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EPP SA-2

OTWAY BASIN

PROGRESS AND TECHNICAL REPORTS
FOR THE PERIOD 2/11/92 TO 23/2/95

Submitted by

Lakes Oil Ltd and Tyers Petroleum Pty Ltd
1995

MINES AND ENERGY
SOUTH AUSTRALIA

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ENVELOPE 8741

TENEMENT: EPP SA-2; Otway Basin

TENEMENT HOLDER: Lakes Oil Ltd (operator and sole permittee until 8/12/94); Tyers Petroleum Pty Ltd (operator and sole permittee after 7/12/94)

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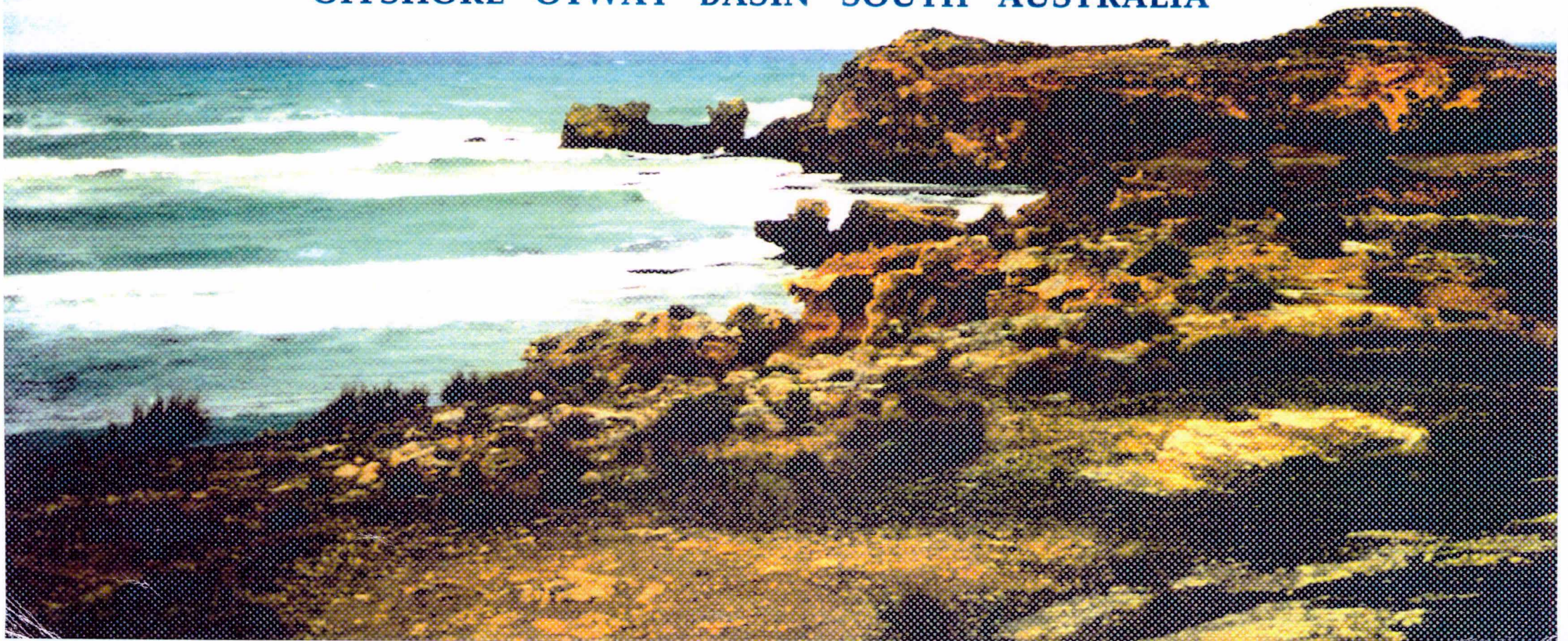
LAKES OIL LIMITED

A REVIEW OF THE GEOLOGY, GEOPHYSICS AND DIRECTIONS FOR FUTURE PETROLEUM EXPLORATION

EPP SA-2

OFFSHORE OTWAY BASIN SOUTH AUSTRALIA



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REVIEW OF THE GEOLOGY GEOPHYSICS AND DIRECTIONS FOR FUTURE PETROLEUM EXPLORATION EPP SA-2 OFFSHORE OTWAY BASIN SOUTH AUSTRALIA

Prepared by:
Guy Holdgate & Associates Pty Ltd
Of:
Tyers Petroleum Pty. Limited
For:
Lakes Oil Limited

November, 1993

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1. INTRODUCTION

EPP SA-2 was granted to Lakes Oil Limited (Lakes) on 2nd November 1992. The permit is located immediately offshore in the South Australian waters of southeastern South Australia (*figure 1*).

The area measures approximately 45 km long and up to 5 kilometres wide, comprising a total of 340 square kilometres over 12 graticular blocks. The city of Mt. Gambier is located 20 kilometres north of the permit.

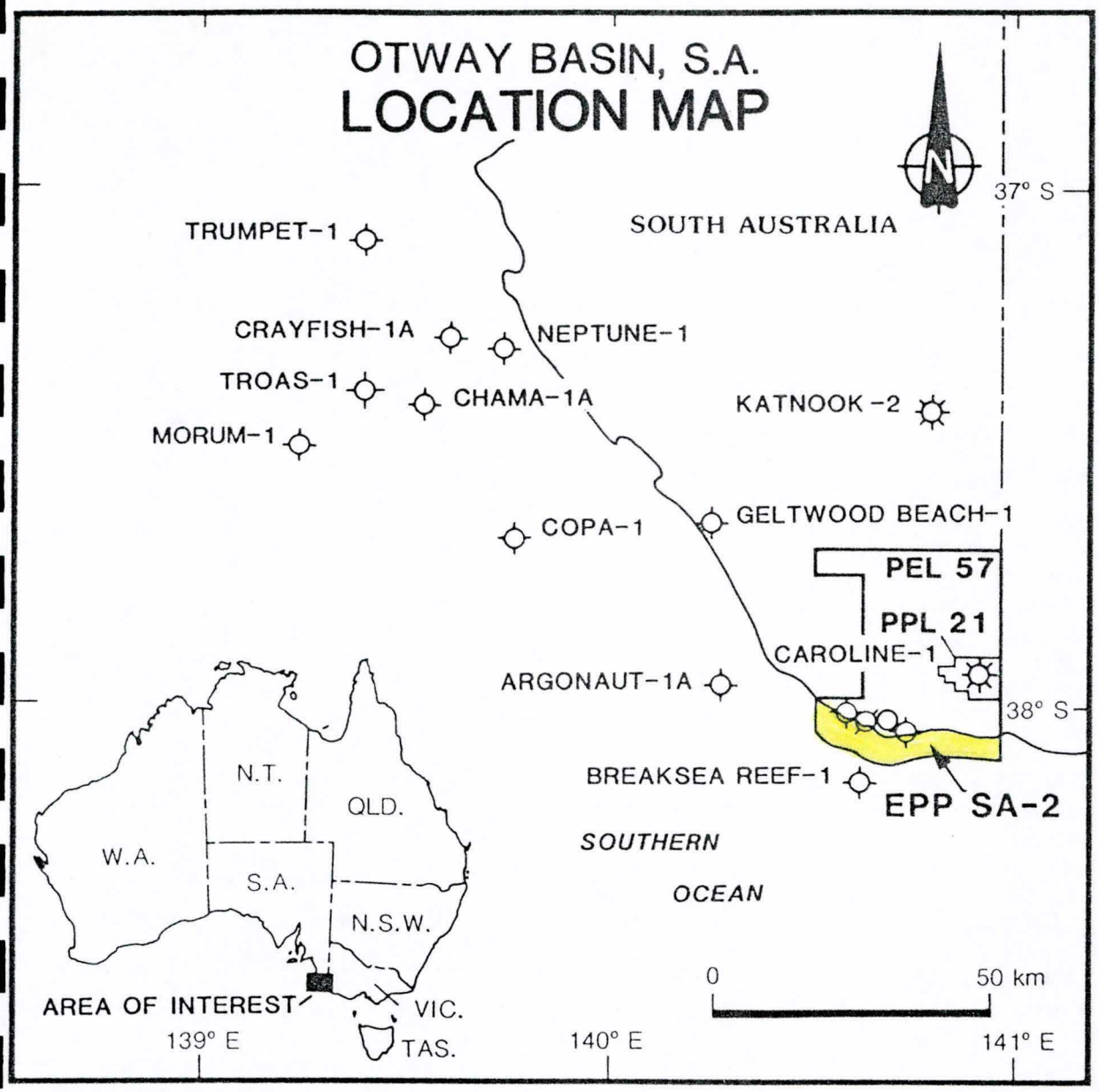
The Caroline Carbon Dioxide production licence is located onshore shortly north of SA-2, and petroleum gas production occurs from the Penola Trough about 60 kilometres to the north. No wells have been drilled in the SA-2 area, and only the tails of a few seismic lines have been shot into the southern edge of SA-2. Important wells nearby include Breaksea Reef-1, Mt. Salt-1, Caroline-1 and Northumberland-1, of which the first three have had at least some hydrocarbon indications at Waarre Sandstone level.

2. GEOLOGY

A stratigraphic column is shown on *figure 2*.

Palaeozoic/Pre Cambrian

Epidiorite greenstones of Cambrian/Pre-Cambrian age, outcrop in a narrow arcuate band at Rockland 150 kilometres North North East of SA-2 in the Grampian Ranges. This outcrop style involving greenstones parallells a similar outcrop in the Stavely Zone to the east of the Grampian Ranges. The arcuate curvature of both outcrops is concave towards the west adopting a South West - North East trend to the south into the Otway Basin. It is possible that the Rocklands structural lineament, could represent the contact between Kanmantoo and Lachlan Fold Belt basement terrains, as recent radiometric dating placed them in the Pre-Cambrian. The greenstone belt represents a tectonically active zone of weakness known here as the Kindalyn Transfer Fault Zone. As the Otway Basin opened up as an eastward advancing rift, a correction occurred in the form of a South West - North East strike slip Transfer Fault as the rift passed through this pre-existing corridor of weakness. Within this zone structures at



PERMIT MAP

Figure 1

OTWAY BASIN, S.A.
STRATIGRAPHIC TABLE

AGE	GROUP	FORMATION & DOMINANT LITHOLOGY	ENVIRONMENT OF DEPOSITION	HYDROCARBON DISCOVERIES & SHOWS
QUATERNARY	POST-HEYTESBURY	WHALERS BLUFF FORMATION, etc Lst, Clyst NEWER VOLCANICS Volc		
TERTIARY – PLIOCENE				
TERTIARY – MIOCENE	HEYTESBURY	GAMBIER LIMESTONE Lst; PORT CAMPBELL LIMESTONE Lst; GELLIBRAND MARL Marl, Clay, Slt CLIFTON FORMATION Sst	marine to marginal marine	
TERTIARY – OLIGOCENE	NIHRANDA	MEPUNGA FORMATION Sst,sandy Lst; NARRAWATURK MARL Marl, Slt, Mdst	marginal marine to marine	
TERTIARY – EOCENE	WANGERRIP	DILWYN FORMATION Sst, Slt, Sh; PEMBER MUDSTONE MEMBER Mdst	fluviatile	
TERTIARY – PALEOCENE	WANGERRIP	PEBBLE POINT FORMATION Sst, Slt, Clyst, Coal	marine	Lindon 1
LATE CRETACEOUS	SHERBROOK	TIMBOON SAND Sst, Cong, minor Coal	fluviatile	
LATE CRETACEOUS	SHERBROOK	PAARATTE FORMATION Sst, Slt, Mdst	marginal marine to paralic	Voluta 1 Pine Lodge 1
LATE CRETACEOUS	SHERBROOK	NULLAWARRE GREENSAND Sst; BELFAST MUDSTONE Mdst, Sst, minor Slt; PINE LODGE SAND	marginal marine to marine	CAROLINE (CO_2) NORTH PAARATTE
LATE CRETACEOUS	SHERBROOK	FLAXMAN FORMATION Sst, Mdst		WALLABY CREEK Grumby 1
LATE CRETACEOUS	SHERBROOK	WAARRE SANDSTONE Sst, Slt, minor Mdst	continental to marginal marine	Windermere 1
EARLY CRETACEOUS	OTWAY	EUMERALLA FORMATION Sst, Slt, Clyst, Coal	fluviatile	Windermere 1 KATNOOK 1 Hawkesdale 1 Woolsthorpe 1
EARLY CRETACEOUS	OTWAY	PRETTY HILL SANDSTONE Sst, Slt, Sh, minor Coal		
LATE-MIDDLE JURASSIC		CASTERTON BEDS Sst, Slt, Sh, Volc, minor Coal	fluviatile with minor volcanics	
PALAEOZOIC		BASEMENT		

Sst Sandstone; Sh Shale; Slt Siltstone; Clyst Claystone; Cong Conglomerate; Mdst Mudstone; Lst Limestone; Volc Volcanics; Gas field/well; Gas show; Oil well; Oil show

Figure 2

top Otway Group level show preferred North East trends (e.g. Galatea, Normanby, Haines, Caroline, Stokes River Anticline) but are masked by the fault trends of the Tertiary where North West - South East faulting soles out in the Belfast Mudstone (*Figure 3*).

Hotspur-1 and Mocamboro-1 encountered Palaeozoic meta sediments within the Glenelg Block. These sediments represent economic basement. Devonian granites and Permian glacials also outcrop north of the basin, the latter have been thought as one source for the Pretty Hill Sandstone beds.

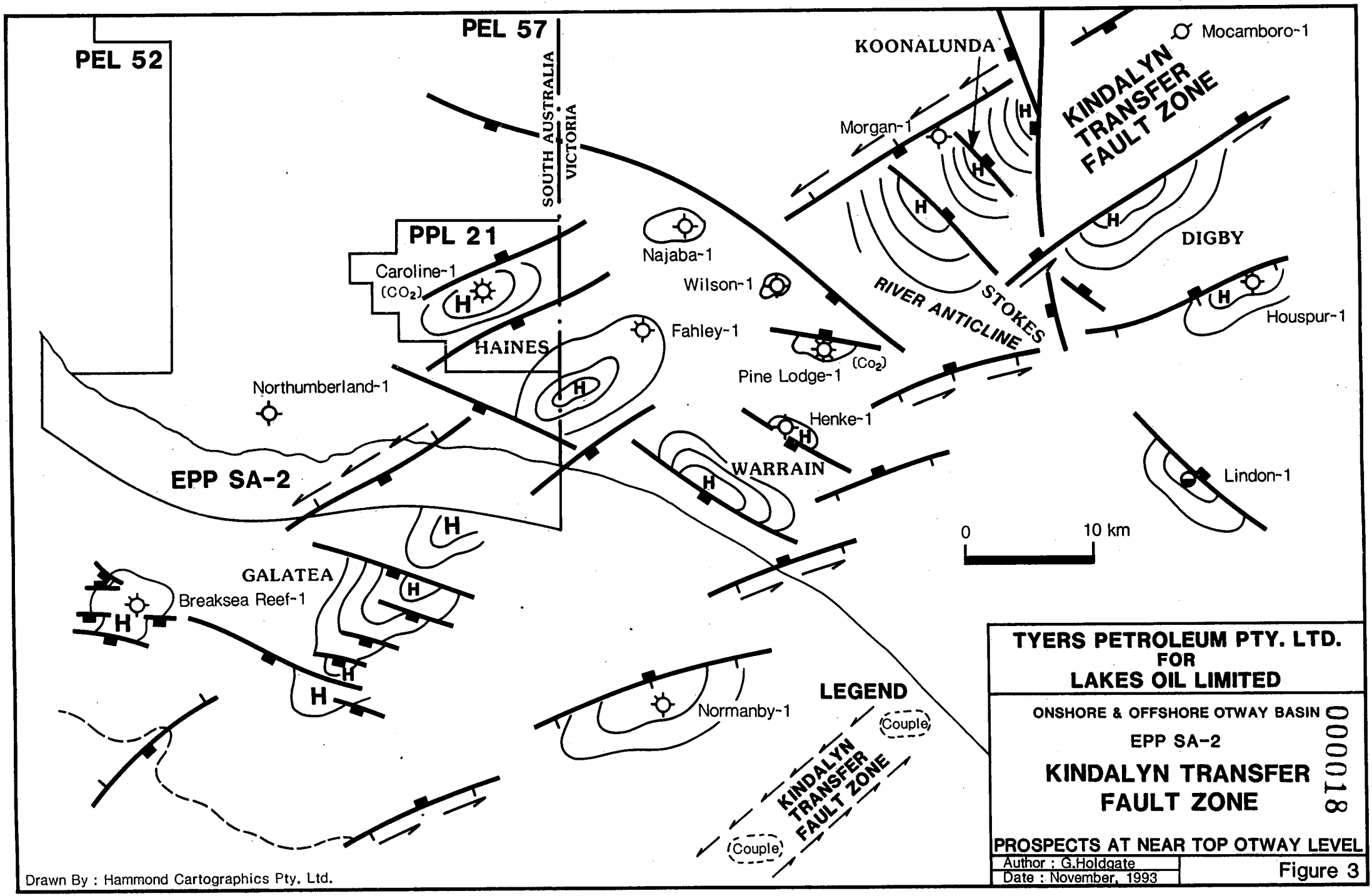
Jurassic

The Casterton Beds are the earliest known Otway Basin sediments which include dark shales and volcanics. They infill the axial core of the initial North West - South East rift as seen in the Penola Trough. Seismic data and recent Victorian Geological Survey drilling indicates that the Casterton Beds are also present in the core of the Kyndalyn Transfer Fault Zone as it was structurally active at this time. A high level of organic entrapment occurred at this time when anoxic conditions are believed to have prevailed, and the recent bore contained hydrocarbon shows at this level.

Lower Cretaceous

The Pretty Hill Sandstone is the lowest stratigraphic unit of the Otway Group, and has been encountered at Mocamboro-1, and Hotspur-1 within the Study Area. At Mocamboro-1 it is typically developed and similar to the type section, comprising medium coarse grained quartz sandstones with minor lithics and shales. The Pretty Hill Sandstone tends to adopt a lithological character consistent with the basement terrain adjacent to the north. In this case, at Mocamboro-1 it has a similar mineralogical make-up to the Permian at outcrop to the north with garnets present in both.

At Hotspur-1 a thin conglomerate is present which is equivalent to the Pretty Hill Sandstone. Here, local reworking of a residual Paleozoic High could be responsible.


PEL 52
PEL 57
SOUTH AUSTRALIA
VICTORIA
PPL 21
Caroline-1
(CO2)
HAINES
Fahley-1
Najaba-1
Wilson-1
Pine Lodge-1
(Co2)
Northumberland-1
EPP SA-2
WARRAIN
Henke-1
KOONALUNDA
Morgan-1
KINDALYN TRANSFER FAULT ZONE
Mocamboro-1
DIGBY
STOKES RIVER ANTICLINE
Houspur-1
Lindon-1
0
10 km
GALATEA
Breaksea Reef-1
Normanby-1
LEGEND
Couple
KINDALYN TRANSFER FAULT ZONE
Couple
TYERS PETROLEUM PTY. LTD.
FOR
LAKES OIL LIMITED
ONSHORE & OFFSHORE OTWAY BASIN
EPP SA-2
KINDALYN TRANSFER FAULT ZONE
PROSPECTS AT NEAR TOP OTWAY LEVEL
Author : G.Holdgate
Date : November, 1993
Figure 3
Drawn By : Hammond Cartographics Pty. Ltd.
000018

Sediments equivalent to the Pretty Hill Sandstone occur within an envelope across Victoria both in outcrop and in the sub-surface. Important outcrops are at Dergholm, Barrabool Hills, Arthurs Seat, Rhyll, Griffith Point and Tyers (Gippsland Basin). This unit has well developed porosity and is also seen in wells such as Casterton-1, Pretty Hill-1, Garvoc-1, Stoneyford-1 and Duck Bay-1 (Gippsland Basin). Currently gas production from the Pretty Hill Sandstone occurs at Katnook in the Penola Trough.

The Eumeralla Formation overlies, in part unconformably, the Pretty Hill Sandstone, and comprises thick sequences of sandstones, siltstones, shales and thin coals. A thin sand identical to the Pretty Hill Sandstone occurs near the base of this formation. The presence of this Heathfield Sand could represent temporary access back to the Pretty Hill's provenance possibly due to river capture.

Sediments within the Eumeralla Formation are immature first cycle in nature with abundant volcanolithics. Sedimentation was rapid, there being little opportunity for re-working. The sediment transport direction was directed West North West corresponding to the axis of the eastward advancing rift. The volcanogenic provenance for these sediments which are rich in chlorite, is thought to be associated with volcanic activity along transfer faults, such as the Kyndalyn, which were active throughout the development of the rift occurring as "tectonic pulses".

Strike-slip movement in a left lateral sense occurred at the end of the Lower Cretaceous on the Kyndalyn Transfer Fault Zone. This set up a series of anticlines such as the Haines, Stokes River, Digby and Galatea Structures (*figure 3*). This resulted in considerable stripping and truncation of Lower Cretaceous sediments within the cores of these major domes.

Upper Cretaceous

On to this truncated surface was deposited the basal Upper Cretaceous aged Waarre Sandstone, with an environment of deposition being typically braided river. The Waarre Sandstone has been reached at Caroline-1, Najaba-1, Breaksea Reef-1 Argonaut-1, and Normanby-1 and may be present in Mt. Salt-1 and Fahley-1. This is the primary exploration objective in the SA-2 area and major gas discoveries and production come from this unit in the Victorian Otway Basin.

The overlying Belfast Mudstone represents the incoming of the basin's first marine sediments as the pull-apart of Antarctica gained pace. This mudstone unit provides regional seal to the Waarre Sandstone. At the conclusion of Belfast times, prograding deltaic intertongueing shales and sandstones prevailed, and at this level the Nullawarre Glauconitic Sandstone occurs, as seen at Pine Lodge-1, Glenaulin-1 and Caroline-1. This sandstone produced Carbon Dioxide on production test at Pine Lodge-1. Upper Cretaceous sedimentation continued with the Paaratte Formation and concluded with the Timboon Sandstone. The whole Upper Cretaceous represents one of the major depositional cycles of the Otway Basin (Bock and Glenie, 1965).

Tertiary

The Upper Cretaceous/Tertiary contact throughout the Otway Basin is represented by a major unconformity onto which the Palaeocene aged Pebble Point Formation was deposited. Seismically this is the most easily mappable horizon. This interval is iron rich and lateritic, with the laterite derived from lateritic material being transported into the basin, and also due to in situ lateritisation on the margins (Tabassi and Davey, 1986). In places it can be very porous (e.g. Northumberland) and would constitute the second major exploration target in the SA-2 area.

A second Otway Basin depositional cycle commenced with the marine incursion of the Pember Mudstone. This unit can also be silty and sandy, and has pronounced sand lenses within it. The Dilwyn Formation (proper) follows comprising up to six coarsening upward cycles which occur in fluvio-deltic style similar to the Latrobe Group in the Gippsland Basin.

The basin's third depositional cycle occurs as the Oligocene to Miocene aged Narrawaturk/Mequnga/Clifton/Heytesbury (Gambier Limestone) Group marine carbonate sediments which overlie conformably or locally disconformably the Dilwyn Formation.

The pull apart of Antarctica accelerated during Gellibrand Marl deposition giving way to Gambier Limestone where open marine conditions prevailed. Pliocene uplift and erosion saw the stripping back of some of these units and the formation of a Pliocene marine wedge on the outer continental shelf and slope areas. Some of this latest structuring is probably still continuous today (Sprigg, 1986).

140° 15'
140° 30'
140° 45'
141° 00'
38° 00'
38° 10'
38° 20'

KNIGHTS DOME
MIRRAWA
TARTWARP
SOUTH AUSTRALIA
VICTORIA
FAULT
MIRRAWA/PINE LODGE TREND
KNIGHTS
DOME/
Caroline-1
Fahley-1
Fahley-2
Wilson-1
Pine Lodge-1
Wanwin-1
Wanwin-3
Henke-1
Palpara-4
WARRAIN
Glenalg-1
Warrain-7
WARRAIN TREND
Kentgrove-1
Mt Salt-1
Argonaut-1
Douglas Point-1
UMPHERSTONE
Northumberland-1
NORTHUMBERLAND/ GALATEA TREND
SEISMIC LINE SS 27 (Fig. 5)
EPP SA-2
GALATEA
Breaksea Reek-1
BREAKSEA REEF TREND

740 740 780 860 900 900 860 880 900 980 1000 960 1000 960 980 1000 1000 1000 1000 1020 1040 1240 1180 1160 1380 550 480 810 700 800 710 810 750 680 1020 1000 1040 750 750 1000 1000 980 900 1020 1000 1000 1100 920 940

Structural Closures at Base Tertiary Unconformity

920 Time Depth to Crest of Structure (ms TWT)

0 5 10 km

Derived from EPP 18, Otway Basin, Ultramar Australia Ltd. and various onshore surveys.
Drawn By : Hammond Cartographics Pty. Ltd.

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FOR
LAKES OIL LIMITED

ONSHORE & OFFSHORE OTWAY BASIN

EPP SA-2

TIME STRUCTURE & TRENDS MAP BASE OF TERTIARY UNCONFORMITY

Author : G.Holdgate
Date : November, 1993

ENCLOSURE 2

000039

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OFFSHORE OTWAY BASIN

EPP SA-2

TOP BELFAST MUDSTONE

TIME STRUCTURE

Author : G.Holdgate

Date : November, 1993

ENCLOSURE 3

Kentgrove-1

Caroline-1

Mt Salt-1

Argonaut-1

SOUTH AUSTRALIA
VICTORIA

38° 00'

Douglas Point-1

Northumberland-1

EPP SA-2

SEISMIC
LINE SS 27
(Fig. 5)

Breaksea Reef-1

38° 10'

Main Closures

0 5 10 km

38° 20'

Derived from EPP 18, Otway Basin,
Ultramar Australia Ltd.

140° 15'

140° 30'

140° 45'

141° 00'

Drawn By : Hamrnond
Cartographics Pty. Ltd.

Drawn By : Hammond Carto. P/L.

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OFFSHORE OTWAY BASIN

EPP SA-2

NEAR TOP OTWAY GROUP

(APPROXIMATE TO WAARRE SANDSTONE)

TIME STRUCTURE

Author : G.Holdgate

Date : November, 1993

ENCLOSURE 4

Kentgrove-1

Caroline-1

Mt Salt-1

Argonaut-1

SOUTH AUSTRALIA
VICTORIA

Douglas Point-1

GRAVITY HIGH

Northumberland-1

EPP SA-2

SEISMIC LINE SS 27 (Fig. 5)

GALATEA

Breaksea Reef-1

Main Closures

0 5 10 km

38° 00'

38° 10'

38° 20'

140° 15'

140° 30'

140° 45'

141° 00'

Derived from EPP 18, Otway Basin, Ultramar Australia Ltd.

0000041

A

A'

SA-2 AREA

ARGONAUT-1A

BREAKSEA REEF-1

MT.SALT-1

CAROLINE-1

PALPARA-4

WARRAIN-7

WHALERS BLUFF FORMATION

KENTBRUCK-5

COBBOBOONEE-2

MOUZIE-1

NEWER VOLCANICS

GORAE-4

GORAE-2

NARRAWONG-13

00

500

1000

1500

2000

2500

3000

3500

4000

4500

5000

IMMATURE

EARLY MATURE

MIDDLE MATURE

R̄o 0.4

R̄o 0.5

R̄o 0.6

R̄o 0.7

R̄o 0.8

R̄o 0.9

GAMBIER LIMESTONE

NIRRANDA GROUP

PEMBER MUDSTONE MEMBER

PEBBLE POINT FORMATION

BURRUNGULE MEMBER

HEYESBURY & NIRRANDA GROUPS
(Foraminifera Zones 3 to 11)

OLDER VOLCANICS

DILWYN FORMATION
(M. diversus zone)

(M. diversus zone)

SHERBROOK GROUP
(UPPER CRETACEOUS)

BELFAST MUDSTONE

WAARRE SANDSTONE

OTWAY GROUP
(LOWER CRETACEOUS)

0 10 20km

Drawn By : Hammond Cartographics P/L

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FOR
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ONSHORE & OFFSHORE OTWAY BASIN
EPP SA-2

ARGONAUT-1 TO NARRAWONG-13

COMBINED STRATIGRAPHY, ISOREFLECTANCE & SOURCE ROCK MATURITY CROSS SECTION

For location of cross section see ENCLOSURE 7

Author : G.Holdgate
Date : November, 1993

ENCLOSURE 5

000042

B

B'

SA-2 AREA

ARGONAUT-1

BREAKSEA REEF-1

NORMANBY-1

DISCOVERY BAY-1

VOLUTA-1

00

500

1000

1500

2000

2500

3000

3500

4000

4500

5000

IMMATURE

EARLY MATURE

MIDDLE MATURE

GAMBIER LIMESTONE

PLIOCENE

NIRRANDA GROUP

PEMBER MUDSTONE

DILWYN FORMATION

PEBBLE POINT FORMATION

CURDIES

PAARATTE FORMATION

BELFAST MUDSTONE

WAARRE SANDSTONE

Ro 0.4

Ro 0.5

Ro 0.6

Ro 0.7

Ro 0.8

Ro 0.9

3306

3707

3974

4468

Vertical Scale 1:2,000

Drawn By : Hammond Cartographics P/L

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OFFSHORE OTWAY BASIN
EPP SA-2
ARGONAUT-1 to VOLUTA-1

COMBINED STRATIGRAPHY, ISOREFLECTANCE & SOURCE ROCK MATURITY CROSS SECTION

For location of cross section see ENCLOSURE 7

Author: G.Holdgate
Date : November, 1993

ENCLOSURE 6

000043

140° 30'
140° 45'
141° 00'
141° 15'
38° 00'
38° 15'
5800000mN
5790000mN
5780000mN
5770000mN
460000mE
470000E
480000mE
490000mE
500000mE
510000mE

KENTGROVE-1
MOUNT SALT STRUCTURE 3
MOUNT SALT STRUCTURE 4
MOUNT SALT STRUCTURE 2
MOUNT SALT STRUCTURE 1
MOUNT SALT STRUCTURE 5
MT. SALT
CAROLINE-1
FAHLEY-1
FAHLEY-2
WANWIN-1
WILSON-1
WILSON
WANWIN-3
PALPARA-4
HAINES
SAOW 1
SAOW 2
DOUGLAS POINT-1
NORTHUMBERLAND-1
GLENELG-1
WARRAIN-7
WARRAIN
EPP SA-2
BREAKSEA REEF
BREAKSEA REEF-1
GALATEA
NORMANBY-1
NORMANBY
H

0 200 400 600 800 1000
METRES

8741-1

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FOR
LAKES OIL LIMITED

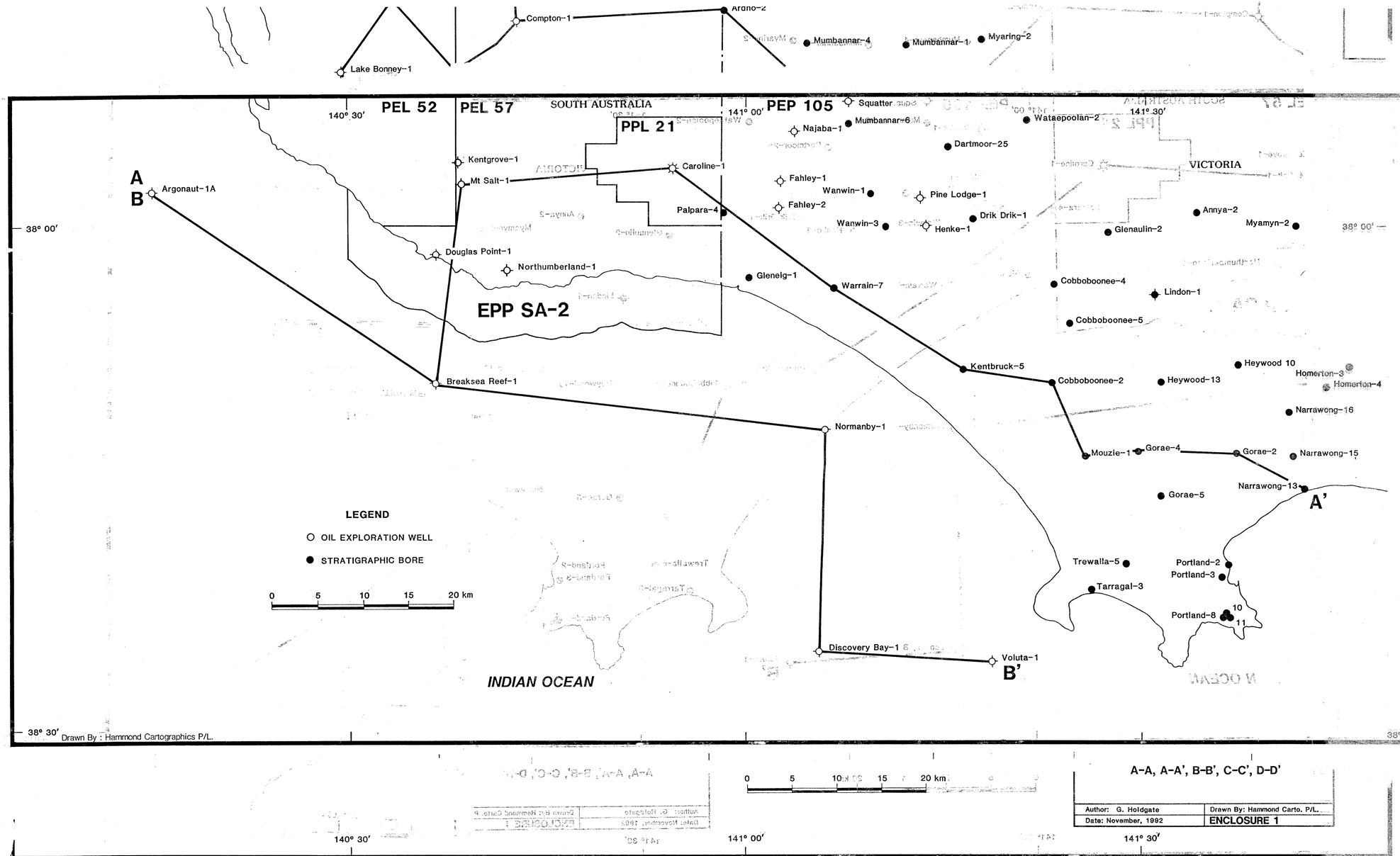
ONSHORE & OFFSHORE OTWAY BASIN
EPP SA-2 & ADJACENT AREAS

SEISMIC COVERAGE
& MAIN STRUCTURES

Author : G.Holdgate
Date : November, 1993

ENCLOSURE 1

Drawn By : Hammond Carto. P/L.



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FOR
LAKES OIL LIMITED

OFFSHORE GTWAY BASIN
EPP SA-2

WELL LOCATION & CROSS SECTION LOCATIONS

Author : G.Holdgate
Date : November, 1993

ENCLOSURE 7

0 5 10 15 20 km

A-A, A-A', B-B', C-C', D-D'

Author: G. Holdgate
Date: November, 1992

Drawn By: Hammond Carto. P/L.

ENCLOSURE 1

140° 30'

140° 45'

141° 00'

141°

- 38° 00'

- 38° 15'

5800000mN

5790000mN

5780000mN

5770000mN

KENTGROVE-1

MOUNT SALT STRUCTURE 1

MOUNT SALT STRUCTURE 2

MOUNT SALT STRUCTURE 3

MOUNT SALT STRUCTURE 4

MT. SALT

CAROLINE-1

WILSON-1

WILSON

WANWIN-1

FAHLEY-1

FAHLEY-2

SAOW 1

PALPARA-4

HAINES

WANWIN-3

SAOW 2

DOUGLAS POINT-1

NORTHUMBERLAND-1

GLENELG-1

WARRAIN-7

WARRAIN

EPP SA-2

BREAKSEA REEF

BREAKSEA REEF-1

GALATEA

NORMANBY-1

NORMANBY

H

0 200 400 600 800 1000

METRES

460000mE

470000E

480000mE

490000mE

500000mE

510000mE

Drawn By : Hammond Carto. P/L.

8741-1

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FOR
LAKES OIL LIMITED

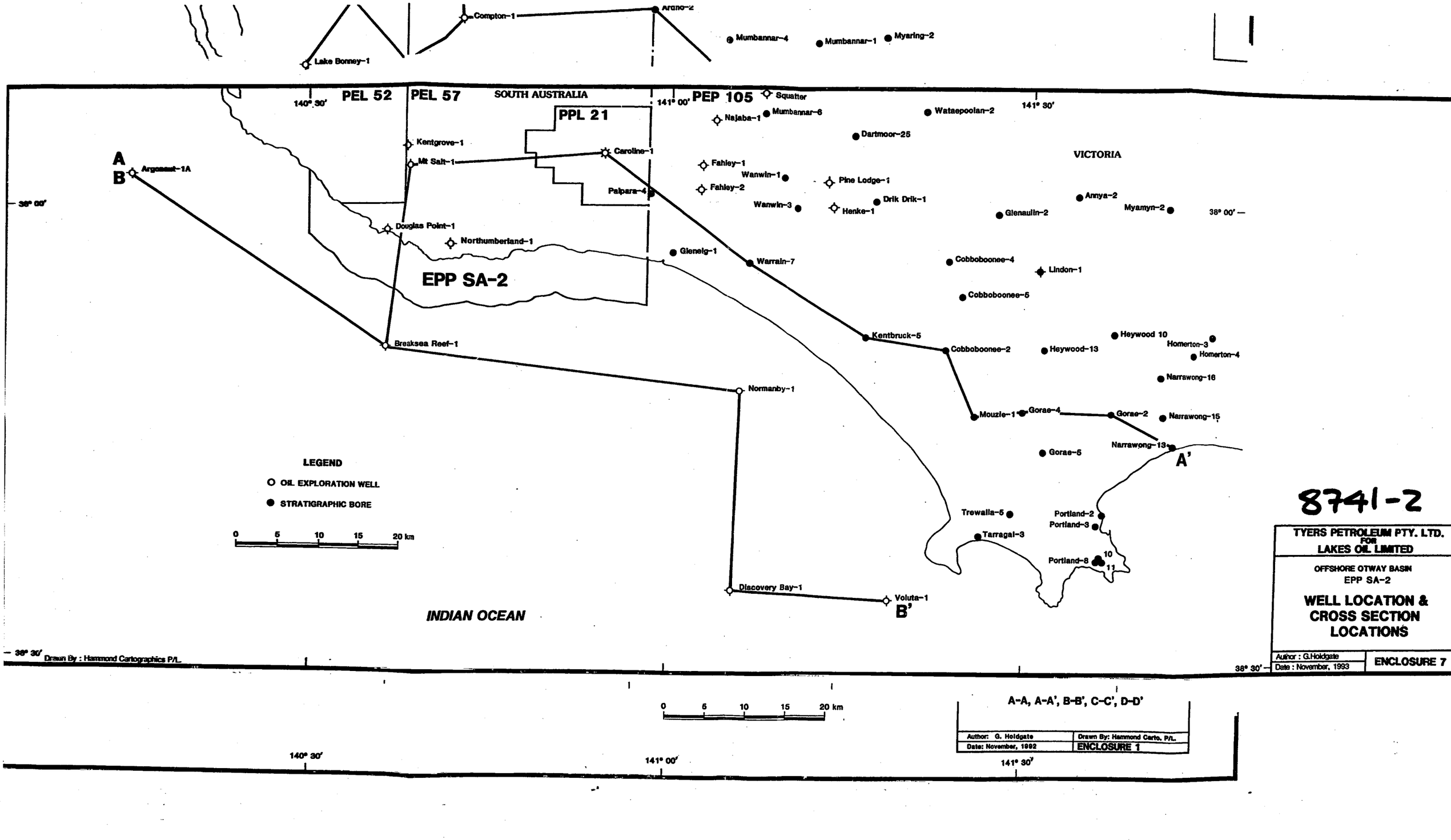
ONSHORE & OFFSHORE OTWAY BASIN
EPP SA-2 & ADJACENT AREAS

SEISMIC COVERAGE & MAIN STRUCTURES

Author : G.Holdgate

Date : November, 1993

ENCLOSURE 1



A-A, A-A', B-B', C-C', D-D'

Author: G. Holdgate	Drawn By: Hammond Carto. P/L.
Date: November, 1992	ENCLOSURE 1

8741-2

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FOR
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OFFSHORE OTWAY BASIN
EPP SA-2

WELL LOCATION & CROSS SECTION LOCATIONS

Author : G.Holdgate	ENCLOSURE 7
Date : November, 1993	

Volcanics

(a) Jurassic (Basal Volcanics)

These volcanics occurred at the commencement of basin development as the eastward advancing rift encountered the pre-existing Kyndalyn Transfer Fault Zone. The sense of half graben development was thickening to the north as the half graben approached the Kyndalyn Transfer Fault Zone. As the rift passed across this zone of weakness, a half graben style thickening to the south was adopted with resulting volcanic activity.

(b) Late Neocomian

This time represents the onset of Eumeralla Formation deposition when sediments were almost entirely derived from a volcanogenic provenance which is believed to be due to strike slip fault induced volcanism on Transfer Faults such as the Kyndalyn.

Sediments deposited prior to this time, are relatively free of volcanolithics (such as the Pretty Hill Sandstone).

(c) Middle Cretaceous

Dykes of this vintage could be expected within the Eumeralla Formation based on onshore Gippsland experience. This volcanic episode is believed to correspond to an accelerated pull apart between Antarctica and Australia.

(d) Oligocene (Older Volcanics)

Dykes of this age are present along the South East edge of the Kyndalyn Transfer Fault Zone. Volcanism of this age can be mapped near Glenaulin and has a clear effect on the geothermal gradient mapping.

(e) Late Tertiary (Newer Volcanics)

Volcanism of this age is also present along the South East edge of the Kyndalyn Transfer Fault Zone. Dykes and associated faulting are seen in outcrop in the Moleside area on the Glenelg River Gorge.

3. HISTORY OF EXPLORATION IN THE SA-2 AREA

In the 1920's and 1930's interest was shown in the SA-2 area by wildcatters who had an appreciation of the oil seep at Lakes Entrance in the onshore Gippsland Basin.

In the vicinity of the mouth of the Glenelg River these early explorers were encouraged by reported oil occurrences: the Glenelg River mouth bitumen "eruption", stranded bitumen particularly at Cape Northumberland and along the coast, and the Haines Landing oil "seep".

Dip attitudes were mapped in the Glenelg River Gorge and the geologist Lyne identified anticlinal flexure in the Gambier Limestone.

The S.A.O.W.C. wells 1, 2 and 3 were drilled into the Dilwyn Formation on what Lyne believed was a near surface structurally closed anticline. Bore No. 2 had reported oil and gas indications from within the Dilwyn Formation.

In the same period a joint South Australian - Victoria Government effort drilled the Nelson bore which reached the Upper Cretaceous.

Sprigg mapped the Penola Sheet area as a government geologist in 1949 and recognized the Nelson Fault. In 1961 he saw a prospect at "Haines" where anticlinal flexure in the Gambier Limestone combined with the down-to basin Glenelg Fault sets up a near surface structural closure. Intensive structural drilling at Dartmoor in the 1960's saw the identification of the "Dartmoor Block"/Stokes River Anticline (Kenley, 1971)

In the early 1960's Frome Broken Hill seismically mapped the Victorian side of the Gambier Embayment including through what are now restricted areas (eg National Park). They identified the major structures at Pebble Point level as being primarily orientated North West - South East (Richards & Samz, 1962) along down-to-basin faults. Also importantly they mapped a North East - South West fault trend that offsets the North West trends. Basement mapping by Alliance and others in the 1960's using outcrop, gravity, magnetics and structure hole drilling defined the Digby and Tahara structure areas, and seismic/gravity was used to drill the Caroline structure.

In the 1970's Abele mapped the (Oligocene-Miocene) Gambier Limestone in the vicinity of Nelson as part of his PhD thesis and saw structural closures. He used fossil marker beds to map the area. Shell Australia undertook further seismic surveys in the Victorian Gambier Embayment.

In the 1980's Beach explored where seismic access was possible in the Northumberland, Burrungule and Mt. Gambier areas of South Australia and in the Dartmoor, Digby to Glenelg areas of Victoria. They achieved the Otway Basin's most important oil recovery: Lindon-1; oil to surface on DST from the base Tertiary which is believed to be sourced from the Lower Cretaceous (Tabassi and Davey, 1986). Beach also mapped the Stokes River Anticline and the North East plunging nose at Fahley-1 where significant gas and fluorescence shows were recorded.

In the offshore Ultramar took up previous exploration acreage from Esso and in the early 1980's seismically mapped the EPP18 area immediately to the south of SA-2 at base-Tertiary, top-Belfast and near top-Otway levels. This resulted in definition at the 3 levels of a closed structure at Breaksea Reef and a South West plunging structure at Galatea. The crest and limits of this second structure lay further north outside the EPP18 lease within the current SA-2 area. Later the Breaksea Reef structure was drilled to Waarre level where wet gas shows were recorded but due to drilling difficulties no logs or testing was carried out. Beach/onshore and Ultramar/offshore mapping was not coordinated and an appreciation of the regional extent of the North West trends at Pebble Point level and the North East structures at near top Otway was not noted. As a result this report endeavours to merge for the first time onshore and offshore data. Later Ultramar relinquished EPP18 without any further drilling, and subsequent activities by Cultus were concentrated on shelf margin plays at the northwestern end of the lease. Currently the area comes up for renewal.

In the adjacent Victorian offshore area Phillips carried out more detailed seismic prospecting from previous 70's BHP - Esso work, and later BP/Gas & Fuel Corporation drilled Normanby-1 which recorded wet gas on RFT in the Waarre Sandstone.

The most recent well in the area is Lakes' Northumberland - 1 which was found to be dry at the Pebble Point level. The well was terminated in the Paaratte Formation.

Ongoing water well drilling activities in addition have been used to identify a top Eocene doming west of Nelson where no seismic exists (Tyers, 1992).

4. HYDROCARBON OCCURRENCES IN THE SA-2 AREA

Numerous shows of hydrocarbons have been reported in the SA-2 area with a concentration within the Kyndalyn Transfer Fault Zone (figure 3). Proceeding along this tectonically mobile corridor from the continental shelf edge in the South West to basement outcrop in the North East are the following shows:

1. Corresponding to a fault/submarine channel associated with the Galatea Structure, Shoreline's offshore (1983) geochemical survey detected a very large propane sniffer anomaly with a concentration of over 0.11 ppm measured in the sea water. A gas cloud was also observed on sonar.

2. Breaksea Reef-1 had major wet gas shows.

3. Normanby-1 encountered major wet gas shows and at T.D. within the Waarre Sandstone, took a "gas kick". At 3178 m 1.05 cubic feet of wet gas was tested on R.F.T.

   The analysis was

C1	71.1%
C2	20.4%
C3	6.9%

4. The "freshest" Otway Basin stranded bitumen comes ashore at Cape Northumberland on the N.W. edge of the Kyndalyn Transfer Fault Zone. This bitumen has been analysed as mature oil by AMDEL and has active gas embulation (bleeds gas).

5. Intense stranded bitumen occurrence on the coast at Cape Montesqieu where the South East edge of the Kyndalyn Transfer Fault crosses it.

6. Reported bitumen eruption at the Glenelg River mouth where an offset occurs in the Nelson Fault associated with a canyon.

7. At Warrain-7, oil and gas shows were observed while drilling and log anomalies indicated oil and gas. Gas detector "kicks" occurred in the base of the Tertiary and in the Upper Cretaceous Timboon Sandstone corresponding to neutron density log anomalies.

8. Reported oil occurrences in shallow bore-holes on the west flank of the Haines Structure near Donovans within sandstones of the Dilwyn Formation.

9. Commercial Carbon Dioxide production at Caroline-1 from the Waarre Sandstone on the western edge of the Kyndalyn Transfer Fault Zone adjacent to the Haines Structure. Oil is also produced from this well at a rate of approximately 1 barrel/month.

10. Reported oil seepage recorded on the Victoria Geological Survey Parish map at Haines Landing (Geological map, "Palpara" Sheet, County of Follett, 40 chains to 1 inch). This location coincides where the North East plunging axis of the Haines Structure crosses the Glenelg River Gorge as mapped by Frome Broken Hill and Beach Petroleum.

11. Carbon dioxide produced from sand in the upper part of the Belfast Mudstone in Pine Lodge-1.

12. Gas shows and fluorescence at Fahley-1 and Mt. Salt-1 in the Waarre Sandstone and oil shows in the base Tertiary Pebble Point Formation.

13. Gas and fluorescence shows at Najaba-1 from within Waarre Sandstones.

14. Wilson-1 recovered a trace of "marine" oil from a side wall core in base Tertiary sediments which is geochemically comparable to Belfast Mudstone source rock results from Voluta-1. This demonstrates that the base Tertiary oil recovered at Wilson could have migrated locally from source rocks in the Belfast Mudstone.

15. Distinct "flat spots" and high amplitude seismic events in the Waarre and Paaratte Formations on the Stokes River Anticline.

16. A reported oil seep has been mapped at Tea Kettle Creek where the axis of the Stokes River/Koonalunda/Morgan Structure butts into the down thrown side of the Kanawinka Fault and is offset with the Digby Structure on the upthrown side.

17. Oil recovered on D.S.T. from Lindon-1 and 2 on the South East side of the Kyndalyn Transfer Fault Zone.

18. Gas reported at Hotspur-1 in the Otway Group basal conglomerate (Pretty Hill Sandstone equivalent) resting on basement.

19. Hydrocarbons tested from the Victorian Geological Survey's recent bore near Casterton from the Casterton Beds.

5. SEISMIC COVERAGE IN THE SA-2 AREA

Enclosure 1 shows the distribution of seismic lines in and around the SA-2 area. The most immediate onshore lines are the Frome (1961) and Beach (1985) Northumberland Surveys. In the offshore are the Esso 1967 and 1968 surveys, the Ultramar 1981 and 1982 surveys, and the Phillips 1980 offshore surveys. In addition sparker lines were shot to accompany a sniffer survey in 1981 and are designated as the V81 series, and a few special lines designated at the 1972 OT3 SA, and 55 series. Almost all these lines or series fail to cover the SA-2 area as it was not part of the original EPP18 lease boundary and possibly also due to shallower waters. Best part coverage on the southern boundary is by the V81 sparker series of lines, and north tails of the SA, SS and 720T3 special lines - quality of which is generally not good.

Two useful lines in Victoria which extend into the inshore of Discovery Bay are Lines 14 & F12, and show that seismic prospecting is possible in these shallow inshore areas. The RAN hydrographic chart for the area (*Figure 4*) shows most of the area to be less then 6 fathoms increasing to 10 fathoms west of Cape Northumberland. Within the shallow eastern areas reefs occur at Ruby Rock and Breaksea Reef but elsewhere generally water depths exceed 3 fathoms.

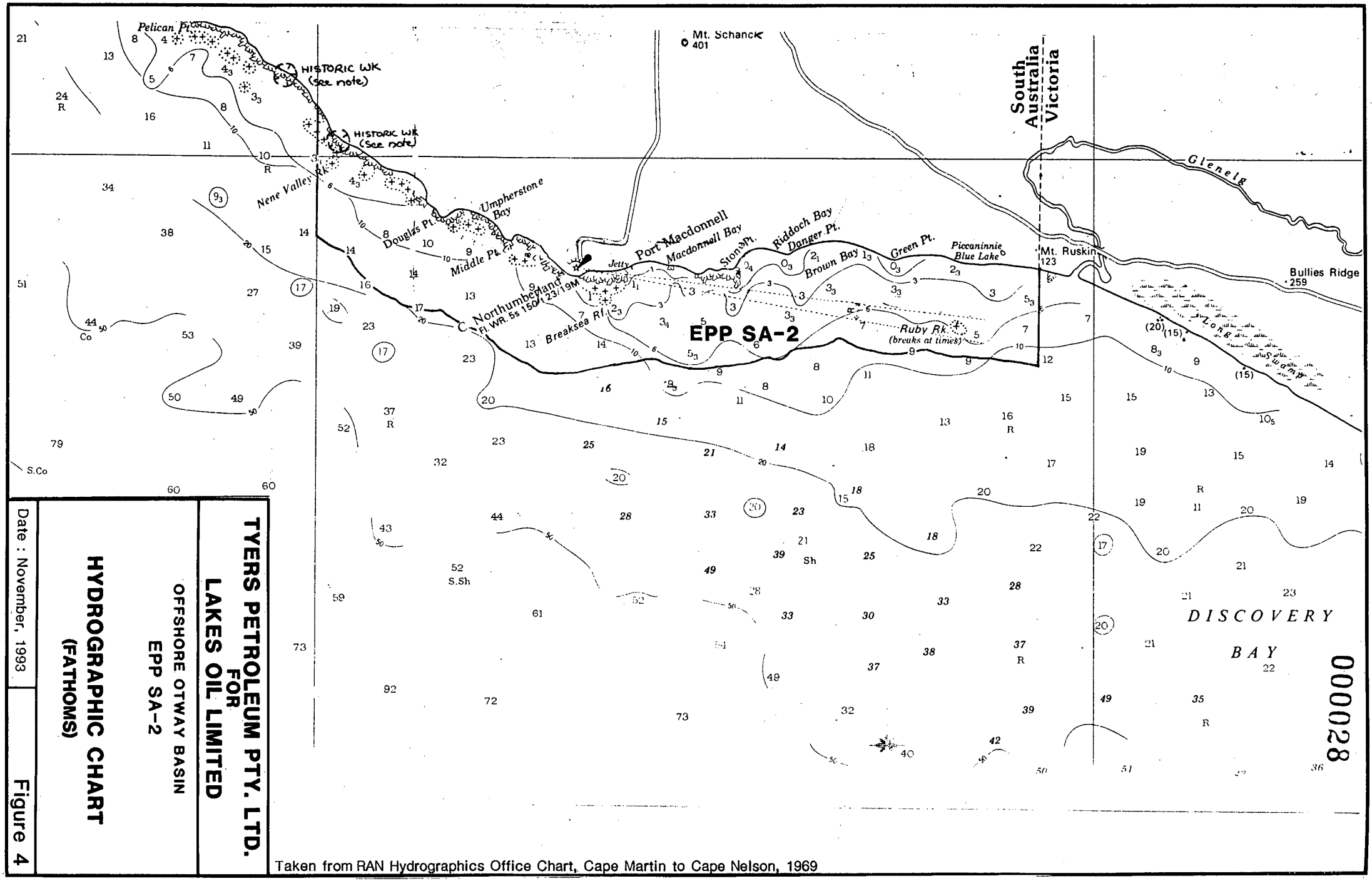
6. SEISMIC PROSPECTING RESULTS IN THE SA-2 AREA

Three seismic horizons were mapped by Ultramar in EPP18 immediately offshore from the SA-2 area and include Base-of-Tertiary, Top Belfast Mudstone, and near Top Otway horizons. These are shown on Enclosures 2, 3 and 4, respectively with additional work from onshore areas being added in the Base-of-Tertiary map. Main conclusions from the results are:

Base-of-Tertiary (*enclosure 2*)

This horizon which represents the unconformity surface between the Pebble Point Formation and top Sherbrook Formation horizon is the most prominent reflector. It clearly shows a dominant series of North West - South East trending faults cutting through this stratigraphic horizon forming a series of structural high closures against down-to-basin faulting. If the maximum TWT heights are plotted for each closure (*enclosure 2*) then a number of trends become more pronounced - these are the Breaksea Reef trend, the Northumberland/Galatea trend, and onshore the Knights Dome/Warrain trend and the Mirrawa/Pine Lodge trend. All four tends are characterised by the propensity and number of large North West - South East fault dependent closures, and their increasing closure depth in the southerly direction. Valid tests on structure of this horizon at Northumberland and Breaksea Reef failed to show the presence of hydrocarbons, but wells in the deeper South East direction e.g. Fahley 1, Warrain 7 and Lindon 1 all had shows and some oil recovery, suggesting the more deeply buried structures may be more prospective where better sealing may occur.

The large closure immediately south of SA-2 on the Northumberland/Galatea trend may indicate similar large closures on this line may occur within the lease area south of Port Macdonell. In the southeast corner of SA-2 line SS27 shows a structural high at shot points 3-130 and 3-134 at around 900 ms TWT(1000-1100m) - *figure 5*, that remains to be closed due to lack of seismic coverage in the East-West directions. This appears to approximate to the crest of the Galatea structure.



Taken from RAN Hydrographics Office Chart, Cape Martin to Cape Nelson, 1969

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OFFSHORE OTWAY BASIN
EPP SA-2

HYDROGRAPHIC CHART
(FATHOMS)

Date : November, 1993

Figure 4

The decreased number of faults of the Base-of-Tertiary style at the near-top-Otway level suggests many of these North West - South East faults may have soled - out in the Belfast Mudstone. Nevertheless most faulting along the four trends is still present at top Otway levels. The earlier development of the North East Kindalyn trend is largely overshadowed by this Tertiary down-to-basin faulting, but many of these earlier trends have continued expression through into the Tertiary e.g. Breaksea Reef, and Galatea.

Top Belfast Mudstone (*Enclosure 3*)

At this horizon fault dependent closure on down-to-basin faulting appears to be still present along the North West-South East Breaksea Reef and Northumberland/Galatea trends, but very little closure has been mapped elsewhere. Onshore in PEL57 this horizon may near approximate to the so called 'Green Horizon' of the Beach mapping (Harrison, 1987). At this stratigraphic level Pine Lodge-1 recovered carbon dioxide in a near-top intra-Belfast Sand which has interegional correlation (Tyers Petroleum, 1992), so within SA-2 this horizon may have commercial interest where costs of drilling offshore may preclude the deeper Waarre type plays.

Near top Otway (*enclosure 4*)

Although North West - South East faulting is still dominant at this level, many of the closures (e.g. Breaksea Reef, Galatea) are showing a North East - South West structural trend which reflects the earlier basement rift Kindalyn Transfer Fault Zone type. Support for this basement trend comes from recent aeromagnetic mapping by AGSO in the Western Otway Basin (Reeves et. al, 1993) where a number of North East cross-cutting (fault?) trends are thought to relate to Early Cretaceous extension (Etheridge et al 1985, 1987). These subsequently underwent reversal in the mid Cretaceous period of regional uplift and erosion (Duddy & Green, 1992). It is likely that the early Upper Cretaceous Waarre sediments show some drape over these pre-existing highs, but the formation can nevertheless be comparatively thick and clean as seen at Minerva and Caroline.

The obvious major play in SA-2 at this level occurs on extensions to the Ultramar mapped Galatea structure north wards into the southeast corner of SA-2. Seismic line SS27 of 1975 vintage crosses the northeast corner of the Galatea structure into SA-2 and clearly shows a northeast continuation to the high and along strike to the Northumberland trend, with down-to-basin fault closures at shot points 3-130 and 3-134, at both Pebble Point and near top-Otway levels (*figure 5*). The shallowest point of the near-top-Otway horizon occurs on this line at about 2.3 seconds TWT or about 3300m. From looking at trends in the available seismic, four way dip at near top Otway on this major structure can be reasonable assumed in the SA-2 area, and the sweep area which extends well South of SA-2 is substantially greater than closure (*figure 3*). That Ultramar favoured drilling the smaller Breaksea Reef instead of Galatea was probably only due to their inability to close the structure to the north where it went into the SA-2 lease.

Another possible near-top-Otway structure may occur in SA-2 off Umpherstone Bay if a down to basin fault trend continues across this area (dashed line on *Enclosure 4*). Gravity data also suggests a high in this area.

7. SOURCE ROCKS & MATURITY IN THE SA-2 AREA

Studies commissioned by Ultramar and the South Australian Department of Mines & Energy e.g. Cooper et al (1982), McKirdy, (1984, 1985) discuss the maturity and source rock potential from the well data in the near SA-2 area. Most opinion recognises the best potential source rocks lie within coals of the Otway Group which would be inclined to be gas prone with some oil source rocks in the Pretty Hill Sandstone and Casterton Beds. The Upper Cretaceous is usually not considered to be buried deep enough and/or have sufficient organic levels to generate at this stage. Therefore assuming the Belfast Mudstone acts as an effective seal, the Waarre Sandstone sourced from Otway Group gas is the most viable target level in SA-2. This does not preclude vertical migration via faults, which then makes the Pebble Point Formation a secondary target where Pember Mudstone could provide seal.

SOUTH

← GALATEA PROSPECT →

← EPP SA-2 AREA

NORTH

3-115 3-118 3-121 3-124 3-127 3-130 3-133 3-136 3-139 3-142

0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

BASE TERTIARY

NEAR TOP OTWAY (Waarre Sandstone)

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SEISMIC LINE SS 27

Author: G.Holdgate

Date: November, 1993

Figure 5

000031

Two enclosures 5 and 6 using data from Cooper et. al (1982) and Holdgate et al (1986) depict the known iso-reflectance contours in two eastwest well sections through the onshore and offshore in the SA-2 area. Correlation by Cooper et. al (1982) of spore colour indices to vitrinite reflectance defined three levels of maturity for the SA-2 area:

Zone A:	immature, reflectance <Ro 0.44%
Zone B:	early mature, reflectance Ro 0.44 - 0.62%
Zone C:	optimum middle mature, reflectance > Ro 0.62%

As seen in enclosures 5 and 6 the SA-2 area has reached early maturity at the Sherbrook - upper Belfast levels, and is at optimum middle maturity for the lower Belfast/Waarre and Otway Group levels. A maximum reflectance of >0.9 Ro was found in the lower part of the Belfast Mudstone in Breaksea Reef-1.

Bitumen strandings and propane sniffer anomalies suggest generation and seepages are occurring in the offshore area to the south of SA-2, and the major sniffer anomaly found by Ultramar 16 kilometres south of Port MacDonnell is broadly coincidental with the southern part of the Galatea structure and with sea bed faulting and channelling (Shoreline, 1983). This structure appears to culminate in the SA-2 area. Mckirdy (1984) considers the bitumen strandings at Cape Northumberland and other nearby coastal areas to be mature oils with low pristine/phytane ratios reflecting deposition of algal source material and migration from a subsurface source over some considerable distance. The fact that gas ebulition has been observed in some of the strandings (Sprigg, 1986) indicates a comparatively immediate source, possibly the same source as the sniffer anomaly offshore. The sniffer anomaly occurs in the same area as a major subsea freshwater discharge, presumably sourced at least from the Gambier Limestone or Dilwyn Formation - the two most likely immediate fresh water aquifers.

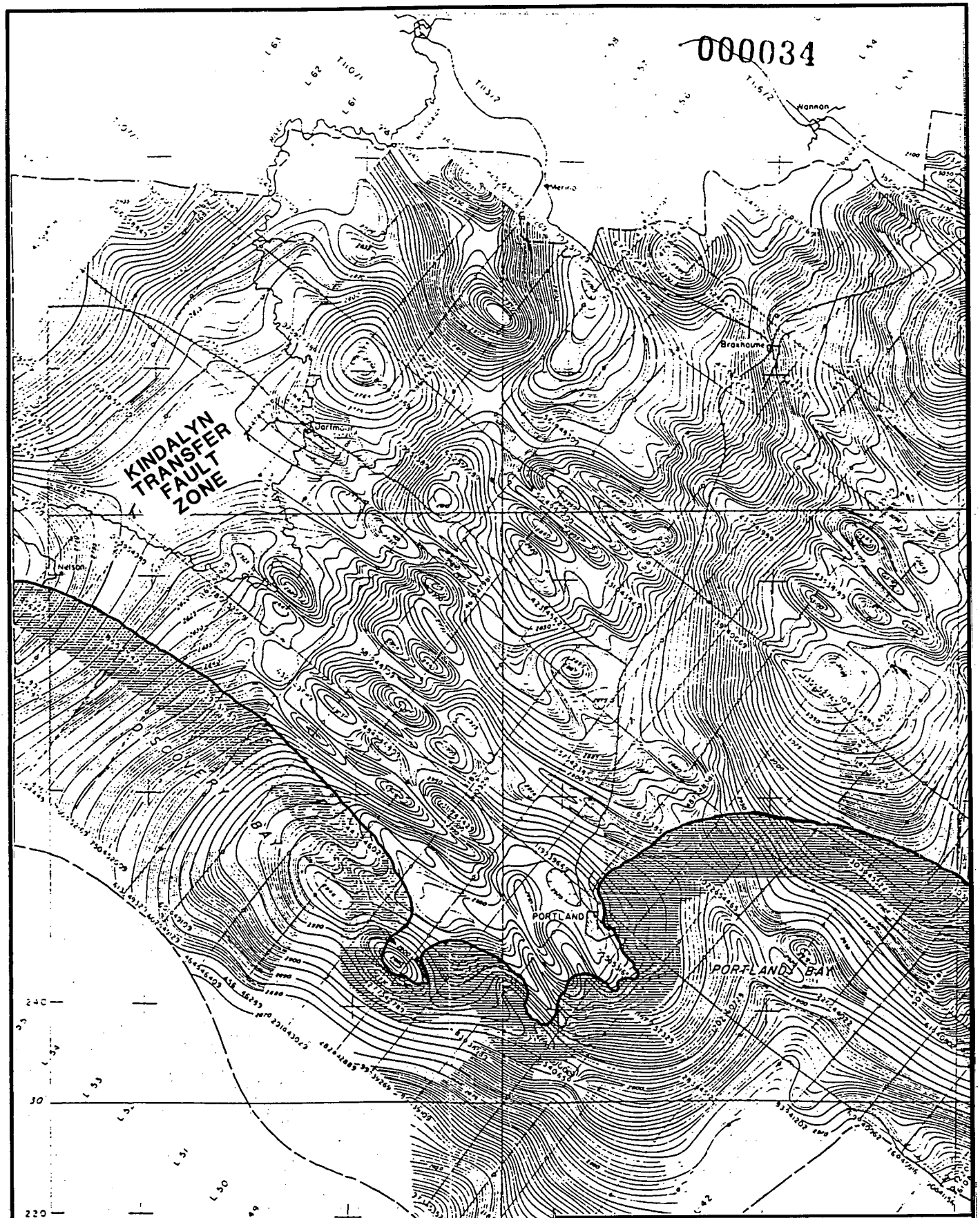
8. FORMATION SEALS IN THE SA-2 AREA

The primary Waarre Sandstone target is sealed by the Belfast Mudstone which at Caroline-1, Breaksea Reef-1 and Mt. Salt-1 was found to be over 500m thick. This should be more than adequate to seal across any fault dependent closure. The secondary Pebble Point objective evidently has more difficulty being adequately sealed across faults, as shown by the recent drilling result at Northumberland-1 where a successful structural test proved dry. Seal at this level would need to be looked at carefully before drilling in the offshore area, but may be improved due to the greater depth of burial, and the more shaly facies of the Pember Mudstone in the Portland Trough area (Holdgate et. al., 1986).

9. GRAVITY/MAGNETIC DATA IN THE SA-2 AREA

Gravity and magnetic data coverage in the SA-2 area is adequate and available to determine the major basinal features. Gravity station coverage exists throughout the onshore, and projections of a gravity high offshore in the Umpherstone Bay area are not unreasonable. A similar gravity high occurs in the Caroline Carbon Dioxide field. Magnetic coverage has recently been enhanced by the AGSO surveys in the Penola Sheet area and this extends coverage into the offshore, and ties in to previous magnetic surveys by Haematite (1960-61). Taken together with the aeromagnetic surveys in the Portland to Casterton area by C G G, their is magnetic evidence for the Kindalyn Transfer Fault Zone seen as a Northeast - Southwest trending magnetic low (figure 6).

000034



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EPP SA-2

AEROMAGNETIC SURVEY SHOWING LOCATION OF THE KINDALYN TRANSFER FAULT ZONE

Date : November, 1993

Figure 6

10. FUTURE EXPLORATION IN THE SA-2 AREA

This study has shown that SA-2 has fair to good hydrocarbon potential both for oil and gas. Further work including drilling is recommended for the block.

Prospects and leads include the following 3 in order of merit:

1. northeast extension and culmination of the large Galatea structure into the southeast corner of SA-2.

2. offshore Umpherstone Bay area.

3. along the trend to the Northumberland structures.

Additional prospects may also occur to the above 3.

It is recommended that seismic surveys be carried out in all feasible areas, and if possible along similar line runs to link into the Ultramar surveys. This could involve up to 50 kilometres of Northeast - Southwest lines, and 45 kilometres of West-East tie lines approximately paralleling the coastline. (Total line run of approximately 95 Kilometres). This would delineate the above three prospects to determine their area of closure. If the Northeast to Southwest direction was found to be impractical due to reefs etc. then closer spaced East West lines would need be substituted.

The Waarre Sandstone represents the most prospective target in the block given the current maturity levels, source rock potential seal, and previous drilling history. A secondary target may occur at the Tertiary - Cretaceous unconformity, but seal and migration pathways to this reservoir remain uncertain. An intermediate additional target is the Pine Lodge Sand equivaltent which has been found to contain Carbon Dioxide near top Belfast Mudstone levels. Drilling depths to test all three stratigraphic levels could involve drilling up to 3300m on the culmination of the Galatea structure, but the upside is the potential for large discoveries, such as has recently been made by BHP-Bridge in the immediate offshore Port Campbell area.

11. CONCLUSIONS

1) The present study has shown that SA-2 has fair to good potential for future discoveries of oil and gas.

2) Seismic prospecting in adjacent areas has delineated at least 3 favourable trends going into the SA-2 area.

3) Seismic surveys of up to 95 line kilometers should be carried out to further delineate these structures and trends.

4) Drilling of one of the most favourable structures should then be undertaken to the Waarre Sandstone stratigraphic level.

5) The potential for a large near shore structure with significant hydrocarbon reserves is quite within the bounds of the SA-2 area.

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