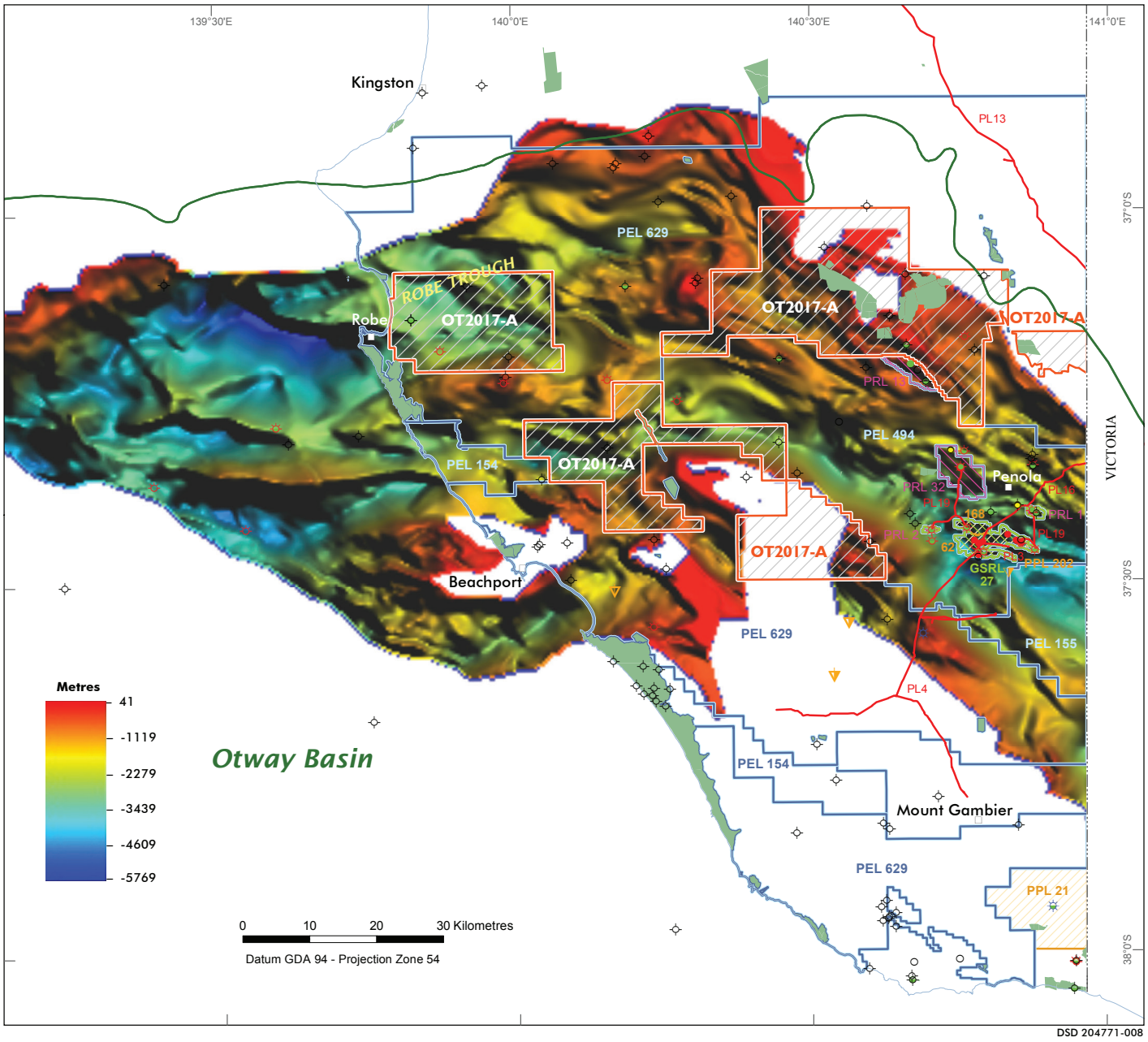
- Abandoned well
- Suspended well

Government of South Australia
Department of State Development

Figure 6 Otway Basin gravity map

Otway Basin, South Australia

CRAYFISH GROUP ISOPACH MAP



Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas
- Otway Basin outline
- Park or reserve – no petroleum exploration access

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Geothermal wells

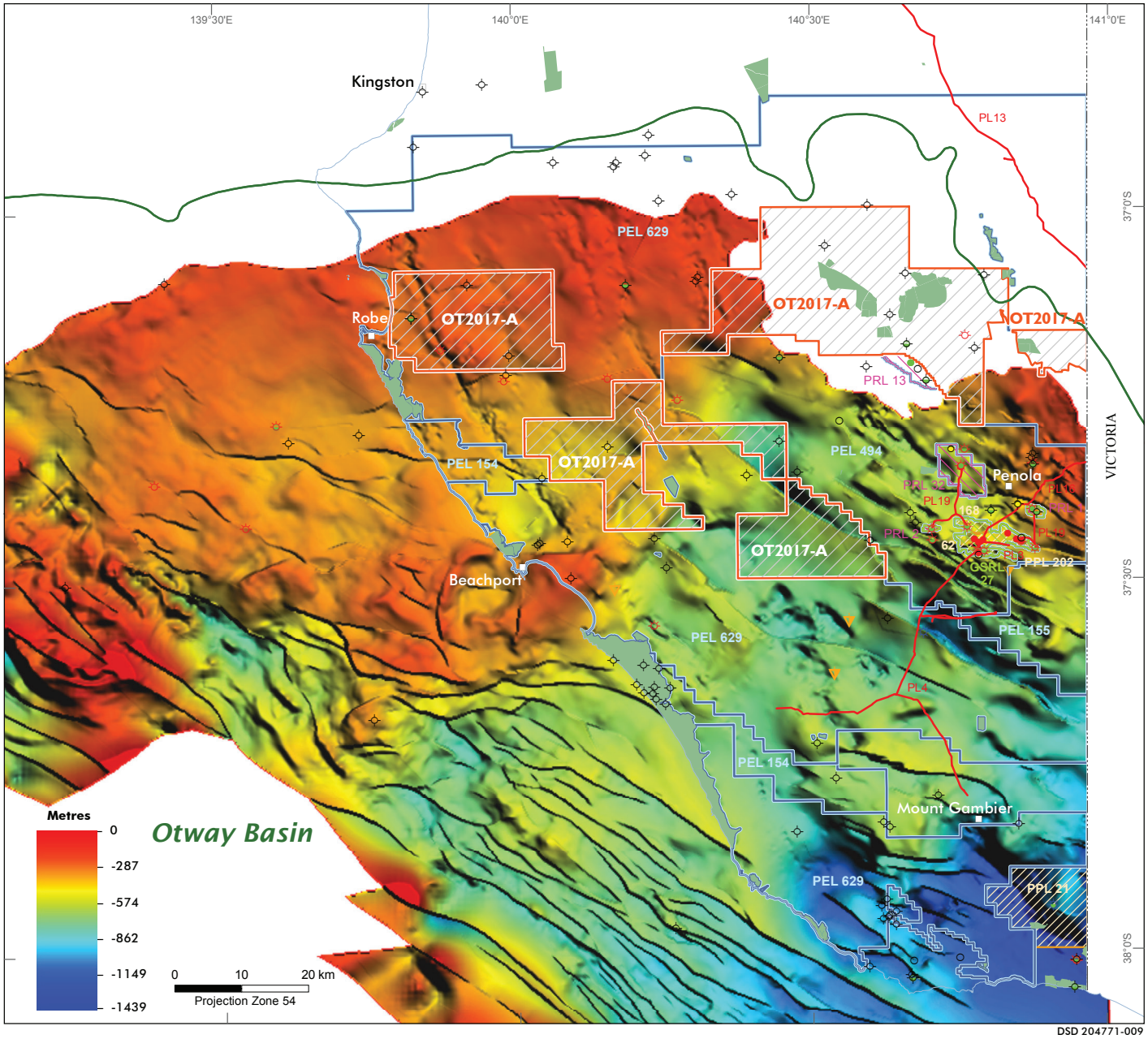
- Abandoned well
- Suspended well

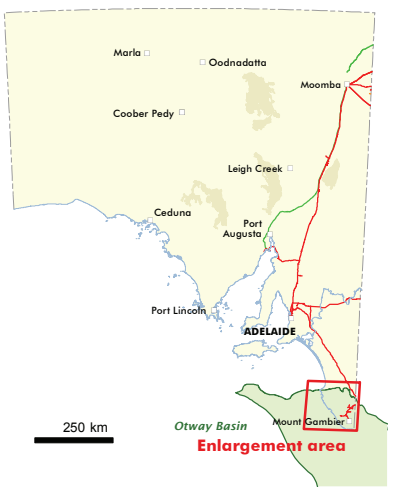
Government of South Australia
Department of State Development

Figure 7 Crayfish Group isopach map

Otway Basin, South Australia

CAINOZOIC SEDIMENTS ISOPACH MAP





Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas
- Otway Basin outline
- Park or reserve – no petroleum exploration access

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Geothermal wells

- Abandoned well
- Suspended well

Government of South Australia
Department of State Development

Figure 8 Cainozoic sediments isopach map

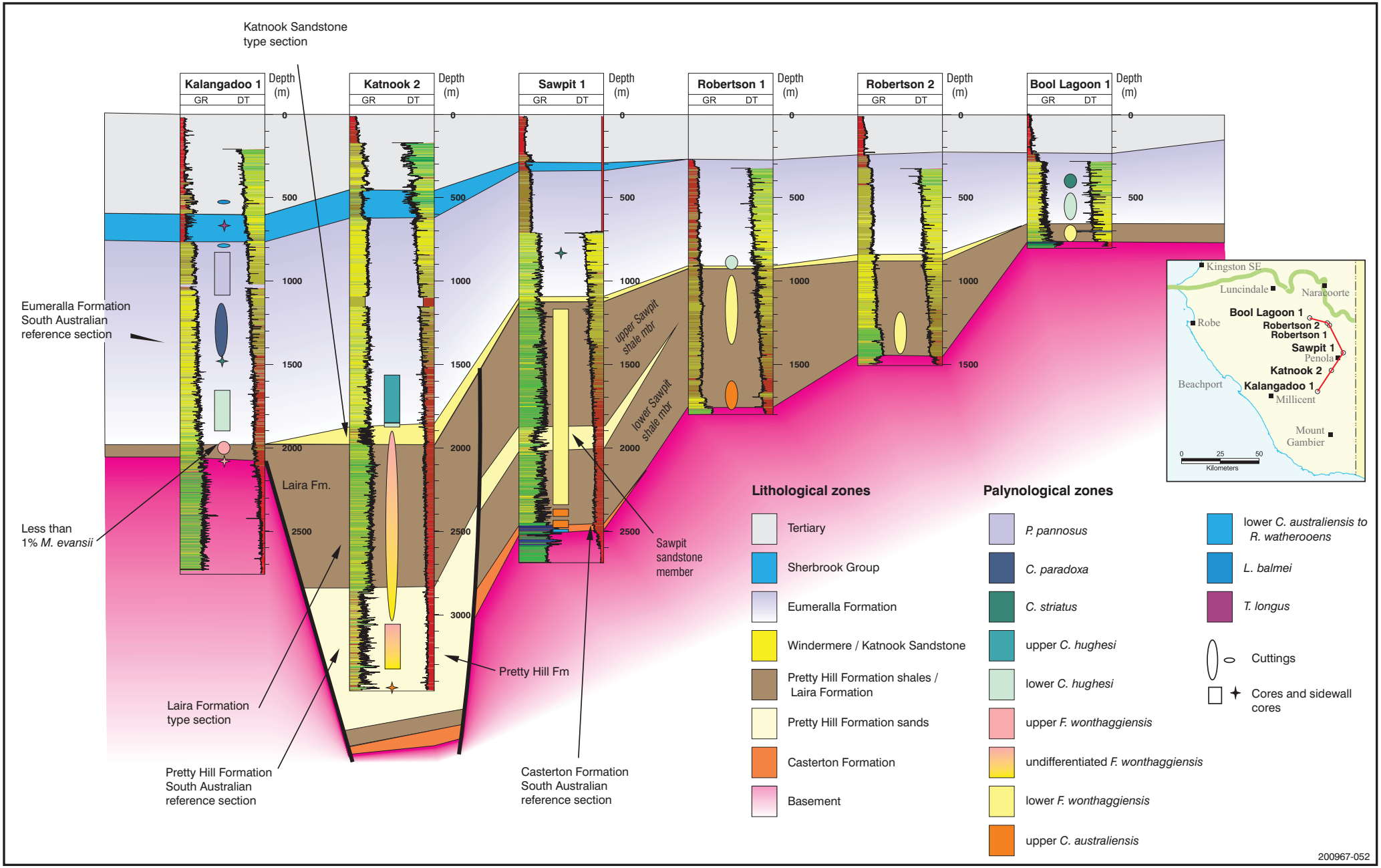


Figure 9 *Wireline log correlation, Kalangadoo 1 to Bool Lagoon 1*

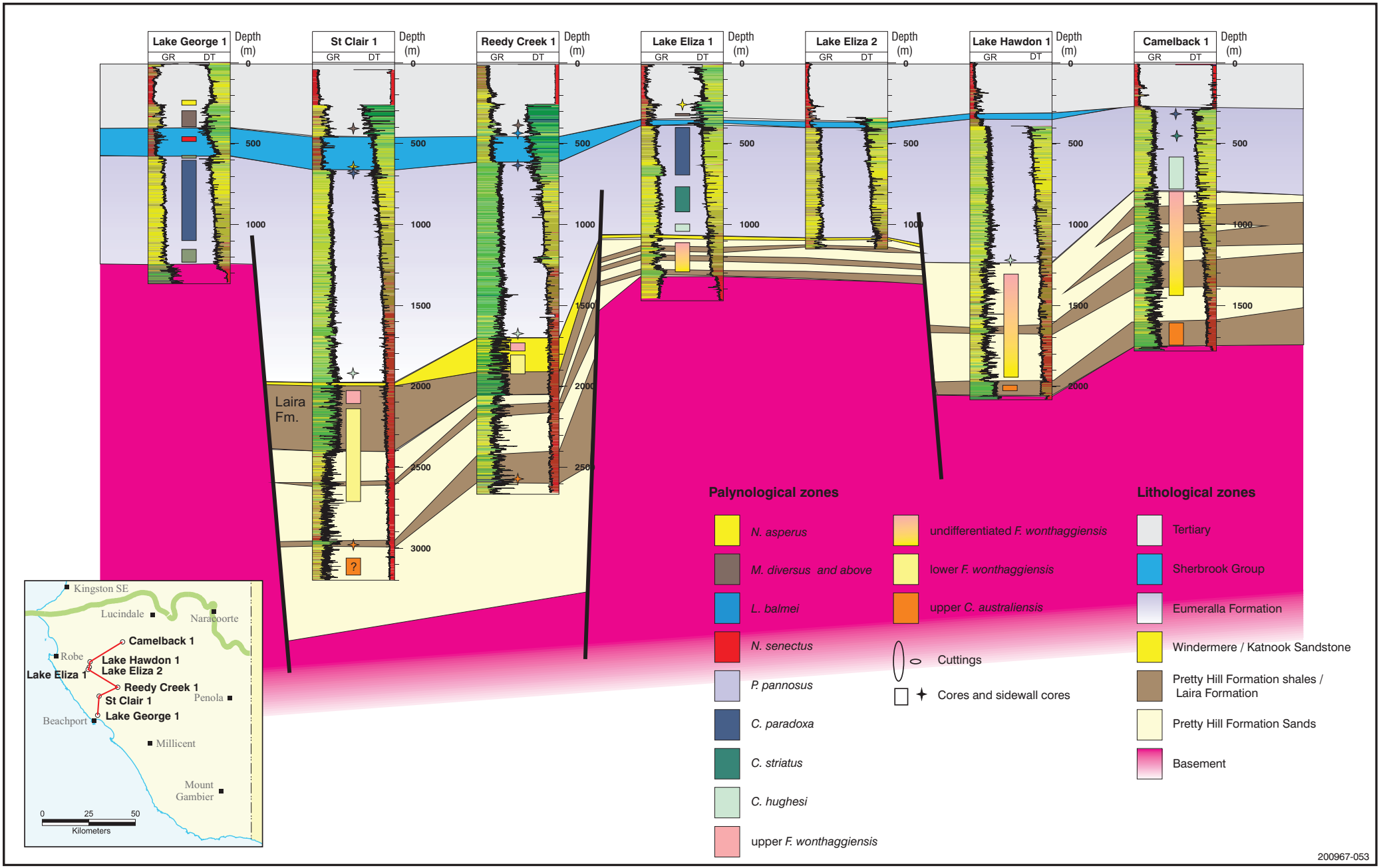


Figure 10 Stratigraphic correlation, Lake George 1 to Camelback 1

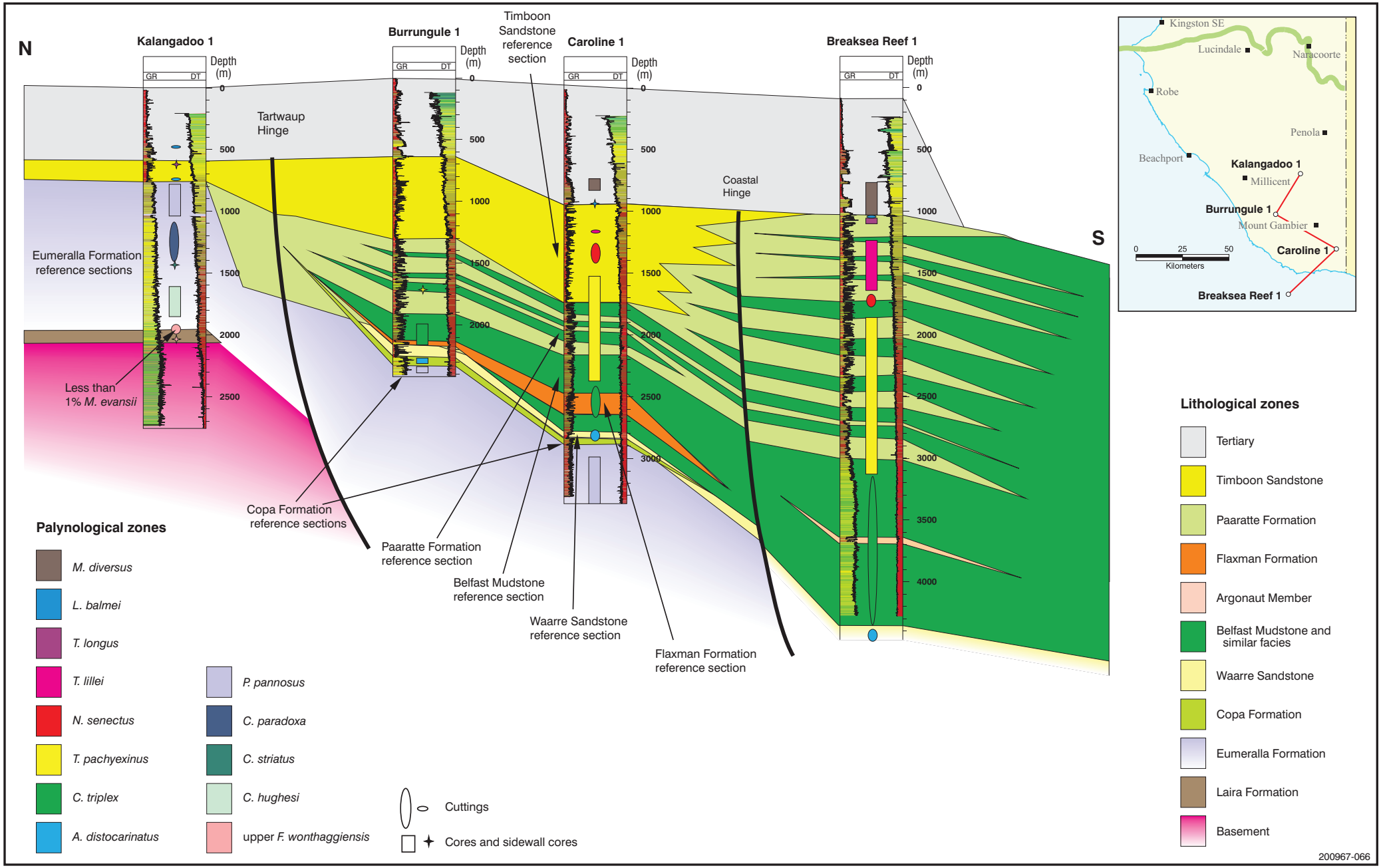


Figure 11 Stratigraphic correlation, Kalangadoo 1 to Breaksea Reef 1

area, based on organic maturity necessary to generate and expel oil and gas, only the Jurassic to Early Cretaceous Casterton Formation and Crayfish Group strata are likely to have effective petroleum source potential (Figs 12 and 13). These source rocks are non-marine, and characteristically have type III to IV kerogen types derived from land plants. Some non-marine type II algal rich shales are present, especially in the early rift succession.

Strata of the Casterton Formation and near the base of Crayfish Group trend (to the south) to being over-mature for oil generation in the deeper portions of half-graben and mature for gas. On the flanks of these half-grabens, the Casterton and near the base of Crayfish Group trend to be early mature to mature for oil generation and expulsion, whilst on basement highs, the same units are immature to marginally mature for oil generation (Figs 15 and 16).

Based on organic maturity levels, the Eumeralla Formation is not deep enough in the northern portion of the basin to be a source and shallow northern targets would rely on long-range migration, which may be impeded by the high density of E–W faults. However, to the south of the Tartwaup Hinge, where thick Sherbrook strata occur, coals and possible deep-water shales within Eumeralla Formation (Fig. 14) are mature for generating and expelling oil and gas, making these strata a suitable source for overlying and up-dip Waarre Sandstone and Flaxman Formation targets.

For the southern portion of the acreage release area, coals and possible deep water shales within Eumeralla Formation, Waarre Sandstone and Belfast Mudstone contain potential type II and III source rocks and are mature for oil to the south of the Tartwaup Hinge (Fig. 17).

Based on isotopic analyses, the CO_2 in Caroline Field is interpreted to have been sourced from deep volcanics, assumed to be part of the Holocene (in age) Mt Gambier volcanic chain, which trends northwest through the Tantanoola Trough. Carbon dioxide from a magmatic source has also been noted in Ladbroke Grove Field and Kalangadoo 1.

Organic maturation profiles in the Otway Basin are strongly influenced by the thickness of the Late Cretaceous and Tertiary strata (Figs 8, 17). In addition, for the Early Cretaceous play, each discrete half-graben appears to have local sedimentological and thermal histories e.g. source rock total organic content

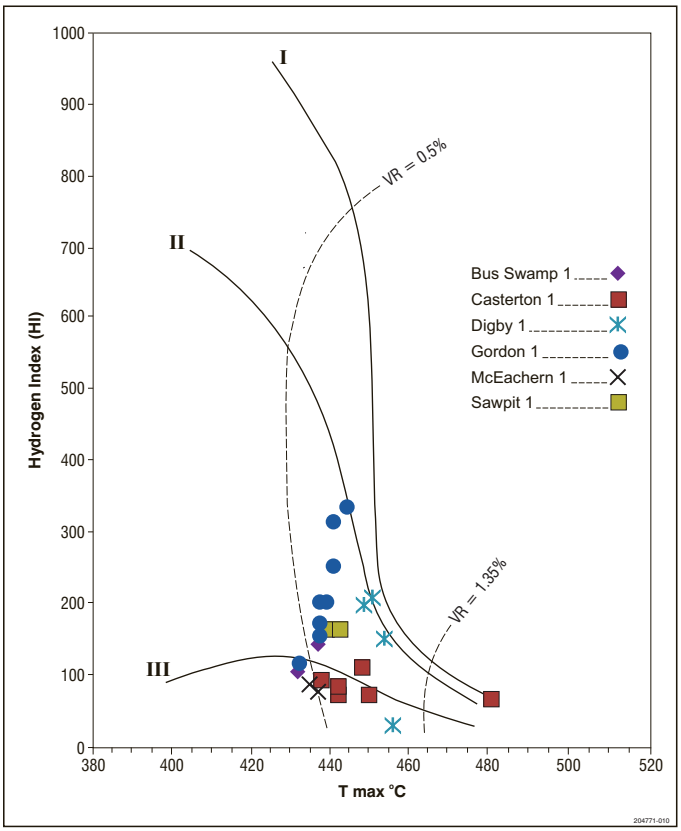


Figure 12 HI vs Tmax plot, Casterton Formation

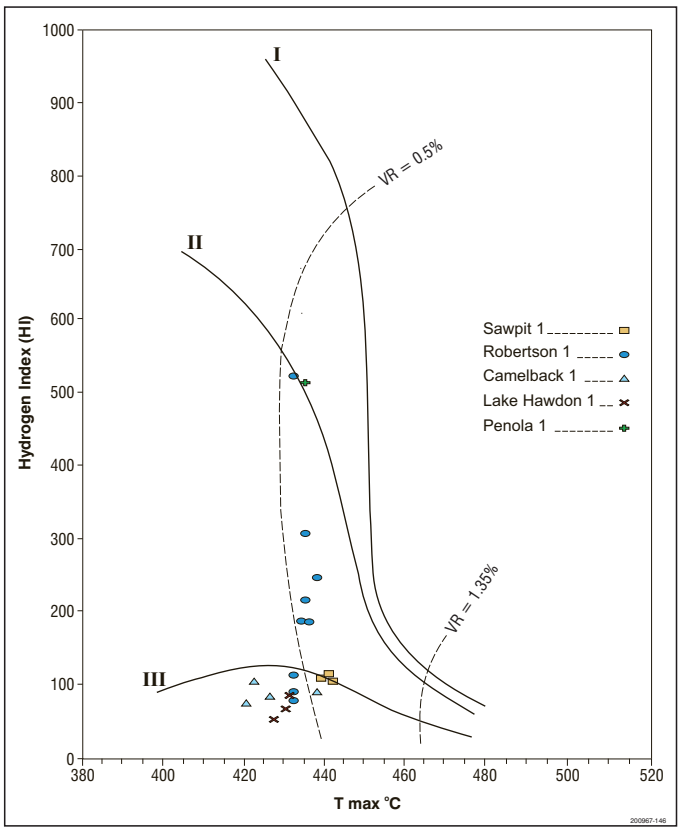


Figure 13 HI vs Tmax plot, Basal unnamed shale/Sawpit Shale

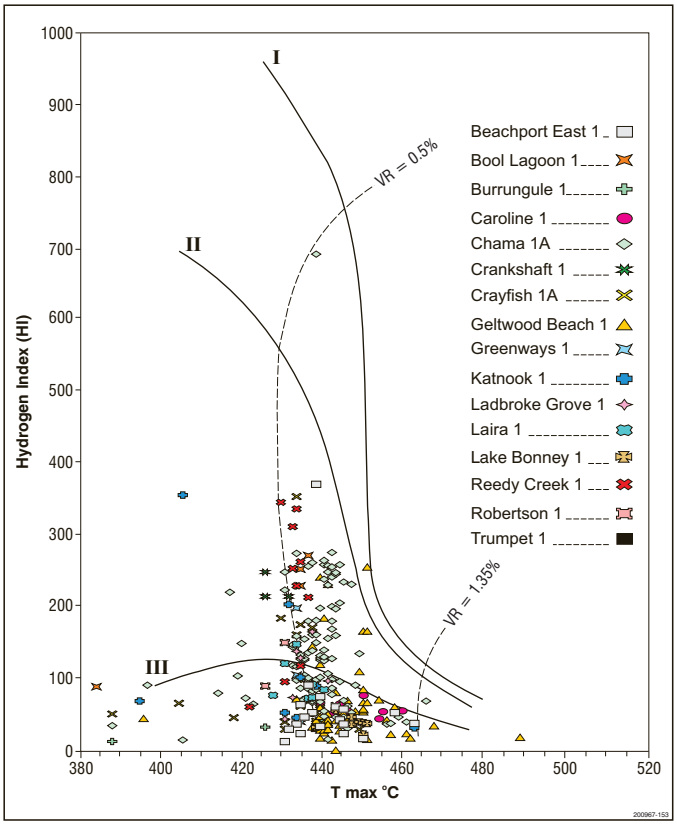


Figure 14 HI vs Tmax plot, Eumeralla Formation

richness, kerogen type and maturity varies as a consequence of the basin architecture.

The South Australian Otway Basin has produced oil/condensate in negligible amounts from Caroline 1, and in 1992, heavy crude was recovered from Sawpit 1 over a 32 m interval below 2514 m. The oil/condensate in Caroline 1 and the heavy oil in Sawpit 1 are presumed to be sourced from Otway Supergroup sediments.

To the east, in 1994, Mylor 1 (in Victoria) intersected retrograde condensate below gas, and this is interpreted to be the result of uplift, post accumulation of liquids-rich gas. The retrograde condensate at Mylor 1 is most probably from the same source as other liquids-rich gas fields in its vicinity (such as the Iona and North Paaratte gas fields) e.g. the Eumeralla of the Otway Supergroup.

Also in 1994, Wynn 1 recorded the first liquid hydrocarbon flow in the South Australian Otway Basin and Killanoola 1 (1998) produced 160 kL (1000 bbl.) on test. Neither the Wynn 1 nor the Killanoola accumulations are currently deemed economic. Jacaranda Ridge 2 (2007) produced 0.16 PJ (0.15 bcf) of sales gas. Hollick 1 and Patrick 1 wells, both drilled in 2010, flowed gas on extended production tests and have produced modest amounts of gas and condensate, which was transported by pipelines to the Katnook Gas Plant, which is currently mothballed.

Reservoirs and seals

The Otway Basin in South Australia contains a range of reservoirs that generally exhibit good porosity and permeability, and are predominantly in non-marine fluvial sandstones. Below-ground, exploration risk associated with reservoir quality and distribution is generally low, but the below-ground risk associated with offset lateral seals is more variable. Almost all sandstones above Palaeozoic basement from Late Jurassic to early Tertiary age are potential conventional reservoirs.

The most important and oldest proven-productive conventional reservoir in the South Australian sector of the Otway Basin is the Early Cretaceous Pretty Hill Formation, which hosts the commercial Katnook, Ladbroke Grove, Haselgrove, Haselgrove South and Redman gas fields, and flowed significant amounts of oil, condensate and gas from Wynn 1, Killanoola 1, Jacaranda Ridge 1 and Jacaranda Ridge 2.

In the Katnook Field, Pretty Hill Formation sandstones have porosities in excess of 25%, permeabilities in excess of 1000 mD, and flowed over 451,000 m^3 (16.01 mmcf) gas per day on test. Reservoir permeability does not appear to uniformly decrease with depth of burial, plausibly related to dissolution diagenesis.

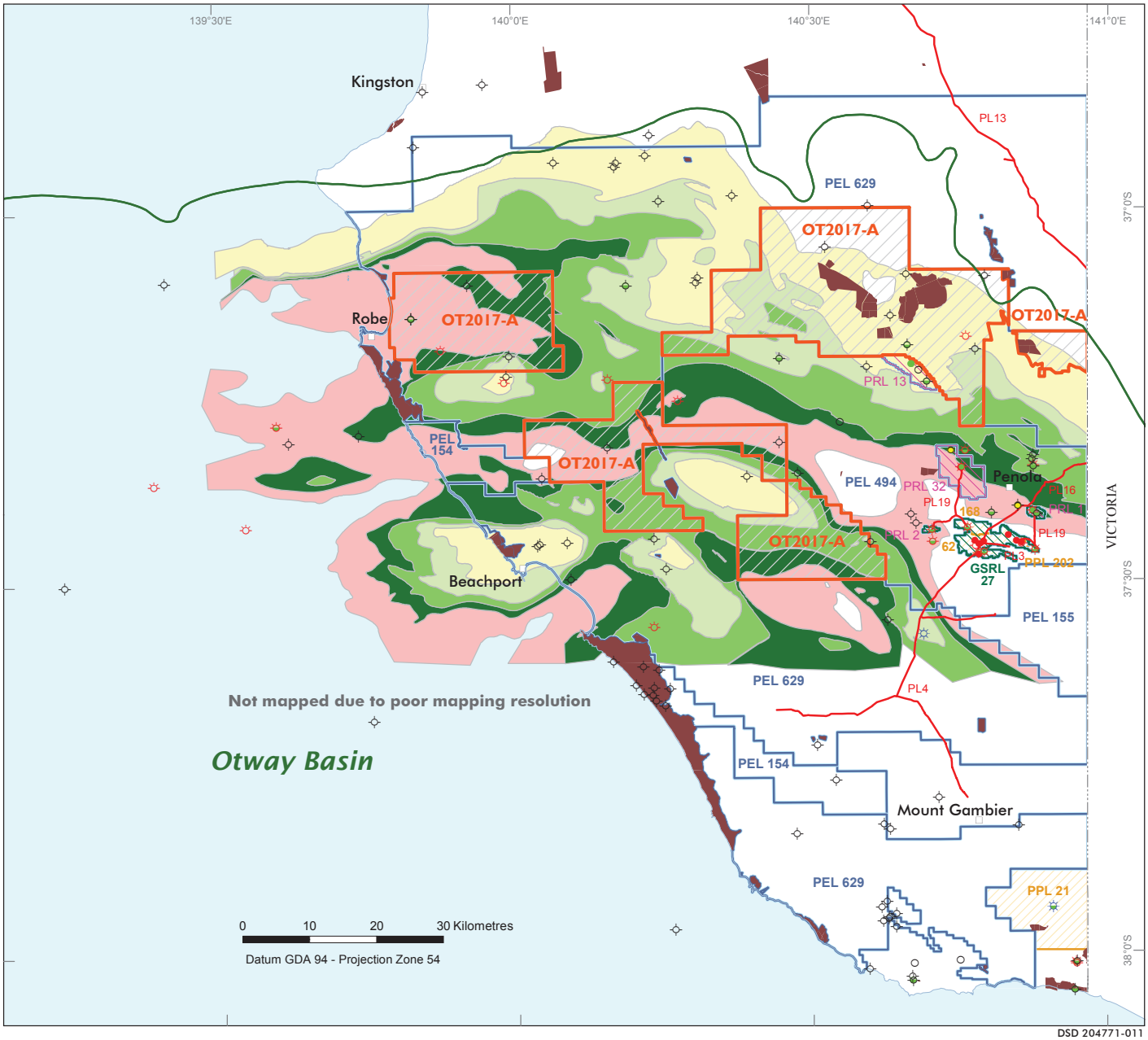
Some intra-Pretty Hill Formation shales and the Laira Formation form good top seals to the underlying Pretty Hill Formation reservoirs. However, offset lateral seal capacity poses below-ground risks for conventional traps at these levels.

Reservoir quality is excellent in the Windermere Sandstone Member – Katnook Sandstone reservoir. The Katnook Sandstone has profitably flowed gas from Katnook 1, and a 2 m gas column exists within Crankshaft 1. The Windermere and Katnook Sandstones are usually thicker toward the centres of the Early Cretaceous troughs.

The Eumeralla Formation along the northern and western flank of the Otway Basin tends to be a poor vertical and lateral (offset across fault) seal and limits accumulations to thin hydrocarbon columns.

Otway Basin, South Australia

MATURITY at BASEMENT – CASTERTON - BASE PRETTY HILL FORMATION



Vitrinite reflectance maturity

- Less than 0.5% Immature
- 0.5% to 0.7% Early mature (oil)
- 0.7% to 1.0% Mid mature (oil)
- 1.0% to 1.3% Late mature (oil)
- 1.3% to 2.6% Gas generation
- Over mature

Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas
- Otway Basin outline
- Park or reserve – no petroleum exploration access

Petroleum wells

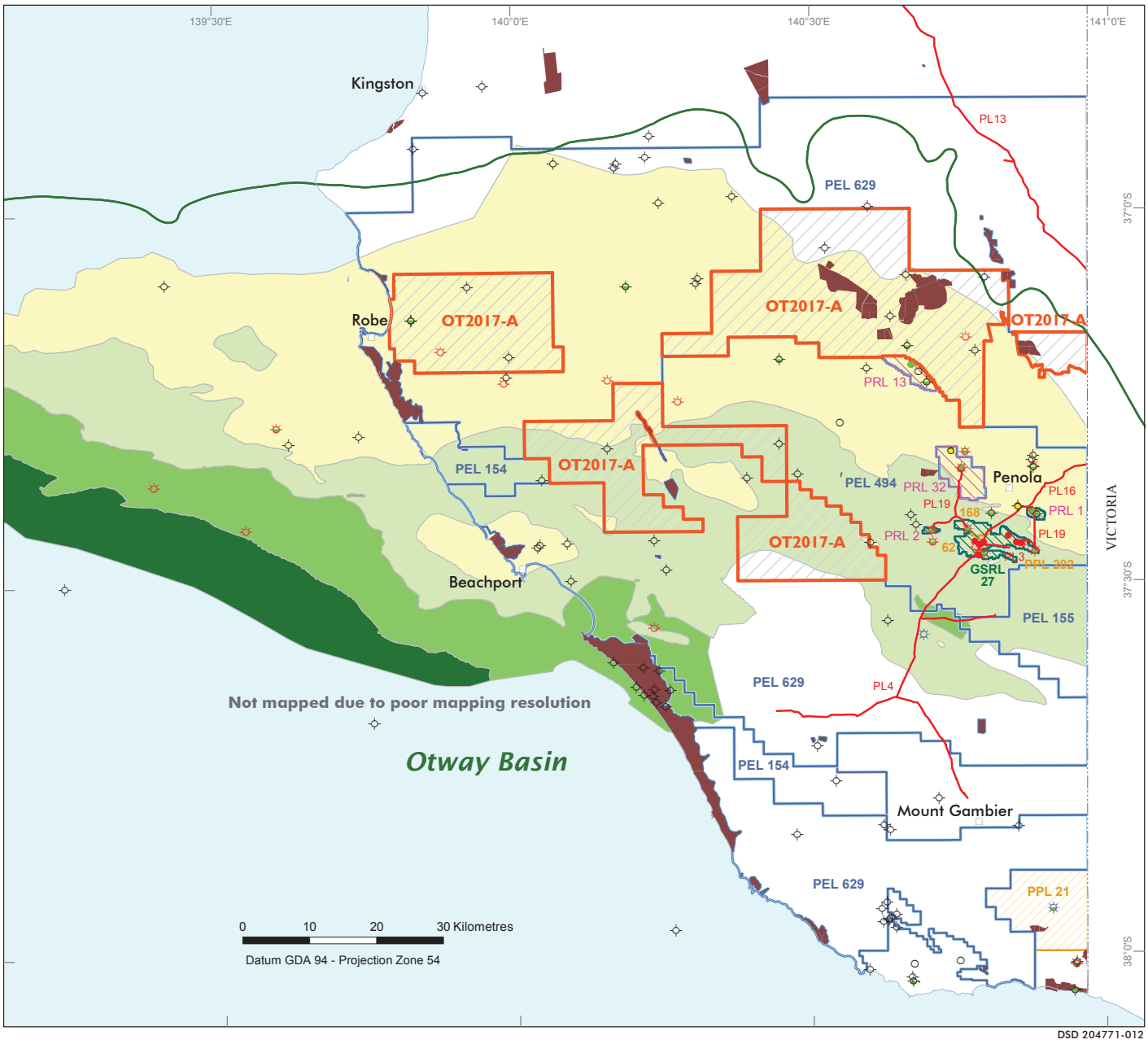
- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Government of South Australia
Department of State Development

Figure 15 Maturity at Casterton–Base Pretty Hill Formation

Otway Basin, South Australia

MATURITY at TOP CRAYFISH GROUP



Vitrinite reflectance maturity

- Less than 0.5% Immature
- 0.5% to 0.7% Early mature (oil)
- 0.7% to 1.0% Mid mature (oil)
- 1.0% to 1.3% Late mature (oil)
- Otway Basin outline
- Park or reserve – no petroleum exploration access

Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Government of South Australia
Department of State Development

Figure 16 Maturity at Top Crayfish Group

The Waarre Sandstone – Flaxman Formation/ Belfast Mudstone reservoir/seal couplet hosts the commercial Caroline CO_2 field which also produces approximately 10,000 litres of oil per year. This proves the viability of this system as a potential hydrocarbon trap within the southern portions of OT2017-A, south of the Tartwaup Hinge. Additionally, there is evidence to the east, in the Victorian extent of the Otway Basin, for natural gas fields with low CO_2 content in proximity to the Boggy Creek CO_2 field e.g. the Naylor, Croft and McIntee gas fields. Three-dimensional (3D) seismic can resolve where traps are bounded by deep-seated versus shallower faults. Experience suggests the chance for encountering higher levels of CO_2 where gas accumulations are nearer to deep-seated faults, onshore in the Otway Basin.

The most recent Otway Basin exploration wells were drilled by Beach Energy in the Penola Trough in 2014. Jolly 1 and Bungaloo 1 were drilled to assess the potential for liquids rich gas within the Lower Sawpit Shale and the Casterton Formation.

Beach reported that the potential for reservoirs in the Lower Sawpit Shale and Casterton Formation had been confirmed. Encouraging oil shows were recorded near the base of the Lower Sawpit Shale in Bungaloo 1 and that the wells confirmed the potential for a Sawpit Sandstone conventional gas play in the deeper Penola Trough where the Sawpit Sandstone has good reservoir quality at depths of 3170 m in Jolly 1 (average porosity of 13% over a 330 m interval; source: Beach Energy PESA Deal Day presentation, June 2016).

Petroleum entrapment

In the northern part of the basin, where exploration is for Otway Supergroup targets, Pretty Hill Formation reservoirs of the fields in the Penola Trough comprise complex, steep sided, E–W tilted fault blocks, with the upper Sawpit shale member and Laira Formation acting as the seals. Common palaeo-hydrocarbon columns have been intersected and leakage was probably caused by the ineffective offset lateral seals. The location of leakage depends on the interaction between the seal, associated faults, and the regional stress field.

Recognised traps for Windermere reservoirs comprise unfaulted low relief domes (close to the resolution limit of seismic mapping) sealed by the Eumeralla Formation. The base Eumeralla seal is likely to improve towards the southwest. Considerable potential exists for stratigraphic traps, either as meandering fluvial channels in the Eumeralla Formation (as in Katnook Field), or as pinch-outs of the Pretty Hill Formation to the north.

The Flaxman–Waarre units have proven to be excellent gas reservoirs in the Victorian portion of the basin, and in South Australia contain the Caroline CO_2 field. Traps are generally northeast tilted fault blocks, bounded by closely spaced rift parallel faults. Offshore, potential exists for overpressured submarine slope-fan traps encased within the Belfast Mudstone (Fig. 11). As stated earlier, natural gas fields with low CO_2 content in proximity to the Boggy Creek CO_2 field e.g. the Naylor, Croft and McIntee gas fields. In this play area, the acquisition of 3D seismic proved to be a valuable strategy to differentiate between structures bounded by deep-seated master faults (as conduits for CO_2 to migrate from deep igneous sources) and structures only affected by faults that do not extend to potential igneous CO_2 source levels.

Undiscovered resources

The Otway Basin in South Australia is only modestly explored, with high potential for further discoveries (Fig. 12). Commercial gas production has been achieved from a number of fields in the South Australian extent of the onshore Otway Basin. To date, there are no declared discoveries of oil or natural gas in unconventional reservoirs in the Otway Basin.

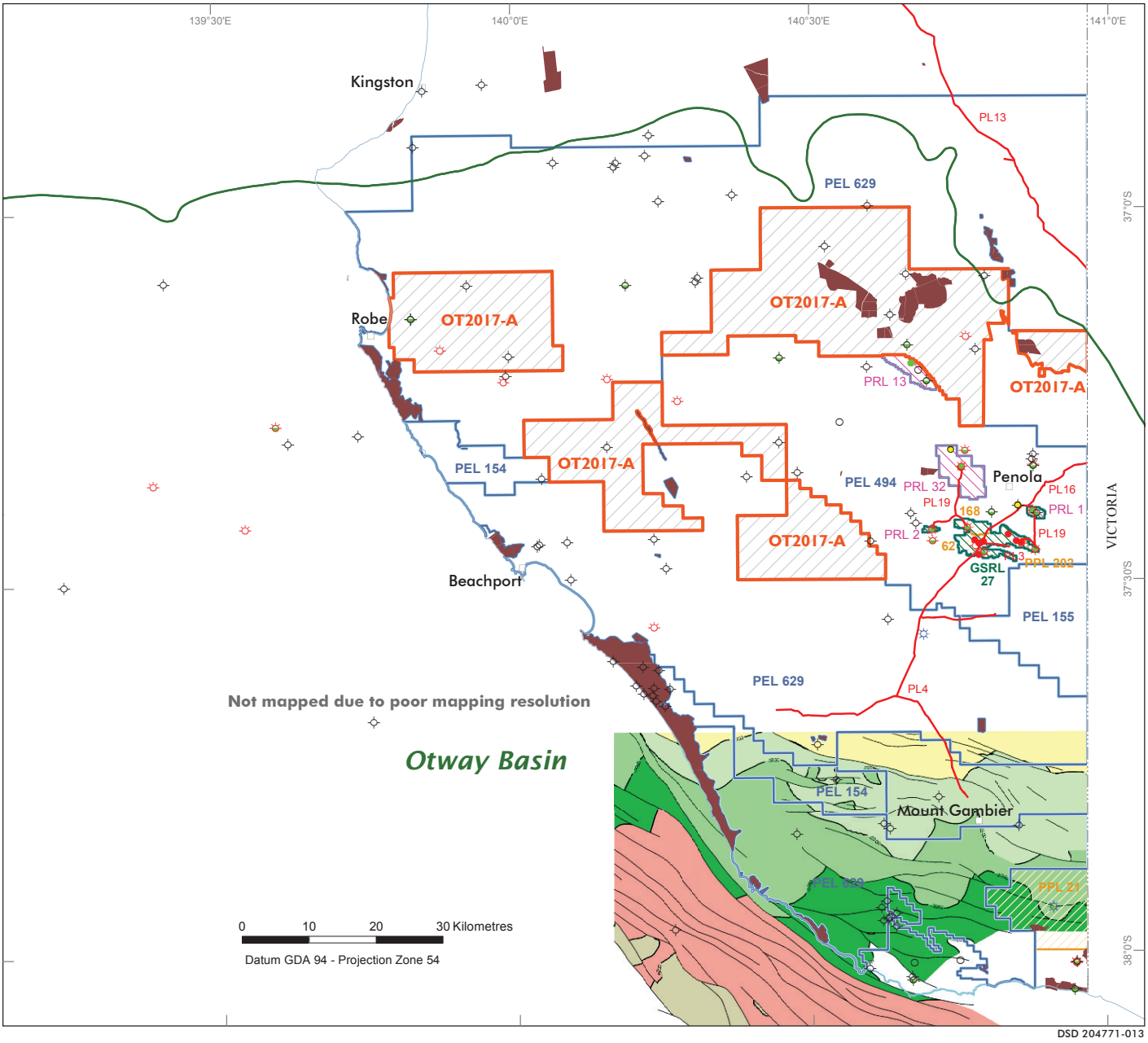
Oil discoveries to date are limited, but there is considerable potential for significant oil discoveries in the future. The potential for oil and gas discoveries in the Otway Basin offshore from South Australia is as yet unquantified.

EXPLORATION POTENTIAL

The OT2017-A block is being offered at a time when the entire south eastern Australian gas market is accessible via the SEA GAS pipeline. The block contains a diversity of plays and both proven conventional oil and wet gas targets and potential unconventional shale gas reservoirs and shale oil targets that are discussed below.

Otway Basin, South Australia

MATURITY at TOP EUMERALLA FORMATION



Vitrinite reflectance maturity

- Less than 0.5% Immature
- 0.5% to 0.7% Early mature (oil)
- 0.7% to 1.0% Mid mature (oil)
- 1.0% to 1.3% Late mature (oil)
- 1.3% to 2.6% Gas generation
- Over mature
- Otway Basin outline
- Park or reserve – no petroleum exploration access

Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Government of South Australia
Department of State Development

Figure 17 Maturity at Top Eumeralla Formation

Existing infrastructure is a key factor in reducing the uncertainty for the economic prospects of gas plays in the Otway Basin.

Proven Conventional Plays

Table 1 summarises the undiscovered potential for recoverable sales gas resources in the key plays of the onshore South Australian portion of the basin.

Table 1 *Estimated undiscovered recoverable sales gas resources in conventional reservoirs in the onshore South Australian extent of the Otway Basin.*

PLAY	UNDISCOVERED POTENTIAL PJ (~bcf) Probability that the ultimate potential will exceed the stated value:					
	90%		50%		10%	
Waarre–Flaxman	30	(27)	150	(137)	560	(513)
Crayfish	120	(110)	680	(623)	2330	(2135)
Total	**180**	**(165)**	**900**	**(825)**	**2760**	**(2530)**

Note: Totals do not add arithmetically as they are Monte Carlo simulations. Current to 2000. Source: Morton J.G.G. and Boult PJ. 2001.

Proven plays in South Australia include the fault bounded 4-way dip closures in the Pretty Hill Formation, Sawpit Sandstone and Windermere Sandstone in the Penola trough (oil and or wet gas), although gas discoveries to date are relatively modest in size (average recoverable reserves per field in SA portion of the basin is ~20 PJ (19 bcf)). Fault leakage is a key below-ground risk factor for trapping petroleum.

Some discoveries in the offshore Victorian portion of the basin are an order of magnitude larger – up to 350 PJ (~321 bcf) in the Minerva Field and ~0.8 tcf in the Thylacine discovery.

In the northern part of the basin, where exploration is for Otway Supergroup targets, Pretty Hill Formation reservoirs of the fields in the Penola Trough comprise complex, steep sided, E–W tilted fault blocks, with the upper Sawpit shale member and Laira Formation acting as the seals. Common palaeo-hydrocarbon columns have been intersected and leakage was probably caused by ineffective offset lateral seals. The location of leakage depends on the interaction between the seal, associated faults, and the regional stress field.

Traps for Windermere reservoirs comprise unfaulted low relief domes (close to the resolution limit of seismic mapping) sealed by the Eumeralla Formation. The base Eumeralla seal is likely to improve towards the SW. Considerable potential exists for stratigraphic traps, either as meandering fluvial channels in the Eumeralla Formation (as in Katnook Field), or as pinch-outs of the Pretty Hill Formation to the north.

Potential Unconventional Plays

In February 2017, Geoscience Australia released a report titled *Interim Otway Basin Unconventional Resource Assessment* which provides the first assessment of shale and tight resources for the entire onshore portion of the Otway Basin. Adopting a probabilistic volumetric assessment methodology, the report identified 7.6 tcf of potentially recoverable Gas in Place (GIP) from tight sandstones of the Eumeralla Formation and Crayfish Sub-group and 1.5 billion barrels of oil and condensate from shales within the Eumeralla Formation, Crayfish Sub-group and Casterton Formation assuming 5% median assessed volume (P50) (Table 2).

Table 2 *The estimate for onshore Otway Basin (in South Australia and Victoria) potential for recoverable tight and shale gas-in-place (GIP) and oil-in-place (OIP) resources assumes a 5% recovery from median assessed in-place volumes (P50).*

	Potentially recoverable GIP (trillion cubic feet (tcf))		Potentially recoverable OIP (billion barrels (bbbl))	
	SA and Vic.	SA only	SA and Vic.	SA only
Tight resources	5.8	2.51	0.4	0.25
Shale resources	1.7	0.44	1.0	0.25
Total tcf	**7.6**	**2.96**	–	–
Total bbbl	–	–	**1.5**	**0.5**

Note: Probabilistic summation has been used. Source: Geoscience Australia, 2017.

Shale gas plays

The principal targets for gas in unconventional shale reservoirs in the onshore Otway Basin are thick basal shale sequences of the Upper and Lower Sawpit shales within the Otway Supergroup and the underlying Casterton Formation (Fig. 5). These non-marine shales all have good to excellent shale gas potential in the deeper portions of the basin and shale oil potential on the flanks of the deeper troughs which are individually discussed below. Complex faulting resulting from rift tectonics could be advantageous for unconventional reservoir permeability e.g. the potential for gas saturated natural fracture networks.

Casterton Formation

The Casterton Formation represents the richest source rock of the Otway Supergroup that is thought to be the source of commercial gas accumulations now in production in the Penola Trough region. It comprises pre-rift to early syn-rift interbedded shales, siltstones and sandstones and volcanic lithologies that have only been sparsely intersected in wells. The formation reaches a maximum known thickness of 230 m in Casterton 1 and 43 m in Sawpit 1 although it is thought to be up to 500 m in the Robe Trough based on seismic interpretation. To date, the formation has been mostly intersected on the northern flanks where it is marginally organically mature for oil generation and expulsion (as evidenced by oil shows in several wells) but has more recently been intersected in the deeper portions of the Penola Trough where it reached a thickness of 126.5 m in Bungaloo 1 and 91.4 m in Jolly 1 ST1 wells drilled by Beach Energy in 2014.

Casterton Formation total organic content (TOC) values range from 0.6 to 9 percent, averaging 1.9 percent (39 samples; 6 wells). Pyrolysis Tmax vs Hydrogen Index (HI) cross plot shows that these organic rich shales are type II (algal rich oil prone kerogen) to type III (gas prone) at the threshold of the oil window (Fig. 12). However, in the deeper portions of the Penola, Robe and Saint Clair troughs, Casterton Formation source rocks are expected to be gas prone with liquids potential.

Organic maturity modelling indicates that the Casterton Formation lies within the gas generation and expulsion window at depths in excess of 3800m in the Penola Trough and Robe Trough (Fig. 15) but may be locally shallower in the Robe Trough where seismic coverage is poor.

Beach Energy and JV partner Cooper Energy have been exploring the northern margin of the Otway Basin in Victoria and estimates the Casterton Formation, within PEP 171, could contain more than 25 trillion cubic feet of gas and significant oil volumes. The Victorian PEP JV has submitted an application to suspend the licence for 12 months due to an ongoing moratorium on petroleum exploration and development imposed by the Victorian State Government.

Beach Energy drilled Bungaloo 1 and Jolly 1 ST1 in the Penola Trough in the first half of 2014, targeting conventional and unconventional reservoirs in the base Crayfish Group and the Casterton Formation. Favourable indications for both conventional and unconventional reservoirs were identified and Bungaloo 1 has been suspended with gas shows for future re-entry and appraisal.

Upper and Lower Sawpit shale gas plays

The Upper and Lower Sawpit shales represent lacustrine deposits at the base of the Crayfish Group and can reach thicknesses up 900 m and 250 m thick). The shales are better developed on the northern flank of the Penola Trough, away from the axial drainage in the central part of the trough which is dominated by stacked fluvial channel fill of Pretty Hill Sandstone or Sawpit Sandstone (Boult and Hibburt, 2002).

Pyrolysis analyses of samples from the Upper and Lower Sawpit Shales indicate that the shale is dominated by type III gas-prone kerogen with some type II algal-rich kerogen present (Fig. 13). TOC values range 0.37 to 2.61 percent and average 1.12 percent (10 wells, 87 samples).

Organic maturity modelling in the Katnook area of the Penola Trough indicates that peak gas generation from the Casterton Formation and Upper and Lower Sawpit Shales occurred in the Maastrichtian (~73 million years ago) and has remained in the gas generation and expulsion window to present day at depths below ~3800 m (Fig. 15).

The key below ground uncertainties for Upper and Lower Sawpit shale prospects are:

- Complex faulting; and
- Limited well control in the depocentre of the Penola Trough (to enable better understanding of gas saturation).

Shale oil plays

Unnamed unit

A sequence of interbedded metasediments, tuffaceous sediments and organically rich shale was first identified within basement in Sawpit 1 over the interval 2510–2606 m. A low sulphur (~0.8%) medium gravity API (33° – 35°) paraffinic oil was recovered from drill stem test (DST) 1 over the interval 2514–2546 m (1.5 bbl oil, 0.5 bbl mud) with a vitrinite reflectance

(Vr) ~0.71 (Source: Sawpit 1 well completion report). This oil has features in common with the basal Casterton beds although the match is not complete and sits within the range of the rift lake Hainan Island oils (source: Sawpit 1 well completion report). The same sequence was intersected in Sawpit 2 over the interval 2473–2546.5 m and whilst it is also assigned to basement, the composite log suggests a deeper alternate basement pick at 2546.5 m. Oil shows over the interval 2517–2547 recorded 20 to 30% very dull yellow gold fluorescence with instant weal diffuse cut. Subsequent Rock-Eval pyrolysis over the interval 2517–2543 m returned average TOC values of 8.05% (range: 1.82–14.78), S2 values averaging 35.89 (range: 4.69–68.43) and HI values averaging 410.6 (range: 258–489) indicating a wet gas to oil rich type 2 (non-marine) algal rich source rock.

The same unit also occurs in Bungaloo 1 (3428.5–3675 m) and Jolly 1 ST1 (3861–3976.6 m) where it is likely to be in the wet gas window (based on a Vr value of 0.94 near the base of the base Casterton Formation (Bungaloo 1 Core 4, SWC 3326 m) and remains untested.

A date of undifferentiated Jurassic to Late Jurassic (R.Watherooensis/APJ621 zone) has been assigned to the yet to be formalised unit (Source; Bungaloo 1 well completion report).

The Energy Resources Division from DSD is currently seismically mapping the lateral and vertical extent of this unit ahead of formalising the stratigraphic nomenclature of the unit (Fig. 5).

Casterton Formation

As previously discussed, the Casterton Formation represents the richest source rock of the Otway Supergroup and the most likely to be prospective for shale oil. Pyrolysis Tmax vs HI cross plot shows that these organic rich shales are type II (algal rich oil prone kerogen) to type III (gas prone) at the threshold of the oil generative window (Fig. 12).

Organic maturity modelling suggest that the northern flank of the Otway Basin represents the most prospective area for shale oil play (Fig. 15) where the Casterton Formation lies in the oil generative window at depths between 2300 m to ~3050 m (early mature for oil; Rv 0.7 to 1.0 percent) and ~3050 m to 3800 (later mature for oil; Rv 1.0 to 1.3 percent) in the Robe, Penola, Rivoli and St, Clair troughs.

Tight gas play

Pretty Hill Formation basal sandstones

Potential exists for tight gas in the basal sandstones of the Pretty Hill Formation (including the Sawpit Sandstone), particularly in the deeper portions of the Penola and Robe Troughs.

Infrastructure and markets

Eight commercial gas fields have been discovered in the Otway Basin in South Australia and total original gas-in-place is estimated at 128 PJ (121 x 10^{12} Btu) sales gas.

Cumulative production for the Katnook Complex for the period 1991 to end June 2015 is 71.46 PJ sales gas and 65,840 KL (414,166 bbl.) condensate. No sales gas or condensate production has been reported from the Otway Basin since 2012.

Carbon dioxide is also produced from Caroline 1 well with cumulative production (to end June 2016) of 807,500 tons (14.12 bcf) of saleable CO_2 since production commenced in 1968. In mid-January 2017, Air Liquide made the decision to cease production and commence decommissioning of the Caroline Plant.

A flowline network exists to allow gas from wells in the Katnook, Haselgrove, Haselgrove South and Redman gas fields to be piped to a gas treatment plant located 300 m southeast of Katnook 1, which was built in 1991. Since 2013 the Katnook Plant and gathering flowline network, now owned by Beach Energy, have been mothballed (with non-corrosive and non-toxic gas) as existing gas fields have been depleted.

To 2012, sales gas was sold at the outlet from the Katnook Plant and delivered to markets serviced by the South East Pipeline System (SEPS). To 2012, condensate was stored onsite at the Katnook Plant before transportation by road tanker to the Shell Refinery in Geelong, Victoria.

Epic Energy owns and operates a 46 km long, 150 mm diameter pipeline, from the Katnook gas processing plant to the Kimberly Clark Pulp Mill (previously APCEL Pulp Mill) at Snuggery, 7 km SE of Millicent (Fig. 1). A second line,

also 150 mm diameter and 19 km long, runs from this line to Mt Gambier. A third line, 50 mm diameter, runs from Katnook due east for 4.5 km to the former Safries potato chip factory site (purchased by The Midfield Group in 2014), 9 km south of Penola. The pipelines were constructed in 1990 and have a maximum operating pressure of 10,000 kPa (1450 psi). A fourth line, 11.5 km long and 89 mm diameter, was constructed in the second half of 2000, connecting Kalangadoo to Nangwarry timber mill. None of these pipelines have compression installed.

In 2002–03, the SEA Gas pipeline was constructed to transport offshore Otway gas from the Minerva Gas Processing Plant in Port Campbell, Victoria to Adelaide. Origin Energy Retail Ltd constructed and commissioned the South East South Australia (SESA) Pipeline in 2005, and was acquired by APA Group in 2007. This 45 km pipeline connects the SEA Gas Pipeline in Victoria to Epic Energy's South East Pipeline System (SEPS) and the Ladbroke Grove Power Station. As gas production from Ladbroke Grove Field ceased in late 2006 and the Katnook Gas Plant is now mothballed, sales gas from the SESA pipeline now feeds both turbines of the Ladbroke Grove Power Station and the SEPS.

In addition to the power station, the main gas customers are the Kimberly Clark paper mill near Millicent, where gas replaced the use of LPG and brown coal briquettes; and domestic and industrial customers in Mt Gambier, which were previously supplied tempered LPG via a reticulation network. The Nangwarry lateral has been mothballed, while the lateral supplying the former Safries potato chip factory (Safries Lateral) is currently suspended whilst the factory is converted to a dairy processing facility, with the decision to mothball dependent on new commercial discussions.

Opportunities exist for small peaking power stations in a more competitive electricity market. The strategic location of the Ladbroke Grove Field adjacent to the main electricity link between Adelaide and Victoria, led to Origin Energy taking the opportunity to use the high-CO_2 gas to fire a 40 MW power station. Gas sourced from the Ladbroke Grove Field supplied power into the national electricity grid from early 2000 until late 2006.

In addition, the south east of South Australia and western Victoria exhibit a high diversity of local industry — consequently, opportunities for gas marketing linked to industry development in the region are good given the industry base and service provision in the region. The region is strategically located between the major cities of Adelaide and Melbourne and the eastern Australian market.

DATA AND INFORMATION

A comprehensive summary of the Otway Basin is available in *The Petroleum Geology of South Australia Volume 1* (2nd Edition). This volume include chapters on structural and tectonic history, litho- and biostratigraphy, source rocks and maturity, reservoirs, seals, trap development, discovered reserves, field reviews, undiscovered potential, and exploration history. The publication can be downloaded via the Department of State Development Energy Resources Division (DSD-ERD) website (http://www.petroleum.statedevelopment.sa.gov.au/), and is also available for free on the Petroleum and Geothermal in South Australia USB.

Previous exploration data and reports are readily available from DSD-ERD in digital format on portable hard drives, including:

- well completion reports (also downloadable from the DSD-ERD website via the South Australian Resources Information Gateway (SARIG))
- geographic information system (GIS) datasets including wells, seismic, tenements, pipelines
- seismic survey shot point location data
- seismic survey reports and archive stack data (SEGY format)
- digital well logs (DLIS/LIS format)
- velocity survey check shot information
- structure maps and datasets
- Petroleum Exploration and Production System (PEPS-SA) database with production, well, seismic and engineering data (also downloadable from the DSD-ERD website)
- company prospectivity reports (also downloadable from the DSD-ERD website via SARIG)

SARIG can be accessed via map.sarig.sa.gov.au. SARIG provides an interactive map window to view, query and download data including spatial

data such as regional seismic horizon maps of key Otway Basin horizons, tenement data etc. More information on products and data can be accessed by selecting 'Data and Publications' on the DSD-ERD website home page.

The following reports and datasets can be accessed from a dedicated SARIG link but also accessed individually below:

- Selected petroleum geology reports relevant to OT2017-A
- Selected petroleum geophysical reports relevant to OT2017-A
- Selected petroleum well completion reports relevant to OT2017-A
- Selected SEG-Y seismic line data – OT2017-A
- GIS shapefile dataset and ESRI ArcGIS project – OT2017-A
- Acreage release block tenement map – OT2017-A
- Otway Basin Hot Sedimentary Aquifers and SEEBASE Study (FrogTech 2010)
- Hot Sedimentary Aquifer Study (FrogTech 2010) Seismic TWT Grids
- Hot Sedimentary Aquifer Study (FrogTech 2010) Seismic Time-Depth Grids
- PEPS-SA download
- *Petroleum and Geothermal Energy Act 2000*

LAND USE AND ACCESS

History of petroleum operations in the south east of South Australia

The entire extent of the Otway Basin in South Australia has been held within petroleum licences (almost continuously) for decades. Petroleum exploration in the region dates back to the 1880s.

Exploration and production of gas and oil has been conducted for over one hundred years in the south east of the South Australian extent of the Otway Basin. This includes over 101 petroleum wells drilled (since 1915) and gas production through the Katnook gas processing facility between 1991 and 2011 (Fig. 2). Furthermore, 10,495 line kilometres of two-dimensional (2D) geophysical surveys and 5262 km^2 of three-dimensional (3D) geophysical surveys have been acquired in the south east of South Australia (Fig. 3).

Despite exploration, development and production activities being located in and adjacent to the highly valued Coonawarra wine growing region of south east South Australia (Fig. 19), potentially affected people, enterprises and organisations have been demonstrably able to continue their various agricultural activities in compatible, contemporaneous coexistence with the petroleum activities. Outcomes have been demonstrably safe and without significant, perceptible, associated, negative impacts on the environment, enterprises or the health and safety of people. In short, the sustainability of multiple-land use, including access for petroleum exploration, development and production is demonstrable.

Regulatory framework

In April 2016, the Australian Competition and Consumer Commission (ACCC) inquiry into Australia's east coast gas supply (https://www.accc.gov.au/regulated-infrastructure/energy/east-coast-gas-inquiry-2015) concluded that government(s) should consider adopting regulatory regimes to manage the risks of individual gas supply projects on a case by case basis rather than using blanket moratoria. South Australia's framework is recognised as efficiently and effectively deploying leading practices in this regard:

- The grant of a *Petroleum and Geothermal Energy Act 2000* (PGE Act) licence provides a unique entitlement to progress relevant petroleum, geothermal and gas storage projects and operations.
- Gaining approval for on-ground activities is a separate (case-by-case) step that follows the grant of a PGE Act licence. South Australia's regulatory framework involves robust stakeholder consultation, ensuring that the concerns of potentially affected people, enterprises and organisations are taken into account when decisions are made to approve (or otherwise) on-ground activities regulated under the PGE Act.
- The exploration and development of oil and gas (including the use of fracture stimulation) will not be permitted in agricultural areas of South Australia unless petroleum licensees address all valid impacts, underpinned by considerable research on the natural, social and economic environment (which must

include for example impacts on the tourism, food, wine and fibre industries). Indeed, approval for on-ground operations will be only be gained (if gained) after South Australia's regulators are satisfied that:

- All risks that will adversely affect other users of the land will be avoided; and
- All concerns from potentially affected people (including land owners, enterprises, cultural heritage and native title groups, community groups, and other government departments) have been adequately addressed.

- In order for a licensee to undertake operations in accordance with the PGE Act, an Environmental Impact Report (EIR) must be prepared by the licensee in consultation with all potentially affected people, enterprises and organisations. This document addresses the potential impacts on the social, natural and economic environments (which includes public health and impacts on brands), and outlines the extent to which these impacts are likely and manageable.
- On the basis of the information provided in the EIR and in accordance with Section 98 of the PGE Act, the EIR is reviewed by experienced professionals in the Department of State Development's Energy Resource Division (DSD-ERD) in consultation with other relevant co-regulatory agencies not limited to: the Department for Environment, Water and Natural Resources; the Environment Protection Authority; Health SA; Department of Planning, Transport and Infrastructure; Safework SA and Primary Industries and Regions – South Australia. The consultation process with co-regulatory agencies results in the classification of the level of impact (low, medium or high) of the proposed activity using a set of publicly developed and disclosed criteria[3]. A Statement of Environmental Objectives (SEO) must then be prepared:

  a) For low impact to medium impact activities – on the basis of an EIR; or

  b) For high impact activities – on the basis of an environmental impact assessment under Part 8 of the *Development Act 1993*.

- The SEO must state the environmental objectives to be achieved in carrying out specified activities, as well as the assessment criteria used to assess whether the objectives have been achieved by the licensee.
- The EIR/SEO must demonstrate how potential negative impacts are prevented through appropriate design, construction and modelling and importantly how this will be measured and monitored. The approval of an EIR/SEO must be in accordance with consultation requirements under Section 101 to 103 of the PGE Act. If a petroleum project cannot demonstrate compliance with these regulatory requirements, then approval for the project will not be granted. This holds true for all projects regulated under the PGE Act.
- In addition to the requirements of the PGE Act, SEOs refer to requirements of co-regulation (for example for the protection of water) of other Acts. In this way, non-compliance with relevant co-regulation becomes a non-compliance under the PGE Act. In short – the SEO is a co-regulatory instrument that allows South Australia to be efficient and effective, without duplicative processes to assess and regulate land access for all proposed petroleum, geothermal energy and gas storage exploration, development and production projects.

The successful bidder will be required to meet South Australia's best practice environmental requirements before being approved to conduct exploration activity on the block.

DSD-ERD acts as a one-window to government for explorers in obtaining necessary environmental approvals on the occasions when they are required from co-regulators in other government agencies. Approvals to conduct field operations etc. are first submitted to DSD, which arranges distribution to the other relevant government agencies for comment. DSD-ERD personnel are available to assist licensees prepare the necessary paperwork. Only after the robust approvals process described above does the Minister for Mineral Resources and Energy DSD issue necessary approvals (or otherwise).

An objective based co-regulatory approach applies in SA for the regulation of the upstream petroleum industry to reduce compliance costs and deliver better environmental outcomes.

3 The Criteria for Classifying the Level of Environmental Impact of Regulated Activities (PDF 232KB) https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/PGRG004.pdf

The following EIR and SEOs exist for area-specific and location-specific upstream petroleum and geothermal operations in the Otway Basin:

Annear J.A. 2013. *Statement of Environmental Objectives for Geophysical Operations in the Otway Basin, South Australia*. South Australian Department for Manufacturing, Innovation, Trade, Resources and Energy. Report Book 2013/00008.

Roberts D. 2001. *Environmental impact report for seismic operations in the Otway Basin, South Australia, 3rd edn*. South Australian Department for Manufacturing, Innovation, Trade, Resources and Energy. Report Book 2013/00009.

Beach Energy 2013. *Environmental Impact Report for Drilling, Completions and Initial Production Testing in the Otway Basin, South Australia*.

Beach Energy 2013. *Statement of Environmental Objectives for Drilling, Completions and Initial Production Testing in the Otway Basin, South Australia*.

Air Liquide Australia 2013. *Environmental Impact Report for Caroline Carbon Dioxide Purification Plant in the Otway Basin, South Australia*.

Air Liquide Australia 2013. *Statement of Environmental Objectives for Caroline Carbon Dioxide Purification Plant in the Otway Basin, South Australia*.

Origin Energy 2002. *Environmental Impact Report for Katnook and Ladbroke Grove Gas Plants*.

Adelaide Energy 2011. *Statement of Environmental Objectives for Katnook and Ladbroke Grove Gas Plants*.

Epic Energy 2004. *Environmental Impact Report for the South East Pipeline System*.

Epic Energy 2009. *Statement of Environmental Objectives for the South East Pipeline System*.

APA Group 2016. *Environmental Impact Report for the SESA Katnook/Ladbroke Grove Gas Pipeline*.

APA Group 2016. *Statement of Environmental Objectives for the SESA Katnook/Ladbroke Grove Gas Pipeline*.

While fracture stimulation has been a routine, safe process in the Cooper Basin for decades, there have been no fracture stimulation projects proposed to date in the south east of South Australia in the Otway Basin. When and if a proposal for fracture stimulation in the Otway Basin arises, a location-specific and activity-specific EIR will need be prepared to inform a pertinent SEO, and both of these regulatory instruments will be the subject of public consultation as described above.

Control zones can be specified in SEOs to protect unique values and importance. The appropriateness of defined upstream petroleum operations within control zones will be informed with targeted consultation focused on potentially affected people, enterprises, organisations and co-regulators. This will ensure that relevant risks to unique values are managed to an acceptable level through appropriate design, location, construction and operation, including monitoring of any proposed activities.

Natural Resources Committee Inquiry – Unconventional Gas Final Report

On 29 November 2015, the Natural Resources Committee (NRC) published its *Final Report Inquiry into Unconventional Gas (fracking) in the south east of South Australia*. This final report made 5 recommendations and 10 findings, including proposing amendments to the PGE Act to define terms such as 'risk' and 'consultation processes', and introducing formal guidelines for community engagement and consultation. A routine review of the PGE Act has been initiated as part of a continuous improvement review cycle to address new issues, administrative matters and potential enhancements identified since 2000. The issues raised by the NRC recommendations where relevant will be addressed through public consultation that will be a key feature of the PGE Act review process.

National parks and reserves

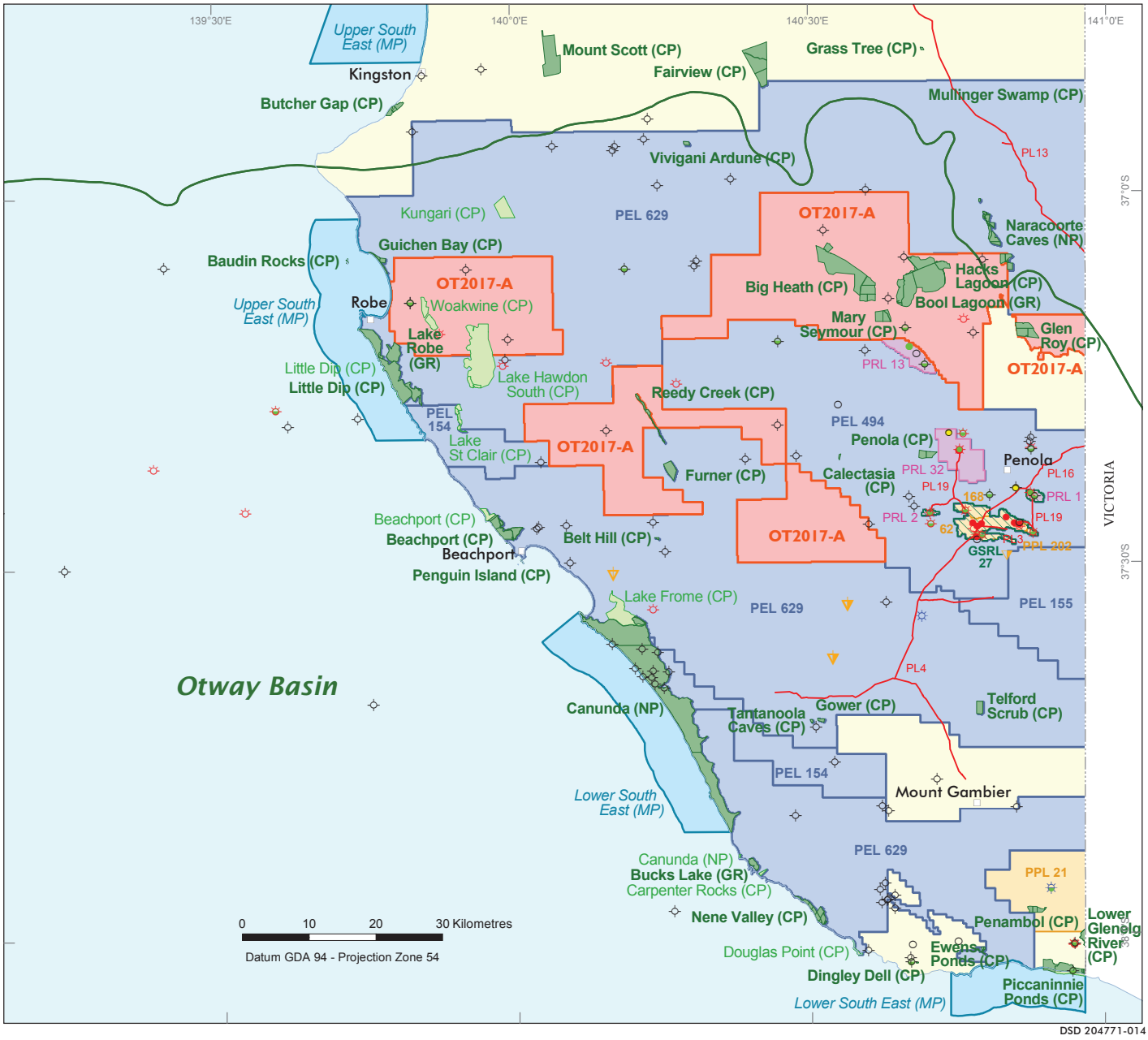
There are a number of national parks and other areas of remnant native vegetation in the area, in some of which exploration is permitted, the typically small size of the no exploration access parks makes it possible to work around them (Fig. 18). The reserves have been created to conserve the best examples of vegetation and landforms in the region. There are three types of South Australian reserves including conservation parks, national parks and regional reserves. The conditions of access vary from park to park, based upon the type of reserve classification, the activity proposed and its likely impact on the environment.

Primary industries

The Department of Primary Industry and Regions SA (PIRSA) regard the south east region of South Australia as a highly modified landscape where broad-scale land clearance and extensive cross-catchment drains have converted what was once a wetland dominated landscape into agricultural and forestry production on a vast scale (Fig. 19).

Otway Basin, South Australia

NATIONAL PARKS and RESERVES



Parks and Reserves

- Park or reserve – no petroleum exploration access
- Park or reserve – petroleum exploration access
- South Australia Marine Parks Network
- Otway Basin outline

Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Geothermal wells

- Abandoned well
- Suspended well

Government of South Australia
Department of State Development

Figure 18 Otway Basin national parks and reserves

Otway Basin, South Australia

LAND USE and ACCESS

Parks and Reserves

- Park or reserve – no petroleum exploration access
- Park or reserve – petroleum exploration access
- Marine Parks Network – petroleum exploration access

Land use

- Cropping
- Forestry
- Grazing
- Horticulture
- Irrigated grapes
- Coonawarra Wine Region

Petroleum tenements

- OT2017-A acreage release block
- Petroleum exploration licence (PEL)
- Petroleum production licence (PPL)
- Petroleum retention licence (PRL)
- Gas storage retention licence (GSRL)
- Pipeline licence (PL) – gas

- Otway Basin outline

Petroleum wells

- CO_2 well
- CO_2 well with oil shows
- Dry hole
- Dry hole with oil shows
- Gas shows
- Gas well
- Gas well with oil shows
- Oil and gas well
- Oil and gas shows
- Oil well
- Proposed or currently drilling
- Resource play well

Geothermal wells

- Abandoned well
- Suspended well

Government of South Australia
Department of State Development

Figure 19 Otway Basin land use and access

For a detailed description of the landscape and drainage system in the south east of South Australia – see: http://www.pir.sa.gov.au/aghistory/left_nav/natural_resources/water_resources_and_irrigation/history_of_the_south_east_drainage_system_-_summary/history_of_the_south_east_drainage_system_-_summary.

Beef cattle production is the most significant product in the south east, forestry is the second largest, followed by sheep and lambs, wine grapes and milk production. The region produces nearly one third of the value of South Australia's agricultural produce from only 2% of its land mass.

The south east is characterised by a near-surface unconfined aquifer which is the main water supply for the landholders, and this requires consideration while conducting exploration activities.

European heritage

A number of sites of European heritage significance such as historic buildings and structures and geological monuments occur in the region. These are indicated on environmental sensitivity maps held by DSD. The majority of the sites are small and easily avoided by exploration activities.

Aboriginal heritage and native title

In South Australia it is an offence to disturb or destroy Aboriginal sites, objects or remains. Standard procedures for determining the presence of Aboriginal heritage prior to the commencement of activities have been determined. These procedures involve consulting with the relevant Aboriginal organisation(s) and maintaining a watch for sites, objects or remains during activities. Generally the sites are no larger than a few hundred square metres and are easily avoided. Since the inception of the *Aboriginal Heritage Act 1988*, there have been no conflicts between Aboriginal heritage sites and exploration or production activities in South Australia. Licence holders are encouraged to develop a dialogue with regard to Aboriginal heritage and related matters with Aboriginal people having associations with the lands coincident with their licence area(s). Native title as referenced in the *Commonwealth Native Title Act 1993*, may be applicable on e.g. non-freehold or non-perpetual leasehold land. There are currently no native title applications over the areas on offer, and native title is not likely to be a significant issue in the SA Otway Basin area, as most land is freehold or perpetual leasehold. Heritage must nonetheless be well protected.

Geothermal Exploration Licences

A number of Geothermal Exploration Licences (GELs) coincide with petroleum exploration and production licences in the Otway Basin region (Fig. 20). The GEL licensee must be notified of activities in PELs, and may object to the activity and claim compensation if their activities or resources are affected. Likewise the GEL holder must notify the PEL holder of their activities, and the PEL holder may also object and claim compensation.

Associated Activities Licences

Associated Activities Licences (AALs) are now available under the *Petroleum and Geothermal Energy Act 2000*. These licences allow explorers to undertake activities (e.g. seismic surveys) or establish facilities in proximity to petroleum exploration, retention and production licences. AALs are typically used to enable the recording of full-fold seismic within a PEL by recording tails of seismic lines outside the licence area.

CLIMATE

The climate in the south east of South Australia is characterised by mild dry summers and cold wet winters, consequently exploration activities are generally conducted in the summer and autumn months of December through to April. However, with advanced preparation of sites it is possible to conduct activities year round. For more information on weather in the region:

http://www.bom.gov.au/climate/averages/tables/cw_026021.shtml

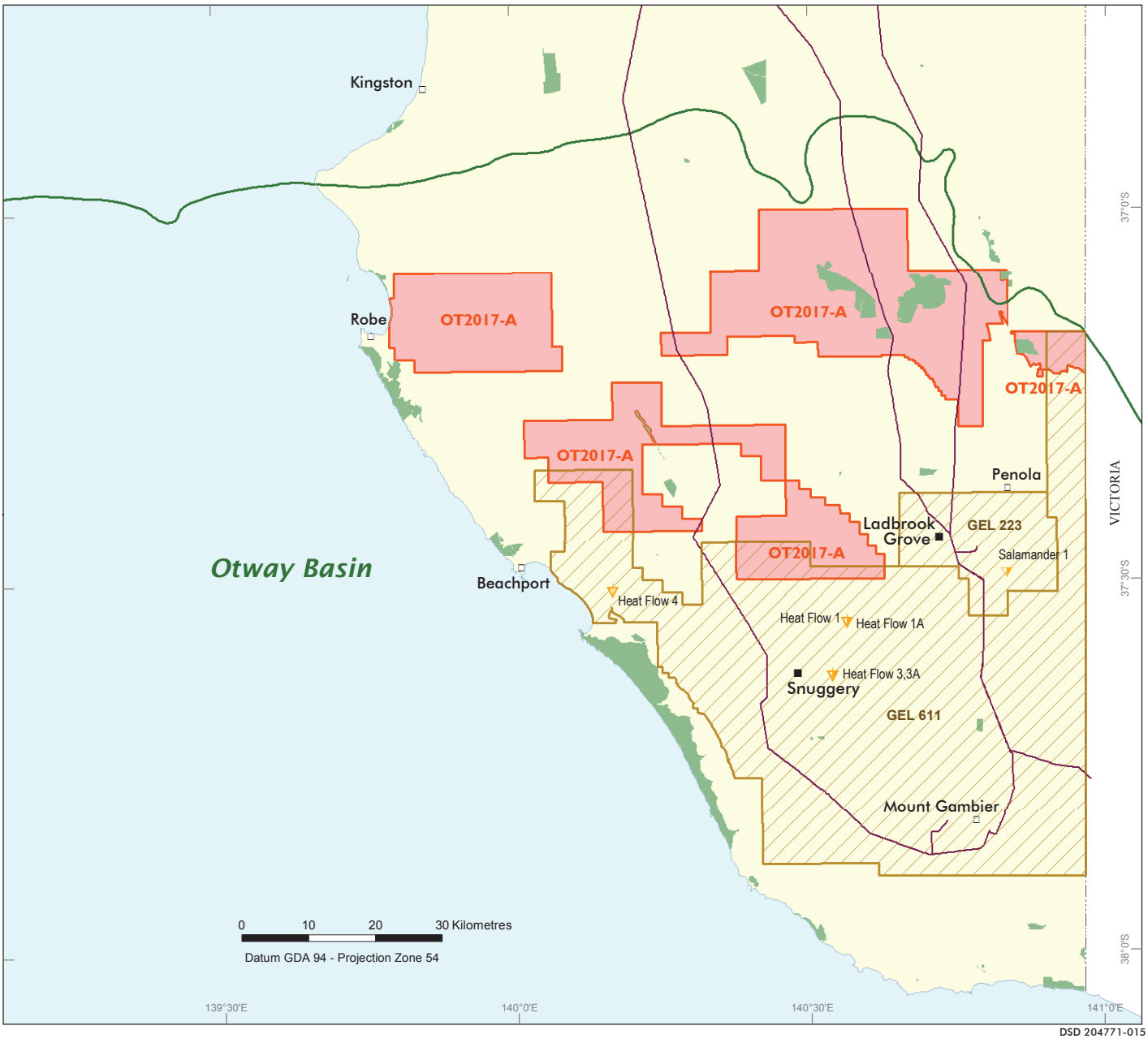
BIDDING AND AWARD PROCESS

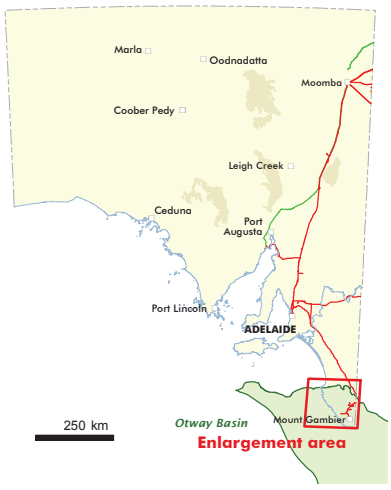
Winning bidders will be selected on the basis of the total five-year work program bid. The work program must be completed within the overall area of the PEL. It must include a statement of exploratory operations the applicant proposes to carry out in the first five-year licence term. It is expected that at least one petroleum exploration well would be included in the program.

Bids will be assessed using the philosophies expressed in "Selecting the winning bid". For

Otway Basin, South Australia

GEOTHERMAL LICENCES





Petroleum tenements

OT2017-A acreage release block

Geothermal tenement

Geothermal Exploration Licence (GEL)

Geothermal wells

Abandoned well

Suspended well

Infrastructure

Power station

Transmission lines

Otway Basin outline

Park or reserve – no petroleum exploration access

Government of South Australia
Department of State Development

Figure 20 Otway Basin geothermal licences

a review of how this process has been applied see "Shaping the Cooper Basin 21st century renaissance". The specific scoring scheme is detailed in "OT2017-A Bid Assessment Policy".

Relevant OT2017-A Application and Award procedures and forms can be accessed at the following links:

- OT2017-A PEL Application Form
- Application and Award Procedures and Forms OT2017-A Acreage Release

In general, it is important to note that the timing of well drilling and seismic or other data acquisition will be taken into account. Key assessment criteria include but are not necessarily limited to:

- The number of exploration wells to be drilled in the PEL, their nature of subsurface targets to be drilled and their timing;
- The number of years the applicant is prepared to guarantee the program;
- The extent to which proposed wells are supported by existing or new programmed seismic data;
- The amount and nature of seismic surveying (i.e. 2D versus 3D) to be carried out and its timing;
- Other data acquisition (e.g. gravity, aeromagnetic or geochemical surveys);
- Seismic reprocessing to be carried out; and
- The adequacy of the applicant's financial resources and technical expertise to satisfactorily undertake the proposed work program and overall regulatory compliance.

In addition to the above criteria, where bids are similar, the benefits of the introduction of new explorers into the area may be taken into account. In the case of cascading bids (i.e. multiple or hybrid bids by one applicant or joint venture), only the highest bid will be considered.

Refer to the section describing South Australia's regulatory framework to gain an appreciation of the activity approvals process that follows the grant of a petroleum licence pursuant to the *Petroleum and Geothermal Energy Act 2000*.

The Minister is expected to announce the winning bidder(s), together with details of work programs, by late October 2017.

CONTACT INFORMATION

Comments, inquiries and applications for the exploration licence should be addressed to:

Executive Director, Energy Resources Division
Department of State Development
Level 7, 101 Grenfell Street
Adelaide SA 5000 AUSTRALIA

Phone National (08) 8463 3204
Fax National (08) 8463 3229

Phone International +61 8 8463 3204
Fax International +61 8463 3229

Web site http://www.petroleum.statedevelopment.sa.gov.au/

The envelope containing your application must be marked '**Confidential — contains PEL application**'.

Closing date and time

The closing date for OT2017-A applications is **4.00 pm Australian Central Standard Time on Friday 29 September 2017**.

REFERENCES

BOULT P.J. 2005. *Morum Sub-basin petroleum system*. South Australia. Department of Primary Industries and Resources. Narrated PowerPoint presentation (unpublished).

BOULT P.J., CAMAC B.A. and DAVIDS A.W. 2002. 3D fault modelling and assessment of top seal structural permeability — Penola Trough, onshore Otway Basin. *APPEA Journal* 42(1):151-166.

BOULT P.J. and HIBBURT J.E. (Eds) 2002. *The petroleum geology of South Australia. Volume 1: Otway Basin*. 2nd edn. Department of Primary Industries and Resources, South Australia.

EDWARDS D.S., STRUCKMEYER H.I.M., BRADSHAW M.T. and SKINNER J.E. 1999. Geochemical characteristics of Australia's southern margin petroleum systems. *APPEA Journal* 39(1):297-321.

JONES R.M., BOULT P.J., HILLIS R.R., MILDRREN S.D. and KALDI J. 2000. Integrated hydrocarbon seal evaluation in the Penola Trough, Otway Basin. *APPEA Journal* 40(1):194-211.

JORAND C., KRASSAY A. and HALL L. 2010. *Otway Basin Hot Sedimentary Aquifers and SEEBASE Project*. Department of Primary Industries and Resources, South Australia. Report Book 2010/00010.

LOVIBOND R., SUTTHILL R.J. and SKINNER J.E. 1995. The hydrocarbon potential of the Penola Trough, Otway Basin. *APPEA Journal* 35(1):358-371.

LYON P.J., BOULT P.J., HILLIS R.R. and BIERBRAUER K. 2007. Basement controls on fault development in the Penola Trough, Otway Basin, and implications for fault-bounded hydrocarbon traps. *Australian Journal of Earth Sciences* 54:675-689.

MCCLAY K.R., LONGLEY I.M., FITZPATRICK J.P., KING S.J. and SOMERVILLE R.M. 2001. Analogue modelling of extensional fault architecture: comparisons with natural rift fault systems. In: Hill K.C. and Bernecker T. (Eds). *Eastern Australasian Basins Symposium, A refocussed energy perspective for the future, Melbourne, 2001*. Petroleum Exploration Society of Australia. Special Publication pp. 573-584.

MORTON J.G.G. 1990. Revisions to stratigraphic nomenclature of the Otway Basin, South Australia. Geological Survey of South Australia. *Quarterly Geological Notes* 116:2-19.

MORTON J.G.G. and BOULT P.J. 2001. Undiscovered petroleum resources. In: Boult P.J. and Hibburt J.E. (Eds) 2002. *The petroleum geology of South Australia. Volume 1: Otway Basin*. 2nd edn. Department of Primary Industries and Resources, South Australia.

NORVICK M.S. and SMITH M.A. 2001. Mapping the plate tectonic reconstruction of southern and southeastern Australia and implications for petroleum systems. *APPEA Journal* 41(1):15-35.

PALMOWSKI D., HILL K.C and HOFFMAN N. 2004. Structural-stratigraphic styles and evolution of the offshore Otway Basin – a structural seismic analysis. In: Boult P.J., Johns D.R. and Lang S.C. (Eds). *PESA's Eastern Australasian Basin Symposium II, Adelaide 2004*. Petroleum Exploration Society of Australia. Special Publication pp. 75-96.

TEASDALE J., PRYER L., STUART-SMITH P., ROMINE K., LOUTIT T., ETHERIDGE M., SHI Z., FOSS C., VIZY J., HENLEY P. and KYAN D. 2001. Otway and Sorell basins SEEBASE Project. SRK Consulting report, SRK Project Code: GA701. Department of Primary Industries and Resources, South Australia. Open file Envelope 9889 (unpublished).