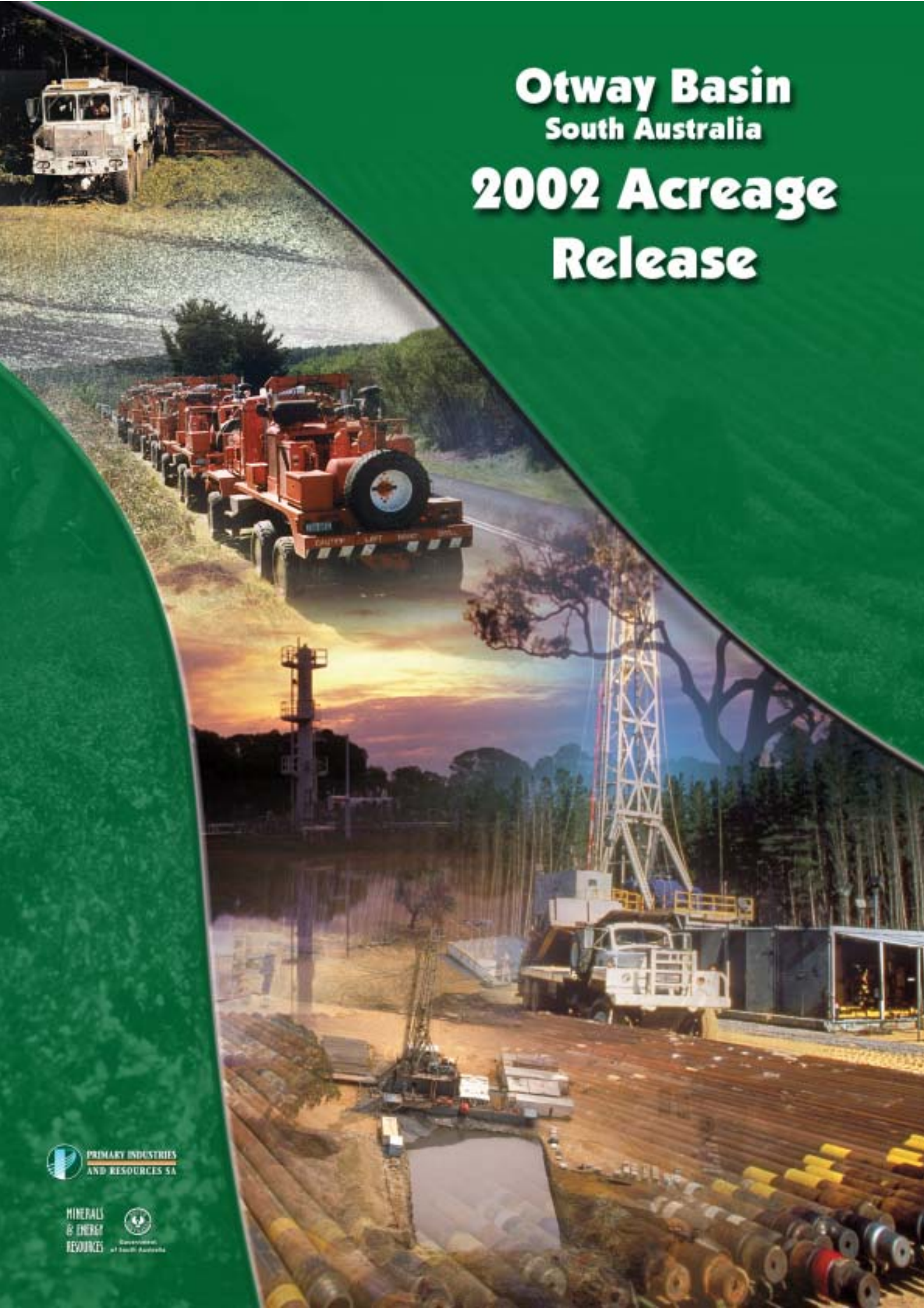
Otway Basin
South Australia
2002 Acreage Release



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Government of South Australia

Otway Basin exploration opportunities —
Blocks OT2002-A and B

Compiled by
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Petroleum Group

October 2002

Petroleum Exploration Data Package 12

PRIMARY INDUSTRIES AND RESOURCES SA

MINERALS & ENERGY RESOURCES
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SHORTENED FORMS

General

bbl	billion barrel
PEL	petroleum exploration licence

Measurements

bcf	billion cubic feet
btu	British thermal unit
h	hour
kL	kilolitre
km	kilometre
kPa	kilopascal
MW	megawatt
PJ	petajoule
psi	pounds per square inch
t	tonne

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Otway Basin exploration opportunities — Blocks OT2002-A and B

Peter J. Boult and Elinor A. Alexander

EXECUTIVE SUMMARY

Two onshore blocks in the onshore Otway Basin of South Australia are offered for petroleum exploration licences (PELs) on the basis of competitive work program bidding (Fig. 1, Table 1). Block OT2002-A contains mostly Early Cretaceous targets and a small area with additional Late Cretaceous targets. Block OT2002-B contains only Early Cretaceous targets. Bidding closes at 4.00 p.m. on Thursday, 22 May 2003, and it is planned that the winning bids will be announced in June 2003. Two Early Cretaceous plays exist within these areas:

- A newly identified play, which comprises distal lake deposits of the Lower Eumeralla Formation overlying Crayfish Group and Windermere Sandstone reservoirs.
- The proven play from within the Penola Trough (i.e. Pretty Hill Sandstone, shale rich Laira Formation reservoir–seal couplet).

These areas are being offered at a time when the economics controlling commercialisation in the Otway Basin are rapidly changing, with the entire South East Australian gas market becoming available via the SEAGAS Pipeline Licence 13 (Fig. 1).

Table 1 Summary of areas on offer in 2002 for the Otway Basin, South Australia

Block	Area (km^2)	Petroleum wells	Seismic (km)	SEG-Y (km)
OT2002-A	1423	9	1695	1155
OT2002-B	903	2	608	494

OT2002-A covers all of the previous PEL 75, which was cancelled in May 2002, and part of the previous PEL 66 and 72, which were relinquished in June 2001 and March 2002 respectively. OT2002-A comprises half of the St Clair Trough, the onshore part of the Rivoli and Geltwood Beach Troughs and part of the Tantanoola Trough (Fig. 2). Primary targets are sandstone reservoirs in the Early Cretaceous Crayfish Group, sealed by either the Laira Formation or distal lake deposits of the lower Eumeralla Formation. One well in the area (Rendelsham 1) had significant gas shows but lacked good reservoir.

OT2002-B covers parts of the previous PEL 66, PEL 57 and PEL 32, which were relinquished in June 2001, February 2000 and November 2001. OT2002-B comprises part of the Tantanoola and Penola Troughs (Fig. 2). The block contains only two wells, which were both drilled on the Tantanoola High. The Tantanoola Trough Crayfish sequence has never been penetrated. The main gas producing area (Petroleum Production Licence 62) of the Katnook graben lies directly to the north of OT2002-B.

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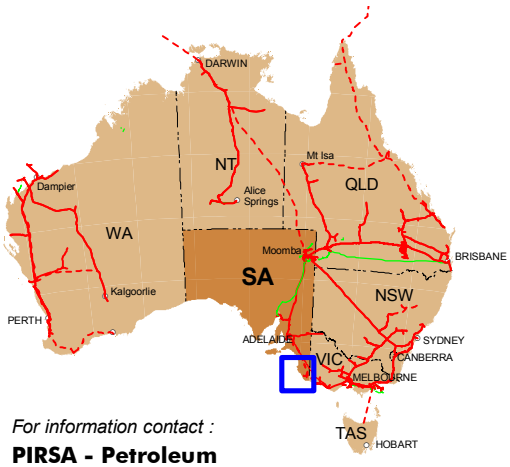
Otway Basin - South Australia
PETROLEUM TENEMENTS



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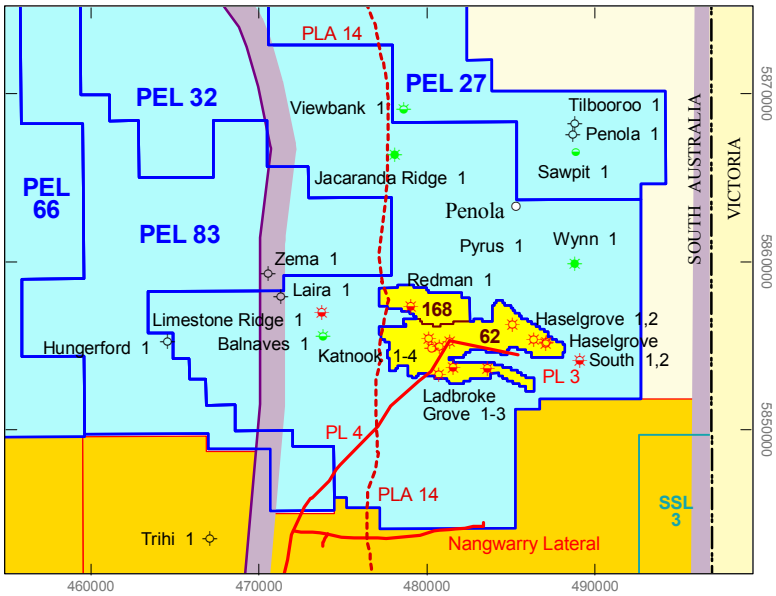
KATNOOK ENLARGEMENT



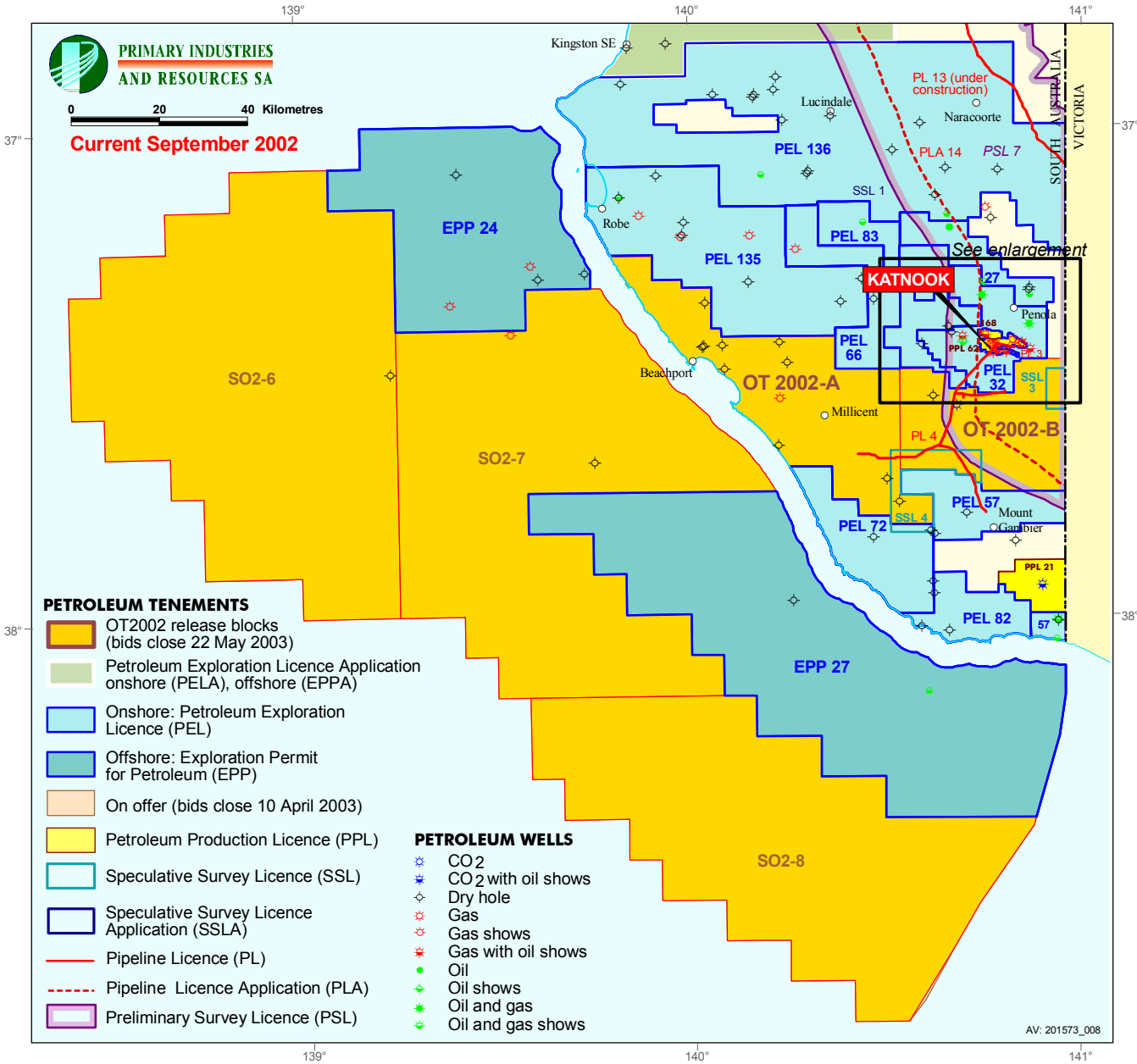


Figure 1 Petroleum Tenements in the Otway Basin

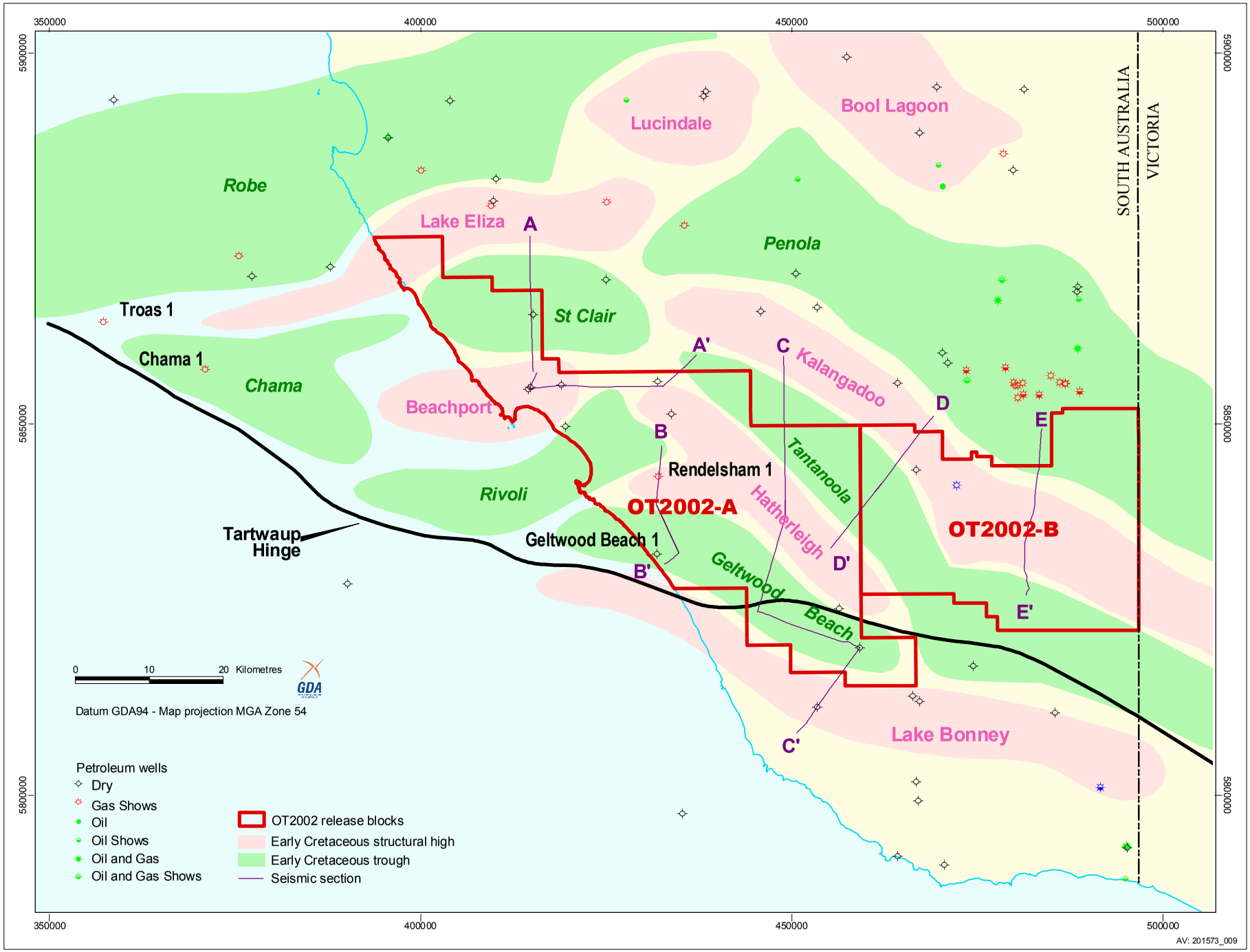


Figure 2 Early Cretaceous structure of the Otway Basin

Applications

Applications may be made for either or both of the two areas, OT2002-A and B. Licences are offered on the basis of the most competitive five-year work program. In the event that more than one area is offered to an applicant for a licence, there is no obligation for the applicant to accept any or all of the offers. It should be noted that there are no criteria limiting the number of exploration licences which may be offered to one applicant. Comments, inquiries and applications for exploration licences may be addressed to:

Director, Petroleum Group	Phone:	National	(08) 8463 3204
Office of Minerals and Energy Resources		International	+61 8 8463 3204
Primary Industries and Resources South Australia	Fax:	National	(08) 8463 3229
Level 7, 101 Grenfell Street		International	+61 8 8463 3229
ADELAIDE SA 5000	Web site:	www.petroleum.pir.sa.gov.au	
Australia	Email:	pirsa.petroleum@saugov.sa.gov.au	

The envelope containing your application(s) must be marked 'Confidential — PEL application'. Successful bids will be announced in June 2003.

The closing date for OT2002-A and B applications is 4.00 p.m. on Thursday 22 May 2003.

PETROLEUM GEOLOGY

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, which were formed as a result of the separation of Australia and Antarctica. The Otway Basin is part of the Australian Southern Rift System, formed along Australia's southern margin during a period of rifting and continental breakup which separated Australia and Antarctica. The northern margin of the basin extends up to 80 km inland, while the southern margin lies at the base of the continental slope some 160 km offshore. Approximately 70% of the basin is offshore. The basin straddles the South Australian – Victorian State border.

Summary

Age	?Jurassic – Late Cretaceous
Area in South Australia	50 000 km^2 (19 300 sq. miles)
Depth to target zones	1000–4000+ m (3300–13 000 ft)
Thickness	up to 9 km (5 miles)
Hydrocarbon shows	commercial gas from the Early Cretaceous Pretty Hill Formation and Windermere Sandstone Member and from Late Cretaceous Waarre Sandstone in Victoria; 2000 bbl recovered on test from Sawpit Sandstone
First commercial discovery in South Australia	1987 gas (Katnook 1)
Production (May 2002)	35 PJ (33.2 x 10 Btu) sales gas; 41 669 kL (262 095 bbl); 651 x 10 t saleable carbon dioxide (Caroline 1)
Basin type	rift
Depositional setting	fluvial–lacustrine – deltaic-marginal marine – deep water marine

Reservoirs	braided and meandering fluvial, deltaic and slope fan sandstones
Regional structure	early half grabens, sag, late shelf collapse
Seals	marine and lacustrine shales
Source rocks	early restricted lacustrine, coals, later marginal marine to marine
Depth to oil–gas window	oil 1700–3800+ m (5580–12 470 ft); gas 3800–5200+ m (12 470–17 000 ft)
Number of wells	84 exploration, 8 development–appraisal
Seismic line km	22 061 km 2D offshore, 8895 km 2D onshore; 452 km^2 3D

Seismic studies have shown that the structural evolution of the Otway Basin 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 have been found to contain at least one giant oil field.

A recent Primary Industries and Resources South Australia (PIRSA) survey of Australian explorers indicated the Australian petroleum industry regarded the onshore Otway Basin as the second most prospective basin in South Australia after the Cooper Basin. The main risk factors indicated by those surveyed were seal–structural integrity and small targets. Sophisticated fault leakage analysis of prospects is now being conducted by some operators prior to drilling and regional three-dimensional (3D) seismic surveys are now addressing the first risk factor. The economics of small discoveries have been improved by the proximity to markets for gas discoveries and the potential use of small gas discoveries for peak electricity generation opportunities in the national electricity market (as demonstrated by the 80 MW Ladbroke Grove Power Station). The construction of a pipeline from Victoria–Adelaide through the region by the SEAGAS consortium will also favourably improve the economics of small gas discoveries in the Otway Basin.

Source rock distribution and maturity modelling

There are numerous source rocks throughout the Late Jurassic to Tertiary section of the western Otway Basin (Fig. 3). Current knowledge of the source potential of the Crayfish Group sediments is restricted to the area north of the Tartwaup Hingeline. These source rocks are non-marine, Type III to IV kerogen-type derived from land plants with some non-marine Type II algal-rich shales occurring, especially in the early rift succession. Sediments of the Crayfish Group tend to be over mature for oil generation in the deeper portions of half graben and mature for gas. On the flanks of these troughs they tend to be early mature to mature for oil, whilst on basement highs they are immature to marginally mature for oil generation (Figs 4, 5).

Basal coals of the Eumeralla Formation (Fig. 6) are the most prospective source rocks of the Otway Cretaceous section, but are mostly immature in the area north of the Tartwaup Hinge. By comparison, the source potential of the Late Cretaceous section is generally low and is restricted to the area south of the Tartwaup Hinge.

Maturation profiles are strongly influenced by the thickness of Tertiary carbonates of the Heytesbury Group. In addition, each discrete half graben or structural province appears to have its own intrinsic sedimentological and thermal history. Accordingly, source rock distribution, richness, kerogen type and quality can be highly variable as a consequence of the basin architecture.

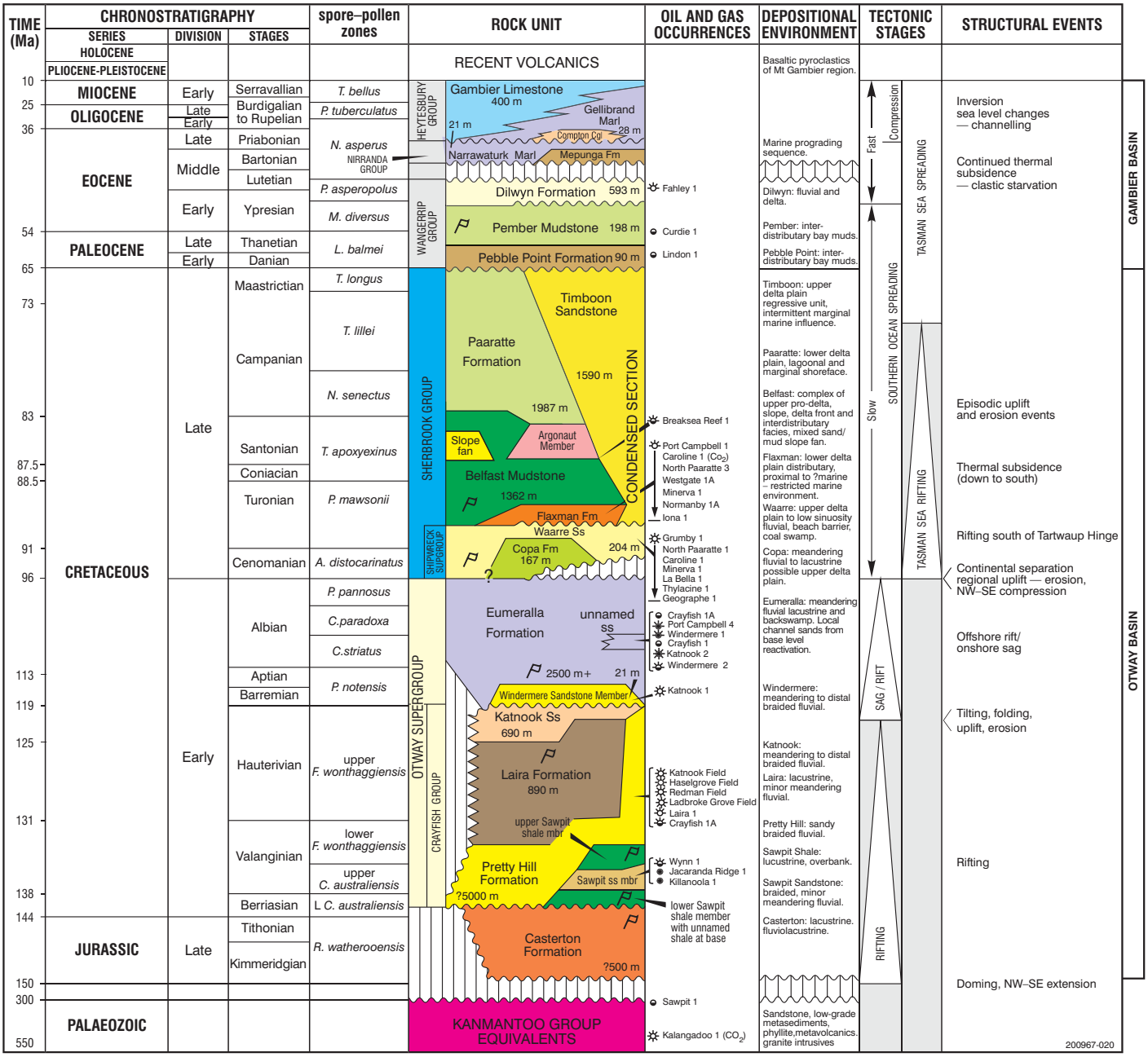


Figure 3 Stratigraphic column for the Otway Basin.

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. Exploration risk associated with reservoir quality and distribution is generally low, but risk associated with seal is more variable. Almost all formations from Palaeozoic basement to early Tertiary sands are potential reservoirs.

The most important and oldest established 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 gasfields, and flowed significant amounts of oil and gas from Wynn 1, Killanoola 1 and Jacaranda Ridge 1. Some intra-Pretty Hill Formation shales and the Laira Formation form good top seals to the underlying Pretty Hill reservoirs, however, where shallow faulting penetrates the Laira Formation, structural permeability controlled by the in situ stress field is a significant risk.

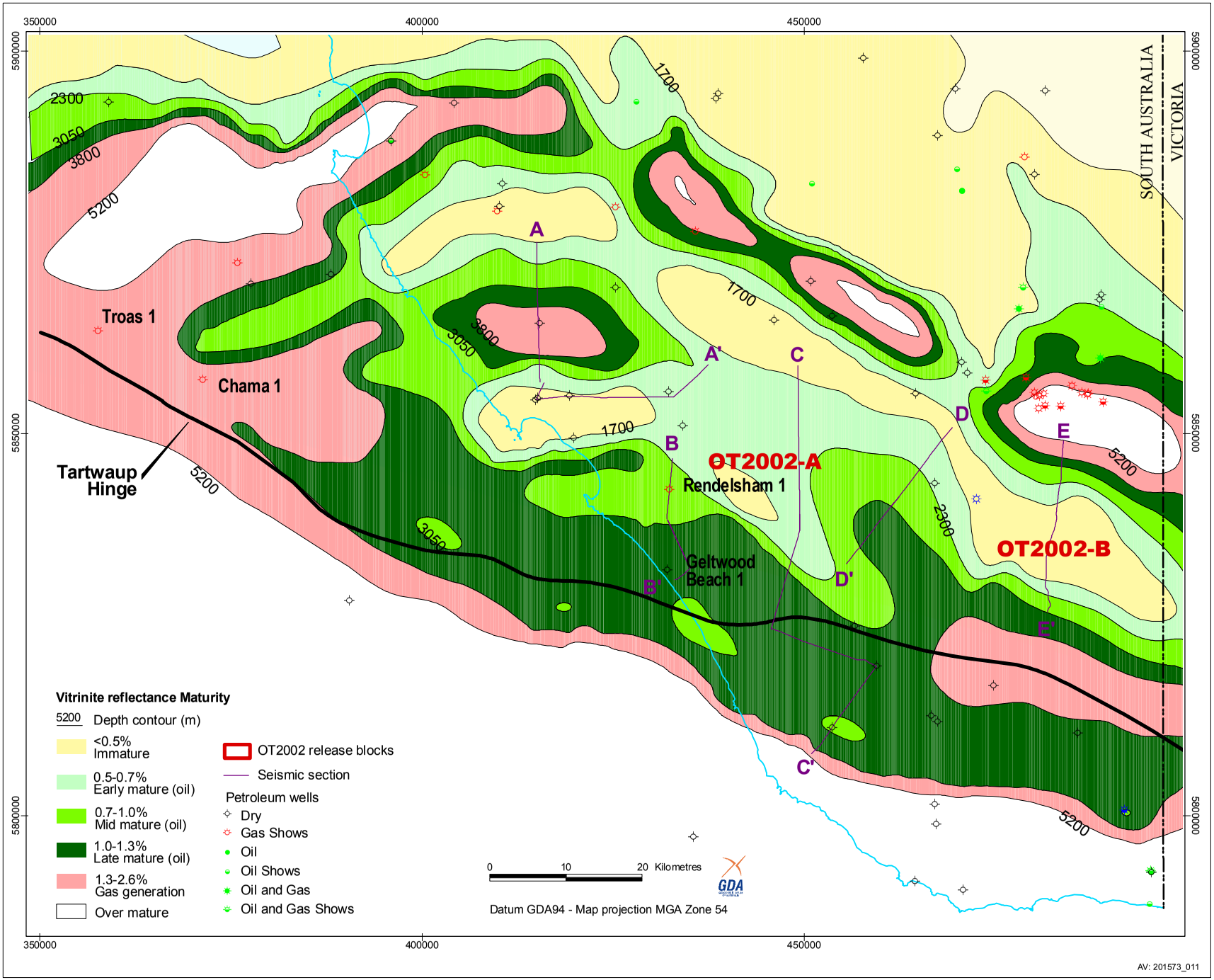


Figure 4 Oil and gas maturity at basement level equivalent to Casterton Formation

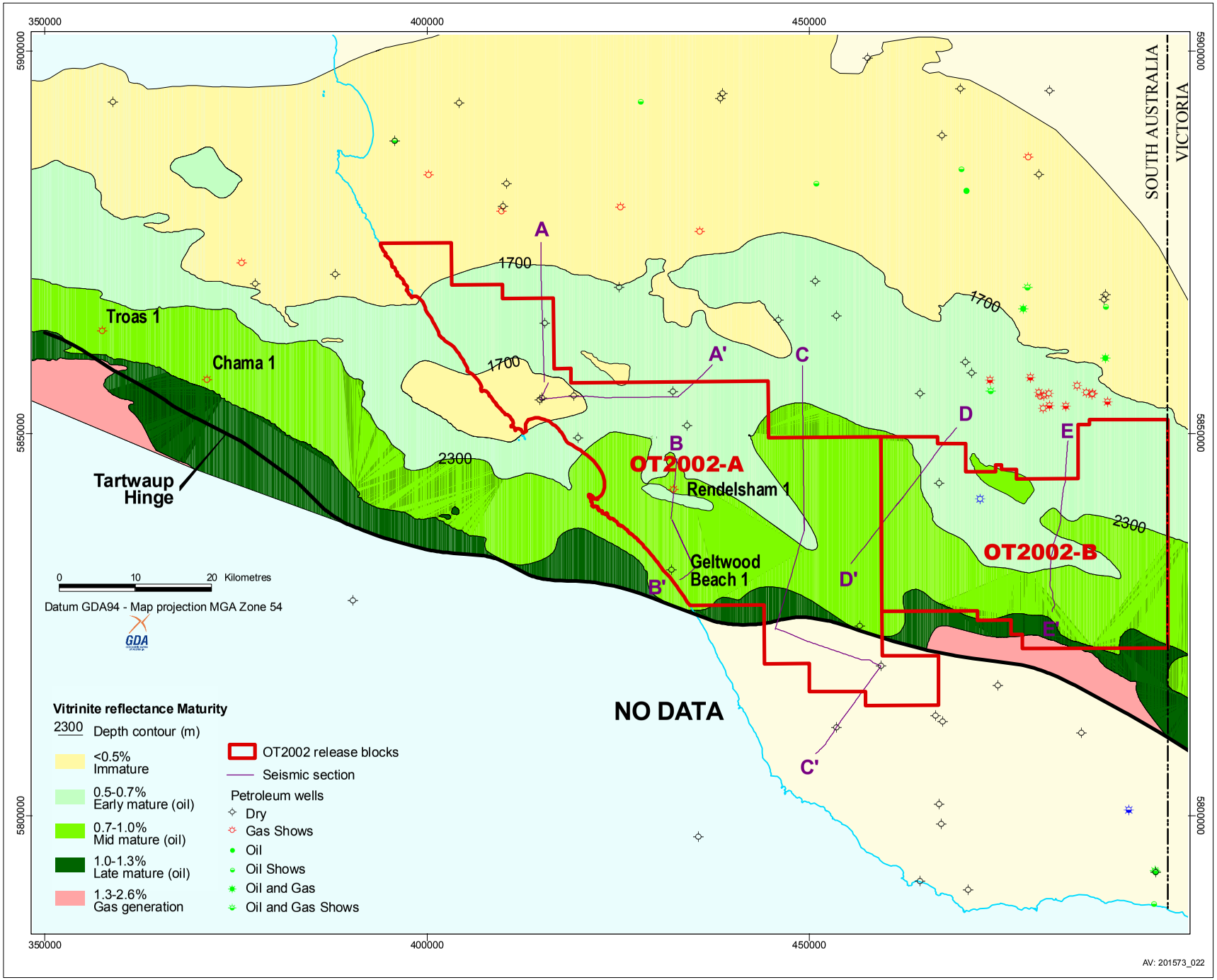


Figure 5 Bed maturity map, top Crayfish Group, equivalent to Eumeralla basal coals

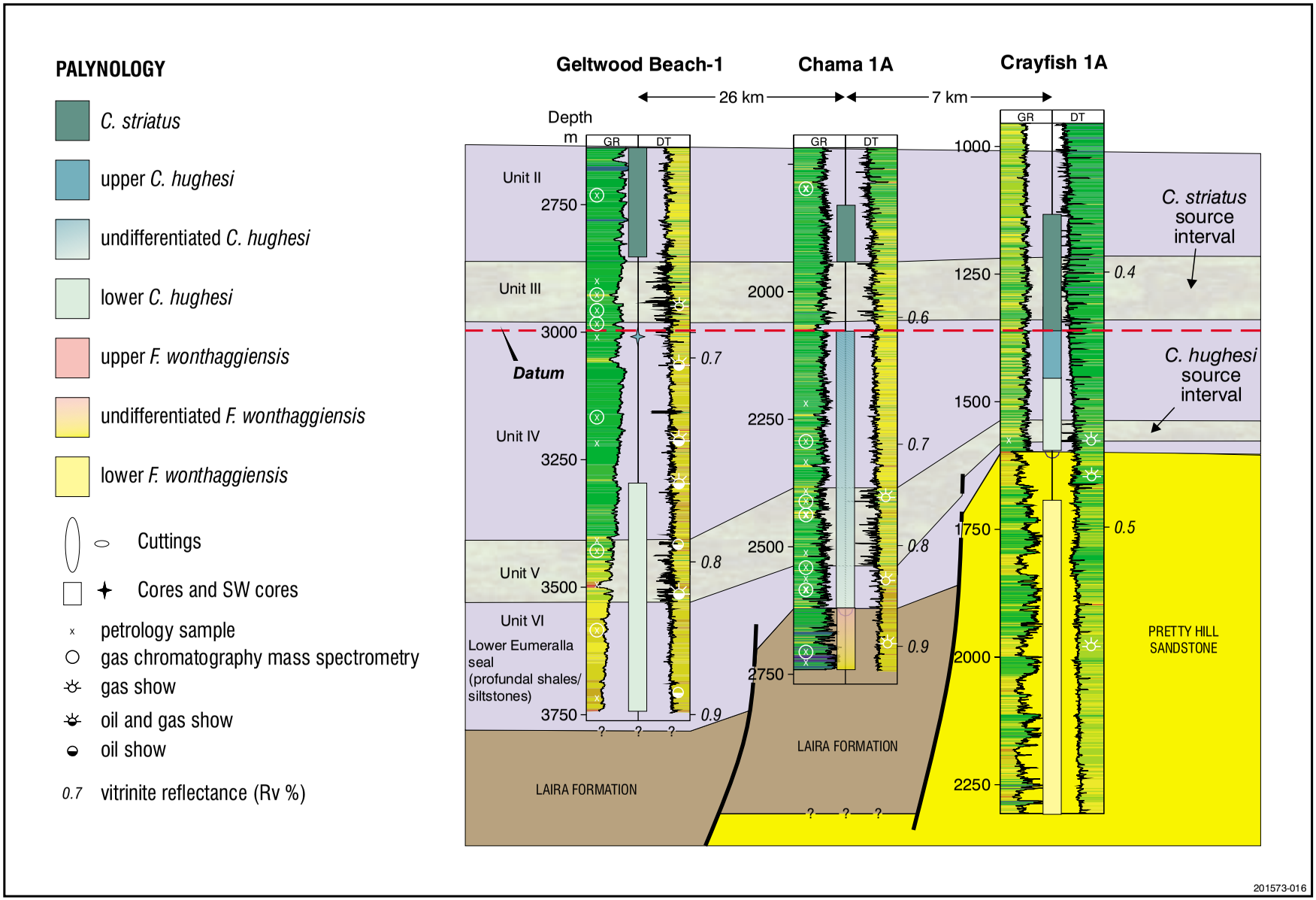


Figure 6 Cross-section from Geltwood Beach 1 to Crayfish 1A (after Tupper et al., 1993).

The Windermere Sandstone Member – Katnook Sandstone reservoir has had commercial gas production from Katnook 1 and a 2 m column exists within Crankshaft 1. However, the thin hydrocarbon columns have resulted in water production problems. The Windermere and Katnook Sandstone isopach (Fig. 7) indicate that it is thicker toward the centres of the Early Cretaceous troughs.

The seal capacity of the basal Eumeralla Formation increases closer to its depositional centre (Fig. 8), where more profundal lacustrine shales and finer grained siltstones were deposited. Near the Eumeralla Formation depositional edge, its seal capacity along with faulting is a major risk for the commercial accumulation of petroleum beneath it. If the Windermere and Katnook Sandstones are developed in the as yet completely untested Tantanoola and Geltwood Beach Troughs in a similar manner to the Penola and Rivoli Troughs (Fig. 7), then accumulations within this reservoir are likely to be much larger in the more distal troughs because of better sealing capacity of Unit VI of the Eumeralla Formation which overlies them.

The Late Cretaceous Waarre Sandstone and the upper Flaxman Formation sands are host to the Caroline carbon dioxide field (Caroline 1 is South Australia's most valuable well). They are economically significant reservoirs in both the on and offshore Victorian portion of the basin. The lower Flaxman Formation shale and Belfast Mudstone are their respective seals.

Petroleum entrapment

The primary risks associated with traps in the Otway Basin have been identified as fault and top seal leakage and carbon dioxide charge. The intensity of faulting in the Otway Basin provides a significant risk to trap integrity where such traps rely on fault closure. Tertiary to recent compression has selectively reactivated earlier faults and may have had significant impact on their propensity for leakage. Early Cretaceous shales are more indurated–brittle than Late Cretaceous shales and more prone to rupture during fault reactivation.

The basal Eumeralla seal is likely to be more ductile than the Laira Formation and therefore less likely to fail during Tertiary reactivation. In addition, shear stresses, which cause dilation on reactivated faults, are possibly smaller towards the centre of the basin over the Tantanoola, Geltwood Beach and Rivoli Troughs, thus reducing seal leakage risk.

Undiscovered resources

The Otway Basin in South Australia is an immature exploration province, with high potential for further discoveries. Although gas discoveries to date are relatively modest in size (average recoverable reserves per field is ~20 bcf), some discoveries in the Victorian portion of the basin are an order of magnitude larger (Fig. 9). Oil discoveries have only recently been made, and there is considerable potential for significant oil discoveries in the future. Table 2 summarises the undiscovered potential for gas in the key plays of the onshore South Australian portion of the basin only.

Table 2 Undiscovered potential of key plays, onshore Otway Basin, South Australia

Play	Undiscovered potential (bcf)		
	Probability that the ultimate potential will exceed the stated value		
	90%	50%	10%
Waarre–Flaxman	30	150	560
Crayfish	120	680	2330
Total	**180**	**900**	**2760**

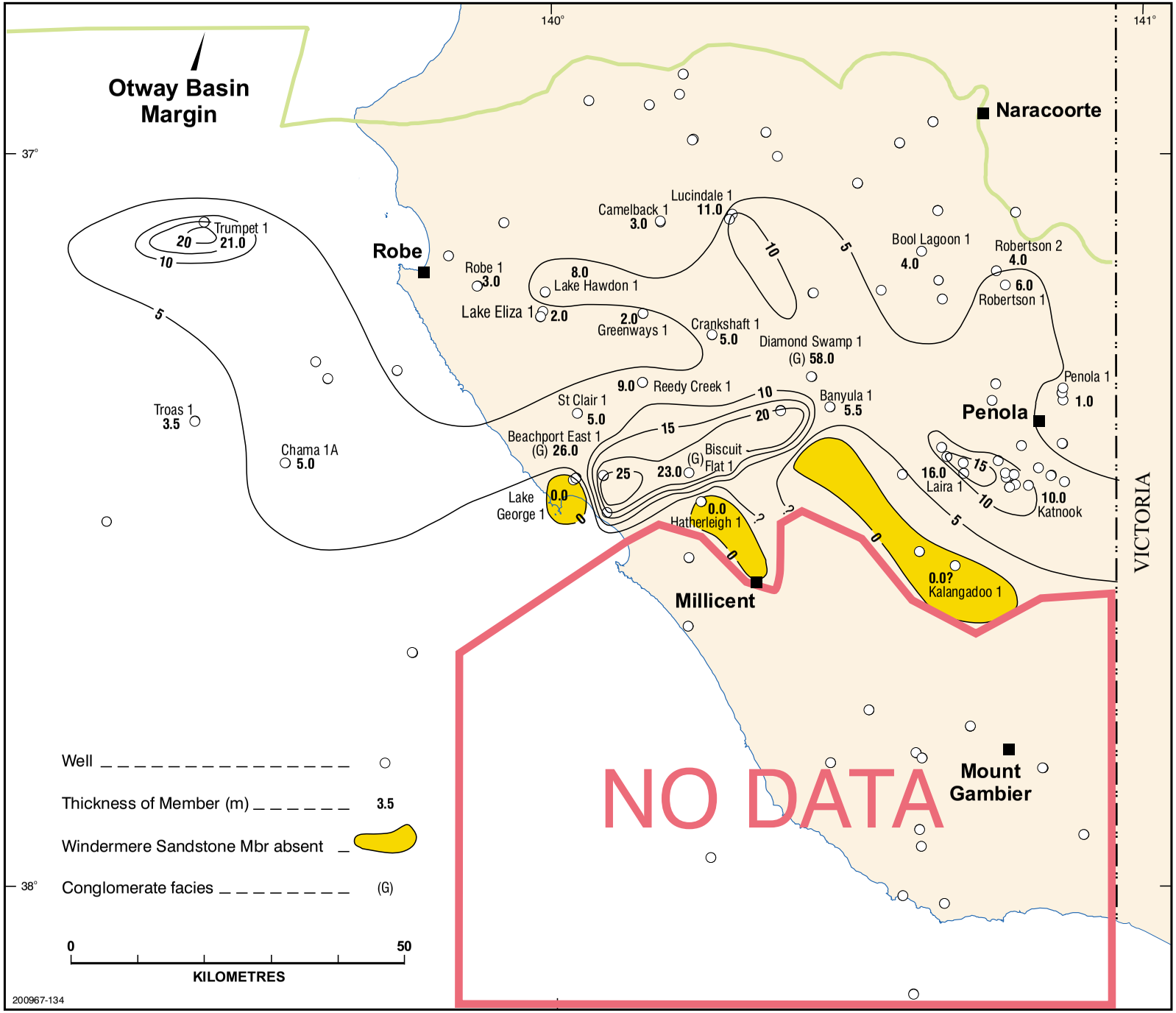


Figure 7 Isopach of the Windermere Sandstone reservoir

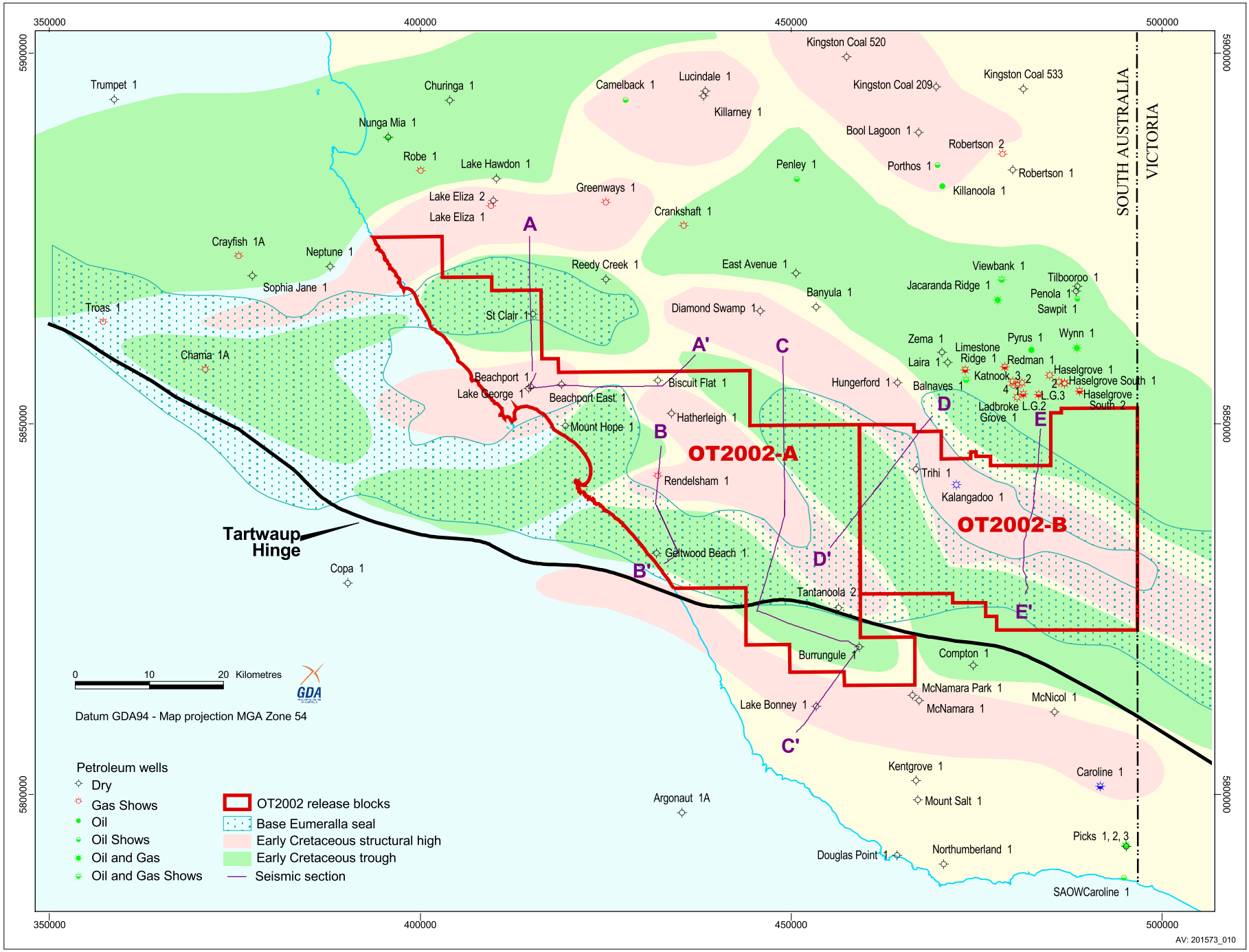


Figure 8 Early Cretaceous structure and Upper Crayfish play fairway

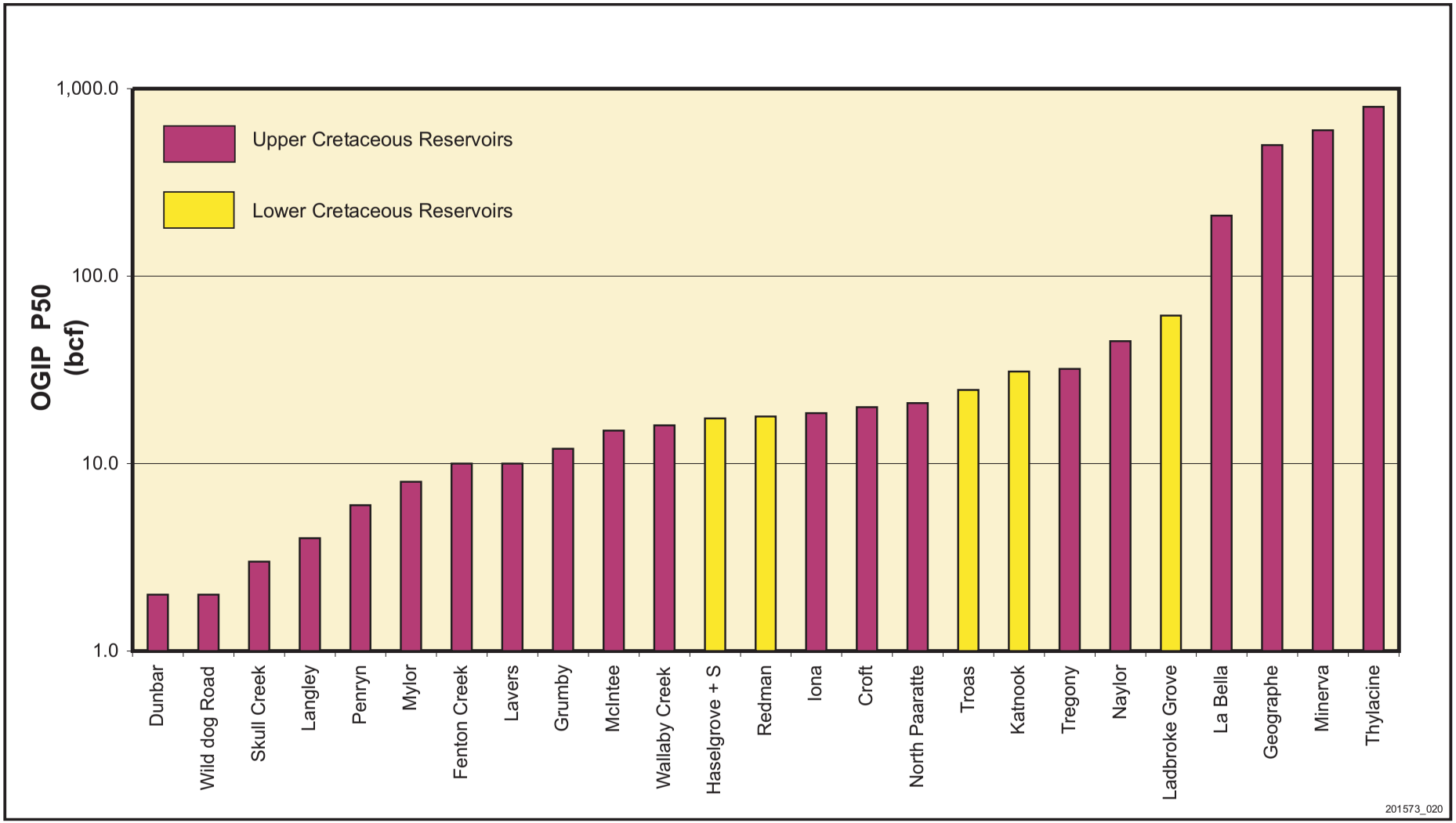


Figure 9 Otway gasfield sizes (2002)

INFRASTRUCTURE AND MARKETS

Five gas fields have been discovered in the Otway Basin in South Australia and total resources are estimated at 100 bcf. Epic Energy owns and operates a 46 km long pipeline, 150 mm diameter, from the Katnook gas processing plant to the Apcel paper mill at Snuggery, 7 km southeast of Millicent (Fig. 1). A second line, also 150 mm diameter and 19 km long, runs from this line to Mount Gambier. A third line, 50 mm diameter, runs from Katnook due east for 4.5 km to the Safries potato chip factory, 9 km south of Penola. A fourth line, 12 km long and 89 mm diameter, was constructed in the second half of 2000, connecting Kalangadoo to Nangwarry timber mill. The pipelines were constructed in 1990 and have a maximum operating pressure of 10 000 kPa (1450 psi). None of these pipelines have compression installed.

Gas from producing wells in the Katnook, Haselgrove and Redman gasfields is piped to a gas treatment plant located 300 m southeast of Katnook 1. The plant is operated by Origin Energy Resources Ltd, as operator for the joint venture, and has supplied about 2.8 bcf of gas per year to local domestic and industrial markets since 1991. The gas requires a minimum of processing to yield sales gas, which is then sold at the pipeline outlet from the Katnook Plant. The main gas customers are Kimberly Clark near Millicent (where gas replaced the use of liquefied petroleum gas, LPG, and brown coal briquettes), the Safries potato chip factory near Penola (which was attracted to the area by the natural gas supply), and domestic and industrial customers in Mount Gambier (which were previously supplied tempered LPG via a reticulation network). Condensate is stored onsite at the Katnook Plant before transportation by road tanker and sale to the Adelaide Refinery at Port Stanvac.

Opportunities created for small power stations in the more competitive electricity market, and the strategic location of the Ladbroke Grove Field adjacent to the main electricity link between Adelaide and Victoria, led to Origin Energy seeing an opportunity to make the field commercial by using the high carbon dioxide gas to fire a 40 MW power station. The power station utilises an advanced turbine design capable of burning the low-quality gas. The station began supplying power into the national electricity grid in January 2000. A second turbine was added in May 2000, boosting generating capacity to 80 MW. With both turbines operating, annual production of sales gas for the Penola Trough was increased to 7.94 bcf per year for the year ending May 2002. The total investment in the electricity development project by Origin is about $65 million and the maximum electricity price that can be obtained by generators is currently capped at A$5000/MW h. During a heat wave in southern Australia in October 2000, the Ladbroke Grove Power Station generated A$1.8 million in revenue compared with A$48 000 on the corresponding day a week before.

A pipeline with a capacity of roughly 125 PJ pa will be constructed by the SEAGAS consortium between Victoria and Adelaide. First gas flows are scheduled for first quarter 2004. Laterals connecting to this additional infrastructure will allow direct access from the PELA areas to the whole South Australian market. The threshold find-size for gas in the onshore Otway has been modest. In addition, the south east of South Australia and western Victoria exhibit a high diversity of industry. Consequently, opportunities for gas marketing linked to local industry developments in the region are good.

EXPLORATION ACCESS

Climate and land use

The climate in the South East 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 advance preparation of sites, it is possible to conduct activities year round. The main land use in the area is for mixed farming, ranging from sheep and cattle grazing to crops and wine grapes. Most land is freehold, and as such native title is not an issue in the area (although Aboriginal heritage issues may need to be considered). The South East is characterised by a near-surface unconfined aquifer, which is the main water supply for the landholders, which requires consideration while conducting exploration activities.

National parks and reserves

There are a number of national parks and other areas of remnant native vegetation in the area; in some of these, exploration is permitted and in others their small size makes it possible to work around them (Fig. 10). 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.

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 PIRSA. 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 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 their licence area. Native title may be applicable on non-freehold 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 South Australian Otway Basin area, as most land is freehold or permanent leasehold.

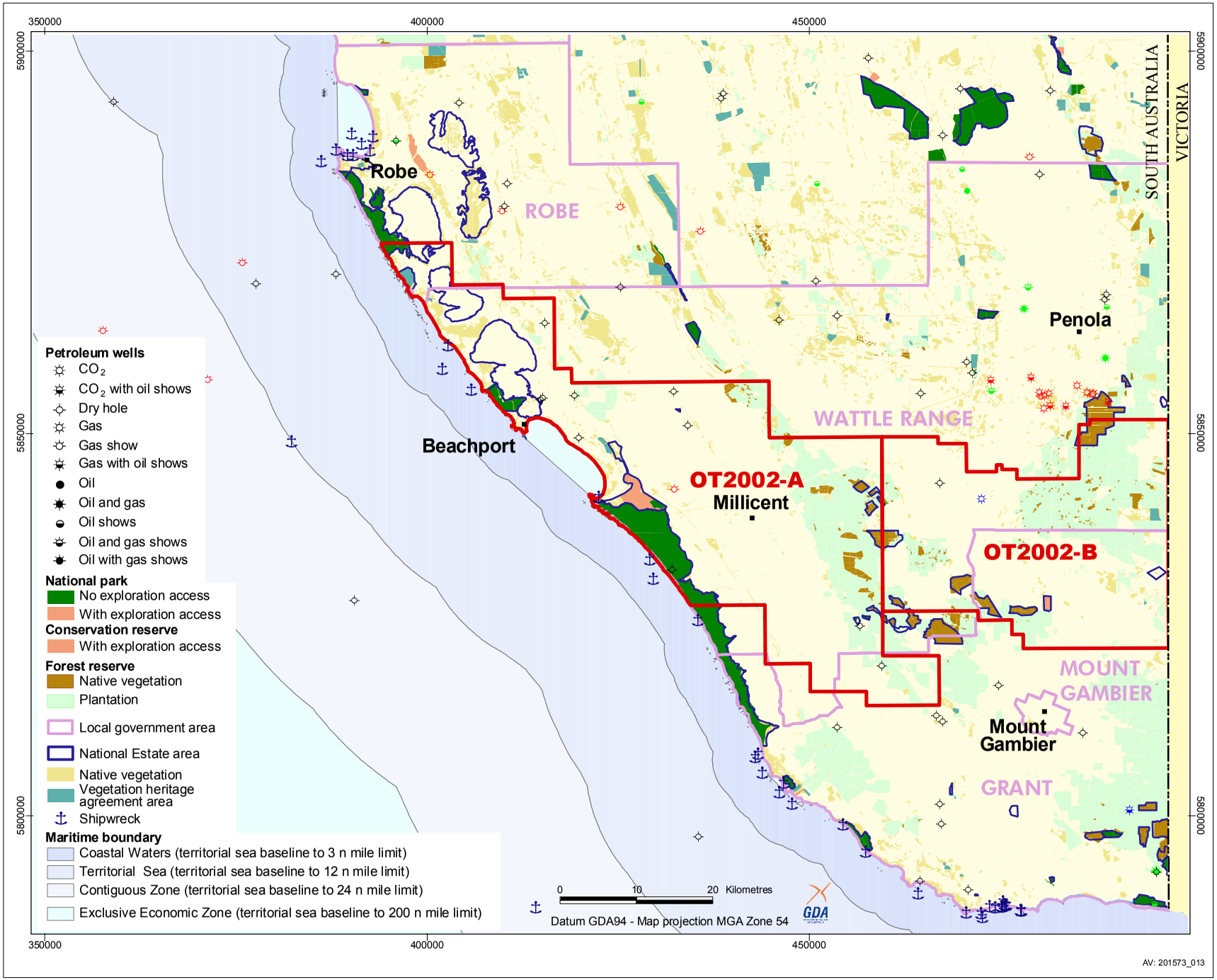


Figure 10 National parks, reserves, maritime boundaries and environmentally sensitive zones, Otway Basin

Environmental management

PIRSA Petroleum Group acts as a one-stop shop for explorers in obtaining any necessary environmental approvals on the occasions when they are required from other government agencies. Approvals to conduct field operations etc. are first submitted to PIRSA, which arranges distribution to the other relevant government agencies for comment and then issues the necessary approvals. Petroleum Group staff are available to assist licensees prepare the necessary paperwork.

PIRSA Petroleum Group has introduced an objective-based co-regulatory approach to the regulation of the upstream petroleum industry to reduce compliance costs and deliver better environmental outcomes. As this is a move away from prescriptive regulation and the pre-existing 'command and control' regime, a change in both culture and method are required. There will still be inspection of field operations, including audits by PIRSA authorised officers.

The following relevant documents have been produced by PIRSA petroleum Group and are available in hard copy or digital formats:

Cockshell, D.C. and Langley, K.R., 2001. Statement of environmental objectives seismic operations in the Otway Basin, South Australia. *South Australia. Department of Primary Industries and Resources. Report Book,* 2001/020.

Roberts, D., 2001. Environmental impact report for seismic operations in the Otway Basin South Australia (2nd edn). *South Australia. Department of Primary Industries and Resources. Report Book,* 2001/010.

AVAILABLE DATA

Open file well and seismic data available for Blocks OT2002-A and B are listed in Tables 3 and 4. Location of key seismic lines are displayed in Figure 11 (seismic lines shown in Figs 12–16).

Table 3 Exploration wells drilled in Blocks OT2002-A and B

Well	Operator	Spud	Total depth (m)	TD Formation
OT2002-A				
Beachport 1	South East Oil	01.09.1961	1208	Eumeralla Fm.
Geltwood Beach 1	Beach	22.08.1963	3749	Eumeralla Fm. Unit VI
Lake George 1	Esso	04.10.1964	1369	Basement
Saint Clair 1	Gas And Fuel Corp (Victoria)	11.03.1993	3284	Crayfish Gp.
Burrungle 1	Alliance	18.06.1975	2438	Eumeralla Fm.
Hatherleigh 1	Sagasco	01.10.1990	1908	Basement
Rendelsham 1	Sagasco	26.03.1994	2775	Basement
Mount Hope 1	Boral	12.07.1996	220	Sherbrook Gp.
OT2002-B				
Kalangadoo 1	Alliance	13.05.1965	2755	Basement
Trihi 1	Boral	14.071999	1222	Eumeralla Fm.

Table 4 Seismic data recorded in Blocks OT2002-A and B

Survey	No lines	Line km	SEG-Y available
OT 2002-A			
61 OT01	7	20.9	N
62 OT01	83	223.4	N
63 OT02	1	13.5	N
64 OT01	4	28.7	N
64 OT02	2	21.1	N
69 OT02	22	148.5	N
69 OT03	1	16.4	N
70 OT02	1	6.5	N
71 OT02	4	30.3	N
74 OT01	5	30.4	N
80 OT01	7	70.8	Y
84 OT01	2	12.1	Y
85 OT02	2	7.3	Y
85 OT03	11	80.3	Y
85 OT04	4	45.4	Y
86 OT02	8	59.8	Y
86 OT04	10	32.4	Y
87 OT02	2	4.0	Y
88 OT03	1	1.6	Y
90 OT02	2	12.7	Y
90 OT03	12	167.9	Y
90 OT04	11	49.9	Y
91 OT01	15	244.6	Y
91 OT02	9	51.4	Y
92 OT02	7	64.7	Y
92 OT04	6	32.8	Y
92 OT06	2	34.3	Y
93 OT03	10	119.1	Y
97 OT02	2	29.9	Y
98 OT01	1	9.8	Y
98 OT02	1	4.5	Y
98 OT04	1	1.0	Y
99 OT01	2	12.5	Y
99 OT02	1	2.0	Y
99 OT04	1	2.7	Y
00 OT02	1	1.8	Y
Total		**1694.9**	**1155.1**

Survey	No lines	Line km	SEG-Y available
OT 2002-B			
61 OT01	2	19.9	N
64 OT01	2	15.3	N
64 OT02	2	26.8	N
64 OT03	3	11.8	N
65 OT03	2	9.9	N
70 OT02	1	16.5	N
74 OT01	2	9.2	N
85 OT04	7	164.6	Y
86 OT04	5	12.6	Y
86 OT05	2	1.4	Y
87 OT01	1	3.8	Y
87 OT02	1	0.6	Y
88 OT01	7	35.5	Y
90 OT01	1	6.7	Y
90 OT02	4	41.9	Y
92 OT06	2	13.8	Y
93 OT02	11	93.7	Y
94 OTXX1	1	4.3	
95 OT03	5	14.4	Y
98 OT02	2	29.2	Y
99 OT01	3	25.6	Y
99 OT03	8	17.6	Y
00 OT01	4	13.9	Y
00 OT02	2	19.0	Y
Total		**608.2**	**494.5**

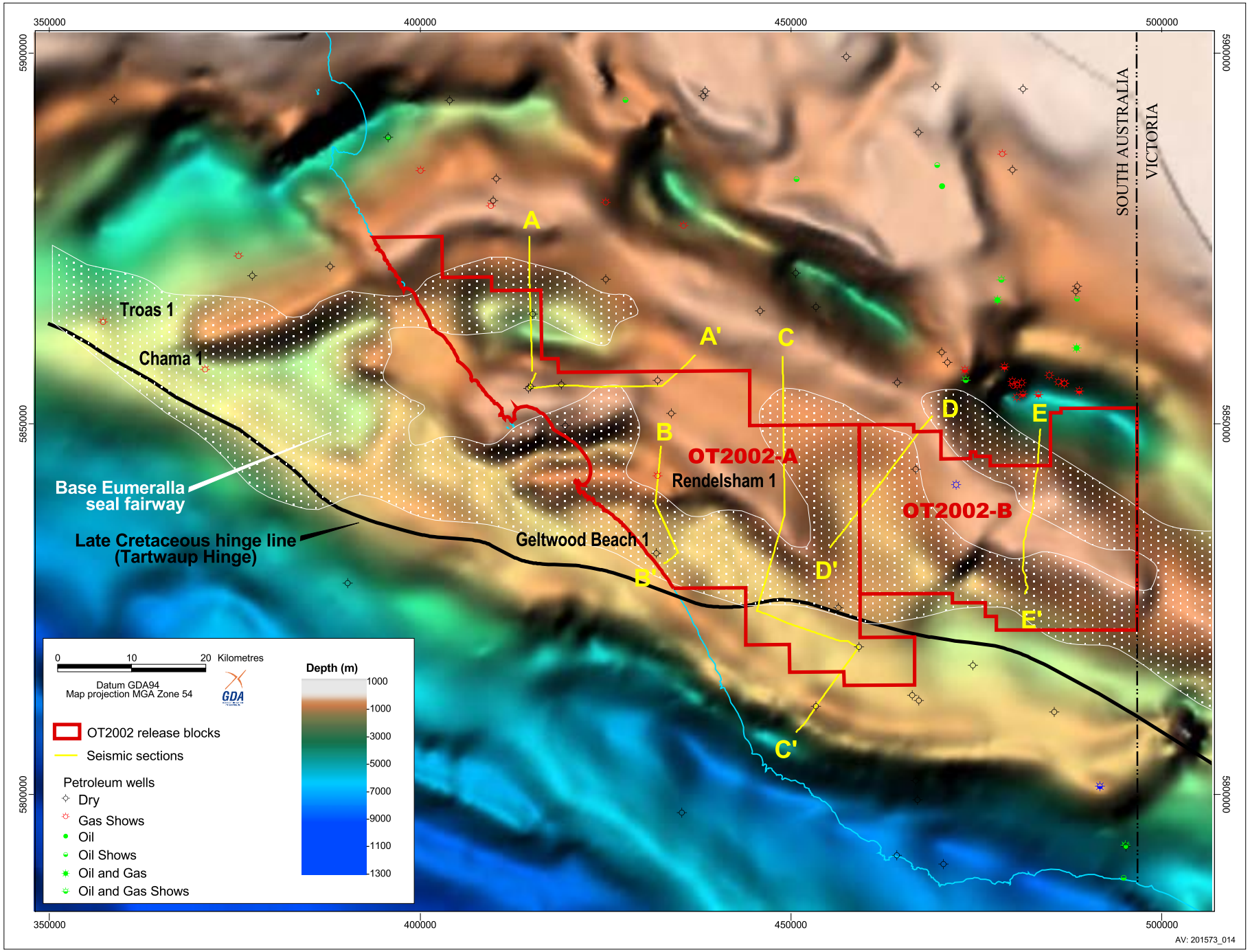


Figure 11 Potential field interpretation of depth to Basement showing example seismic locations

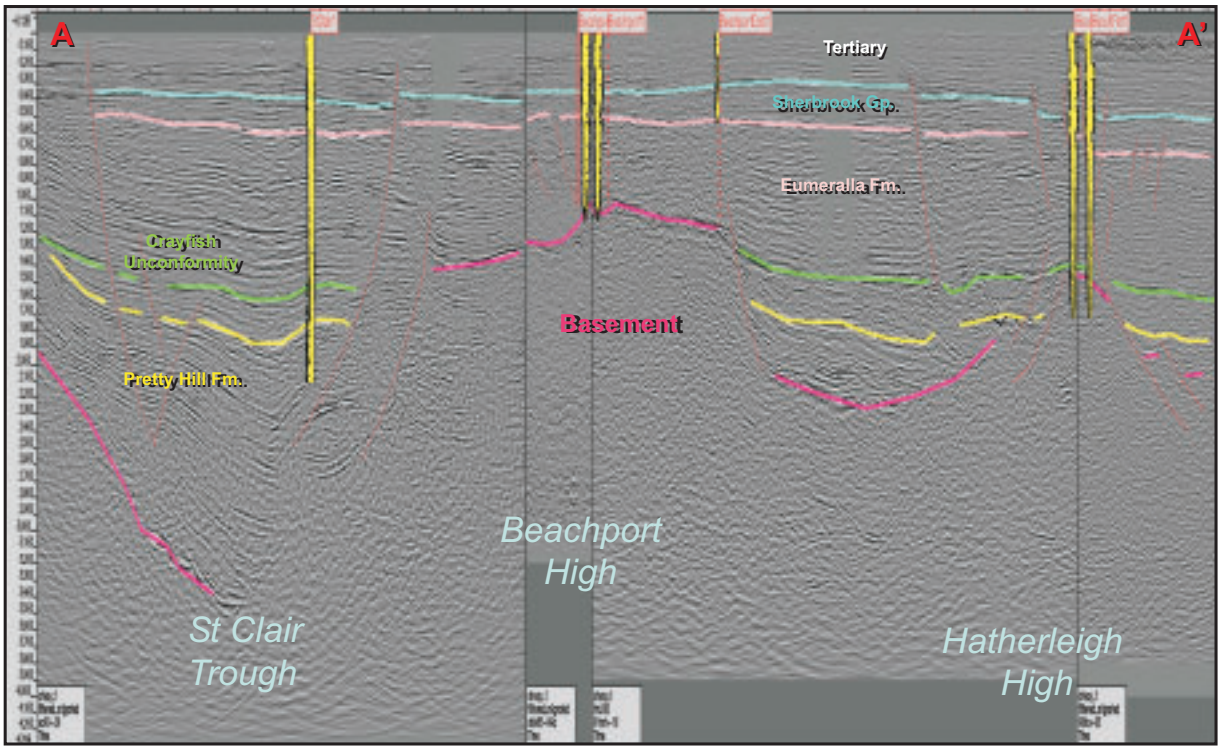


Figure 12 Seismic section A–A', St Clair Trough to Hatherleigh High.

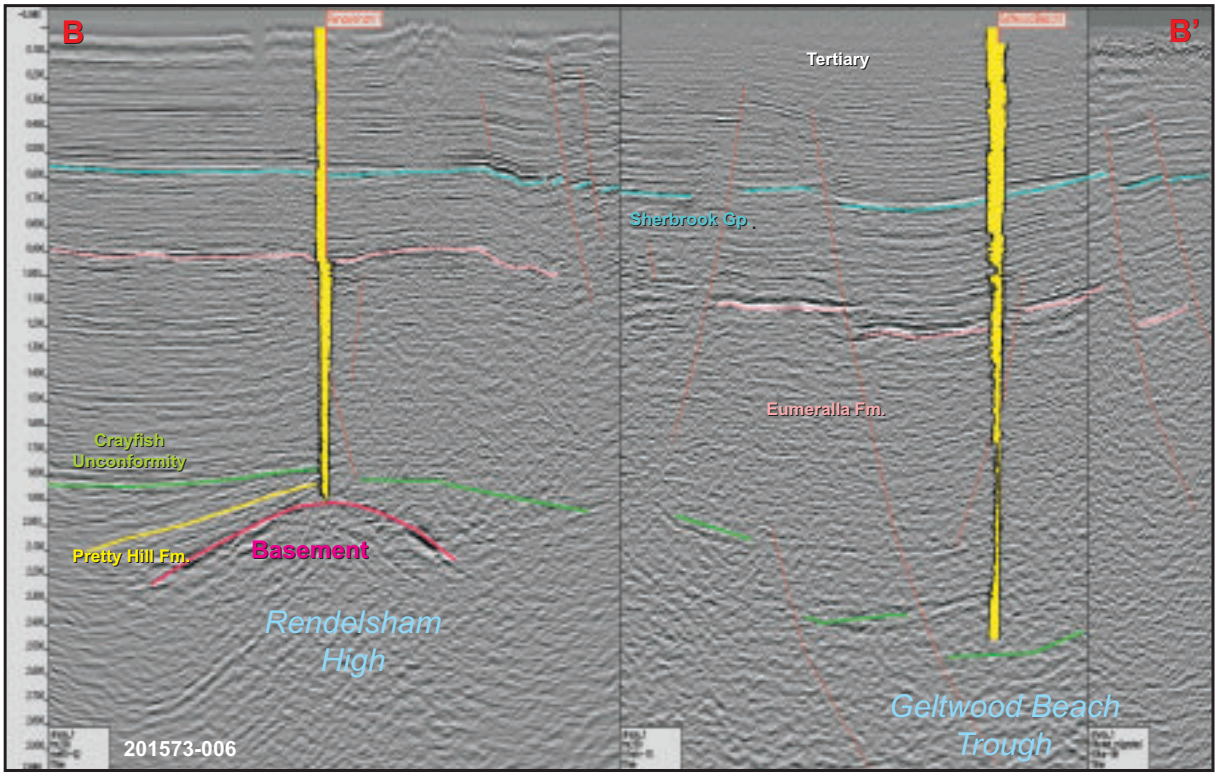


Figure 13 Seismic section B–B', Rendelsham High to Geltwood Beach Trough.

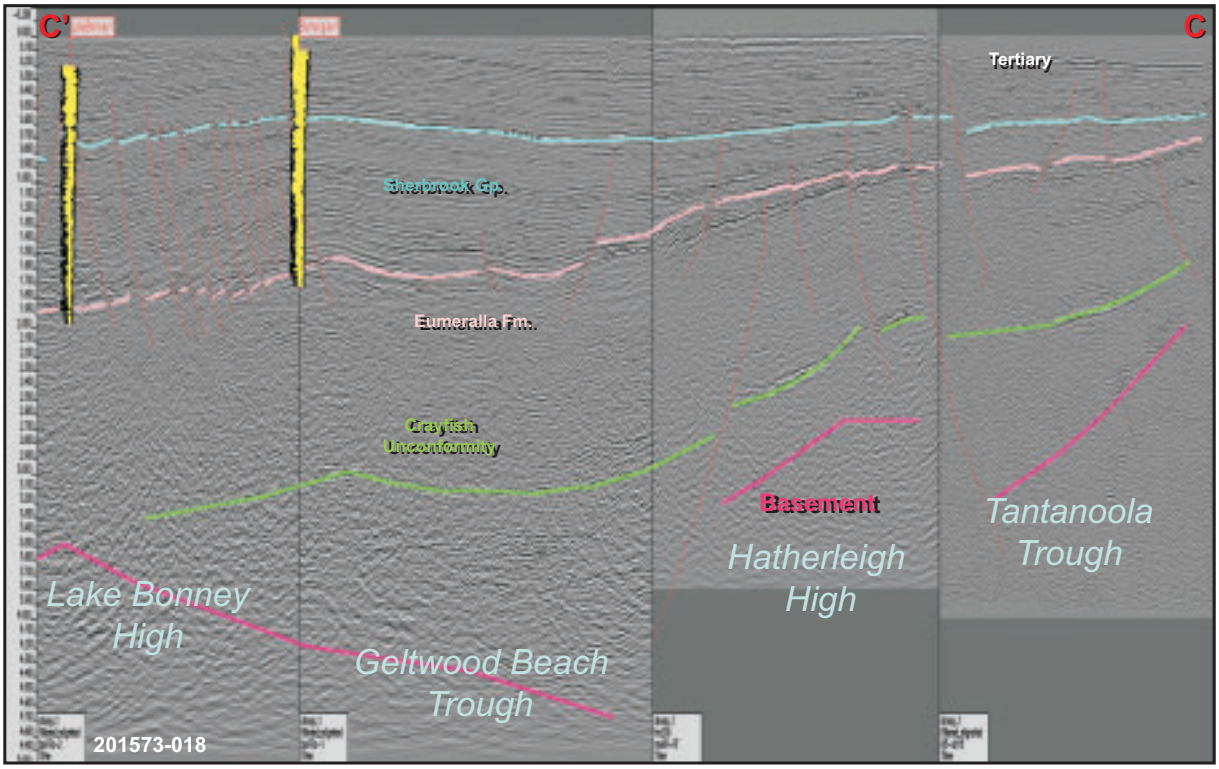


Figure 14 Seismic section C–C', Lake Bonney High to Tantanoola Trough.

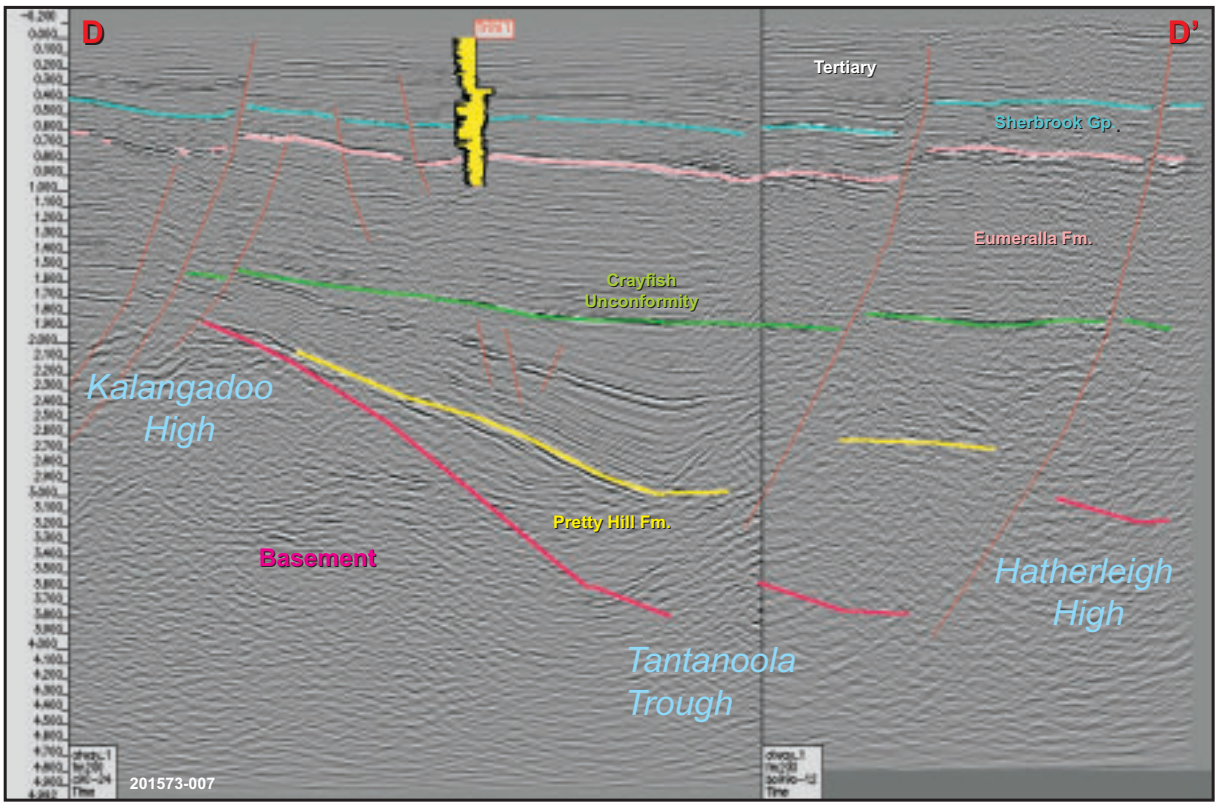


Figure 15 Seismic section D–D', Kalangadoo High to Hatherleigh High.

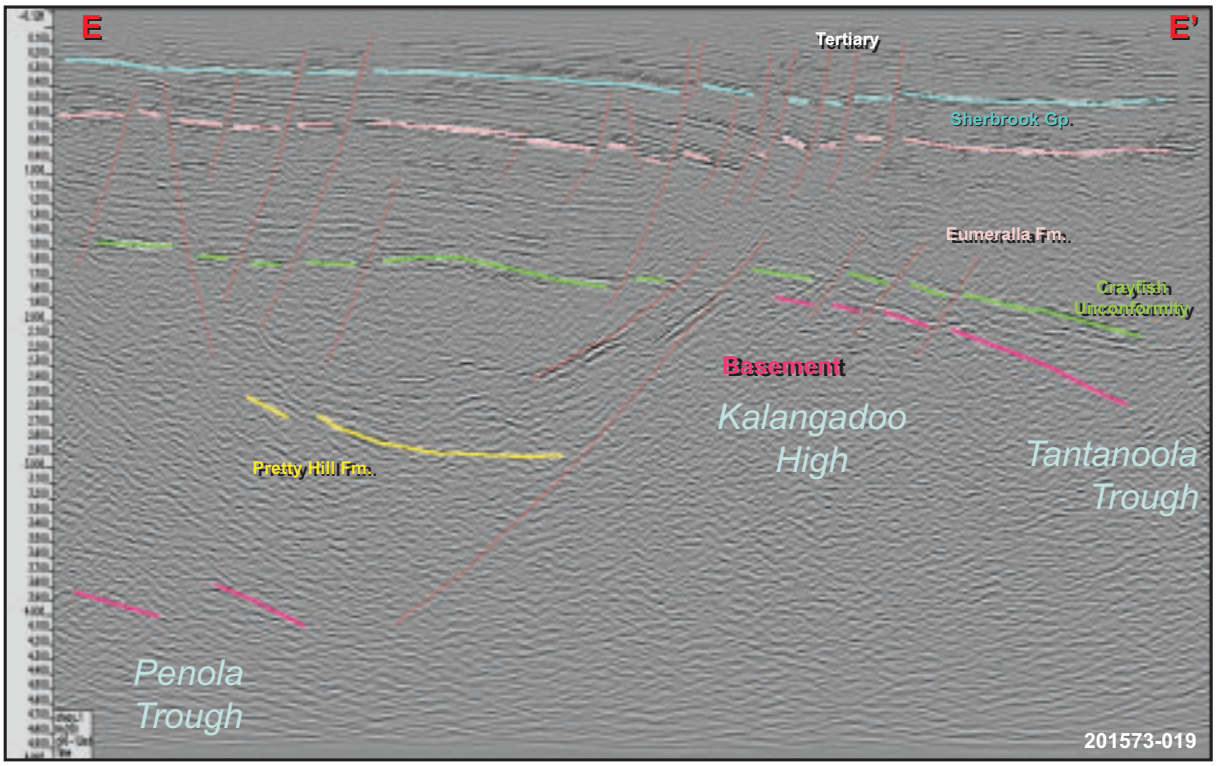


Figure 16 Seismic section E–E', Penola Trough to Tantanoola Trough.

BID ASSESSMENT

Information on the bid assessment process is included in Alexander and Morton (2002), a copy of which is available in this CD.

The closing date for OT2002-A and B applications is 4.00 p.m. on Thursday 22 May 2003.

BIBLIOGRAPHY – FURTHER READING

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Tupper, N.P., Padley, D., Lovibond, R., Duckett, A.K. and McKirdy, D.M., 1993. A key test of Otway Basin potential: the Eumeralla-sourced play on the Chama Terrace. APEA Journal, 33(1):77-93.