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Record 1978/91

A REVIEW OF PETROLEUM EXPLORATION AND PROSPECTS IN THE OTWAY BASIN REGION

by

C.S. Robertson, D.K. Cronk, S.J. Mayne, and D.G. Townsend.

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SUMMARY

Petroleum exploration carried out in the Otway Basin region has been reviewed up to December 1976 to provide an assessment of existing information on the basin and to determine what further exploration is required.

The region reviewed includes the Otway Basin in South Australia and Victoria, the Torquay Basin in southern Victoria, and the area of continental shelf west of Tasmania, the sedimentary cover of which latter area is named the Sorrel Basin in this review.

Mesozoic and Cainozoic sedimentation in the region has been greatly influenced by the separation of Australia and Antarctica, beginning in the Eocene, and the tectonic events which preceded separation. Lower Cretaceous rocks are mostly fluviatile to estuarine sediments derived from highlands both to the north and south. Where wells have penetrated below the Lower Cretaceous, these sediments are underlain by Lower Palaeozoic rocks. Periodic block faulting occurred in the Middle Cretaceous, splitting the region into a number of sub-basins. Shallow-water clastics were deposited during a marine transgression from the west in the Late Cretaceous. Sedimentation became largely calcareous, following continental separation in the early Tertiary and the Tertiary sequence contains evidence of a series of transgressive-regressive cycles.

The region has been fairly well explored by geophysical methods and by drilling. However the only significant petroleum shows encountered were in the central, onshore part of the region near Port Campbell, where substantial, but non-commercial gas flows were discovered in the early 1960s. Exploration to date indicates that the prospectivity of the overall region is low, but further exploration is warranted in some areas.

INTRODUCTION

This Record is a summary of petroleum exploration and prospects in the Otway Basin region, which extends from the vicinity of Kangaroo Island southeast through onshore and offshore portions of southeastern South Australia and western Victoria to west of Tasmania (Fig. 2), an area of some 40 000 km^2 onshore and 200 000 km^2 offshore. The area contains late Mesozoic to Cainozoic sediments up to 7 500 m thick. Lower Palaeozoic igneous, metamorphic, and sedimentary rocks form economic basement throughout most of the area.

Onshore, geological mapping was done by the Geological Survey of South Australia (GSSA) in 1951 and from 1965 to 1969, and by the Geological Survey of Victoria (GSV) from 1963 to 1973. One 1:250 000 map, one 1:253 440, and nine 1:63 360 maps have been published. Three 1:250 000 maps have been issued as preliminary editions. A 1:1 000 000 map covering the entire basin is published in Reynolds (1971) and a 1:500 000 map is published in Wopfner & Douglas (1971).

The geology of the Otway Basin has been described by Leslie (1966), Weeks & Hopkins (1967), White (1968), Wopfner & Douglas (1971), Reynolds (1971), and Ellenor (1976). Most of the available subsurface data has been obtained during petroleum exploration.

This summary is based on information available to the Bureau of Mineral Resources, Geology and Geophysics (BMR) up to December 1976. Much of the petroleum exploration carried out by industry in the region up to 1974 both onshore and offshore was subsidised by the Australian Government under the terms of the Petroleum Search Subsidy Act (PSSA). Final reports on subsidised wells and subsidised geophysical surveys containing both basic and interpretative data, are available to the public. Subsidised operations are identified as such in Appendixes 1 and 2.

Reports on surveys carried out by BMR and the state geological surveys are also publicly available.

Data from unsubsidised company operations are not generally available to the public, although in some cases company personnel have published exploration articles based on company information. Under the provisions of the Petroleum (Submerged Lands) Act (P(SL)A), which applies to operations in offshore areas since 1968, the Designated Authority for the state in question may publicly release basic (non-interpretative) data from exploration operations five years after their receipt, or after the operator has relinquished title to the areas on which the operations were carried out. Therefore, some of the data from unsubsidised company operations referred to but not discussed in this review may not yet be available to the public.

GEOLOGY

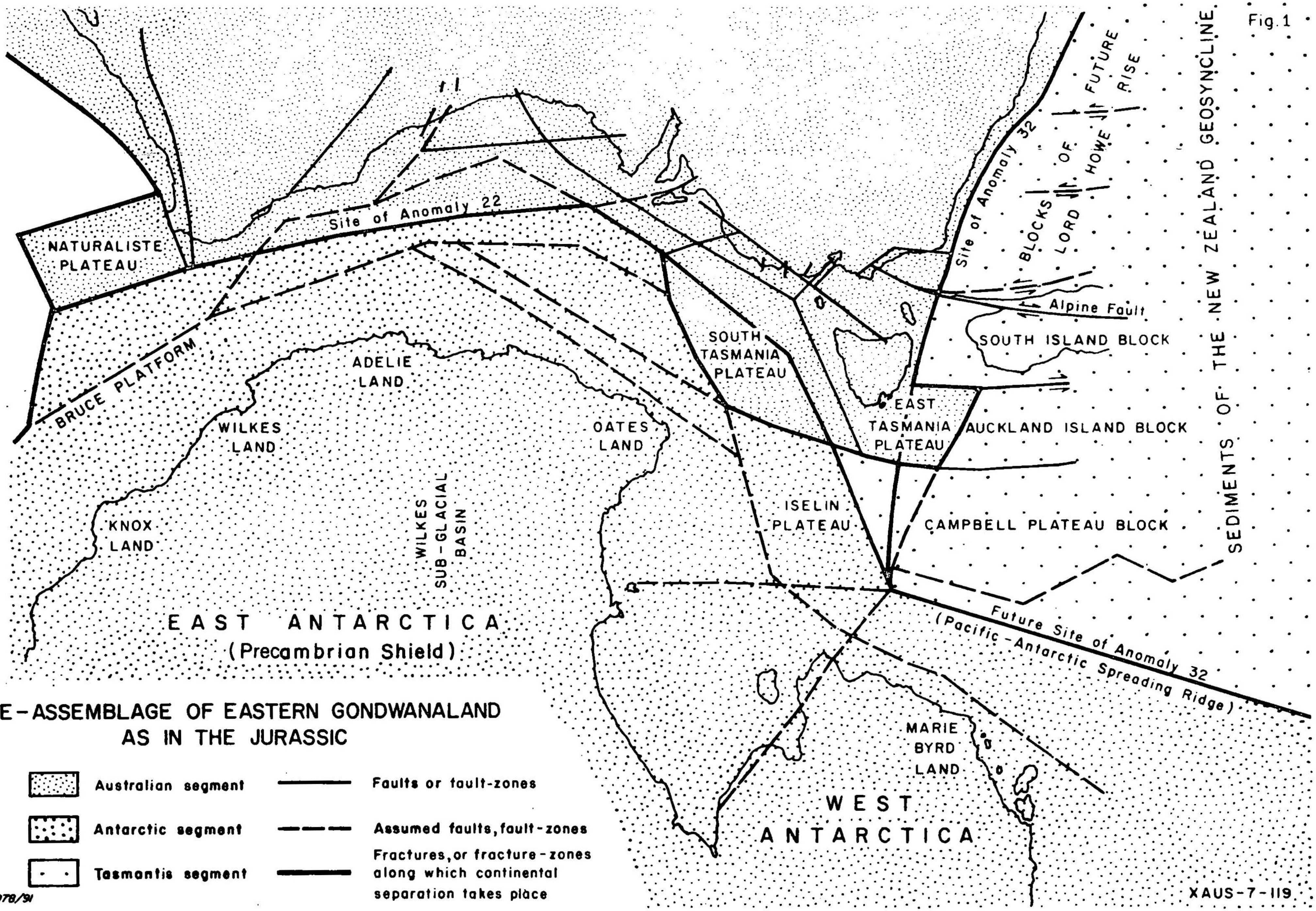
Tectonic framework of southern Australian marginal basins

The Mesozoic to Tertiary sedimentary basins of southern Australia owe their origin to the breakup of eastern Gondwanaland. Before breakup, in approximately Middle to Late Jurassic times, East Antarctica may have been the site of a swell (cf. the present-day Scandinavian and East African swells) or an 'undation' (van Bemmelen, 1972) surrounded by peripheral fractures. These fractures (Fig. 1) probably became the sites of spreading ridges during the episodes of continental plate separation which followed; including the separation of 'Tasmantis', that is the Campbell Plateau, New Zealand and the Lord Howe Rise, from eastern Gondwanaland, which took place from about 80 m.y. to 60 m.y. B.P. (Upper Cretaceous to Paleocene), and the separation of Australia from Antarctica beginning about 45 m.y. B.P. (Eocene) and continuing to the present.

In the early stages of the separation of 'Tasmantis' oceanic crust (dated by magnetic anomaly 32) began forming between Marie Byrd Land and the Campbell Plateau on the one hand, and between Australia and the New Zealand region on the other (Hayes & Ringis, 1973; Molnar & others, 1975) (Fig. 1). The rift-site between Australia and New Zealand seems to have been oriented parallel to the structural trends of the rocks in the Lachlan and New England Fold Belts. The 'Tasmantis' Plate is assumed to have broken into several blocks as it moved away from Australia and Antarctica: each block separated by strike-slip faults, the movements along which decreased from south to north. These blocks became the Campbell Plateau, New Zealand, and the Lord Howe Rise.

The separation of Australia from Antarctica was preceded by minor faulting in the Late Jurassic: many old faults were reactivated in the Adelaide Fold Belt, the Polda Basin, and possibly along belts of ancient strike-slipping as envisaged by Harrington & others (1973) southwest of South Australia and Victoria, and north and west of Tasmania. Vulcanism, which is probably indicative of a tensional regime, was widespread in the Otway, Bass, and Gippsland Basins.

In the region of tensional stress between Australia and Antarctica a major crustal downwarp developed extending from the Naturaliste Plateau in the west to Marie Byrd Land in the east. The stresses were relieved by the development of rift-valleys, whose formation marked the beginning of the taphrogenic stage of continental separation.



RE-ASSEMBLAGE OF EASTERN GONDWANALAND AS IN THE JURASSIC

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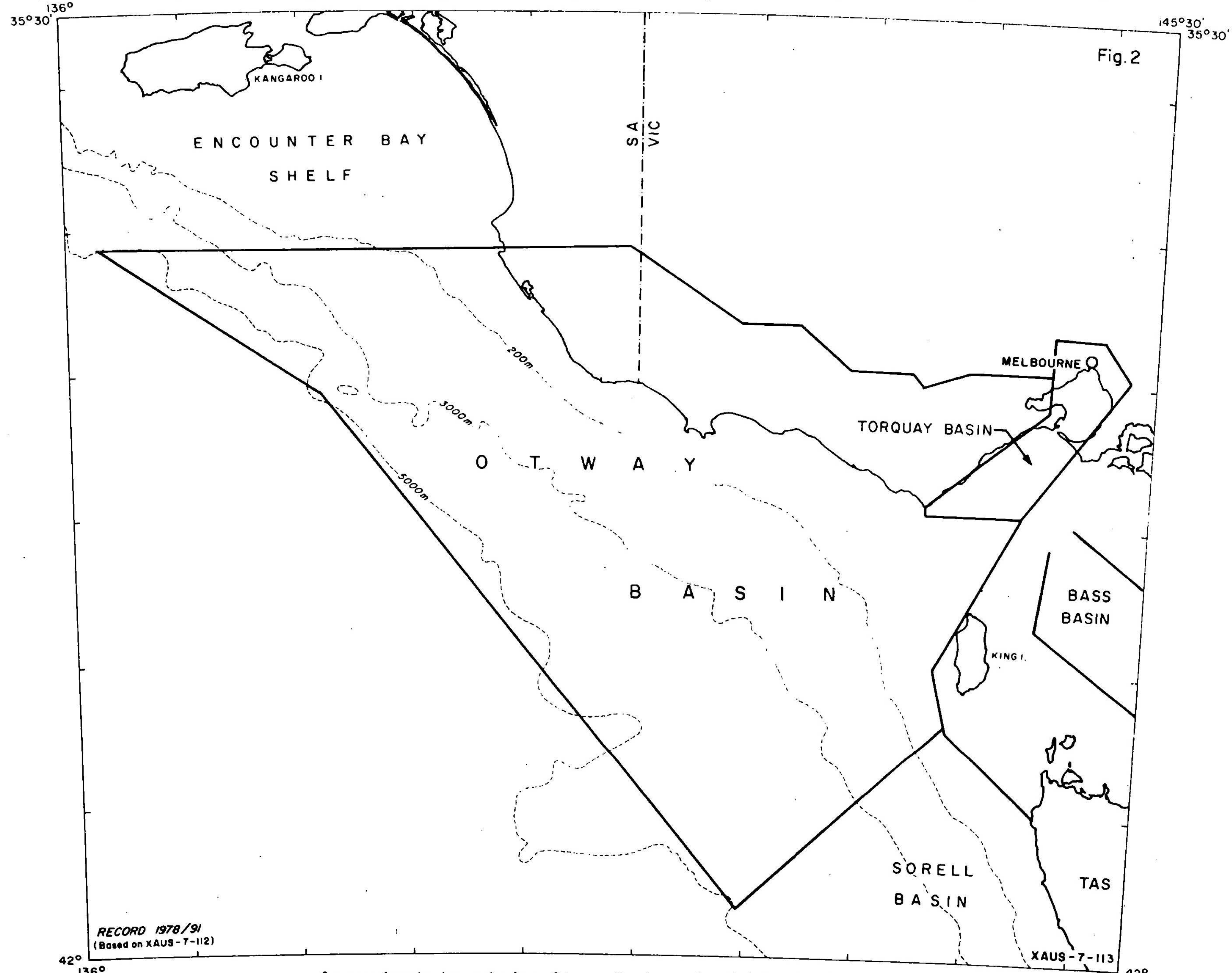


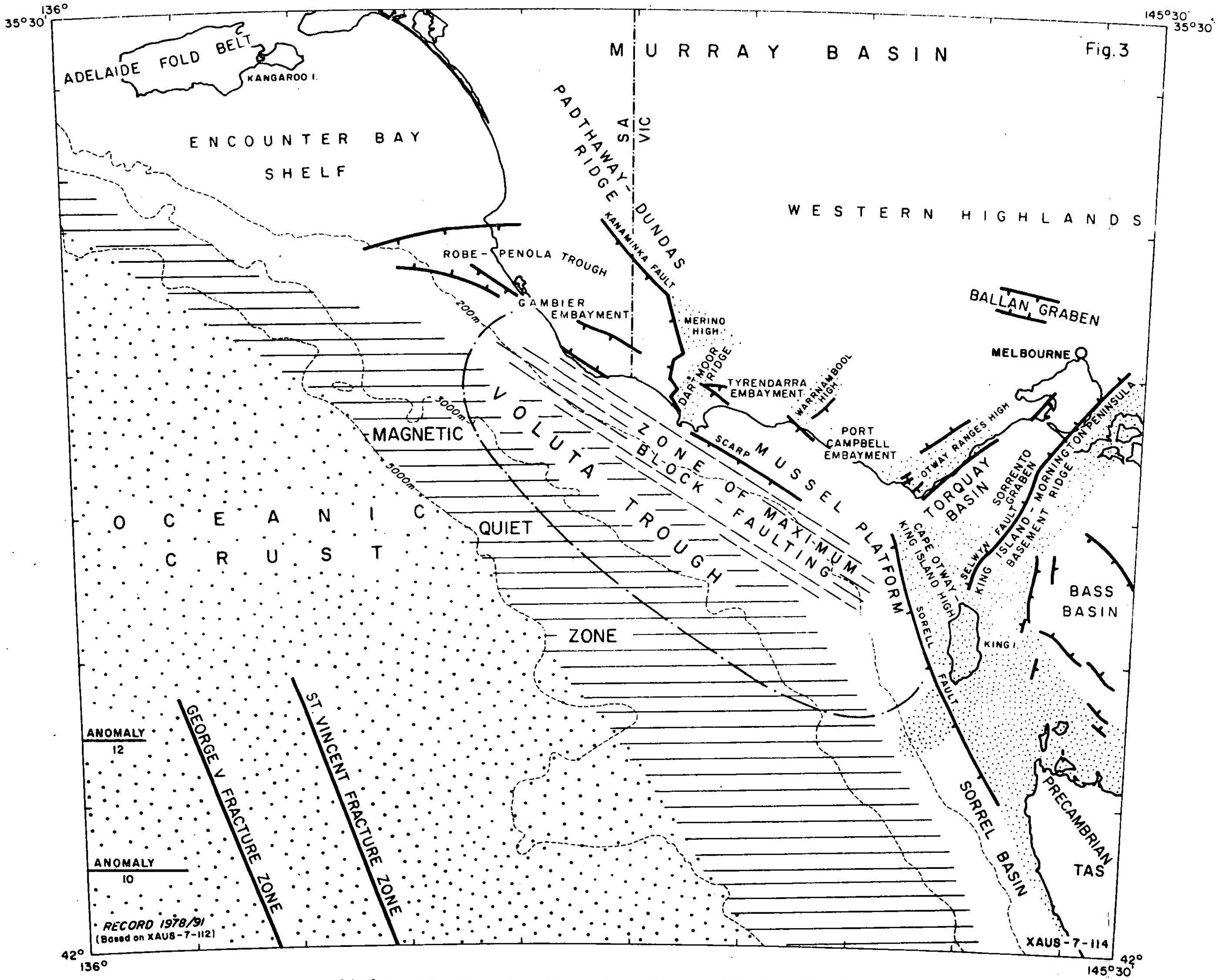
Approximate boundaries–Otway Basin and adjoining basins.

During the Middle Cretaceous, when much of Australia was covered by epeiric seas, there may well have been a marine connection from the young Indian Ocean in the west via the crustal depression across the Eucla Basin area to the Eromanga Basin in the northeast and perhaps even to the Canning Basin in the north. This time of maximum marine transgression was also the climactic stage of faulting in the taphrogen. The most marked faulting seems to have occurred near bends in the future zone of separation, such as the Duntroon Embayment west of Kangaroo Island and the Voluta Trough (Fig. 3) northwest of King Island. The main axis of the rift-valley system formed is presently indicated by the Outer Continental Margin Ridge which is a basement ridge marking the edge of the southern Australian continental margin and which today is situated approximately along the 36th parallel. Tilted fault-blocks dipped away from the rift-valley axis, the most significant being those of the Outer Continental Margin Ridge and the Great Australian Bight Ridge (Boeuf & Doust, 1975) farther north. Periodic block faulting occurred during the Middle Cretaceous, and some of the horst blocks formed at this time were extensively eroded.

During the Late Cretaceous much of the rift valley system continued to subside, with deposition of shallow-water marine sediments. However the Upper Cretaceous sequence is missing along much of the continental edge, Boeuf & Doust (1975) have interpreted this in terms of a prolonged period of uplift along the axis of the rift valley prior to continental break-up.

The separation of Australia from Antarctica was accomplished by seafloor-spreading at right angles to the presently observed east-west magnetic anomaly pattern (Weissel and Hayes, 1972) and by strike-slip faulting in the region southwest of Victoria and Tasmania. In the reconstruction of eastern Gondwanaland it is assumed that the South Tasmania Plateau was originally located as shown in Figure 1, and was left behind in its present position south of Tasmania as a micro-continent during the separation process.

The onset of continental separation can be dated by sea-floor magnetic anomalies. The oldest magnetic anomaly associated with sea-floor spreading in the Southern Ocean is anomaly 22, which is dated at 45-46 m.y. B.P. (Tarling & Mitchell, 1976). This date implies that continental break-up began in the Eocene. Anomaly 22 is presently at about 36°S on the Australian side of the spreading centre, and about 67°S on the Antarctic side. However, on the basis Brown (1975) has suggested of seismic-stratigraphic evidence that separation occurred as early as latest Cretaceous.



Major structural elements, Otway Basin Region

Major faulting ended in the early Tertiary with the onset of sea-floor spreading following break-up. Nevertheless, movement on old faults still continued while the continental margin blocks sank to their new base at about 5000 m below mean sea level.

The so-called 'basins' of southern Australia take their names from areas where the sedimentary pile attracted geologists' attention for one reason or another. They are in fact only parts of one mega-unit of deposition brought into existence by continental separation, and the value of separate basin names resides chiefly in their providing useful designations of geographic areas for discussion. Figure 7 shows total sediment thickness in the southern Australian region.

The western part of the sedimentary mega-unit is referred to as the Bremer Basin and the central part as the Great Australian Bight Basin, with extensions to the north and northeast referred to as the Eucla and St Vincent Basins. The eastern part of the sedimentary mega-unit contains; the Otway Basin which lies mainly in the Victorian corner of the southern continental margin the Torquay Basin (formerly 'Torquay Embayment') is a graben adjunct to the Otway Basin whose existence and location is probably related to the bend in the continental margin southwest of Cape Otway); the Sorell Basin (see Section 2.2) lying to the northwest and west of Tasmania; the Bass Basin located to the north of Tasmania which is unique in the region in being virtually an intra-continental basin formed by grabenoid crustal collapse along mega-lineaments, and the most easterly, Gippsland Basin which is essentially of graben type, the governing faults resulting primarily from Tasman Sea rifting, but the internal structure being effected to some degree by Southern Ocean rifting.

Figure 2 shows the approximate boundaries of the 'basins' in the region considered in this review.

<u>Sedimentation in marginal basins</u> The sedimentary record for the southern Australian marginal basins accords with a widely recognized pattern for continental margin trailing-edge basins (Falvey, 1974). This pattern may be summarised as follows (youngest sequence at top):

III Prograding regime sequence
II Syn and post-taphrogenic sequence
I Pre-taphrogenic intracratonic sequence

In southern Australia the sediments of Phase I are those laid down in the rift valley system, and, as far as they have been sampled, are characteristically fluviatile, lacustrine, or paralic. Holomarine sediments may be present in areas which are now covered by very deep water.

The sediments of Phase II are characteristically shallow-water clastics, laid down during the Late Cretaceous, but it may be noted that already by this time, oceanic conditions prevailed in the western approaches of the incipient Southern Ocean, where at DSDP Site 264 south of the Naturaliste Plateau Late Cretaceous nanno-ooze rests on oceanic crust.

The sediments of Phase III are almost universally separated from those of Phase II by the Cretaceous/Tertiary ('Danian') unconformity (Pl. 1). In the west, sedimentation is almost exclusively carbonate, and this phenomenon extends eastwards in time, reaching maximum development in the Late Miocene. Phase III is also noteworthy for the number of transgressions-regressions that took place in that time-bracket.

Basin boundaries and subdivisions

It has already been mentioned that subdivision of the sedimentary sequences on the southern Australian continental margin into discrete basins is somewhat arbitrary. In fact the term 'basin', implying in normal English usage a rounded, semi-enclosed container, is particularly inappropriate for aggregates of sediments on the southern margin, which extend outward for some 3000 km. However we follow tradition by dividing the sediments currently being reviewed into discrete 'basins'.

Three basins are recognised in the region covered by this review. The Otway Basin is by far the largest; the others are the Torquay Basin and the Sorell Basin. The term 'Otway Basin' has been in widespread use since about 1960, although its limits have not always been precisely defined. The Torquay Basin was until recently commonly referred to as the 'Torquay Embayment', a subdivision of the Otway Basin. We have followed the recent practice of the Geological Survey of Victoria in referring to it as a separate basin. We propose 'Sorell Basin' as a new name which we consider more appropriate than previous terminology for sediments west of Tasmania and which in the case of 'West Tasmania Basin' avoids possible confusion with the western portion of the Tasmania Basin onshore. Portions of the Sorell Basin have been referred to informally in the past as the 'King Island Sub-basin' and the 'West Tasmania Basin'.

The Otway Basin is a west-northwest-trending Mesozoic-Tertiary sedimentary depression which straddles the coast from Cape Jaffa in South Australia to Cape Otway in Victoria and from there extends southwards to the west of King Island. Following Wopfner & Douglas (1971), the northern limit of the basin is taken as the edge of thick (greater than 450 m) Early Cretaceous to Tertiary sedimentation. The northern boundary extends from the continental shelf-edge west of Cape Jaffa along the faulted southern margin of the Encounter Bay Shelf (Figs 2 and 3) to the coast, east along the northern margin of the Robe-Penola Trough, then east-southeast through Hamilton to Camperdown, and eastward almost to Geelong. The eastern margin is marked onshore by the Otway Ranges High, where Lower Cretaceous sediments crop out, and offshore by shallow basement in the vicinity of King Island. The southwestern margin lies offshore in deep water and is still poorly defined. In the western part of the basin there is evidence of a basement ridge more or less parallel to the shelf edge, located on the continental slope or continental rise. There may be some grounds for regarding this ridge as the southwestern margin of the Otway Basin proper, but there are sediments of considerable thickness seawards of the ridge in deep water; we leave the southwestern margin of the Otway Basin imprecise at this stage.

Onshore at least, the Otway Basin is divided into several sub-basins or 'embayments' by basement ridges over which the sedimentary sequence thins (Wopfner & Douglas, 1971). Offshore these basement ridges are of less significance and the basin sub-divisions used onshore are therefore less applicable. The part of the basin in South Australia and in the extreme western part of Victoria, west of about 141°30'S, is known as the Gambier Embayment. This is separated from the Tyrendarra Embayment to the east by the Dartmoor Ridge, which is apparently a basement ridge with positive gravity expression, and the Merino Uplift to the north of it (Fig. 3).

The Tyrendarra Embayment is partly separated on the eastern side from the Port Campbell Embayment by the Warrnambool High, a broad structurally positive area where seismic and gravity data indicate a shallower basement and a thinning of some stratigraphic units. The Port Campbell Embayment comprises the eastern portion of the basin onshore, between the Warrnambool High in the west and the Otway Ranges High in the southeast.

Offshore a deep trough of Mesozoic to Tertiary sediments, the 'Voluta Trough', extends southeast from the South Australian portion of the basin towards northwestern Tasmania (Fig. 3). This trough is fringed on its northeastern and eastern margins by a shelf area, the 'Mussel Platform' (Denham & Brown, 1976).

The Torquay Basin is a northeast-trending graben extending from near Melbourne southwest to the area offshore from Cape Otway. In the Port Phillip Bay area the graben (also known as the Port Phillip Graben or Sunkland) lies between the Selwyn Fault to the southeast and the Bellarine Fault to the northwest (Fig. 3). The main part of the basin lies between the Otway Ranges High to the northwest and the King Island-Mornington Peninsula Basement Ridge to the southeast. To the southwest the Torquay Basin is partly separated from the Otway Basin by an area of relatively shallow basement between Cape Otway and King Island.

The Sorell Basin includes Mesozoic-Tertiary (possibly Permian to Recent) sediments beneath the continental shelf, slope and rise northwest and west of Tasmania. The northern boundary of the basin is formed by the extension of the King Island-Mornington Peninsula ridge to the southwest of King Island. This basement ridge separates the Sorell Basin and the Bass Basin from the Otway Basin. Shallow basement in the area between King Island and the northwestern corner of Tasmania separates the Sorell and Bass Basins. This area of shallow basement is bounded on the southwest side by the Sorell Fault (Fig. 3). The western limits of the Sorell Basin are in deep water where the sediments have not been investigated in detail, so that the western boundary is indefinite. Similarly, the southern boundary is poorly defined. Sparse seismic data suggests that sedimentary cover on the continental shelf south of Macquarie Harbour (i.e., south of about $42^{o}30'S$) is thin, but little is known of sediments in deeper water in this area.

The Sorell Basin is divided into several small sub-basins by northwest-trending fault-bounded basement ridges. An area of relatively thick sediments on the continental shelf south of King Island, has in the past been informally referred to as the 'King Island Sub-basin' of the Otway Basin. It is useful to retain this sub-basin name, but the sub-basin now becomes part of the Sorell Basin. The other main area of thick sedimentation on the continental shelf lies to the west of Macquarie Harbour.

Stratigraphy of the Otway Basin region

The stratigraphy of the region under review is described in a number of publications, and a detailed description will not be repeated here. For a fuller description of the stratigraphy the reader is referred to Parkin (1969), (particularly) Wopfner & Douglas (1971), Reynolds (1971) and Douglas & Ferguson

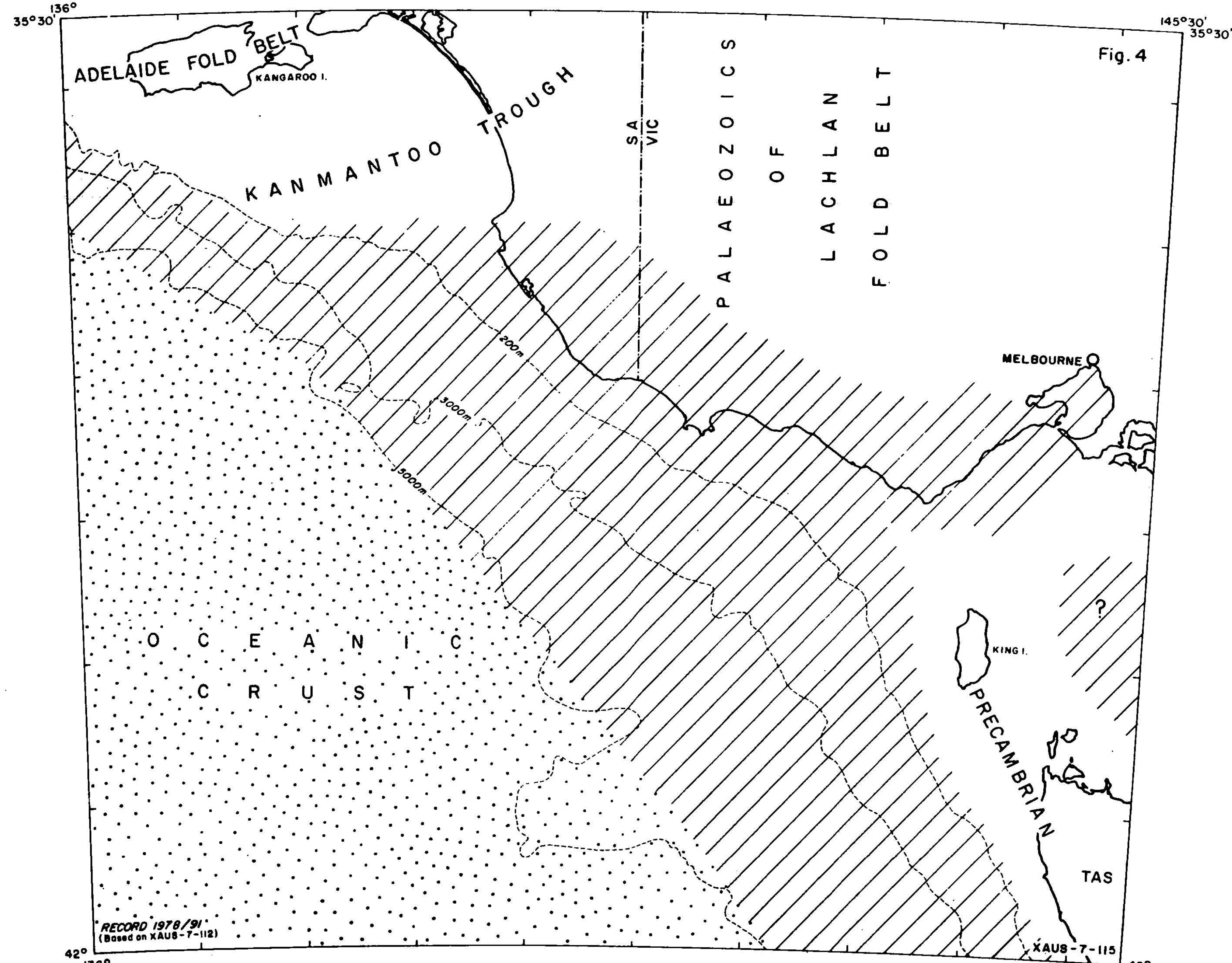
(1976). In Appendix 3 the stratigraphic sequences and lithologies penetrated in 18 wells scattered throughout the region are summarised. Plates 11 to 13 present three diagrammatic cross-sections which illustrate stratigraphic relationships in the region.

Basement in the area reviewed consists mainly of Early and Middle Palaeozoic rocks of the Lachlan Fold Belt, but in some areas - such as those near King Island and northwestern Tasmania - basement consists of Precambrian rocks.

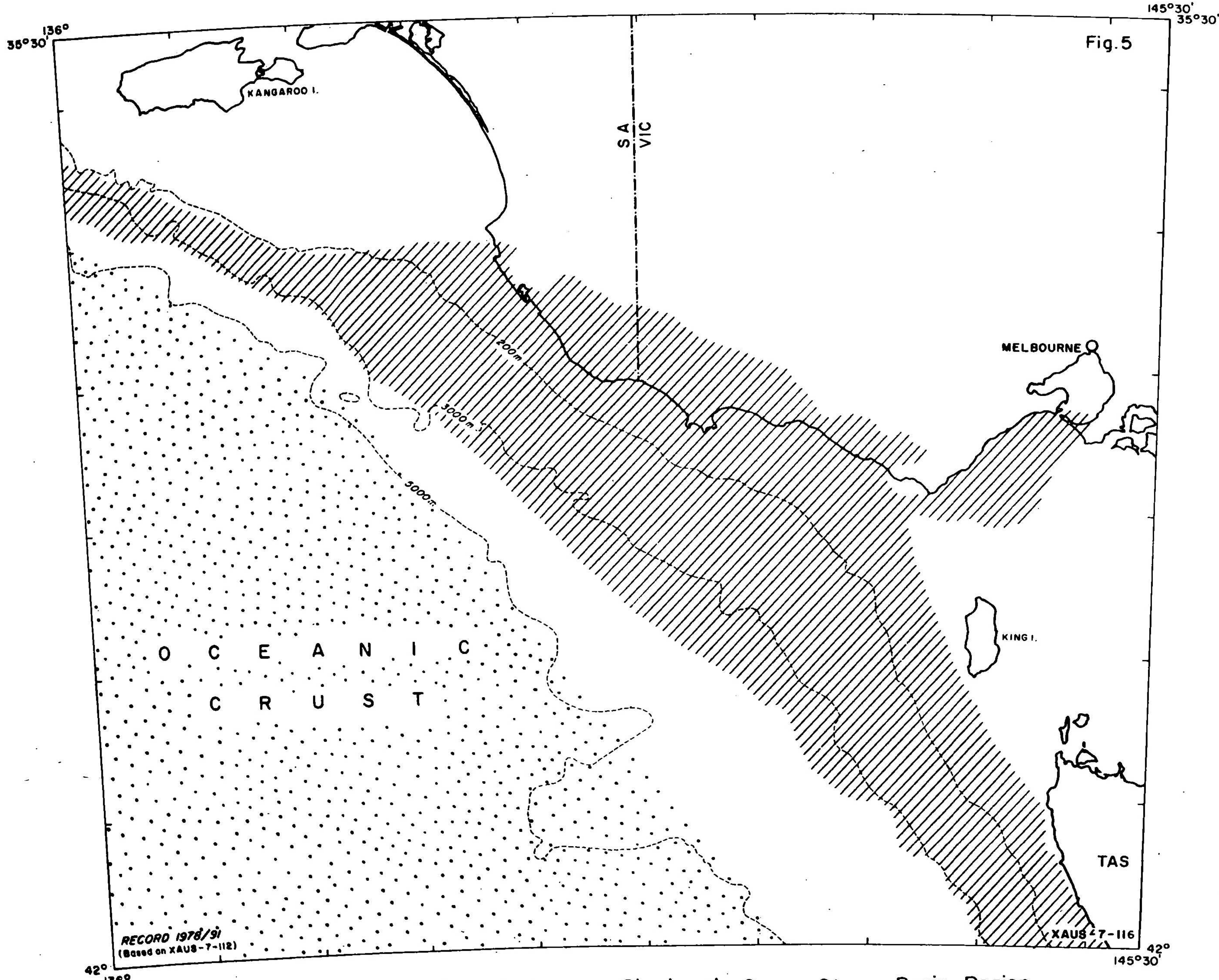
The summary given in the following pages relates the major features of the stratigraphy to the tectonic development of the region. Plate 1 summarises the comparative depositional history of the southern Australian marginal basins. Figure 7, based on seismic surveys shows in a generalised manner the total sediment thickness in the Southern Australian region.

Pre-taphrogenic, intra-cratonic trough sequence The first phase of sedimentation within the Otway and related basins is represented by the Otway Group, whose areal distribution is shown in Figure 4. Rock types range from coarse clastics to coal, with interbedded volcanics in some units and volcanic rock fragments in others. The environment of deposition was probably one of alluvial plains and freshwater lakes, with adjacent highlands on the northern (Victorian) and southern (Antarctic) flanks.

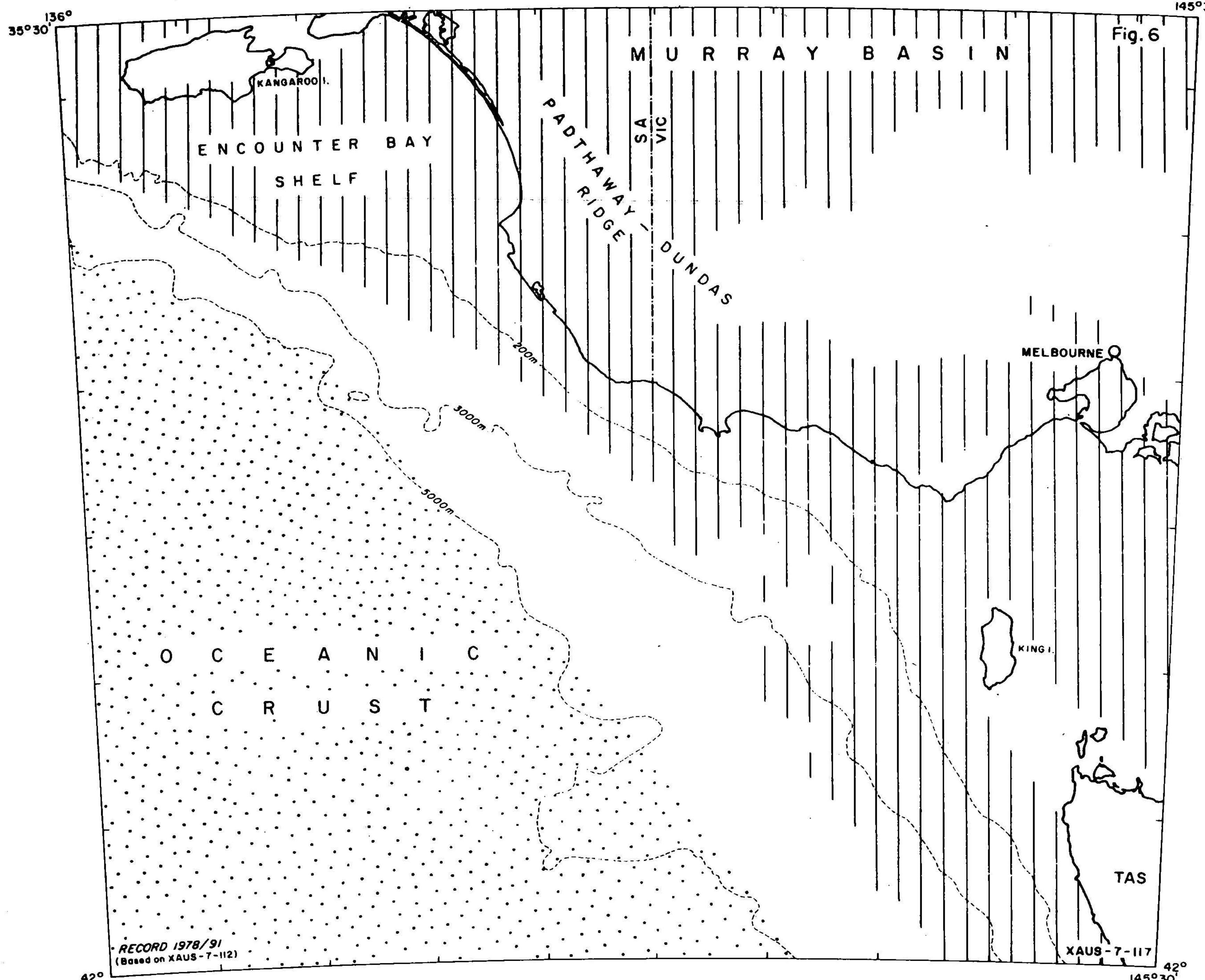
Syn and post-taphrogenic sequence Marked faulting occurred in the Middle Cretaceous, which was the climatic, pre-separation stage in the breaking apart of the Australian-Antarctic crustal plate. The Otway Group on its ancient basement was shattered into an array of fault-blocks - horsts, grabens, shelves, slopes, and scarps, and the sea inundated the depressed floor of the rift valley or syneclise which developed. The mostly Late Cretaceous Sherbrook Group consists of sediments laid down in this shallow sea. Then sediments constitute a complete transgression - regression sequence (Plate 1), with the Belfast Mudstone representing the most typical facies. On the Mussel Platform the Sherbrook sediments rest with strong unconformity on the block-faulted Otway and Palaeozoic rocks, and are less than 2000 m thick. In the Voluta Trough, however, the sediments are about 5000 m thick and in some places deposition may have been continuous, from Early to Late Cretaceous. The Sherbrook sequence thins southwards onto a basement ridge probably covered by Otway Group sediments. It seems likely that the Sherbrook Group deposition area was entirely on the Australian side of the fracture-zone along which the two continents separated.



Distribution of the Lower Cretaceous Otway Group, Otway Basin Region



Distribution of the Upper Cretaceous Sherbrook Group, Otway Basin Region



Distribution of the Tertiary, Otway Basin Region

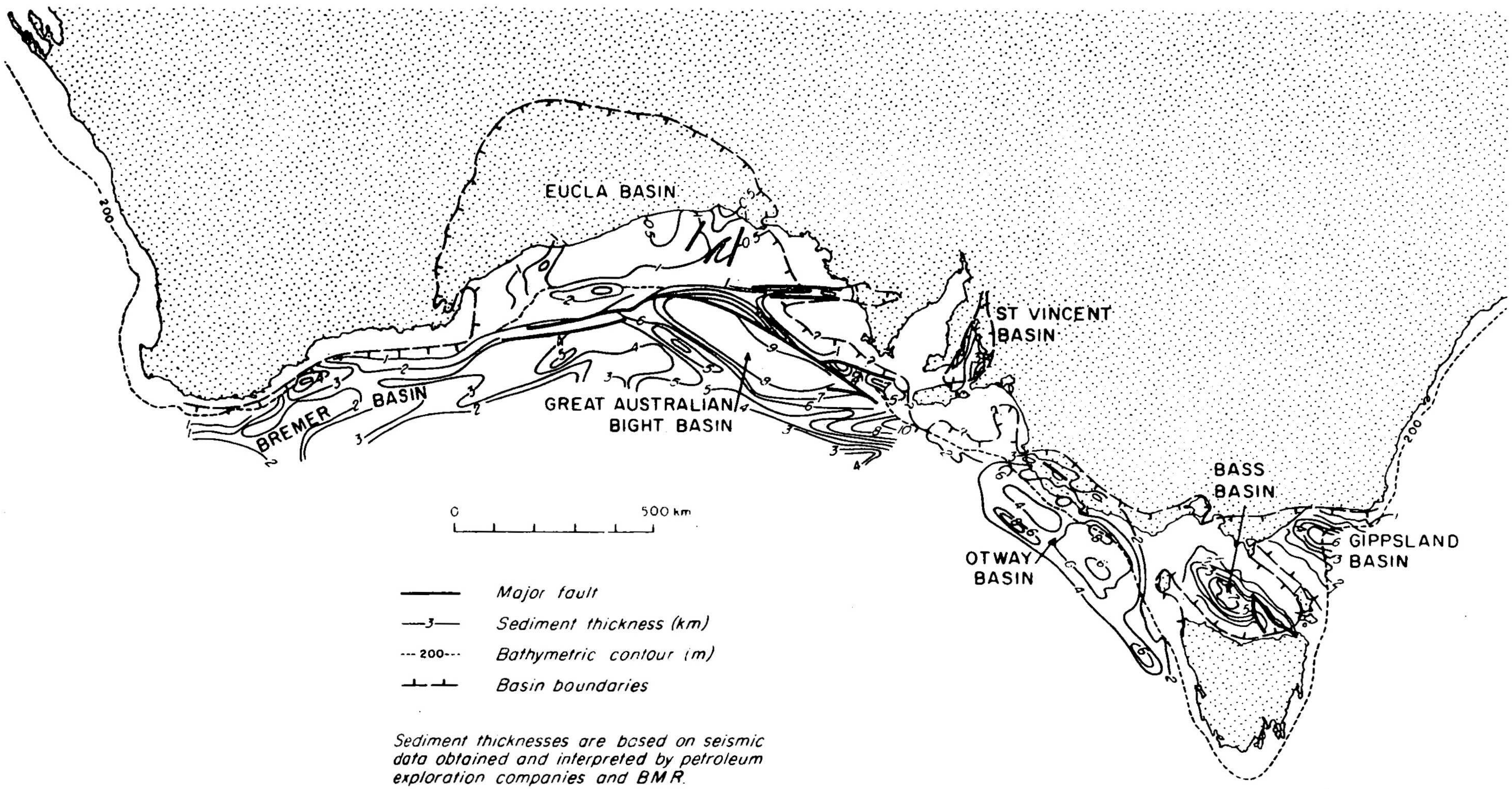


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Fig 7 Generalised total sediment thickness, southern Australian region.

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Prograding regime sequence The 30-million year Sherbrook cycle, with its syndepositional faulting and thick sedimentation, terminated at the end of the Cretaceous. A new regime of 10 million year cycles began in the Tertiary (Plate 1). The Tertiary transgressive-regressive cycles resulted in the deposition of prograding sediment wedges in a sea which was initially only a narrow gulf, but which developed through sea-floor spreading to become the Southern Ocean.

During the Tertiary the supply of clastic sediments diminished markedly and marls and limestones were commonly deposited (Pl. 1). The Tertiary sequence thins to the west and is cut by channels containing Pliocene-Recent fill. Only minor faulting is seen in the Victorian Tertiary, but faulting has been more intensive in the Tertiary of the South Australian part of the basin.

Vulcanism in the Otway Basin region Four phases of volcanic activity are distinguished in the southern Australian basins (Pl. 1) three of which are developed in the Otway Basin. These gave rise to the Dundas Volcanics, the 'Older Volcanics' and the 'Newer Volcanics'.

The Dundas Volcanics consist of basaltic varieties of lavas occurring within the Casterton Beds of western Victoria and in the Penola region of South Australia. They are of Late Jurassic/Early Cretaceous age, and 'the abundance of detritus of volcanic origin is the outstanding feature of the Eumeralla sediments' (Reynolds, 1971).

Vulcanism waned during the Middle Cretaceous, i.e. the period of major block-faulting, and almost ceased in the Late Cretaceous.

The Paleocene to Miocene Older Volcanics are found, both in outcrop and underground, in the general Bellarine Peninsula-Torquay Embayment area, whilst the Pliocene to Recent Newer Volcanics occur, almost wholly onshore, from Melbourne to Millicent. The volcanics at JOIDES Deep Sea Drilling Project (DSDP) Site 282 off the west coast of Tasmania probably belong to the Older Volcanics. Site 282 is located at $42^{o}14.76'$S and $143^{o}29.18'$E. The following table summarises the characteristics of the Older and Newer Volcanics; Figure 8 shows their distribution.

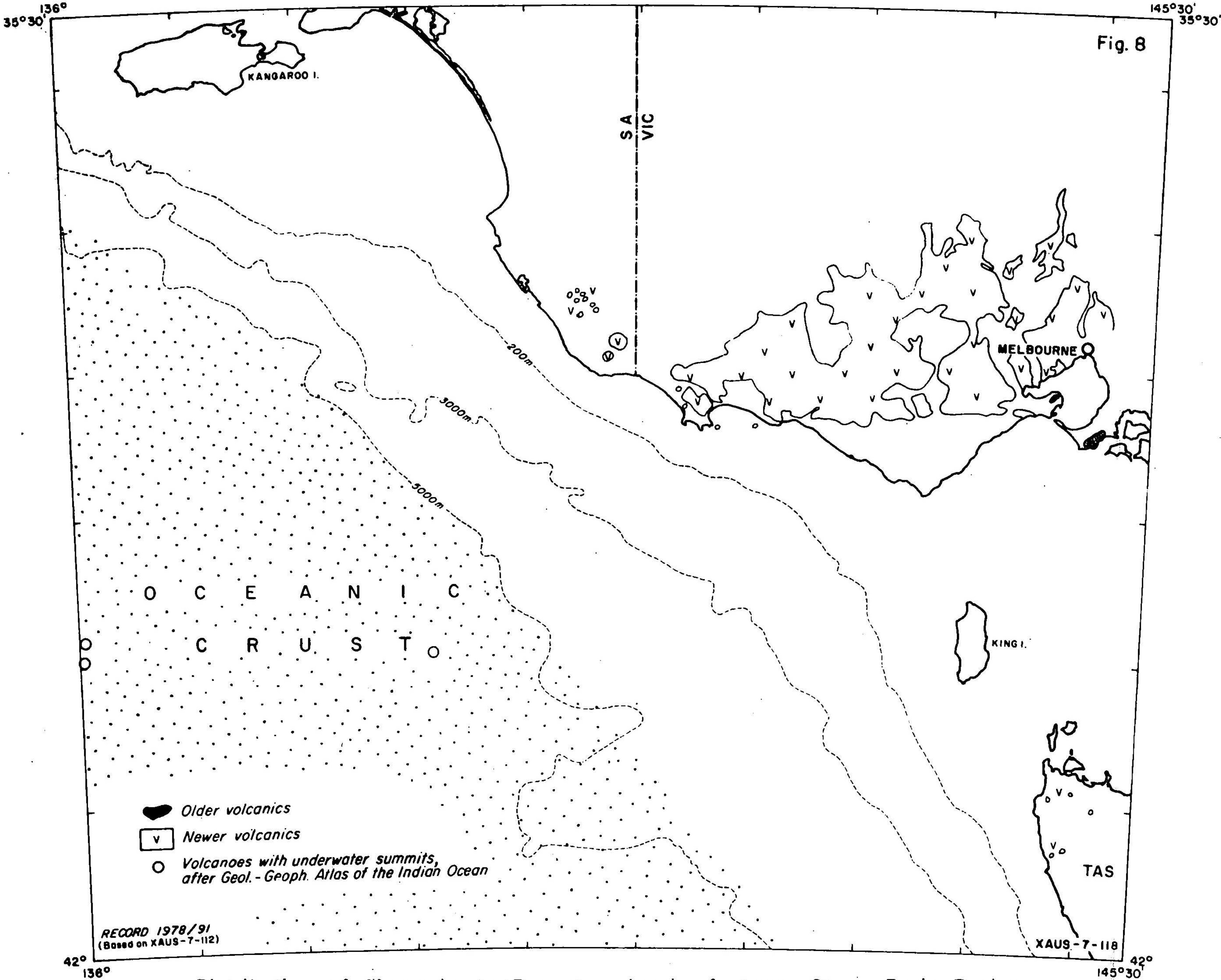
TABLE 1. COMPARISON OF OLDER AND NEWER VOLCANICS

	OLDER VOLCANICS	NEWER VOLCANICS
Parent magma	Olivine-basalt.	Olivine-tholeiite (i.e. closer to saturation than the Older basalts).
Age	Paleocene to Early Miocene	Pliocene to Recent Activity at Mount Gambier as recent as 1400 y.b.p.
Location	Occur chiefly east of Geelong.	Occur almost wholly west of Melbourne
Mode of occurrence	Usually preserved in grabens (e.g. Ballan Graben) or on uplifted and dissected blocks (e.g. in South Gippsland and Bogong High Plains).	Form an almost continuous lava field.

TABLE 1 (Cont'd)

	OLDER VOLCANICS	NEWER VOLCANICS
Feeder mechanism	Many feeder dykes exposed, but few vents remain. Dykes trend northwest.	Almost 500 vents have been recognized, mostly in Victoria. Volcanoes may overlie dykes, which trend parallel to the continental shelf.
Flow size	Most flows are less than 50 m thick, with greatest known total of 400 m.	Most flows are less than 30 m thick, with a maximum known total of 150 m. Flows are up to 65 km long.

Wellman & McDougall (1974) relate these igneous provinces to Cainozoic igneous activity in eastern Australia, and consider the likelihood that igneous activity was due to the passage of the Australian plate over a mantle plume or 'hot-spot'.



Distribution of Mesozoic to Recent volcanic features, Otway Basin Region

GEOPHYSICAL EXPLORATION

The first known geophysical exploration for petroleum in the Otway Basin consisted of a magnetometer survey on Knights Dome in south-eastern South Australia by J.M. Rayner in 1930. The dome was drilled with inconclusive results. There was little serious geophysical exploration in the basin until the 1950's, when surveys were done by the Bureau of Mineral Resources (BMR), the South Australian Department of Mines (SADM) and the Frome-Broken Hill Company Pty Ltd. The tempo of exploration, both onshore and offshore, increased in the 1960's and continued steadily into the early 1970's. In these last two decades a number of petroleum exploration companies have been involved in exploration, in addition to BMR and SADM.

By the end of 1976 there was good geophysical coverage of the whole of the basin by all three of the main methods: magnetic, gravity and seismic. Reynolds (1971) lists and discusses some of the results of geophysical surveys done up to 1965. Wopfner & Douglas (1971) gives a good summary of geophysical exploration, particularly seismic results, in the western portion of the basin up to mid-1970. Appendix 2 (of this review) contains complete lists of geophysical surveys in the Otway Basin up to 1976. Appendix 2 includes information for each survey such as the survey operator, geophysical contractor involved, the year, size of survey and the PSSA or P(SL)A reference file number (for data held by BMR), or other reference. More than 80 geophysical surveys have been done in the region.

Magnetic surveys

The locations of aeromagnetic flight lines and marine magnetic traverses are shown in Plate 3. It is evident that most of the basin has been covered fairly closely by magnetic survey lines at about 5 km spacing. Magnetic coverage at regional scale extends over the whole basin. Plate 4 shows interpreted depths to magnetic basement, based mainly on various company reports.

The earliest aeromagnetic survey in the basin was by the Zinc Corporation in 1948 over the onshore region between Portland and Cape Jaffa (Pl. 3). The South Australian portion of this region was surveyed in more detail by the South Australian Department of Mines in 1955. The SADM survey consisted of about 6400 km of traverse with a line spacing of 1.6 km. The most recent interpretation of this survey was done by Compagnie Generale de Geophysique under contract to BMR in 1964 (BMR, 1965). The survey showed sediment thickness to increase from 500 m or less in the north to more than 5000 m in the Mount Gambier area. The rapid increase in basement depth from north to south is apparently associated with fault zones trending west-northwest. In addition to magnetic basement anomalies, a number of magnetic anomalies were recognised which were interpreted to originate at shallow and intermediate depths. These were considered to be related to volcanic material, generally associated with fault zones.

Most of the offshore portion of the Otway Basin was covered by the Bass Strait-Encounter Bay aeromagnetic survey done for Hematite Exploration in 1961. This was an extensive survey, with line spacing varying from about 3 km in areas of special interest to 32 km in other areas. The results indicated that, north and northwest of Cape Jaffa, magnetic basement is relatively shallow, with depths of 1000 m or less (Pl. 4). Basement is deeper to the southeast of Kangaroo Island, where magnetic trends are approximately east-west. A small north trending graben was indicated to the southwest of Cape Jaffa. Little reliable depth information was obtained along much of the Victorian offshore area, but in the eastern offshore part of the basin a magnetic basement ridge was indicated between Mornington Peninsula and King Island. This ridge forms the boundary between the Torquay Basin and the Bass Basin in this region. To the northwest of the ridge the magnetic results indicate an indeterminately deep basement overlain by volcanics which produce shallow magnetic anomalies.

The area offshore from the west coast of Tasmania was covered by the Offshore Tasmania aeromagnetic survey done for Esso Exploration in 1966-67. Flight lines were roughly normal to the coast with a spacing of about 5 km. Indications were that magnetic basement is generally shallow near the west Tasmanian coast and that it deepens to the southwest. A northwest-trending graben, with sediments up to 3 km thick, was indicated near the coast south of Point Hibbs (Pl. 4). This graben is correlated with Lower Paleocene sediments which occur onshore to the southeast. Another possible graben trending northwest approaches the coast between Point Hibbs and Macquarie Harbour to the north. Maximum sediment thickness is similar to that in the previously-mentioned graben. The area where magnetic basement is deepest in this region is located about 60 km west of Point Hibbs. Here magnetic basement is up to 7 km deep, but unfortunately water depths in the area exceed 2000 m.

In 1968 the Young Rocks aeromagnetic survey was flown for Hematite Petroleum in the area south and southeast of Kangaroo Island. Flight-line spacing was between 3 and 6 km. The results showed that magnetic basement was at depths of less than 2000 m over most of the area surveyed, but depths of up to 4000 m were indicated at the southwestern extremity of the survey area. The results also showed a number of faults and other structural features.

The most recent aeromagnetic survey in the Otway Basin was the Portland-Geelong aeromagnetic survey done for Shell Development in 1970. This was a major survey covering almost the whole of the onshore part of the basin in Victoria and offshore areas within about 20 km of the coast. Flight lines were spaced about 5 km apart and totalled more than 8300 km in length. The survey followed a decade of seismic surveys in the area, with the objectives of obtaining an overall picture of basement topography and of elucidating the structural and stratigraphic history of sub-basins. Success in achieving these objectives varied from area to area. Anomalies arising from three different horizons were recognised. In the north and northwest of the survey area anomalies associated with surface or near-surface volcanics tended to obscure the magnetic characteristics of deeper horizons. In the south and southeast anomalies arising from intermediate depths were interpreted as representing either deeper volcanics or the top of Mesozoic sediments. Over much of the survey area it was possible to recognise longer wavelength anomalies representative of magnetic basement. The latter shows a general deepening to the south, to a maximum depth of about 4000 m. The magnetic data helped to delineate offshore extensions of major structural features such as the Dartmoor Ridge, the Tyrendarra Embayment and, possibly, the Colac Trough. A magnetic basement trough southwest of Port Phillip Bay was also indicated.

In addition to aeromagnetic surveys, a number of marine magnetic traverses have been surveyed in the offshore parts of the basin in conjunction with seismic surveys (Pl. 3 and Appendix 2). The BMR Continental Margin geophysical survey in 1972 and Shell's Deepwater Scientific survey in 1972-73 traversed the whole of the continental slope in the Otway Basin region, where there is little aeromagnetic coverage. However these surveys comprise rather widely spaced traverse lines. Little interpretation of marine magnetic data is available, but the recorded magnetic profiles are useful, particularly in conjunction with seismic sections, in recognising the presence of volcanics and shallow basement. Cameron and Pinchin (1974) have interpreted marine magnetic data off the west coast of Tasmania and Willcox (1976) has provided interpretation of BMR Continental Margin magnetic data offshore from the Gambier Embayment.

Gravity surveys

About a dozen gravity surveys of varying sizes and station spacings have been done in the Otway Basin. Plate 5 is a regional gravity anomaly map in which the onshore anomalies (Bouguer anomalies) are based on BMR's Regional Gravity Map of Australia project, while the offshore anomalies (free-air anomalies) are derived from the BMR Continental Margin Geophysical Survey. Regional gravity provinces named on Plate 5 are from Fraser's (1976) rationalisation of Australian gravity province nomenclature.

Onshore, petroleum exploration companies have covered much of the basin with fairly detailed gravity surveys directed at elucidating structural details and locating drilling targets in conjunction with seismic surveys. Plate 5 does not, therefore, reflect the large amount of detailed gravity information available onshore. Preliminary Bouguer anomaly maps of the onshore areas at 1:250 000 scale are available from BMR, and more detailed maps of some areas are available in final reports on the company surveys (Appendix 2).

Regional gravity offshore There is no detailed gravity coverage offshore, the only information available being from several regional marine surveys which included gravity readings (Appendix 2). The regional gravity picture in the offshore areas is dominanted by an intense gravity gradient, becoming more negative seawards from about the edge of the continental shelf. The landward side of this gravity gradient is marked by a chain of positive anomalies located on and close to the edge of the continental shelf, while the seaward side is marked by a similar chain of negative anomalies. These pronounced regional anomalies observed in the vicinity of the continental slope are the result of the combined effects of the rapid increase in thickness of the low-density water layer and the thinning of the crust from continental to oceanic areas, effects which are discussed by Willcox (1976). Unfortunately these regional gravity effects tend to obscure the gravity effects of near-surface geology over much of the continental shelf and slope. However, a number of basement 'highs' and depressions which are known onshore have associated gravity anomalies that extend offshore. For example, a negative gravity anomaly south-west of the entrance to Port Phillip Bay (Pl. 5) is evidently associated with an accumulation of sediments in the Torquay Basin. The positive anomaly offshore from Beachport in South Australia correlates with a known basement 'high' which extends both onshore and offshore.

Regional gravity onshore Onshore gravity surveys up to 1965 have been discussed by Bigg-Wither & Pitt in Reynolds (1971). They attempted to correlate gravity anomalies with aeromagnetic and seismic data. The Special Bulletin of the Geological Surveys of South Australia and Victoria (Wopfner & Douglas, 1971) includes a Bouguer anomaly map of most of the onshore Otway Basin (west of 144^{o}E) at a scale of 1:500 000, with 2 milligal contour intervals. In the same Bulletin J. Hall discusses the interpretation of gravity anomalies in the western Otway Basin based on information available up to about 1965. By 1965 the regional gravity features of the onshore part of the basin had been clearly defined. A number of these gravity features (or gravity units) are shown on Plate 5.

The main structural features of the onshore Otway Basin are clearly reflected by Bouguer gravity anomalies. The northern limits of the basin are marked by a series of discontinuous west-northwest-trending gravity gradients (not so evident on Plate 5 as on more detailed maps) extending from near Kingston in South Australia southeast through Hamilton. Bouguer anomalies are more positive to the north of these gradients. About 20 km north of Warrnambool the gradients turn more easterly towards Geelong and Melbourne. Bigg-Wither & Pitt suggest that the gradients may be the expression of a long, faulted zone. While this may be true, the gradients do not generally correspond to a rapid, fault-related increase in thickness of Otway Basin sediments across the zone. The gravity gradients possibly reflect the presence of faults older than the Otway Basin, which have nevertheless influenced the extent of sediments in the basin. A northeast-trending gravity gradient at the eastern edge of the basin clearly corresponds with the Selwyn Fault, which cuts the Mornington Peninsula and forms the southeastern margin of the Torquay Basin ('Port Phillip Embayment').

In the western onshore portion of the basin the gravity map is dominated by a northwesterly-trending, elongated negative gravity anomaly which extends from the South Australian coast immediately north of Robe (Pl. 5) to the vicinity of Casterton in western Victoria. This gravity 'low' is associated with the Penola Trough, a deep sedimentary trough formed by sagging of Palaeozoic basement and containing 3-4000 m of Mesozoic and Tertiary sediments (Wopfner & Douglas, 1971).

A positive gravity anomaly in the Dartmoor area of southwestern Victoria corresponds with an area of shallow basement. To the east of this, north of Portland Bay, a broad negative gravity anomaly corresponds with the thicker sedimentary section in the Tyrendarra Embayment. In fact, relatively low Bouguer anomalies extend from the Portland area 130 km along the coastal region towards Port Campbell, interrupted only by the presence of a positive gravity anomaly to the northwest of Warrnambool. Seismic surveys indicate a thinning of sediments over this feature, known as the Warrnambool High, which partially separates the Tyrendarra Embayment to the west from the Port Campbell Embayment to the east.

East of Port Campbell the gravity map shows a positive gravity anomaly trending northeast parallel to the coast northeast of Cape Otway. This anomaly clearly correlates with the Otway Ranges, a topographic expression of a positive structural unit in which Lower Cretaceous Otway Group sediments are elevated above surrounding Tertiary sediments.

To the north of the Otway Ranges, relatively low gravity anomalies east of Colac suggest the possible presence of a sedimentary depression. Correlation of a negative gravity anomaly northeast of the Otway Ranges with the Torquay Basin both onshore and offshore, has already been mentioned.

Detailed gravity surveys onshore Between 1964 and 1966 Alliance Oil Development conducted three semi-detailed gravity surveys in the southeastern part of the Gambier Embayment. These surveys involved about 1800 stations read at 0.8 km intervals along roads. The objectives were to map structure, particularly on basement, and to locate structural leads which might prove to be hydrocarbon traps. These aims were achieved only to a limited extent.

In 1968-69 a large gravity survey was done for Esso Exploration and Production in the northern portion of Gambier Embayment. Stations were again read at 0.8 km intervals along roads and tracks, the number of stations totalling more than 2000. The gravity results were useful in helping to define a number of structures in the area. These include the basement 'high' of the Padthaway Ridge in the north of the area and the Beachport 'high' in the south. Between these major structurally elevated areas gravity anomalies indicated the Penola Trough in the east (estimated depth to basement 3800 m) and the broader and deeper Robe Trough in the west, where basement depths exceeding 6000 m are indicated offshore by seismic work. Near the junction of these two troughs, two basement 'highs' indicated by previous exploration were outlined in more detail and a new 'high' was indicated. Some other structural leads were also evident from the gravity.

In 1970 Planet Exploration conducted the Casterton gravity survey on the northeast flank of the Penola Trough where it extends into Victoria. This survey consisted of about 1200 gravity stations read at 0.4 am intervals along traverses 2 km apart. The gravity results suggested that the survey was located over the Padthaway basement ridge, which is probably intersected in the area by a series of north-trending faults. As a result of the gravity survey three rather shallow basement 'highs', suitable for more detailed seismic investigation, were indicated.

In the Victorian part of the onshore Otway Basin (excluding the Gambier Embayment) the most important gravity surveys were by Shell Development between the years 1968 to 1971. In this period Shell conducted three major surveys totalling more than 7400 gravity stations read at 0.8 km intervals on surveyed traverses or on roads and tracks. About half the onshore area of the basin in Victoria was covered by these surveys, from Portland in the west to Geelong in the east.

The aims of the surveys were principally to outline basement fault blocks with the gravity method as a prelude to detailed mapping of fault traps by seismic means. The surveys provided some useful indications of structural trends and basement structure, but in many areas the structure, particularly faulting, and variations in basement composition proved too complex to allow reliable gravity interpretation. The last survey, the Colac-Geelong gravity survey in 1971, suggested the presence of a sediment-filled depression east of Colac, with a maximum sediment thickness of about 3500 m southeast of that town to the north of a major fault with 2000 m throw on the north flank of the Otway Ranges. Three local gravity maxima in the Colac-Gellibrand area were interpreted as representing elevated basement blocks.

Seismic surveys

The extent of seismic coverage in the Otway Basin is illustrated by the seismic line location maps in Plates 6 and 7. Seismic coverage onshore is rather patchy, but there is moderately dense coverage in the areas where sedimentary rock thicknesses are greatest. However, much of the earlier seismic information is of poor quality. Offshore there is fairly dense seismic coverage of most of the continental shelf, with line spacing varying from about 2 to 10 km. More sparse regional coverage extends over the continental slope.

Plates 8 to 10 present regional seismic depth contours for various horizons. These maps are not accurate in detail, but they do serve to illustrate the gross structure of the region at several levels, and to indicate approximate depths at which particular horizons occur. Plate 8 is a composite map showing contours on the deepest mappable horizons in various areas. Plate 9 shows contours at or near the base of the Sherbrook Group, while Plate 10 shows contours on the base of the Tertiary sediments.

Onshore surveys The earliest seismic survey in the Otway Basin was an experimental seismic survey done by BMR in 1956 at the request of Frome-Broken Hill Pty Ltd near Heywood in the Tyrendarra Embayment. The objective of the survey was to test the applicability of the seismic method, particularly on basalt-covered areas. It was shown that even the simple techniques available at that time were effective in mapping sediments to a depth of 3000 m in non-basalt areas and that, with difficulty, some results could be obtained on the basalt.

Seismic surveys in the Otway Basin up to 1965 are discussed in BMR (1966). They re-interpreted most of the available seismic data and prepared seismic reflection-time contour maps and isochron maps based on three horizons, the deepest of which is considered to represent the base of the Sherbrook Group (Reynolds, 1971). More than a dozen exploration company surveys had been done up to 1965.

The quality of the reflection data from these early onshore surveys was at best only fair. In the western part of the Otway Basin difficult surface conditions usually gave poor results. In 1965 and 1966 BMR did experimental surveys designed to determine the best and most economical techniques for use in the main problem areas, which were areas of volcanic cover in southwest Victoria and areas of Gambier Limestone cover, sand-dune cover and an interdunal poor-reflection area in southeast South Australia. The 'Vibroseis' method and conventional shothole methods were tried for comparison. The results are described by Schwing & Moss (1974).

Rochow, in Wopfner & Douglas (1971) discusses in some detail the results of seismic surveys, both onshore and offshore, in the Gambier Embayment up to about 1965. In that publication he provides a fence diagram of the Embayment based on seismic sections, a time contour map of the base of the Otway Group, depth contour maps on the base of the Gambier Limestone and the Lower Tertiary, and an isopach map of the Lower Tertiary sediments.

Up to 1967 reflection-seismic surveys in the Gambier Embayment used the single coverage technique; results were generally poor, particularly on the deeper horizons. From 1967 onwards Alliance Oil, Planet Exploration, Esso Exploration and Shell Development have explored the sub-basin with multiple coverage (CDP) techniques involving 3 to 24- fold coverage and using weight-drop and 'Vibroseis' energy sources in addition to explosives in shotholes. Data quality varied from poor to good, the quality being generally proportional to the degree of multiplicity used to attenuate seismic noise.

The major seismic surveys in the onshore Gambier Embayment since 1965 were two surveys done for Esso in 1969 and 1971, which totalled 451 km of mainly 6 to 12-fold coverage; and the Tartwaup seismic survey for Alliance in 1973-74, which involved 308 km of 12- and 24-fold seismic-reflection traverses. The Esso surveys were located in the northern part of the Embayment, the Alliance survey in the southeast.

The objectives of the Esso surveys were to investigate a number of positive gravity anomalies believed to be associated with structurally elevated fault blocks. In particular, they were aimed at mapping the Pretty Hill Sandstone, which was known from the Crayfish No. 1 well offshore to the west as a possible reservoir formation. The seismic work confirmed that the gravity anomalies were associated with Early Cretaceous faulting, which had resulted in the formation of a number of basement 'highs'. The Pretty Hill Sandstone was indicated to thin abruptly over the basement 'highs' or to wedge out against the 'highs'. Esso drilled several of the structures in 1969 without success. The seismic data showed that pre-Mesozoic basement depth varied between 700 m in the northeast and about 5000 m near the coast to the west.

The Tartwaup seismic survey involved the use of a 'Vibroseis' energy source and began with field experiments to determine the most suitable technique for use in the survey area, which was known to be a poor record area. The objective of the survey was to investigate structure at the level of the Waarre Formation at the base of the Sherbrook Group. The quality of the data obtained was poor to fair. The data were fairly reliable at the base of Tertiary level, but less so at the base of Sherbrook level. The survey indicated the existence of a number of east-southeast-trending faults downthrown to the south, with sediments mainly dipping northwards from the coast. A large east-trending anticline with two separate, closed culminations was mapped a few miles northwest of Mount Gambier, and several minor structural leads were indicated.

In the area of the Dartmoor Ridge Planet Exploration and Alliance Oil conducted a number of small surveys up to 1970. Seismic results confirmed relatively shallow basement. In 1972 Shell Development carried out the Dartmoor seismic survey, consisting of 217 km of 12-fold CDP coverage, to establish regional control over the Dartmoor Ridge. Generally poor results showed the area to be complexly faulted. One of two major faults mapped was associated with the Dartmoor gravity ridge. It was difficult to map structure reliably beneath the base of Tertiary, but mapped structure at this level tended to reflect structure on Upper Cretaceous hydrocarbon objective horizons. Some structural leads were indicated at the base of Tertiary level.

In the Tyrendarra and Port Campbell Embayments and the intervening area all of the onshore seismic surveys since 1965 have been done for Shell Development. From 1966 to 1973 Shell conducted 8 seismic surveys totalling more than 2000 km of traverses involving mainly 6 or 12-fold CDP coverage and using either explosives, 'Vibroseis', or weight drops as energy source.

The objectives of these Shell surveys were normally to extend seismic rbconnaissance coverage and to detail structural leads indicated by gravity or earlier seismic surveys. The quality of seismic data obtained varied from poor to good, depending on the surface conditions, the depth of the target horizons and the techniques used. As may be expected, quality of the later surveys shows a general improvement over the earlier ones. The seismic horizons mapped varied from survey to survey, depending mainly on the thickness of the sedimentary sequence investigated. Where the latter was of moderate thickness it was sometimes possible to map pre-Mesozoic basement - although usually not very reliably; in some cases the Pretty Hill Sandstone, near the base of the Lower Cretaceous Otway Group, was also mapped. Other horizons mapped by seismic means were intra-Eumeralla Formation horizons, horizons near the top of the Otway Group or base of the Upper Cretaceous Sherbrook Group, base of the Paleocene Wangerip Group, and base of the Oligocene-Miocene Heytesbury Group. Most, if not all, of the structures mapped as possible hydrocarbon traps depended at least partly on faulting for closure. Much of the area investigated by Shell is complexly faulted. The faulting makes seismic interpretation difficult in many cases. However, many fault-controlled structures have been mapped; a number have been drilled, without success.

The Torquay Basin has little onshore extent; only three land seismic surveys have been carried out. The Torquay seismic survey was done for Oil Development near the coast southwest of Torquay (Pl. 6) in 1960. Data quality was poor, but in the west of the survey area reflections from as deep as 1500 m indicated strata dipping to the south-southwest. These reflections evidently represent Lower Cretaceous sediments. In 1967 BMR carried out the East Otway Basin seismic survey (Branson & Mathur, 1974) to investigate the structure and thickness of sediments in areas of low Bouguer gravity anomalies east of Geelong and near the entrance to Port Phillip Bay. Like the previous survey, this survey involved use of a single coverage reflection technique and the results were poor below the thin Tertiary section. However, the results indicated the presence of thicker sediments in the gravity 'low' areas than in the adjacent areas of positive gravity anomalies. The most recent seismic survey in the onshore Torquay Basin was the Paraparap seismic survey made for Pursuit Oil northwest of Torquay in 1972. This survey indicated the presence of a south-plunging anticline at Lower Cretaceous level with possible closure provided by an east-west fault.

Offshore surveys The first marine seismic survey made in Australian waters was carried out by Geophysical Services International for Frome-Broken Hill Company Pty Ltd in 1961. This survey employed a 'Sonoprobe' gas-gun energy source, and consisted of 314 km of seismic lines close to the coast west of Port Campbell to investigate closure on a structure which had been partly mapped onshore. Altogether there have been about 30 offshore seismic surveys in the Otway Basin since 1961, and the results of all but a few of these are available to the public.

As already mentioned (Rochow, in Wopfner & Douglas, 1971) the results of offshore seismic surveys in the Gambier Embayment up to about 1965 had established some of the main features of the sedimentary sequences offshore. Basement was shown to be shallow in the areas to the north and west of Cape Jaffa. The northern limit of the Otway Group sediments in the Gambier Embayment coincided with a major fault or hinge-line extending in an east-west direction both onshore and offshore about five miles south of Cape Jaffa, corresponding to the southern margin of the Padthaway Ridge. The Robe-Penola Trough, immediately south of the Padthaway Ridge was a depressed area in the Early Cretaceous which received a considerable thickness of Otway Group sediments. The southern part of this depressed area was uplifted and eroded in the Early Cretaceous to form the Kalangadoo - Beachport 'high', a broad synclinal structure was preserved as the Robe-Penola Trough. A further downwarp to the south took place in the Early Cretaceous. This resulted in some sedimentation on the shelf area which had developed over the Robe-Penola Trough, but the maximum downwarp occurred south of a new fault zone or hinge-line near the southern edge of the Robe-Penola Trough. South of this hinge-line a large thickness of Upper Cretaceous sediments accumulated.

In the years 1966-69 Esso Exploration conducted five seismic surveys in the offshore Otway Basin region. Most of these ranged over the whole of the region from South Australian waters to Tasmanian waters and included the Gambier Embayment. One small survey (Otway EU-68) was confined to an area near the coast in the Gambier Embayment. The surveys involved 6 or 12-fold multiple-coverage techniques with explosives or 'Aquapulse' (propane and oxygen in rubber explosion chamber) used as the energy source. Data quality varied from poor to good. The surveys were done to extend seismic reconnaissance coverage over the region and to detail structural or stratigraphic leads as prospective drilling targets. Complex faulting in the Cretaceous sediments made reliable seismic mapping difficult, particularly on the earlier surveys. A number of potential hydrocarbon traps were outlined, and some of them drilled without success.

In 1970 Hematite Petroleum conducted a reconnaissance survey over the edge of the continental shelf at the northwest end of the Otway Basin southeast of Kangaroo Island (Baudin seismic and magnetic survey). Results were disappointing since the survey failed to find prospective thicknesses of sediments in areas with reasonable water depths.

In 1972 and 1973 three seismic surveys were done for Esso in the northern, offshore part of the Gambier Embayment. These surveys, totalling about 950 km, used airguns as energy source with 24-fold and 48-fold coverage. Data quality was fair to good. The surveys aimed to detail structures in two areas. On the shelf area north of Crayfish No. 1 Upper Cretaceous sediments are thin and the Lower Cretaceous Pretty Hill Sandstone was the main hydrocarbon objective. The second area investigated was about 40 km southwest of Crayfish. Here the Otway Group is much deeper, and seismic horizons near the top of the Otway show much faulting, down to seaward with east-southeasterly trends. Hydrocarbon objectives in this area were Waarre Formation and Paaratte Formation sands. All of the prospects mapped during these surveys depended on faulting for closure. Two of the prospects were tested, by Trumpet No. 1 and Morum No. 1 wells.

Seismic exploration in the Offshore Otway Basin in Victorian waters has proceeded more or less independently in two areas. Most surveys in a near-shore strip within about 25 km of the coast have been made for Shell Development and Interstate Oil, while surveys over the remainder of the Victorian continental shelf have been done with either Esso Exploration or Hematite Petroleum as operator. It is convenient to consider the two areas separately.

The biggest seismic survey in the near-shore area was the Otway Basin marine seismic survey (1770 km), for Shell in 1966. A follow-up survey was done the same year to provide more detail on areas of particular interest, and a small refraction seismic survey was done in 1967. Data provided by these surveys was of fairly poor quality, generally inadequate for reliably mapping structures within the Cretaceous. Nevertheless some prospects were indicated. The Pecten and Voluta prospects were tested by drilling, but without success.

No further seismic work was done in the near-shore area until late 1973 when Interstate Oil conducted a survey of 408 km aimed at obtaining improved data to define structure within the Otway Group east of Warrnambool. The quality of data obtained was much improved over that of earlier surveys and it was possible to map structure down to an horizon in the lower part of the Otway Group. Two prospects were indicated in the offshore part of the Port Campbell Embayment. Another seismic survey, to investigate structures in this area in more detail, was done for Interstate Oil in 1975. Seismic interval velocities for the Otway Group in this area are high and lend doubt as to the reservoir qualities of the Pretty Hill Sandstone, if present, in the area. The Waarre Sandstone could be a possible reservoir target.

A good review of seismic exploration in the offshore part of the Otway Basin explored by Esso and Hematite is given by Denham and Brown (1976). Although much marine seismic work had been done in the area prior to 1972, Hematite Petroleum decided that little of that work was of sufficiently good quality to allow proper evaluation of the basin. That company therefore undertook three seismic surveys in 1972, 1973 and 1974 using the best seismic technology available to provide a network of modern survey lines. These surveys totalled more than 4500 km of 24-fold to 72-fold CDP data, which showed considerable improvement in quality over previously obtained data. Some refraction lines were also shot to assist in the recognition of the top of the Otway Group.

Seismic reflection record quality from these surveys in 1972-74 was good down to the base of the Tertiary. The Tertiary sediments show extensive foreset bedding, the foreset wedges becoming younger seawards. Dip is invariably seawards and there are no indications of closed Tertiary structures or stratigraphic traps. There is generally an obvious difference in dip marking the unconformity between the Tertiary and the top of the Sherbrook Group. Seismic reflection quality deteriorates considerably beneath this unconformity, particularly in the 'Voluta Trough', where the Sherbrook Group is up to 4500 m or more in thickness. The unconformity with the Otway Group is not always very apparent on reflection sections, except on the 'Mussel Platform'. The latter occupies the northeastern and eastern margins of the basin and is separated from the 'Voluta Trough' by faulting. In the deeper part of the basin, where there are no wells extending to the Otway Group, the top of the Otway Group has been identified by refraction probes, which record an increase in velocity of about 600 m/s to a fairly uniform 4600 m/s (Denham and Brown, 1976). Most of the Cretaceous section is extensively faulted on the 'Mussel Platform'. Reliable seismic mapping of structures within the Cretaceous is made difficult by the structural complexity, the presence of multiples from Tertiary reflectors and generally poor reflection quality.

The offshore portion of the Torquay Basin has been fairly extensively explored since the first reconnaissance seismic surveys in the area for Hematite in 1962 and 1964 confirmed the presence of considerable thicknesses of sediments. Shell's surveys in 1966, which introduced digital recording and processing of 6-fold CDP data, provided further control on the northern and western flanks of the basin. As a result of this work Nerita No. 1 well was drilled. This provided stratigraphic control for the seismic data and suggested that the top of the Otway Group represented economic basement in that area.

Between 1966 and 1968 Esso carried out three marine seismic surveys which covered the southern flank of the embayment and outlined the Snail prospect. The Torquay Embayment seismic survey was done for Hematite in 1971-72 to extend reconnaissance cover and to map prospective structures prior to drilling a well. This survey employed airguns as energy source and 24-fold CDP cover. Reflection quality was fairly good over most of the area and the results were integrated in the final report with those from earlier surveys by Hematite, Shell and Esso. Two horizons were mapped, one within the Torquay Group and the other corresponding to the top of the Eastern View Coal Measures. The results showed the Eastern View Coal Measures to range in depth from about 600 m round the margins of the embayment to about 1400 m at its centre. A number of structural prospects were indicated. Of these only the Snail prospect has been drilled.

The southwestern margin of the Torquay Basin was further explored in 1973 by Interstate Oil in their Cape Otway survey. Data quality was good to the base of the Tertiary. A probably fault-controlled north-northeast-trending trough was indicated on the eastern side of Cape Otway. Tertiary sediments within the trough have a maximum thickness of about 1400 m.

The Sorell Basin has been covered by a network of reconnaissance seismic lines which give a broad outline of sediments northwest and west of Tasmania. Hematite's Cape Grim to Cape Jaffa seismic survey in 1964-65 was the first to extend reconnaissance lines into area. Two surveys by Esso in 1966 and 1967 included a number of seismic lines south of King Island which indicated the presence of a sub-basin south of King Island ('King Island Sub-basin'), which opened seawards to the southwest. Some 1500 m of Tertiary sediments were indicated, and also some pre-Tertiary section, but the latter was difficult to map because of poor data.

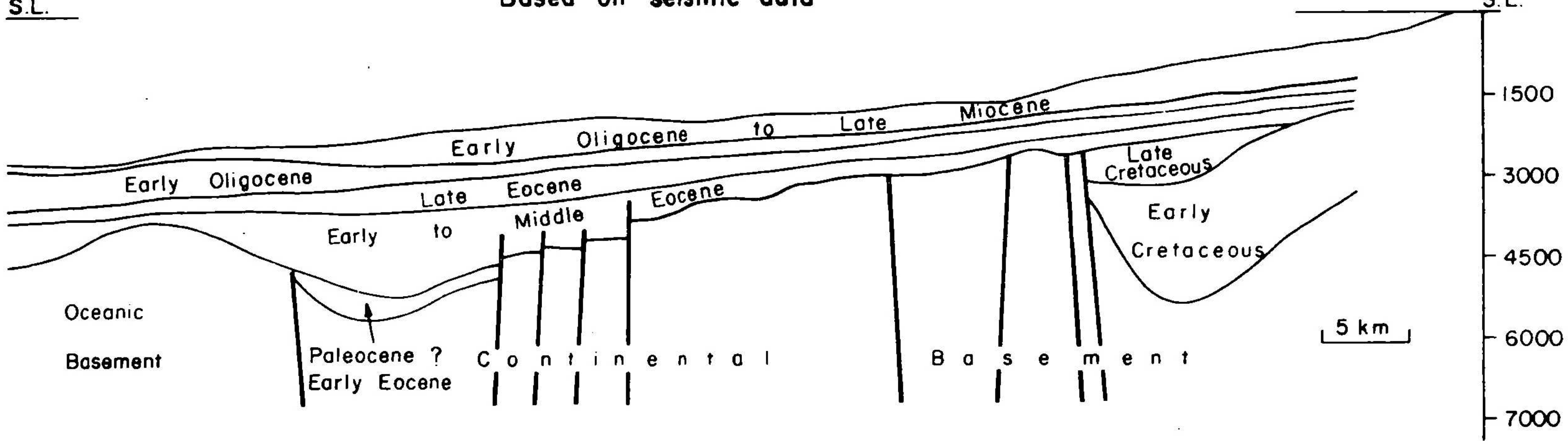
In 1969 Magellan Petroleum surveyed a number of single-fold sparker reconnaissance seismic lines across the outer margin of the continental shelf and the continental slope northwest of Tasmania, mostly in deep water. Seismic data quality was poor, particularly below the Tertiary.

From 1968 to 1971 Esso conducted four seismic surveys totalling about 1700 km on the continental shelf off western and southwestern Tasmania. The surveys employed 'Aquapulse' and airgun energy sources mostly with 12-fold CDP coverage. Some stratigraphic control for the seismic work was provided by Esso's Clam No. 1 well offshore from the northwestern corner of Tasmania, which was completed as a dry hole in 1969. This well reached a total depth of 1622 m in metamorphic rocks. The seismic surveys indicated that basement is generally shallow over the continental shelf south of Macquarie Harbour and in an area about 70 km north of Macquarie Harbour. Sediments are thickest in the areas north and east of Clam No. 1 in the north and in the offshore extension of the Macquarie Harbour Graben. In the latter area there are indications of up to 4300 m of sediments, possibly including Cretaceous and Permo-Triassic sediments as well as Tertiary. Some potential traps have been mapped.

Fig. 9

SORELL BASIN CROSS-SECTION AT APPROX. LAT. 42° S

Based on seismic data



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The continental slope in the Otway Basin region has been fairly sparsely covered by the BMR Continental Margin geophysical survey in 1972 and the Shell Deepwater Scientific survey in 1973. The BMR survey consisted of parallel traverses generally about 40 km apart extending over the whole of the continental shelf and the continental slope to water depths of about 4000 m. The Shell survey involved zig-zag lines over the continental slope and continental rise, the ends of the grid being about 150 km apart. Both surveys included gravity, magnetic and seismic measurements.

The BMR survey used a 120 kJ sparker seismic energy source and both single-channel and six-channel seismic cables. Single-channel shipboard monitor seismic sections were made. The shooting configuration will permit 6-fold CDP stacking of the data recorded on magnetic tape at a later date if required. The quality of the single-fold sparker sections is mostly poor and the base of sediments is generally unrecognisable. A regional unconformity, probably between Upper Cretaceous and Eocene, can be traced over a large part of the continental slope (Cameron and Pinchin, 1974; Willcox, in prep.).

The Shell Deepwater Scientific survey employed an airgun energy source in conjunction with a 24-fold CDP coverage. The processed sections from this survey are of fairly good quality and show a maximum penetration of several seconds reflection time below sea bottom. The survey results are discussed by Boeuf and Doust (1975). They provide new information on the transitional zone between the continental shelf and the adjacent oceanic areas. On the continental slope Tertiary sediments generally dip seaward whereas underlying faulted and eroded Cretaceous sediments dip landwards in some areas. In the vicinity of the lower slope or continental rise a basement ridge separates the sedimentary depocentre in deep water from the Otway Basin proper to the north. Considerable thicknesses of Tertiary and Cretaceous sediments are indicated in deep water areas.

PETROLEUM POTENTIAL

History of petroleum exploration

The history of petroleum exploration in the Otway Basin has been discussed in considerable detail in Wopfner and Douglas (1971) and is summarised by Leslie (1966), Reynolds (1971), and more recently by Ellenor (1976). These references form the basis for the following account.

Interest in oil exploration was aroused in the Otway Basin in the last quarter of the 19th century following reports of stranded bitumen along the coast and numerous oil seepages. A number of shallow wells were subsequently drilled at randomly selected sites since the poor outcrop in the basin hampered early attempts to evaluate the structure of the subsurface. Few of these wells penetrated the Tertiary sediments to any significant depth. The first comparatively deep holes to be drilled in the basin were two water bores, Portland No. 1 and Bolwarra No. 1, which reached depths of 690 m and 459 m respectively in Tertiary sediments; both bores were drilled by the Victorian Mines Department in 1894 as part of a coal search program.

South Australian Oil Wells Company drilled the first oil exploration well in the Otway Basin in 1915. The well, Robe No. 1, tested a Pleistocene aeolianite dune ridge thought to represent an anticline. It reached a depth of 1373 m after penetrating for the first time a thick section of Lower Cretaceous sediments beneath the Tertiary. Following this, several exploratory wells were drilled by a number of companies up until World War Two. Few of the wells penetrated the Tertiary sediments to any significant depth and all were abandoned within the Tertiary Knight Group without encountering any significant shows of hydrocarbons. Their general lack of success may be partly attributed to the fact that there was often little basis for the selection of drilling sites.

The discovery of oil at Rough Range in Western Australia caused a renewal of interest in the Otway Basin's hydrocarbon potential. The potential was further increased in 1959 by the discovery of a previously unknown marine Upper Cretaceous sub-surface section (Kenley, 1959) in the Belfast No. 4 Bore (drilled for water by the Victorian Department of Mines) west of Warrnambool, Victoria. In the same year Frome-Broken Hill drilled Port Campbell No. 1 which encountered significant but uneconomic flows of wet gas in the Waarre Sandstone (from 1724 m to 1728 m). This discovery initiated the exploratory phase which has prevailed until recently and also lead to comprehensive geological studies being undertaken by the Geological Surveys of South Australia and Victoria, as well as BMR. During this latest phase of petroleum exploration no commercial hydrocarbon discoveries were made although many small shows have been recorded.

Appendix 1 lists the petroleum exploration wells in the Otway Basin region, showing operators, locations, total depths, and other information.

Oil and gas occurrences

Of more than 100 wells drilled in the Otway Basin region only a minority have had any petroleum shows of noteworthy extent. These wells are listed in the following table.

TABLE 2. WELLS IN WHICH GAS OR OIL SHOWS WERE RECORDED

COMPANY	WELL	YIELD
Alliance	Caroline No. 1	Carbon dioxide, yielding 2280 Mcf/D, stabilising to 2495 Mcf/D, from the Waarre Fm
	Kalangadoo No. 1	2.68 MM cf/D, CO_2 waning
	Robertson No. 1	very gassy salt water
Amalgamated	Blackford No. 1	minor gas
	Murrabinna No. 1	"
Beach Petroleum	Geltwood Beach No. 1	slight gas cut of methane, ethane, and propane
Esso	Crayfish No. 1	minor gas (95% methane) in Pretty Hill Sst.
	Lake Eliza No. 1	gassy salt water in Pretty Hill Sst. 99% methane
	Lake Eliza No. 2	ditto
Frome-Broken Hill	Eumeralla No. 1	trace of oil and gas, from Otway Group
	Ferguson's Hill No. 1	7-10 Mcf/D of methane and ethane, from upper Otway Group
	Flaxman's No. 1	Paaratte Fm, gas-cut salt water (methane, ethane and nitrogen)

TABLE 2. WELLS IN WHICH GAS OR OIL SHOWS WERE RECORDED

COMPANY	WELL	YIELD
		Waarre Fm, very small gas flow, and gas-cut salt water (methane and ethane)
		upper Otway Group, gas-cut salt-water
		Otway Group 250 Mcf/D (max.), waning + small quantity 51.2^{o} A.P.I. condensate
Frome-Broken Hill	Port Campbell No. 1	Waxy oil from the Paaratte Fm, and gas, initially at 4.2 MMcf/D, from the Waarre Fm (methane 72.5%; ethane 5.5%; CO_2 14.2%) + 6 bbls/D 65^{o} API condensate
	Port Campbell No. 2	Gas from the Waarre Fm
	Port Campbell No. 3	flowed gas from the Paaratte and Waarre Fms
	Port Campbell No. 4	Gas initially at 219 Mcf/D (methane 82.2%, ethane 6.6%) from the Eumer-alla Fm + 5 bbls/d 38.2^{o} API oil
	Sherbrook No. 1	gas traces in the Otway Group
Interstate	Garvoc No. 1	salt water with CO_2 and oil trace from Pretty Hill Sst

TABLE 2. WELLS IN WHICH GAS OR OIL SHOWS WERE RECORDED

COMPANY	WELL	YIELD
	Woolsthorpe No. 1	gas and oil shows in the Eumeralla Fm and Pretty Hill Sst
Planet	Heathfield No. 1	Gas trace in Merino Group
	Tullich No. 1	very grassy saltwater in Merino Group (i.e. Lower Otway Group)
Pursuit	Hindhaugh Creek No. 1	Methane and nitrogen, and a high geothermal gradient
Shell	Rose Creek No. 1	Fair to good gas shows from the Eumeralla Fm and the Pretty Hill Sst; shows related to carbonaceous beds
	Hawkesdale No. 1	minor gas show in a basal unit below the Pretty Hill Sst
	Nerita No. 1	Minor methane shows in Eastern View and Otway Groups
	Pecten No. 1A	90-145 Mcf/D (max.) of methane and ethane from Waarre Sst
	Voluta No. 1	minor methane and traces of ethane and propane from Belfast Mudstone equivalents

Table 2 shows that the most significant petroleum occurrences were either in the Waarre Formation or in other sandstones beneath the Otway Group/ Sherbrook group unconformity. The Pretty Hill Sandstone and other sandstones in the lower part of the Otway Group have yielded many traces of gas and oil, as have several sandstones in the Sherbrook Group.

The most encouraging signs of petroleum accumulations have come from the four Port Campbell wells (Table 3 and Plate 2), especially from Nos. 1 and 4. Port Campbell No. 1 initially flowed 4.2 MMcf/D from the Waarre Formation, but the pressure and rate of flow of gas dropped rapidly during testing and did not recover. The well started to make salt water in increasing volume and it was concluded that the hydrocarbon reservoir was small. However, it could not be determined whether the sandstone reservoir was a relatively small lens or had been truncated by faults which had closed it from communication with some larger reservoir.

At the level of the top of Otway Group seismic horizon, Port Campbell No. 4 well (Appendix 3) is located northeast of the culmination of a northeast-trending anticline. The anticlinal trend is on the south, downthrown side of a west-northwest-trending fault. Seismic interpretation suggests a throw of the order of 300 to 400 metres in the vicinity of the well. At the level of the Lower Tertiary seismic horizon the well is on a structural nose between two faults trending as above, with downthrow to the south, and on the top of the Wangerrip Group horizon the well is located on the west side of a broad gentle anticline centred west of Cooriemungle. Gas flows from No. 4 well were considerably smaller than from No. 1.

The occurrence of carbon dioxide gas in the southeastern part of the Gambier Embayment is an interesting phenomenon. This gas was encountered in significant quantities in both Kalangadoo No. 1 well and Caroline No. 1 well (Appendix 3). The latter well has produced carbon dioxide for commercial purposes since 1968. Mulready (1977) considers that in the Kalangadoo occurrence the gas occurs at the unconformity between the basal part of the Otway Group and basement, whilst the gas in the Caroline well is in the Waarre Formation equivalent, faulted against downthrown Belfast Mudstone. The origin of the carbon dioxide is unknown, but it is considered most likely to be of volcanic origin, being derived as juvenile carbon dioxide from the Newer Volcanics intruded into Otway Group sediments.

Source rocks and maturation

The fact that most of the hydrocarbon occurrences detected in the Otway Basin region have been in the Otway Group or in the Waarre Sandstone immediately overlying the Otway Group suggests that the Otway Group itself is the source of the hydrocarbons. The underlying Palaeozoic rocks of the Lachlan Fold Belt are overmature and can be ruled out as a source. Rocks younger than the Early Cretaceous appear to have less source potential than the Otway Group.

The organic matter from many of the wells has been analyses by chemical and microscopic methods by petroleum exploration companies, CSIRO, and BMR to determine its potential for petroleum generation. Few of these analyses have been published. In general, the results have been discouraging, as no definite source rocks have been identified.

The type of carbonaceous matter present in the Otway Group is predominantly humic and therefore likely to be a potential source for gas rather than oil. The majority of samples tested, from the Eumeralla Formation, the Pretty Hill Sandstone, and correlatives at the base of the Otway Group, showed nil or poor source potential, but there were some exceptions in which individual samples showed moderate or good potential.

The Upper Cretaceous Belfast Mudstone is in many places a very thick, dark, marine shaly siltstone unit which might be expected to have some source potential. However, analyses of samples from this formation have proved disappointing. The microfauna of the formation in many of the wells drilled suggest that it may have been deposited in an oxidising marine environment. Examination of cores from the unit shows the sediments underwent extensive reworking by burrowing organisms. These factors may have adversely affected the preservation of organic material. There are areas offshore where the Belfast Mudstone is very thick and where it has been only sparsely tested by drilling (e.g. the south-eastern part of the Gambier Embayment). It could still prove to have hydrocarbon source potential in areas where it may have been deposited in a less oxidising environment.

The Tertiary sediments contain abundant organic material of plant and marine origin. In the Torquay Basin the Eastern View Coal Measures contain large volumes of brown coal of similar age to that considered to be a source for the hydrocarbons in the Gippsland Basin. However, it appears that the brown coals in the Torquay Basin have insufficient thermal maturity to have generated petroleum. It seems likely that most, if not all, of the Tertiary sediments in the Otway Basin region are thermally immature.

Figure 10 shows thermal gradient contours for the Otway Basin region derived from temperature measurements in (some) 47 wells. Although measurements in individual wells were probably not very accurate, the overall results are fairly consistent. They show that the highest thermal gradients occur near the northern margin of the Otway Basin and along the western side of a region of shallow basement near King Island, and that they decrease in a more or less regular manner basinward (and to seaward). There appears to be an anomalous area of high thermal gradient east of Cape Jaffa in South Australia, but as this anomaly is based mainly on measurements in only two wells, it should perhaps not be regarded as proven at this stage.

It is commonly considered that the temperature range 65° to 150°C represents a suitable range for the generation of petroleum. The approximate depths at which these two temperatures would be expected are shown on the thermal gradient contours in Figure 10. It is evident that with present-day temperatures the depth zone conducive to petroleum generation is within reach of the drill over practically the whole of the Otway Basin region. However, there may be an area in the southeastern corner of South Australia, particularly offshore, where it is necessary to drill to depths in excess of 3250 m in order to reach the present-day temperature zone for maturation of oil or 'wet' gas.

In the Torquay Basin, CSIRO studied samples from Hindhaugh Creek No. 1 well (Pursuit Oil N.L., 1969) and concluded that all of the Lower Cretaceous section is post-mature for oil. Only dry gas could possibly have been generated, but the destruction of porosity makes even the preservation of dry gas unlikely. All of the wells which have been drilled in the Torquay Basin have encountered hard, tight Otway Group rocks for which the same general conclusion may be drawn. This result suggests that palaeotemperatures in this part of the region have been higher than they are today, perhaps because of a thermal event which also produced local volcanic activity.

Occurrences of gas and oil in the Port Campbell area in the Otway and Sherbrook Groups demonstrate that hydrocarbons have been generated in this area or in nearby areas (perhaps offshore) - at least in small amounts.

Source-rock analyses on wells in the Tyrendarra Embayment indicate that the area is immature for petroleum generation. The preservation of porosity in quartz sandstones in the Gambier Embayment suggests that that area is not postmature, and it may well be immature, at least in part. However, lack of adequate organic source material is probably also a factor in the absence of significant petroleum shows in the Tyrendarra and Gambier Embayments.

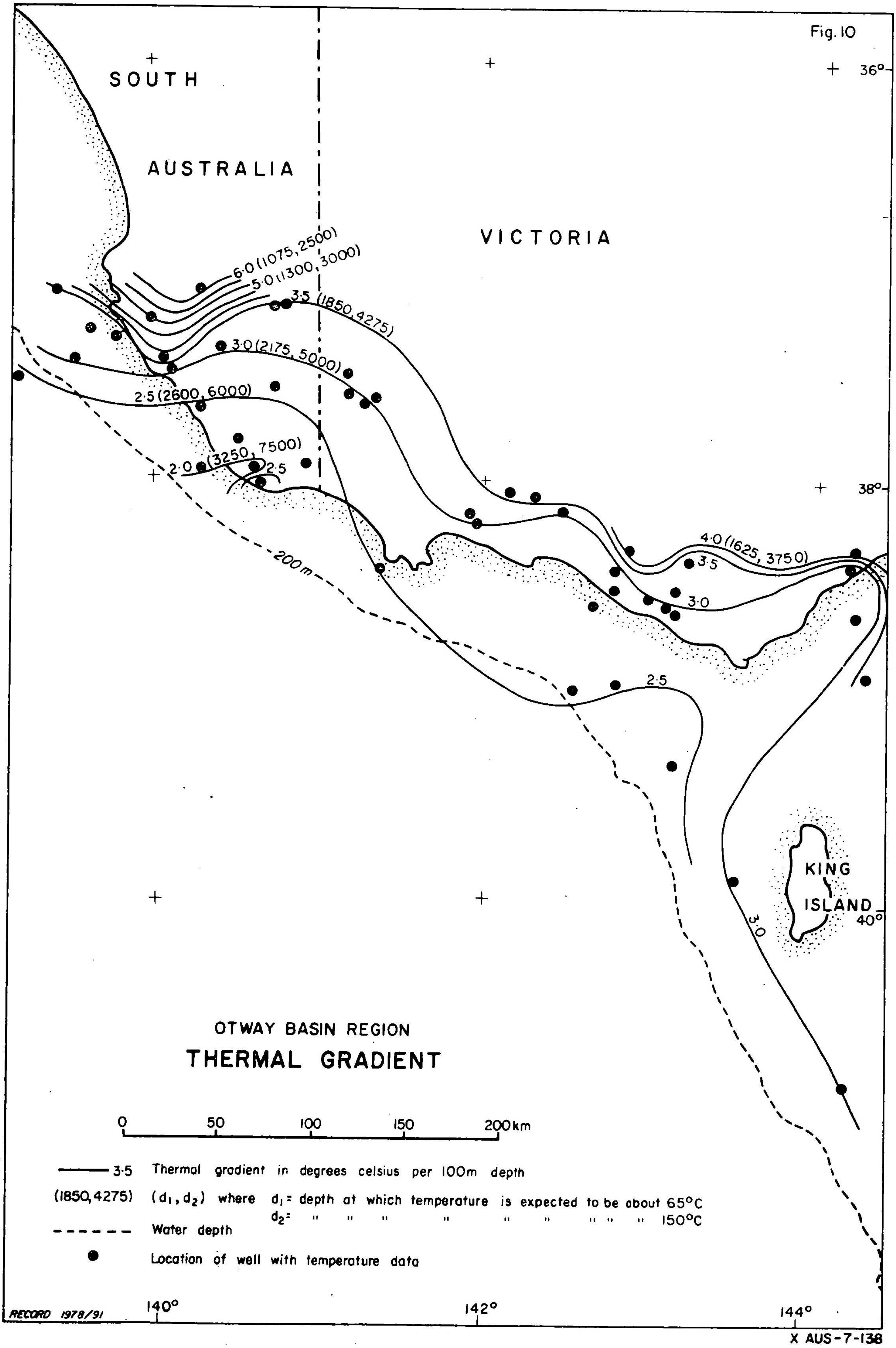
Fig. 10
36°
38°
40°
SOUTH
AUSTRALIA
VICTORIA
KING
ISLAND
6·0 (1075, 2500)
5·0 (1300, 3000)
3·5 (1850, 4275)
3·0 (2175, 5000)
2·5 (2600, 6000)
2·0 (3250, 7500)
2·5
4·0 (1625, 3750)
3·5
3·0
2·5
3·0
200m
OTWAY BASIN REGION
THERMAL GRADIENT
0 50 100 150 200 km
3·5 Thermal gradient in degrees celsius per 100m depth
(1850, 4275) (d1, d2) where d1 = depth at which temperature is expected to be about 65°C
d2 = " " " " " " " " " 150°C
Water depth
Location of well with temperature data
RECORD 1978/91
140°
142°
144°
X AUS-7-138

Reservoirs and cap-rocks

A number of potential reservoir beds which have associated impervious cap-rocks are known from the Otway Basin region. These are discussed in some detail by Scorer (in Reynolds, 1971) and by Wopfner, Kealey, & Thornton (in Wopfner & Douglas, 1971). The most important reservoirs are sands in the lower part of the Otway Group, chiefly the Pretty Hill Sandstone, which is capped by overlying shale, greywacke, siltstone, and mudstone; and the Waarre Formation at the base of the Sherbrook Group, capped by the Flaxmans Formation and the Belfast Mudstone. The Pebble Point Formation at the base of the Tertiary Wangerip Group, capped by mudstone and siltstone of the Dilwyn Formation, is a further possibility where it is not water-flushed.

The Pretty Hill Sandstone is the best known member of alluvial/deltaic sandy beds occurring in the lower part of the Otway Group. The term 'Pretty Hill Sandstone' has been loosely applied to a number of such sandstones. The Pretty Hill Sandstone proper is typically developed in the Tyrendarra Embayment (e.g. Pretty Hill No. 1 well, Appendix 3), where it increases in thickness southwestwards towards the coast. This thickening implies that it was derived from a source to the south, possibly from a horst block which has now subsided into the Voluta Trough. The following table illustrates occurrences of the sandstone in the Warrnambool area.

TABLE 3. OCCURRENCES OF PRETTY HILL SANDSTONE, WARRNAMBOOL AREA

Well	Thickness	Porosity (%)	Permeability (millidarcies)	Petroleum shows
Pretty Hill No. 1	582 m	20-25	197-2756	none
Hawkesdale No. 1	251 m	15-32	up to 5000	fluorescence & smell
Woolsthorpe No. 1	363 m	17-22	54 to 9784	fluorescence
Garvoc No. 1	153	13-22	2 to 661	fluorescence & oil trace

The Pretty Hill Sandstone or equivalent extends rather erratically eastward into the Port Campbell Embayment. Its time-equivalent in the eastern part of the Gambier Embayment is the Geltwood Beach Formation, which is primarily a chloritic mudstone, but includes several sandstone horizons. Farther west, southeast of the Encounter Bay Platform, Lower Otway Group sandstones are well developed. In Crayfish A-1 (Appendix 3) these are 1600 m thick ('Crayfish Sand') with fair to good porosities and very variable permeabilities.

The Waarre Sandstone was considered by Hawkins & Dellenbach (1971) to be confined to the Port Campbell Embayment and the Otway Ranges. It is thin or absent in the Tyrendarra Embayment, but sandstones with Waarre Sandstone affinities exist in the Gambier Embayment, especially on the southern flanks of the Beachport-Kalangadoo 'high'. The Waarre Sandstone in Victoria averages about 34 m in thickness, and consists of fine to locally very coarse-grained sandstones with intercalated siltstones and carbonaceous shales (Ellenor, 1976). It has good reservoir properties. Although sands within the Upper Sherbrook Group (Paaratte Formation) also have high porosities and permeabilities, the Waarre Sandstone is the main Upper Cretaceous petroleum objective.

The Pebble Point Formation is widespread in extent and exhibits a variety of lithofacies (Hawkins & Dellenbah, 1971). It averages about 46 m in thickness in the Port Campbell Embayment, 42 km in the Tyrendarra Embayment, and 56 m in the Gambier Embayment. Porosity in the sandstones ranges from low to moderate, depending on diagenetic changes. The chemically cemented rocks have low porosity. No hydrocarbons have been found. Lutites in the overlying Dilwyn Formation could act as cap-rock in a trap situation.

Traps for petroleum

Faults of the taphrogenic stage of continental break-up are the most prominent tectonic features in the Otway Basin region; these are responsible either directly or indirectly for the majority of the potential hydrocarbon traps known in the region. The following trapping mechanisms are either known to be or inferred to be present in the region:

1. Purely fault-traps (reservoir faulted against cap-rock or bounded by impervious fault zones)
2. Fault-induced folds
    (a) bending concomitant with syndepositional, down-to-basin faulting
    (b) bending by thrust derived from transcurrent movements.

3. Stratigraphic traps

   (a) pinchouts, particularly against basement 'highs'

   (b) unconformities, sealing of older, porous beds by younger cap-rocks.

An example of the first type of trap was believed to exist in the horst block prospect tested by Rowans No. 1 (Appendix 3) onshore in the Port Campbell Embayment. It was expected that lateral seal of the Waarre Formation would be provided by faulting. However, it was determined that the throw of the fault was insufficient to bring the impervious Belfast Mudstone, which proved thinner than anticipated, against the Waarre Formation to a sufficient extent to provide an effective lateral seal.

The prospect tested by Mussel No. 1 (Appendix 3) offshore in Victoria was an example of the second type of trap - it illustrates a common situation: syndepositional faulting has produced an anticlinal fold and thrown the Waarre Sandstone against the Belfast Mudstone. Unfortunately the hole was dry. In the Argonaut prospect a similar structural situation was expected, but drilling of Argonaut No. 1 proved that a facies change had substituted sediments with significant sandy content for the anticipated Late Cretaceous shale which was expected to form an impervious seal.

Possible stratigraphic traps occur around the many horsts which are to be found in the region and around other basement 'highs'. Examples are the prospect tested by Lake George No. 1 on the Beachport 'high' in onshore South Australia, and the Clam prospect drilled on an offshoot of the King Island - Mornington basement ridge northwest of Tasmania. Clam No. 1 (Appendix 3) was drilled on a large pre-Mesozoic basement 'high'. It tested both structural closure at the basal Tertiary level and a thick wedge of Cretaceous sediments pinching out updip against basement. The deeper target proved to be 22 m of sandy siltstone believed to be the pinching out extremity of the Waarre Formation. Its porosity was generally in the range 10-16 percent with up to 20 percent in a few stringers, but the hole was dry.

Prospectivity

Since 1960 some 70 petroleum exploration wells have been drilled in the Otway Basin region, 15 of them offshore. Although some areas, particularly offshore, remain relatively sparsely drilled, it may be concluded from exploration to date that the prospectivity of the region is poor. There is still some potential for discoveries to be made, but these are unlikely to be prolific.

Petroleum prospectivity onshore seems poor. The Port Campbell Embayment area, which is the only area in the region where wells have produced good hydrocarbon shows, has been fairly well tested onshore without any commercial discoveries. Since 1972 Shell has drilled two wells in the area, Rowans No. 1 and North Eumeralla No. 1. In both wells the Tertiary and Upper Cretaceous sediments were flushed by fresh water, a situation which is prevalent in much of the onshore Otway Basin. The lack of hydrocarbons in Rowans No. 1 was considered by Ellenor (1976) to be primarily due to the absence of a suitable source rock sequence in the vicinity. The good shows in the Port Campbell wells to the southeast were ascribed to limited generation in nearby Lower Cretaceous sources in a deeper, more basinward position. In Ross Creek No. 1, drilled near the Otway Ranges high, the Pretty Hill Sandstone was hard and tight due to secondary silicification, indicating that it had probably had a severe thermal history, as did the Early Cretaceous section in the Torquay Basin farther to the east.

Exploration in the onshore parts of the Tyrendarra Embayment and Gambier Embayment has yielded less encouragement than in the Port Campbell Embayment. The problems seem to be similar; flushing of the upper sequences by fresh water and lack of adequate source beds. Inadequate maturation of source material west of the Port Campbell Embayment may also be a factor. The occurrence of substantial quantities of carbon dioxide gas in two structures in the Gambier Embayment (Caroline and Kalangadoo) testifies to the fact that gas-trapping mechanisms exist in the area, but the almost total absence of hydrocarbons with the carbon dioxide tends to suggest that significant hydrocarbon generation has not occurred in the vicinity. A further problem in many areas is the difficulty of obtaining seismic data of adequate quality to map the target horizons in situations complicated by faulting. It must be concluded that the chances of making petroleum discoveries onshore in the Otway Basin are poor, and any discoveries made are likely to be small.

Because of the known occurrences of petroleum onshore in the Port Campbell area, the area immediately offshore from the Port Campbell Embayment, which is in a more basinward situation to the structures drilled onshore, commends itself as reasonably prospective. Only one well, Pecten 1A (Appendix 3) has been drilled in this area. Pecten encountered gas shows below 1200 m in the Sherbrook Group. The Otway Group, encountered at 1796 m, lacked permeability. Nautilus A-1 (Appendix 3) and Mussel No. 1, drilled about 30 km further offshore than Pecten, had no hydrocarbon shows. The failure of these latter two wells has dampened hopes that more prolific source beds might be present in combination with reservoirs in the deeper, offshore portion of the basin down-dip from Port Campbell. Several possible hydrocarbon traps have been indicated by seismic work in the area around Pecten and east of that well. It is desirable that one or more additional wells should be drilled in this area to establish whether hydrocarbons are present in commercial quantities.

In the offshore part of the Torquay Basin the hydrocarbon objectives have been quartzose clastics in the Eastern View Coal Measures overlying the Otway Group. Two wells, Nerita No. 1 and Snail No. 1 (Appendix 3) have tested this section in valid closures without finding hydrocarbons. Prospectivity in the Torquay Basin must be regarded as low.

The area offshore west of the Port Campbell Embayment and east of about 140°E longitude in South Australia has not been fully explored and its prospectivity is therefore largely unknown. There area, however, some discouraging factors. Only two wells have been drilled, Argonaut No. 1 and Voluta No. 1 (Appendix 3). Because of mechanical difficulties Voluta No. 1 terminated at 3973 m in Belfast Mudstone. It did not reach either of its two primary target horizons. Argonaut No. 1 terminated in the Waarre Formation and did not penetrate the Otway Group. Neither well encountered hydrocarbons. Disappointing results onshore in the Tyrendarra and Gambier Embayments tend to downgrade the prospectivity of the offshore areas near the coast where water depths are moderate and the Waarre Formation and Otway Group are at drillable depths. Farther offshore the main target reservoirs are mostly at uneconomic drilling depths, and suitable structural traps are difficult to define adequately by seismic means.

The northwestern offshore part of the Otway Basin is more favourable from the point of view that reservoir formations are at accessible depths, but five wells have been drilled in this area, southwest of Cape Jaffa, without success. Trumpet No. 1 was drilled on a faulted anticline on the 'Crayfish Shelf', where Tertiary and Upper Cretaceous sediments are thin, to test the Pretty Hill Sandstone. This formation was encountered at 1303 m, and consisted of thick sandstones with interbedded silts and shale. The well is considered a valid test of the formation in a potential hydrocarbon trap, but there were no hydrocarbon shows. The other four wells were drilled farther south in the hinge zone between the 'Crayfish Shelf' and the area of much thicker Upper Cretaceous sedimentation to the southeast. This zone offered the possibility of testing well developed Pretty Hill sands at moderate depths in a situation up-dip from a thick Cretaceous sedimentary sequence. The fact that the most attractive prospects have been drilled without hydrocarbon shows has downgraded the area to the point where the prospectivity must be regarded as low.

The Sorell Basin has been tested by only one well, but indications are that prospectivity of the basin is poor. Clam No. 1, drilled in the King Island Sub-basin, penetrated about 1000 m of Tertiary and 350 m of Upper Cretaceous sandstones before entering Palaeozoic sediments. There were no hydrocarbon shows. Much of the continental shelf west of Tasmania has shallow basement. There are two relatively small areas of thicker sediment accumulation apart from the King Island Sub-basin: two closed structures have been mapped in one of these, a sedimentary trough west of Macquarie Harbour. Total sediment volume is small and there is no reason to think that the sediments are any more petroliferous than those tested offshore in the region to the northwest.

The petroleum potential of sediments in deep water on the continental slope and rise in the Otway Basin region is unknown, but knowledge of sediments elsewhere in the region suggests that it is probably poor, or at best fair.

FUTURE EXPLORATION RECOMMENDED

There is widespread aeromagnetic coverage over the region and little need for further aeromagnetic surveying at the present stage of exploration. Magnetic surveying in conjunction with future marine seismic surveys could be useful in detecting volcanic rocks within the sedimentary sequence.

Regional gravity coverage exists over the whole of the area reviewed. Detailed gravity surveys have been tried, with limited success in defining structure, over fairly extensive areas of the onshore Otway Basin. A closer spacing of marine gravity traverses over the continental shelf and slope of the region would be useful in helping to elucidate the regional structure of the continental margins, but further gravity surveying is not recommended as a direct contribution to petroleum exploration.

There is considerable scope for further detailed, high effort seismic surveying, both onshore and offshore. Plates 6 and 7 indicate a fairly good coverage of seismic lines over most of the region, but in fact this coverage is somewhat misleading because much of the earlier seismic work is of inadequate quality to define petroleum objectives. Much of the region consists of poor seismic record areas; onshore because of difficult surface conditions in parts of western Victoria and south-eastern South Australia, and over the whole region because of the complexity of faulting associated with continental break-up and separation. Future definition of drilling targets therefore requires seismic detailing using the most modern, high effort technology available.

As indicated in the previous section, there are few areas in the Otway Basin region where further drilling of prospects can be recommended at present with much hope of success. The area with the best chance of success seems to be that immediately offshore from the Port Campbell Embayment. The one well which has been drilled (Pecten 1A), which encountered gas shows, is hardly enough to condemn this area. Further prospects probably exist in the area, and it is recommended that one or more of these should be tested by drilling.

CONCLUSIONS

By Australian standards the Otway Basin region has been moderately well explored for petroleum during the past twenty years, but the results of exploration to date have been rather discouraging. The most significant petroleum shows consisted of gas in non-commercial quantities in wells near Port Campbell.

The Lower Cretaceous Otway Group appears to be the most likely source for petroleum in the region. Although this formation is widespread and very carbonaceous, analyses of samples have indicated that it does not generally contain good source beds. Such organic material as it does contain is predominantly humic in character and therefore more likely to produce gas rather than oil.

In the Torquay Basin the most prospective section is postmature for petroleum. Petroleum shows in the Port Campbell Embayment indicate that at least small quantities of gas have been generated in this area, but the absence of significant shows in wells elsewhere in the region is evidently due to the lack of adequate source material, immature generating conditions, or flushing by meteoric waters (prevalent onshore).

The prospectivity of the region as a whole is considered poor. The most prospective area would seem to be the area immediately offshore from the Port Campbell Embayment, where only one well has been drilled and where other drilling prospects probably exist.

A considerable amount of geophysical work has been done over the region. From the point of view of petroleum exploration, there is little need for further magnetic or gravity surveys except in conjunction with marine seismic surveys. Over much of the region it is difficult to record good quality seismic data from potential petroleum target horizons. The detailed seismic work required to delineate future drilling targets will therefore require application of the most modern, high effort seismic techniques.

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APPENDIX 1

PETROLEUM EXPLORATION WELLS, OTWAY BASIN REGION

COMPANY Well Name BMR file no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet Area	Elevation GL/WD* DF/KB/RT (metres)	Date spudded TD reached	TD (metres)	Status
ADELAIDE OIL EXPLORATION CO.								
Mount McIntyre No. 1	37 140	34 32	10 50	J54/6	GL - KB -	?	319	PA (dry)
Riddoch	c37 140	30 45	00 00	J54/6	GL - KB -	? 1915	319	PA (dry)
ALLIANCE OIL DEVELOPMENT (AUST.) N.L.								
Burrungule No. 1	37 140	46 32	16 18	J54/6	GL 27.4 KB 81.8	18.6.75 13.7.75	2435	PA (dry)
Caroline No. 1 BMR file 66/4222	37 140	56 54	30 30	J54/6	GL 64.0 KB 68.9	2.9.66 29.1.67	3371	Gas show Well completed as a CO_2 producer
Kalangadoo No.1 BMR File 65/4153	37 140	34 41	40 40	J54/6	GL 66.8 KB 72.8	Spud 13.5.65 Respud 31.5.65 28.8.65	2758	PA (2.6 MM cf/D)
Kentgrove No. 1	38 140	56 37	00 23	J54/10	GL 21.0	6.11.76 1.12.76	991	PA
Lake Bonney No. 1 BMR file 67/4261	37 140	50 28	39 21	J54/6	GL 21.3 KB 26.5	13.7.67 25.8.67	2911	PA (dry)
Mount Gambier No. 1	37 140	46 38	20 10	J54/6	GL 41.1 KB -	? 1948	640	PA (dry)
Mount Salt No. 1 BMR file 62/1100	37 140	57 37	25 43	J54/7	GL 21.3 KB 26.2	9.5.62 21.9.62	3061	PA (dry) some fluorescence of unknown origin
Mount Salt No. 1 Structure Holes: No. 1	37 140	58 38	07 24	J54/6	GL 21.6 KB 23.2	24.1.62 19.1.62	307	PA (dry)
No. 2	37 140	57 37	22 41	J54/6	GL 21.3 KB 22.9	26.1.62 3.2.62	304	PA (dry)
No. 3	37 140	56 36	35 54	J54/6	GL 21.6 KB 23.2	6.2.62 10.2.62	304	PA (dry)
No. 4	37 140	57 38	03 24	J54/6	GL 20.7 KB 22.3	13.2.62 17.2.62	304	PA (dry)
No. 5	37 140	57 37	39 04	J54/6	GL 21.6 KB 23.2	20.2.62 1.3.62	304	PA (dry)
BMR file 62/1100								
Penola No. 1 BMR file 62/1071	37 140	20 52	38 35	J54/6	GL 62.1 KB 63.7	7.2.61 18.4.61	1519	PA (dry)
Robertson No. 1 BMR file 67/4237	37 140	11 46	25 47	J54/6	GL 52.4 KB 57.0	29.11.69 14.3.67	1800	PA (very gassy salt water)
Robertson No. 2 BMR file 67/4250	37 140	10 45	20 40	J54/6	GL 52.1 KB 56.7	29.4.67 7.5.67	1506	PA (dry)

* Key to abbreviations is given at end of Appendix 1

APPENDIX 1 (cont.)

COMPANY Well Name BMR file no. if subsidised	Latitude South Longitude East o ' "	1:250 000 Sheet Area	Elevation GL/WD DF/KB/RT (metres)	Date spudded TD reached	TD (metres)	Status
AMALGAMATED OIL WELLS COMPANY						
Blackford Bore	36 48 00 140 01 10	J54/2	GL - KB -	?	416	PA (minor gas show)
Murrabinna H.D.	c36 45 00 140 05 00	J54/2	GL - KB -	?	415	PA (shows of inflammable gas reported)
ASSOCIATED OIL CO.						
Unnamed	?	?	GL - KB -	1923/26	643	PA (dry)
BEACH PETROLEUM N.L.						
Geltwood Beach No. 1 BMR file 62/1403	37 39 44 140 14 25	J54/6	GL 4.6 KB 9.1	22.8.63 11.11.63	3749	PA (slight gas cut of C_1, C_2, C_3)
Geltwood Beach Structure Holes: No. 1	37 40 14 140 15 08	J54/6	GL 32.5 KB -	21.7.62 5.8.62	442	PA (dry)
No. 2	37 39 51 140 14 12	J54/6	GL 35.4 KB -	9.8.62 17.8.62	369	PA (dry)
No. 3	37 39 18 140 12 57	J54/6	GL 34.3 KB -	23.8.62 2.9.62	369	PA (dry)
No. 4	37 38 36 140 12 17	J54/6	GL 34.0 KB -	4.9.62 12.9.62	369	PA (dry)
No. 5	37 38 48 140 14 00	J54/6	GL 40.0 KB -	19.9.62 25.9.62	369	PA (dry)
No. 6	37 38 53 140 15 38	J54/6	GL 34.3 KB -	28.9.62 16.11.62	431	PA (dry)
No. 7	37 37 20 140 14 30	J54/6	GL 33.5 KB -	10.10.62 28.10.62	491	PA (dry)
No. 8	37 37 04 140 12 54	J54/6	GL 43.9 KB -	16.2.63 28.2.63	412	PA (dry)
No. 9 BMR file 63/1403	37 36 38 140 09 52	J54/6	GL 34.1 KB -	13.3.63 21.3.63	424	PA (dry)
COORONG OIL COMPANY						
Coorong (Messent) No. 1 (=Bore N)	c36 09 00 139 38 00	J54/2	GL - KB -	1924	198	PA (dry)
Coorong (Santo) No. 1 (=Bore No. 1)	c36 08 00 139 57 00	J54/2	GL - KB -	1924	200	PA (dry)
Coorong (Santo) No. 2 (=Bore No. 2)	c36 07 00 139 41 00	J54/2	GL - KB -	1924	214	PA (dry)
Coorong (Santo) No. 3 (=Bore No. 3)	c36 10 00 139 38 00	J54/2	GL - KB -	1924	284	PA (dry)
Salt Creek (C.O.C.) No. 1	36 07 10 139 41 50	J54/2	GL - KB -	1922	284	PA (dry)

APPENDIX 1 (cont.)

COMPANY Well Name BMR file no. if subsidised	Latitude South Longitude East o ' "	1:250 000 Sheet Area	Elevation GL/WD DF/KB/RT (metres)	Date spudded TD reached	TD (metres)	Status
ENTERPRISE OIL COMPANY						
Coorong (E.O.C.) No. 1	c36 50 00 139 50 00	J54/2	GL - KB -	?	142	PA (dry)
Coorong (E.O.C) No. 2	c36 50 00 139 50 00	J54/2	GL - KB -	?	62	PA (dry)
Lacepede No. 446	?	?	GL - KB -	1933	62	PA (dry)
Lacepede No. 442	c36 50 00 139 59 00	J54/2	GL 9.4 KB -	1934	142	PA (dry)
Salt Creek (E.O.C.) No. 1	c36 08 00 139 46 00	J54/2	GL - KB -	1932	189	PA (dry)
Salt Creek (E.O.C.) No. 2	c36 09 00 139 54 00	J54/2	GL - KB -	1933	137	PA (dry)
ESSO EXPLORATION AND PRODUCTION AUST. INC.						
Argonaut No. A-1 BMR file 68/2018	37 58 18 140 15 52	J54/6	WD 77.1 KB 28.3	14.5.68 29.6.68	3707	PA (dry)
Chama No. 1	37 25 36 139 30 36	J54/6	WD 85.3 KB 28.3	16.1.70 24.1.70	1288	PA (dry)
Chama No. 1A	37 25 36 139 32 36	J54/6	WD 83.2 KB 28.3	26.1.70 28.2.70	2748	PA (dry)
Clam No. 1 BMR file 69/2016	40 51 52 144 12 55	K55/1	WD 101.8 KB 30.1	19.7.69 3.8.69	1623	PA (dry)
Crayfish No. A-1 BMR file 67/4266	37 17 22 139 35 50	J54/6	WD 49.4 KB 28.3	24.9.67 20.12.67	3200	PA (minor gas show)
Lake Eliza No. 1 BMR file 69/2027	37 13 56 139 59 06	J54/6	GL 8.5 KB 12.2	6.9.69 22.9.69	1473	PA (gas show)
Lake Eliza No. 2	37 13 13 139 59 08	J54/6	GL 9.1 KB 13.4	31.8.73 10.9.73	1158.2	PA (gas show)
Lake George No. 1 BMR file 69/2030	37 27 09 140 02 35	J54/6	GL 3.7 KB 7.3	4.10.69 15.10.69	1369	PA (dry)
Lucindale No. 1 BMR file 69/2034	37 05 56 140 18 42	J54/6	GL 47.5 KB 50.9	31.10.69 8.11.69	980	PA (dry)
Morum No. 1	37 30 09 139 14 07	J54/5	WD 286 KB 294	1.5.75 2.6.75	2439	PA (dry)
Mussel No. 1 BMR file 69/2021	38 57 46 142 46 22	J54/6	WD 85.3 RT 30.2	18.8.69 7.9.69	2450	PA (dry)
Nautilus No. A-1 BMR file 68/2008	38 58 42 142 32 47	J54/12	WD 64.0 RT 27.1	13.4.68 15.5.68	2011	PA (dry)
Neptune No. 1	37 18 13 139 44 09	J54/6	WD 35.4 RT 9.8	27.12.73 12.1.74	2438	PA (dry)
Prawn No. A1 BMR file 67/4273	39 21 25 143 06 27	J54/16	WD 107.9 RT 27.1	28.12.67 2.4.68	3193	PA (dry)
Trumpet No. 1	37 05 47 139 24 42	J54/5	WD 49.4 KB 9.8	11.12.73 26.12.73	2256	PA (dry)

APPENDIX 1 (cont.)

Well Name BMR file no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet Area	Elevation GL/WD DF/KB/RT (metres)	Date spudded TD reached	TD (metres)	Status
ESSO EXPLORATION AND PRODUCTION AUST. INC. (contd.)								
Whelk No. 1	39 143	53 33	58 21	J54/16	WD 103 KB 30.5	6.3.70 16.3.70	1446	PA (dry)
FROME-BROKEN HILL CO. PTY LTD								
Eumeralla No. 1 BMR file 63/1061	38 141	12 56	43 01	J54/11	GL 46.9 KB 50.9	7.11.62	3142	PA (trace of oil & gas)
Ferguson's Hill No. 1 BMR file 63/1061	38 143	37 09	20 41	J54/12	GL 194.5 KB 198.4	24.12.63 6.5.64	3546	PA (7-10Mcf/D of C_1, C_2)
Flaxman's No. 1 BMR file 62/1074	38 142	33 46	00 00	J54/12	GL 62.8 KB 67.4	3.5.61 25.8.61	3514	PA (250 Mcf/D of C_1, C_2, C_3 & some 51.2 API condensate)
Port Campbell No. 1 BMR file 62/1020	38 142	34 57	57 50	J54/12	GL 102.7 KB 105.8	9.9.59 9.12.59	1818	PA (produced a substantial flow of gas, initially 4.2 MMcf/D but not sustained; waxy oil recorded)
Port Campbell No. 2 BMR file 62/1064	38 142	35 59	48 30	J54/12	GL 81.1 KB 86.6	12.7.60 1.12.60	2696	PA (gas show)
Port Campbell No. 3	38 142	33 55	00 00	J54/12	GL 64.0 KB -	-.1.61 -.2.61	1686	PA (gas show)
Port Campbell No. 4 BMR file 64/4063	38 142	32 58	20 30	J54/12	GL 130.1 KB 134.1	10.6.64 12.7.64	2597	PA (dry)
Pretty Hill No. 1 BMR file 62/1115	38 142	13 07	30 30	J54/11	GL 57.6 KB 61.9	7.9.62 13.10.62	2478	PA (dry)
Sherbrook No. 1 BMR file 63/1045	38 143	37 07	33 16	J54/12	GL 142.3 KB 146.3	19.11.63 18.12.63	1656	PA (dry)
GEELONG FLOW OIL CO.								
Geelong Flow Oil No. 1	c38 144	18 20	04 15	J55/9	GL - KB -	1948	at least 625	PA (gas-cut water H_2 63%)
GENERAL EXPLORATION COMPANY OF AUST. PTY LTD.								
Douglas Point No. 1 BMR file 73/226	38 140	01 35	33 44	J54/10	GL 2.9 KB 5.5	23.5.73 18.6.73	1207	PA (dry)
Lake Eliza No. 2	37 139	13 59	13 08	J54/6	GL 9.1 KB 13.4	31.8.73 10.9.73	1158	PA (dry)
HEMATITE PETROLEUM PTY LTD								
Snail No. 1 BMR file 72/3159	38 144	53 18	52 10	J55/9	WD 81.1 KB 9.8	26.11.72 6.12.72	1235	PA (dry)
H.N.H. MIRAMS ESQ.								
Mirams No. 1	38 141	14 07	00? 00	J54/11	GL c27 KB -	-.-.42 11.2.42	383	PA (dry)
INTERSTATE OIL LTD								
Garvoc No. 1 BMR file 68/2020	38 142	19 52	19 33	J54/12	GL 107.3 KB 110.6	21.6.68 6.7.68	1533	PA (oil trace & strong cut of CO_2)
Purrumbete No. 1 BMR file 68/2021	36 143	21 12	56 27	J54/12	GL 144.8 KB 148.1	13.7.68 30.7.68	1829	PA (dry)

APPENDIX 1 (cont.)

Well Name BMR file no. if subsidised	Longitude East o	 '	 "	1:250 000 Sheet Area	Elevation GL/WD DF/KB/RT (metres)	Date spudded TD reached	TD (metres)	Status
INTERSTATE OIL LTD (contd.)								
Woolsthorpe No. 1 BMR file 68/2018	38 142	08 29	08 47	J54/11	GL 121.9 KB 125.3	18.5.68 12.6.68	1971	PA (gas and oil shows)
JOHN HENRY RESOURCES PTY LTD								
Beachport East No. 1 BMR file 73/220	37 140	27 05	00 10	J54/6	GL 12.2 KB 16.8	14.8.73 24.8.73	1429	PA (dry)
Diamond Swamp No. 1 BMR file 73/221	37 140	21 23	46 23	J54/6	GL 10.7 KB 14.9	14.7.73 7.8.73	1595	PA (dry)
KANIVA SYNDICATE								
Tarpeena Bore	c37 141	32 14	00 00	J54/7	GL - KB -	1960	622	unknown
MERSEY VALLEY OIL CO.								
Mumbannar No. 1	37 141	51 03	37 19	J54/7	GL c61 KB -	1926	335	PA (dry)
MOUTAJUP OIL CO.								
Moutajup No. 1	37 142	42 16	20 10	J54/7	GL c226 RT -	?	55	PA (dry)
OIL DEVELOPMENT N.L.								
Anglesea No. 1 BMR file 62/1217	38 144	24 11	26 53	J55/9	GL 19.8 KB 23.5	23.5.62 7.11.62	3067	PA (dry)
OIL SEARCH LTD								
Knights Dome No. 1	37 140	49 40	10 00	J54/6	GL - KB -	1931	95	PA (dry) Pilot hole bore?
Mount Gambier No. 1	37 140	50 35	00 00	J54/6	GL - KB -	1930	614	PA (dry)
PLANET EXPLORATION COMPANY PTY LTD								
Casterton No. 1 BMR file 65/4135	37 141	36 20	54 06	J54/7	GL 140.5 KB 143.9	13.2.65 28.4.65	2495	PA (dry)
Casterton No. 2	37 141	39 13	05 20	J54/7	GL 66.4 KB 69.8	20.10.67 29.10.67	1526	PA (dry)
Heathfield No. 1 BMR file 64/4019	37 141	37 11	38 08	J54/7	GL 70.1 KB 74.4	6.3.64 21.4.64	2286	PA (gas trace)
Tullich No. 1 BMR file 64/4088	37 141	31 09	00 00	J54/7	GL 78.6 KB 82.9	4.8.64 2.9.64	1635	PA (dry)
POINT ADDIS COMPANY								
Lake Coole (Comaum) No. 1	37 140	13 59	08 15	J54/6	GL 91.4 KB -	-.-.1925 7.9.25	357	PA (dry)
Palpara No. 1	37 140	59 59	22 35	J54/6	GL 26.8 KB -	1925	357	PA (dry)
Torquay No. 6	38 144	23 15	50 07	J55/9	GL - KB -	?1923	257	unknown
Torquay No. 7	38 144	23 15	43 07	J55/9	GL - KB -	?1923	251	unknown

APPENDIX 1 (cont.)

COMPANY Well Name BMR file no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet Area	Elevation GL/WD DF/KB/RT (metres)	Date spudded TD reached	TD (metres)	Status
PORT PHILLIP OIL CO.								
Williamstown Bore	37 144	52 53	10 19	J55/5	GL c3 KB -	-.-.24 -.2.24	c137	PA (dry)
PURSUIT OIL N.L.								
Hindhaugh Creek No. 1 BMR file 69/2026	38 144	16 12	43 07	J55/9	GL 70.7 KB 74.7	21.8.69 3.11.69	2372	PA (dry gassy (methane & nitrogen) water only indication of hydrocarbons
SAINT HELEN'S OIL SYNDICATE								
Geelong Oil Bore	c38 144	07 21	30 25	J55/9	GL - KB -	?1934	at least 98	PA (dry)
SHELL DEVELOPMENT (AUST.) PTY LTD								
Hawkesdale No. 1 BMR file 69/2032	38 142	04 17	51 57	J54/11	GL 135.3 KB 139.0	2.12.69 28.12.69	1774	PA (gas trace)
Moyne Falls No. 1 BMR file 69/2032	38 142	04 11	09 30	J54/11	GL 146.3 KB 150.0	15.11.69 26.11.69	1008	PA (dry)
Nerita No. 1 BMR file 67/4258	38 144	37 13	43 45	J55/9	WD 74.7 DF 34.1	1.7.67 2.8.67	2042	PA (dry)
North Eumeralla No. 1 BMR file 73/275	38 141	09 53	51 30	J54/11	GL 54.9 KB 63.4	30.11.73 21.1.74	2968	PA (dry)
Pecten No. 1 BMR file 67/4239	38 142	40 40	19 42	J54/12	WD 62.2 DF 34.1	26.3.67 3.4.67	270	PA due to mechanical problems
Pecten No. 1A BMR file 67/4239	38 142	40 39	41 56	J54/12	WD 62.5 DF 34.1	12.4.67 4.6.67	2851	PA (90-145 Mcf/D C_1 96.3%, C_2 1.85%)
Ross Creek No. 1 BMR file 74/200	38 143	31 08	57 34	J54/12	GL 152 KB 161	18.2.74 29.4.74	3661	PA (gas show)
Rowans No. 1 BMR file 72/896	38 142	27 47	35 19	J54/12	GL 66.4 RT 70.7	18.4.72 2.5.72	1798	PA (dry)
Voluta No. 1 BMR file 67/4263	38 141	25 18	47 48	J54/11	WD 91.7 KB 34.1	25.8.67 8.12.67	3974	PA (dry)
SOUTH AUSTRALIAN OIL WELLS CO.								
Anglesea No. 1	c38 144	24 11	15 20	J55/9	GL c2 KB -	1922	141	PA (dry)
Anglesea No. 2	c38 144	24 10	45 40	J55/9	GL c69 KB -	-.-.22 24.7.22	at least 230	PA (dry)
Caroline No. 1	c38 140	02 58	00 00	J54/10	GL 4.6 KB -	1915	256	PA (dry)
Caroline No. 2	c37 140	58 58	00 00	J54/6	GL 30.5 KB -	1915	476	PA (dry)

APPENDIX 1 (cont.)

COMPANY Well Name BMR file no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet Area	Elevation GL/WD DF/KB/RT (metres)		Date spudded TD reached	TD (metres)	Status
SOUTH AUSTRALIAN OIL WELLS CO. (continued)									
Caroline No. 3	c37 140	58 58	00 00	J54/6	GL KB	30.5 -	1915	556	PA (dry)
Caroline No. 4	c37 140	58 58	00 00	J54/6	GL KB	30.5 -	1915	374	PA (dry)
Hindmarsh No. 1	34 140	40 30	00 00	I54/10	GL KB	- -	?1918/19	467	PA (dry)
Robe (Waterhouse) No. 1	c37 139	11 52	20 40	J54/6	GL KB	- -	1915	1373	PA (dry)
S.A. Oil Wells No. 1	c37 142	41 14	30 00	J54/7	GL KB	- -	1921	56	PA (dry)
S.A. Oil Wells No. 1A	55 m SW of No. 1			J54/7	GL KB	239.2 -	1921	154	PA (dry)
S.A. Oil Wells No. 2	c37 142	41 15	30 00	J54/7	GL KB	- -	1921	92	PA (dry)
S.A. Oil Wells No. 3	c37 142	42 15	00 00	J54/7	GL KB	c233 -	1922	73	PA (dry)
S.A. Oil Wells No. 4	c37 142	39 14	30 00	J54/7	GL KB	c241 -	1922	86	PA (dry)
S.A. Oil Wells No. 5	c37 142	41 16	18 10	J54/7	GL KB	- -	1922	11	PA (dry)
S.A. Oil Wells No. 6	c37 142	41 12	15 00	J54/7	GL KB	- -	1922	at least 72	PA (dry)
S.A. Oil Wells No. 7	c37 142	41 10	00 50	J54/7	GL KB	- -	1922	53	PA (dry)
S.A. Oil Wells No. 8	c37 142	44 14	10 20	J54/7	GL KB	- -	1922	84	PA (dry)
Tantanoola No. 1	37 140	44 31	10 10	J54/6	GL KB	- -	?	467	PA (dry)
SOUTH AUSTRALIAN PRODUCERS OIL BORE									
unnamed		?		?	GL	-	1940-?1944	372	unknown
SOUTH EAST OIL COMPANY									
Beachport No. 1 BMR file 62/1211	37 140	26 02	55 15	J54/6	GL KB	4.0 5.5	1.9.61 28.12.61	1208	PA (dry)
SOUTHERN OCEAN OIL CO.									
unnamed		?		?	GL KB	- -	1925	811	PA (dry)
Coorong (S.O.O.C.) No. 1	36 139	52 55	40 10	J54/2	GL KB	- -	pre 1925	357	PA (dry)

APPENDIX 1 (cont.)

COMPANY Well Name BMR file no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet Area	Elevation GL/WD DF/KB/RT (metres)		Date spudded TD reached	TD (metres)	Status
SOUTHERN OCEAN OIL CO. (continued)									
Coorong (S.O.O.C.) No. 2	36 139	51 50	10 40	J54/2	GL KB	- -	1927	689	PA (dry)
Lacepede No. 1		?		?	GL KB	- -	pre 1922	357	PA (dry)
Lacepede No. 2		?		?	GL KB	- -	1925	811	PA (dry)
TORQUAY OIL WELLS CO.									
Torquay No. 1	38 144	20 17	58 52	J55/9	GL KB	- -	-.-.23 8.12.23	443	PA (dry)
Torquay No. 2	38 144	20 18	54 03	J55/9	GL KB	- -	-.-.23 13.10.23	273	PA (dry)
Torquay No. 3	38 144	20 18	47 11	J55/9	GL KB	- -	-.-.24 25.1.24	257	PA (dry)
Torquay No. 4	38 144	21 18	00 10	J55/9	GL KB	- -	-.-.24 5.7.24	218	PA (dry)
Torquay No. 5	38 144	20 17	30 32	J55/9	GL KB	- -	-.-.24 17.10.24	213	PA (dry)
VICTORIAN STATE DEPT OF MINES AND BUREAU OF MINERAL RESOURCES									
Nelson Bore (-Glenelg No. 1)	38 141	03 00	20 10	J54/11	GL KB	6.1 -	-.11.45 -.11.45	2227	PA (dry)
WESTERN PETROLEUM N.L.									
Nelson No. 1	c38 141	03 00	00 10	J54/11	GL KB	- -	1940	468	unknown
WESTERN PETROLEUM N.L. PRODUCING OILFIELDS LTD									
Portland No. 1 or Portland North No. 1	38 141	19 34	18 15	J54/11	GL KB	- -	1942	864	PA (dry)

Abbreviations

TD - Total depth

RT - Rotary table

KB - Kelly bushing

DF - Derrick floor

GL - Ground level

WD - Water depth (offshore)

c - approximately

PA - Plugged and abandoned

APPENDIX 2

GEOPHYSICAL SURVEYS - OTWAY BASIN REGION

Aeromagnetic surveys

Map symbol	Survey Name	Year	Operator	Contractor	Survey altitude (m)	Traverse spacing (km)	Total traverse length (km)	Reference or file number✓
ZnC		1948	Zinc Corporation	Oscar Weiss	-	-	-	Sprigg, R.C. (1952)
BMR	Melbourne-Adelaide	1954-62	BMR@	-	450	-	-	BMR maps J54/B1-1 & J55/B1-1
SADM	Gambier-Otway	1955	South Australian Department of Mines	Adastra-Hunting	-	-	-	BMR Rec. 1965/130
MBOS	Murray Basin	1955	Murray Basin Oils Syndicate	Adastra-Hunting	-	-	-	O'Driscoll E.P.D (1962)
F-B	Murray River Basin	1955	Frome-Broken Hill	World Wide Aerial Surveys	-	-	-	F-BH (1955) (Map only)
H.E.	Encounter Bay and Bass Strait	1960-61	Haematite Exploration	Aero Service	610	3-10	15,000	PSSA 62/1710 -11
P.O.	Murray Basin	1962-63	Planet Oil	" "	-	8	35,400	PSSA 62/1732
Esso	Offshore Tasmania	1966-67	Esso Exploration	" "	1140, 1060,& 460	4	3,000	" 66/4626
H.E.	Young Rocks	1968	Hematite Petroleum	CGG	460	3	2,860	" 68/3055
Shell	Portland-Geelong	1970	Shell Development	CGG	730	5	8,330	" 70/373

NOTE: Seismic surveys which also involved magnetic measurements along traverses are indicated by numbers on Plate 3. Information on these surveys may be obtained by reference to the map number key in the left hand column of Appendix 2, Offshore seismic surveys.

@ BMR Long Line Traverse

✓ The letters PSSA preceding a file number indicate that an operation was subsidised.

APPENDIX 2 (continued)

Gravity surveys

Survey Name	Year	Operator	Contractor	Traverse spacing (km)	Station spacing (km)	No. of stations	Reference or file number
Adelaide-Melbourne gravity traverse	1949	BMR	-	-	20	20	File 4905-1, 2A & 2B
Western District gravity	1949-50	"	-	-	1	400	File 4906-1 to 3
Cape Jaffa gravity	1950-52	South Australian Department of Mines	-	-	1	150	Grant (1954)
Naracoorte-Penola gravity	1950-54	South Australian Department of Mines	-	-	1	500	File 57682-4
Melbourne-Bendigo regional traverse	1951	BMR	-	-	10	40	File 5103-1
St. Arnaud-Bendigo regional traverse	1956	"	-	-	10	20	File 5608-1
West Victoria regional traverse	1956	"	-	-	10	60	File 5609-1 & 2
Hamilton-Colac regional traverse	1956	"	-	-	2,10	60	File 58-504 to 506
Dartmoor-Heywood gravity	1957	Frome-Broken Hill	-	-	2	300	File 61-675
Gambier Sunklands gravity	1957	" " "	-	2	0.1	600	Richards (1957)
OPP No. 14 Near Horsham Horsham Vic. gravity	1958	BMR	-	3	3	279	BMR Rec. 58/84
Melbourne-Bendigo regional traverse	1959	"	-	-	15	10	File 5903-1 to 4
Port Phillip Bay and adjacent areas gravity	1957-58	"	-	3	3	300	BMR Rec. 59/34 & 65/64
Mackenzie River area gravity	1958	"	-	2	2	127	BMR Rec. 59/43
Port Campbell gravity	1960	Frome-Broken Hill	-	-	1	200	File 61-665
Casterton gravity	1961	Planet Exploration	Adastra	-	1	300	Unsubsidised
Warrnambool gravity	1961-62	Frome-Broken Hill	-	-	1	242	File 61-670
Hamilton gravity	1962-63	" " "	-	-	1.6	409	File 61-660
Colac regional gravity	1962-63	" " "	-	-	1.6	690	File 62-720
Kalangadoo gravity	1964	Alliance Oil Development	Namco	5	0.8	540	PSSA 64/4805
Caroline-Killanoola gravity	1966	" " "	Geosurveys	2	0.8	1054	PSSA 66/4820
Coleraine gravity	1966	" " "	"	9	2	182	PSSA 66/4821
Hawkesdale gravity	1968	Shell Development	"	3	0.8	1958	PSSA 68/3035
Otway EV-68 gravity	1968-69	Esso Exploration & Production	Geophysical Assoc.	5	0.8	2088	PSSA 68/3056

APPENDIX 2 (continued)

Gravity surveys (contd.)

Survey Name	Year	Operator	Contractor	Traverse spacing (km)	Station spacing (km)	No. of stations	Reference or file number✓
Geelong-Anglesea gravity	1969	Mr J. Say	Geosurveys	1.6	0.8	412	Unsubsidised. Refer to well file 69/2026
Terrang-Portland gravity	1969	Shell Development	"	3	0.8	3314	PSSA 69/3054
Casterton detailed gravity	1970	Planet Exploration	Petty Geophysical	2	0.4	1179	PSSA 70/86
Colac-Geelong gravity	1971	Shell Development	Geosurveys	1	0.8	2157	PSSA 71/560

✓The letters PSSA preceding a file number indicate that an operation was subsidised.

APPENDIX 2 Contd.

Onshore seismic surveys

Map key number	Survey name	Year	Operator	Contractor	Seismic energy source	Traverse length (km)	CDP coverage (fold)	Reference or file number ✓
1a	Heywood seismic	1956	BMR	-	Explosives	100	1	BMR Ref 1958/28
1b	Portland-Timboon seismic	1958	Frome-Broken Hill	United Geophysical	-	60	-	Unsub-sidised
1c	Princetown-Warrnambool seismic	1959	Frome-Broken Hill	United Geophysical	-	-	-	"
1d	Gambier seismic	1960 -61	General Exploration	Geoseismic	Explosives	144	1	PSSA 62/1512
2a	Port Campbell-Warrnambool seismic	1961	Frome-Broken Hill	Ray Geophys.	-	-	-	Unsubs. F-BH (1961b)
2	Port Campbell seismic	1961	Frome-Broken Hill	" "	Explosives	290	1	PSSA 62/1523
3a	Gambier Sunklands seismic	1961	General Exploration	Geoseismic	"	-	-	Unsubs. General Ex. (1961)
4a	Mayurra seismic	1961 -62	Beach Petroleum	"	"	214	1	PSSA 62/1564
4b	Yambuk-Portland seismic	1961 -62	Frome-Broken Hill	Ray Geophysical	"	-	-	Unsubs. F-BH (1962)
5	Casterton seismic	1962	Planet Exploration	Namco International	"	343	1	PSSA 62/1597
5a	Dartmoor-Nelson seismic	1961 -62	Frome-Broken Hill	Ray Geophysical	"	-	-	Unsubs. F-BH (1962a)
5b	Torquay seismic	1962	Oil Development	Geoseismic	"	175	1	PSSA 62/1526
6	Princetown seismic	1963	Frome-Broken Hill	Ray Geophysical	"	214	1	PSSA 63/1505
7	Murrayville-Casterton seismic	1963	Planet Exploration	Austral Geopros-pectors	"	66	1	PSSA 63/1529
8	Branxholme-Koroit seismic	1963 -64	Frome-Broken Hill	Ray Geophysical	"	138	1 & 6	PSSA 63/1535
9	Cooriemungle seismic	1963 -64	Frome-Broken Hill	" "	"	116	1	PSSA 63/1550
10	Timboon Area seismic	1964	Frome-Broken Hill	United Geophysical	"	135	1	PSSA 64/4500
11	Curdie Vale seismic	1964	Frome-Broken Hill	" "	"	88	6	PSSA 64/4504
12	Penola seismic	1964	Alliance Oil	Namco International	"	272	1	PSSA 64/4515
13	Merino seismic*	1964	" "	National McCollum	"	24	1	PSSA 64/4535
14	Koroit seismic and magnetic	1964	Frome-Broken Hill	United Geophysical	"	108	1	PSSA 64/4552
14a	Tullich seismic and magnetic	1964	Planet Exploration	Namco International	"	60	-	PSSA 64/4571
14b	Otway and Sydney Basin Seismic	1964	BMR	Seismograph Service	Vibroseis	150	2 & 3	BMR Rec. 1965/198

APPENDIX 2 Contd.

Onshore seismic surveys

Map key number	Survey name	Year	Operator	Contractor	Seismic energy source	Traverse length (km)	CDP coverage (fold)	Reference or file number ✓
15	Kalangadoo-Lucindale seismic*	1965	Alliance Oil	Namco International	Explosives	135	1	PSSA 65/4582
15a	Otway Basin seismic	1965	BMR	-	Explosives	10	1	BMR Rec 1966/25
15b	Gambier seismic	1965	BMR		"	15	1	BMR Rec. 1966/176
15c	SE Australia seismic	pre-1965	South Australian Department of Mines	-	"	500?	-	SA Dept of Mines
16	Port Fairy-Nelson seismic	1966	Shell Development	United Geophysical	"	177	1 & 3	PSSA 66/11062
17	Caroline-Killanoola seismic*	1966	Alliance Oil	Namco Geophysical	"	100	1	PSSA 66/11108
18	Bahgallah seismic	1967	Planet Exploration	Petty Geophysical	"	30	1 & 6	PSSA 67/11147
19	Mt Schank seismic	1967	Alliance Oil	Namco Geophysical	"	13	6	PSSA 67/11189
19a	East Otway seismic	1967	BMR	-	"	61	1	BMR Rec. 74/186
20	Hawkesdale seismic	1968	Shell Development	GSI #	"	386	6	PSSA 68/3053
21	Otway 069A seismic	1969	Esso Exploration	Geophysical Associates	"	293	3 & 6	PSSA 69/3003
22	MacArthur-Portland seismic*	1969-70	Shell Development	GSI #	"	362	6	PSSA 69/3080
23	Gambier Trough seismic	1970	Alliance Oil	Ray Geophysical	Weight drop	93	6	PSSA 70/210
24	Wannon seismic	1970	" "	" "	"	24	6	PSSA 70/425
25	Warrnambool-Pomborneit seismic	1970-71	Shell Development	GSI #	Vibroseis Explosives	421	6 & 12	PSSA 70/926
26	Nelson-Koroit seismic	1970-71	Shell Development	Petty Geophysical	Explosives	225	6 & 12	PSSA 70/963
27	Otway 071A seismic	1971	Esso Standard Oil	Ray Geophysical	Weight drop	158	6 & 12	PSSA 71/74
28	Dartmoor seismic	1972	Shell Development	Ray Geophysical	"	217	12	PSSA 72/757
29	Colac-Geelong seismic	1972	Shell Development	GSI #	Vibroseis	265	12	PSSA 72/805
30	Paraparap seismic	1972	Pursuit Oil	Geophysical Exploration Services	Explosives	54	6	PSSA 72/831
31	Otway Coastal Strip seismic	1973	Shell Development	Mandrel Industries	Weight drop	236	12	PSSA 73/200

APPENDIX 2 Contd.

Onshore seismic surveys

Map key number	Survey name	Year	Operator	Contractor	Seismic energy source	Traverse length (km)	CDP coverage (fold)	Reference or file number ✓
32	Tartwaup seismic	1973-74	Alliance Oil	Seismograph Service	Vibroseis	308	12 & 24	PSSA 73/245
33	Ross Creek seismic	1973	Shell Development	Seismograph Service	"	12	12	PSSA 73/264
34	Lake Mundi seismic	1974	Planet Exploration	Geophysical Exploration Services	Explosives	43	6	PSSA 74/214

* Includes refraction seismic

Geophysical Service International

✓ The letters PSSA preceding a file number indicate that the operation was subsidised.

APPENDIX 2 Contd.

Offshore seismic surveys

Map key number	Survey name	Year	Operator	Contractor	Seismic energy source	Traverse length (km)	CDP coverage (fold)	Reference or file number
35	Southwest Victoria seismic	1961	Frome-Broken Hill	GSI #	Gas gun	314	1	PSSA 62/1553
35a	Flinders Island to Kingston seismic	1962-3	Hematite Explorations	Western Geophysical	Explosives	1200	1	PSSA 62/1645
35b	Warrnambool-Princetown seismic	1962	Frome-Broken Hill	GSI #	-	-	-	Unsubs. F-BH (1961b)
36	Southwest Victoria seismic	1963	Frome-Broken Hill	Western Geophysical	Explosives	1080	1	PSSA 63/1511
37	Cape Grim to Cape Jaffa seismic	1964-5	Hematite Explorations	Western Geophysical	"	3015	1 & 3	PSSA 64/4561
38	Offshore Otway Basin seismic	1965-6	Shell Development	Western Geophysical	"	1770	6	PSSA 65/11052
39	Otway seismic	1966-7	Esso Exploration	GSI #	"	3800	6	PSSA 66/11121
40	PEP 22-D1 seismic*	1966	Shell Development	Western Geophysical	"	779	6	PSSA 66/11124
41	Cape Bridgewater seismic*	1967	Shell Development	GSI #	"	15	-	PSSA 67/11175
41a	ESSA R.V. Oceanographic cruise seismic, gravity and magnetic	1967	Atlantic Oceanic Labs	-	Airgun	-	-	Von der Borch (1967)
42	Otway EP-67 seismic and magnetic	1967-8	Esso Exploration	GSI #	"	1593	12	PSSA 67/11188
43	Tasmania EE-68 seismic and magnetic	1968	Esso Exploration	Western Geophysical	Aquapulse	291	"	PSSA 68/3013
44	Otway ER-68 seismic and magnetic	1968	Esso Exploration	Western Geophysical	"	1786	"	PSSA 68/3036
45	Otway EU-68 seismic and magnetic	1968	Esso Exploration	Western Geophysical	"	83	"	PSSA 68/3052
46	West Tasmania T69A seismic and magnetic	1969	Esso Exploration	Western Geophysical	"	475	"	PSSA 69/3000
47	Geltwood Beach seismo	1969	Beach Petroleum	Geoseismic	Aquaflex	28	6	PSSA 69/3019
48	Tasman-Bass Strait seismic and magnetic	1969	Magellan Petroleum	Teledyne Exploration	Sparker	1369	1	PSSA 69/3023
49	Otway 069B seismic and magnetic	1969	Esso Exploration	Western Geophysical	Aquapulse	331	12	PSSA 69/3061
49a	West Tasmania T70A seismic	1970	Esso Exploration	Western Geophysical	"	140	"	P(SL)A 70/7

APPENDIX 2 Contd.

Offshore seismic surveys

Map key number	Survey name	Year	Operator	Contractor	Seismic energy source	Traverse length (km)	CDP coverage (fold)	Reference or file number
50	Baudin seismic and magnetic	1970	Hematite Petroleum	Western Geophysical	Aquapulse	490	3 & 12	PSSA 70/178
50a	West Tasmania T70C seismic	1970-71	Esso Exploration	GSI #	Airgun	20	24	P(SL)A 71/7
51	Torquay Embayment seismic and magnetic	1971-72	Esso Exploration	" #	"	225	24	PSSA 71/883
52	Otway Basin-072A seismic	1971-2	Esso Australia	" #	"	581	24	P(SL)A 72/10
53	Otway Basin-072B seismic	1972	Esso Australia	" #	"	199	48	P(SL)A 72/11
54	Port Macdonnel seismic	1972	Alliance Oil	Geosurveys	Aquaseis	71	3	PSSA 72/1089
55	Shell Deepwater Scientific seismic gravity and magnetic	1972-3	Shell	Shell BIPM.	Airgun	1400	24	P(SL)A 72/30
56	Portland-King Island (H02) seismic	1972	Hematite Petroleum	GSI #	"	268	48	PSSA 72/3020
57	Otway Basin -073A seismic	1973	Esso Australia	" #	"	166	24	P(SL)A 73/3
58	Cape Nelson-Cape Otway (H03) seismic*	1973	Hematite Petroleum	" #	"	2894	24	PSSA 73/257
59	Cape Otway seismic* and magnetic	1973	Interstate Oil	" #	"	408	24	PSSA 73/266
60	Otway Basin (H04) seismic* and magnetic	1974	Hematite Petroleum	" #	"	1369	48 & 72	P(SL)A 74/20
61	Princetown seismic and magnetic	1975	Interstate Oil	" #	"	252	24	P(SL)A 75/1
62	BMR Continental Margin seismic, gravity and magnetic	1972	BMR	Compagnie General de Geophysique	Sparker	4000	1	BMR Rec. 74/15

* Includes refraction seismic.

\# Geophysical Service International.

APPENDIX 3

STRATIGRAPHIC TABLES, OTWAY BASIN REGION

ESSO NAUTILUS A-1

K.B. 28.4
W.D. 99.7

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Miocene-Oligocene	Port Campbell Limestone	?128.1-1-381.3	253.2	calcarenite from 304.8 m
	Gellibrand Marl equivalent	381.3-417.9	36.6	hard calcareous siltstone and marl
		-491.1	73.2	clayey siltstone, minor traces coal & glauconite
		-674.1	183.0	siltstone with about 20% fragments of bryozoa etc.
		-826.6	152.5	marl, fossiliferous; 20-40% limestone
		-866.2	39.6	75 to 90% limestone; the rest is shale
		-1073.6	207.4	40-60% limestone; rest is dark shale
		-1232.2	158.6	75-100% shale; rest is limestone
		-1244.4	12.2	shale
		1244.4-1616.5	372.1	shale with from 10% to 50% limestone
		-1724.2	107.7	50%-100% limestone, hard, finely granular; the rest is shale, very hard
	Basal Tertiary sand	1724.2-1744.6	20.4	70%-80% limestone 20%-30% sand
Late Cretaceous	Sherbrook Group Belfast Mudstone	1744.6 to T.D. at 2012.1	267.5+	shale, blackish, non-calcareous, trace pyrite

SHELL ROWANS NO. 1

R.T. 70.76 m
G.L. 66.49 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
	Heytesbury Group			
	Port Campbell Limestone	0-239.1		chiefly grainstone; minor packstone; glauconitic in part
	Gellibrand Marl	239.1-580.1		glauconitic, fossiliferous
	Clifton Formation	580.1-597.8		limestone limonitic, sandy; some quartz sandstone
	Nirranda Group			
	Narrawaturk Marl	597.8-642.3		slightly glauconitic fossiliferous
	Mepunga Formation	642.3-805.2		chiefly quartz sand, with sandstone, siltstone, marl.
	Wangerrip Group	805.2-1001.9		interbedded quartz sands and siltstone
	Sherbrook Group			
	Paaratte/Curdies Formations	1001.9-1256.6		interbedded chiefly quartz sand/sandstone, coarse and fine-grained; minor siltstone; some thin coal
		-1271.9		siltstone and quartz sandstone, interbedded
		-1369.5		predominantly soluble clays; minor siltstone
	Nullawarre Greensand	1369.5-1525		quartz sandstone, unconsolidated, dominantly coarse, cemented with green chlorite(?); minor siltstone, glauconitic
	Belfast Mudstone	1525 -1554.6		claystone, very glauconitic; sandy in upper part
	Flaxmans Formation	1554.6-1589.4		quartz sands and soluble clays; sandy glauconitic dolomite near base; basal clay bed
	Waarre Formation	1589.4-1631.8		quartz sandstone loosely consolidated, dominantly medium-grained, carbonaceous, minor claystone and siltstone
	Otway Group	1631.8 to T.D. at 1799.5		lithic sandstones, minor claystone and siltstones; thin coals

INTERSTATE/SHELL GARVOC NO. 1

K.B. 110.7
G.L. 107.4

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Recent-Pleistocene	Newer Volcanics		24.1	basalt
Miocene-Oligocene	Heytesbury Group			
	Port Campbell Limestone	27.5- 198.3	170.8	white, soft, vuggy, shell fragments
	Gellibrand Marl	198.3- 478.9	280.6	
	Clifton Formation	478.9- 518.5	39.6	sandstone, calcareous
Eocene	Nirranda Group			
	Narrawaturk Marl	518.5- 587.1	68.6	marl, grey, sandstone, fine-grained, calcareous, greenish
	Mepunga Formation	587.1- 663.4	76.3	sandstone, clean, coarse; with brown siltstone, argillaceous, sideritic
Early Cretaceous	Otway Group			
	Eumeralla Formation	663.4-1049.2	385.8	interbedded sandstones and siltstones; traces of coal and pyrite
	Geltwood Beach Formation	1049.2-1363.4	314.2	interbedded sandstones, siltstones, shale; traces of coal
	Pretty Hill Sandstone	1363.4-1515.9	152.5	medium-grained to conglomeratic; minor siltstone and traces of shale, pyrite and coal
Pre-Mesozoic		1515.9 to T.D. at 1535.7	19.8+	quartz-mica schist

ESSO CLAM NO. 1

K.B. 30.2
W.D. 101.9

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Miocene	Port Campbell Limestone	132.1- 323.3	191.2	limestone hard, fossiliferous
Oligocene	Jan Juc Marl (Gellibrand equivalent)	323.3- 417.2	93.9	marl with interbedded limestone; lowermost 12 m is reddish brown soft mudstone
Eocene	Browns Creek Group equivalent	417.2- 543.8	126.6	sandstone, quartz, unconsolidated, clean. Resembles Mepunga
Paleocene	Wangerrip Group			
	Rivernook Formation	543.8- 631.4	87.6	mudstone, with loose, silty fine-grained quartz sandstone
	Dilwyn Formation	631.4- 850.3	218.9	sandstone, massive, with a few thin argillaceous interbeds
Late Cretaceous-Early Palaeocene	"Clam Conglomerate"	850.3- 955.6	105.3	well-rounded pebble-to-cobble conglomerate of quartzite and chert
Late Cretaceous	Sherbrook Group			
	Curdies-Paaratte Formations undifferentiated	955.6-1253.6	298.0	quartz sand, loose, porous, fine to medium-grained; some interbeds of hard siltstones
	Belfast Mudstone	1253.6-1281.0	27.4	mudstone, light to brown-grey
	Waarre Formation	1281.0-1303.0	22.0	sandy siltstone and silty sandstone of very low porosity - the pinching out extremity of the Waarre Fm.
? Devonian-Carboniferous	"red beds"	1303.0-1493.3	190.3	varicolored siltstone pebbles and cobbles in brick-red siltstone; unfossiliferous
? Early Palaeozoic		1493.3-1541.2	47.9	siltstone; unfossiliferous
Pre-Cambrian	Rocky Cape Group	1541.2 to T.D. at 1623.5	82.3+	phyllite

ESSO ARGONAUT A-1

K.B. 28.3 m
W.D. 77.1 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Miocene-Oligocene	Gambier Limestone	268.2- 310.1	41.9	coquina limestone, very soft, porous, permeable
		310.1- 326.1	16.0	50% coquina limestone, 50% siltstone, soft brown, calcareous and carbonaceous
Late Eocene	Kingston Greensand	326.1- 354.2	28.1	sand grains, very coarse to pebbly; traces of pyrite, coal, glauconite
Eocene-Paleocene	Knight Group, undifferentiated	354.2- 426.7	72.5	sand grains, very coarse to pebbly + 15% to 25% brown carbonaceous siltstone
		426.7- 498.3	71.6	clay, brown, carbonaceous
		498.3- 536.8	38.5	sand grains, medium grained to very coarse; some clay
		536.8- 566.9	30.1	60%-80% clay, brown silty + 20%-40% sand as above
		566.9- 624.8	57.9	clay, silty; sand, fine to very coarse; much pyrite
		624.8- 649.2	24.4	silt, and sand fine to pebble-size with some lithics
		649.2- 710.2	61.0	clay, silty; 40% sand very fine to coarse; partly micaceous, pyritic carbonaceous
	Bahgallah Formation (Pebble Point equivalent)	710.2- 726.9	16.7	sand, quartz, loose fine to very coarse; pyrite
Late Cretaceous	Sherbrook Group Curdies-Paarratte undifferentiated	726.9- 996.7	269.8	60% sand, fine to coarse, subangular to rounded quartz, 30% siltstone, grey, hard, 10% coal
		996.7-1554.5	557.8	60% sand, white, clear, fine to coarse, subangular to subrounded; 40% silty mudstone, grey-brown
		1554.5-2316.5	762.0	90% sand, unconsolidated, fine to very coarse; 10% siltstone, grey
		2316.5-3063.2	746.7	50% sand, as above 50% shale, blackish, very carbonaceous

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
	Belfast Mudstone	3063.2-3544.8	481.6	shale, blackish, very carbonaceous, silty and sandy in part, slightly pyritic
	Waarre Sandstone	3544.8 - T.D. at 3707.2	162.4+	sandstone, clear to white, very fine to medium generally non-porous; shale, grey with abundant glauconite

ESSO MUSSEL NO. 1

R.T. 30.2 m
W.D. 85.3 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Tertiary				
Miocene-Oligocene	Port Campbell Limestone	115.5- 411.5	296.0	no samples, but assumed to be a porous calcarenite with abundant fossils (coquina)
	Gellibrand Marl	411.5- 847.3	435.8	gradational from Port Campbell Lst.
	Clifton Formation	847.3- 862.6	15.3	pinkish limestone, correlated with Prawn-1, and Port Campbell
Eocene	Browns Creek Group			
	Narrawaturk Marl	862.6- 984.5	121.9	greenish
	Mepunga Sandstone	984.5-1242.4	257.9	upper 120 m quartzose, coarsening upwards, with up to 30% calcareous fossil fragments lower 130 m is interbedded sst and siltstone
Paleocene	Wangerrip Group			
	Rivernook Formation	1242.4-1296	53.6	siltstone, quartzose, dark brown
	Pebble Point Formation	1296 -1399.6	103.6	sandstone, medium to coarse-grained, with silty nodules in upper 10 m, and interbeds of siltstone and shale in lower 60 m
Mesozoic				
Late Cretaceous	Sherbrook Group			
	Belfast Mudstone	1399.6-2010.1	610.5	monotonous column of shaley siltstone to silty shale; sand interbeds in upper 100 m.
	Flaxmans Formation	2010.1-2083.6	73.5	shaley siltstone with interbeds of silty sandstone
	Waarre Formation	2083.6-2225.0	141.4	sandstone fine to medium-grained, well-sorted, subangular/subrounded, friable quartz sand; thinly interbedded with black carbonaceous shale. Porosities up to 25.5% and permeabilities up to 1650 MD
Early Cretaceous	Otway Group	2225.0 to T.D. at 2450	225 +	shale, dark grey, interbedded with dolomitic and carbonaceous siltstones; medium to very coarse sandstone lenses; coal

ESSO CRAYFISH A-1

K.B. 28.4 m
W.D. 49.4 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Miocene-Oligocene	Gambier Limestone	239.3- 334	94.7	siltstone, calcareous, glauconitic, with chert; limestone coquina, sandy, glauconitic
Eocene-Paleocene	Wangerrip (Knight) Group	334.0- 365.8	31.8	mudstone; marl; sandstone fine-grained, tight, hard
Late Cretaceous	Sherbrook Group	365.8- 477	111.2	sandstone, fine coarse-grained clear quartzose, partly pyritic, very minor coal in upper 15 m
Early Cretaceous	Otway Group	477 - 557.8	80.8	sandstone, quartzose, pyritic, with soft clay
		557.8- 762	204.2	mudstone, glauconitic, pyritic; mudstone quartzose, sandy; siltstone; sandstone, fine-grained, quartzose, glauconitic pyritic.
		762 -1173.5	411.5	clay, mudstone, shale, and siltstone, mostly carbonaceous; coal in rare thin beds
		1173.5-1597.2	423.7	shale and sandstone, carbonaceous pyritic, in part glauconitic. Some coal
	Pretty Hill equivalent	1597.2-2301.2	704.0	60% sandstone fine to medium grained, in part unconsolidated 40% shale carbonaceous, with quartzose siltstone; coal in occasional thin bands
		2301.2 to T.D. at 3199.5	898.3+	sandstone, somewhat arkosic; up to 40% shale, carbonaceous

BEACH PETROLEUM GELTWOOD BEACH NO. 1

K.B. 9.2 m
G.L. 4.6 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Quaternary		4.6- 18.3	13.7	calcareous sand
Miocene-Oligocene	Gambier Limestone	18.3- 298.6	280.3	bryozoan limestone
Late Eocene	Buccleuch Group	298.6- 301.8	3.2	green clay and ferruginous quartz grit
Middle-Early Eocene	Knight Group	301.8- 585.2	283.4	brown sand and grit, with some carbonaceous siltstone, passing down into brown-grey sandstone
Paleocene-Late Cretaceous	?	585.2-1121.7	536.5	grey quartz grit and pebbly mudstone passing down into feldspathic sandstone
Cenomanian-Albian	"Merino Group"	1121.7-2170.2	1048.5	sandstones and siltstones
Albian-Aptian	"Runnymede Formation"	2170.2 to T.D. at 3749.0	1578.8	interbedded mudstones and sandstones

SOUTH EAST OIL SYNDICATE BEACHPORT NO. 1

R.T. 5.5 m
G.L. 4.0 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Quaternary		0- 85.3	85.3	unconsolidated shell sand, sandy limestones and flint
Early Oligocene	Gambier Limestone	85.3-256.0	170.7	limestone, bryozoal, marl, flint
		234.7-256.0	21.3	basal glauconitic member
Late Eocene	Buccleuch Group (upper part)	256.0-274.3	18.3	marl, green, glauconitic; clay, sideritic; unconsolidated quartz grains and pebbles at base
Late to Middle Eocene	Knight Group	274.3-554.7	280.4	sands, quartz, and clays, unconsolidated
Late Cretaceous ?	Pa~~a~~ratte or Waarre Formation	554.7-582.2	27.5	interbeds of black pyritic slightly feldspathic sandstone, and quartz sands and pebbles
Early Cretaceous	Merino Group	582.2 - T.D. at 1207.9	625.7+	mudstone, carbonaceous, siltstone and sandstone; calcareous sandstone and limestone; lignite and coal near base of penetrated formation

FROME-BROKEN HILL EUMERALLA NO. 1

R.T. 50.9
G.L. 46.9

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Oligocene	Glenelg/Heytesbury Group			
	Portland Limestone	0- 16.8	16.8	limestone, porous, fossiliferous, freshwater-bearing
	Heywood Marl	16.8-307.0	290.2	
	Nelson Formation	307.0-386.5	79.5	sandy siltstone to silty marl, calcareous, limonitic
Eocene	Knight/Wangerrip Group (undifferentiated)	386.5-835.2	448.7	sandstones and siltstones interbedded; pyrite, coal, limonite; dolomitic bands towards base
Late Cretaceous	Sherbrook Group			
	Paarratte Formation	835.2-902.2	67.0	interbedded grey-brown siltstones in part glauconitic, and fine to medium-grained porous quartz sandstones, in part dolomitic
	Belfast Mudstone	902.2-947.3	45.1	siltstone, sandy, very fossiliferous, very glauconitic towards base
Early Cretaceous	Otway Group	947.3 to T.D. at 3141.9	2194.6+	interbedded sandstones-siltstones-mudstones to about 1920 m, then a monotonous carbonaceous siltstone-mudstone sequence to 2774 m, below which cleaner, more porous and permeable sandstones occur as interbeds

FROME-BROKEN HILL PRETTY HILL NO. 1

R.T. 61.6
G.L. 57.6

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Miocene-Oligocene	Heytesbury/Glenelg Group			
	Portland Limestone	0- 128.0	128.0	
		128- 341.4	213.4	soft blue-grey marl
	Heywood Marl	341.4- 382.8	41.4	limestone, with some grey marl
Eocene-Paleocene	Knight/Wangerrip Group	382.8- 722.4	339.6	sandstone, medium to coarse-grained, with grey-brown siltstone interbeds. Dolomite near base
Late Cretaceous	Paarratte Formation	722.4- 791.8	69.4	interbedded siltstones and sandstones, in part carbonaceous, pyritic, quartzose, few dolomite bands
	Belfast Mudstone	791.8- 844.3	52.5	sandy siltstones, glauconitic
	Flaxmans Formation	844.3- 890.6	46.3	sandstone, limonitic, medium to very coarse-grained, with grey glaunconitic sst.
Early Cretaceous	Otway Group	890.6-1817.8	927.2	sandstones, siltstones, mudstones
	Basal sandstone	1817.8-2400	583.2	clear quartz grains, fine to coarse, very porous Some coaly matter
"Basement Complex"		2400 to T.D. at 2477.7		"diabase"

SHELL NERITA NO. 1

D.F. 34.2 m
W.D. 74.7 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Early Miocene-Latest Oligocene	Torquay Group ?Puebla Formation	-188.5		marl (no cuttings above 185.5)
	Jan Juc Formation Point Addis Limestone Member	188.5-227.5	39.0	bioclastic lime packstone
		-259.6	32.1	marl, with packstone
		-297.1	38.1	grainstone, packstone, and wackestone
		-359.9	62.2	marl, with packstone and wackestone
Eocene-Oligocene	Demons Bluff Formation	359.9-389.8	29.9	chiefly quartz sand, with streaks of clay and dolomite
	Anglesea Siltstone Member	389.8-637.8	248.0	claystone and shale
	Boonah Sandstone	637.8-779.3	141.5	quartz sand, with minor claystone, silt, and coal
Eocene-Paleocene	Eastern View Coal Measures	779.3 to T.D.at 2043.5	1264.2+	quartz sand and sandstones, interbedded with claystone, siltstone, some coal seams, minor dolomite, and dolomite cement

HEMATITE SNAIL NO. 1

K.B. 9.8 m
W.D. 81.1 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Miocene	Torquay Group Puebla Formation	90.9-455.1	364.2	claystone and marl, with bioclastics and minor siltstone and sandstone
Late Eocene-Oligocene	Jan Juc Formation	455.1-648.4	193.3	glauconitic claystone and marl, with interbedded siltstone, calcarenite, sandstone, sand and fossiliferous limestone. The upper limestone may correlate with the Point Addis Lst of Nerita No. 1
Eocene	Demons Bluff Formation	648.4-784.5	136.1	monotonous, silty, glauconitic, claystone, of Anglesea Siltstone Member onshore
Eocene- Mid Paleocene	Eastern View Coal Measures	784.5-885.7	101.2	sandstone, poorly consolidated, clay-choked, glauconitic; minor beds of carbonaceous claystone, clayey sand, and very minor shale and dolomite
Early Cretaceous	Otway Group	885.7 to T.D. at 1235.6	349.9+	sandstone, lithic, zeolitic, kaolinitic(?), with minor carbonaceous siltstone

SHELL PECTEN NO. 1 & 1A

D.F. 34.13
W.D. 62.5

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
?Pleistocene				limestone
Oligocene-Miocene	Heytesbury Group			
	Limestone unit	167.6- 381.0	213.4	limestone, bioclastic, glauconitic, with some marl, silty and sandy
	Marl unit	381.0- 573.0	192.0	marl with some limestone
Late Eocene	Nirranda Group			
	Narrawaturk Marl	573 - 655.3	82.3	marl, green-grey; minor bioclastic limestone
	Mepunga Formation	655.3- 801.6		quartz sandstone, upper part limonitic, lower part white; glauconitic crystalline limestone 724 to 732 m, and thin clay beds
Paleocene-Eocene	Wangerrip Group			
	Dilwyn Formation	801.6-1057.1	255.5	silt, lignitic, interbedded with quartz sandstone, fine to very coarse-grained. 9601 to 1028 = Riverrook Member
Late Cretaceous	Sherbrook Group			
	Curdies Formation	1057.1-1436.5	379.4	in upper part quartz sandstone interbedded with clay and silt, glauconitic, trace of coal near top; in lower part, shale and minor sandstone, both glauconitic
	Paarratte Formation	1436.5-1607.5	171.0	1436.5-1521.9 Quartz sandstone, with interbeds of shale, siltstone; glauconitic
				1521.9-1607.5 Clay interbedded with silt; as above
	Belfast Mudstone	1607.5-1739.2	131.7	siltstone, glauconitic; minor quartz sandstone
	Flaxmans Formation	1739.2-1770.9	31.7	siltstone, glauconitic, interbedded with quartz sandstone, dense, white
	Waarre Formation	1770.9-1792.1	26.2	quartz sandstone, dense, fine-grained; minor clay, and unconsolidated medium to coarse-grained quartz sandstone

SHELL PECTEN NO. 1 & 1A (contd.)

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Early Cretaceous	Otway Group			
	Unit 1	1797.1-2273.8	476.7	sandstone sublithic-subfeldspathic, dense, interbedded with siltstone, claystone and traces of coal
	Unit 2	2273.8 to T.D. at 2852.4	578.6+	interbedded sandstone, siltstone, claystone, coal traces, as above

SHELL VOLUTA NO. 1

D.F. 34.1 m
D.W. 91.7 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Pleistocene				dune limestone
Late Miocene				clay
Middle Miocene				limestone
Early Miocene-Oligocene	Heytesbury Group Mount Gambier Formation			
	Upper Unit	294.5- 444.8	150.3	bioclastic lime grainstone
		444.8- 502.3	57.5	marl interbedded with bioclastic lime grainstone
	Middle Unit	502.3- 702.6	200.3	dolomites
	Lower Unit	702.6- 816.6	114.0	marls and limestones, with some clay and siltstone beds
	Nelson Formation	816.6- 839.4	22.8	quartz sand, porous, medium to fine-grained
Paleocene	Wangerrip Group Dilwyn Formation	839.4-1275.6	436.2	interbedded sandstones, claystones, siltstones; some coal seams
	Rivernook Member	1275.6-1303.0	27.4	claystone, silty; minor siltstone and sand
	Pebble Point Formation	1303 -1336.6	33.6	quartz sand, coarse, ferruginous; minor silty clay
Late Cretaceous	Sherbrook Group Curdies Formation	1336.6-1548.4	211.8	quartz sand, fine to coarse, unconsolidated, some silty claystone/shale; rare coal
	Paarratte Formation	1548.4-2164.1	615.7	quartz sandstones interbedded with clayey siltstones; some streaks of dolomite or dolomite cement; in part carbonaceous, glauconitic, pyritic
	Belfast Mudstone	2164.1 to T.D. at 3973.7	809.6+	an upper and a lower sandstone/siltstone/shale unit separated by a siltstone unit

INTERSTATE OIL WOOLSTHORPE NO. 1

K.B. 125.3
G.L. 121.9

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Recent-Pleistocene	Newer Volcanics	3.4- 36.6	33.3	
Pleistocene-?Pliocene	?Whalers Bluff Formation	36.6- 45.7	9.1	sandstone, yellow-brown, fine to coarse-grained, poorly sorted
Miocene-Oligocene	Heytesbury Group			
	Port Campbell Limestone	45.7- 176.8	131.1	
	Gellibrand Marl	176.8- 283.5	106.7	
	Clifton Formation	283.5- 317	33.5	limestone and sandstone
Early Cretaceous	Otway Group			
	Eumeralla Formation	317.0-1082.0	765.0	sandstone, fine to medium-grained, lithic, tight, micaceous, carbonaceous, argillaceous; siltstone and shale as above; minor coal, coarse sandstone at base
	Geltwood Beach Formation	1082 -1460	378.0	interbeds of siltstone and shale, micaceous and carbonaceous, with minor sandstone; traces of coal
	Pretty Hill Sandstone	1460 -1822.7	362.7	sandstones, with interbeds of carbonaceous silt-stone and shale
	Casterton Beds	1822.7-1947.7	125.0	interbeds of siltstone, shale, sandstone quartzose, lithic, micaceous, carbonaceous, argillaceous; minor coal
?Late Jurassic		1947.7 to T.D. at 1971.1	23.4+	basalt

ALLIANCE CAROLINE NO. 1

K.B. 37.5 m
G.L. 32.6 m

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
Quaternary		4.9- 7.9	3.0	unconsolidated quartz sand
Miocene-Oligocene	Glenelg Group			
	Gambier Formation	7.9-195.1	187.2	bioclastic limestone, calcarenite and dolomite; some marl, sandstone and chert
Late Eocene	"Browns Creek Group" equivalent			
	Nelson Formation	195.1-198.7	3.6	no samples, possibly a very coarse-grained sandstone
Eocene-Paleocene	Wangerrip Group			
	Dilwyn Formation:			
	Unit 1	198.7-600.5	401.8	sandstone poorly consolidated and poorly sorted; 25% interbedded siltstone + some clay and rare coal stringers
	Unit 2	600.5-740.7	140.2	fine-grained sandstone and about 35% siltstone
	Unit 3	740.7-926.6	185.9	poor recovery, chiefly brownish lutites, with pale sandstones
Paleocene	Pebble Point Formation	926.6-951.9	25.3	sandstone, pebble conglomerate, some limonite ooliths
Late Cretaceous	Sherbrook Group			
	Curdies Formation	951.9-1210.1	258.2	sandstone, poorly sorted, weakly cemented, very fine to very coarse-grained; siltstone and shale interbeds, and rare stringers of coal
	Paarratte Formation			
	Macdonnel Member	1210.1-1739.2	529.1	sandstone, very friable, with less than 15% interbedded siltstone and shale
	Caroline Member	1739.2-2155.6	416.4	sandstone as above, with 48% interbedded siltstone and shale

ALLIANCE CAROLINE NO. 1 (contd.)

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
	Belfast Mudstone	2155.6-2462.8	307.2	shale or mudstone grading downwards to siltstone with minor sandstone
	Transition Unit	2462.8-2493	30.2	siltstone (like the above), with several sandstone interbeds like those in the Waarre Formation
Late to Early Cretaceous	Otway Group Waarre Formation			
	Unit 1	2493 -2610.6	117.6	orthoquartzite with interbeds of siltstone and shale
	Unit 2	2610.6-2718.8	108.2	shale with some siltstone; 38% interbedded orthoquartzite
	Unit 3	2718.8-2788.9	70.1	protoquartzite and 27% siltstone and shale
	Unit 4	2788.9-2840.7	51.8	protoquartzite and orthoquartzite; 20% siltstone
	Transition Unit	2840.7-2892.6	51.9	interbedded sandstone, siltstone and shale
	Eumeralla Formation	2892.6 to T.D. at 3371.1	478.5+	47% sandstone, 53% interbedded shale and siltstone and traces of coal

FROME-BROKEN HILL PORT CAMPBELL NO. 4

R.T. 134.2
G.L. 130.2

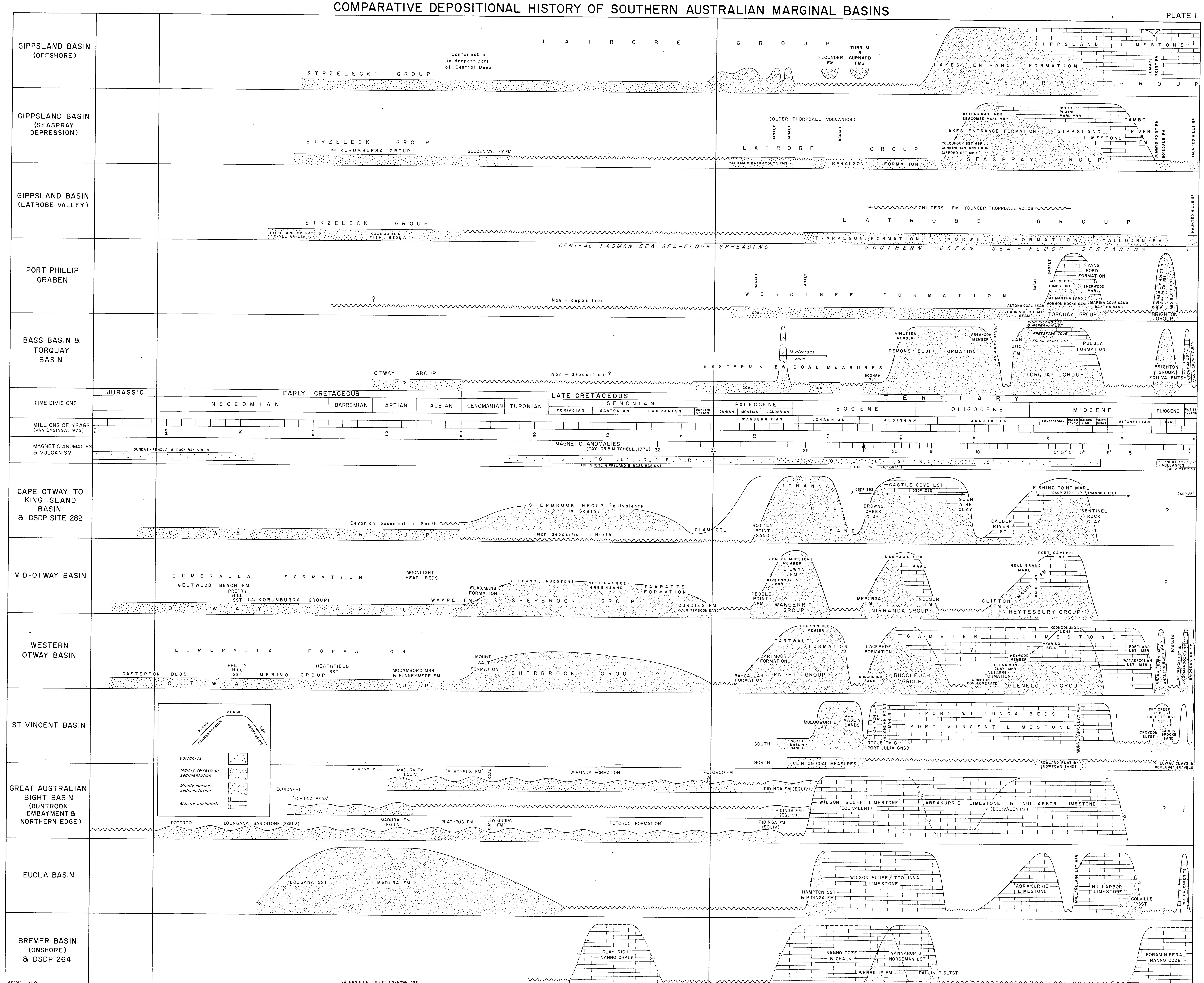
AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
	Heytesbury Group			
	Port Campbell Limestone	0- 72.3	72.3	calcarenite, soft, fossiliferous
	Gellibrand Clay	72.3- 294.0	221.7	marl, glauconitic, fossiliferous
	Clifton Formation	294 - 309.3	15.3	limestone, sandy, glauconitic; quartz grains coarse, angular, ironstained
	Unit 4	309.3- 394.4	85.1	marl, glauconitic, sandy, fossiliferous
	Wangerrip Group			
	Unit 1	394.4- 446.2	51.8	sand, coarse, angular, ironstained, unconsolidated, fossiliferous
	Unit 2	446.2- 633.5	187.3	sand, as above, with brown, micaceous silty clay matrix and interbeds
	Unit 3	633.5- 760.1	126.6	siltstone, glauconitic, chloritic, pyritic with ankerite and dolomite lenses; interbeds of clear, medium to coarse-grained sand
	Unit 4	760.1-1055.9	295.8	sand, clear, medium to coarse-grained carbonaceous, pyritic, with liths of metamorphic and igneous rocks; siltstone, ligneous, glauconitic, grading down to form coal bands
	Sherbrook Group			
	Paarratte Formation	1055.9-1224.0	168.1	siltstone, carbonaceous, interbedded with very fine-grained quartz sandstone, pyritic and glauconitic in parts; thin streaks of coal
	Nullawarre Greensand	1224.0-1339.9	115.9	sandstone, dark green, medium to very coarse-grained

FROME-BROKEN HILL PORT CAMPBELL NO. 4 (contd.)

AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY
	Sherbrook Group contd.			
	Belfast Mudstone	1339.9-1477.7	137.8	siltstone-mudstone, glauconitic, carbonaceous, micaceous, pyritic, fossiliferous
	Flaxmans Formation	1477.7-1516.5	38.8	sandy siltstone. Distinguished from Belfast Mudstone by coarser grains, occurrence of lithic grains, and common oxidation of iron-bearing minerals
	Waarre Formation	1516.5-1626.3	109.8	sandstone, clean, fine to coarse-grained; minor carbonaceous siltstones
	Otway Group			
	Unit 1	1626.3-1687.6	61.3	sandstone, of quartz, feldspar, rock-fragments, mica; in calcareous and chloritic matrix; interbeds of siltstone and mudstone
	Unit 2	1687.6 to T.D. at 2598.6	911.0+	sandstones, in part thick-bedded and massive, interbedded with siltstones and mudstones; thin conglomerates

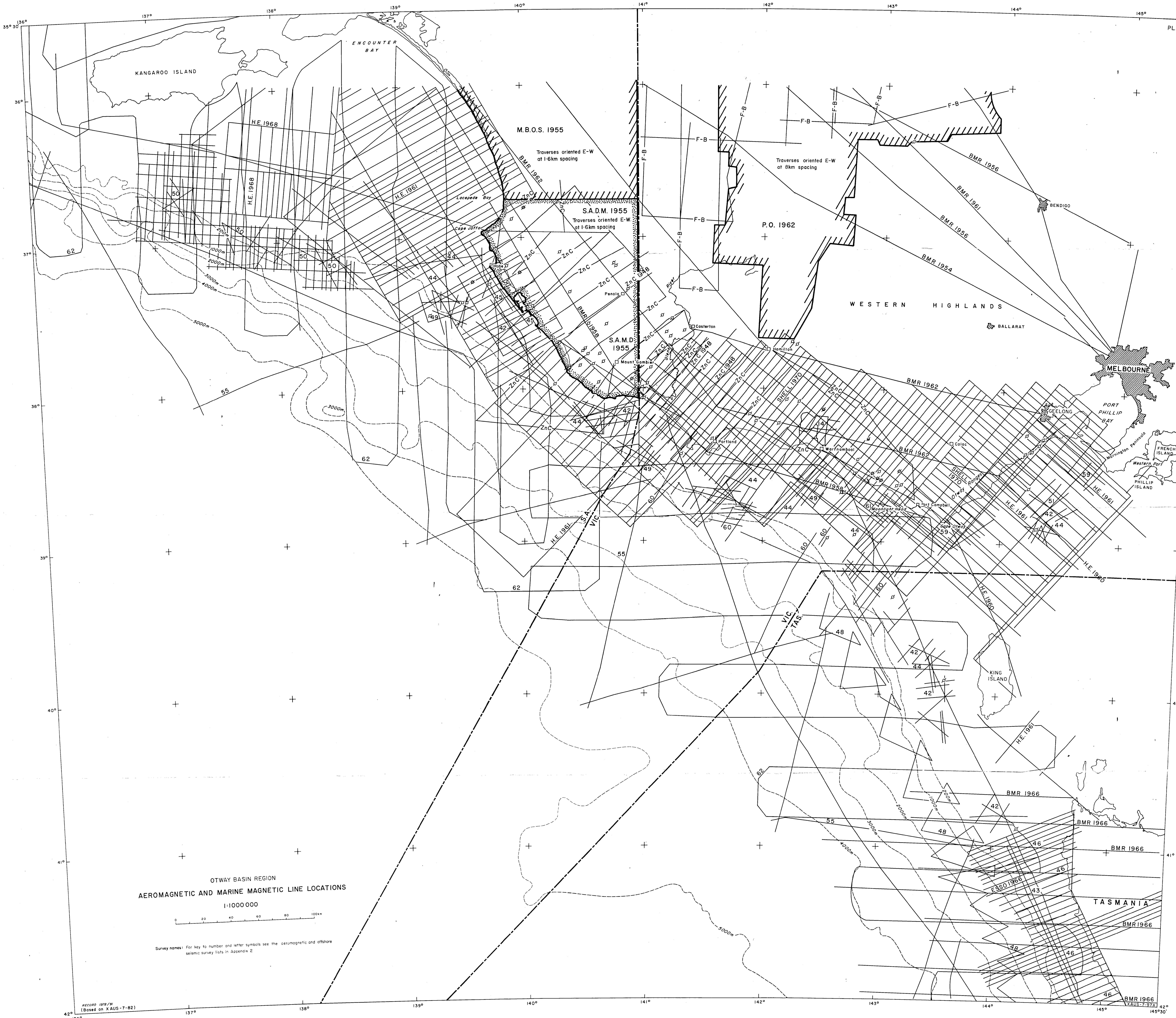
COMPARATIVE DEPOSITIONAL HISTORY OF SOUTHERN AUSTRALIAN MARGINAL BASINS

PLATE I



RECORD 1978/91

XAUS-7-92



OTWAY BASIN REGION

AEROMAGNETIC AND MARINE MAGNETIC LINE LOCATIONS

1:1000000

0 20 40 60 80 100km

Survey names: For key to number and letter symbols see the aeromagnetic and offshore seismic survey lists in Appendix 2.

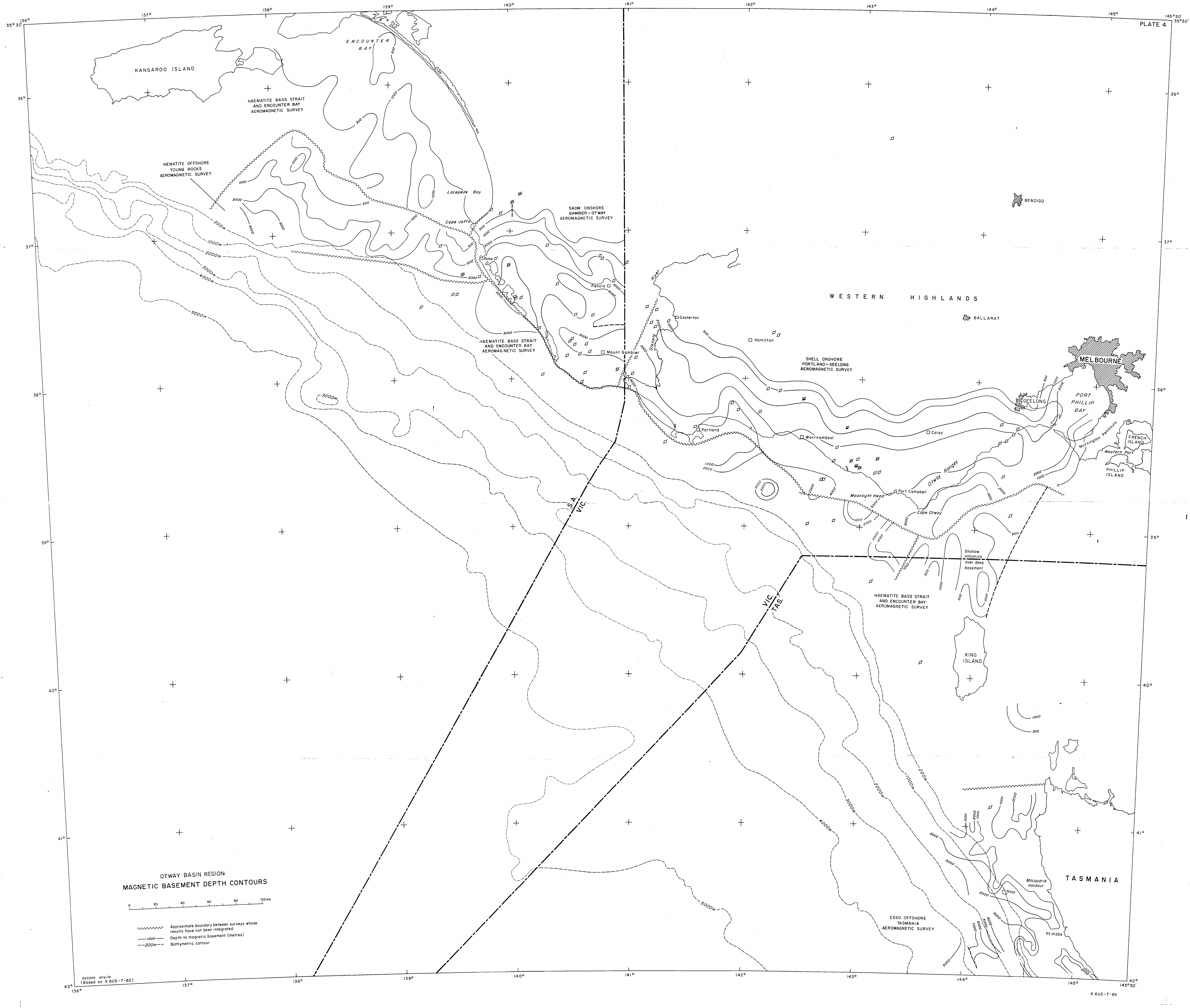


PLATE 4
KANGAROO ISLAND
ENCOUNTER BAY
HAEMATITE BASS STRAIT AND ENCOUNTER BAY AEROMAGNETIC SURVEY
HEMATITE OFFSHORE YOUNG ROCKS AEROMAGNETIC SURVEY
Lacepede Bay
Cape Jaffa
Robe
Penola
Mount Gambier
SADM ONSHORE GAMBIER–OTWAY AEROMAGNETIC SURVEY
BENDIGO
WESTERN HIGHLANDS
BALLARAT
Casterton
Hamilton
Glenelg River
SHELL ONSHORE PORTLAND–GEELONG AEROMAGNETIC SURVEY
MELBOURNE
GEELONG
PORT PHILLIP BAY
Mornington Peninsula
Western Port
FRENCH ISLAND
PHILLIP ISLAND
Portland
Warrnambool
Colac
Otway Ranges
Moonlight Head
Port Campbell
Cape Otway
Shallow volcanics over deep basement
S.A. VIC.
VIC. TAS.
KING ISLAND
TASMANIA
Macquarie Harbour
Pt Hibbs
ESSO OFFSHORE TASMANIA AEROMAGNETIC SURVEY
OTWAY BASIN REGION
MAGNETIC BASEMENT DEPTH CONTOURS
0 20 40 60 80 100 km
Approximate boundary between surveys whose results have not been integrated
1000 Depth to magnetic basement (metres)
200m Bathymetric contour
RECORD 1978/91
(Based on X AUS-7-82)
X AUS-7-89

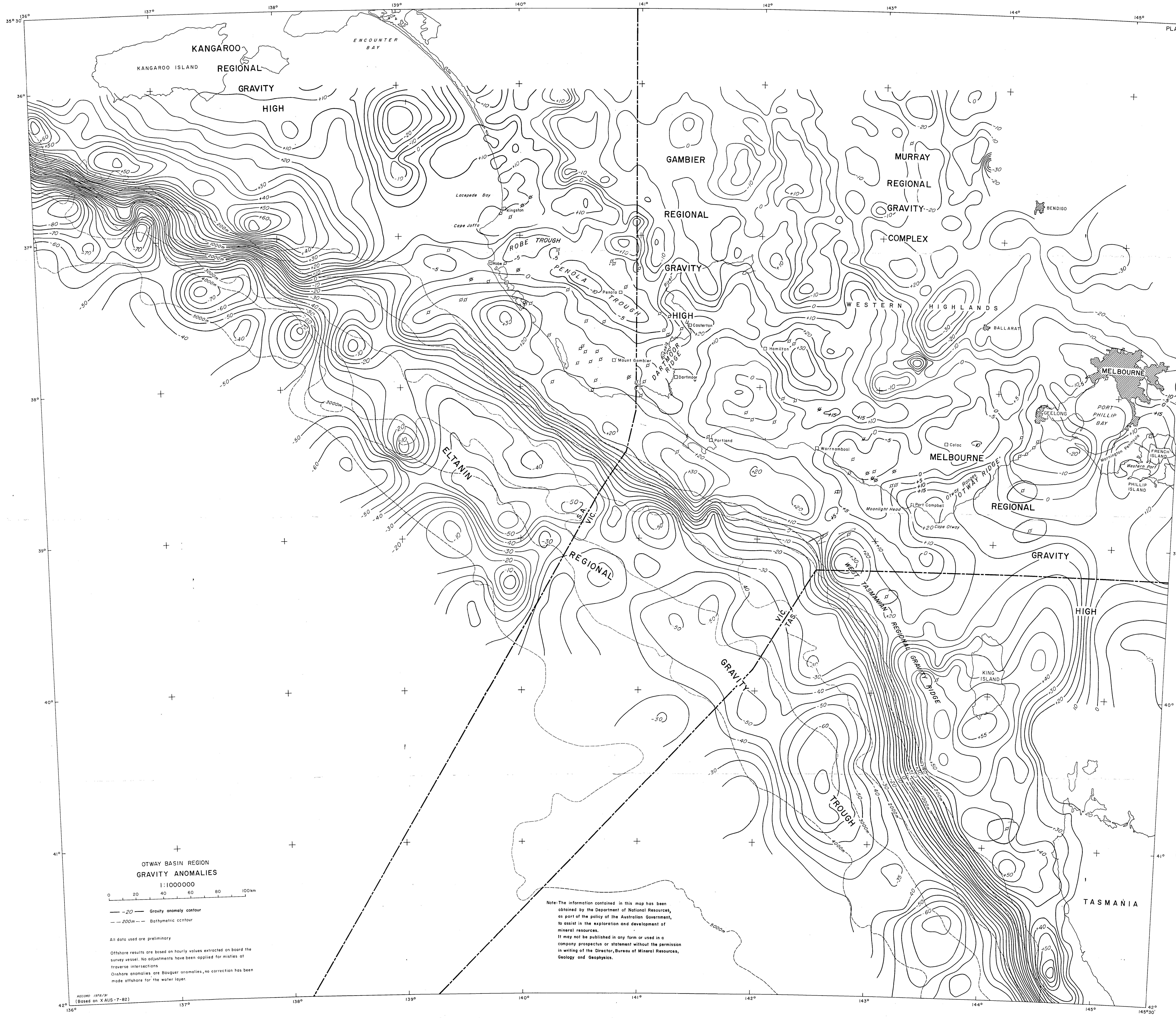
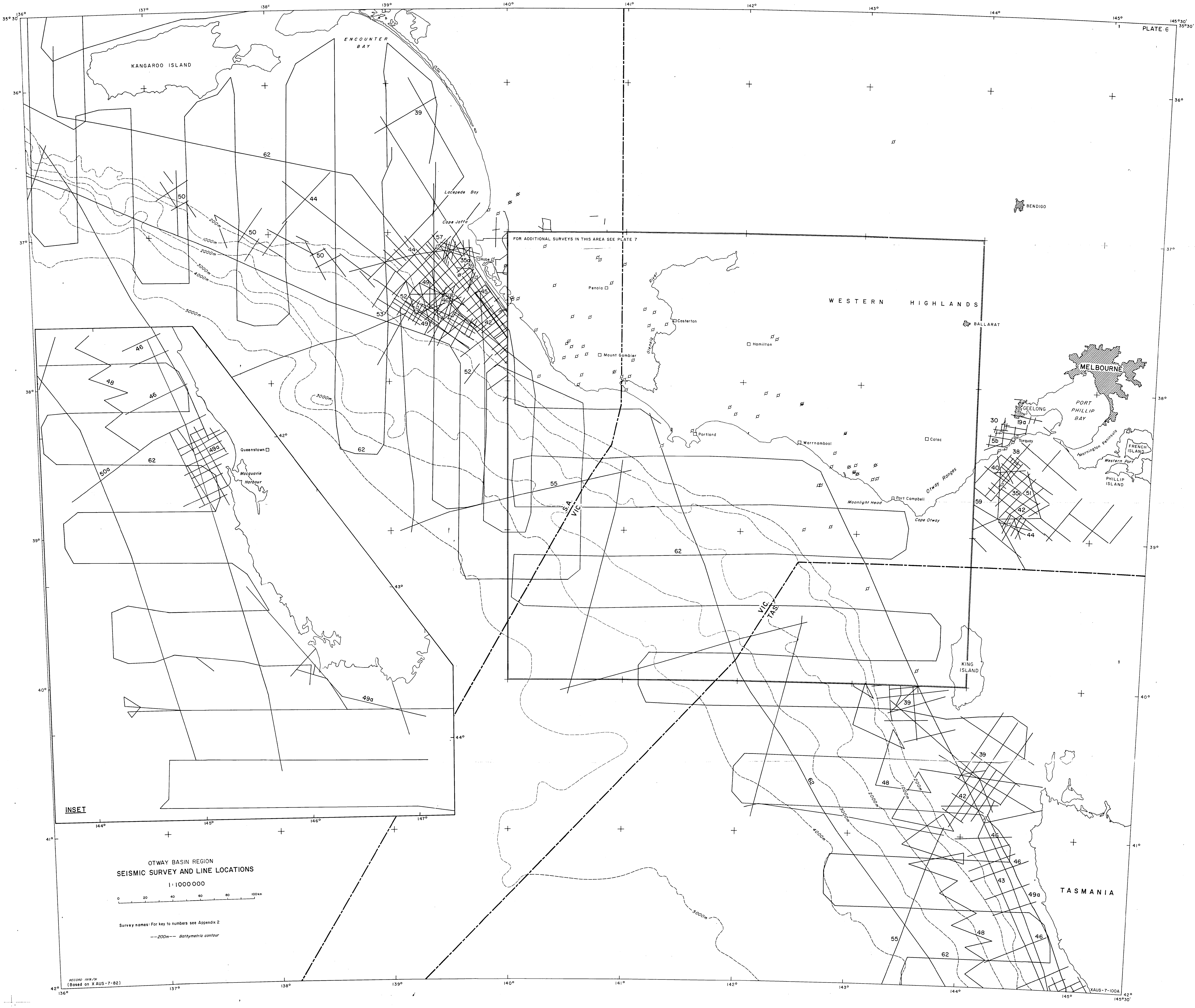


PLATE 5
KANGAROO REGIONAL GRAVITY HIGH
KANGAROO ISLAND
ENCOUNTER BAY
GAMBIER REGIONAL GRAVITY HIGH
MURRAY REGIONAL GRAVITY COMPLEX
BENDIGO
WESTERN HIGHLANDS
BALLARAT
MELBOURNE
PORT PHILLIP BAY
GEELONG
ROBE TROUGH
PENOLA TROUGH
DARTMOOR RIDGE
Lacepede Bay
Kingston
Cape Jaffa
Robe
Penola
Casterton
Hamilton
Mount Gambier
Dartmoor
Portland
Warrnambool
Colac
Port Campbell
Moonlight Head
Cape Otway
OTWAY RIDGE
MELBOURNE REGIONAL GRAVITY HIGH
FRENCH ISLAND
PHILLIP ISLAND
Western Port
Mornington Peninsula
ELTANIN REGIONAL GRAVITY TROUGH
S.A. VIC.
VIC. TAS.
WEST TASMANIAN REGIONAL GRAVITY RIDGE
KING ISLAND
TASMANIA
OTWAY BASIN REGION
GRAVITY ANOMALIES
1:1000000
0 20 40 60 80 100 km
-20 Gravity anomaly contour
200m Bathymetric contour
All data used are preliminary
Offshore results are based on hourly values extracted on board the survey vessel. No adjustments have been applied for misties at traverse intersections
Onshore anomalies are Bouguer anomalies, no correction has been made offshore for the water layer.
RECORD 1978/91
(Based on X AUS-7-82)
Note: The information contained in this map has been obtained by the Department of National Resources, as part of the policy of the Australian Government, to assist in the exploration and development of mineral resources.
It may not be published in any form or used in a company prospectus or statement without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.
X AUS-7-90



OTWAY BASIN REGION

SEISMIC SURVEY AND LINE LOCATIONS

1:1000000

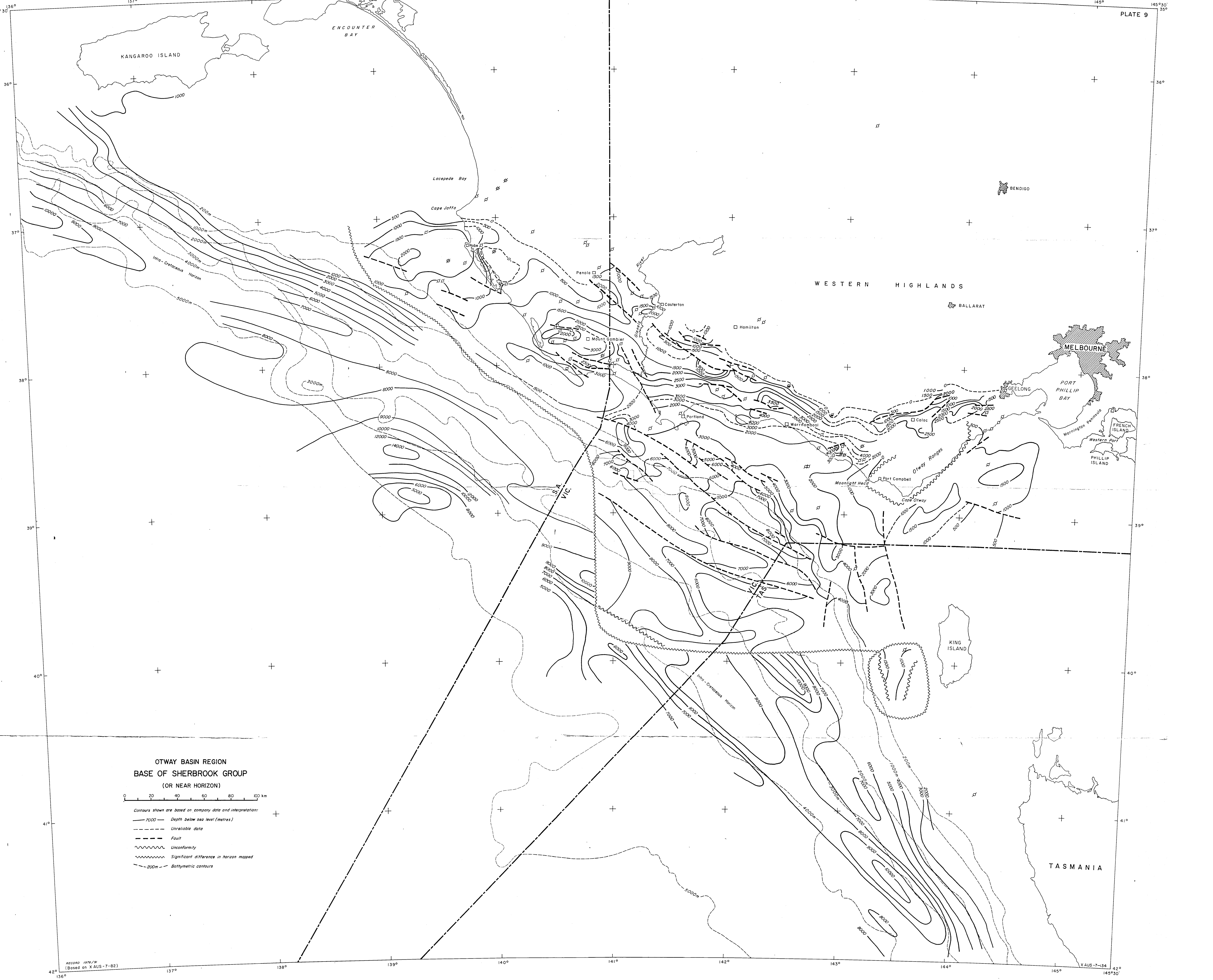
0 20 40 60 80 100km

Survey names: For key to numbers see Appendix 2

--200m-- Bathymetric contour


PLATE 7
OTWAY BASIN REGIONAL
SEISMIC SURVEY AND LINE LOCATIONS
1:500 000
0 10 20 30 40 50km
Survey names: For key to numbers see Appendix 2
RECORD 1978/91
XAUS-7-99A
140°00′
140°30′
141°00′
141°30′
142°00′
142°30′
143°00′
143°30′
144°00′
37°00′
37°30′
38°00′
38°30′
39°00′
39°30′
40°00′

PLATE 9



KANGAROO ISLAND
ENCOUNTER BAY
Lacepede Bay
Cape Jaffa
Robe
Penola
Casterton
Hamilton
Mount Gambier
Portland
Warrnambool
Colac
GEELONG
MELBOURNE
BENDIGO
BALLARAT
WESTERN HIGHLANDS
PORT PHILLIP BAY
Mornington Peninsula
Western Port
FRENCH ISLAND
PHILLIP ISLAND
Otway Ranges
Port Campbell
Moonlight Head
Cape Otway
KING ISLAND
TASMANIA
S.A.
VIC.
TAS.
Intra-Cretaceous Horizon
OTWAY BASIN REGION
BASE OF SHERBROOK GROUP
(OR NEAR HORIZON)
0 20 40 60 80 100 km
Contours shown are based on company data and interpretations
7000 Depth below sea level (metres)
Unreliable data
Fault
Unconformity
Significant difference in horizon mapped
200m Bathymetric contours
RECORD 1979/81
(Based on X AUS-7-82)
X AUS-7-134

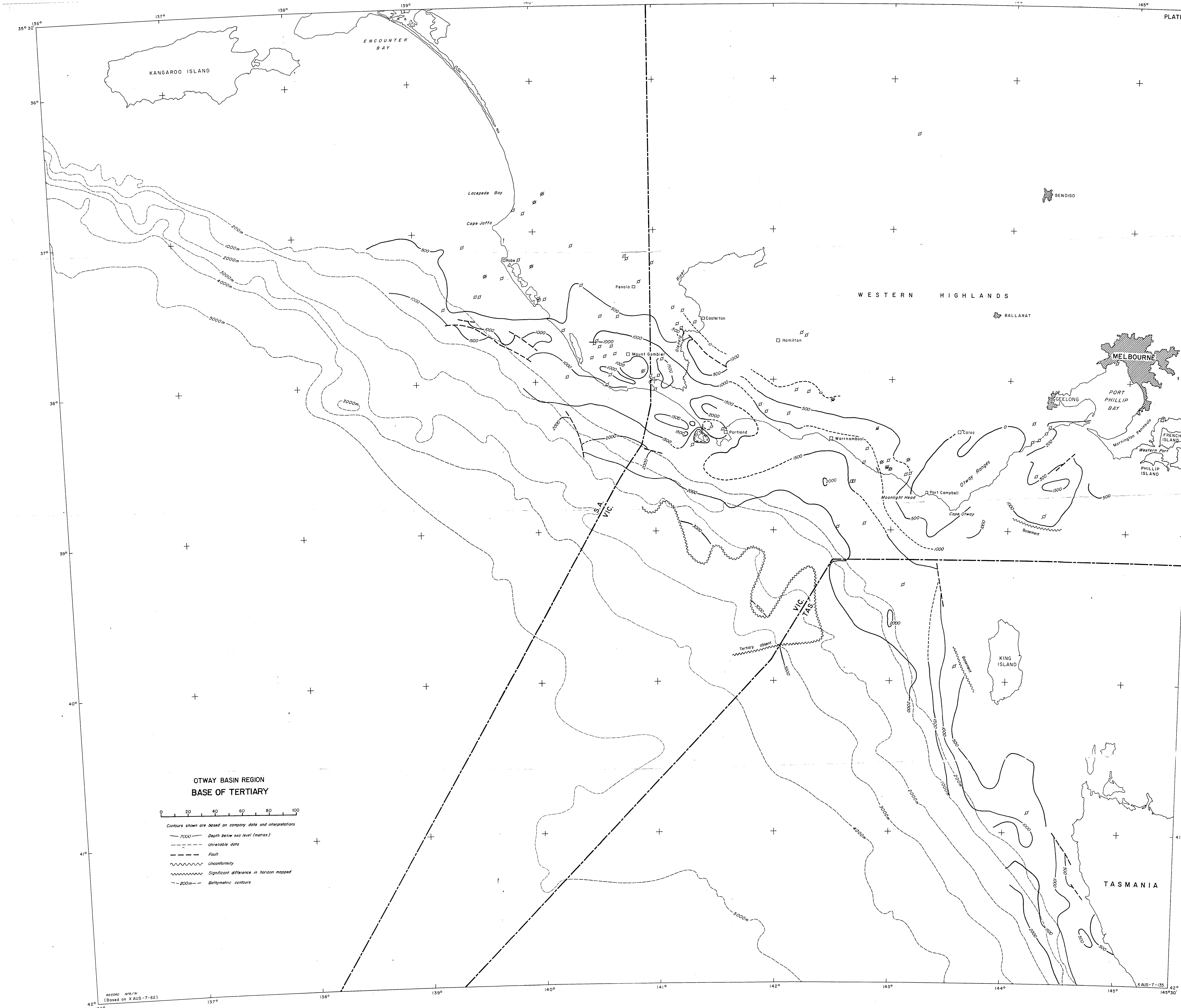
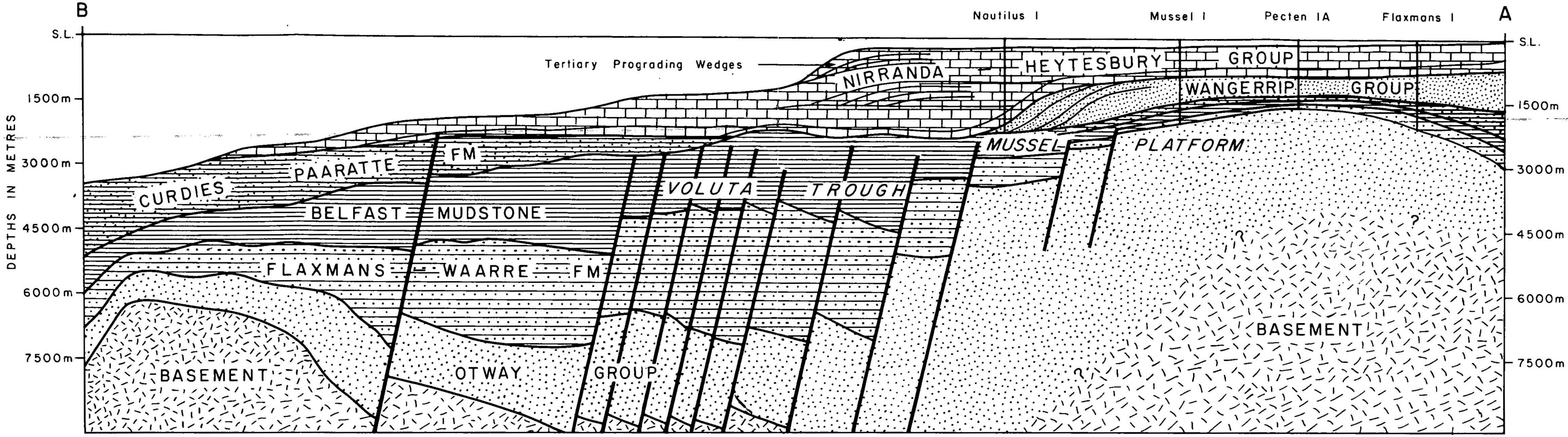
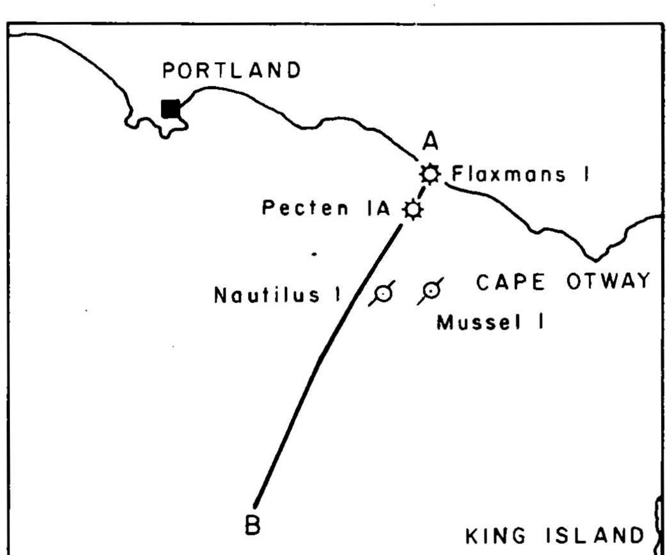


PLATE 10
OTWAY BASIN REGION
BASE OF TERTIARY
0 20 40 60 80 100
Contours shown are based on company data and interpretations
7000 Depth below sea level (metres)
Unreliable data
Fault
Unconformity
Significant difference in horizon mapped
200m Bathymetric contours
KANGAROO ISLAND
ENCOUNTER BAY
Lacepede Bay
Cape Jaffa
Robe
Penola
Mount Gambier
Casterton
Hamilton
Portland
Warrnambool
Colac
Port Campbell
Moonlight Head
Cape Otway
Otway Ranges
WESTERN HIGHLANDS
BENDIGO
BALLARAT
MELBOURNE
GEELONG
PORT PHILLIP BAY
Mornington Peninsula
FRENCH ISLAND
Western Port
PHILLIP ISLAND
KING ISLAND
TASMANIA
S.A.
VIC.
TAS.
Tertiary absent
Basement
RECORD 1978/91
(Based on X AUS-7-82)
X AUS-7-135





NE - SW CROSS-SECTION
THROUGH OTWAY BASIN

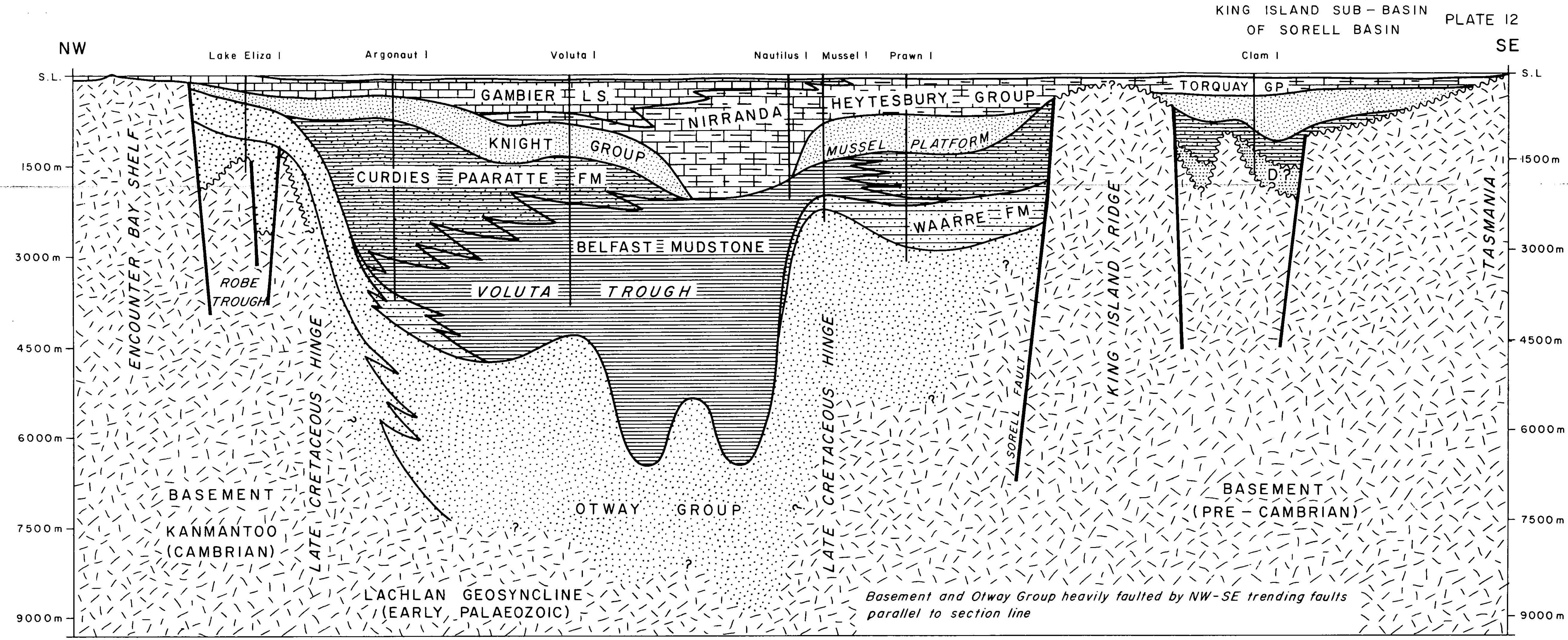
$\frac{V}{H} = \frac{1}{4 \cdot 5}$

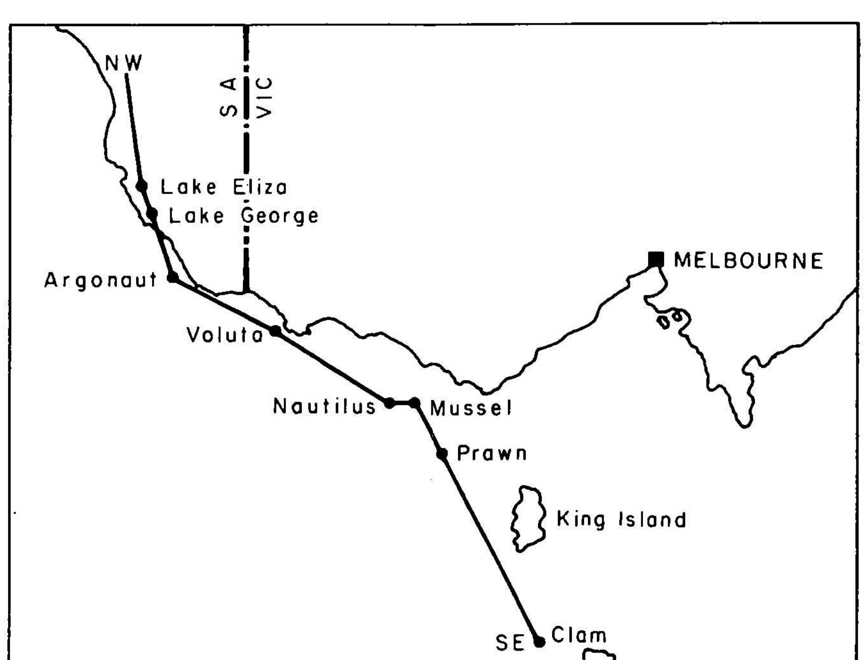
BASED ON DENHAM AND BROWN (1976), Fig. 9

102

X AUS-7-126

PLATE 12





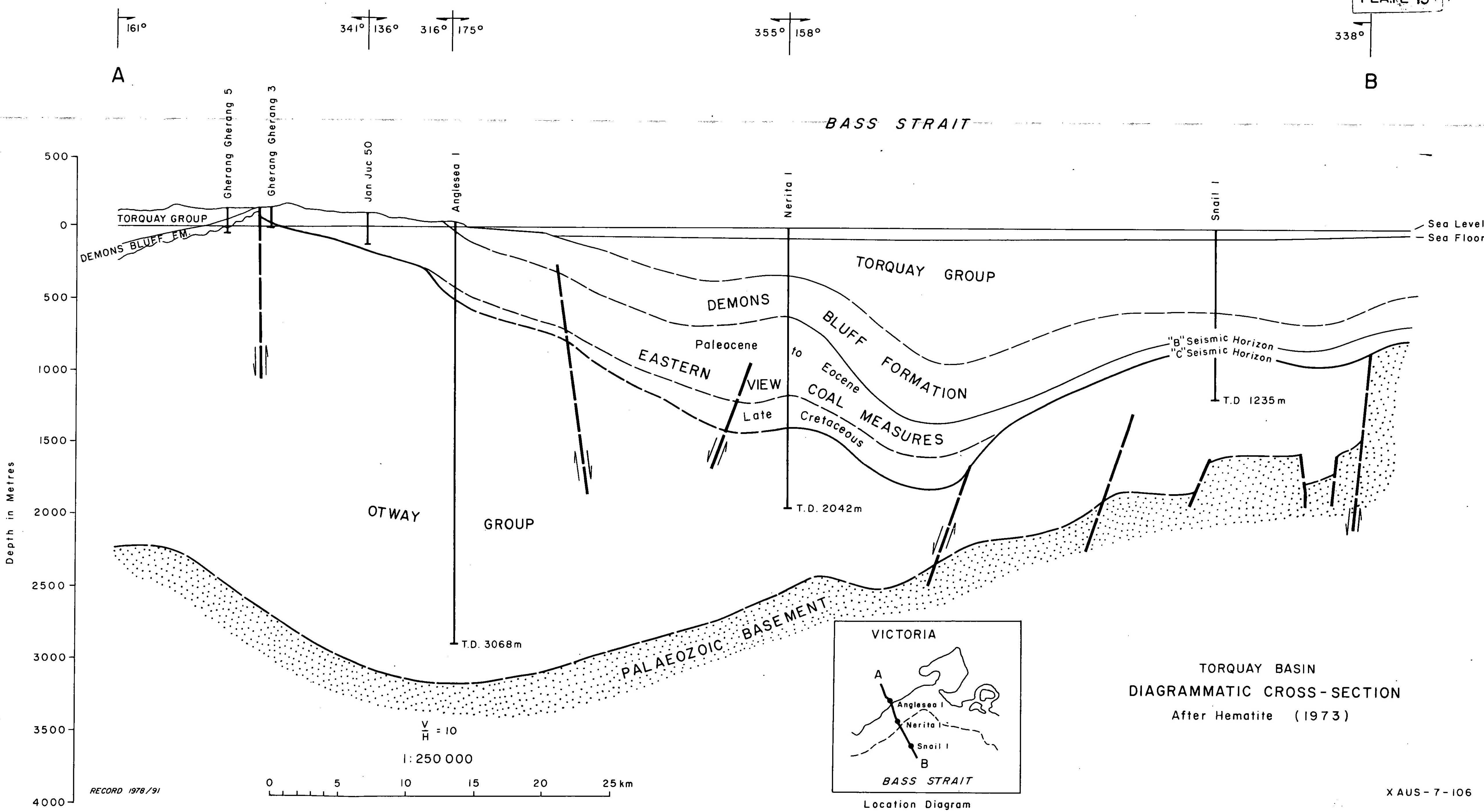
NW-SE CROSS-SECTION THROUGH OTWAY BASIN REGION

0 100 200km

103

RECORD 1978/91

X AUS-7-127



TORQUAY BASIN

DIAGRAMMATIC CROSS-SECTION

After Hematite (1973)

RECORD 1978/91

X AUS-7-106