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VIC/P16

OTWAY BASIN, VICTORIA

Bass Strait Oil & Gas (Holdings) N.L.

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Victoria, 3205.

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FIGURES

TABLE

1. INTRODUCTION

Bass Strait Oil and Gas (Holdings) N.L. is the operator and a title-holder of the petroleum exploration permit Vic/P.16 in the eastern Otway Basin (see Figure 1). The permit was awarded on February 5th 1980, for a period of six years tenure.

Exploration programmes have indicated that within the permit there are source, seal and reservoir lithologies, together with a number of seismically defined structures with good four way closure. It is anticipated that one of these, the Abalone Prospect will be evaluated by drilling in 1984. The primary target is the Waarre Sandstone at a depth of approximately 2,400 m. The reserves of the Abalone structure have been estimated at 1.8 billion barrels of in-place oil.

Partners are sought to participate in the drilling of this well, Abalone 1, and in so doing earn an interest in the permit Vic/P.16. Farminees could earn 80% of the permit by paying 100% of the cost of the well, or other similarly proportionate percentages. The smallest percentage to be considered would be 12.5% of the cost of the well for 10% interest in the permit.

Although the culmination of the Abalone Prospect is within Vic/P.16, approximately 43% of the structure extends into the contiguous permits T.17P and T.20P in the Tasmanian waters. Bass Strait Oil and Gas (Holdings) N.L. through a subsidiary is also operator and a title-holder to these permits. After drilling of Abalone 1, farminees would be given an option to additionally farm-in to T.17P and T.20P.

Figure 1

PERMITS VIC/P16, T17P & T20P.

BASS STRAIT OIL & GAS (HOLDINGS) N.L.

COMPILED:	R. H. BARTLETT
DRAWN BY:	R. H. BARTLETT
DATE:	16 / 12 / 1983

2. REGIONAL GEOLOGY

The Otway Basin is a northwest-southeast trending marginal depocentre, that extends from Cape Jaffa in South Australia, eastwards for 500 km to the Mornington Peninsula in Victoria (see figure 2). Thick sequences of volcanogenic and fluvio-deltaic sediments of the Otway and Sherbrook Groups are overlain by pro-grading Tertiary clastic and carbonate sediments of the Wangerrip, Nirranda and Heytesbury Groups (see Figure 6). Sediment thickness within the depocentres may well have exceeded 7,500 m.

The basin was initiated in the Late Jurassic - Early Cretaceous, as an intracratonic trough within Ordovician metasediments. Development occurred through basement downwarps, and a series of normal faults sub-parallel to the basin axis. At this time similar sediments were being deposited in Gippsland, Bass and Otway Basins (see Figure 3). The Otway Group is stratigraphically and lithologically equivalent to the Strzelecki Group of the Gippsland Basin. However the individual characteristics of the three basins developed throughout the Upper Cretaceous and Tertiary times as a consequence of rifting between Australia and Antarctica.

During the early part of the Late Cretaceous, regional movements subdivided the Otway Basin into a number of embayments (see Figure 2).

West			East
Gambier Embayment	Tyrendarra Embayment	Port Campbell Embayment	Torquay Sub-Basin

Although sedimentation was essentially continuous throughout the basin, each embayment was a centre of active subsidence within which the thickness and nature of the sediments had their own style. The Torquay Sub-Basin, particularly offshore, was sufficiently different (more continental during the Upper Cretaceous than the marine influenced Port Campbell Embayment), and so is best considered as a Sub-Basin.

The southern boundary of the Otway Basin is uncertain, but is taken to be the limit of the continental shelf. Within the offshore part of the basin there are two dominant structural features; the Mussel Platform where there may be no more than 1500 m of Upper Cretaceous sediments separated by a strong angular unconformity from the Lower Cretaceous sediments, and the Voluta Trough where Upper Cretaceous sediments may be 5,000 m thick and almost conformable with the Lower Cretaceous.

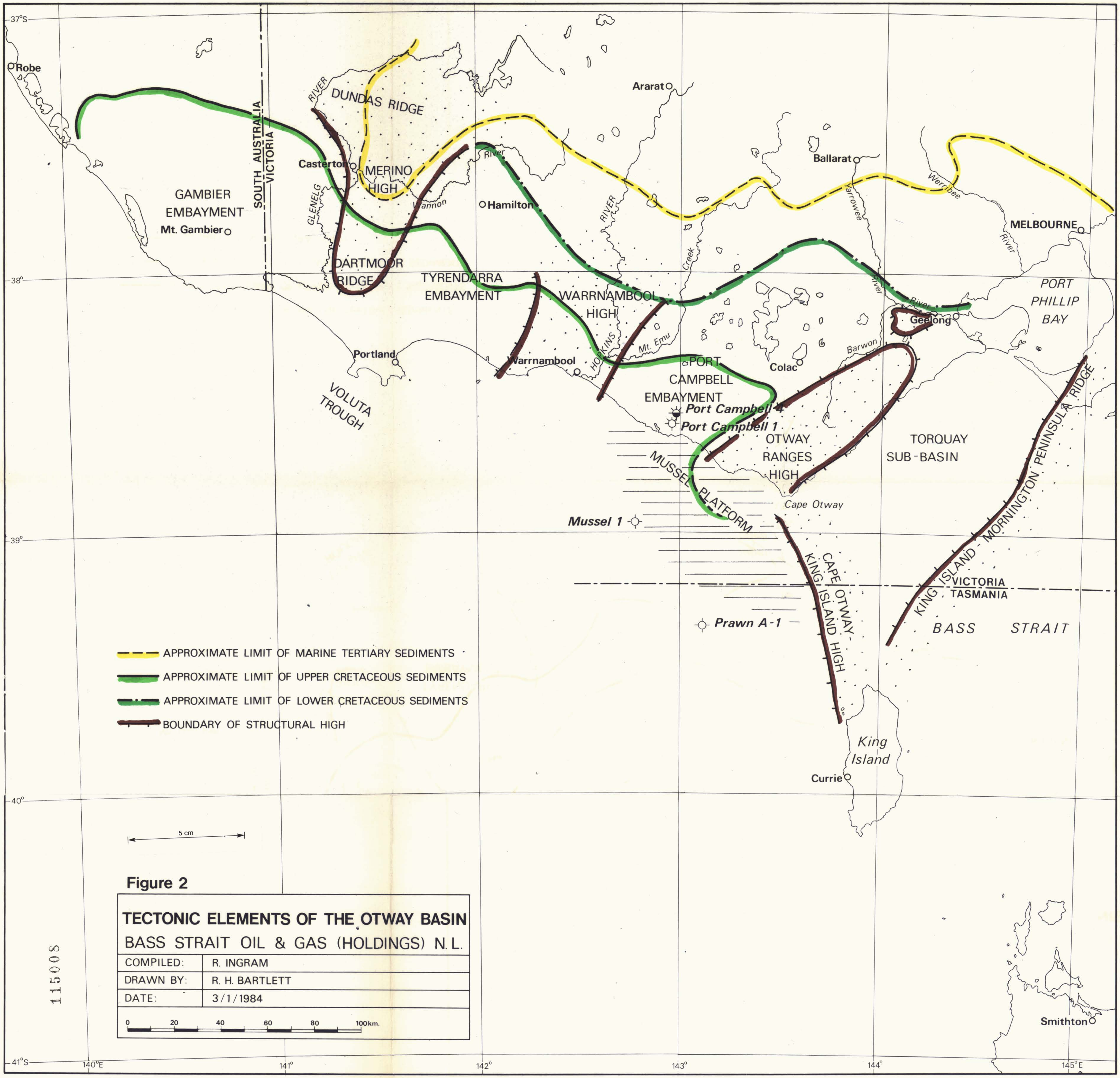

Figure 2

TECTONIC ELEMENTS OF THE OTWAY BASIN	
BASS STRAIT OIL & GAS (HOLDINGS) N.L.	
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DRAWN BY:	R. H. BARTLETT
DATE:	3/1/1984

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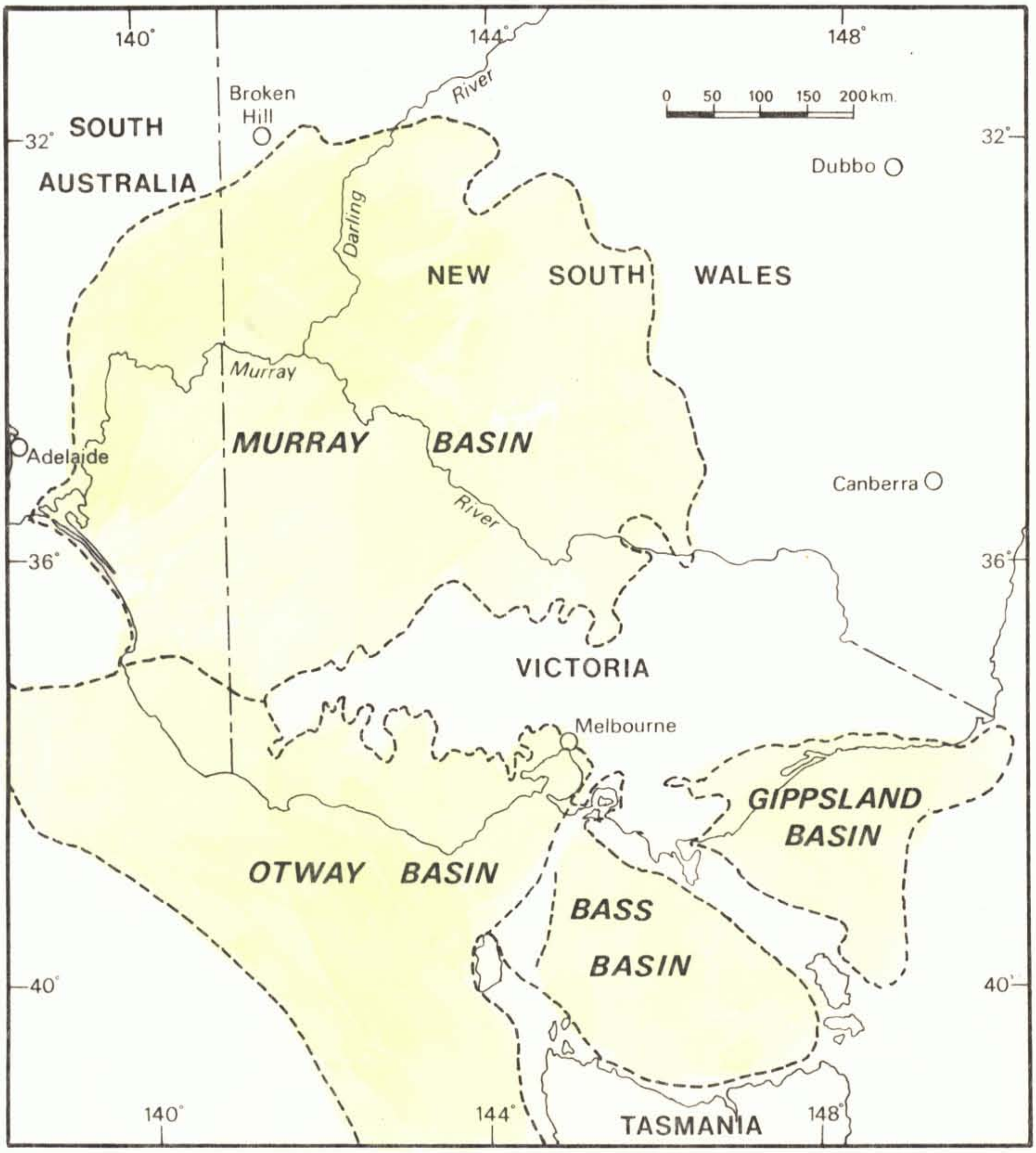
TERTIARY BASINS OF SOUTHEASTERN AUSTRALIA Figure 3



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3. EXPLORATION HISTORY

Although the earliest exploration wells were in 1939, the major discoveries for the basin occurred with the 9 wells drilled by Frome-Broken Hill between 1959 and 1964 in the Port Campbell embayment in which there were significant flows of wet gas, and a small flow of free oil (see Figure 5).

Offshore exploration in the basin commenced with reconnaissance seismic surveys conducted by Frome-Broken Hill in the period 1960-1963, and also by Hematite Petroleum in 1965. This was followed by the shooting of regional and prospect seismic grids from 1966 to 1969 by Esso and Shell. A re-assessment of all seismic data was conducted by Hematite in 1971 and they concluded that none of the existing seismic data was of sufficient quality to assess the basin and a further 4,500 kms of seismic data was gathered from 1972 to 1974.

The most recent phase of exploration in the basin has been the work of Beach Petroleum and the Gas and Fuel Corporation in developing the Port Campbell gas (North Paaratte, Wallaby Creek and Grumby Fields), and continuing the onshore exploration. While offshore, a consortium headed by Phillips Australian Oil Co. recently completed drilling Bridgewater Bay 1, their second exploration well in Permit Vic/P.14 in the western section of the basin.

The Otway Basin is considerably under-explored with about 60 onshore and 12 offshore exploration wells. Seismic interpretation has in the past been hampered by shallow, high energy reflecting horizons that have prevented penetration to the Cretaceous sediments. Improved seismic resolution and penetration should encourage further exploration to develop the basin's hydrocarbon potential.

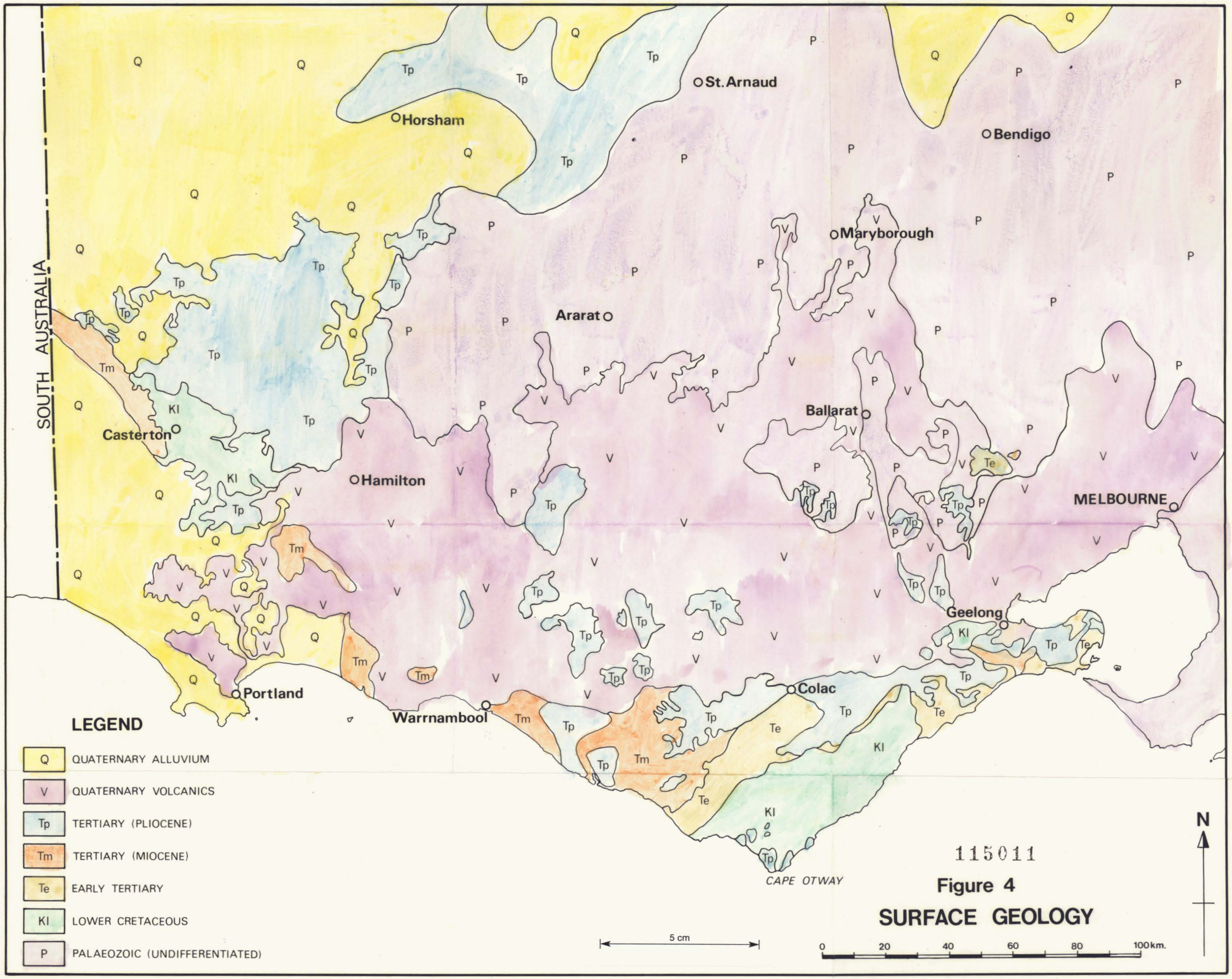

Figure 4
SURFACE GEOLOGY

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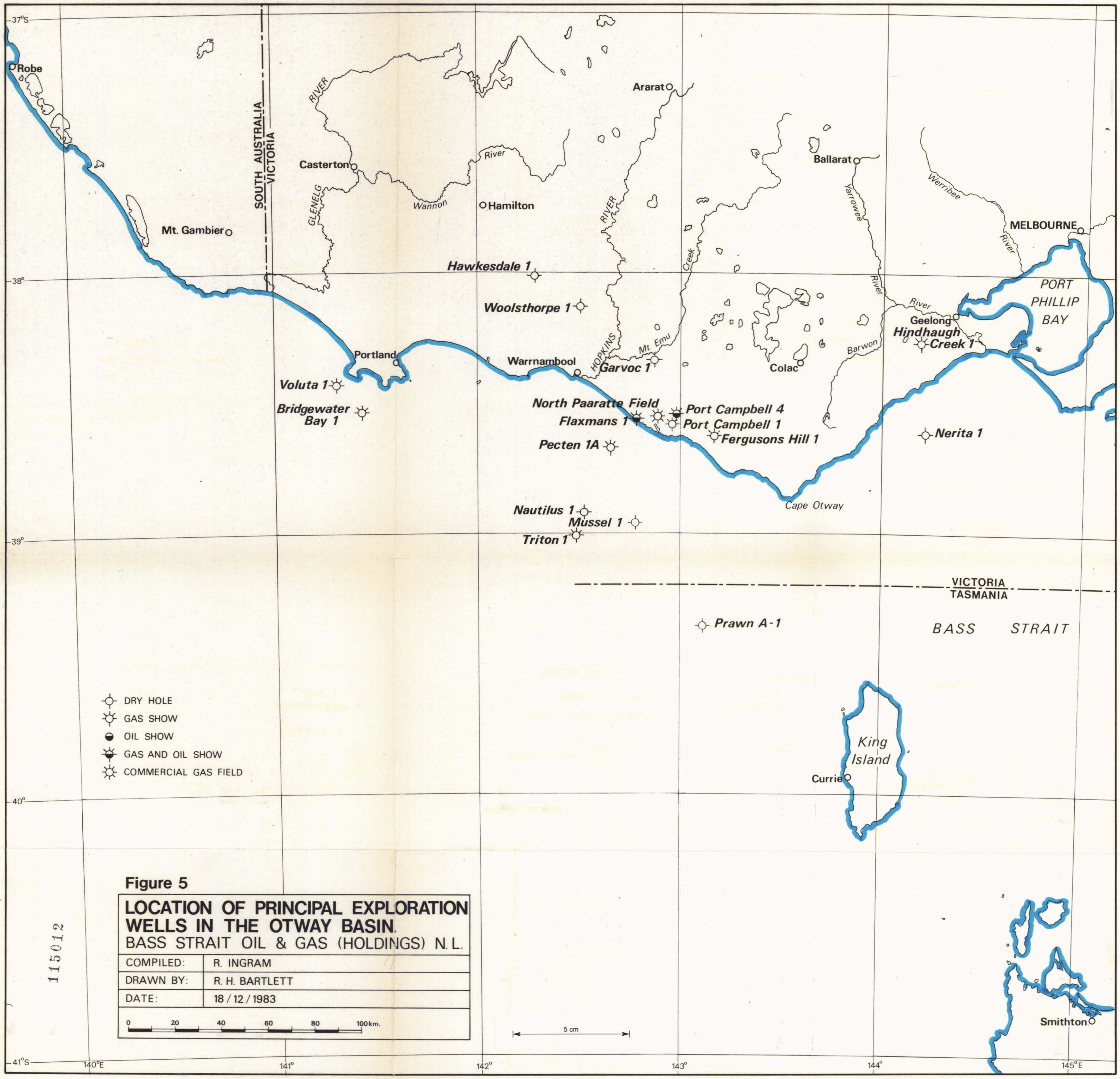

Figure 5

LOCATION OF PRINCIPAL EXPLORATION WELLS IN THE OTWAY BASIN.

BASS STRAIT OIL & GAS (HOLDINGS) N.L.

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DRAWN BY:	R. H. BARTLETT
DATE:	18 / 12 / 1983

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4. STRATIGRAPHY (see Figure 6)

The Otway Group is a dominantly fluviatile and lacustrine deposit of surprisingly uniform clastic sediments, that may exceed 3,500 m thickness. Few holes have completely penetrated this sedimentary group to reach basement, and most of these holes have been located on the margins of the basin where there is a thinner sedimentary cover. The Otway Group outcrops in the Merino Uplift, the Otway Ranges High and the Barrabool Hills. The maximum thickness may be offshore along an axis parallel to the present coastline, however no offshore holes have penetrated the complete sequence to reach basement.

The Sherbrook Group is characterised by a series of transgressive-regressive cycles during which fluvio-deltaic to marginal marine clastic sedimentation developed.

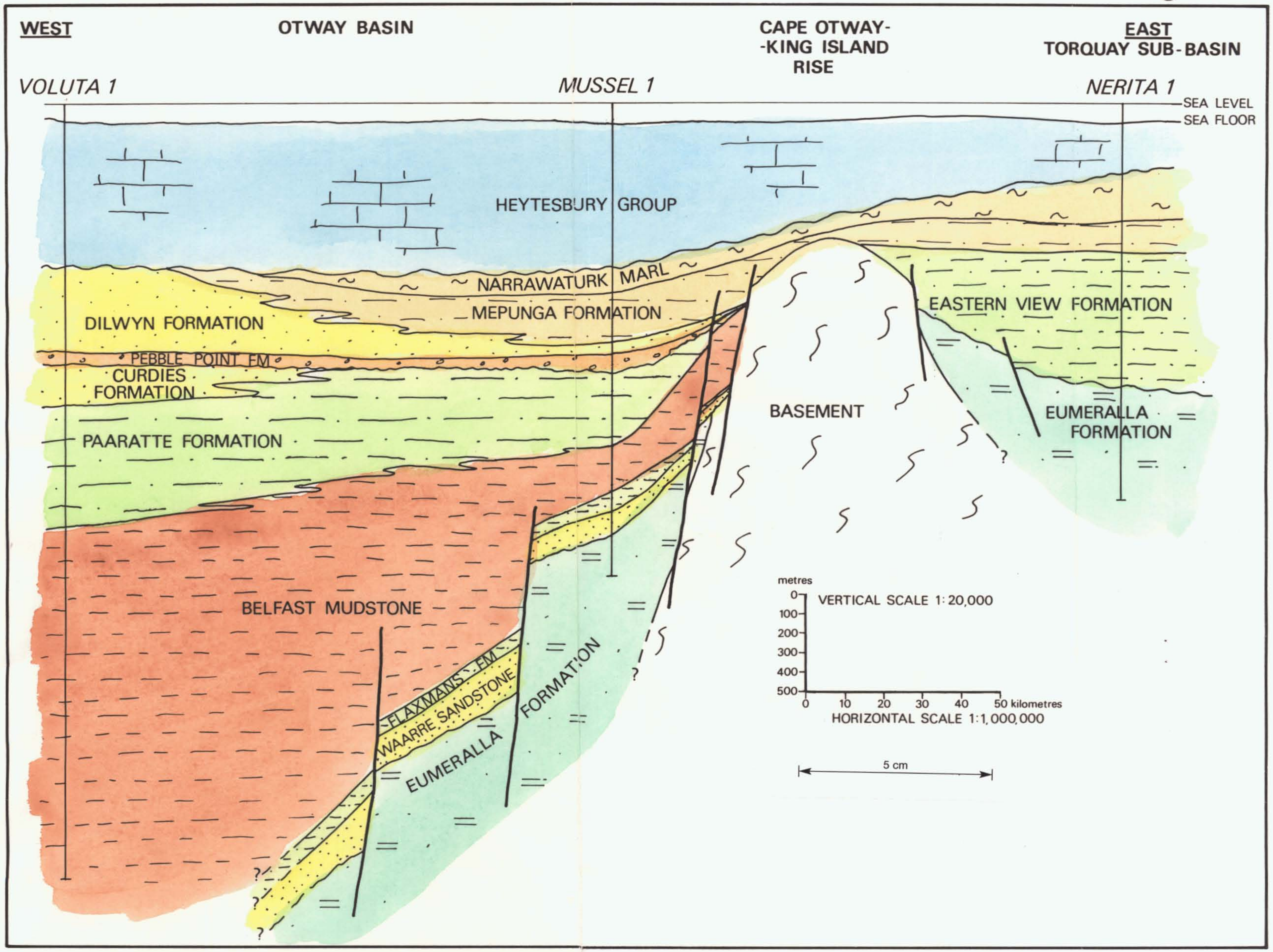
Numerous sandstone and conglomerate formations within this Group have reservoir potential, particularly the Waarre Sandstone, the Flaxmans, Paaratte and Curdies Formations. There is limited outcrop of the Sherbrook Group and so formations are defined from bore-hole information. Major unconformities separate the Sherbrook Group from the Otway Group (below) and the Wangerrip Group (above). Falvey has referred to these respectively as the "rift onset unconformity" (base Sherbrook) and the "breakup unconformity" (top Sherbrook), and related them to the tectonics associated with rifting between Australia and Antarctica.

After the major basinwide unconformity, the Pebble Point Formation was deposited as a major transgressive marine sediment of medium to coarse clastics. This initial deposit of the Wangerrip Group, and the succeeding Dilwyn Formation outcrop extensively. However widespread fresh water flushing has affected their potential as reservoirs for hydrocarbons. The recent flow of oil from the Pebble Point Formation in Lindon 1, drilled by Beach Petroleum indicates that some sections of the Wangerrip Group may have been protected from flushing.

The Nirranda and Heytesbury Groups are prograding shelf deposits of marine marls, dolomites and limestones, but have little potential in petroleum exploration.

CROSS SECTION WEST-EAST

Figure 7A



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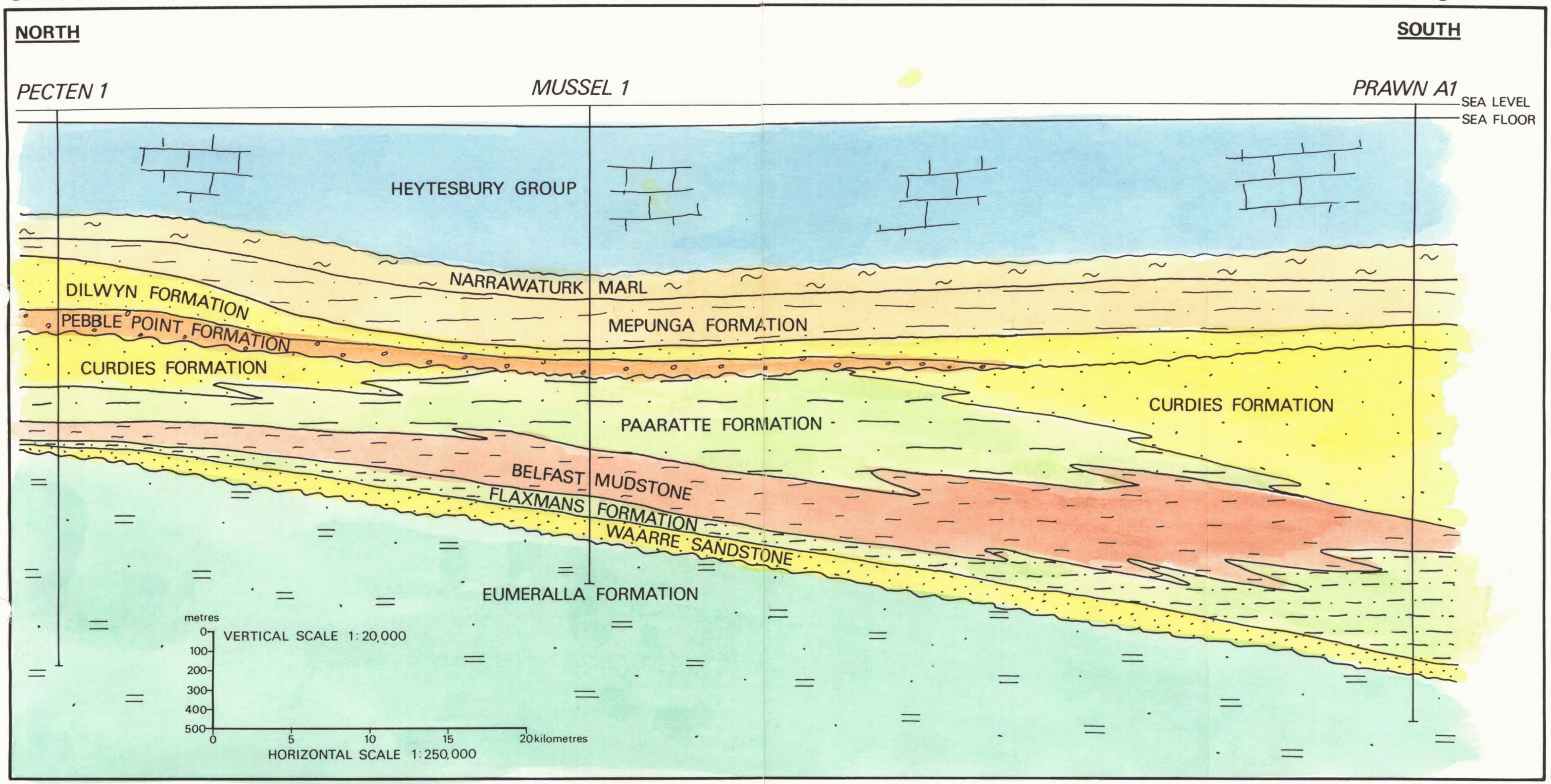
CROSS SECTION NORTH-SOUTH

Figure 7B



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5. SOURCE ROCKS AND GEOCHEMISTRY

Organic petrology and geochemistry have indicated that while many potential source rock sediments occur in the Otway Basin, only the deepest are sufficiently mature for generation. It is assumed here that the "window" for oil generation occurs between the vitrinite reflectance values 0.7% - 1.3%.

Belfast Mudstone

This has been considered by many exploration companies as the prime source bed for the basin. However vitrinite reflectance values at Prawn A1 (Ro = 0.75%) and Mussel 1 (Ro = 0.63%) indicate that it is only marginally mature.

Eumeralla Formation

The Eumeralla Formation has good total organic carbon, exceeding 1% in 44 out of 61 samples analysed from various wells throughout the Otway Basin and reaching 4.64% in Mussel 1.

Vitrinite reflectance values for the Eumeralla Formation in exploration wells near the Abalone Prospect (see figure 8) are:-

Flaxmans 1	0.92%	
Mussel 1	0.64%	(near top of section)
Pecten 1A	0.64%	(near top of section)
Prawn A1	0.94%	
Sherbrook 1	0.98%	

indicating that the formation, particularly at deeper levels, is within the oil generating window.

Direct hydrocarbon indications within the Eumeralla Formation are (see also Table 1.):-

Fergusons Hill 1	gas, fluorescence
Flaxmans 1	gas, condensate
Garvoc 1	fluorescence, tr. oil
Hindhaugh Creek 1	gas, tr. oil
Hawkesdale 1	fluorescence
Port Campbell 3	gas
Sherbrook 1	oil staining

The Eumeralla Formation is up to 3500m thick, and widespread throughout the basin, and so represents a considerable volume of generative sediment.

Basement subsidence curves prepared by Paltech (see Figure 9) show that although there was a rapid early subsidence prior to structuring in the Mid-Cretaceous, the sediments did not enter the generative zone until after structuring.

The Eumeralla Formation is believed to be the source of the various Port Campbell gas fields.

Casterton Beds and Deeper Sources

The Casterton Beds are gas prone, but they have been penetrated by so few wells that their occurrence is unpredictable.

It is possible that Permian sediments in the basement could be a source of hydrocarbons. However little information is available to confirm this.

Therefore the Eumeralla Formation is the most likely source of hydrocarbon generation.

TABLE 1. Selected hydrocarbon indications from wells drilled in the Otway Basin.

Fergusons Hill 1	1657 - 1665m.	0.1 - 1.5 x 10^3 cu.m/day gas.
Flaxmans 1	3195 - 3514m.	7 x 10^3 cu.m/day gas, small quantity 51.2 A.P.I. condensate.
Garvoc 1	1365 - 1386m.	gas cut mud, plus fluorescence and traces of oil.
Grumby 1	Waarre Sandstone	223 x 10^3 cu.m/day gas, plus condensate.
Hindhaugh Creek 1	710- 724m.	small flow of combustible gas.
North Paaratte 1	1443 - 1454m.	283 x 10^3 cu.m/day gas.
Pecten 1	1771 - 1774m.	2.5 - 4.1 x 10^6 cu.m/day gas.
Port Campbell 1	1727 - 1747m.	petroliferous gas.
Port Campbell 3	1510 - 1513m.	gas cut salt water plus condensate.
Port Campbell 4	1789 - 1792m.	0.7 cu.m/day of 34.7^{o} A.P.I. free oil plus emulsion and 2.4 cu.m/day gas.
Tullich 1	1134 - 1154m.	gas and salt water - flared briefly.
Wallaby Creek 1	Waarre Sandstone	277 x 10^3 cu.m/day gas plus condensate.

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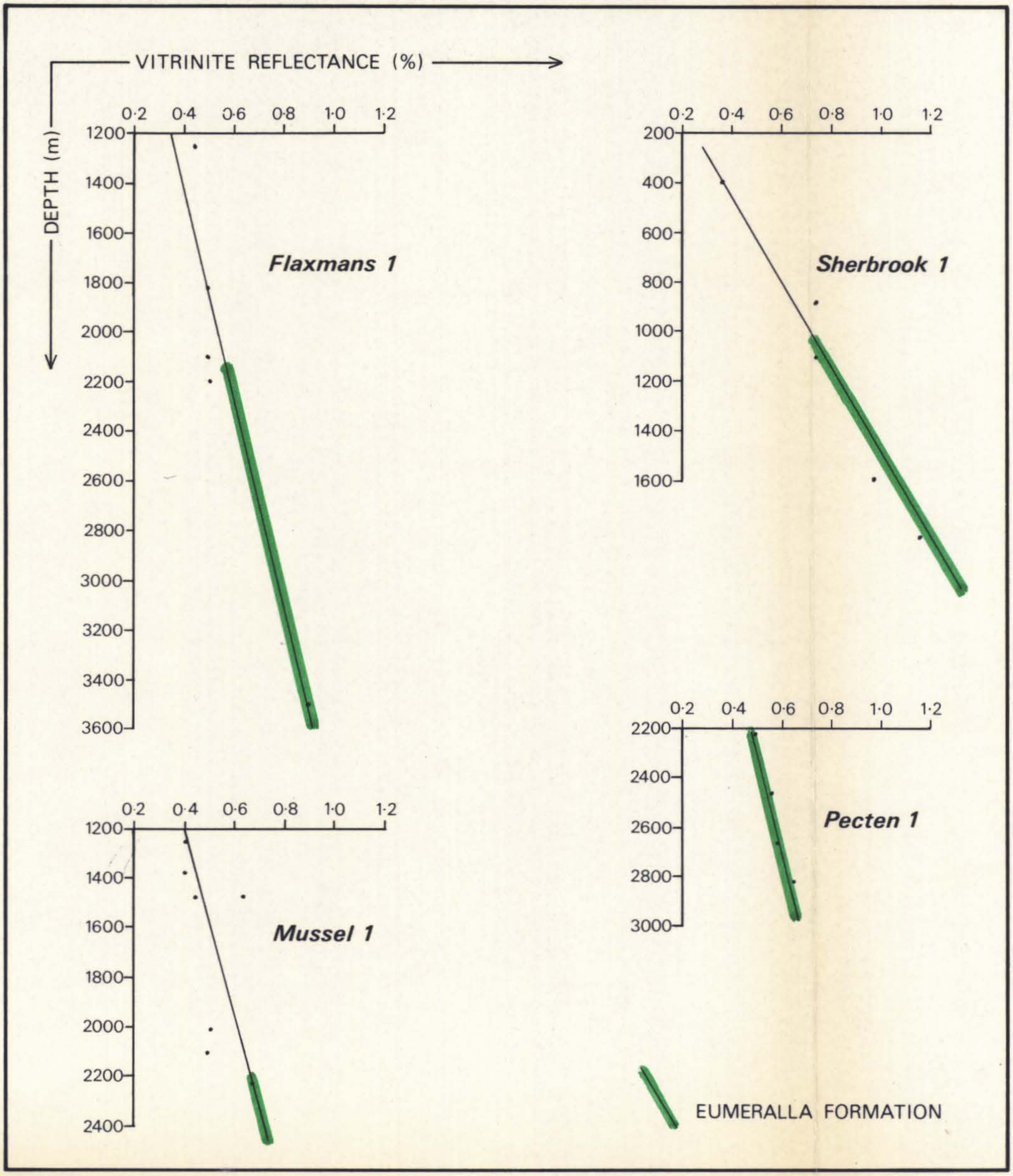
GRAPHS OF VITRINITE REFLECTANCE vs DEPTH FOR SELECTED WELLS IN THE OTWAY BASIN

Figure 8



6. RESERVOIRS AND ASSOCIATED CAP ROCKS

While porous, permeable sediments occur in all stratigraphic groups (Heytesbury, Nirranda, Wangerrip, Sherbrook and Otway), the shallower formations are prone to fresh-water flushing. Therefore it is unlikely that suitable target reservoirs would occur in the Heytesbury or Nirranda Groups.

Both the Dilwyn and Pebble Point Formations could be potential reservoirs, as lithologically they are often clean quartz sands with good porosity and permeability. The Pebble Point Formation is frequently conglomeratic, while offshore both Dilwyn and Pebble Point may contain a significant silt component. The Narrawaturk Marl often caps the Dilwyn and the Pember Mudstone Member often caps the Pebble Point. However this may not occur, and the reservoirs may be uncapped. More-over onshore they are exposed at the surface over a considerable area, and so subject to fresh water flushing. The recent discovery of oil in the Pebble Point Formation of Lindon 1 and other similar discoveries on VMD water Bores (Timboon 5, Wangoom 2) show that flushing may not be complete.

Major reservoirs occur in the Sherbrook Group, notably:-

Curdies Formation capped by mudstone units of the Dilwyn and Pebble Point Formations.

Intra-Paaratte Formation and Intra-Belfast Mudstone sandstones, each capped by intra-formational mudstones. Such intra-formational sands often lack the continuity to form a significant reservoir.

Waarre Sandstone capped by Flaxmans Formation and Belfast Mudstone, is a major exploration target for the basin. At Mussel 1, a core in the Waarre Sandstone was described as:

"Fine to medium grained, well sorted, sub-angular to sub-rounded, friable quartz sand. It is thinly interbedded with black, micaceous, carbonaceous, fissile, shale. Burrowing is occasionally observed. Results of core analyses indicate sand porosities ranging up to 25.5% and permeabilities up to 1650 MD. These sands persist for 264 feet to a depth of 7100 feet and then interbedding of silty sand and siltstone occurs with siltstone dominating and increasing towards the base".

The Waarre Sandstone is reservoir for the Port Campbell gas fields and has been reservoir for hydrocarbon shows on other exploration wells in the basin, including Pecten 1A and Mussel 1. It is the primary exploration target for Abalone 1.

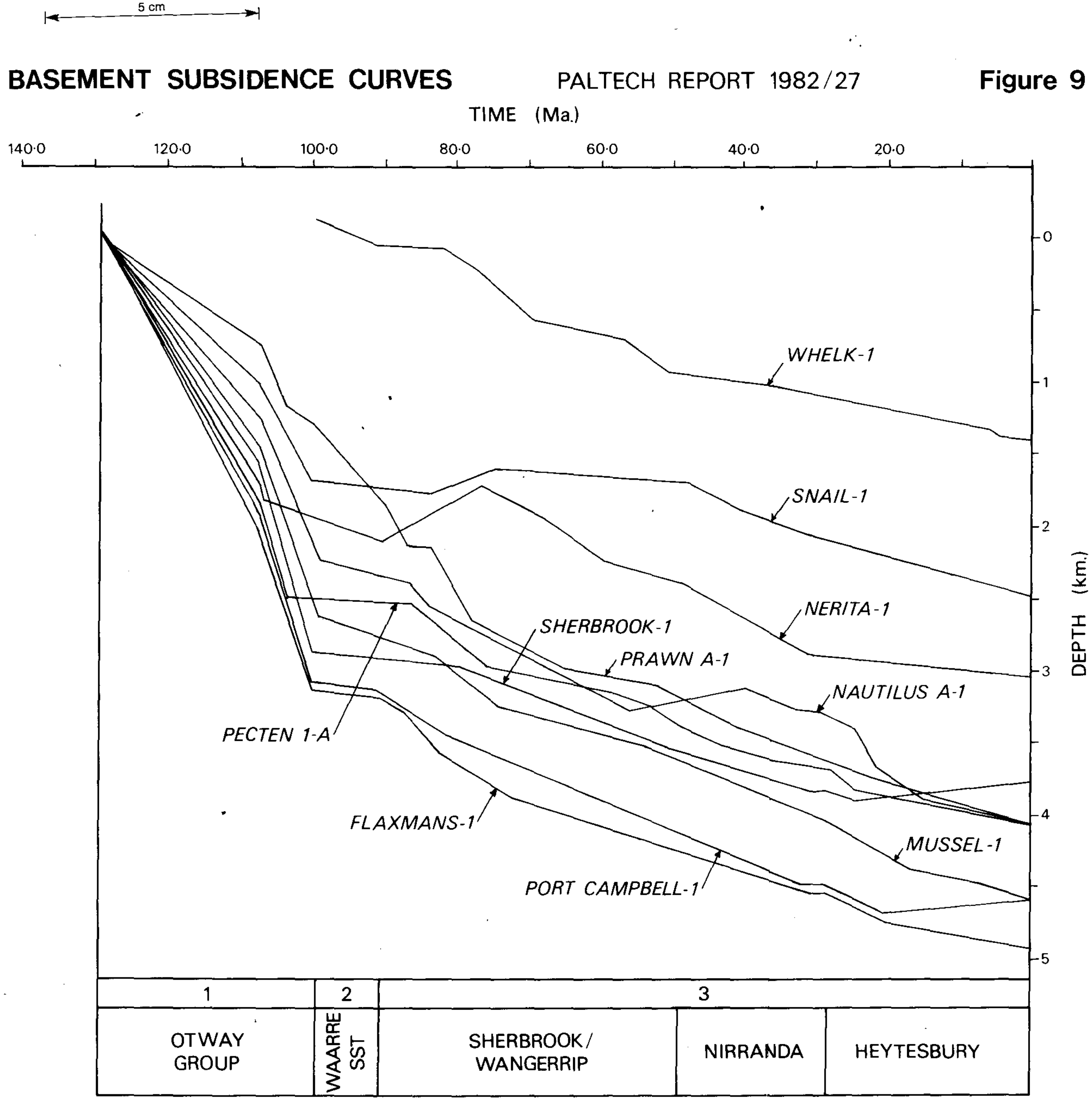
Eumeralla Formation - Several intra-Eumeralla Formation sands occur, particularly in the upper parts of the section, such as the "Heathfield Sandstone" in the western Otway Basin. These sands are capped by overlying impermeable shales and silts of the Eumeralla Formation. Although these sands have been responsible for hydrocarbons (gas and oil) on Eumeralla 1, Fergusons Hill 1, Flaxmans 1, Hindhaugh Creek 1, Heathfield 1, Sherbrook 1 and various Port Campbell wells, the sands often lack lateral continuity.

Pretty Hill Sandstone - Deposited early in the basin's development the Pretty Hill Sandstone has been an exploration target for many wells. Although widespread throughout the basin it's thickness has proved to be quite variable. At Pretty Hill 1 it was a clean, mature, well sorted quartz sandstone, 582m thick, and more than 1600m at Crayfish 1 in South Australia. The cap rocks are the overlying fine grained sediments of the Eumeralla Formation. Hydrocarbon indications have been found on Hawkesdale 1, Woolsthorpe 1, Tullich 1, and Garvoc 1. However the depth of this formation has prevented it's exploration except at the shallower basin margins.

BASEMENT SUBSIDENCE CURVES

PALTECH REPORT 1982/27

Figure 9



7. GEOHISTORY AND ITS RELEVANCE TO RESERVOIRING

Basement subsidence plots (see figure 9) were constructed by Paltech; these show that rapid subsidence occurred early in the Late Cretaceous, and with further slow subsidence in later times as a combined product of sediment compaction and tectonics.

Vitrinite reflectance values at the top of the Eumeralla Formation average 0.8% (ranging 0.7% - 0.9%), and are therefore just entering the zone of maturity. However the average thickness of the Eumeralla Formation is 2.0 - 3.0 kms, and with a regional vitrinite reflectance gradient of 0.2%/km, the reflectance values at the base of the Eumeralla Formation would be

Ro = 0.8 + (2.0 x 0.2)

Ro = 0.8 + 0.4

Ro = 1.2% - i.e. fully mature. Therefore the Eumeralla Formation may well straddle the full zone of maturity (0.7 - 1.3%), and in past times has been immature.

Structures developed during the Upper Cretaceous and Early Tertiary would be well placed to receive generated hydrocarbons.

Rapid subsidence early in the Late Cretaceous (see figure 9) brought the Eumeralla Formation to marginal maturity. Further subsidence in the Late Cretaceous and Early Tertiary enhanced this maturity. In addition a high temperature event locally affected the Otway Ranges High, over-maturing the sediments of this area, raising the vitrinite reflectance to Ro = 6%. Halo-ing the Otway Ranges High are zones of decreasing vitrinite reflectance. This thermal event locally distorts the maturity patterns of the adjacent Port Campbell Embayment and Torquay Sub-Basin. It could also affect sediments to the south on the Mussel Platform.

8. PLAYS IN VIC/P16

1. Rotated Fault Block Structures

Upper Cretaceous to Early Tertiary normal faults, down thrown to the south west and dipping to the north east form the principal structural controls for reservoiring in Vic/P.16. Mid-Tertiary compressions, possibly as a component of wrenching (see Blake), have arched these structures into the fault, increasing the volume of the reservoir. Complete closure is effected by northwest-southeast roll-overs.

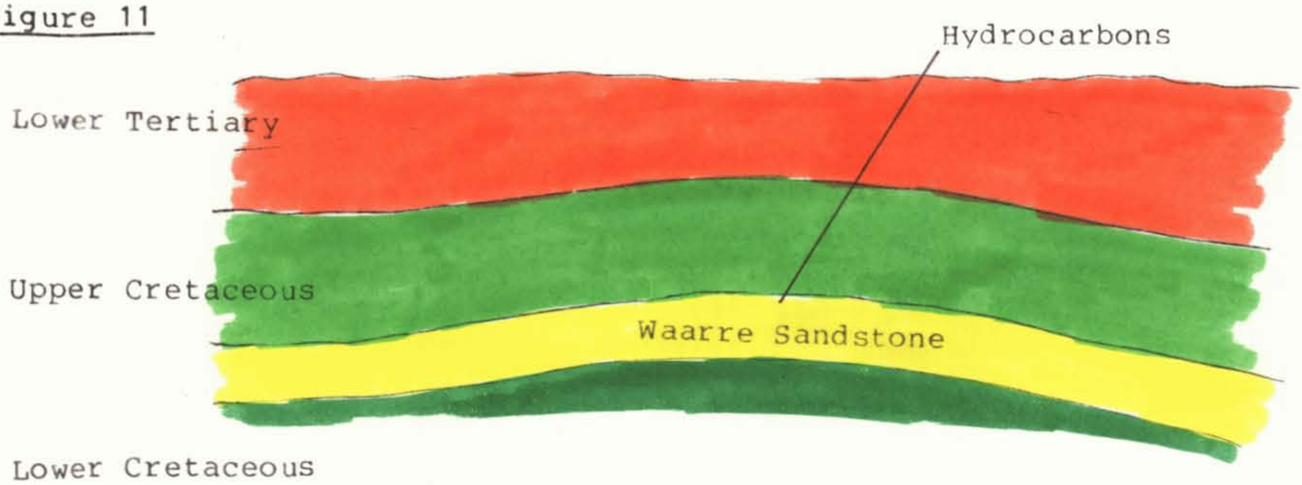
All Lower and Upper Cretaceous reservoirs would be favoured by these structures.

Figure 10

2. Anticlinal Structures

Mid to Late Tertiary wrenching movements may have occurred, producing compression as a component of these movements and generating a variety of anticlinal structures. These may have formed too late for the deeper, early maturing sources.

Figure 11

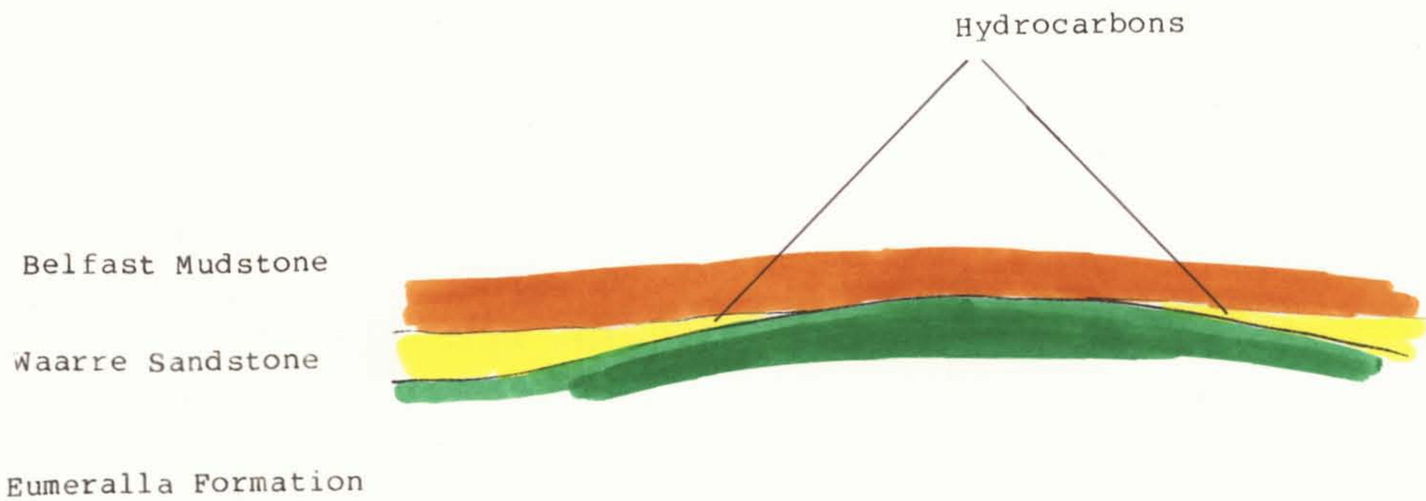


3. <u>Pinch-out Structures</u>

The Lower Cretaceous sediments (Pretty Hill Sandstone and Eumeralla Formation) pinch out against Lower Palaeozoic basin margins, and it is possible that hydrocarbons may migrate up-dip into such traps.

Similarly the Waarre Sandstone often thins over and pinches out against palaeo highs of Lower Cretaceous sediments.

Figure 12



9. Abalone Prospect

The Abalone Prospect includes an area of 61 km^2 of which approximately 57% is within Vic/P.16, and the remaining 43% is included within T17P and T20P (see figure 14).

The structure is bounded by a number of north north west - south south east trending normal faults. Full closure is effected by folding.

A tie was taken to Prawn A1 along the lines OMQ81-31, OBV81-1, OBV81-4 (see figure 13). Seismic interpretation was guided by two features:

1. the character and continuity of the reflection at the Waarre Sandstone Horizon
2. the sudden increase in velocity (by 2,000 ft/sec) to a fairly uniform 15,000 ft/sec at the top of the Otway Group. (Denham and Brown, 1976).

the culmination of the structure is in Vic/P.16 and is located at shotpoint 1260 on line OMQ81-31. This is approximately at 143° 03.1'E, 39° 10.5'S.

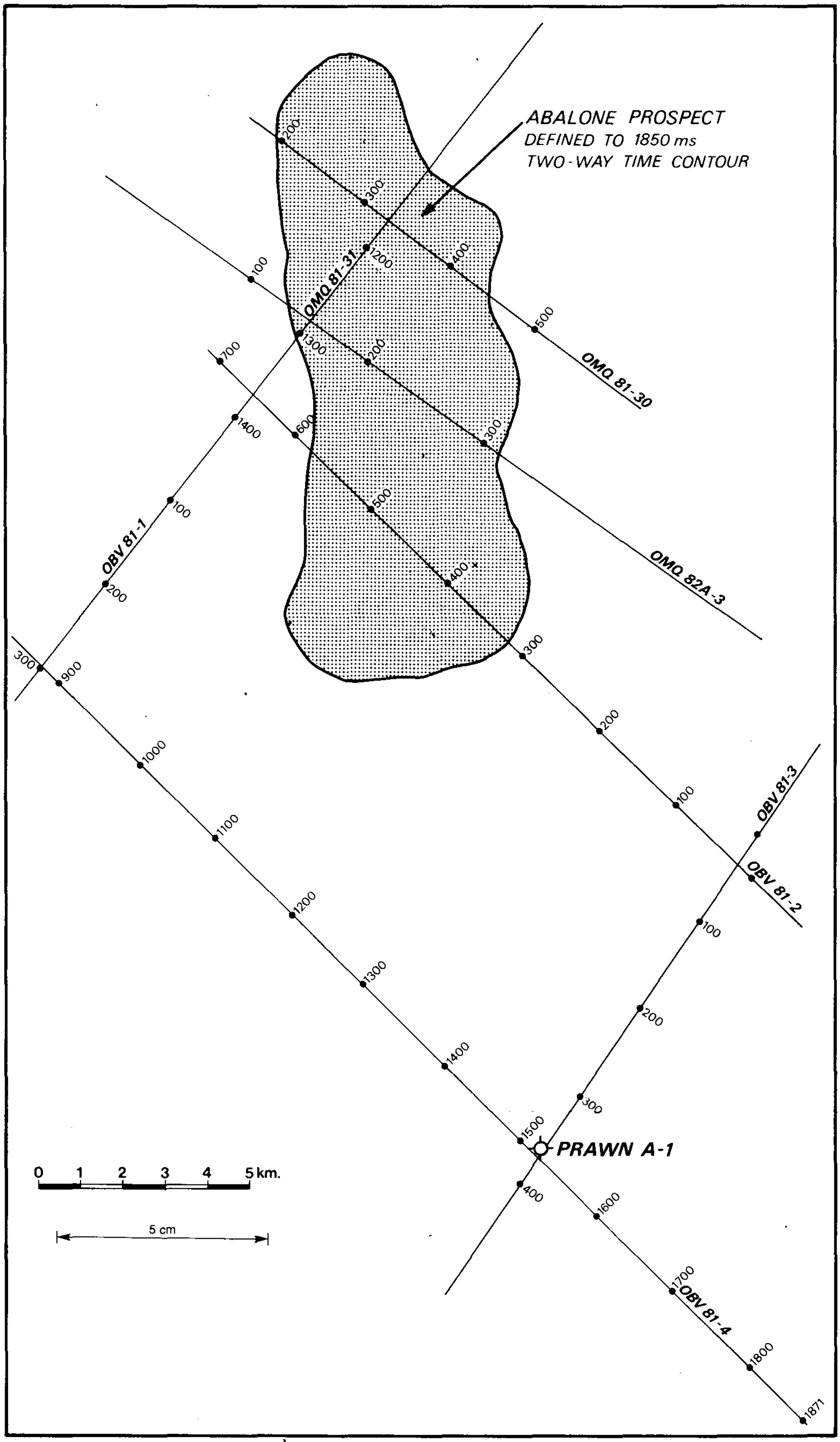
The Waarre Sandstone and Sherbrook Group thin to the north over the Mussel Platform, but is of the order of 150m thickness over the Abalone Structure.

Although the Waarre Sandstone is at a depth of approximately 2400m, it is suggested that a well drilled in this location may need to set a total depth of 2800m to confidently reach the top Otway, and then to complete the evaluation of the Upper Eumeralla sands.

Water depth is anticipated at 90m.

The Waarre Sandstone is the primary target, but inter-Paaratte and Curdies Formation sands must also offer good potential. Shallower targets will lack structure for reservoiring, but deeper targets, such as intra-Eumeralla and Pretty Hill Sandstone levels could exist, but would need further seismic definition.

TIE FROM PRAWN A1 TO ABALONE PROSPECT **Figure 13**



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10. RESERVE ESTIMATES ON ABALONE STRUCTURE

Reservoir is Waarre Sandstone at a depth of approximately 2500m and sealed above by the Belfast Mudstone.

Assumptions

1. Vertical displacement due to down faulting within structure is approximately equal to area above the 1750 m.s. contour.
2. Reservoir and hydrocarbon characteristics taken as for those in Bass Basin prospects.
3. Structure is triangular shaped in section.

Area Closing Contour	61 km^2 (1850 m.s. contour)
Gross Column	150 metres (vel. 3000m/sec)
Porosity Assumed	20%
Oil Saturation Assumed	75%
Net to Gross Reservoir Assumed	50%
Formation Volume Factor Assumed	1.2%

Area in Acres	=	6100 hectares x 2.47	= 15073.1 acres
Height in Feet	=	150 x 3.28	= 492 feet
Volume of Structure	=	7415965.2 x 0.5	= 3707982.6 acres feet
Volume of Barrels	=	3707982.6 x 7758	= 2.877×10^{10} bbls.

TOTAL RESERVE

$$= 2.877 \times 10^{10} \times \frac{0.5}{1.2} \times 0.2 \times 0.75$$

$= 1.798 \times 10^{9}$ bbls.

= 1.8 Billion Barrels.

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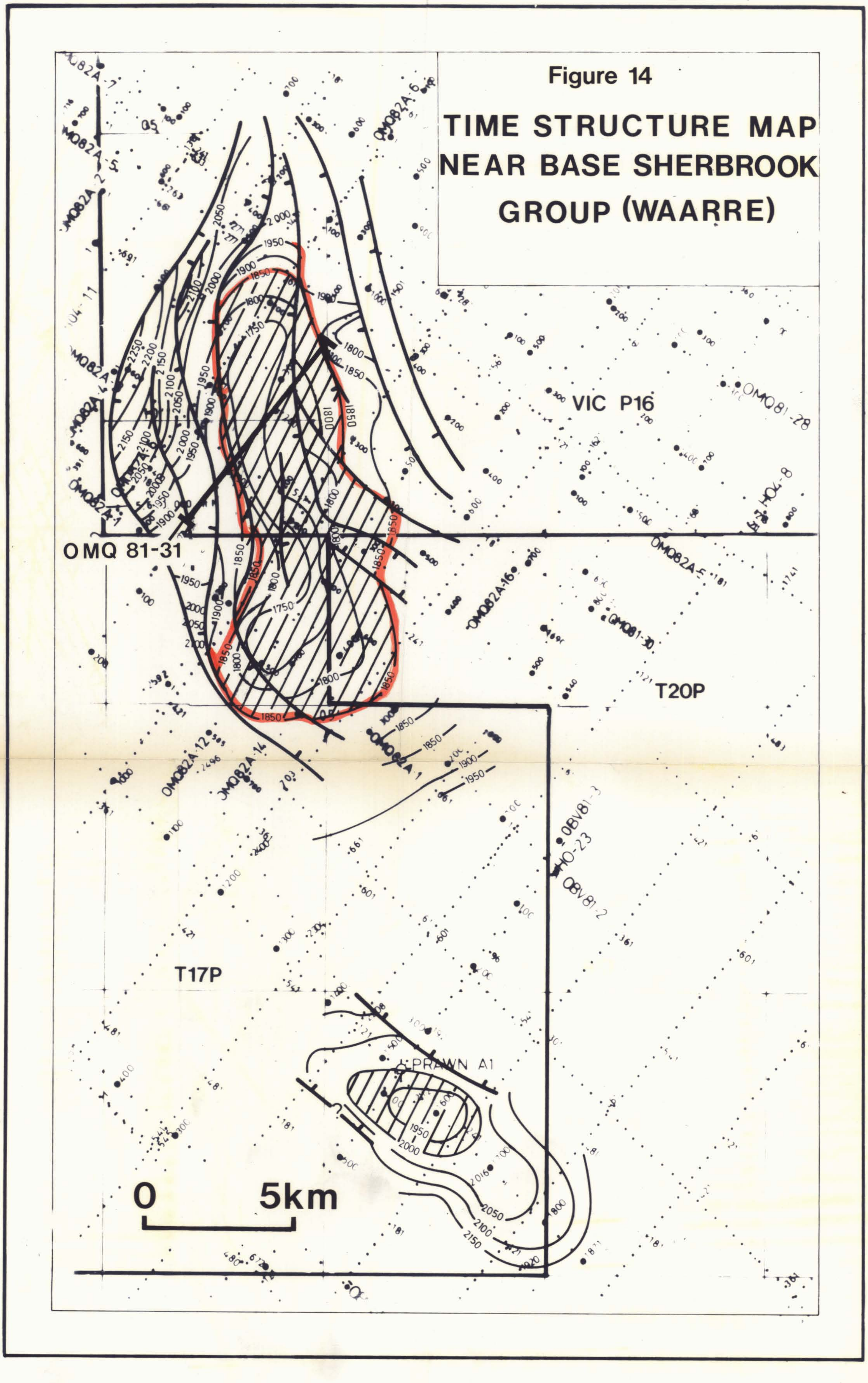

Figure 14

TIME STRUCTURE MAP NEAR BASE SHERBROOK GROUP (WAARRE)

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Figure 15

OMQ 81 – 31