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Record 1978/111

A REVIEW OF PETROLEUM EXPLORATION AND PROSPECTS IN THE GIPPSLAND BASIN

by

C.S. ROBERTSON, K.L. LOCKWOOD, E. NICHOLAS and H. SOEBARKAH

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ABSTRACT

Petroleum exploration carried out in the Gippsland Basin up to February 1976 has been reviewed to provide a current assessment of knowledge of the basin and to determine the need for further exploration.

The Gippsland Basin is a Late Mesozoic to Cainozoic Basin located mainly offshore in the northeastern portion of Bass Strait, between the mainland of Australia and Tasmania. It is roughly triangular in shape, being narrowest onshore in Victoria to the northwest and broadening towards the edge of the continental slope to the southeast. It contains up to 4500 m of fluvio-deltaic and marine sediments, which have been subjected to faulting, drape folding and channel erosion.

To date, the Gippsland Basin has been by far the most prolific petroleum producing basin in Australia, with initial reserves of more than 300×10^6 m^3 of oil and 200×10^9 m^3 of natural gas. The basin has been actively explored geophysically since the early 1960s and all of the larger and more obvious structures have been drilled. The basin still has some exploration potential at deeper levels than the main Eocene producing zones, but detailed seismic mapping of deeper horizons is difficult and requires the best seismic technology available.

It seems likely that the greater part of the recoverable petroleum in the basin has already been found, but there is some potential for further discoveries.

INTRODUCTION

This Record is a summary of petroleum exploration and prospects in the Gippsland Basin, which is located mainly offshore from the southeastern coast of Victoria.

The Gippsland Basin underlies an area of 63 000 km^2 to the 200 m bathymetric contour and contains up to 4500 m of Late Mesozoic and Cainozoic sediments. The oldest part of the sequence, of Late Jurassic and Early Cretaceous age, was deposited in an east-west rift, which Hocking (1972) named the Strzelecki Basin. These sediments crop out onshore at the western end of the Gippsland Basin, but have been intersected by only a few near-shore wells in the offshore area where the rift has been defined by geophysical exploration. In this review the Late Jurassic and Early Cretaceous sequence is regarded as part of the Gippsland Basin and 'Strzelecki Basin' is used informally as a term of convenience.

The summary is based on information available up to February 1976, including restricted information supplies to BMR under the Petroleum (Submerged Lands) Act (P(SL)A). It is intended that this summary should be useful in the formulation of future exploration programs by BMR and in the evaluation of exploration by petroleum companies.

GEOLOGY

General

A bibliography of the large volume of literature covering the geology of the Gippsland Basin was published by the Geological Survey of Victoria in 1973 (Thomson & others, 1973) as a first step in a reappraisal of the basin. The bibliography includes reference to many unpublished works. The most recent comprehensive reviews of the Gippsland Basin are by Threlfall & others, (1976) and Colman (1976).

The onshore part of the basin in Victoria was mapped at 1:250 000 scale between 1966 and 1972. All five sheet areas are published, three in a provisional form. Mapping at 1:63 360 scale was carried out in 1969 and 1970. Eight maps at this scale have been published.

Two major factors which have stimulated interest in the stratigraphy of the onshore area have been the economically important deposit of brown coal in the Latrobe Valley, and the recovery of oil in 1924 from a well drilled for water at Lakes Entrance.

In the offshore area, much geological information has resulted from petroleum exploration, particularly that by the partnership, entered into in 1964, between Broken Hill Proprietary Limited's subsidiary Haematite Explorations Proprietary Limited (later known as Hematite Petroleum Proprietary Limited) and Esso Exploration Australia Inc.

Drilling operations both onshore and offshore are listed in Appendices 1a and 1b, and a map showing simplified geology and the location of petroleum exploration wells is presented as Plate 1.

The bibliography contains a selection of the more important references, and is not intended to be comprehensive.

Basin setting

The Gippsland Basin has a roughly triangular shape, being narrowest onshore to the northwest and broadening offshore to the south-east. The northern boundary is an unconformable contact between basin sediments and rocks of the Tasman Fold Belt, and the northwestern boundary with the Otway Basin is the Selwyn Fault on Mornington Peninsula and extending from Westernport Bay eastwards at least to the shelf break (Fig. 1). It is ancestral to the central deep basin.

Geological history

The evolution of the Gippsland Basin has been discussed by Weeks & Hopkins (1967), Richards & Hopkins (1969), Griffiths (1971), Hocking (1972), Elliott (1972), Gunn (1975), Threlfall & others (1976) and Colman (1976). In terms of plate tectonics, the development of the basin has been attributed variously to two separate phases of continent separation along new plate boundaries. The first of these was the separation of the Lord Howe Rise and New Zealand from eastern Australian from about 80 m.y. to 60 m.y. B.P. The second was the separation of Antarctica from southern Australia, which began about 45 m.y. ago and which is still in progress.

Burke & Dewey (1973) cited the Gippsland Basin as one of numerous examples throughout the world of rift valleys which developed as arms of radiating, triple rift valley systems. According to these authors, rifts extending northeast and south from a point east of the Gippsland Basin developed into a crustal spreading ridge, which gave rise to the separation from Australia of the Lord Howe Rise and New Zealand, while the third rift or arm of the 'triple junction' extending westward remained as a 'failed arm' or 'aulacogen'. This developed into the Gippsland Basin.

Gunn (1975) supported this basic concept, but pointed out that it is the 'Strzelecki Basin' rather than the overlying Gippsland Basin which should be identified as the 'failed arm'. The 'Strzelecki Basin' developed as a half-graben in the Late Jurassic and Early Cretaceous. The major subsidence occurred along the southern fault system, and deposition was accompanied by volcanism. Up to 3500 m of fluviatile sediments of the Strzelecki Group was deposited, derived predominantly from a northern source. Seismic evidence along the northern and southern margins of the basin indicates that this sequence is more intensely deformed than the overlying sequence, and, where intersected in off-shore wells, the top of the Strzelecki Group is marked by an angular unconformity.

(Fig. 1). The southwestern boundary in partly an exposed or subsea unconformable contact between basin sediments and basement rocks on the northeastern flank of a southeast-trending elevated area of basement, the Bassian Rise, which separates the Gippsland Basin from the Bass Basin and partly the crest of the rise where it is covered by sediments. The eastern boundary (and offshore limit) of the basin is undefined. Basin sediments extend beyond the shelf break, which is located near the 200 m bathymetric contour. The basin consists of an east-trending central deep trough separated from northern and southern platforms by bounding faults.

The 'Strzelecki Basin' (Hocking, 1972) is an east-west rift bounded on the west by the Palaeozoic rocks of the Mornington Peninsula.

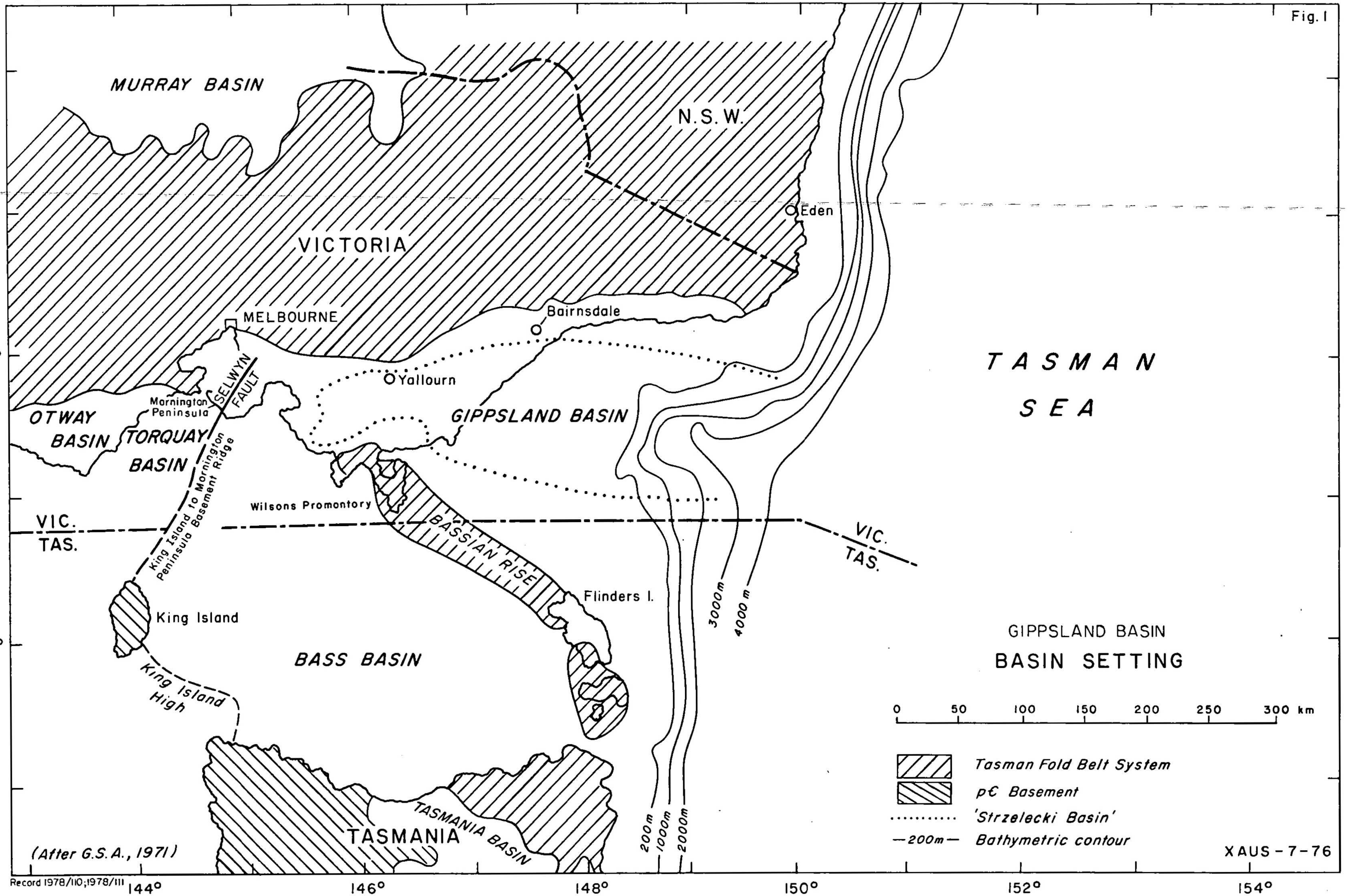
Fig. I
MURRAY BASIN
N.S.W.
VICTORIA
Eden
MELBOURNE
Bairnsdale
Yallourn
SELWYN FAULT
Mornington Peninsula
OTWAY BASIN
TORQUAY BASIN
GIPPSLAND BASIN
TASMAN SEA
King Island to Mornington Peninsula Basement Ridge
Wilsons Promontory
VIC.
TAS.
BASSIAN RISE
Flinders I.
King Island
King Island High
BASS BASIN
TASMANIA
TASMANIA BASIN
200m
1000m
2000m
3000m
4000m
GIPPSLAND BASIN
BASIN SETTING
0 50 100 150 200 250 300 km
Tasman Fold Belt System
p€ Basement
'Strzelecki Basin'
—200m— Bathymetric contour
(After G.S.A., 1971)
XAUS-7-76
Record 1978/110;1978/111
36°
38°
40°
144°
146°
148°
150°
152°
154°

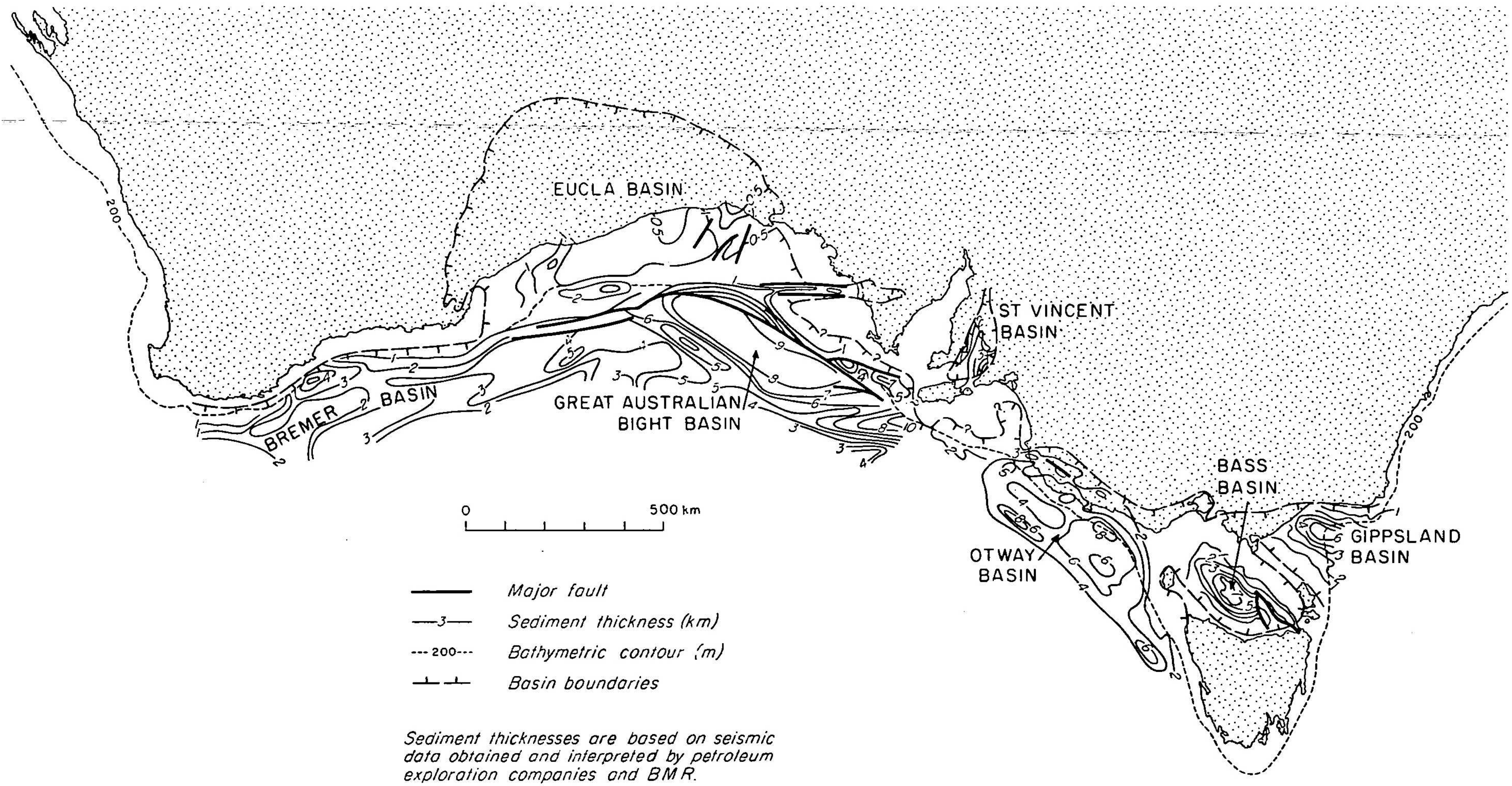

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Fig 1A Generalised total sediment thickness, southern Australian region.

The non-marine sediments of the Strzelecki Group were evidently deposited during the tensional, rifting stage of continental break-up which preceded the sea-floor spreading that opened up the Tasman Sea. Based on the evidence of ocean floor magnetic lineations (Hayes & Ringis, 1973) sea-floor spreading is believed to have taken place between 80 and 60 m.y. B.P. (Late Cretaceous to Early Paleocene). These dates are compatibel with the recovery of Upper Cretaceous marine shales from the Deep Sea Drilling Program Site 283 (Geotimes, 1973) (Figure 1A).

The next major period of basin development took place between the Late Cretaceous and the Late Eocene, with the deposition of up to 5000 m of fluviodeltaic clastics and coal of the Latrobe Group. Subsidence began at the eastern end of the 'Strzelecki Basin' as a result of northwest-trending normal faulting and tilting of basement fault blocks. Deposition, which was initially accompanied by volcanism, moved westwards with time and continued without a major break until the end of the Eocene. The area of sedimentation expanded rapidly in the Late Eocene to cover most of the present day basin. The volcanism was most common the central deep basin, and was associated with the tilting of basement fault blocks.

Threlfall & others (1976) considered that the development of the Gippsland Basin (including the Strzelecki Group) is attributable to the movement of the Tasmanian continental block relative to Australia and Antarctica during the break-up of Gondwanaland. They proposed that the relative movement of the Tasmanian block to the southwest created a tensional system in which two separate depressions, the Gippsland and Bass Basins, were formed by crustal thinning. They conceded that the separation of Australia and the Lord Hose Rise-New Zealand continental mass may have had some bearing on the structural complexities of the Lower Cretaceous rocks, but considered that the effect of this separation 'is not particularly evident from the data available in the Gippsland Basin'.

The same authors recognised two distinct structural styles within the basin: basin-forming normal faults, active principally from Early Cretaceous to Early Eocene, and en echelon anticlines and shear faults, generated during the Late Eocene-Early Oligocene and Late Miocene (Fig. 2). The basin-forming faults are ascribed to the tensional regime resulting from the southwest movement of Tasmania and the rotation of Antarctica away from Australia. Presumably, the shear faults and the anticlines which developed between them were considered to have been produced by the same tensional regime, although Threlfall & others (1976) are not specific on this point.

It is tempting to postulate that the initial east-west rifting which resulted in the deposition of the Strzelecki Group is attributable to events preceding and connected with the opening of the Tasman Sea, while the later development of shear faults and anticlines in the Gippsland Basin was related to the separation of Antarctica and Australia. Evidence for such a postulate is largely circumstantial, the ages of the two types of faults in the Gippsland Basin being consistent with known dates of plate tectonic events related to the separation of Australia from Lord Howe Rise-New Zealand and Antarctica respectively.

The Latrobe Group is characterised by an almost basin-wide unconformity at the top and by large-scale channels of several ages. While there is no evidence for the existence of open-marine conditions during the deposition of the group, there is evidence for marginal marine conditions in the form of discrete dinoflagellate ingressions. These were described by Partridge (1976) (Figure 6) and related to eustatic cycles, within the context of a relative overall rise in sea level during the Paleocene and Eocene. In a chronographic section (Figure 7) Partridge shows the distribution of a series of sedimentary sequences within the Latrobe Group as a function of geological time. The section shows each sequence onlapping the basin margins at its base and being truncated towards the margins at its top, and also a general landward encroachment towards the northwest. The landward encroachment is accompanied by the development of an increasingly more widespread area of non-deposition on the seaward, southeasterly, side. It is suggested that the apparent non-deposition of fine-grained sediments may have been due to the removal

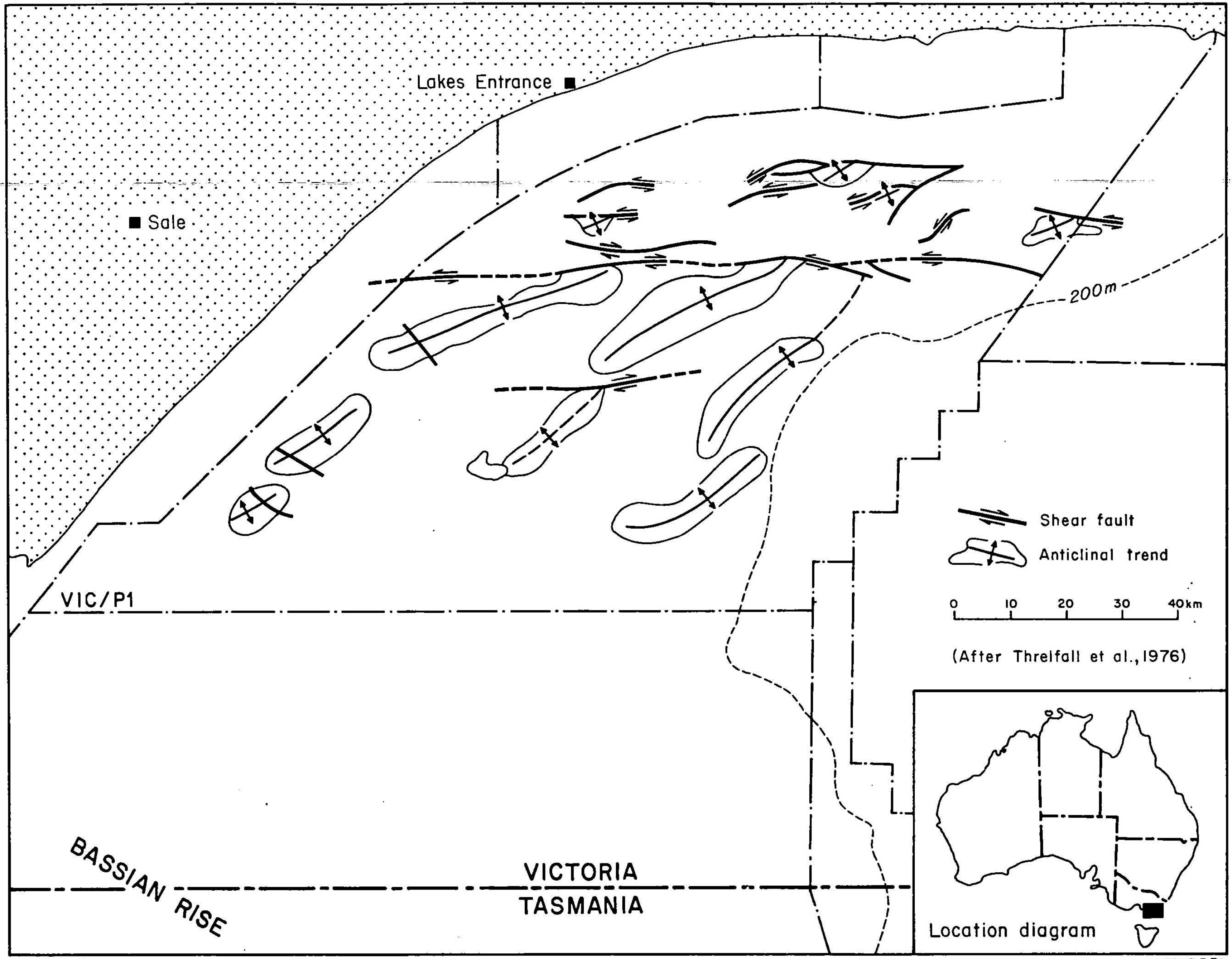

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Fig. 2 Late Eocene - Early Oligocene and Late Miocene anticlines and shear faults.

of such sediments by the action of strong currents on the shallow Gippsland shelf. The concept that fine-grained sediments were being supplied, but were by-passing the shelf during this time is supported by the finding of fine-grained terrigenous sediments of Paleocene and Eocene age in the DSDP Site 283 (Fig. 1A) in the Tasman Sea. Partridge, therefore, considers that the unconformity at the top of the Latrobe Group should be regarded as being as much the result of non-deposition as of erosion, and that, where erosion occurred, it was associated with the large-scale channelling during major low stands of sea-level in the Early and Middle Eocene. These channels will be discussed further under the heading 'Stratigraphy'.

Sedimentation in the Middle to Late Eocene was widespread on the southern platform of the basin and onshore on the northern platform, but restricted to the westernmost part of the central basin.

Marine conditions were established over the basin in the Early Oligocene, during the continuing overall marine transgression. Sediment type changed from the mainly coarse-grained clastics of the Latrobe Group to the calcareous shale and marl of the Lakes Entrance Formation. The marine shale was deposited in a narrow wedge around the basin margins, only a thin veneer of pelagic shale being deposited in the basin centre. Late in the Early Oligocene a drop in sea-level caused erosion of the shale on the margins, over most anticlinal crests and perhaps in the youngest of the Eocene channels. With a renewed rise in sea level, deposition of shale and marl continued through the Middle and Late Oligocene and, offshore, into the Early Miocene, onlapping the basin margins and structural 'highs'.

During the Miocene there was a gradual change in sedimentation from the shale and marl of the Lakes Entrance Formation to the bryozoan limestone and marl of the Gippsland Limestone. Upper Miocene limestone formed the present continental shelf and slope within the area of the basin.

The Miocene sequence is characterised offshore by two major depositional features, which are described by Threlfall & others, (1976). A massive linear slump zone occurs on the southern platform, and complex channelling is evident over the remainder of the basin. The northwest-trending slump zone can be traced seismically for more than 130 km. It was formed when a northerly-prograding wedge of marls and limestones slumped towards the basin centre during structural movement which activated the south-bounding fault. Structural movements and sea-level changes were responsible for the complex submarine channels. The heads of the channels are filled with a coarse mixture of skeletal fragments and sand grains and the middle and distal portions are filled mainly by micritic limestone with low porosity. The micritic limestone presents problems in seismic mapping of underlying strata because of its very high velocity compared to that of the surrounding rocks.

Mention has already been made of structural deformation in the Gippsland Basin from late Eocene to Miocene. This deformation was related to east-west strike-slip faults, as a result of which large en echelon anticlines were developed between continuous fault zones. Strike-slip movement occurred in the Late Eocene to Oligocene, and in the Late Miocene, and during each period the movement was accompanied by the intrusion and extrusion of mafic igneous rocks and the rejuvenation of some of the older, basin-forming faults.

The final episode in the development of the Gippsland Basin was a period of marine regression and a return to continental clastic sedimentation in southeastern Gippsland. Marine sedimentation continued on the continental shelf. The highland region north of the basin and the South Gippsland Hills along the western margin were uplifted during the Kosciusko uplift in the Late Pliocene, and structures around the northern edges of the basin were rejuvenated. Many plunged eastward as a result of basinward tilting.

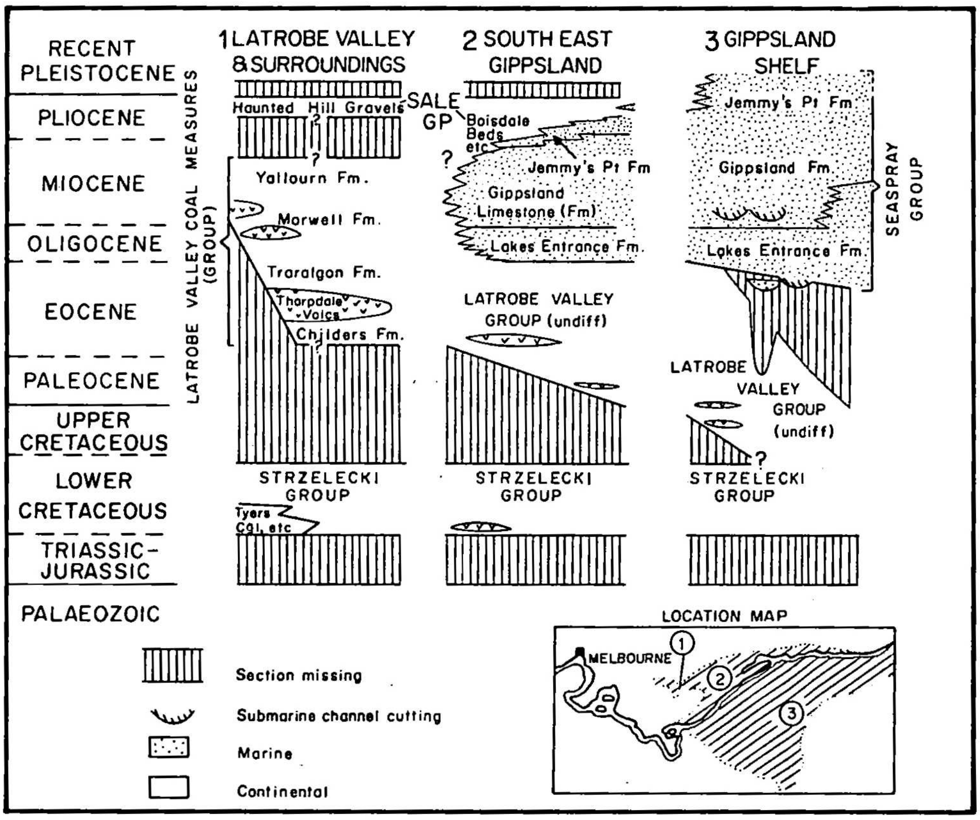

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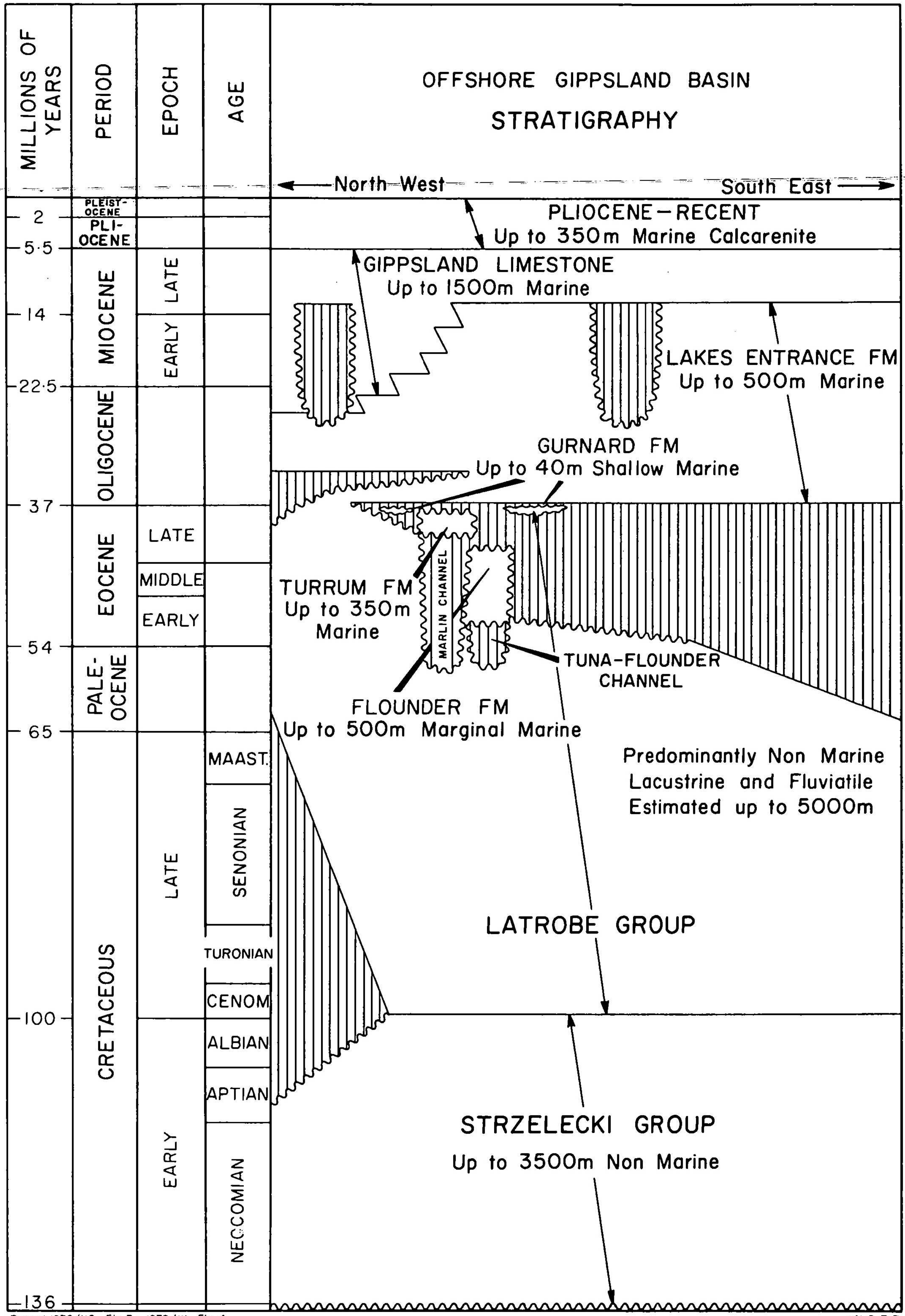
Fig. 3 Stratigraphic chart, Gippsland Basin (after Hocking, 1972)

Fig. 4



Record 1978/110, Fig. 7; 1978/111, Fig. 4

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(After Threlfall et al., 1976)

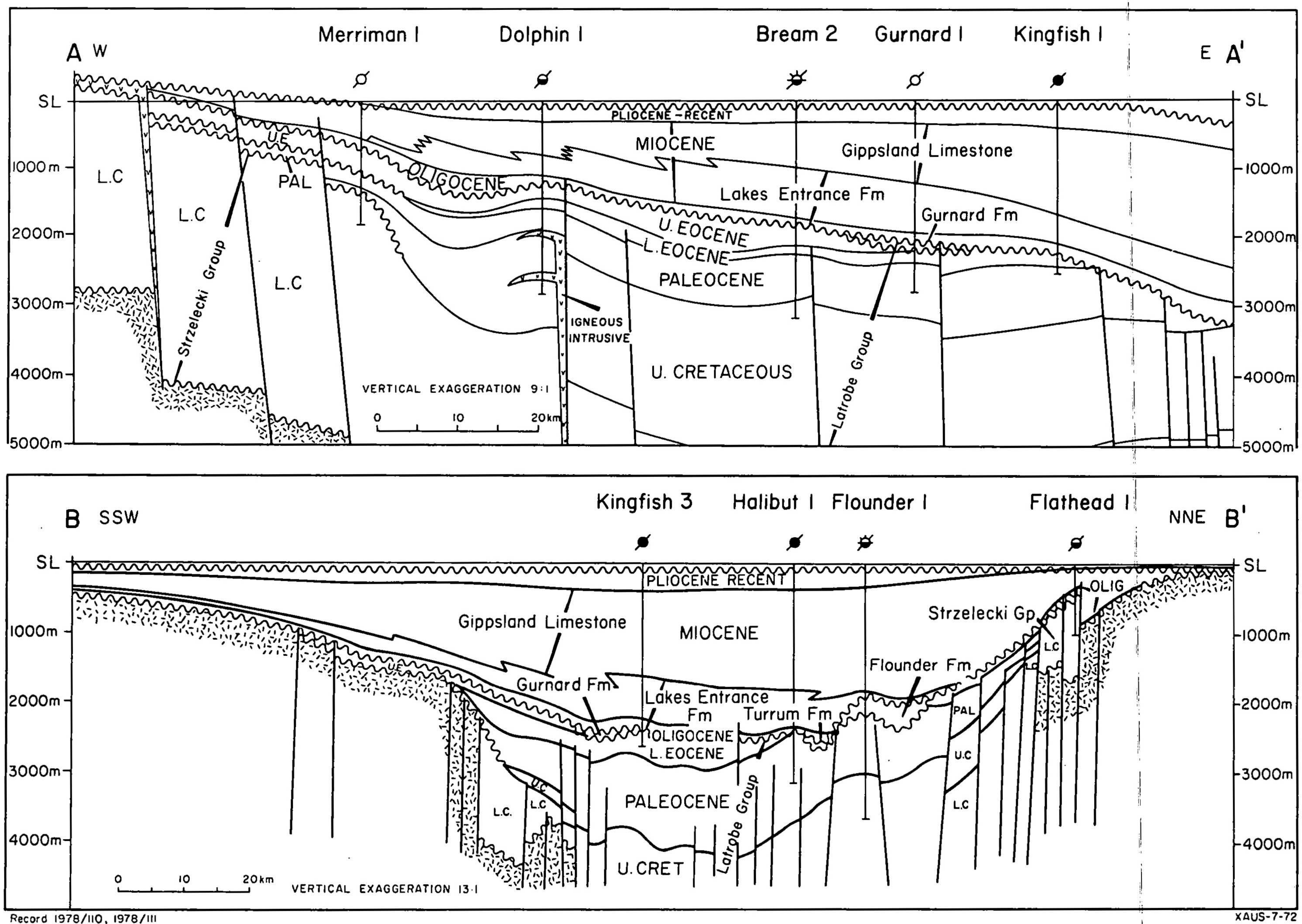


Fig. 5 Geological Cross Sections – Offshore Gippsland Basin (After James and Evans, 1971 and Beddoes, 1973)

Stratigraphy

This section is based mainly on James & Evans (1971), Threlfall & others (1976), and Partridge (1976) who presented the sequence for the offshore area, and a number of authors, principally Gloe (1967), Traill (1968), Hocking (1972), Haskell (1972), and Colman (1976), for the onshore part of the basin. It includes a brief treatment of several stratigraphic units which have been recognised by some authors as separating the Strzelecki Group from the Latrobe Valley Coal Measures, and by others as formations within the coal measures sequence, and indicates some of the contradictions contained in the literature in relation to these units.

Figures 3 and 4 show the stratigraphy presented by Hocking (1972), and Threlfall & others (1976). Figure 5 shows geological cross-sections after James & Evans (1971) and Beddoes (1973).

Knowledge of time-stratigraphic relations in the Gippsland Basin has been derived from the recognition of spore-pollen assemblages in the Late Cretaceous to Eocene non-marine and marginal marine interval, and of planktonic foraminiferal zonules in the Oligocene to Pliocene marine sequence. Seismic data, and electrical log data in areas of close well control, have also contributed to the understanding of the stratigraphy.

The Cretaceous spore-pollen zones are derived from zones proposed by Dettman & Playford (1969), and the planktonic foraminiferal zonules are a refinement of those originally defined by Taylor (1966) for Barracouta No. 1 well. The spore-pollen zones are described by Stover & Evans (1973), and Stover & Partridge (1973). Partridge (1976) presents the recent changes that have been made to the zonation and gives a recent correlation of the zones with the International Geological Time Scale (Fig. 6). The changes, including that of the position of the Cretaceous/Tertiary boundary from the base to the top of the T. longus zone, are based on his unpublished work. Partridge also recognises a series of dinoflagellate assemblage zones in the Latrobe Group (Fig. 6). The zones represent discrete ingressions of dinoflagellates and are interpreted as indicative of rises in sea level. The zones are widespread, covering areas up to 2500 km^2. The dinoflagellate assemblages which are also recorded from the Otway Basin and from New Zealand in sequences dated by planktonic foraminifera provided the correlation with the International Time Scale. Figure 7 is Partridge's chronographic section for the Gippsland Basin based on the spore-pollen, dinoflagellate, and planktonic foraminiferal zones.

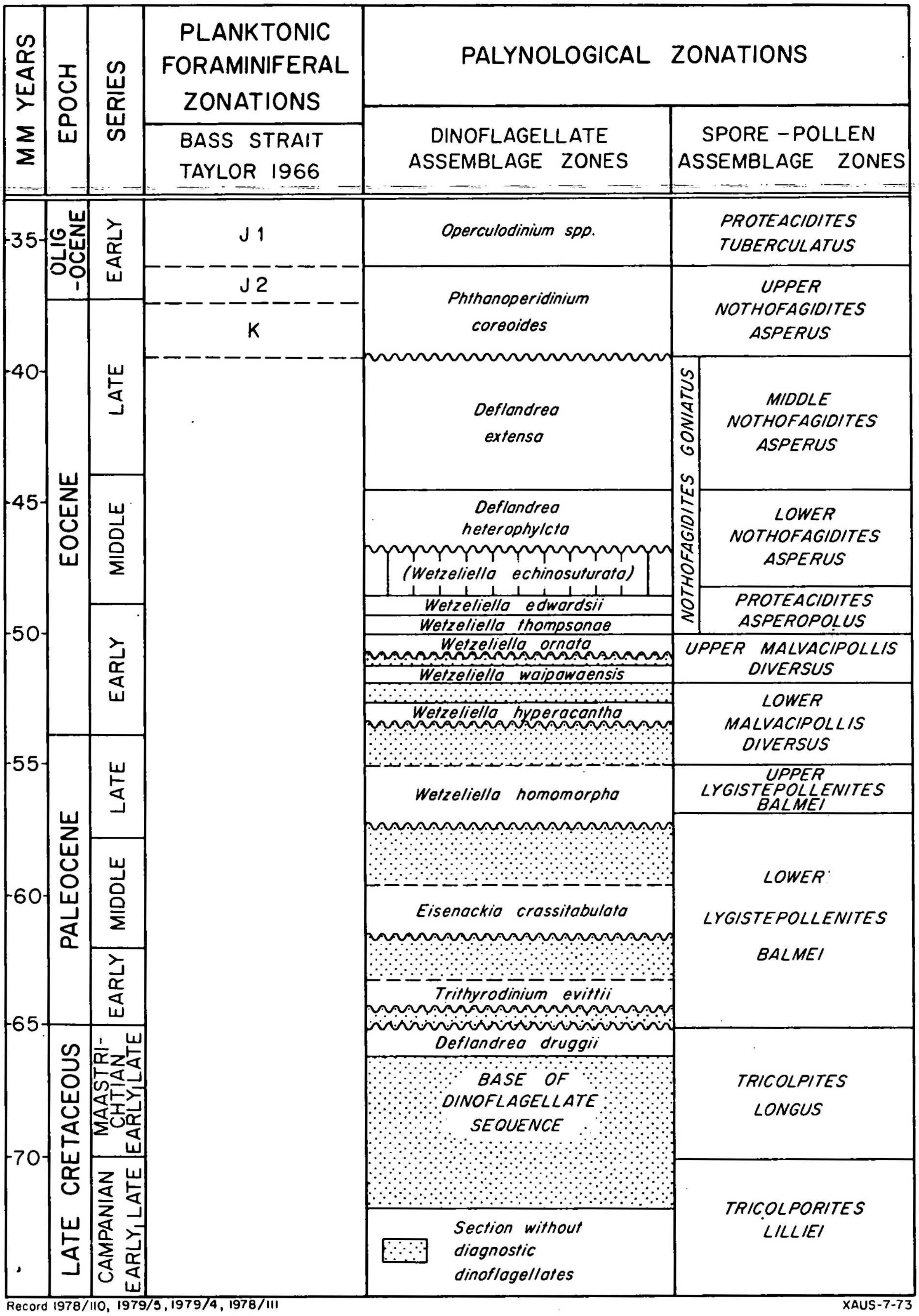
Seismic data (Steele, 1976) have been used for the recognition of discrete time-stratigraphic units within the Latrobe Group and overlying Lakes Entrance Formation, through the application of the concept of sequences as defined by Vail & others, (1975). A sequence is defined as a time-stratigraphic unit that is bounded by unconformities, or their correlative conformities, at its top and base. The seismic sequences recognised in the Latrobe Group and Lakes Entrance Formation have been tied into the palynological and foraminiferal zones at the well control.

Basement Basement rocks are exposed onshore to the north and west of the basin, and offshore where they form islands along the Bassian Rise. They comprise Ordovician and Silurian rocks of the north-trending Tasman Fold Belt overlain by Devonian to Early Carboniferous redbeds. Non-marine sediments of Permian age are also exposed to the north of the basin and have been intersected in one onshore well, Duck Bay No. 1.

The Tasman Fold Belt sequence consists of folded and slightly metamorphosed sediments of Ordovician and Silurian age, which were deformed and intruded by massive granites and granodiorites during the Devonian Tabberabberan Orogeny. The overlying post-orogenic Devonian-Carboniferous red-beds, comprise conglomerate, sandstone and pebbly mudstone with interbedded rhyolite, rhyodacite and trachyte.

Onshore, basement has been intersected by a number of wells north of latitude 38°45'S, but offshore it has been reached by only four wells, located on the southern margin. Groper No. 1, Bluebone No. 1, and Mullet No. 1 bottomed in granite, and Groper No. 2 in red siltstone, presumed to be Devonian to Carboniferous in age.

Fig. 6



Correlations of planktonic foraminiferal and palynological zonations of the Gippsland Basin with the Geological Time Scale

(After Partridge, 1976)

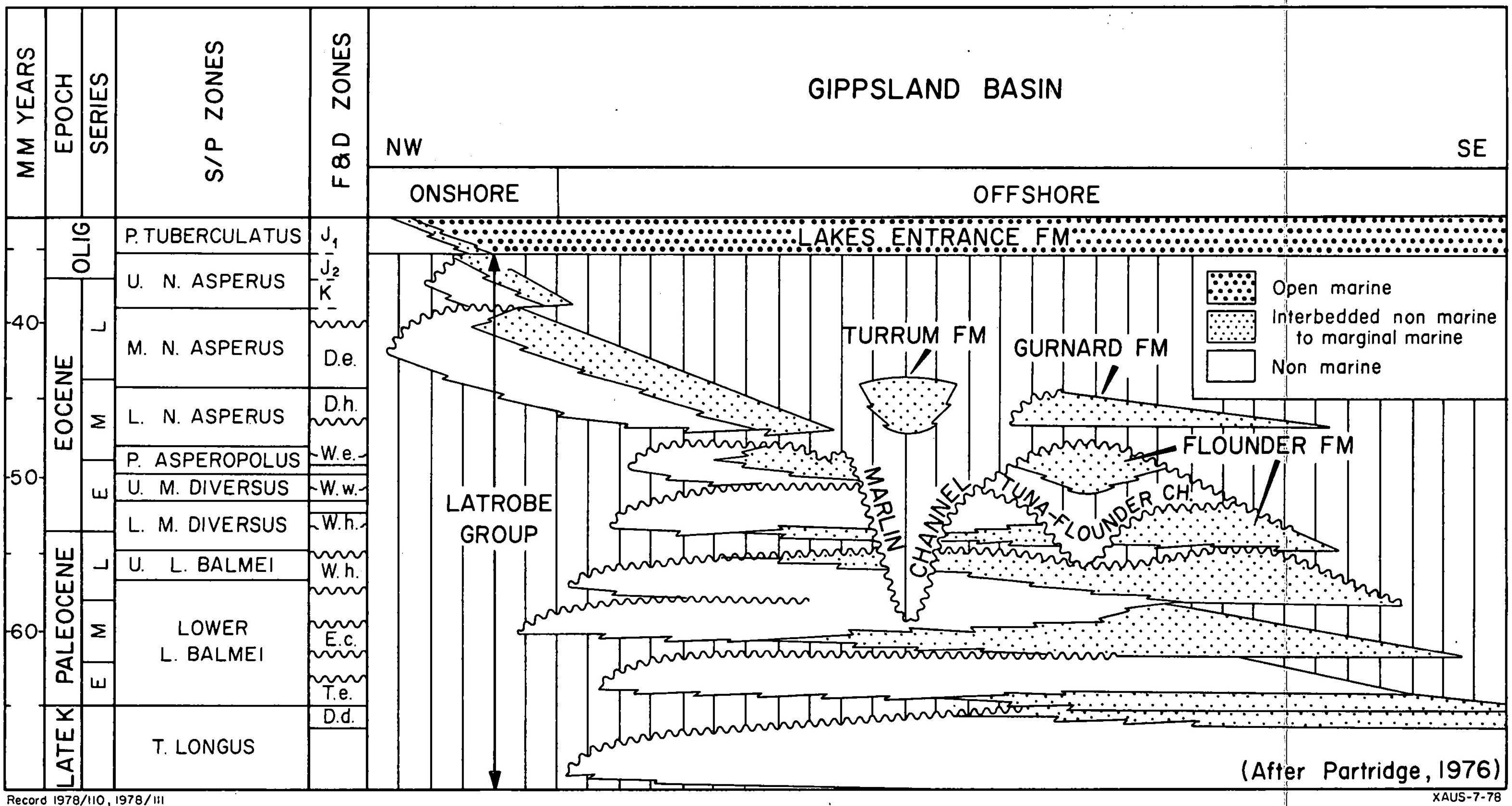


Fig. 7 Chronographic section Gippsland Basin

The aeromagnetic data suggest that the character of the basement underlying the centre of the basin is similar to that already described, except in the area of the Bream structure, where a large magnetic anomaly is indicative of a deep mafic intrusive.

Strzelecki Group The group was originally defined by Medwell (1954) as a Jurassic unit. Palynological evidence has since dated it as mainly Neocomian to Albian, but it contains some Late Jurassic sediments. The Group crops out onshore (Pl. 1), and has been penetrated offshore in Emperor No. 1 (159m), Flathead No. 1 (589m), Wahoo No. 1 (154m), Golden Beach No. 1A (610m), Perch No. 1 (1354m) and possibly in Moray No. 1 (745m). The maximum thickness of the Group is unknown. The sequence comprises non-marine sandstone with interbedded siltstone, mudstone, claystone and minor coal. The sandstone is predominantly medium-grained, feldspathic, and volcanolithic, with abundant kaolinitic and chloritic clay matrix and minor calcareous cement, and is mainly impermeable. The Group appears to have resulted from rapid deposition on a steadily subsiding fluvial plain. The Tyers Conglomerate and associated quartzose sandstone units at the base of the sequence were derived from the adjacent Palaeozoic craton. Basal early Cretaceous volcanics about 100 m thick, composed of chloritized basalts and minor tuff, occur in the sub-surface near the northern margin of the basin about 30 km west of Lakes Entrance, and constitute a major source for the overlying sediments.

Latrobe Valley Group This term is used by Hocking (1972) to include the offshore Latrobe Group of Esso and its stratigraphic equivalent onshore in south-east Gippsland (Fig. 2). He describes the depositional environment as 'an extensive, aggrading fluvial plain and an adjacent high-constructive delta system nearer the present shelf edge........ Sediment supply was primarily from the north but also from the southwest'. The group shows an overall increase in deltaic facies to the southeast and a similar vertical facies changes due to the transgressive nature of the sequence. Onshore and offshore in the Gippsland coastal area, the sequences encountered broadly comprise an upper mainly sandstone section representing lower fluvial plain and sub-aerial delta plain facies, overlying fluvial and deltaic swamp deposits, including coal and carbonaceous mudstone. Offshore, toward the edge of the Gippsland Shelf, the sequence in the Halibut field (Franklin & Clifton, 1971) consists of distributary and interdistributary (including lacustrine) deposits of the delta plain.

Threlfall & others (1976) describe three time-rock units in the Latrobe Group:

(i) Late Cretaceous. The late Cretaceous sequence consists of shale, minor coal and poorly-sorted sandstone, and is non-marine where penetrated. The unit progressively onlaps the Early Cretaceous Strzelecki Group unconformity surface towards the basin margins, where in Emperor No. 1, Perch No. 1, and Moray No. 1 only the youngest Upper Cretaceous sediments are present. It is possible that Lower and Upper Cretaceous sequences could be conformable in the centre of the basin - in Tuna No. 1 the spores and pollen assemblages in the Late Cretaceous sediments at total depth were interpreted as having Early Cretaceous affinities. Late Cretaceous marine shale was recovered from the DSDP hole 283 in the Tasman Sea (Fig. 1A), indicating the presence of a shoreline along the east coast of Australia and Tasmania at this time.

(ii) Paleocene to Early Eocene. Sediments of this age reach a maximum thickness of 1500 m in the centre of the basin. Encroachment of the shoreline from the southeast produced a zone of progradation and palaeo-slope development which can be distinguished on northwest-trending seismic sections in the southeastern part of the basin. Little or no sediment accumulated beyond this zone, owing to non-deposition and erosion. The Kingfish, Bonita, Albacore, Mackerel and Stonefish wells located from southwest to northeast along the encroaching shoreline intersected stacked sequences of beach, shoreface and offshore sediments. The non-marine sediments were deposited in alluvial and delta-plain environments, with the main direction of stream flow and sediment transport being from the northwest to the southeast. Carbonaceous shales and coals are interbedded with sandstones of point-bar and braided stream origin.

(iii) Early-Late Eocene. During the Early-Late Eocene, there was a reduction of normal fault movement in the basin and a general slowing down in the rate of sediment accumulation. Latrobe Group sediments of this age reach a maximum thickness of 700 m. Braided stream and point bar sandstones and coal make up a higher percentage of the sequence than in the underlying units, particularly in the northeast.

During the Early Eocene, in the northeastern part of the basin, a roughly southeast-trending channel was cut into the top of the Latrobe Group to a maximum depth of about 650 m. The channel is termed the Tuna-Flounder channel and the sediments that fill it, the Flounder Formation (after Flounder No. 1). The lower part of the formation is a massive sandstone, which is interpreted as a 'grainflow' deposit that both cut and partly filled the channel. The upper part of the Flounder Formation is a shaly, micaceous, pyritic siltstone, which is interpreted as a prograding estuarine deposit that filled the channel during continued subsidence of the area in the Middle and Late Eocene.

Further channelling occurred in the northeastern area in the latest Eocene, following the tectonic events that produced the en echelon anticlines and shear faults discussed previously. Erosion occurred on the crests of the anticlines and on the basin margins, and drainage systems trapped by the tectonic events cut the Marlin Channel, probably by subaerial erosion in the upper reaches, but by subsea erosion in the middle and lower reaches.

The channel trends southeasterly and eroded the Flounder Formation in addition to the Latrobe Group. The Turrum Formation, named after Turrum No. 1 (Appendix 3), fills the Marlin Channel and has been mapped from seismic data. It reaches 300 m in thickness, and in Turrum No. 1 consists of dark grey-brown shale with rare coarse clastic interbeds. Benthonic and rare pelagic foraminifera occur in the formation, which is interpreted as a marine deposit that filled the channel during continuing marine inundation of the basin in the Late Eocene. In contrast to the Tuna-Flounder Channel the original clastic material in the erosional channel has not been preserved.

The Gurnard Formation (named after Gurnard No. 1) is a Late Eocene unit which occurs sporadically in the eastern two-thirds of the basin. It comprises up to about 35 m of glauconitic, very fine-grained sandstone, siltstone, and mudstone, containing assorted pebbles, which is interpreted as a shallow marine facies deposited on the eroded Latrobe Group surface during the continuing rise in sea level and northwesterly migration of the shoreline in the Late Eocene.

Haskell (1972) uses the term Latrobe Group for the Late Cretaceous to Eocene sequence onshore, and describes two formations in the pre-Eocene part of the sequence.

Golden Beach Formation. Haskell proposed this name for a sequence which, in various well completion reports, had either wholly or partially been included informally in the Strzelecki Group as the Golden Beach Beds or Formation. The type section is that intersected between 1707 m and 2377 m in Golden Beach No. 1A. Other wells which intersected the formation are Colliers Hill No. 1, Dutson Downs No. 1, and Golden Beach West No. 1. The formation consists of medium to coarse-grained sandstone with interbedded siltstone and mudstone. Palynological evidence indicates a Late Cretaceous (Cenomanian to Turonian) age (Dettman 1966a, 1970) and a non-marine depositional environment. The sandstone beds are up to 30 m thick and are locally cross-bedded.

Traill (1968) proposed the term Barracouta Sandstone for a Late Cretaceous sequence encountered in Barracouta No. 1A and of similar lithology to the Golden Beach Formation, which he stated also occurs in the offshore wells Cod 1A, Marlin 1A, Golden Beach 1A, and the onshore wells Merriman No. 1, Lake Reeve No. 1, North Seaspray No. 1, Golden Beach West No. 1, Dutson Downs No. 1, and Hollands Landing No. 1. Comparison of Haskell's and Traill's papers indicates that the two terms were proposed for the same interval. James & Evans (1971) stated that palynological evidence subsequent to Traill's work does not support his recognition of the Barracouta Sandstone as a formation in the offshore area.

Childers Formation. This term has been applied to a predominantly sandstone unit that crops out in the west Gippsland Highlands in the Warragul 1:250 000 Sheet area (Geological Survey of Victoria, 1966), where it is dated as Oligocene, and separated from the overlying Latrobe Valley Coal Measures by a basalt unit, the Thorpdale Volcanics. In the absence of the Thorpdale Volcanics, which thin eastwards in the subsurface, the Childers Formation does not appear to be lithologically distinct from the overlying coal measures. There is confusion in the literature with respect to the age and lithology of this unit. Traill (1968) described it as a series of brackish water clays and slates, and Haskell (1972) described this formation in the sub-surface in the coastal area as a predominantly sandstone unit overlying the Golden Beach Formation, and cited the sequence between 1449 and 1715 m in Golden Beach West No. 1 as typical of the formation. This unit contains micro flora of Paleocene age (Dettmann 1966a & b). Hocking (1972) gave the age of the formation as Eocene.

Traralgon, Morwell and Yallourn Formations. Hocking (1972) considered the Traralgon Formation in the Latrobe Valley and surroundings as the time equivalent of the Latrobe Valley Group in coastal Gippsland, and the Morwell and Yallourn Formations as the non-marine time equivalents of the marine Lakes Entrance Formation and Gippsland Limestone respectively. Boutakoff (1955) described the Morwell and Yallourn (Groups) as consisting of 'thick brown coals with subordinate clays passing eastwards into gravels and sandstones'.

Latrobe Valley Coal Measures. Hocking (1972) confined the use of this term to the coal measures of Eocene to Miocene age in the Latrobe Valley and surroundings. He gave the unit group status, and recognised the five formations shown in Figure 3 and described briefly in the foregoing. Haskell (1972) on the other hand, regarded the coal measures as a formation comprising the Eocene part of the Latrobe Group, and divided the pre-Eocene part into the Golden Beach Formation and the Childers Formation.

Colman (1976), in a review of the onshore part of the basin used Hocking's classification, but the term Latrobe Group for the two sequences referred to by Hocking as Latrobe Valley Group and Latrobe Valley Coal Measures.

Lakes Entrance Formation. This unit was mapped in the subsurface onshore as a sequence of basal gravels and sands, a glauconitic sandstone member, and a micaceous marl. It is Oligocene and up to 230 m thick (Crespin, 1943; Boutakoff, 1955; Carter, 1964). It comprises the Colquhoun Gravel Member, the Greensand Member, and the Micaceous Marl Member of Hocking & Taylor, (1964). Offshore (James & Evans, 1971) the name is applied to a sequence of marine mudstone, up to 455 m thick, which overlies the Latrobe Group. The mudstone is usually olive-green and contains a variable amount of argillaceous and calcareous material, and abundant bryozoal fragments, foraminifera, pyrite and glauconite. The boundary with the overlying Gippsland Formation is gradational, lying within the Oligocene onshore, and within the Miocene offshore in the centre of the basin.

Gippsland Limestone. Onshore, the formation comprises up to 900 m of Miocene limestone and marl overlying the Lakes Entrance Formation. Offshore, the formation reaches a thickness of up to 1500 m, and mainly consists of limestone, calcarenite, and marl. The sediments infilling the Miocene sub-marine canyons are also considered part of this formation. These are mainly calcareous mudstone with subordinate micritic limestone, but in the area of the Barracouta field there is a quartz-carbonate sand unit, which is interpreted as possibly a channel-head facies (Esso, 1966).

Jemmy's Point Formation. Hocking (1972) used the term for a late Miocene to early Pliocene sequence of glauconitic-limonitic sandstone and siltstone in southeast Gippsland. Offshore, the youngest sedimentary unit consists of a largely calcarenite sequence up to 300 m thick (Franklin & Clifton, 1971; James & Evans, 1971) which Hocking also assigned, although tentatively, to the Jemmy's Point Formation.

Hocking (Fig. 2) included the three formations just described in the Seaspray Group.

Sale Group. Hocking (1972) described this group as representing the final phase of the major transgressive/regressive cycle which produced the sedimentary fill of the Gippsland Basin and the return to continental clastic sedimentation in southern Gippsland. He included the Plio/Pleistocene Haunted Hill Gravels, and the Pliocene Boisdale Beds (Fig. 3) with a combined thickness of up to 260 m, as typical units (Jenkin, 1968).

Quaternary sediments. A relatively thin veneer of Quaternary sediments was deposited across southeast Gippsland after a period of extensive erosion (Jenkin, 1968).

GEOPHYSICAL EXPLORATION

The earliest geophysical surveys in the Gippsland Basin were carried out by BMR. Gravity surveys by BMR began in 1948 and continued in limited areas until 1961. Aeromagnetic surveys by BMR covered most of the onshore basin and a significant part of the offshore basin by 1956. BMR further investigated gravity and magnetic anomalies by small-scale seismic surveys until the early 1960s, since when most of the work has been carried out by petroleum exploration companies.

During the 1960s, the emphasis of geophysical activity moved from onshore to offshore. The surveys also became larger in scale and coverage, and increased in technical complexity. Numerous marine seismic surveys were carried out between 1963 and 1975. Important offshore petroleum reserves were discovered and exploited during the period.

Geophysical activity onshore has declined from the levels experienced in the early 1960s. Only one minor seismic survey and one regional gravity survey (by BMR) have been undertaken this decade, and the latter was not specifically directed at petroleum objectives.

This section will describe the history of geophysical operations in the Gippsland Basin, and review their results on a regional scale.

Magnetic surveys

The locations of magnetic surveys in the Gippsland Basin are indicated on Plate 2. Individual surveys are also listed in Appendix 2 and are cross-referenced to the map by means of map key numbers.

Airborne magnetic surveys by BMR (McCarthy, 1952; Goodeve, 1956) had covered the onshore areas of the basin and most of the near offshore areas by 1956. Individual flight lines have not been indicated on Plate 2 for this detailed work, but flight lines were oriented north-south and spaced 1.6 km apart. Flight altitude was 300 m. Offshore aeromagnetic coverage was extended by Haematite Explorations during 1960-61 into the central Gippsland Basin. This work was part of a large survey covering much of Bass Strait and extending west into South Australian waters (Haematite, 1965). An aeromagnetic survey in 1967 for Magellan Petroleum was undertaken in deeper water along the outer shelf and upper continental slope, but details are unavailable.

Magnetic data have been collected in the offshore Gippsland Basin during marine geophysical surveys from 1968 to 1973, and results from parts of three surveys are available under the Petroleum Search Subsidy Acts. These consisted of two surveys by Magellan (East Gippsland and Tasman-Bass Strait), and one by Esso Exploration (the G69A survey, see Appendix 2).

Regional magnetic traverses in deep water were undertaken during Esso's G71A survey, the BMR Continental Margin geophysical survey of 1971-72, and the Shell Deepwater Scientific survey of 1972-73.

Results. Quilty (1965) has documented the results of the BMR aeromagnetic surveys. Contours of depth to magnetic basement for the onshore and near offshore parts of the basin in Plate 3 have been taken from his interpretation. In the area immediately northeast of the Kent Group, the contours depend on the company's interpretation of the results of Haematite's survey (Haematite, 1965). The good agreement between these two interpretations along the common survey boundary has permitted presentation of continuous contours across the boundary area between the two surveys in Plate 3.

Results shown for the remainder of the Gippsland Basin are adapted from a report available under PSSA (Magellan, 1969). Magnetic intensities measured at sea level during a marine seismic survey were recomputed using the method of upward continuation to a plane 300 m above sea level, and integrated with magnetic intensities measured at that altitude during a previous aeromagnetic survey. This enabled a more complete definition of the anomaly pattern to be made than was possible using marine magnetic or aeromagnetic data alone. However both survey areas were narrowly confined so that optimum definition of anomalies may not have been achieved. Because no significant overlap existed between Magellan's results and those described previously, the two sets of data are presented as separate sets of contours on Plate 3.

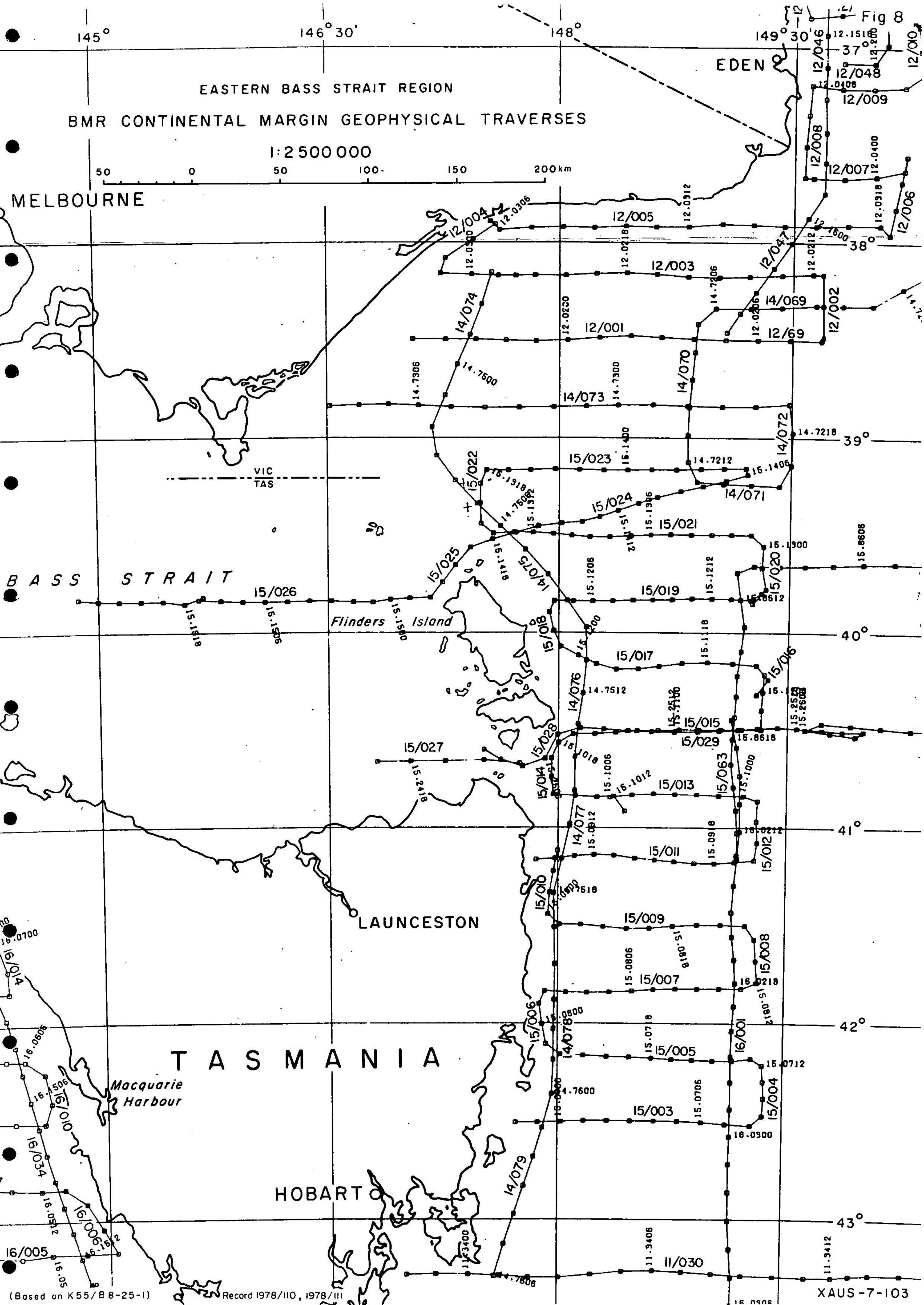
General agreement between them is observed between 39°S and 40°S. Magnetic results from later marine surveys are mostly presented in company reports in profile form, and interpreted depths to magnetic basement are not available.

A strong magnetic contrast between basin sediments and Palaeozoic rocks was observed around the onshore basin boundary, together with a tendency for Palaeozoic tectonic axes, as expressed by magnetic anomalies, to continue across the boundary beneath the basin. Maximum basin thickness was indicated to occur mainly offshore in an east-west trough extending from the coast to the 200 m isobath. A large area of shallow magnetic basement was indicated over the eastern part of the Victorian offshore area, extending to 40 km south of the coast. The presence of basalt flows within the sedimentary section in the western onshore area reduced the reliability of some basement depth estimates, but the presence of an easterly-plunging anticlinal basement feature intersecting the coast near 38°30'S was indicated.

To the south and southwest of the area of deepest basinal development, magnetic basement gently shallows, and represents a set of ridges with interfingering embayments of sediment which thin toward the southwest. The Gippsland Basin is bordered along its entire southwest margin by a region of shallow or outcropping basement rocks known as the Bassian Rise. Although short wavelength, high amplitude anomalies, typical of shallow basement were mapped near Wilson's Promontory and Flinders Island, the Bassian Rise produces no intense magnetic anomalies along much of its length.

Magnetic results have suggested that areas of significant sediment thickness may exist in deep water around the rim of the Bass Canyon, which is the name given to the prominent northwesterly-trending embayment of deep water in eastern Bass Strait between 38°30' and 39°S, and on the continental slope to the south. A total sediment isopach map would be preferable to a basement depth map for the presentation of results in rapidly varying water depths, but Plate 3 permits the following general observations:

Fig 8


EASTERN BASS STRAIT REGION
BMR CONTINENTAL MARGIN GEOPHYSICAL TRAVERSES
1:2500000
50 0 50 100 150 200km
145°
146°30'
148°
149°30'
37°
38°
39°
40°
41°
42°
43°
MELBOURNE
EDEN
VIC
TAS
BASS STRAIT
Flinders Island
LAUNCESTON
TASMANIA
Macquarie Harbour
HOBART
12/004
12/005
12/003
12/001
12/046
12/048
12/009
12/008
12/007
12/006
12/047
12/002
12/69
14/069
14/070
14/071
14/072
14/073
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14/075
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15/026
15/027
15/028
15/029
15/063
16/001
16/005
16/006
16/010
16/014
16/034
11/030
(Based on K55/B8-25-1)
Record 1978/110, 1978/111
XAUS-7-103

On the north wall of the Bass Canyon, sediment thickness indicated by the magnetic data ranges from 3 to 5 km in water depths of 1 - 2 km. Survey coverage is sparse at the canyon head, but the presence of 1 - 2.5 km of sediment is indicated. Up to 4 km of sediment may be present on the western wall. This sediment distribution is consistent with an erosional origin for the canyon. Further south, at about 39°20'S a graben containing a maximum of 4 km of sediment in water depth of 1 km exists (Pl. 3). In general, the shape of the magnetic basement surface in the area of the slope appears complex relative to that in the shelf area. However, this apparent complexity may simply be due to the fact that the contours are based on a larger number of depth estimates in the slope area.

Cameron & Pinchin (1974) have interpreted the results of BMR Continental Margin geophysical traverses (Fig. 8) as indicating the presence of a line of intrusive features which have strong magnetic expression. This line extends from NSW to south of latitude 40°S, and cuts across the trend of the Bass Canyon. The emplacement of the intrusives within the continental slope during Jurassic time, as a consequence of rifting of Gondwanaland, has been postulated by Cameron & Pinchin.

<u>Gravity surveys</u>

Geophysical exploration in the Gippsland Basin began in 1948, with the initiation of a series of gravity surveys by BMR. Neumann (1974) has summarised the work and results for the period 1948-1961. Principal objectives were the location of coal deposits and the delineation of structure in coal-producing areas. Details of gravity surveys in the Gippsland Basin are given in Appendix 2, but not all individual surveys for the period covered by Neumann have been listed. For additional details the reader is referred to Thyer & Williams (1948), Dooley (1952), Dooley & Mulder (1953), Neumann (1951, 1960), Lonsdale (1963), and Neumann & Lonsdale (1973).

In 1966, a small gravity survey was conducted for Woodside (Lakes Entrance) Oil Co. immediately east of Lake Wellington over a seismically-defined high at the level of the Latrobe Valley Coal Measures. No significant gravity anomaly was mapped.

The other gravity surveys conducted in the Gippsland Basin were regional surveys. In 1973-74, a regional helicopter survey by BMR covered the onshore areas with gravity stations on an 11 km grid (Zadoroznyj, 1975). Offshore, gravity data were collected along the traverses of the BMR Continental Margin geophysical survey (Cameron & Pinchin, 1974) and by Shell Development (Australia) in their Deepwater Scientific survey, 1972-73.

Results. Bouguer anomalies over onshore areas, and free air anomalies over offshore areas are presented in Plate 4, which is a preliminary version of a comprehensive and current gravity map now in preparation by BMR. Descriptions of the onshore gravity features have been given in detail by Neumann (1974) and on a regional scale by Zadoroznyj (1975).

A large closed gravity 'low' along the coast northeast of Wilson's Promontory is a prominent feature of the map. It partly coincides with, but does not extend as far to the southeast as, a magnetically indicated basement depression (Pl. 3). Displacement of the gravity 'low' relative to this depression may be due to the countervailing positive gravity effect associated with crustal thinning to the southeast.

Other prominent features are a north-aligned gravity ridge over the slope area south of 39°S, a 'high' of similar magnitude seen in the extreme northeast corner of Plate 4, and the deep gravity trough which separates these two areas of positive gravity anomalies. This last feature is largely caused by the negative effect of deep water in the Bass Canyon, while the positive areas are parts of a much longer belt present around much of the Australian continental margin. The presence of the positive belt has been attributed to the combination of two effects: deep-lying mantle material becoming more shallow to seaward, and the layer of sea water becoming thicker to seaward. However, the line of intrusive bodies described in the preceeding section closely coincides with the gravity ridge, and dense intrusives may contribute to the increase in gravity values.

Seismic surveys

Plate 5 illustrates the density of seismic coverage in the Gippsland Basin. Individual surveys may be identified by the map key numbers which refer to Appendix 2.

Land surveys. The earliest seismic surveys in the Gippsland Basin were done by BMR during the 1950s. Commonly, these surveys involved a limited number of traverses recorded over gravity and/or magnetic anomalies to test for the presence of closed structures. In some cases structures were confirmed (Garrett, 1955), but not in others (Vale, 1952). Combined reflection and refraction traverses, whose objectives were related to both oil and coal exploration, were later recorded (Lodwick & Moss, 1959; Fowler, 1961). Reduced ambiguity of interpretation resulted from this dual technique approach, and the presence of a great thickness of pre-Tertiary section was indicated in the Latrobe Valley.

The first reflection seismic surveys by geophysical contractors were undertaken for Woodside (Lakes Entrance) Oil Company, beginning in 1960, in the vicinity of Lake Wellington. A drilling location was recommended after two such surveys, and drilling results subsequently confirmed the presence of very thick Jurassic section.

One dip reversal, suggested by the Woodside work, was more closely investigated by Arco Ltd during a survey in 1962. This survey also extended seismic coverage east from Lake Wellington to Lakes Entrance, and to the southwest in an area inshore from the Ninety Mile Beach. Refraction traverses formed part of this work. Closure was confirmed on at least one structure.

Other minor surveys, using the refraction and single coverage reflection seismic techniques, were undertaken onshore in the extreme west and east of the basin for A.P.M. Development and W.Y.P. Development, respectively.

Of greater interest were two surveys, which involved the application of higher multiplicity of coverage (600% CDP) to explosive reflection work in 1964, and the use of the Vibroseis energy source for reflection work in 1965. The first of these surveys, near the coast south of Sale, for Arco Ltd, achieved a significant gain in record quality compared to previous results, but no continuous horizon could be mapped below the Tertiary. The second, by Woodside (Lakes Entrance) Oil along the coastal region to the southwest of Lake Wellington, resulted in data quality sufficient for the mapping of two small closed structures associated with a positive gravity anomaly. Multiples generated at the coal horizons were attenuated to a degree and this enabled some valid pre-Tertiary dip to be observed, but no continuous pre-Tertiary events could be mapped.

Marine surveys. Following assessments of the prospectivity of the onshore Gippsland Basin in the early 1960s exploration was largely diverted to the offshore areas, where considerable thicknesses of sedimentary section had already been established from aeromagnetic surveys (see section on magnetic surveys).

The first marine seismic survey was undertaken for Arco Ltd in a narrow near-shore strip parallel to the Ninety Mile Beach, in 1962. The objectives of this reconnaissance survey were to test for offshore extensions of known structural trends, and determine sediment thickness. These objectives were realised from the fair to good quality results obtained for the Tertiary section. The detector cable was designed to allow two records of each shot to be made, using different spread lengths.

However, the first extensive reconnaissance marine seismic survey was done in 1963, for the operating company Haematite Explorations (later Hematite Petroleum). The detector cable was of similar design to that used the previous year, and permitted some discrimination against multiple reflections on the criterion of large moveout. Several structures with considerable area and vertical closure were mapped, as were large areas in the northeast and extreme western parts of the basin, where thin Tertiary section was interpreted to be resting directly on shallow basement.

Following its farm-in agreement with Haematite (see Petroleum Potential), Esso proceeded with an exploration program in the central part of the offshore Gippsland Basin, beginning with the Gippsland Shelf seismic survey of 1964. Good results from this multiple (600%) coverage survey, together with some well control, led to a basic understanding of the nature of potential hydrocarbon traps in the area. A notable discovery was the palaeocanyon trending southeast from Lakes Entrance, which was subsequently found to be a critical element in trap formation. Several structures were mapped.

Following the discovery of the Barracouta field in 1965 the area surrounding it became ineligible for subsidy and the seven marine seismic surveys in the Gippsland Basin listed in Table 1, which were undertaken during the period 1966-69, were only partly subsidised. Data from survey lines shot between 1965 and March 1972 inside certain circular areas ('excluded circles' around petroleum discoveries), whose centres and radii are given in Table 1 and which are shown in Plate 1, are not publicly available through the Petroleum Search Subsidy Act 1959-73. Moreover, data from unsubsidised surveys done before the Petroleum (Submerged Lands) Act 1967-74 became effective in late 1968 are not generally available in BMR, whereas data from later offshore surveys are available on a restricted basis under the terms of the Act. This is the case for the last 3 surveys in Table 1. Confidential P(SL)A data are held by the Designated Authority in Victoria and by BMR. The following discussion of seismic survey results is based on all survey lines available in BMR.

The second survey undertaken by the Esso/Haematite partnership, the Eastern Bass Strait survey of 1966, had multiple objectives. These were to investigate stratigraphic trap potential around the basin margin by collecting single coverage seismic data, and to use the multiple coverage technique to detail structures already discovered. At least three features were upgraded to prospect status, and additional new leads were discovered. Rapid lateral facies changes associated with channel filling were interpreted as the cause of complex velocity variations, but fair qualith data were obtained.

The next survey by Esso, entitled the EC-67 survey, explored the stratigraphic trap potential in the southwest of the basin by the application of digital recording and computer processing technology. The improvement in data quality and resulting confidence in interpretation ensured the continued adherence by the operator to these techniques. A higher multiplicity (1200%) and an alternative energy source ('Aquapulse') were subsequently coupled to the new digital technology during the EH-68 and G69A Surveys. The limit of the Latrobe Group delta complex to the southwest was precisely defined by such work, but no stratigraphic traps could be defined.

Surveys by Esso for which little or no company interpretative material is available include G69B, G70A, G71B, G72A, G73A, G73B, and G74A; the areal coverage of these surveys ranged from widespread (e.g. G72A) to localised (e.g. G70A was entirely on the Tuna structure, and G73B on the Marlin field). The only energy source used since 1970 for surveys in the central part of the offshore Gippsland Basin has been the airgun array.

Other operators have been active in the more distal parts of the basin. Shell Development in 1965 explored the northeastern area with the objective of defining the thickness and the northern limits of the basin sediments. Four-fold multiplicity of coverage produced good quality results, and led to the conclusion that Tertiary sediments overlie Palaeozoic basement on the northeastern margin of the basin. Closed structurally high areas were mapped and interpreted as basement topographic features of low prospectivity. The Sole structure, located near the western extent of this early reconnaissance survey (see Sole No. 1 well, Pl. 1), was subsequently detailed in 1967 during a major sparker survey, which was notable for the contemporaneous shipboard interpretation of unprocessed data undertaken. Limited closure was mapped at the Latrobe Group level. Reconnaissance seismic work also indicated the presence of a large central, structurally high area in the extreme east of the Gippsland Basin. In 1970 this was investigated seismically and shown to be underlain by an irregular basement surface, the highest knolls of which appeared from seismic character to be remnants of intrusive plugs. Seismic horizons were mappable near the base of the sedimentary section, above basement. This section was indicated to be

200 to 900 m in thickness. One other detailed seismic survey was conducted over a structural lead ('Shark') to the southeast of the Sole structure, in 1973. Improved data quality was achieved over previous results by means of different processing, and the Shark structural lead in the intra-Latrobe section was better defined. However, the structure has not been drilled.

Seismic exploration in deeper water south and east of the central part of the basin began in 1968, when Magellan Petroleum conducted a survey along the outer edge of the continental shelf and partly onto the slope. Both dynamic and static time corrections were applied in novel ways during processing of the data, to allow for relatively sharp changes in water layer thickness. A velocity inversion was found to be associated with the presence of substantial thicknesses of Latrobe Group sediments. A closed structure was mapped at the top of this formation in water depths of 100-120 m, near the Victoria-Tasmania border. Basement reflections of poor reliability were mapped, and found to corrspond reasonably well in depth with interpreted magnetic basement.

As part of a much larger seismic survey in 1969, Magellan made use of a single coverage sparker reconnaissance technique in an attempt to extend knowledge of section thickness and basin configuration to the eastern boundary of the Gippsland Basin. The survey also included CDP seismic reflection work to define in more detail the closed structure located in the previous year. While the latter objective was realised, and a structural trap confirmed, the eastern boundary of the basin remained undefined, because results indicated that sediments extended beyond the limits of the survey.

The Sailfish seismic survey of 1970, on behalf of N.S.W. Oil and Gas Company, covered in more detail a deep-water area initially explored by Magellan in the southeastern corner of the basin. Some refraction work was attempted during this survey, but it achieved little success, owing to sonabuoy failure. However reflection traverses located a number of anomalous features which were diagnosed, from fairly good quality data, as reefal in origin, a conclusion shown to be erroneous by a later drill test which intersected pyroclastic rocks at the expected reef level.

Two regional surveys, by Shell Development and BMR, recorded seismic and other geophysical data along widely spaced traverses in and near the Gippsland Basin (see Fig. 8 and Pl. 5). The BMR seismic survey using a sparker energy source achieved poorer energy penetration than the Shell survey with airguns. The higher technology effort on the Shell survey produced fair quality results indicating that continental-type basement in the slope area forms a series of linear north-trending step-faulted blocks, supporting occasional wedges of landward dipping continental sediments. At the base of the slope, the character of the basement changes, suggesting an oceanic-type basement beneath the abyssal sea-floor sediments. It appears that the basin boundary to the east occurs in the mid to lower slope area, where ponding of sediments in discrete wedges is common. A more precise definition of the eastern Gippsland Basin offshore boundary could be derived from further study of the seismic traverses of both this Shell survey and the BMR Continental Margin survey.

Regional results. Regional seismic depth contours, which summarise some of the results of seismic exploration for petroleum in the Gippsland Basin, are presented in Plate 6, at a scale of 1:500 000. The principal horizon chosen for presentation, while often loosely referred to as "the top of the Latrobe", is the unconformity surface at the top of the Latrobe Group. The horizon is strongly diachronous.

This horizon is chosen for presentation because it is the interface between overlying cap rocks of the Lakes Entrance Formation, and the underlying reservoir rocks of the Latrobe Group, which together constitute the most economically important hydrocarbon play in the basin. A coarse contour interval of 250 m has been used for the offshore areas in Plate 6, so that not all significant structures are outlined by the contour pattern. However structural names have been included to indicate locations of structures of major interest. Some details of the nature of potential hydrocarbon traps is given in the next section of this study. The top of the Latrobe Group has been mapped reliably by operating companies in much greater detail than shown. Potential stratigraphic traps have been located within the Latrobe Group, and the history of small scale eustatic Tertiary sea level changes has been determined (Steele, 1976) from high resolution seismic data.

Channel cutting and filling are known to have occurred during the period of deposition of the Latrobe Group, but most channels were partly or wholly filled with intra-Latrobe sediments by the time the Lakes Entrance Formation was laid down. An important exception is the Marlin Channel, which is evident from the contours of Plate 6. It reaches at least as far seaward as the 200 m isobath, near 38°30'S. Channel fill material of Eocene to Miocene age plays an important role in providing a flanking seal for the Marlin Field.

In two areas the Latrobe Group persists down the continental slope to the 1000 m isobath, and beyond, but its southeastern limit cannot be readily determined from the petroleum exploration data alone, which has been confined to the upper slope and shelf area.

The onshore contours shown on Plate 6 define the attitude of the top of the Latrobe Valley Coal Measures (see Geology). In contrast to the offshore horizon discussed above, that shown for the onshore area can be considered isochronous. In some localities the contour map was constructed from good quality reflections from a coal horizon, but in other areas the horizon has been "phantomed". Contour interval onshore is 200 m.

It should be noted that contours have been drawn from a variety of sources during the compilation of Plate 6. While different operating companies have mapped what appears to be the same horizon in different areas, correlation must be made with caution. Boundaries where uncertainties may arise have been indicated on Plate 6.

Seismic velocity variations. The factor causing most problems in the seismic mapping of structures has been the existence of strong horizontal velocity gradients near the base of the Gippsland Formation. The velocity variations have been of sufficient magnitude to mask or distort valid structures, or to falsely indicate the presence of structures at deeper levels. McEvoy (1974) has described the geological causes of these velocity gradients, and the techniques adopted by Esso for limiting their effect on seismic mapping.

Limestones of the Gippsland Formation were deposited in channels eroded into shales of the immediately underlying Lakes Entrance Formation. Locally, a seismic velocity difference of one to two thousand metres per second between limestones and shales occurs at many channel boundaries. Since channels lie over most of the major structures of interest, severe distortion of the seismic time expression of such structures results. Simple conversion to depth using NMO-derived velocities conserves this distortion. Instead, it is necessary to compute a suite of corrected velocities using true velocities determined at well sites as a standard and allowing for channel size and distribution, and velocities of infill material.

A total of five distinct channel systems has been mapped and analysed in detail (Esso, 1974). Their morphology, ages, relationships with each other and with older and younger features, and genesis, are now reasonably well known. Channel mapping and detailed seismic velocity analyses continue to be of prime importance in establishing structure integrity and size in the Gippsland Basin.

PETROLEUM POTENTIAL

The Gippsland Basin has been discussed as a hydrocarbon province by many authors. Wales (1969), Griffith & Hodgson (1971), Hocking (1972), Beddoes (1973), Threlfall & others (1976), and Colman (1973) are the main references used in the compilation of this chapter.

History of petroleum exploration

The offshore Gippsland Basin is Australia's major oil and gas producing province. No major discovery has been made in the onshore area.

Interest in the petroleum potential of the onshore Gippsland Basin dates back to about 1886, when a test bore was drilled near an alleged oil seep near Toongabbie (Poll, 1975). However, serious petroleum exploration began after the discovery of minor oil and gas in Lake Bunga No. 1 bore, drilled by Lakes Entrance Development Co. Pty Ltd near Lakes Entrance in 1924. Subsequent drilling in the area delineated two oil pools, from which about 10 000 barrels of 15^{o} A.P.I. oil were produced in 32 years. The State Department of Mines and several small companies participated in this venture.

Since the Lakes Entrance discovery, about 125 wells have been drilled in the onshore area - mainly concentrated in a long narrow coastal strip, and with about half located near Lakes Entrance (Plates 1 & 1A). There have been no significant indications of hydrocarbons. The modern phase of this activity began with the formation of Woodside (Lakes Entrance) Oil Co N.L. in 1954. Since that time, this company and its associates have been the major onshore title holders, drilling 41 wells since 1955.

Offshore exploration began with the aeromagnetic surveys carried out by BMR between 1951 and 1956, but the major effort was initiated in 1960 when Broken Hill Pty Co Ltd., acting on the advice of a consultant, Lewis G. Weekes, acquired exploration permits covering a large part of the offshore area. BHP then formed a subsidiary company, Haematite Explorations Pty Ltd (later Hematite Petroleum Pty Ltd), which became the permit holder, and in 1964, Esso obtained farm-in rights to the permits. The partnership made the first offshore discovery in February 1965, when gas was discovered in Esso Gippsland Shelf No. 1 (later renamed Barracouta No. 1), Australia's first offshore well. The Marlin gas and oil field was discovered in 1966, and the Halibut and Kingfish oil fields in 1967.

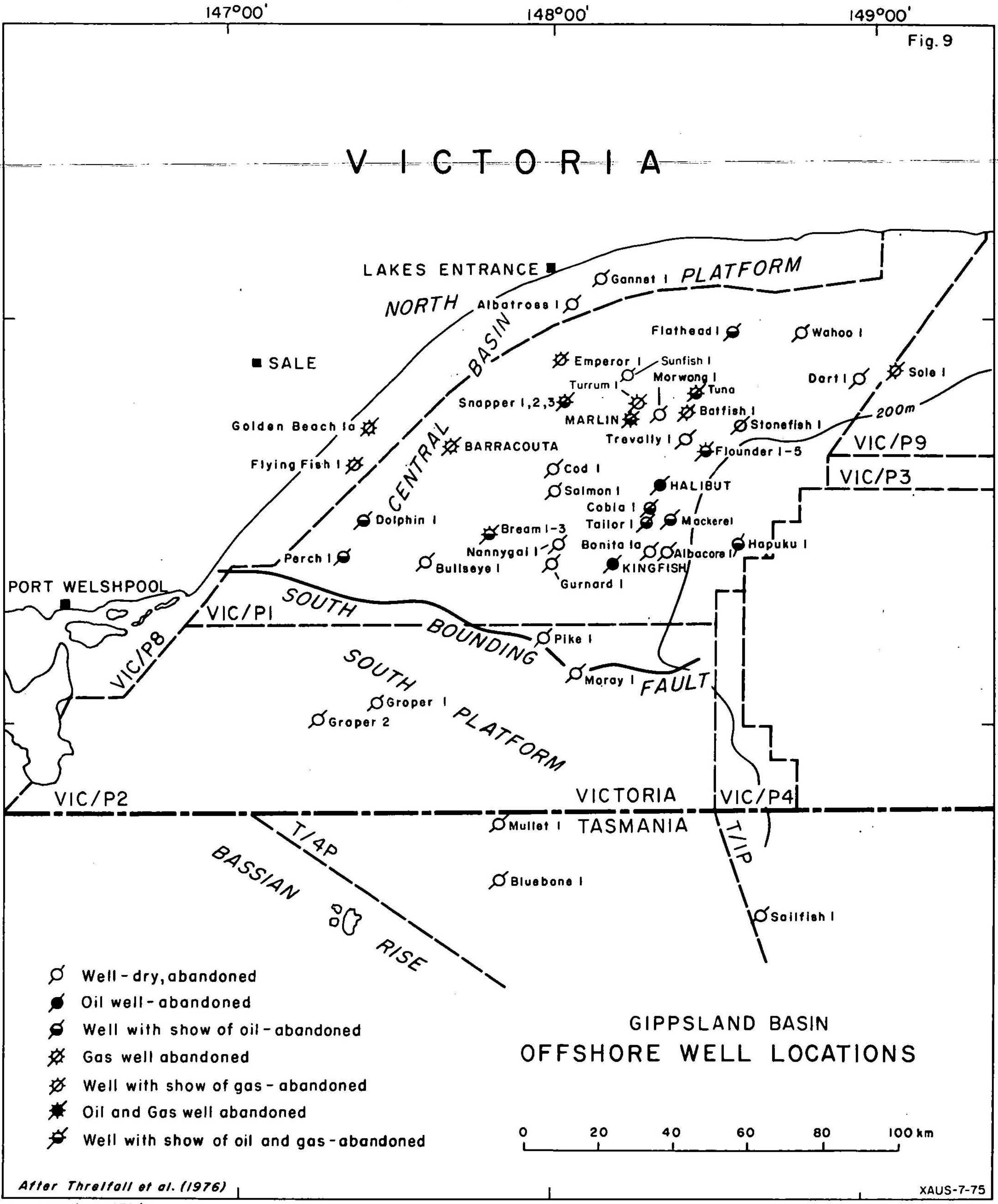
Gas production began from the Barracouta field in March 1969, and from the Marlin field in November 1969, and oil production from the Halibut and Kingfish fields in March 1970 and April 1971 respectively. Oil production from the Barracouta field began in October 1969. Three other fields discovered by Esso/BHP, the Mackerel oil field and the Snapper gas and Tuna oil and gas fields have been declared commercial, but are not as yet producing.

To the time of writing (February 1976), Esso/BHP have drilled 64 exploration and step-out wells (Appendix 1a) in the offshore Gippsland Basin.

Between 1967 and 1971 Woodside (Lakes Entrance) Oil Company N.L. and associates drilled four wells in the offshore strip adjacent to the coast. One of the wells, Golden Beach 1A drilled in 1967 was a gas discovery, but the field has not been developed for production. N.S.W. Oil and Gss N.L., and Shell Development Australia Pty Ltd have each drilled one offshore well, withouth success.

Appendices 1a and 1b list the wells drilled in the basin, Figure 9 shows well locations and Appendix 3 includes the stratigraphic sequences and lithologies penetrated by selected wells which have produced either commercially significant hydrocarbons or significant shows.

Table 2 and Figure 11 give details of the petroleum exploration permits and production licences in force at 31 December 1976.



After Threlfall et al. (1976)

Record 1978/110, 1978/111

Source, reservoir and cap rocks

The interbedded sandstone, siltstone, carbonaceous shale and coal of the Latrobe Group contain both the source and reservoir rocks for the hydrocarbons in the Gippsland Basin.

The major hydrocarbon accumulations are trapped at the erosional surface at the top of the Latrobe Group. The reservoirs are highly porous and permeable, usually massive sandstones predominantly of Eocene age, and the cap rock is provided by the mudstone and marl of the Lakes Entrance Formation, and by the channel-fill sediments. Other accumulations occur in reservoir sands of early Eocene, Paleocene and Late Cretaceous age within the Latrobe Group, which in these cases are capped by shale within the fluvio-deltaic sequence.

The reservoir rocks of the onshore Lakes Entrance oil field occur in the basal part of the Lakes Entrance Formation, in the Colquhoun Gravels and the overlying Greensand Members. The reservoirs are capped by the micaceous marl unit which comprises the top member of the formation. Sands which occur in this unit also contain occasional oil smears. The oil is thought to have originated in the Latrobe Group.

It has been established that the hydrocarbons were formed by the diagenesis of land plant material (waxy leaf cuticle, pollen, spore coatings) associated with the carbonaceous sediments and coal in the Latrobe Group (Brooks & Smith, 1967, 1969; Brooks, 1970; Powell & McKirdy, 1976). Brooks (1970) stated that in sediments containing such material 'petroleum does not form unless the increasing temperatures accompanying deeper burial has been sufficient to alter brown coals to high-volatile bituminous coals with carbon contents near 80 percent'.

Hocking considered that most of the Gippsland Shelf hydrocarbon accumulations have migrated only a short distance from source to reservoirs, and that the generation and subsequent migration took place during the late Eocene to early Oligocene. In support of a short migration he quoted a table of Brooks & Smith (1969) reproduced below, which shows that the paraffins of higher molecular weight in oils from the Gippsland Basin fields and in solvent extracts of the deeply buried offshore coals were of similar molecular distribution.

Relative percentages of n-alkanes in the C19-C29 range in coal and oil from the Gippsland Basin (Brooks & Smith, 1969)

Carbon number	19	20	21	22	23	24	25	26	27	28	29
Coal at 7500 ft (2287.4m) (Marlin No. 1)	9.3	10.2	11.9	13.4	12.4	11.3	10.3	7.6	6.7	4.2	2.9
Oil at 7590 ft (2314.8m) (Kingfish No. 1)	11.7	11.4	11.0	12.0	12.8	10.7	9.6	7.5	6.8	3.9	2.8

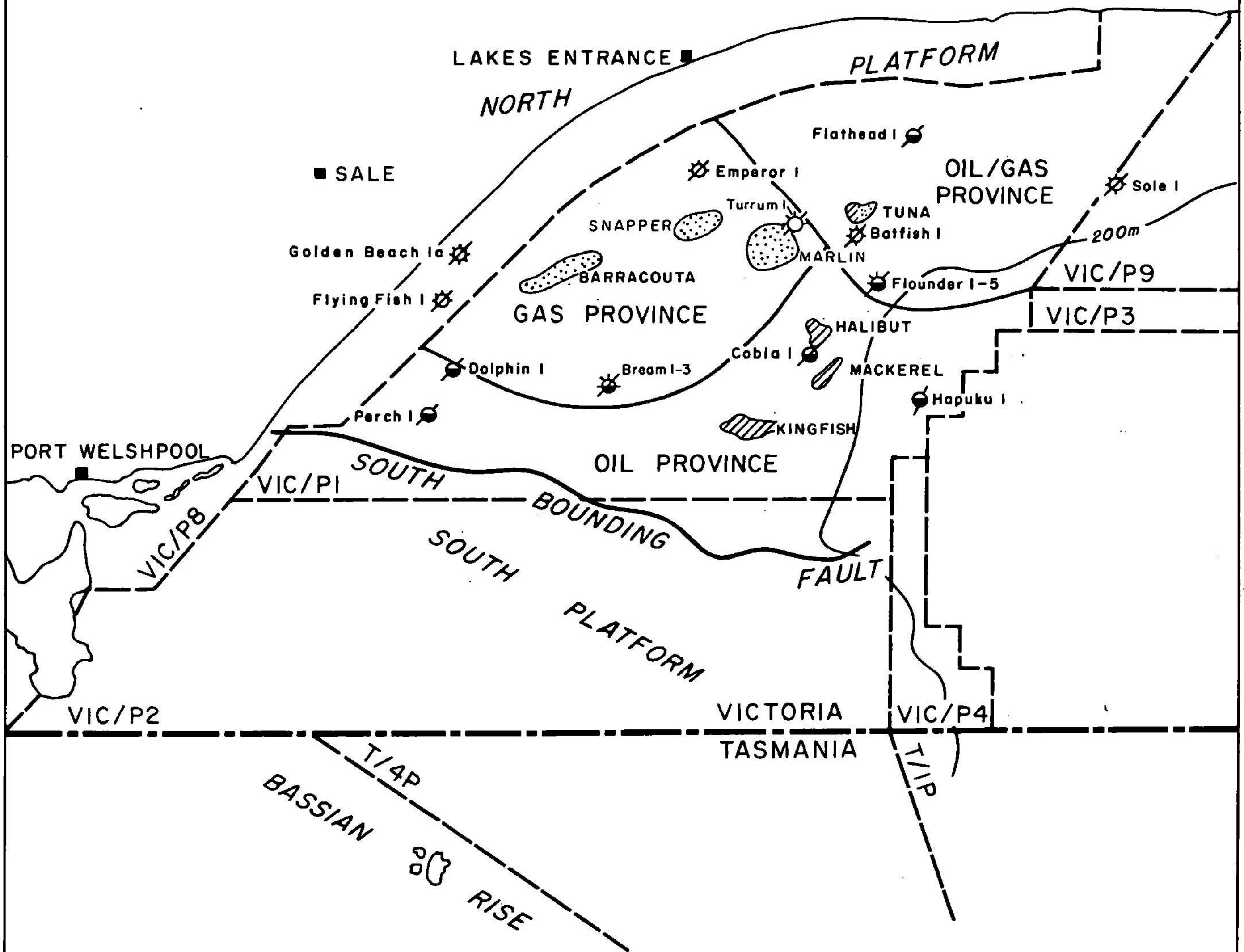
Threlfall & others (1976) have delineated three hydrocarbon provinces in the offshore Gippsland Basin: a gas province in the north and northwest; an oil province in the southwest, and an oil and gas province in the northeast (Fig. 10).

The gas province closely approximates to the areal distribution of non-marine Latrobe Group sediments of Eocene age. The main source of the gas is thought to be the coal, which occurs prolifically in seams up to 30 m thick.

In the oil province all the major oil accumulations are paraffinic in composition. The oil in the Perch and Dolphin structures is napthenic. Source rock studies have indicated that the paraffinic oils were derived mainly from Latrobe Group coals and non-marine shales of Late Cretaceous and Paleocene age. The napthenic composition of the Perch and Dolphin accumulations suggests a marine source, although the oil may have originally been paraffinic and subsequently altered. The overlying Oligocene and Miocene marine shales and marls have poor source rock potential, because of a low organic content.

The oil and gas province contains the Tuna and Flounder fields and the minor accumulations in the Sole and Batfish structures. From the point of view of hydrocarbon accumulation, the province was physically separated from the rest of the basin by uplift during the Early Eocene

Fig. 10



Well with show of oil - abandoned
Oil field
Well with show of gas - abandoned
Gas field
Well with show of oil and gas - abandoned

GIPPSLAND BASIN
HYDROCARBON DISTRIBUTION

0 20 40 60 80 100 km

After Threlfall et al. (1976)

XAUS-7-139

Record 1978/110, 1978/111

and the blocking effect of the Marlin channel. The intra-Latrobe Group oil in the Tuna and Flounder fields is paraffinic and thought to have originated in the non-marine Paleocene and Late Cretaceous Latrobe Group. The source of the gas and minor oil at the top of the Latrobe Group in Tuna is thought to be the estuarine shale of the Tuna-Flounder channel-fill (immediately underlying the reservoir sand. The small volumes of gas which occur in Paleocene sand within the Latrobe Group in the Sole and Batfish structures are thought to have originated in sediments in the immediate vicinity of the structures.

Hydrocarbon traps

Hocking (1972) discussed the hydrocarbon traps in the offshore petroleum province. The traps are primarily structural, occurring as culminations along the major anticlinal axes of the Cainozoic fold belt in the offshore part of the central basin (Figs. 2 and 10, Pl. 6).

The largest culminations seem to be located along the Barracouta-Snapper and Marlin-Tuna anticlinal trends. Those in the deeper part of the basin tend to be smaller, probably because smaller basement fault blocks resulted from the more rapid collapse of the outer part of the craton, and because of the dissection of the structures by submarine channelling.

Wales (1969) discussed the effect of fluid movement in the basin on its petroleum potential, contending that movement of both connate and meteoric water must have undergone several reversals since the deposition of the Latrobe Group: increased formation pressure during depositional phases tending to drive fluids flankwards out of the basin, and periods of uplift and erosion producing the opposite effect. The most basinward fluid traps such as Marlin, Tuna, and Kingfish would have been the least affected, being the furthest removed from the influence of meteoric water movements. In addition, these structures were well placed for early burial beneath the sealing mudstone of the Lakes Entrance Formation. Those closer to the basin margins such as Barracouta and Golden Beach would have lost hydrocarbons, both through the effect of meteoric water movement, and because the acquisition of cap rock occurred later.

The apparent lack of hydrocarbon accumulations in the onshore structures is attributed to the basinward tilting of the structures during the Kosciusko uplift, and the associated flushing by meteoric waters entering aquifer sands within the Latrobe Valley Coal Measures at outcrop on the basin margins.

The oil in the onshore Lakes Entrance field occurs in a stratigraphic trap, which is discussed in some detail by Boutakoff (1964). The boundary between the Colquhoun gravels and sands and the glauconitic sandstone of the Greensand Member is gradational. The glauconitic sandstone seems to form irregular pockets of a shoe-string like maze, mainly in the upper, sandier part of the Colquhoun Gravel Member, and these pockets appear to connect to form a continuous layer below the capping marls. Porosity and permeability are characteristically extremely variable, and the sandstone is often very tight and unproductive. The sands and gravels of the Colquhoun Gravel Member are by contrast very porous and permeable, and water filled, the artesian water moving down-dip mainly through the basal gravels.

It appears that oil floating on the artesian water was trapped in the glauconitic sandstone where a sufficiently porous and permeable patch was continuous with the Colquhoun gravels. Presumably before the influx of fresh water the sands and gravels of the Colquhoun Gravel Member must have contained much more oil and gas than the glauconitic sandstone, in contrast to the present situation where the oil is trapped in the unit that is less amenable to water flushing. The fact that the water is commonly associated with gas reflects the fact that gas can move up-dip over the moving water in the Colquhoun Gravel Member. The only oil associated with the artesian water is confined to floating 'rafts' and scattered smears.

Threlfall & others (1976) summarised the factors which have combined to control the migration and pooling of hydrocarbons in the offshore Gippsland Basin:

' 1. an interconnecting system of porous and permeable sandstones laid down by stream channels trending in a northwest direction;

2. northwest-trending normal faults with anticlines subsequently superimposed approximately at right angles;

3. regional west dip of the Latrobe Group due to the combined effects of the Early Eocene uplift and isostatic adjustment due to sediment loading in the west; and

4. blanket seal of Oligocene and Miocene shales and marls '

Hydrocarbons migrated laterally through the porous and permeable sands in the Latrobe Group, and vertically up the normal faults which offset the intra-Latrobe Group sealing shales, into the culminations along the major anticlinal trends, to be trapped at the top of the Latrobe Group by the overlying marine shales and marls. Where intra-Latrobe Group shales were thick and extensive enough to prevent such movement between fault blocks, the hydrocarbons accumulated in the reservoir sands within the Latrobe Group, as in the Tuna and Flounder fields.

The regional westerly dip of the Late Cretaceous and Paleocene source beds facilitates the movement of oil to the top of the Latrobe Group. Variation in the properties of the oil in the Kingfish field suggests that migration is continuing still.

Meteoric waters entering aquifers in the Latrobe Group cropping out onshore provide a strong water drive in the major hydrocarbon reservoirs at the top of the Latrobe Group.

Oil and gas fields

Griffith & Hodgson (1971) and Threlfall & others (1976) presented Esso/BHP's interpretation of the geology of the Barracouta, Marlin, Kingfish and Halibut fields, and the Kingfish field is described in detail by Bein & others (1973). Colman (1973, 1976) discussed the Lakes Entrance and Golden Beach fields, and a recent appraisal of the Golden Beach field is given in Woodside Oil Ltd (1977). Beddoes (1973) tabulated information on the oil and gas fields in the basin, and detailed information on the exploration wells drilled in them is available in well completion reports (PSSA & P(SL)A). This section is based on the sources cited.*

*A series of Confidential BMR Records by the Petroleum Technology Section BMR on reserve estimates in the non-producing fields was also consulted (listed at end of Selective Bibliography).

The location of the fields is shown on Figure 10. Tables 3a and 3b show petroleum reserves in the Gippsland Basin as at 30 June 1977. Reservoir data are summarised in Tables 4 and 5.

Barracouta oil and gas field. The Barracouta structure mapped on the top Latrobe Group unconformity surface is a closed northeast-trending anticline about 20 km long and 4 km wide. It is cut by a northwest-trending normal fault downthrown to the southwest. The gas is produced from Eocene sands of the Latrobe Group (N.goniatus zone) immediately below the unconformity. Cap rock is the marine mudstone of the Oligocene Lakes Entrance Formation. Oil is produced from intra-Latrobe Group sands of Eocene age (M. diversus zone), some 275 m below the gas/water contact of the gas reservoir. The oil is in a structure which is conformable with that mapped on the unconformity surface, but which has independent closure. The oil is trapped by a seal of interbedded shale and coal. Oil is also produced from the N.goniatus zone from a reservoir which is restricted to a small area to the southwest of the platform.

The Latrobe Group sediments within the Barracouta field comprise massive, laterally extensive sandstones, alternating with shale and coal. The principal sands of the oil and gas reservoirs are interpreted as braided stream deposits.

Marlin gas field. The Marlin structure mapped on the Latrobe Group unconformity surface is a broad feature slightly elongated in a northwesterly direction, with a maximum vertical closure of 275 m over an area of 140 km^2. The northeast flank of the structure is truncated by thenorthwest-trending Marlin Channel.

Gas production is from Eocene sands in the Latrobe Group (N. goniatus and M. diversus zones) immediately below the unconformity. A non-commercial oil accumulation occurs below the gas column.

Kingfish oil field. Mapped on the Latrobe Group unconformity surface, the Kingfish structure is a large east-trending anticline with an areal closure at the oil/water contact of about 65 km^2 and a vertical closure of some 90 m measured at the crest of the structure, just south of one of the two production platforms, the Kingfish B platform. The structural configuration of the enclosed sediments down to approximately the top of the L. balmei zone is that of a westerly plunging anticlinal nose. Log correlations between wells indicate an unconformity surface at this level. Production is from Early Eocene sands (M. diversus zone) at the top of the Latrobe Group.

A detailed stratigraphic analysis of the sediments in the reservoir has permitted the recognition of three distinct depositional phases: The earliest, progradational phase, represented by massive braided stream sandstones; an aggradational phase represented by massive medium-grained to pebbly braided stream sandstones and associated flood-plain deposits; and a final phase of marine transgression represented by clastic sediments of marginal marine origin. The youngest sequence is restricted to the western part of the field, the sediments of the progradational and aggradational phases making up the bulk of the stratigraphic sequence in the field.

Halibut-Cobia oil field. The Halibut field produces from Early Eocene sands (M. diversus zone) at the top of the Latrobe Group. Mapped on the top Latrobe Group unconformity, the Halibut structure is an eroded remnant of a southeast-plunging anticline, the now-eroded crest of which lay some 11 km northeast of the present field. The Lakes Entrance Formation was deposited on the deeply eroded surface of the Latrobe Group. A saddle separates the Halibut field in the northeast from the non-producing Cobia field in the southwest, the lowest part of the saddle being close to the oil/water contact. Cobia No. 1, the only well drilled prior to February 1976 in the Cobia field, discovered a net oil pay of 5.5 m, also in Eocene sediments at the top of the Latrobe Group.

The Halibut field reservoir has been subdivided into ten stratigraphic units based on the cyclical nature of the interbedded sandstone, shale, and coal sequences. The subdivisions have been used as a reliable basis for the calculation of the distribution and size of produceable oil reserves. Development wells from the Halibut platform were designed to drain the reservoir sands just downdip from their truncated edge at the unconformity surface. The number of wells drilled into each individual sandstone unit was determined by the proportion of reserves calculated for it. Careful production planning, designed to cause a uniform encroachment of the water table across the reservoir is expected to result in a high recovery of oil from the field.

Turrum field. The presence of significant gas and oil accumulations has been proven in intra-Latrobe Group sands of Paleocene age below the Marlin Field. The Paleocene intra-Latrobe Group section of the Marlin structure is designated the Turrum field. Mapped at the level of the Paleocene sands (Esso, 1973a) the Marlin structure is dissected by northwest-trending faults downthrown to the southwest, into four distinct fault blocks designated A, B, C and D. Marlin No. 1 (Appendix 3) and Marlin A-6 (development well drilled from the Marlin A platform) drilled in the C Block found 22 m and 43 m of net gas reservoir respectively in Paleocene sands. The platform well also encountered 6 m of net oil sand. Marlin No. A-24 (Appendix 3) was drilled from the Marlin A platform below the Eocene productive horizons to test the Paleocene sands in the D Block. The well encountered 76 m of net gas sands in fifteen zones and a 1.5 m gas cap at a deeper level.

Turrum No. 1 was drilled in the northernmost block. It penetrated two gas sands separated by 91 m of shale and water bearing sandstone. The sands are designated L-1 and L-2, the prefix 'L' denoting the palynological zone Lygistepollenites balmei. The L-1 and L-2 reservoirs together in Turrum No. 1 are correlated stratigraphically with the Paleocene gas reservoirs in Marlin A6, and the L-1 reservoir is correlated with the gas pay in Marlin No. 1. The stratigraphic equivalent of the oil sand in Marlin A-6 is water saturated in Turrum No. 1. Permeability of the reservoir sandstones in Turrum No. 1 ranges from 49 to 430 millidarcies.

Reserves in the Turrum field are subject to major revision (Table 3b).

Bream gas field. The reservoir in the Bream field is a late Eocene sandstone at the top of the Latrobe Group. Mapped on this horizon, the structure is an east-southeast-trending anticline broken by northwest-trending arcuate faults into a central graben flanked by two higher fault blocks. Bream Nos. 2 and 3 were drilled in the eastern and western fault blocks respectively. The central graben has not been tested, Bream

No. 1 in this area having been abandoned because of mechanical problems. Bream No. 3 confirmed the discovery of oil and gas made by Bream No. 2 but the oil column in this well was only 1.5 m thick, compared with 10.7 m in Bream No. 2, and had a high water content. Reserves are subject to major revision (Table 3b) and no plans have been announced for development of the field.

Tuna oil and gas field. The field has an Eocene reservoir (M-1) at the top of the Latrobe Group which contains gas and minor oil, and a Late Cretaceous intra-Latrobe Group reservoir (T-1), which is mainly an oil reservoir with some gas.

Mapped on the top of the M-1 reservoir, i.e., the top-Latrobe Group unconformity, the structure is a northeast-trending anticline truncated on its northern flank by east to northeast-trending faults, downthrown to the north, which provide closure.

Mapped on the top of the T-1 reservoir (a weaker seismic horizon), the structure is similar, but with additional faults on the northern and southwest flanks.

The Flounder Formation in the Tuna-Flounder channel is unconformable on the M-1 horizon, and in places (Tuna Nos. 1 & 3) the Gurnard Formation is present, overlying the Flounder Formation.

The M-1 reservoir contains sands deposited in braided stream, stream-mouth bar, beach, and delta plain environments. Four depositional units have been mapped. The average porosity, and the average water saturation for the whole reservoir are estimated at 23 percent and 19 percent, respectively. In Tuna No. 1 the maximum gross gas column is 75 m. The underlying oil column at 6 m is not considered economic.

The T-1 reservoir contains an upper unit of mainly thin sands, and a lower unit of mainly thick massive sands.

The gross hydrocarbon column in Tuna No. 1 contains 70.7 m of oil reservoir overlain by 24 m of gas reservoir. Average porosity for the whole reservoir is estimated at 21 percent, and average water saturation at 23 percent in the gas cap and 30 percent in the oil zone.

The T-1 oil zone is regarded as the main reservoir in the Tuna field, and the production plan is to produce the gas from the M-1 reservoir only after depletion of the T-1 oil zone.

There are a number of geological problems associated with the development of the Tuna field, which will be the first to have an intra-Latrobe Group reservoir as the primary producer. The exact structural configuration of the T-1 reservoir has been difficult to determine, because it does not produce a good seismic reflector and because of seismic velocity variations in the overlying section, caused by the sediments in the Tuna-Flounder channel. A further complication in the evaluation of the T-1 oil field is the apparent lack of continuity of good oil-bearing sands throughout the reservoir. A production licence has been granted and production is expected to start in 1979.

For additional details on the Tuna field the reader is referred to Esso (1973b & 1976).

Snapper gas field. Mapped on the top-Latrobe Group unconformity, the Snapper structure is a northeast-trending anticline broken into four fault blocks by a series of northwest and west-trending faults. All but the easternmost block have been tested by drilling. Snapper No. 1 located in the central of the three tested blocks discovered oil and gas in Eocene sediments at the top of the Latrobe Group, and oil and gas were later confirmed in the outer two blocks by the drilling of Snapper Nos. 2 and 3. The reservoir is designated the N-1 reservoir after the palynological zone Nothafagidites asperus. Snapper No. 1 also encountered a series of small hydrocarbon shows in a thin tight sand below the N-1 reservoir.

In the N-1 reservoir, the oil below the gas column in Snapper No. 1 occurs in a 2.4 m thick sandstone which overlies 2.7 m of shale. In Snapper No. 2, the oil is in a thin sand overlying a thick shale, and in the No. 3 well it is in thin sands with too high a water content for the oil to be considered recoverable.

The field is expected to be developed in the future as a gas producer.

Mackerel oil field. The Mackerel structure mapped on the top-Latrobe Group unconformity is a northeast-trending anticline divided into three blocks by two northwest-trending faults. Mackerel Nos. 1 and 2 were drilled in the largest central block and Mackerel Nos. 3 and 4 in the northeastern and southwestern blocks, respectively. A 90-m deep channel cuts the top of the Latrobe Group in the vicinity of Mackerel No. 1.

The top Latrobe Group reservoir sands are of Paleocene age and have permeabilities greater than 2000 millidarcies.

Production is expected to start from the Mackerel field in the early part of 1978.

Flounder oil field. In the Flounder structure oil and gas occurs in a Paleocene sandstone reservoir within the Latrobe Group. Mapped on the reservoir horizon, the structure is an east-northeast-trending anticline which is broken into three main fault blocks, a central graben flanked by two higher fault blocks, by a system of northwest-trending arcuate faults. Flounder Nos. 2, 3, and 4 were drilled in the Central (2 and 3) and northeastern block, and Flounder No. 1 in the southwestern block. In addition to the oil and gas reservoir discovered by Flounder No. 1, the No. 2 well also discovered oil in the Eocene Flounder Formation of the Latrobe Group. The limits of the Paleocene oil and gas field were established by Flounder Nos. 3 and 4.

A production licence has been granted but the reserves are subject to major revision (Table 2b) and no development dates are known.

Golden Beach gas field. This field is located offshore close to the coast in VIC/P8. Mapped on the top-Latrobe Group unconformity, the structure is an east-trending anticline which is separated by a saddle from the onshore Baragwanath Anticline (Pl. 1). The discovery well, Golden Beach No. 1A, encountered gas between 614 and 633 m at the top of the Latrobe Group with a gross and net thickness of 20 m. The gas produced on testing was virtually pure methane, with a calculated open flow potential of 0.8 $m^3 \times 10^6$ per day.

The calculated recoverable reserves in the Golden Beach gas field were recently downgraded from 4.2 $m^3 \times 10^9$ to 0.85 - 1.0 $m^3 \times 10^9$, as a result of a development study carried out by Woodside Oil Ltd (1977). The report discussed the characteristic of the gas reservoir, which were deduced mainly from wireline log interpretation of Golden Beach No. 1A. The reservoir sandstone comprises a fining upwards sequence which becomes shaly in the upper part with consequent decrease in porosity and gas saturation. The sandstone is the stratigraphic equivalent of the N-1.1 gas reservoir of the Barracouta field. In Golden Beach, the unit is more than 15 m thicker than at Barracouta, owing to less severe erosion on the top-Latrobe Group unconformity.

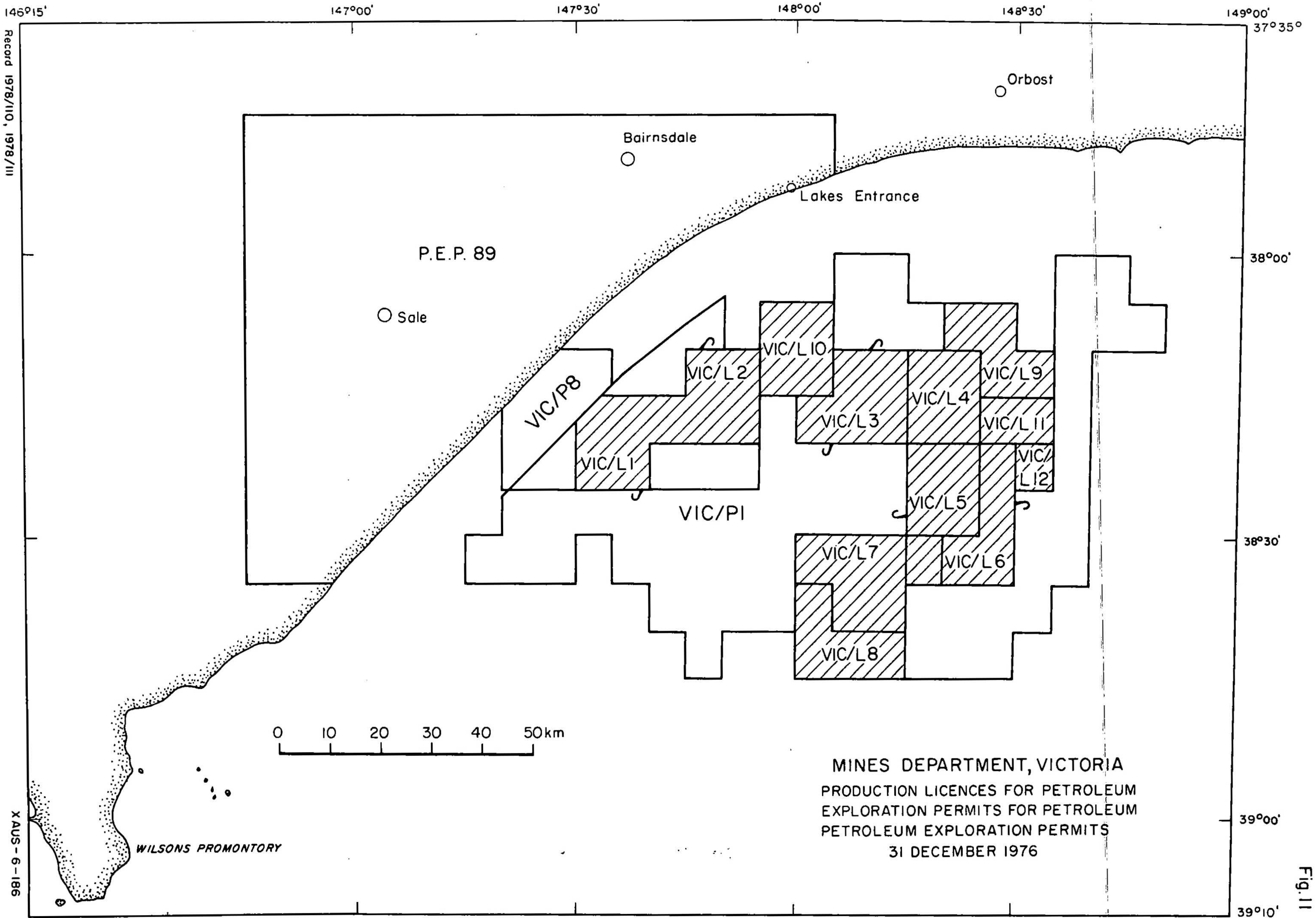
The relatively thin gas column, underlying water, which would result in water coning in producing wells, and the reduced permeability in the upper part of the reservoir are all factors that would control and limit the productivity of the field. The calculated recoverable reserves are based on a 50 to 55 percent recovery factor.

Lakes Entrance oil field. The trapping mechanism in this field has already been discussed in some detail. The oil accumulation occurs in an area of about 15 km^2 and lies at a depth between 300 and 380 m. Production from the field ceased in 1956.

Prospectivity - Offshore

Central deep basin area. This area, which lies mainly in petroleum exploration permit VIC/P1 (Fig. 11), has proved to be the most prospective part of the Gippsland Basin, containing all the commercial fields discovered to date. It remains by far the most prospective part of the basin as far as future discoveries are concerned.

In the first phase of exploration, the targets were structural traps mapped on the top-Latrobe Group unconformity, the prospective horizons being Eocene sands at the top of the Latrobe Group, immediately below the unconformity. Exploration has now reached the stage when the most favourable of these traps have been tested, and attention over the past few years has been directed towards deeper horizons within the Latrobe Group. Commercially significant discoveries have been made in



MINES DEPARTMENT, VICTORIA

PRODUCTION LICENCES FOR PETROLEUM
EXPLORATION PERMITS FOR PETROLEUM
PETROLEUM EXPLORATION PERMITS
31 DECEMBER 1976

Record 1978/110, 1978/111

XAUS-6-186

Fig. 11

intra-Latrobe Group sands of Paleocene age in the Turrum and Flounder fields, and Late Cretaceous age in the Tuna field. Exploration of these deeper levels is hampered by the lack of good basin-wide structural control.

The prospectivity of the eastern part of the central basin, which extends into deep water, has yet to be evaluated. The Latrobe Group probably comprises only Late Cretaceous sediments over much of this area. Only one well, Hapuku No. 1 (Esso, 1975) has so far been drilled. It was located in 323 m of water on a northeast-trending anticline mapped on the top of the Latrobe Group unconformity, which was the primary objective horizon. A deeper unconformity, predicted to be of early Eocene age (M. diversus zone), was interpreted as an erosional surface cutting into both Paleocene and Late Cretaceous sediments. A number of northwest-trending tensional faults were interpreted in the Late Cretaceous section, extending upwards to the M. diversus unconformity. Possible sands immediately below the unconformity, and within the fault-bound Late Cretaceous sequence were also drilling objectives. The section penetrated (Appendix 3) differed from that predicted in that the well encountered a Paleocene section which, although thin, is considered to be complete; the lack of section is attributed to sediment starvation rather than erosion of an originally thicker sequence. The lack of Eocene, Oligocene, and early Miocene sediments is similarly explained. The horizon which has been interpreted as the M. diversus unconformity is reinterpreted as a depositional palaeoslope.

Hydrocarbons were present in sandstones with poor reservoir characteristics in the primary objective horizon immediately below the top of Latrobe Group unconformity. An interpreted 7.9 m of net oil sand was present between 2812.7 - 2839.5 m. A sharp increase in water saturation is interpreted below this zone, and 7.9 m of net oil sand with very high water saturations are interpreted (between 2839.5 and 2851.7 m). This oil would probably not be recoverable.

Formation interval tests on sands within the Late Cretaceous sequence recovered only traces of oil of no economic significance. The lack of hydrocarbon in this section is thought to be due to the absence of a shale seal at the faults.

Southern platform area. This section covers the area between the South Bounding Fault and the Bassian Rise, and coincides roughly with the petroleum exploration titles Vic/P2 & P4 and parts of T/IP and 4 P (Fig. 9).

The most prospective unit in the area is considered to be the Latrobe Group, which is of Eocene age south of the South Bounding Fault and pinches out on the Bassian Rise. Present seismic coverage indicates that there are very few structural traps in this part of the basin, and exploration drilling to date has been to test primarily stratigraphic traps. Wells drilled are Pike No. 1 and Moray No. 1 on the downthrown northern side of the South Bounding Fault, Groper Nos. 1 and 2, Mullet No. 1, and Bluebone No. 1 on stratigraphic pinchouts of the Latrobe Group onto the Bassian Rise, and Sailfish No. 1 on a postulated biohermal reef near the edge of the continental shelf.

The Pike Prospect was interpreted as a stratigraphically controlled intra-Latrobe Group potential trap, comprising a reservoir sand deposited in an offshore bar depositional environment, with up-dip and lateral seal provided by facies change to impermeable sediments of marine and paralic origin, and the top seal being provided by the shales and marls of the Lakes Entrance and Gurnard Formations. Following drilling, the absence of hydrocarbons is attributed to the lack of an up-dip and/or lateral seal. The postulated offshore-bar reservoir sand proved to have the physical characteristics (well-sorted, well-rounded grains, no shaly or silty laminae) of a beach sand, and could consequently be expected to be part of a laterally extensive sandstone unit.

Moray No. 1 tested a fault-dependent stratigraphic closure against the South Bounding Fault. The Latrobe Group proved to be an almost continuous sand section, lacking the predicted interbedded shale or siltstone sealing units. The absence of hydrocarbons may also have been due to a lack of seal along the fault plane.

Groper Nos. 1 and 2 (Esso 1969 a & b) were located near the up-dip pinchout of the Latrobe Group onto the Bassian Rise, top and bottom seals being provided by the Lakes Entrance Formation and granitic basement, respectively.

The Latrobe Group in Groper No. 1 contained about 75% sand, interpreted as mainly braided stream deposits, with porosities varying from 25 - 30%, but the sand was water filled.

Groper No. 2, drilled up-dip from the first well, also penetrated similar sands in the Latrobe Group with excellent reservoir characteristics.

The Lakes Entrance Formation, comprising mudstone with minor glauconitic skeletal limestone, appears to form an excellent seal in the Groper area. A possibly larger limestone content in the area near to the pinchout of the Latrobe Group, with consequent increase in porosity and reduction in sealing capacity, was tentatively advanced by the operator as an explanation for the lack of hydrocarbons.

Mullet No. 1 and Bluebone No. 1 located on two separate stratigraphic plays to the northeast of the Groper wells were equally unsuccessful:

In Mullet No. 1, the Latrobe Group was a predominantly sandstone sequence. Porosities were good, but the sands contained only water. The Lakes Entrance Formation contained a higher proportion of skeletal limestone than in the Groper wells, and directly above the Latrobe Group the addition of reworked sand made it considerably more porous.

In Bluebone No. 1, the Latrobe Group comprised interbedded silty sandstone and mudstone, the sands having only moderate porosity and poor permeability. The Lakes Entrance Formation had a higher sandstone content than in Mullet No. 1, consisting mainly of argillaceous, glauconitic sandstone with minor sandy mudstone. Core analysis indicated 40% porosity.

Sailfish No. 1 (N.S.W. Oil and Gas Company N.L., 1971) was drilled in the shallower water part of T/IP, most of which lies in water depths greater than 180 m. The well was drilled as a test of one of a group of seismic anomalies which were interpreted as possible Miocene reefs. However, in Sailfish No. 1, the anomaly proved to be due to the presence of 180 m of pyroclastic rocks of Miocene or younger age. The well was abandoned in the volcanic section, and the presence or absence of the Latrobe Group was not established.

In summary, the drilling results in the Southern Gippsland Basin have not been encouraging. The results of the wells drilled to test stratigraphic traps along the up-dip pinchout of the Latrobe Group onto the Bassian Rise suggest that the Lakes Entrance Formation may not have provided adequate top seal for any hydrocarbons generated. The lithology of the Latrobe Group penetrated in the wells also indicates a low source rock potential.

The results of the Sailfish well strongly suggest that the untested seismic anomalies in that area are due to the presence of volcanic rocks and not to reef development. However the potential of the Latrobe Group has yet to be tested.

The lack of success in the southern area is reflected in Company relinquishments of permit areas. All the acreage held in VIC/P4 and T1/P was surrendered in 1974, together with that part of T/4P which was held in the Gippsland Basin. All the acreage held in VIC/P2 was surrended in October 1976. Prospectivity of the southern platform area is regarded as fairly low.

<u>Northern platform area</u>. The prospectivity of this area is limited by the rapid northward thinning and shallowing of the Latrobe Group against the strongly faulted northern margins (Fig. 5). There is a greater probability of water flushing than in the central deep basin area. However the possibility that structural traps could have received hydrocarbons by up-dip migration from the deeper basinal areas means that small but commercially significant discoveries may be made, although drilling results have not been encouraging. Six wells have been drilled in the area (Fig. 9): Albatross No. 1 and Gannet No. 1, located near the coast in VIC/P8; Flathead No. 1, Wahoo No. 1, and Dart No. 1, farther east in VIC/P1; and Sole No. 1, the most easterly well in the basin, located in VIC/P9 in a water depth of 129 m. Sole No. 1 discovered significant but non-commercial gas in intra-Latrobe Group Paleocene sands. Oil shows were reported in the Flathead No. 1 well, but no oil produced on testing.

The results of drilling on the Northern Platform area illustrate the factors contributing to the relatively low prospectivity of the area compared with the central deep basin area.

Sole No. 1 encountered a gas reservoir at the top of the Latrobe Group (810 m KB). A petrophysical evaluation of the reservoir (Shell, 1973) gave a net pay of 15 m, an average porosity of 33.5% (range 28 - 38%), and an average water saturation of 29%. Gas recovered during formation interval testing was 96 percent methane. Shell reported total gas initially in place of $10.6 \times 10^9 m^3$, but BMR using a map revised by ESSO estimated $7.7 \times 10^9 m^3$. The low reservoir pressure of 1218 psia means that even initially, compression would be required for production, and a low recovery factor could be expected (BMR file 68/1128, Application for Exploration Permit VIC/P9). VIC/P9, in which Sole No. 1 was drilled, was surrendered by the operating company in December 1975, as was most of VIC/P8.

Flathead No. 1 encountered oil shows from the top of the Lakes Entrance Formation at 447 m (KB) to a depth of 502 m in the Strzelecki Group. The Latrobe Group proved to be 7 m thick instead of the predicted 106 m. Formation interval testing recovered only a scum of oil from two of the eleven formation interval tests, and two production tests also failed to recover any oil. Core analysis indicated that sandstones from the Latrobe and Strzelecki Groups had oil saturations ranging from 5 - 22%, with permeabilities from less than 10 md to more than 500 md. The net thickness of sandstones with permeabilities greater than 100 md is 17 m. Source rock analysis indicated that source rocks for gas occur within the Strzelecki Group.

Albatross No. 1 and Gannet No. 1 were both drilled to test seismically defined traps at the top of the Latrobe Group, in which closure was dependent on a combination of dip and stratigraphic wedgeout. Both wells penetrated the Early Cretaceous Strzelecki Group. The Latrobe Group in Albatross contained an upper unit of muddy, gravelly sandstones interbedded with thin clean sandstones, and a lower unit of mainly clean sands with occasional thin coals and mudstones. Only minor gas readings (mainly methane) were recorded during drilling. In Gannet No. 1, the only indication of hydrocarbons in the Latrobe Group were also gas shows, mainly of methane, during drilling. In this well, the basal unit of the Lakes Entrance Formation was a porous sandstone with poor potential as a hydrocarbon seal. Both wells were abandoned in the Strzelecki Group after penetrating it for 515 m (Albatross No. 1) and 753 m (Gannet No. 1). The drilling proved the Strzelecki Group in this area to be much thicker than predicted.

Wahoo No. 1 was drilled about 20 km to the northwest of Sole No. 1 and the same distance east of Flathead No. 1. There were no indications of hydrocarbons. Good reservoir sands were present in the Latrobe Group, but these were water saturated. The lack of hydrocarbons may be due to a lack of seal on the fault closure or to the fact that the well was sited too low on the structure. If the latter is the case, the small areal closure on the structure probably means that any up-dip accumulation of hydrocarbons would be uneconomic. It is interesting to note that the thickness of the Latrobe Group was 130 m, in contrast to the 7 m encountered at Flathead.

Dart No. 1 was located 10.4 km southwest of Sole No. 1, on a southwest-plunging nose down-dip from the Sole structure. Seismic interpretation suggested the possibility of lateral facies changes within the Latrobe Group between the two wells providing an up-dip seal for a stratigraphic accumulation of hydrocarbons. However, although the well intersected 200 m of Latrobe Group sediments containing excellent reservoir sands, no hydrocarbons were detected, indicating that the postulated permeability barrier between the two structures was absent.

Prospectivity-Onshore

Latrobe Group. Drilling results in the onshore area, where a large number of wells have penetrated the prospective zone at the top of the Latrobe Group, indicate that the lack of hydrocarbons in this zone is due to flushing by meteoric waters. In Duck Bay No. 1, located due north of Lake Victoria, electric log analysis indicated 100 percent water saturation, after small gas shows were recorded during drilling. Brackish water with small amounts of dissolved methane was produced in Dutson Downs No. 1 on drillstem testing. Similarly, in Lake Reeve No. 1 and Seaspray No. 1, testing of zones in the upper part of the Latrobe Group, where gas shows were recorded during drilling, produced only fresh water. In Golden Beach West No. 1, gas-cut fresh water was obtained in the upper zone, and tests of deeper zones in the Latrobe Group produced only fresh water.

Strzelecki Group. Indications of hydrocarbons have been rare in the Strzelecki Group which has only been fully penetrated by one well, Duck Bay No. 1, near the northern margin of the Strzelecki Basin. Wellington Park No. 1, located south of Lake Wellington in the deeper basin, drilled 2635 m of Strzelecki Group without reaching the base. In this well there were indications of oil in a sand recovered in a core at 2251 m, but drill-stem testing was unsuccessful. The sand had a porosity of 5.8 percent and a permeability less than one millidarcy. Drill-stem tests at deeper levels recovered brackish formation water containing a small amount of methane in zones of low porosity and permeability and with some fracturing. In North Seaspray No. 1, a sand, which the well completion report placed in the Strzelecki Group, but which may be in the Golden Beach Formation of the Latrobe Group (Colman, 1973), produced wet gas at a rate of 1400 to 2800 cubic metres per day. The net thickness of the sand was only 1.2 m and it was not recognised in the follow-up well, North Seaspray No. 2. Oil and gas shows of dubious reliability were recorded in Woodside Nos 1 and 2.

Seaspray Group. The reservoir rocks in the Lakes Entrance oil and gas field which occur in the basal part of the Lakes Entrance Formation have been discussed in the section on source, reservoir, and cap rocks. Oil shows have been recorded from the equivalent part of the formation in Colquhoun Nos. 1 and 4 and the Gippsland Oil Co. wells 1 and 3 in the outer parts of the Lakes Entrance area (Pl. 1A). Minor gas shows have been recorded in the Gippsland Limestone, in Duck Bay No. 1 and Pelican Point No. 1, located to the southwest of the Lakes Entrance area.

The prospectivity of the onshore part of the Gippsland Basin is considered to be low.

FUTURE EXPLORATION RECOMMENDED

Geophysical

The attitude of magnetic basement beneath the Gippsland Basin is well known from the large scale airborne and seaborne magnetic surveys which have been undertaken there. At the present advanced state of exploration of the basin, there is no justification for further large scale magnetic surveys. However, the collection of magnetic data during the course of future seismic surveys may help differentiate between volcanic build-ups and reefal developments, particularly near the eastern margin of the basin, although experience to date indicates that the intrasedimentary pyroclastics which are known to occur have little magnetic expression in the basin.

Gravity coverage over the basin is quite sparse, consisting of only a few widely spaced traverses from the BMR Continental Margin survey. The principal features of the offshore gravity field have been established, however, and preliminary interpretations of these are in reasonable agreement with interpretations of other geophysical surveys. There is in existence a large body of good quality seismic data. Hence, detailed marine gravity surveys are not required at the present stage of petroleum exploration. Some further confirmatory regional gravity traverses could be useful in establishing the structural framework of the region.

The southeastern boundary of the Gippsland Basin is not well known. In particular, the limit of the economically significant Latrobe Group remains unmapped. A thorough appraisal of all available geophysical data in the east of the basin is required, leading to recommendations on locating further geophysical traverses. It would be desirable for further work, perhaps by BMR or academic organisations, to include seismic refraction work to determine the depth and dip of intra-crustal discontinuities at several localities on the continental slope. The results of such work would help to eliminate the ambiguities inherent in interpreting the gravity anomalies observed, and would perhaps assist in analysis of the chain of possibly intrusive features near the edge of the continental shelf referred to in 'Geophysical Exploration' (Cameron & Pinchin, 1974).

<u>Geological</u>

Exploration results to date suggest that the major effort should continue to be made in the central basin, and that it should be directed particularly towards further evaluation of the intra-Latrobe Group sequence. This sequence is stratigraphically very complicated, consisting of many minor sequences separated by boundaries which may be unconformities in some locations, but may grade laterally into boundaries with concordant beds above and below. These minor sequences commonly exhibit onlapping, offlapping, prograding, and channelling. Lithological trends may cut across time-stratigraphic sequence boundaries. Fortunately, improved seismic data and interpretational techniques should allow better mapping of time-stratigraphic units and extrapolation of well data away from wells in the future (Steele, 1976), so that potential hydrocarbon traps within the Latrobe Group may be better defined after careful study.

In the southeastern Gippsland Basin, consideration should be given to drilling a well on the structure delineated by Magellan's Tasman-Bass Strait seismic survey, to obtain stratigraphic control on the Latrobe Group and some indication of its hydrocarbon potential in this part of the basin.

CONCLUSIONS

The more prospective areas of the Gippsland Basin have been extensively explored, and it seems likely that the greater part of the recoverable petroleum in the basin has already been discovered. Nevertheless, further exploration could lead to the discovery of moderate additional reserves.

The central portion of the basin has proved to be the most prospective part, with production from Eocene sands near the top of the Latrobe Group. The most favourable prospects in this play have now been tested. Some commercially significant discoveries have been made in deeper intra-Latrobe Group sands of Paleocene age in the central part of the basin. Probably the best prospects for future discoveries lie in further detailed investigation of these deeper sands.

The eastern margin of the basin near the edge of the continental shelf has so far been only sparsely drilled. The few wells drilled have not been very encouraging, but the area cannot be said to lack potential without further exploration.

The southern portion of the basin, south of the South Bounding Fault, lacks structural traps. The lack of success in drilling a number of primarily stratigraphic traps in this part of the basin has seriously downgraded the area.

Similarly, the prospects of the northern portion of the basin, including the onshore area, appear to be poor. The prospective zone at the top of the Latrobe Group has been extensively tested onshore, and it appears that the lack of hydrocarbons is due to flushing by meteoric waters.

Geophysical exploration of the basin has been extensive. Future needs are primarily for more high technology seismic surveying to locate and map potential petroleum traps in the deeper sands of the Latrobe Group in the central deep part of the basin. From a more academic point of view, there is a need to complete the regional gravity coverage of the offshore portion of the basin and perhaps to undertake crustal studies of the continental slope region on the eastern edge of the basin.

RESOURCE ASSESSMENT

This assessment of petroleum resources is confined to undiscovered resources, and was derived by the application of the Monte Carlo simulation technique to the prospect-by-prospect method. A computer program SIMULAT (Riesz, 1978), which estimates petroleum resources using Monte Carlo simulation was employed.

ESSO have submitted maps of the Sweep prospect, which is located about halfway between the Tuna field and Wahoo No. 1, and of the Seahorse prospect, which lies about 12 km northeast of the Barracouta field (Plate 1). Mapping is continuing on the Mado prospect in the vicinity of the Flounder field. The Sweep prospect is mapped on the 'top Latrobe Group' seismic horizon, and the Seahorse, on the 'top Latrobe Group', '*P.asperopolas*', and '*M. diversus*' horizons.

The Company has also reported on a continuing computer-based project which has resulted in the production of preliminary depositional maps and isopachs of the intra-Latrobe Group, based on lithological logs and palynological zones in the wells. A revised structural map of the 'top Latrobe Group' seismic horizon will be used as a datum from which structural maps will be made for each intra-Latrobe Group time-stratigraphic unit.

With maps available on only two undrilled prospects, an estimate of the total undiscovered resources can obviously not be made at this stage using the prospect-by-prospect method. However, preliminary estimates have been made, based on a general appraisal of current knowledge (Robertson, 1978). The mean values derived in this way are 56 billion cubic metres (2 trillion cubic feet) of gas, and 17 million cubic metres (110 million barrels) of oil.

Prospect-by-prospect method

The derivation of the ranges of values assigned to the reservoir parameters is given in the following sections. The results of the resource assessment are presented in Figures 12, 13a & b.

Sweep prospect

Mapped on the 'top Latrobe Group' seismic horizon, (ESSO, 1976b) the Sweep prospect is a northeast-trending anticlinal closure, truncated on the northeast by a northwest-trending fault. The thickness of the Latrobe Group is estimated from geophysical data to be about 260 m, which compares with 200 m in Dart No. 1 and 213 m in Sole No. 1 (Plate 1). Sole No. 1, which encountered a non-commercial gas accumulation at the top of the Latrobe Group, was used as an analogue for the Sweep prospect.

Trap volume: Three areas were measured by planimetry. The trap volume was derived by multiplication of the areas by 45 m (compare 43 m gross gas column in Sole No. 1).

area (km^2)	3.6	5.7	11.4
weighting	0	1	0
volume ($m^3 x 10^6$)	160	250	510
weighting	0	1	0

Net pay: Net pay in Sole No. 1 was 35% of the gross gas column. The following range was adopted for Sweep:-

%	30	50	80
weighting	1	1	0

Trap fill: The range adopted was:

%	50	75	100
weighting	0	1	0

Porosity: The range adopted was derived from consideration of porosity values in Sole No. 1 (28-38%), Flathead No. 1 (34-41%), and Dart No. 1 (30%+).

%	25	30	40
weighting	0	1	0

Water saturation: Average water saturation in Sole No. 1 was 29%. The following range was adopted:-

%	20	30	60
weighting	0	1	0

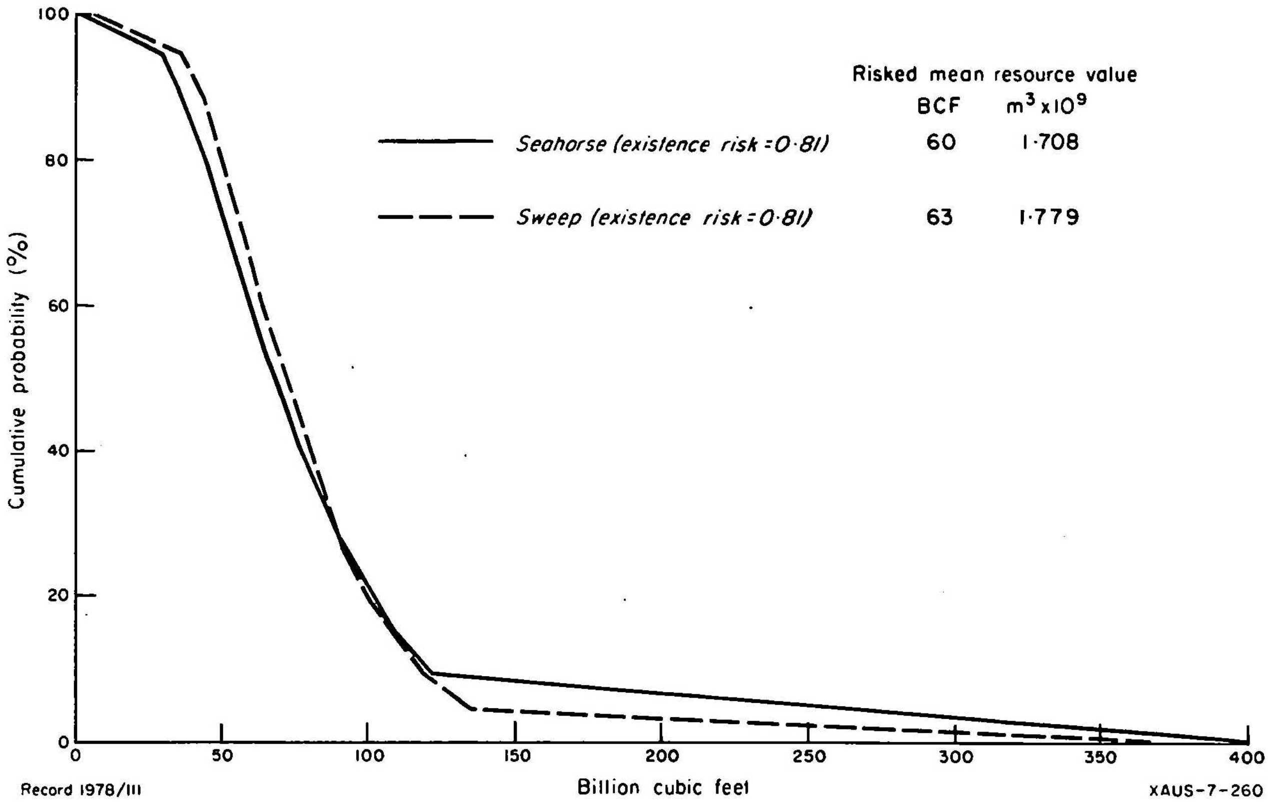


Fig.12 Gippsland Basin, Seahorse and Sweep prospects – hypothetical undiscovered gas resources

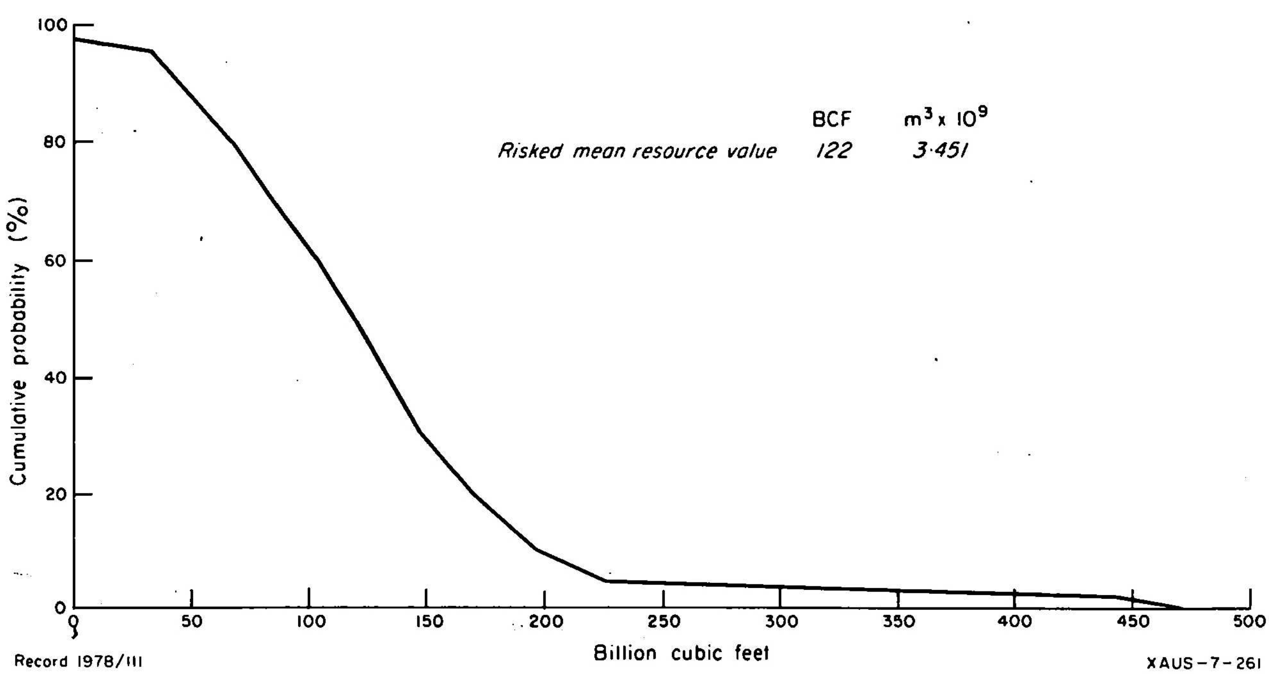


Fig.13 Gippsland Basin, Seahorse and Sweep prospects – hypothetical undiscovered gas resources, total risked resource values

Reservoir temperature and pressure: The geothermal gradient at Sweep is 2°F/100' (3.64°C/100m).

A temperature of 515° Rankin was calculated for the postulated reservoir depth. A pressure of 1550 psig was derived from consideration of pressures measured during Formation Interval Testing in Sole No. 1.

Gas deviation factor: The following range was adopted:-

Z	0.745	0.755	0.765
weighting	0	1	0

Recovery factor: The following range is based on expected recovery from producing fields in the Gippsland Basin:

%	60	70	80
weighting	0	1	0

Formation volume factor: The value used for the formation volume factor was 1.0

Seahorse prospect

The structure is a northeast-trending anticlinal closure bounded by northwesterly and easterly intersecting faults (ESSO, 1977). The maps on the 'top Latrobe Group' and the '*M. diversus*' seismic horizons were used for the assessment. Data from the Barracouta field, including a reservoir drainage study (ESSO, 1975b), were used to derive the reservoir parameters.

Estimates were made for a possible gas reservoir immediately below the 'top Latrobe Group' unconformity, and a possible intra-Latrobe Group oil reservoir within the *M. diversus* zone, using the Barracouta field as an analogue.

Gas reservoir

Trap volume: Three areas were measured by planimetry. The trap volume was derived by multiplication of the areas by 305 m, which is the thickness of the section from the top of the Latrobe Group to the base of the *N. goniatus* zone (top *M. diversus* zone). In the Barracouta field, the gas reservoir is in the *N. goniatus* zone immediately below the top Latrobe Group unconformity.

area (km^2)	0.62	2.06	5.43
weighting	0	1	0
volume ($m^3 x 10^6$)	180	620	1650
weighting	0	1	0

Net pay: In Barracouta No. 1 the net pay in the N-1 gas zone is 26% of the thickness of the N. goniatus zone. The following range was adopted for the Seahorse prospect:-

%	15	25	30
weighting	0	1	0

Trap fill: The following range was adopted:-

%	50	75	100
weighting	0	1	0

The following ranges were adopted for porosity, water saturation, and formation volume factor, after consideration of Barracouta field data.

Porosity

%	18	20	26
weighting	0	1	0

Water saturation

%	15	20	60
weighting	0	1	0

Formation volume factor: The value used for the formation volume factor was 1.6.

Reservoir temperature and pressure: A temperature of 632° Rankin and a pressure of 1700 psig were adopted.

Gas deviation factor: The range used was the same as that for the Sweep prospect.

Oil reservoir

Trap volume: Three areas were measured by planimetry. A thickness of 280 m was adopted for the M. diversus zone (279 m in Barracouta No. 1). The trap volume was derived by multiplication of the areas by 280 m.

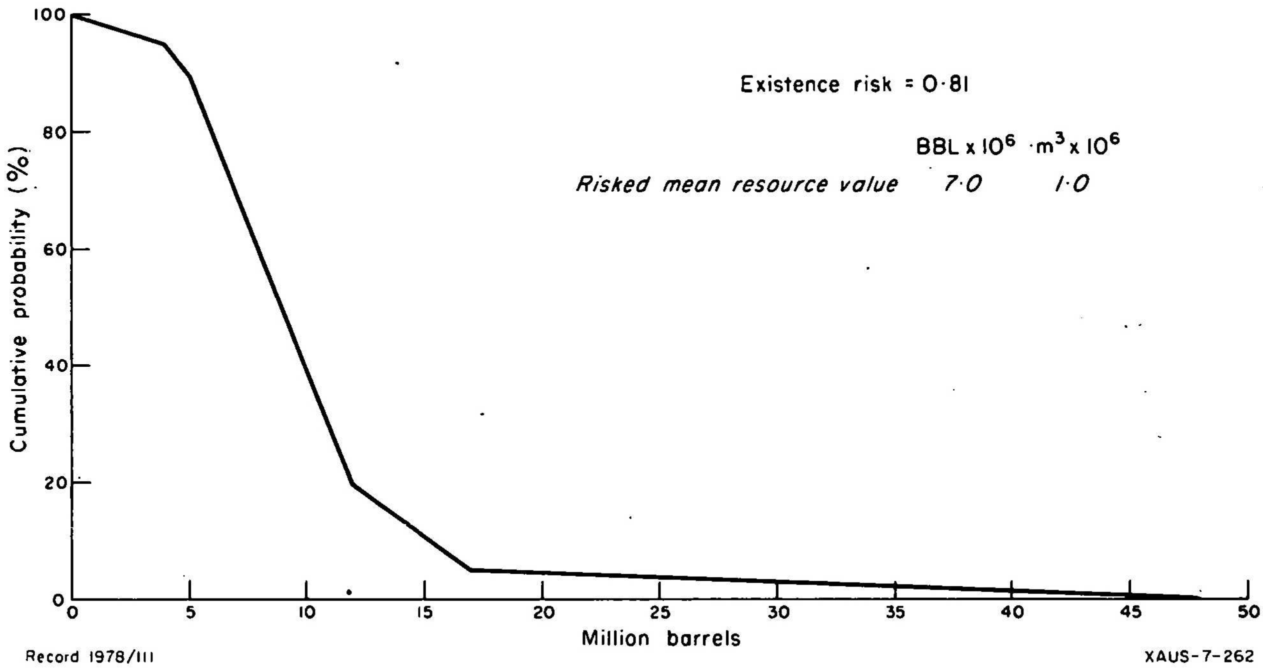


Fig.14 Gippsland Basin, Seahorse prospect – hypothetical undiscovered oil resources

area (km^2)	1.0	2.81	4.62
weighting	0	1	0
volume ($m^3 x 10^6$)	280	780	1290
weighting	0	1	0

Net pay: In Barracouta, the oil column is approximately 6% of the *M. diversus* zone thickness. The following range was chosen for the Seahorse prospect:-

%	30	50	80
weighting	0	1	0

Trap fill: The same range as for the gas reservoir was used.

All other parameters were chosen after consideration of Barracouta M-1 oil reservoir data.

Porosity:

%	20	23	25
weighting	0	1	0

Water saturation:

%	25	30	35
weighting	0	1	0

Recovery factor:

%	20	40	50
weighting	0	1	0

Temperature and pressure: The temperature used was 636° Rankin, and the pressure 2530 psig.

Formation volume factor: The value used was 1.6.

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Table 1. Partly subsidised marine seismic surveys in the Gippsland Basin, and the radii and centres of excluding circles affecting data availability for each survey.

(See Pl. 1).

Survey name	BMR file no.	Radii & centres of excluding circles
Eastern Bass Strait	PSSA 66/11070	20 mi Barracouta Nos. 1 & 2
EC - 67	PSSA 67/11184	40 mi Barracouta Nos. 1 & 2 and 30 mi Kingfish No. 1
*Sole Structure	PSSA 67/11187	40 mi Marlin No. 1
EH - 68	PSSA 68/3015	40 mi Barracouta No. 2 and 50 mi Kingfish Nos. 2 & 3
East Gippsland	PSSA 68/3049 and P(SL)A 68/1	50 mi Kingfish No. 1 and 50 mi Halibut No. 1
G 69 A	PSSA 68/3058 and P(SL)A 69/4	40 mi Barracouta Nos. 1 & 2 and 50 mi Kingfish No. 1
Tasman - Bass Strait	PSSA 69/3023 and P(SL)A 69/11	50 mi Kingfish No. 1 and 50 mi Halibut No. 1

* Final report on entire survey is now available.

Table 2. Gippsland Basin: Production licences for petroleum, exploration permits for petroleum, petroleum exploration permits, 31 December 1976

Type of Authority	Number	Tenement Holder	Blocks	Licence Area	Date of Expiry
Production Licence for Petroleum	Vic/L1	Hematite Petroleum Pty Ltd., and Esso Exploration and Production Australia Inc.	4	Barracouta Field	31-3-88
	Vic/L2		5	Barracouta Field	31-3-88
	Vic/L3		5	Marlin Field	31-3-88
	Vic/L4		4	Marlin Field	31-3-88
	Vic/L5		5	Halibut Field	13-5-89
	Vic/L6		4	Halibut Field	13-5-89
	Vic/L7		5	Kingfish Field	17-7-89
	Vic/L8		4	Kingfish Field	17-7-89
	Vic/L9		4	Tuna Field	27-2-95
	Vic/L10		4	Snapper Field	23-10-95
	Vic/L11		2	Flounder Field	22-12-95
	Vic/L12		1	Flounder Field	22-12-95
Exploration Permit	Vic/P1	Hematite Petroleum Pty Ltd	57		23-10-79
	Vic/P8	Woodside Oil N.L., Planet Exploration Company Pty Ltd., Australian Oil and Gas Corporation Ltd., Continental Oil Company of Australia Ltd., Woodside Petroleum Development Pty Ltd	8		9-9-81

NOTES

Petroleum Exploration Permit 89 (P.E.P. 89) expired 31-12-1976 - no application for extension

The Mackerel Field is included in Vic/L5

Table 3. Estimates of the recoverable, proved plus probable, petroleum reserves in the Gippsland Basin as at 30.6.77

3a

FIELDS	Hydrocarbon Liquids (10^6 bbl) Crude Oil	Well condensate and Plant Products	Liquefied Petroleum Gas (LPG)	Natural (SALES) Gas ($10^9 ft^3$)
INITIAL RECOVERABLE RESERVES				
Barracouta (M-1, N-1, &N4)	25	28	67	1857
Halibut	653	-	33	28
Kingfish	952	-	100	206
Marlin	2	71	129	2763
Tuna (T-1, M-1)	40	9	18	424
Snapper (N-1)	-	65	89	2464
Mackerel	256	-	31	21
TOTAL	1928 ($306.53 \times 10^6 m^3$)	173 ($27.5 \times 10^6 m^3$)	467 ($74.25 \times 10^6 m^3$)	7763.0 ($219.82 \times 10^9 m^3$)
CUMULATIVE PRODUCTION				
Barracouta (M-1, N-1, & N4)	13.0	3	6	162.5
Halibut	378	-	20	20
Kingfish	446	-	46	116.0
Marlin	-	8	10	237
Tuna (T-1, M-1)	-	-	-	-
Snapper (N-1)	-	-	-	-
Mackerel	-	-	-	-
TOTAL	837.0 ($133.07 \times 10^6 m^3$)	11.0 ($1.75 \times 10^6 m^3$)	82.0 ($13.04 \times 10^6 m^3$)	535.5 ($15.16 \times 10^9 m^3$)

Table 3 cont.

3a

FIELDS	Hydrocarbon Liquids (10^6 bbl) Crude Oil	Well condensate and Plant Products	Liquefied Petroleum Gas (LPG)	Natural (SALES) Gas ($10^9 ft^3$)
		CURRENT (REMAINING) RESERVES		
Barracouta (M-1, N-1, & N4)	12	25	61	1694.5
Halibut	275	-	13	8
Kingfish	506	-	54	90
Marlin	2	63	119	2526
Tuna (T-1, M-1)	40	9	18	424
Snapper (N-1)	-	65	89	2464
Mackerel	256	-	31	21
TOTAL	1091.0 (173.46 x $10^6 m^3$)	162 (25.76 x $10^6 m^3$)	385.0 (61.21 x $10^6 m^3$)	7227.5 (204.66 x $10^9 m^3$)

3b

		INITIAL RECOVERY		
Cobia	100 to 190	-	1.5	1.5
Turrum	-	8.5	19.5	500.0
Bream	-	10.0	12.5	490.0
Golden Beach	-	-	-	33.0
Flounder	35.0	10.0	14.0	155.0
TOTAL	72.5 (11.53 x $10^6 m^3$)	28.5 (4.53 x $10^6 m^3$)	47.5 (7.55 x $10^6 m^3$)	1179.5 (33.4 x $10^9 m^3$)

TABLE 3 cont.

Notes

TABLE 3a indicates the initial and current reserves of those fields which have been declared commercial and combines both the Proved and Probable reserves.

TABLE 3b indicates those theoretically recoverable reserves which are either: geologically proved but considered uneconomic under present conditions, or are awaiting further appraisal and, therefore, subject to major revisions.

Definitions

Proved reserves:	Those reserves established by drilling in a reservoir of known lateral extent, and included within an arbitrary radius of one mile from a well bore.
Probable reservies:	Those reserves established in a reservoir beyond the radius of one mile from a well and reasonably assumed to be contained within the limits of the reservoir as indicated by seismic and geological control.
Sales gas:	A mixture of methane and lesser amounts other hydrocarbon gases and containing less than 3% CO_2. In effect, the raw gas obtained from a well after processing to remove condensate and LPG, and CO_2 in excess of 3%.
M	*M. diversus* palynological zone
N	*N. goniatus* palynological zone
T	*T. lillei* palynological zone

N.B.

B.H.P. Press statement released during editing of this review:-

Additional reserves Kingfish field - 27.02 x $10^6 m^3$ oil

Revised estimate of reserves for Mackerel field - 60.41 x $10^6 m^3$ oil

Reserves for Cobia plus West Kingfish fields - 47.69 x $10^6 m^3$ oil (approx)

CURRENT CRUDE OIL RESERVES BASS STRAIT - 317.97 x $10^6 m^3$

Source of information - Department of Mines, Victoria.

From Petroleum Technology Section, BMR. CONFIDENTIAL

Table 4. Summary of data, producing fields Gippsland Basin (after Threlfall & others, 1976)

FIELD	RESERVOIR NAME	HYDROCARBONS	GRAVITY °API at 15.6°C	RESERVOIR CHARACTERISTICS POROSITY %	PERMEABILITY (md)	WATER SATURATION %	INITIAL RESERVOIR CONDITIONS TEMPERATURE °C	PRESSURE kPa
BARRACOUTA	N-1 (N-1.1, N-1.2)	Gas	-	18-26	> 1000	average 20	76	11 644 (1129m subsea)
	N-4	Oil	-	-	-	-	-	-
	M-1	Oil	61	2-25	> 1000	25-35	90	14 000 (1388m subsea)
HALIBUT	M-1	Oil	43	15-27	> 1000	average 17	104	23 529 (2349m subsea)
KINGFISH	M-1 (M-1.1 to M-1.7)	Oil	47.5	18-21 (range of averages)	50-1000 (range of averages)	11-42 (range of averages)	102	22 758 (2288m subsea)
MARLIN	N-1	Gas	-	15-27	> 1000	18-25	76	15 482 (1510m subsea)
	M-1	Oil & Gas	-	-	-	-	-	-

Notes

Each reservoir is identified both according to the first letter of its spore-pollen assemblage zonation and the order of downward occurrence within that zone. Zones are: Nothofagidites goniatus - Late Eocene; Malvacipollis diversus - Early Eocene; Lygistipollenites balmei - Paleocene, and Tricoleporites lilliei - Late Cretaceous.

TABLE 5. SUMMARY OF DATA, NON-PRODUCING FIELDS GIPPSLAND BASIN (Confidential)

FIELD	RESERVOIR NAME OR STRATIGRAPHIC LOCATION	HYDROCARBONS	GRAVITY °API at 15.6°C	RESERVOIR CHARACTERISTICS			INITIAL RESERVOIR CONDITION	
				POROSITY (inter-granular) %	PERMEABILITY (md)	WATER SATURATION %	TEMPERATURE °C	PRESSURE kPa
SNAPPER	N-I (Top Latrobe Gp)	Gas & Oil Primarily gas	30	average 30	-	-	74 (1392.32m)	14151.8
TUNA	M-I (Top Latrobe Gp)	Gas & Oil Primarily gas		average 23	-	average 19	80.55 estimated	-
	T-I (Intra-Latrobe Gp)	Oil & Gas Primarily oil	40.5	average 21	-	average 30 (23 in gas cap)	93.3 (2014.11 m)	17831.3
MACKEREL (No. 4 well)	Top Latrobe Gp	Oil	47.6-50	2-24	1800-3600	-	104.4 (2401.21 m)	23426
COBIA	Top Latrobe Gp	Oil	42.7(2406.7m) 44.0(2393.89m)	10.3-24.8	20-700	-	104.4 (2396.94 m)	23508.68
TURRUM	Intra-Latrobe Gp	Gas & Oil	57.8 Marlin (A-6 oil sand)	-	49.430	-	-	-
BREAM	Top Latrobe Gp	Gas & Oil	-	Good to excellent	average 970 (1-12,000)	-	Estimated Gas: 90 Oil:90.5	Gas:19030.1 (1917.8m) Oil: 19085.3 (1934.56m)

TABLE 5 cont.

FLOUNDER	Top Latrobe Gp (Flounder Fm. No.2 well)	Oil	-	-	-	-	-	-
	Intra-Latrobe Gp	Oil & Gas	36.6-47.4	average 14 (No. 1 well)	0-92		116.6	25215.05 (2528.62 m)
				average 15 (No. 2 well)	0-1610		97.2	21083.4 (2137.25 m)
				5-25 (No. 3 well)	0-1610			
GOLDEN * BEACH	Top Latrobe Gp	Gas	-	average 33.3	average 266	-	-	-
LAKES ENTRANCE *	Base Lakes Entrance Fm (Colquhoun Gravels and Greensand Mbr)	Oil	15.7	36-37	average less than about 10	70-85	28.9	4 134 (365.5m)

* Non-Confidential

APPENDIX 1a

PETROLEUM EXPLORATION WELLS

GIPPSLAND BASIN

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "			1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ALLIANCE OIL DEVELOPMENT AUSTRALIA N.L.								
Tarwin Meadows No. 1	38 145	43 51	26 36	J55-10	7.6 11.0	7-6-65 26-7-65	1202	PA
ARCO LTD								
Bellbird No. 1	38 147	12 00	54 45	J55-11	132 134.4	18-11-63 11-12-63	762	PA
Carr's Creek No. 1	38 147	17 15	32 55	J55-11	23.7 27	23-3-63 9-4-63	1679	PA
Duck Bay No. 1 BMR file 64/4614	37 147	56 39	45 36	J55-7	20.7 24	15-2-64 26-2-64	1292	PA
Merriman No. 1 BMR file 63/1301	38 147	20 10	52 43	J55-11	20.4 23.8	21-2-63 17-3-63	1830	PA
North Seaspray No. 1 BMR file 62/1305	38 147	17 12	38 13	J55-11	23.5 26.8	21-11-62 13-12-62	1524	PA
Seaspray No. 1 BMR file 64/4002	38 147	19 09	39 43	J55-11	29.6 32.9	20-1-64 1-2-64	1693	PA
South Longford No. 1	38 147	11 05	54 46	J55-11	92.6 94.2	14-12-63 7-1-64	3795	PA
Southwest Bairnsdale No. 1 BMR file 63/1224	37 147	52 21	06 58	J55-7	68.6 71.9	8-1-63 13-2-63	1197	PA

* Key to abbreviations is given at the end of Appendix 1a.

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East o	'	"	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ARCO LTD - WOODSIDE (LAKE ENTRANCE) OIL COMPANY N.L. (now WOODSIDE OIL N.L.)								
Wellington Park No. 1 BMR file 62/1077	38 147	08 22	25 30	J55-11	0.6 6.4	6-12-62 3-4-62	3661	PA
AUSTRALIAN PAPER MANUFACTURERS PTY LTD								
Rosedale No. 1 BMR file 62/1035	38 146	08 47	00 00	J55-10	53.64 56.7	27-3-60 10-5-60	1779	PA
BOC OF AUSTRALIA LTD								
Golden Beach No. 1	38 147	15 25	30 21	J55-11	18	3-4-67 28-4-67	420	PA
Golden Beach No. 1A	38 147	15 25	33 20	J55-11	18 12.8	3-5-67 17-7-67	2937	PA Gas well
ENDEAVOUR OIL N.L.								
Albatross No. 1	37 148	57 03	40 00	J55-7	43.3 9.7	30-6-70 14-7-70	1256	PA
Gannet No. 1	37 148	54 08	21 09	J55-7	39.0 9.7	19-7-70 28-7-70	1459	PA

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ESSO EXPLORATION AND PRODUCTION AUSTRALIA INC.						
Albacore No. 1	38 34 00 148 19 54	J55-11	102.4 30.2	6-5-70 4-6-70	3247	PA
Barracouta No. 1 (Gippsland Shelf No. 1) BMR file 64/4124	36 16 41 147 42 45	J55-11	45.7 9.4	27-12-64 31-5-65	2652	PA Gas well
Barracouta No. 2 (Gippsland Shelf No. 2)	38 17 58 147 40 26	J55-11	46.0 9.4	8-6-65 5-7-65	1223	PA Gas well
Barracouta No. 3	38 19 19 147 37 03	J55-11	44.2 9.4	3-8-69 16-9-69	2941	PA Oil shows below gas reservoir
Batfish No. 1	38 13 34 148 24 13	J55-11	68.0 9.4	6-4-70 28-5-70	2975	PA Minor gas & condensate shows
Bluebone No. 1 BMR file 69/2029	39 24 24 147 50 53	J55-15	48.2 9.4	26-9-69 1-10-69	605	PA
Bonita No. 1	38 33 47 148 17 09	J55-11	79.8 30.1	15-10-69 22-10-69	152	PA Technical trouble
Bonita No. 1A	70'NE of Bonita No. 1	J55-11	80.7 30.1	22-10-69 13-11-69	3179	PA
Bream No. 1	38 31 09 147 47 45	J55-11	57.9 9.4	20-1-69 22-1-69	241	PA Technical trouble
Bream No. 2	38 31 21 147 47 53	J55-11	58.2 9.4	24-2-69 17-4-69	3248	PA Hydrocarbon shows

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ESSO EXPLORATION AND PRODUCTION AUSTRALIA INC. (contd)						
Bream No. 3	38 30 47 148 10 34	J55-11	59.1 28.3	16-11-70 10-1-70	3356	PA
Bullseye No. 1	38 35 30 147 33 59	J55-11	58.52 9.75	24-11-73 3-12-73	2369	PA
Cobia No. 1 BMR file 72/2703	38 27 27 148 17 01	J55-11	72.9 9.8	4-8-72 24-8-72	1771	PA Oil well
Cod No. 1 (Gippsland Shelf No. 3)	38 21 43 147 58 33	J55-11	61.5 9.4	20-9-65 15-11-65	2908	PA
Dart No. 1	38 08 43 148 55 27	J55-12	121.3 9.7	16-11-73 22-11-73	1219	PA
Dolphin No. 1	38 29 32 147 22 43	J55-11	39.6 9.4	28-9-67 21-11-67	2884	PA Oil shows
Emperor No. 1	38 05 59 148 00 13	J55-11	56.7 9.4	5-6-70 28-6-70	1995	PA Gas shows
Flathead No. 1	38 01 21 148 32 04	J55-12	52.7 9.4	30-4-69 15-5-69	1065	PA Oil shows Abandoned due to high pressure
Flounder No. 1	38 18 52 148 25 29	J55-11	87.5 28.3	10-7-68 24-9-68	3578	Oil shows
Flounder No. 2	38 19 18 148 26 43	J55-11	99.3 30.1	19-2-69 28-3-69	2841	PA Oil shows

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East o ' "	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ESSO EXPLORATION AND PRODUCTION AUSTRALIA INC. (contd)						
Flounder No. 3	38 18 58 148 28 23	J55-11	110.6 30.1	26-4-69 12-5-69	2565	PA Oil shows
Flounder No. 4	38 27 27 148 29 45	J55-11	119.5 9.8	28-12-72 24-1-73	2623	PA Oil and gas shows
Flounder No. 5	38 18 24 148 16 56	J55-11	99 9	2-2-75 14-2-75	2607	PA
Groper No. 1	38 56 20 147 24 56	J55-11	57.9 9.4	18-12-68 10-1-69	1030	PA
Groper No. 2 BMR file 69/2028	38 58 40 147 14 12	J55-11	230.7 233.8	12-11-69 9-1-70	1249	PA
Gurnard No. 1	38 35 33 147 58 38	J55-11	69.4 9.7	3-10-69 30-10-69	2964	PA
Halibut No. 1	38 23 56 148 18 59	J55-11	71.9 9.4	19-6-67 29-8-67	3051	PA Oil well
Hapuku No. 1	38 33 21 148 32 56	J55-11	379.5 8.5	7-7-75 1-9-75	3650	PA Oil shows
Kingfish No. 1	38 35 58 148 12 35	J55-11	72.8 9.4	9-4-67 29-5-67	2576	PA Oil well
Kingfish No. 2	38 35 55 148 10 13	J55-11	76.2 9.4	28-11-67 25-1-68	2445	PA Oil well

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ESSO EXPLORATION AND PRODUCTION AUSTRALIA INC. (contd)						
Kingfish No. 3	38 35 03 148 06 07	J55-11	74.1 9.4	2-2-68 28-2-68	2529	PA Oil well
Kingfish No. 4	38 35 55 148 05 45	J55-11	75.6 9.7	25-10-73 11-11-73	2509	PA Oil well
Kingfish No. 5	38 34 45 148 14 30	J55-11	78.9 9.8	16-5-74 2-6-74	2512	PA
Kingfish No. 6	38 35 40 148 13 59	J55-11	79 9	1-1-75 24-1-75	2556	PA
Mackerel No. 1	38 28 54 148 21 26	J55-11	98.1 30.1	27-3-69 13-4-69	3049	PA Oil shows
Mackerel No. 2	38 29 14 148 20 18	J55-11	119.5 9.8	14-2-72 18-3-72	2592	PA
Mackerel No. 3	38 28 28 148 21 45	J55-11	98.8 8.9	1-4-72 18-4-72	2633	PA
Mackerel No. 4	38 30 52 148 18 55	J55-11	83.2 9.7	11-2-73 10-5-73	2652	PA Oil shows
Marlin No. 1 (Gippsland Shelf No. 4) BMR file 65/4183	38 14 03 148 13 33	J55-11	60.0 9.4	5-12-65 3-2-66	2586	PA Oil & gas well
Marlin No. 2 (Gippsland Shelf No. 5)	38 15 59 148 10 45	J55-11	57.3 9.4	31-5-66 25-8-66	3050	PA Gas well
Marlin No. 3	38 14 44 148 10 16	J55-11	59.7 9.4	16-12-66 9-1-67	1782	PA

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ESSO EXPLORATION AND PRODUCTION AUSTRALIA INC. (contd)						
Marlin No. 4 BMR file 73/216	38 14 24 148 16 3	J55-11	61.3 9.7	5-10-73 21-10-73	2621	PA Gas & condensate shows
Marlin A-6	38 13 56 148 13 16	J55-11	58.7 24.7	22-8-68 22-11-68	3306	Gas well (development well and deeper pool test)
Marlin A-24 BMR file 73/209	38 13 55 148 13 10	J55-11	58.5 25.0	16-5-73 15-6-73	3349	Suspended (as gas well)
Moray No. 1	38 51 48 148 03 21	J55-11	75.6 8.9	15-6-72 9-7-72	2670	PA
Morwong No. 1 BMR file 72/3225	38 13 43 148 18 45	J55-11	63.4 9.8	10-12-72 25-12-72	2439	PA
Mullet No. 1	39 13 02 147 57 22	J55-15	53.3 9.7	9-1-69 16-1-69	751	PA
Nannygai No. 1	38 33 10 147 59 43	J55-11	68.6 9.8	9-7-72 31-7-72	3019	PA
Perch No. 1	38 34 37 147 19 24	J55-11	42.1 9.4	13-3-68 2-5-68	2867	PA
Pike No. 1	38 46 30 147 56 60	J55-11	73.8 9.7	16-7-73 25-7-73	2134	PA
Salmon No. 1	38 25 16 147 59 15	J55-11	64.0 30.1	13-1-69 16-2-69	3007	PA

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "			1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ESSO EXPLORATION AND PRODUCTION AUSTRALIA INC. (contd)								
Snapper No. 1	38 148	12 00	03 49	J55-11	54.9 10.0	9-5-68 9-12-68	3755	PA Oil and gas well
Snapper No. 2	38 148	11 02	16 37	J55-11	53.3 9.4	16-6-69 23-7-69	3051	PA Oil and gas shows
Snapper No. 3	38 147	12 59	45 11	J55-11	56.7 9.4	24-11-69 22-1-70	3211	PA Oil and gas well
Stonefish No. 1	38 148	15 33	03 36	J55-11	114.9 9.7	26-7-73 25-8-73	3184	PA
Sunfish No. 1	38 148	08 13	26 38	J55-11	24.0 3.0	7-2-74 26-2-74	766	PA
Tailor No. 1	38 148	29 16	45 25	J55-11	76.5 9.4	5-11-69 20-11-69	2590	PA Oil show
Trevally No. 1	38 148	17 23	23 40	J55-11	56.7 9.4	28-1-70 16-2-70	2284	PA
Tuna No. 1	38 148	10 25	25 03	J55-11	60.4 9.4	7-5-68 12-10-68	3641	PA Oil and gas well
Tuna No. 2	38 148	10 23	52 14	J55-11	59.43 9.4	31-10-68 5-12-68	2761	PA Oil and gas well

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
ESSO EXPLORATION AND PRODUCTION AUSTRALIA INC. (contd)						
Tuna No. 3	38 10 10 148 26 50	J55-11	64 9.4	18-2-70 2-4-70	2819	PA Oil and gas well
Turrum No. 1	38 12 10 148 14 41	J55-11	58 30.1	19-5-69 26-6-69	3057	PA
Turrum No. 2	38 14 39 148 14 56	J55-11	61 9.8	5-6-74 8-7-74	2672	PA Oil and gas shows
Wahoo No. 1	38 01 42 148 44 48	J55-11	74.61 9.4	27-5-69 11-6-69	746	PA
HALLIDAY ENTERPRISES PTY LTD						
Crossroads No. 1	38 19 39 149 09 42	J55-11	-	19-5-71 3-6-71	1040	PA
East Reeve No. 1	38 05 50 147 32 57	J55-11	1.5 5.5	19-9-71 25-1-72	1622	PA
Keystone No. 1	38 19 39 147 09 21	J55-11	29.6 34.8	8-2-72 18-2-72	1960	PA
West Seacombe No. 1	38 08 08 147 25 18	J55-11	6.1 11.0	31-12-71 1-1-72	1766	PA

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East °	'	"	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
N.S.W. OIL AND GAS CO. N.L.								
Flying Fish No. 1	38 147	20 21	51 52	55-11	26.2 10.3	7-11-71 29-11-71	1987	PA
Sailfish No. 1 BMR file 71/472	39 148	27 37	24 54	J55-16	84.7 95.4	12-10-71 2-11-71	1422	PA
SHELL DEVELOPMENT (AUSTRALIA) PTY LTD								
Sole No. 1	38 149	07 02	01 04	J55-12	128.93 9.75	28-1-73 8-2-73	1129	PA Gas shows
WOODSIDE (LAKES ENTRANCE) OIL COMPANY N.L. (Now WOODSIDE OIL N.L.)								
No. 1	38 146	35 56	34 10	J55-10	7.9	1955	1831	PA
No. 2	38 146	37 53	32 52	J55-10	7.9	1957	2701	PA
No. 3	38 146	37 53	35 45	J55-10	-	1956	1824	PA
No. 4	38 146	40 50	11 25	J55-10	2.1	1957	821	PA
Colliers Hill No. 1	38 147	11 17	56 30	J55-11	28.5 34.0	9-1-70 3-2-70	1711	PA
Dutson Downs No. 1	38 147	12 21	00 45		1.5 4.8	8-3-66 10-4-66	1862	PA

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "			1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
WOODSIDE (LAKES ENTRANCE) OIL COMPANY N.L. (Now WOODSIDE OIL N.L.) (contd)								
Golden Beach West No. 1	38 147	14 21	55 23	J55-11	8.8 8.5	11-9-65 28-10-65	2290	PA
Hedley No. 1 (W.L.3) O.C. No. 6	38 146	39 32	00 30	J55-10	12.1	1958	1223	PA
Lakes Entrance No. 1	37 147	52 59	00 42	J55-7	52.1 49.6	28-3-66 6-4-66	422	PA
Lake Reeve No. 1	38 147	19 15	42 20	J55-11	5.1 1.5	23-3-65 26-4-65	2022	PA
North Seaspray No. 2	38 147	17 12	58 25	J55-11	27.1 23.4	2-2-65 28-3-65	1633	PA
Salt Lake No. 1	38 147	26 05	53 12	J55-11	19.2 23.1	12-4-70 7-5-70	1644	PA
Seacombe South No. 1	38 147	08 29	30 12	J55-11	-	4-11-70 12-11-70	361	PA
Spoon Bay No. 1	38 147	04 27	56 57	J55-11	-	9-10-70 30-10-70	1400	PA
St Margarets Island No. 1 BMR file 65/4185	38 146	38 50	16 05	J55-10	7.9 4.5	29-1-66 18-2-66	1422	PA
Sunday Island No. 1 BMR file 65/4180	38 146	42 40	19 11	J55-10	6.4 6.0	19-11-65	1830	PA

APPENDIX 1a (contd)

COMPANY Well name BMR file no. (if subsidised)	Latitude South Longitude East ° ' "	1:250 000 Sheet area	Elevation (m) GL/WD DF/KB/RT*	Date spudded TD reached	Total depth (m)	Status Remarks
WOODSIDE (LAKES ENTRANCE) OIL COMPANY N.L. (Now WOODSIDE OIL N.L.) (contd)						
Wellington Park No. 2	38 08 08 147 20 55	J55-11	-	16-3-70 2-4-70	1258	PA
Woodside South No. 1 BMR file 54/4159	38 34 25 146 54 30	J55-10	14.0 10.3	30-5-65 11-7-65	1774	PA

Abbreviations

TD - Total depth
RT - Rotary table
KB - Kelly bushing
DF - Derrick floor
GL - Ground level
WD - Water depth (offshore)
PA - Plugged and abandoned
c - approximately

APPENDIX 1b

GEOLOGICAL AND OTHER SHALLOW DRILLING, GIPPSLAND BASIN

COMPANY	Well Name	Latitude South/Longitude East ° ' " ° ' "	Elevation GL/KB (m)	Date spudded T.D. reached	Total depth T.D. (m)
AMALGAMATED OIL SYNDICATE	No. 1 (Old Goon Nure)	c37 59 00/147 33 00	28	1931	893
ARCO LTD	East Lake Tyers No. 1	37 50 38/148 07 33	3/4	8.10.62 18.10.62	470
	East Nowa No. 1	37 47 47/148 09 42	60/62	21.10.62 26.10.62	364
FROME LAKES PTY LTD	No. 1 (Gippsland)	c38 35 00/146 53 00	-	1956	518
	No. 1A "	c38 33 51/148 52 54	10	1956	598
	No. 2 "	38 38 30/146 46 00	3	1956	473
	No. 3 "	38 35 16/146 50 10	9	1956	572
	No. 4 "	37 59 53/147 09 10	37	1956	553
	No. 5 " (No. 6)	37 52 54/147 32 03	76	1957	472
	Darriman No. 1	38 27 04/147 00 30	35	1955	1442
LAKE WELLINGTON OIL WELLS	No. 1 (Glencoe)	38 13 00/147 14 00	53		676
MIDFIELD OIL COMPANY	No. 1 (Glencoe South)	38 13 43/147 08 34	?		293
OIL SEARCH LTD	No. 1 (Bengworden)	37 57 26/147 25 11	32		282
	No. 2 "	37 57 27/147 27 51	22		331
	No. 1 (Bravo Plant)	37 51 30/147 25 24	85	?	86
	No. 2 " "	" " " " " "	"	?	93
	No. 3 (Steam Drill)	37 53 12/147 27 52	56	?	441
SIGNAL HILL EXPLORATION	No. 1	c38 14 27/147 19 17	28		699
TANGIL-POINT ADDIS COMPANY	No. 1	c38 14 27/147 06 24	76		439
	No. 2	c38 15 26/147 09 38	8		841
TEXLAND OIL COMPANY	Glencoe No. 1	c38 12 45/147 12 51	?		331
VALVE OIL WELLS	No. 1 (Pelican Point)	c38 00 51/147 37 30	3	1929-1933	704

COMPANY	Well Name	Latitude South/Longitude East ° ' " ° ' "	Elevation GL/KB (m)	Date spudded T.D. reached	Total depth T.D. (m)
VICTORIAN STATE DEPT. OF MINES	Bairnsdale				
	No. 3 (Cobbler's Creek)	c37 52 17/147 36 36	6	1938	275
	No. 4 (Forge Creek)	c37 54 51/147 37 30	30	1939	436
	No. 5 (Eagle Point)	c37 54 00/147 40 43	3	1939	473
	Bengworden South				
	No. 1 (Holland's Landing)	c38 03 36/147 27 51	3	1940	1220
	Boole Poole				
	No. 1 (Sperm Whale Head)	c37 51 26/147 40 43	3	1939	948
	Bundalaguah				
	No. 1	c37 58 56/146 52 18	21	1938	185
	No. 2	c37 57 27/147 03 12	20	1938	198
	No. 3	c38 05 06/147 01 04	6	1938	201
	Coongulmerang				
	No. 1	c37 53 12/147 24 40	56	1933	288
	No. 2	c37 48 57/147 26 45	48	1933	195
	No. 3 (Tom's Creek)	c37 53 45/147 22 32	?		367
	Darriman				
	No. 3	c38 24 54/146 58 56	30	1929	368
	No. 4	c38 27 27/147 04 16	30	1937	381
	Dulungalong				
	No. 1	c38 12 45/147 23 26	–	1937	493
	Giffard				
	No. 14	c38 23 00/147 11 20	4	1937	488

COMPANY	Well Name	Latitude South/Longitude East ° ' " ° ' "	Elevation GL/KB (m)	Date spudded T.D. reached	Total depth T.D. (m)
VICTORIAN STATE DEPT. OF MINES (continued)	Glencoe				
	No. 1	c38 11 54/147 06 24	81	1924	112
	No. 2	c38 11 54/147 06 24	44	1929	289
	No. 3	" " " " " "	71	1930	71
	No. 4	" " " " " "	62	1930	105
	No. 5	" " " " " "	55	1930	165
	No. 6	c38 12 45/147 08 32	34	1930	199
	No. 7	c38 11 03/147 09 36			421
	No. 8	c38 09 21/147 12 48	3	1937	428
	Glencoe South				
	No. 2	c38 17 04/147 02 45	188	1932	281
	Goon Nure				
	No. 1 (Romawi)	c37 58 18/147 36 24	30	1938	989
	Meerlieu				
	No. 1	c37 56 26/147 17 12	31	1936	368
	Moormurng				
	No. 1	c37 51 30/147 27 52	53	1932	311
	Nindoo				
	No. 1	c37 51 30/147 16 00	61	1936	162
	Nuntin				
	No. 1	c38 00 51/147 06 24	12	1937	443
	No. 2 (Lake Kakydra)	c38 00 15/147 11 44	1	1939	1085
	Seacombe				
	No. 1	c38 05 57/147 27 56	3	1937	478

APPENDIX 1b (continued)

COMPANY	Well Name	Latitude South/Longitude East ° ' " ° ' "	Elevation GL/KB (m)	Date spudded T.D. reached	Total depth T.D. (m)
	Stradbroke				
	No. 14 (Monkey Creek)	c38 19 33/147 00 34		1930	464
	No. 15	c38 17 00/146 58 56		1930	197
	No. 16 (Merriman's Creek)	c38 17 50/147 02 04		1931	450
	Stratford				
	No. 1	c37 54 03/147 07 25	90	1936	203
	Woodside				
	No. 5	c38 28 18/146 56 48		1926	95
	No. 6	" " " " " "		1926	100
	Wulla Wullock				
	No. 2	c38 00 17/147 04 52		1937	433
	Wurruk Wurruk				
	No. 1 (Sale)	c38 05 00/147 02 08	9	1941	980
	Yeerung				
	No. 1	c38 00 00/147 14 56	7	1936	410
WESTRALIAN OIL LTD	No. 1 (Yarram)	c38 33 18/146 37 20	27	1957	571
AUSTRAL OIL SYNDICATE	Foster's (Bore) No. 1	c37 52 08/147 59 59	28	1936	384
	Imray (Bore) No. 1	c37 52 02/147 59 47	41	1939-40	388
DOME OIL AND MINERALS SYNDICATE N.L.	Dome Frome No. 1 (Lake Tyers No. 1)	37 47 25/148 00 55	39	1957	172
	Dome Frome No. 5 (-Ekberg No. 1)	37 30 00/148 11 00	-	1959	378
(Dome Frome No. 2-4 see FROME LAKES OIL CO.)					
(East End Bore No. 1, see LAKES OIL LTD)					
A.E. EKBERG	Ekberg No. 1 - Dome Frome No. 5				

COMPANY	Well Name	Latitude South/Longitude East ° ' " ° ' "	Elevation GL/KB (m)	Date spudded T.D. reached	Total depth T.D. (m)
FROME LAKES OIL CO. (-F.L.P.L.)	No. 8 (Ballong) Dome Frome No. 2	37 46 47/148 02 45	15	1958	170
	No. 9 (Tarra Tarra)-Dome Frome No. 3				
	No. 10 (Ballong) - Dome Frome No. 4	c37 48 00/148 04 00	42	1958	396
GIPPSLAND OIL CO. LTD	No. 1	c37 51 50/147 51 00	71	28.2.39	536
	No. 2	c37 51 50/147 51 00	62	30.11.39	337
	No. 3 (Nungurner)	c37 51 50/147 51 00	60		443
KALIMNA OIL CO. LTD	No. 1	37 53 20/147 57 08	1	1929	449
	No. 2	37 52 08/147 57 52	46	-	428
LAKES ENTRANCE DEVELOPMENT CO. PTY LTD	No. 1 (Lake Bunga)	37 51 22/148 02 21	2	1924	370
	No. 2	37 52 21/148 00 47	9	1927	389
LAKES OIL LTD	No. 1 (-East End Bore No. 1)	37 48 04/148 21 14	3	1959	375
LAKE VIEW COMPANY	No. 1	37 51 34/148 01 39	43		368
	No. 2	37 52 03/148 00 21	58		409
	No. 3	37 52 15/147 59 42	25		392
MIDFIELD OIL COMPANY	No. 1	37 51 45/148 00 21	60		398
	No. 2	37 51 57/148 00 18	52		403
MIDWEST COMPANY	No. 1	37 51 51/147 59 42	55		402
	No. 2	37 51 51/147 59 42	39		1036

APPENDIX 1b (continued)

COMPANY	Well Name	Latitude South/Longitude East ° ' " ° ' "	Elevation GL/KB (m)	Date spudded T.D. reached	Total depth T.D. (m)
OIL SEARCH LTD	Mac's Oil Well No. 1	37 52 40/147 59 36	12		399
	" " " No. 2	c37 52 34/147 59 23	15		395
	" " " No. 3	c37 52 37/147 59 21	9		399
	No. 1	37 51 54/147 58 37	40		389
	No. 2	37 52 00/147 58 31	43		402
	No. 3	37 51 54/148 00 50	35		399
POINT ADDIS COMPANY	No. 1	c37 53 12/147 50 21	1	1929	442
	No. 2	c37 50 39/147 50 20	1	1930	289
	No. 3	c37 52 25/148 00 03	8	1930	378
	No. 4	c37 52 00/147 59 21	61	1931	411
S.A. OIL WELLS COMPANY	No. 1	c37 50 48/147 57 13	56		381
	No. 2	c37 51 54/148 00 00	46		398
	No. 3	c37 51 54/147 58 03	50		411
	No. 4	c37 51 45/147 59 55	42		382
	No. 5	c37 51 35/147 57 58	42		402
	No. 6	c37 51 51/147 59 55	29		382
	No. 7	c37 51 07/147 59 57	26		382
	No. 8	c37 52 00/148 00 00	43	1932	389
TANGIL NO. 1 COMPANY	No. 1	c37 51 40/148 00 01	59		387
	No. 2	c37 51 46/147 59 18	53		385
TANGIL NO. 2 COMPANY	No. 1	c37 51 35/148 00 21	70		415

COMPANY	Well Name	Latitude South/Longitude East ° ' " ° ' "	Elevation GL/KB (m)	Date spudded T.D. reached	Total depth T.D. (m)
TEXLAND OIL COMPANY	Houghton's No. 1	c37 51 51/148 00 02	49		388
VICTORIAN STATE DEPT. OF MINES	*Bumberrah No. 3	c37 52 51/147 49 17	1	1931	374
	Colquhoun No. 1	c37 52 57/147 58 10	2	1928	428
	" No. 2	c37 51 30/147 56 40	18	1930	297
	" No. 3	c37 53 12/147 53 28	1	1940	443
	" No. 4	c37 53 31/147 58 18	4	1940	460
	" No. 5	c37 52 18/147 56 29	3	1940	382
	" No. 6	c37 52 25/147 57 21	53	1940	444
	" No. 7	c37 52 03/148 02 26	1	1940	372
	" No. 8	c37 51 40/147 58 47	1	1940-41	355
	" No. 9	c37 52 28/148 01 21	2	1941	379
	" No. 10	c37 52 03/148 00 08	42	1941	421
	" No. 11	c37 50 57/147 59 58	60	1941	377
	Colquhoun North No. 1	c37 48 57/147 54 40	30		201
WOODSIDE (LAKES ENTRANCE) OIL COMPANY N.L. (now Woodside Oil N.L.)	No. 7 (-Oilco, No. 1)	37 51 49/146 57 53	42	1957	422
UNKNOWN	Cobden's Bore	c37 52 00/148 04 00	6		459

APPENDIX 2

GEOPHYSICAL SURVEYS

Magnetic surveys

Map key no. (Plate 2)	Survey name and type	Year	Operator	Contractor	Survey altitude	Traverse spacing km	Total traverse length km	Reference
1	Gippsland Basin air-borne magnetic	1951-52 and 1956	BMR	-	1000'	1.6		BMR Recs. 1952/14 and 1956/116 BMR Report 95
2	Bass St.-Encounter Bay airborne magnetic	1960 1961	Haematite "	Aero Service " "	1000' 2000'	48-80 3-20	2400	PSSA 62/1711 and PSSA publication no. 60
3	East Gippsland Basin seismic and magnetic	1968	Magellan	Western Geophysical	Sea Level (S.L.)	5	1020	PSSA 68/3049 P(SL)A 68/1
4	Gippsland G69A seismic and magnetic	1968-69	Esso Australia	Western Geophysical	S.L.	10	438 2570	PSSA 68/3058 P(SL)A 69/4
5	Tasman-Bass St. seismic and magnetic	1969	Magellan	Teledyne	S.L.	4	2590 229	PSSA 69/3023 P(SL)A 69/11
6	Gippsland G71A seismic and magnetic	1971	Esso Australia	Geophysical Services International	S.L.	?	1450	P(SL)A 71/5
7	Shell Deepwater Scientific	1972-73	Shell Development (Australia)	Seismograph Services Ltd	S.L.	50	10904	P(SL)A 72/30
8	BMR Continental Margin Geophysical	1970-73	BMR	Compagnie Generale de Geophysique	S.L.	35		BMR Records 1974/15 and 1974/98

Gravity surveys

Survey name	Year	Operator	Contractor	Traverse spacing km	Station spacing km	No. of stations	Reference
Morwell Anticline	1948	BMR	-	1.0	0.2	189	BMR Record 1948/81
East Gippsland	1949 1951	Lakes Oil BMR	R.H. Ray	Various	0.8	1892	BMR Records 1952/13 and 1953/77
Yallourn-Morwell-Traralgon	1950	BMR	-	Various	0.8	240	BMR Record 1951/10
Longford	1960	BMR	-	2-4	0.4	63	BMR Record 1963/106
Gormandale	1960-1961	BMR	-	2-4	0.4	208	BMR Record 1973/86
Gippsland Basin	1948-1961		(Summary of early surveys)				BMR Record 1974/160
Stockyard Hill	1966	Woodside (Lakes Entrance)	Wongela Geophysical	0.5	0.5	312	PSSA 66/4823
BMR Continental Margin Geophysical	1970-1973	BMR	Compagnie Generale de Geophysique	50	-	-	BMR Records 1974/15 and 1974/98
Shell Deepwater Scientific	1972-1973	Shell Development (Australia)	Seismograph Services Ltd	75	-	-	P(SL)A 72/30
Reconnaissance Helicopter surveys	1973-1974	BMR	Wongela Geophysical	11	11	7658	BMR Record in preparation

Land seismic surveys

Appendix 2 (cont)

Map Key No. (Plate 5)	Survey name and type	Year	Operator	Contractor	Energy Source	No. of km surveyed	CDP coverage %	Reference
1	Avon area reflection	1952	BMR	-	Explosives		100	BMR Record 1952/35
2	Darriman area reflection	1954	BMR	-	Explosives		100	BMR Report 19
3	Latrobe Valley experimental reflection & refraction	1958	BMR	-	Explosives		100	BMR Record 1959/151
4	East Gippsland reflection	1960	Woodside (Lakes Entrance)	Austral Geoprospectors	Explosives	134	100	PSSA 62/1507
5	Rosedale reflection and refraction	1961	BMR	-	Explosives	29	100	BMR Record 61/165
6	Lake Wellington	1961	Woodside (Lakes Entrance)	Austral Geoprospectors	Explosives	218	100	PSSA 62/1552
7	Lakes Entrance reflection and refraction	1962	Arco Ltd	Austral Geoprospectors	Explosives		100	PSSA 62/1591
8	Gormandale refraction	1963	A.P.M. Development	Austral Geoprospectors	Explosives	13.4	-	PSSA 63/1547
9	Seaspray reflection	1964	Arco Ltd	Namco	Explosives	95	600	PSSA 64/4521
10	Woodside-Paynesville reflection	1965	Woodside (Lakes Entrance)	Seismograph Services Ltd Namco	Vibroseis Explosives	100 210	1000 600	PSSA 64/4573
11	Toongabbie reflection and refraction	1968	A.P.M. Developments	GAPL	Explosives	35	100	PSSA 68/3022
12	Bemm River refraction	1970	W.Y.P. Development	Geosurveys	Explosives	29	-	PSSA 70/768

Marine seismic surveys

Appendix 2 (cont)

Map Key No. (Plate 5)	Survey name and type	Year	Operator	Contractor	Energy Source	No. of km surveyed	CDP coverage %	Reference
13	Ninety Mile Beach	1962 -63	Arco Ltd	Western Geophysical	Explosives	-	100-200	PSSA 62/1640
14	Gippsland-Bass St.-Anglesea-S.A.	1963	Haematite	Western Geophysical	Explosives	1610	100-200	PSSA 62/1645
15	Gippsland Shelf	1964	Esso Australia	Western Geophysical	Explosives	1030 130	600 100	PSSA 64/4550
16	Offshore Gippsland Basin	1965	Shell Development	Geophysical Services International (GSI)	Explosives	1000	400	PSSA 65/11045
17	Eastern Bass St.	1966	Esso Australia	GSI	Explosives	3590	100-600	PSSA 66/11070
18	Gippsland EC-67	1967	Esso Australia	GSI	Explosives and Airguns	750	600	PSSA 67/11184
19	Sole Structure	1967	Shell Development	Compagnie de Generale Geophysique	Sparker	320	100	PSSA 67/11187
20	Gippsland EH-68	1968	Esso Australia	Western Geophysical	Aquapulse	1126	1200	PSSA 68/3015
21	East Gippsland Basin seismic and magnetic	1968	Magellan	Western Geophysical	Aquapulse	226 555	1200 1200	PSSA 68/3049 P(SL)A 68/1
22	Gippsland G69A seismic and magnetic	1968-1969	Esso Australia	Western Geophysical	Aquapulse	438 2570	1200 1200	PSSA 68/3058 P(SL)A 69/4
23	Gippsland G69B	1969	Esso Australia	Western Geophysical	Aquapulse	4000	1200	P(SL)A 69/3

Appendix 2 (cont)

Marine seismic surveys

Map Key No. (Plate 5)	Survey name and type	Year	Operator	Contractor	Energy Source	No. of km surveyed	CDP coverage %	Reference
24	Offshore Lakes Entrance	1969	Endeavour	United Geophysical	Airguns	819	2400	P(SL)A 69/7
25	Tasman-Bass St. seismic and magnetic	1969	Magellan	Teledyne	Sparker and Airguns	3000 229	100-2400 100-2400	PSSA 69/3023 P(SL)A 69/11
26	Gippsland G70A	1970	Esso Australia	GSI	Airguns	190	2400	P(SL)A 70/3
27	Sailfish reflection and refraction	1970	N.S.W. Oil & Gas	Teledyne	Sparker Airguns	174 530	100 2400	PSSA 70/884
28	Seaspray	1970	Endeavour	Teledyne	Airguns	400	2400-4800	P(SL)A 70/9
29	Gippsland Basin	1970	Shell Development	GSI	Airguns	860	2400	P(SL)A 70/10
30	Gippsland G71A seismic and magnetic	1971	Esso Australia	GSI	Airguns	1450	4800	P(SL)A 71/5
31	Gippsland G71B	1971	Esso Australia	GSI	Airguns	2980	2400	P(SL)A 71/6
32	Gippsland G72A	1972	Esso Australia	GSI	Airguns	867	2400	P(SL)A 72/14
33	Shell Deepwater Scientific	1972-1973	Shell Development	Seismograph Services Ltd	Airguns	10,904	2400	P(SL)A 72/30
34	Gippsland G73A	1973	Esso Australia	GSI	Airguns	618	2400	P(SL)A 73/14
35	Gippsland G73B	1973	Esso Australia	GSI	Airguns	131	4800	P(SL)A 73/15
36	1973 Seismic Survey	1973	Shell Development	GSI	Airguns	515	2400	P(SL)A 73/19

Appendix 2 (cont)

Marine seismic surveys

Map Key No. (Plate 5)	Survey name and type	Year	Operator	Contractor	Energy Source	No. of km surveyed	CDP coverage %	Reference
37	Northeast Furneaux	1973	Magellan	GSI	Airguns	208	2400	PSSA 73/225
38	Gippsland G74A	1974-1975	Esso Australia	GSI	Airguns	2926	4800	P(SL)A 74/15
39	BMR Continental Margin Geophysical	1970-1973	BMR	CGG	Sparker		100	BMR Record 1974/98

APPENDIX 3

STRATIGRAPHIC TABLES, GIPPSLAND BASIN WELLS

BARRACOUTA NO. 1

AGE	UNIT	Depth (m)	K.B.	Thickness (m)		LITHOLOGY
	Sea level	9				
	Sea floor	45				
MIOCENE	Gippsland Fm	?		763	234-797	Marl, grey to olive grey, fossiliferous, soft, massive, glauconitic dense. Limestone, grey, skeletal, fossiliferous, glauconitic, pyritic and hard.
					797-940	Sandstone, grey, friable, fairly porous and permeable fossiliferous fairly well sorted and quartzose with subrounded to rounded grains set in a calcareous matrix. Limestone, sandy or calcareous sandstone, but carbonate dominant. Marl, as above, minor percentage.
	? Lakes Entrance Fm				940-997	Marl, olive to dark grey, very fossiliferous and glauconitic, pyritic with scattered quartz grains
OLIGOCENE	Lakes Entrance Fm	997	57		997-1054	Shale, calcareous, green-grey, olive-grey, glauconitic, fossiliferous, pyritic with random quartz grains. Lithologically distinct from the section from 940-997 m and ties with the seismic top. Palaeontological disconformity at 940.
UPPER EOCENE	Latrobe Gp	1054	585		1054-1639	Sand, clear-milky, light grey, medium grained, rounded well sorted quartz. Unconsolidated and extremely porous with minor coal fragments and muscovite flakes. Sandstone, as above but finer grained and slightly dolomitic in places. Coal, brown and black. Siltstone, brown-grey, finely pyritic, micaceous and very carbonaceous. Shale (minor) brown-grey, argillaceous dense and grades into siltstone as above.

BARRACOUTA NO.1 (continued)

AGE	UNIT	Depth (m)	K.B.	Thickness (m)		LITHOLOGY
UPPER CRETACEOUS	Latrobe Gp	1639	1013 +		1639-1739	Siltstone, grey to black, carbonaceous, micaceous and pyritic shale, green grey to dark grey grading into siltstone as above sandstone, grey, very fine to medium grained, subangular to subrounded, soft, friable, carbonaceous, dolomitic in spots. Minor medium to coarse quartz grains. Coal, thin bands, brown to black
					1739-2059	Sandstone, grey, green grey to brown grey, very fine to medium angular to subrounded, 95% clean quartz. Minor coal fragments mica flakes and often lithic fragments. Siltstone, brown-grey carbonaceous and micaceous, finely pyritic grading into shale as below. Shale, grey and green grey, dense carbonaceous and micaceous. Coal, dense, black with good conchoidal fracture.
					2059-2140	Same lithology as for 1739-2059 m but sands are coarser, up to pebble conglomerate in grainsize and angular to subangular. Quartz makes up about 95% of the sandstone
					2140-2213	As for 2059-2140 m but sandstones have kaolinitic matrix.
		TD 2652			2213-2652	As for 2059-2140 but matrix appears to be weathered feldspar. Quartz 85-90%, feldspar 5-10%, coal fragments trace of mica, dark rock fragments and pyrite

Notes

1) First well drilled in the offshore Gippsland Basin and first offshore discovery with 108 m of gas column logged in the top of the Eocene Latrobe Gp.
2) The calcareous sandstone unit from 797-940 m within the Gippsland Fm had not been encountered in onshore wells.
3) The section from 940 to 997 m could be included in the Lakes Entrance Fm on palaeontological control but is lithologically distinct from the underlying section (997-1054 m) and the prominent electric and sonic log marker at 997 m coincides with an extensive mappable seismic reflection.
4) The Upper Cretaceous section is lithologically distinct from the Strzelecki Gp. sediments seen onshore and appears devoid of marine fauna although formation water salinities are very high.

Esso (1966)

MARLIN NO. 1

AGE	UNIT	Depth (m)	K.B.	Thickness (m)		LITHOLOGY
	Sea level	9				
	Sea floor	60				
MIOCENE	Gippsland Fm	232		1066	232-323	Sandstone, light grey fine to coarse poorly sorted, argillaceous calcareous, glauconitic and fossiliferous. Lithic and quartz fragments in a marl matrix.
					323-533	Sandstone as above with sandy marl and argillaceous calcarenite
					533-1055	Sandy marl, light grey calcareous and fossiliferous
					1055-1299	Marl mudstone light grey calcareous soft and fossiliferous
OLIGOCENE	Lakes Entrance Fm	1298		80	1299-1378	Mudstone, light grey soft, calcareous and fossiliferous. Trace of shale and brown silty mudstone. Glauconitic at base
EOCENE	Latrobe Gp	1378		600	1378-1478	Sandstone, light grey, quartzose very fine to coarse poorly sorted with finely disseminated pyritic and carbonaceous flecks
						Very glauconitic in top part and generally not calcareous. Minor brown shale and coal
					1478-1978	Sandstone, grey, fine to very coarse porous and permeable interbedded with dolomite bands, dark brown shale and siltstone, and black coal

MARLIN NO. 1 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
UPPER CRETACEOUS	Latrobe Gp	1978	608	1978-2512	Interbedded sandstone, siltstone, shale, coal and dolomite. Sandstone is grey white quartzose dominantly fine grained subangular and fairly well sorted with some disseminated glauconite and a variable white clay matrix. Dolomite is light to medium brown cryptocrystalline dense, hard and contains some dolomitic sandstone
				2512-2586	Dominantly sandstone with minor interbedded siltstone and coal. Sandstone is light grey quartzose fine to very coarse poorly sorted. Porosity and permeability low as a result of kaolinitic matrix.

Notes

1) First significant discovery of oil in the Latrobe Gp 16 m of gross oil sand from 1558-1574 m was logged. Production test from 1561-1566 produced 1182 bpd of 51°-53° oil.
2) First significant gas show in the Upper Cretaceous section. Gross gas column of 180 m was logged from 2149-2329 m. Production test through perforations from 2290-2309 m and 2257-2276 m flowed at a maximum rate of 10.9 MMCFD + condensate at 39 bbl/MMCFG.
3) Stratigraphy is essentially the same as Barracouta No. 1 but Miocene section is complete and 305 m thicker in Marlin No. 1. Palaeontological evidence indicates that the Middle Miocene in Marlin No. 1 is 152 m higher than in Barracouta No. 1 suggesting local structural growth at Marlin No. 1

ESSO (1965)

MARLIN NO. A-24

EOCENE	Latrobe Gp	1582 MD 1393 TVD	590		Interbedded pyritic siltstone and carbonaceous shale, scattered interbeds of sandstone, coal beds

MARLIN NO. A-24 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
PALEOCENE	Latrobe Gp	2368 MD 1983 TVD	744 +	2368-2624	Interbedded carbonaceous siltstone and fine grained sandstone, minor shale and coal beds
				2624-3310	Interbedded carbonaceous shale and siltstone and sandstone, numerous coal beds; sands are gas-bearing to 3173 m, oil-bearing from 3310-3234 m, and water-bearing below that
		3354 TD 2727 TVD		3310-3349	Interbedded micaceous pyritic siltstone and silty clay-choked tight sandstone

Notes

1) The well confirmed the presence of gas and oil in the 'D' fault block immediately to the south of the Marlin platform. 78 m of net gas and 16 m of net oil sand between 2161 and 2603 m.
2) Apart from the gas sand at 2161 m which is not present in other Marlin field wells the Paleocene section is similar to that found in Marlin 1, 2 ans A6 wells

ESSO (1973)

KINGFISH NO. 1

AGE	UNIT	Depth (m) K.B.	Thickness (m)	LITHOLOGY
	Sea level	9		
	Sea floor	77		
MIOCENE	Gippsland Fm	77	691	Limestones marls and sandstones
OLIGOCENE	Lakes Entrance Fm	1768	511	Mudstones and marls
EOCENE	Latrobe Gp	2279	297	Sandstones shales and siltstones
		TD 2576		

Notes

1) Kingfish No. 1 intersected 35 m of gross oil column in coarse grained clastics of Lower Eocene age. The oil water contact occurs at 2306 m

ESSO 1967) In confidence

TUNA NO. 1

AGE	UNIT	Depth (m) K.B.	Thickness (m)	LITHOLOGY
	Sea level	9.4		
	Sea floor	60		
MIOCENE	Gippsland Fm	60	1259	Limestones marls and sandstones
EOCENE	Latrobe Gp Flounder Fm	1319		Interbedded siltstones and sandstones. Interval is predominantly silty at the top and sandy towards the bottom
PALEOCENE	"	1570		Interbedded sandstones siltstones shales and coal
L. CRETACEOUS	"	1970	1017	Volcanics between 2231 and 2234 m
?E. CRETACEOUS	? Strzelecki Gp	2987	654	
		TD 3641		

Notes

1) Tuna 1 provided a standard for the Tolilliei zone in the eastern part of the basin
2) The 'channel' fill at Tuna-1 is sandier than the fill at Flounder or Turrum

ESSO (1968) In confidence

TURRUM NO. 1

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
	Sea level	30			
	Sea floor	89	59		
MIOCENE	Gippsland Fm	89	1206 +		Calcarenites marls and sandstones become more glauconitic towards the base
OLIGOCENE	Lakes Entrance Fm	1295	647		Mainly mudstones glauconitic pyritic carbonaceous and sometimes micaceous
EOCENE	Latrobe Gp. Turrum Fm	1942	109		Mainly siltstone. Lesser amounts of medium to coarse grained micaceous sandstone. Minor coal
PALEOCENE	"	2051	692		Sandstone fine to coarse grained mostly quartzose. Siltstones, mudstones and shales, sometimes micaceous and carbonaceous. Coal stringers common
L. CRETACEOUS	"	2743	314	2743-3050	Predominantly siltstone, sometimes sandy, and coal. Sandstone, fine grained with kaolinitic cement
		TD 3057		3050-3057	Volcanics fine grained intermediate lava-intrusive contact with overlying siltstone

Notes

1) First well to drill the channel fill (Turrum Fm.) of the Marlin anticline

ESSO 1969) In confidence

MACKEREL NO. 1

	Sea level	30		
	Sea floor	128	98	
MIOCENE	Gippsland Fm	128	2053	Limestones and marls, dolomitic in places, abundant Forams
OLIGOCENE	Lakes Entrance Fm	2181	227	Mainly shales and mudstones, glauconitic, pyritic calcareous, with occasional loose quartz grains

MACKEREL NO. 1 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
PALEOCENE	Latrobe Gp	2408	639		Sandstone, siltstones, mudstones, shales and minor coal
(L. Balmei)				2408-2667	Coarse to medium grained quartz sandstone and minor mudstone
				2667-3047	Coaly shales and siltstones become predominent over coarse sandstones
		TD 3047			

ESSO (1969) In confidence

HAPUKU NO. 1

	Sea level	9		
	Sea floor	393	384	
MIOCENE	Gippsland Fm	393	2404	Limestones marls and siltstones. Limestones predominate at the top and calcareous pyritic glauconitic mudstones predominate at the base
EOCENE	Lakes Entrance Fm	2797	14	Glauconitic, pyritic, calcareous, mudstones
EOCENE	Latrobe Gp	2811	3	Pyritic glauconitic claystone and siltstone
PALEOCENE	"	2814	145	Predominately sandstone. Dolomitic pyritic and glauconitic with minor siltstone
LATE CRETACEOUS	"	2959	691	Interbedded sandstones, mudstones, shales and coal seams
		TD 3650		

ESSO (1975) In confidence

SOLE NO. 1

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
	Sea level	10			
	Sea floor	139	129		
MIOCENE	Gippsland Fm	139	671		Mostly marls, grey green fossiliferous and slightly pyritic and glauconitic. Minor thin beds of argillaceous lime mud
EOCENE	Latrobe Gp	810	13		Mainly fine to medium grained slightly pyritic quartz sandstone interbedded with micaceous siltstone
PALEOCENE	"	823	200		As above with thin coal beds at 3180
EARLY CRETACEOUS ALBIAN	Strzelecki Gp.	1023	106	1023-1074	Quartzose sandstone, green mottled, chloritic, micaceous, with lithic fragments and thin beds of claystone
				1074-1129	Claystone, slightly calcareous and chloritic, containing thin beds of quartzose sandstone and siltstone

SHELL DEVELOPMENT (AUSTRALIA) PTY LTD (1973) In confidence

DUCK BAY NO. 1

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
UPPER PLIOCENE	Haunted Hills Gravels and/or Lake Wellington Formation	3	88	12-91	Sand, light grey to yellow, fine to coarse grained; gravel; clay, yellow to grey; and lignite - non-marine
LOWER PLIOCENE	Jemmy's Point Fm	91	30	91-122	Sand, fine to medium grained, with occasional coarse grains, sub-rounded; fossils, predominantly Bryozoan, but with abundant Gastropoda, Pelecypoda and Foraminifera; and marl, medium grey silty, very fossiliferous, glauconitic. The sand and fossils occupy the upper half of the unit and grade downward into the marl. The fossils, except for the smaller forms, appear to have been thoroughly fragmented by wave action.
UPPER MIOCENE	Tambo River Fm	122	6	122-128	Marl, medium grey, silty, very fossiliferous.

DUCK BAY NO. 1 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
MIOCENE	Gippsland Limestone	128	451	128-155	Marl, medium grey-brown, glauconitic, silty poorly consolidated, very fossiliferous.
				155-309	Limestone, white, yellow and light brown, finely crystalline to fine-grained, very fossiliferous and often coquinoidal in upper half, friable to slightly hard, very porous in upper half, argillaceous and tight in lower half, slightly glauconitic.
				309-411	Interbedded limestone as above and marl, grey to green, friable, slightly glauconitic.
				411-579	Claystone, light to medium grey, soft and sticky, slightly fossiliferous and glauconitic, calcareous; and minor marl, grey to grey green, friable.
OLIGOCENE	Lakes Entrance Fm.	579	117	579-667	Claystone, light to medium grey, slightly fossiliferous and glauconitic, calcareous; and marl, medium grey to grey green, friable.
				667-683	Shale, brown green and grey green, firm, moderately to very glauconitic and pyritic, fossiliferous, floating coarse and grains common
				683-696	Sand, dark green grey to medium brown, fine to coarse grained, glauconitic and pyritic, good to fair porosity, slightly argillaceous and micaceous, occasional carbonaceous material, gradational downward into ligneous sand.
LOWER OLIGOCENE TO UPPER EOCENE	Latrobe Valley Coal Measures	696	122	696-818	Sand, fine to very coarse-grained; and gravel, unconsolidated, mostly sub-angular grains, clean to very ligneous, fair to very good porosity; brown coal, brittle to soft, partly silty and shaly; and clay (or Claystone).

DUCK BAY NO. 1 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
LOWER CRETACEOUS	Strzelecki Group	818	150	818-968	Shale-mudstone, dark green grey to dark brown, compact, often silty, carbonaceous; and siltstone, light grey to light brown, argillaceous, carbonaceous, micaceous. From 945 m to 968 m in the cutting become very clayey and the lithology in this interval may more correctly be called claystone.
LOWER PERMIAN?	Volcanics (Un-named)	968	99	968-1067	The major rock type in this section is dark green, highly altered basalt. Tuff, breccia and volcanic ash were seen in core number 5, in which the recovery was only 0.52 m, and as a minor constituend of the cuttings.
LOWER PERMIAN	Un-named	1067	190	1067-1257	Predominantly sandstone, white to light grey, very fine to fine grained with occasional medium size grains, white argillaceous (sericitic) matrix, friable to slightly hard, generally tight, carbonaceous flakes, and laminations common, slightly micaceous; with minor shale, dark brown and medium grey; and siltstone, light grey, partly slightly dolomitic. The age of these sediments has been determined by the identification of spores in core number 6 at 1127 m - 1130 m. No marine fossils have been found in these sediments, and judging by the presence of carbonaceous materials, it is probable that the sequence is non marine in origin. The presence of phosphatic pellets in core number 6 probably indicates a depositional environment with stagnant reducing conditions.

DUCK BAY NO. 1 (continued)

AGE	UNIT	Depth (m)	K.B.	Thickness (m)		LITHOLOGY
ORDOVICIAN	Ordovician Undifferentiated	1257		35	1257-1292	Slate, dark grey, metallic luster, dense, hard, well developed cleavage, partly silty, slightly pyritic; siltstone, siliceous, hard, slightly argillaceous and sandstone, medium to dark grey, fine grained, siliceous, very hard. The cores are cut by numerous milky white to light grey quartz veins 1/8" to ¼" thick, and thin veins of black chert filling fractures.
		TD 1292 (Schlumberger)				

<u>Notes</u>

1) Several small gas shows were recorded in the Gippsland Limestone and in the top of the Latrobe Valley Coal Measures. The electrical and other logs indicate that these shows originated from porous zones with 100% water saturation.
2) No gas shows were recorded in the Lower Cretaceous or Upper Palaeozoic. The Strzelecki Group was completely lacking in reservoir beds, and the Upper Palaeozoic section contained only very thin porous beds have at the best about 20% porosity.

ARCO ltd (1964)

BLUEBONE NO. 1

PLIO-PLEISTOCENE	-	Sea floor	?		Sampling of the cuttings was not carried out until 381 m.
MIOCENE	Gippsland Fm	?	81+	381-462	Marls - light grey green, soft, glauconitic in part slightly pyritic with a trace of fossils. Skeletal limestones - light grey, white, unconsolidated moderately well sorted, glauconitic Trace quartz, unconsolidated medium to coarse grained, angular to rounded. Limestones - light grey, firm to hard, argillaceous, glauconitic with abundant fossiliferous debris, dolomitic, massive.

BLUEBONE NO. 1 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
OLIGOCENE	Lakes Entrance Fm	462	60	462-522	Sandstones - dark grey-green and calcareous, strongly argillaceous and glauconitic; generally massive with minor lamination. The sand grains are poorly sorted, fine to coarse grained, angular to rounded. Mica is abundant and fossils are common. Mudstones - similar to above but having much more than 50% silty material.
EOCENE	Latrobe Gp	522	69	522-591	Sandstones - grey-white, medium to coarse grained, poorly to moderately sorted; in part conglomeratic and pebbly, unconsolidated, with clay matrix. Poor permeability. Mudstone - light brown to dark brown, weakly laminated to massive, soft to perm, weakly carbonaceous and micaceous-sandy in part. No porosity or permeability.
DEVONIAN	-	591	13+	591-594	Weathered zone composed of weathered feldspars and amphiboles and quartz from the underlying granites; clayey.
				594-605	Granite - grey; weakly fractured with infillings of chlorite. Crystalloblastic with coarse grained quartz, plagioclase and orthoclase. Biotite and dark green amphiboles are present as accessories; pegmatitic with very coarse grained porphyroblastic quartz in microcline ground mass.
		TD 605			

Notes

A comparable thickness and facies of the Gippsland Formation was penetrated by Mullet No. 1. The possible age of the formation is not known other than that it is of Miocene age.
The Lakes Entrance Formation in Bluebone No. 1 has, from an inspection of the samples and interpretation of the gamma ray log, a greater sand content than was found in this formation in Mullet No. 1.
Core analysis showed the formation to have 40% porosity.
No hydrocarbons were detected, in the Latrobe Group, the formation being water flushed.

ESSO (1970)

COBIA NO. 1

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
PLIO-PLEISTOCENE	-	Sea floor	152 approx		
MIOCENE	Gippsland Fm	?	2134 approx	259-866	Limestone - grey and brown loosely consolidated with foraminifera and shell fragments, sandy in part.
				866-1817	Marl - grey-white, soft to firm, fossiliferous, trace glauconite and pyrite, minor interbeds of brown, dense limestone.
				1817-2232	Marl - as above.
					Shale - grey, soft to firm, carcareous, fossiliferous, trace of pyrite and glauconite.
OLIGOCENE	Lakes Entrance Fm	2232	150	2232-2341	Shale - grey, soft to firm, bentonitic, trace pyrite and fine grained sand.
					Marl - as above.
				2341-2382	Shale - grey, silty, micaceous, fossiliferous, traces of fine grained sand, very glauconitic at base.
EOCENE	Latrobe Group	2382	212+	2382-2385	Siltstone - grey-green, and olive green, very argillaceous with disseminated sand grains and abundant glauconite and pyrite.
	Gurnard Fm	2382	3		
	Latrobe Group	2385	40	2385-2594	Shale - grey, silty
					Siltstone - tan, firm very glauconitic
PALEOCENE	Latrobe Group	2425	169+		Sandstone - white to tan, very fine to coarse grained, occasionally glauconitic and pyrite in part
					Coal - minor interbeds, black, brittle, conchoidal fractures.
		TD 2594			

Notes A 22.5 m oil column, from the base of the Gurnard Formation (2385 m) to the oil-water contact (2407 m), was discovered in the Cobia No. 1 well.

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY

COBIA NO. 1 (continued)

Notes (continued)

The oil-bearing sands do not appear to be continuous with sands in either Halibut or Mackerel and appear to be of a depositional type which is typically of limited areal extent. Hydrocarbon pooling would appear to be contemporaneous with that at both Mackerel and Halibut.

ESSO (1972)

GROPER NO. 2

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
PLIO-PLEISTOCENE	-	Sea floor	?		Cuttings samples were not recovered until at 472 m.
MIOCENE	Gippsland Fm	?	215	472-527	Coquina - white to pink skeletal debris of bryozoal fragments, echinoid spines and foraminifera; sandy in part, poorly to moderately sorted.
					Mudstone-grey-green; thin minor interbeds of moderately hard fossiliferous and glauconitic mudstone
				527-545	Sandstones - quartzose, unconsolidated, well rounded moderately sorted; minor skeletal debris
					Coquina - pink and white, slightly glauconitic, as above.
				545-670	Coquina - as above; with minor interbeds of grey-green glauconitic mudstone
				670-687	Mudstone - green, soft to moderately hard, fossiliferous (bryozoans and foraminifera) glauconitic, slightly calcareous, non fissile.

GROPER NO. 2 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
OLIGOCENE	Lakes Entrance Fm	687	75	687-725	Marl - white, very glauconitic, very soft to moderately hard, fossiliferous.
				725-760	Mudstone - green-grey, massive, poorly bedded, glauconitic, and calcareous. Very fossiliferous and burrowed. Pyrite nodules common.
					This unit becomes more glauconitic towards the base.
				760-762	Greensand - green, extremely glauconitic and sandy quartzose, fine to coarse-grained, subrounded to well rounded, moderately friable to firm.
EOCENE	Latrobe Group	762	79	762-842	Sandstones - greyish, quartzose, medium to coarse grained, poorly to moderately well sorted subangular to subrounded with good to excellent porosities and permeabilities. Pyrite is common and slight carbonaceous material is prese
					Siltstone - dark brown, carbonaceous pyritic (disseminated and nodular), slightly sandy and micaceous.
					Clays - white to grey, firm, kaolinitic, pyritic blocky.
*DEVONIAN	Avon River Group? Weathered Zone	842 842	33+ 16	842-858	A weathered basement zone was encountered in thi interval; and consisted of a dark red-brown firm plastic clay.
	Unweathered Zone	858	17+	858-875	Siltstone - dark red-brown, very hard and dense: poor laminations dip at approximately $5^{o}-10^{o}$. Minor fine sandy beds show scour and fill and poor rippling.
		TD 876			

GROPER NO. 2 (continued)

AGE	UNIT	Depth (m) K.B.	Thickness (m)	LITHOLOGY

Notes The contact between the Gippsland Formation and the underlying Lakes Entrance Formation is tentatively placed at 687 m and is based on the electric log interpretation and cuttings analysis.

Much of the Gippsland Formation containing sandy coquinas and friable sands, is very permeable. The equivalent section in Groper No. 1 is generally impermeable with no development of porous sandstone intervals.

The presence of a 1.8 m thick basal 'greensand' in the Lakes Entrance Formation in Groper No. 2 indicates that reworking of the Latrobe sands occurred during the Oligocene transgression.

The Lakes Entrance Formation at Groper No. 2, except possibly for the thin basal sand, is seen to act as a good top seal of the Latrobe sediments.

The Latrobe Group was the anticipate pay zone. No hydrocarbons were detected, the formation containing only water.

* This formation was quite unexpected. Study of the thin section has suggested that the unit shows affinities with the Late Devonian Avon River Group found in south eastern Victoria. No fossils were found in samples of this rock. The relationship of the formation to the Devonian Granites found along the trend from Wilson's Promentory to Flinders Island is unknown.

ESSO (1970)

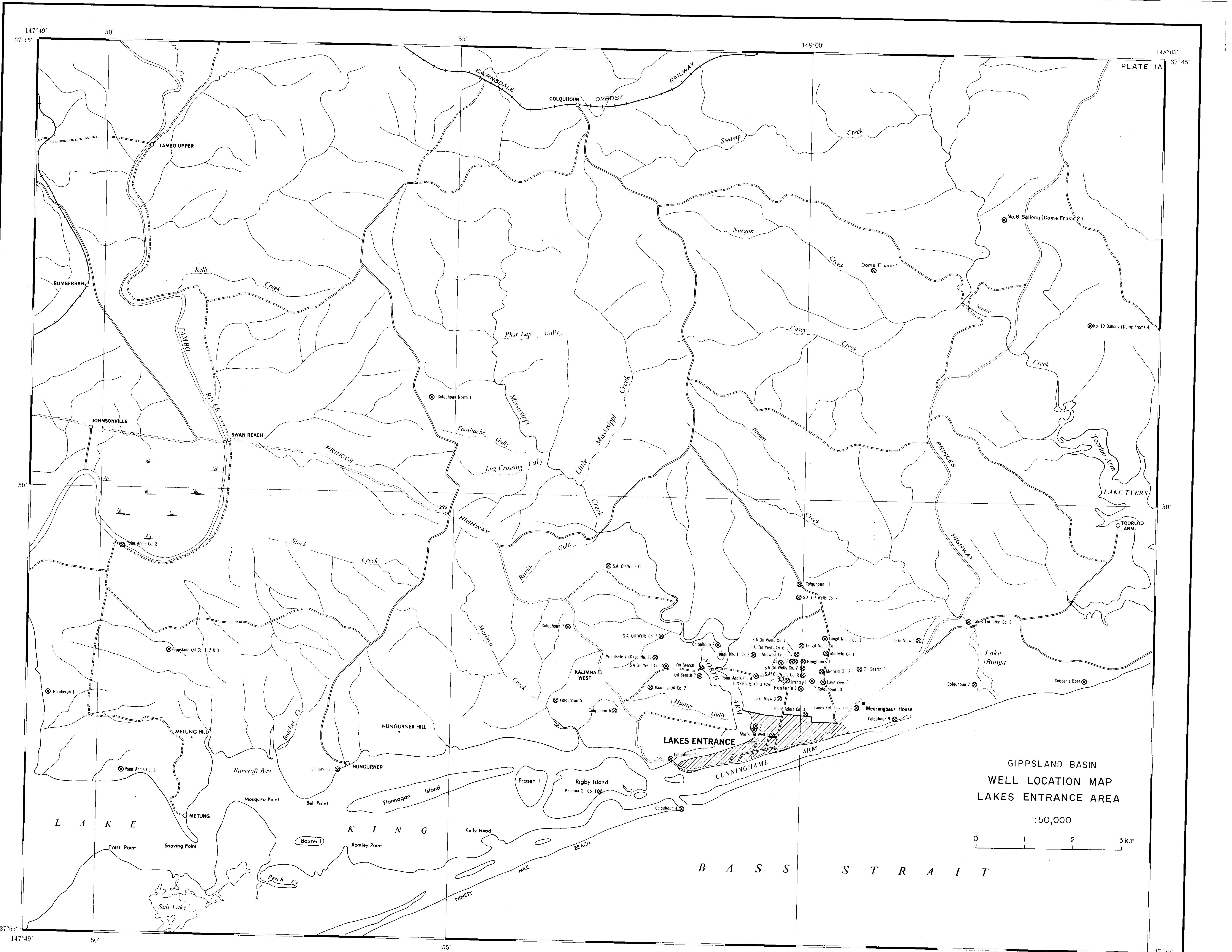
SAILFISH NO. 1

AGE	UNIT	Depth (m) K.B.	Thickness (m)		LITHOLOGY
RECENT-PLEISTOCENE	Sea floor		?		Sea floor samples comprised undifferentiated calcarenite and skeletal limestone
MIOCENE	Gippsland Fm	?	978+	260-1237	Mainly marls
MIOCENE OR EARLIER	Unnamed volcanics	1237	184+	1237-1271	Weathered basic volcanics
				1271-2031	Dominantly dark green volcanics
		TD 231			

Notes No hydrocarbons were encountered in the well and none were indicated by the electric logs

NSW OIL AND GAS COMPANY N.L. (1972)


PLATE 1
GIPPSLAND BASIN
SIMPLIFIED GEOLOGY
1:500 000
0 10 20 30 40 50 km
QUATERNARY
TERTIARY Haunted Hill Gravels and equivalents
TERTIARY Gippsland Limestone
TERTIARY Volcanics – including Thorpdale Volcanics
TERTIARY Latrobe Valley Coal Measures
LOWER CRETACEOUS Strzelecki Group
DEVONIAN Granite
ORDOVICIAN – DEVONIAN Sedimentary rocks of Lachlan Fold Belt
Well – dry, abandoned
Oil well – abandoned
Well with show of oil – abandoned
Well with show of gas – abandoned
Gas well – abandoned
Oil and gas well – abandoned
Well with show of oil and gas – abandoned
Stratigraphic well
200m Bathymetric contour
Circles shown are those proclaimed in connection with the Petroleum Search Subsidy Act, 1959–73 affecting data availability – See Table 1
TASMAN FOLD BELT SYSTEM
TASMAN FOLD BELT SYSTEM
MELBOURNE
PORT PHILLIP BAY
BASS STRAIT
VICTORIA
TASMANIA
FOR WELLS IN THIS AREA SEE PLATE 1A
WILSONS PROMONTORY
PHILLIP I.
FRENCH I.
HOGAN GROUP
KENT GROUP
Cape Everard
Lakes Entrance
Bairnsdale
Sale
Lake Wellington
Toongabbie
Traralgon
Yallourn
Moe
Warragul
Berwick
Mornington
Ocean Grove
Sorrento
Rosebud
Korumburra
Leongatha
Thorpdale
Childers
Yarram
SELWYN FAULT
GEELONG HWY
CALDER HWY
HUME HWY
PRINCES HIGHWAY
SOUTH GIPPSLAND HIGHWAY
NINETY MILE BEACH
ROSEDALE MONOCLINE
BARAGWANATH ANTICLINE
32·2 km (20 MI) Barracouta 1
64·4 km (40 MI) Barracouta 1
64·4 km (40 MI) Marlin 1
80·5 km (50 MI) Halibut 1
32·2 km (40 MI) Barracouta 2
64·4 km (40 MI) Barracouta 2
48·3 km (30 MI) Kingfish 1
80·5 km (50 MI) Kingfish 3
80·5 km (50 MI) Kingfish 1
80·5 km (50 MI) Kingfish 2
Record 1978/110, 1978/111
X AUS-7-70



(Based on XAUS-1-119) Record 1978/110, 1978/111

XAUS-7-52

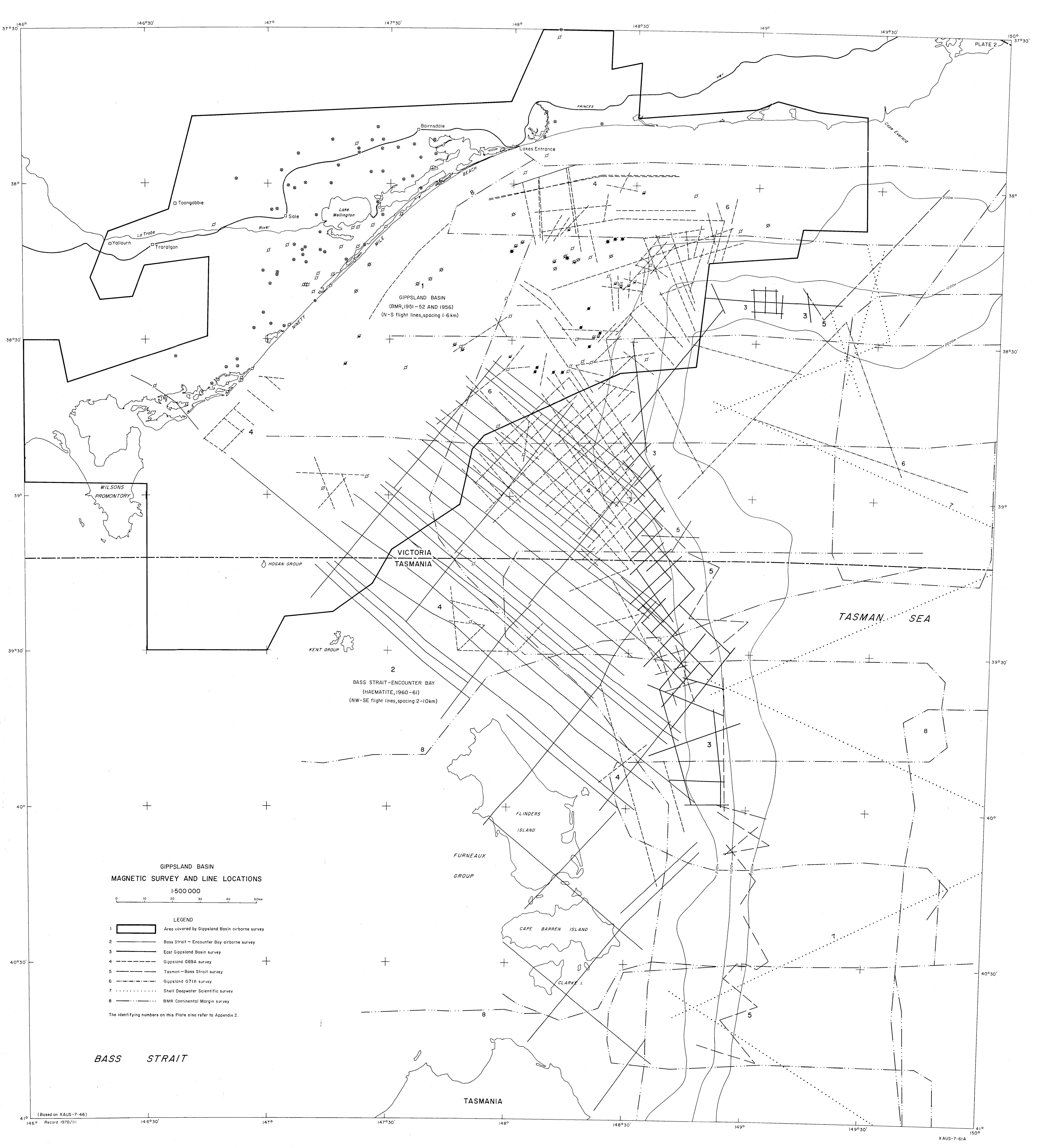
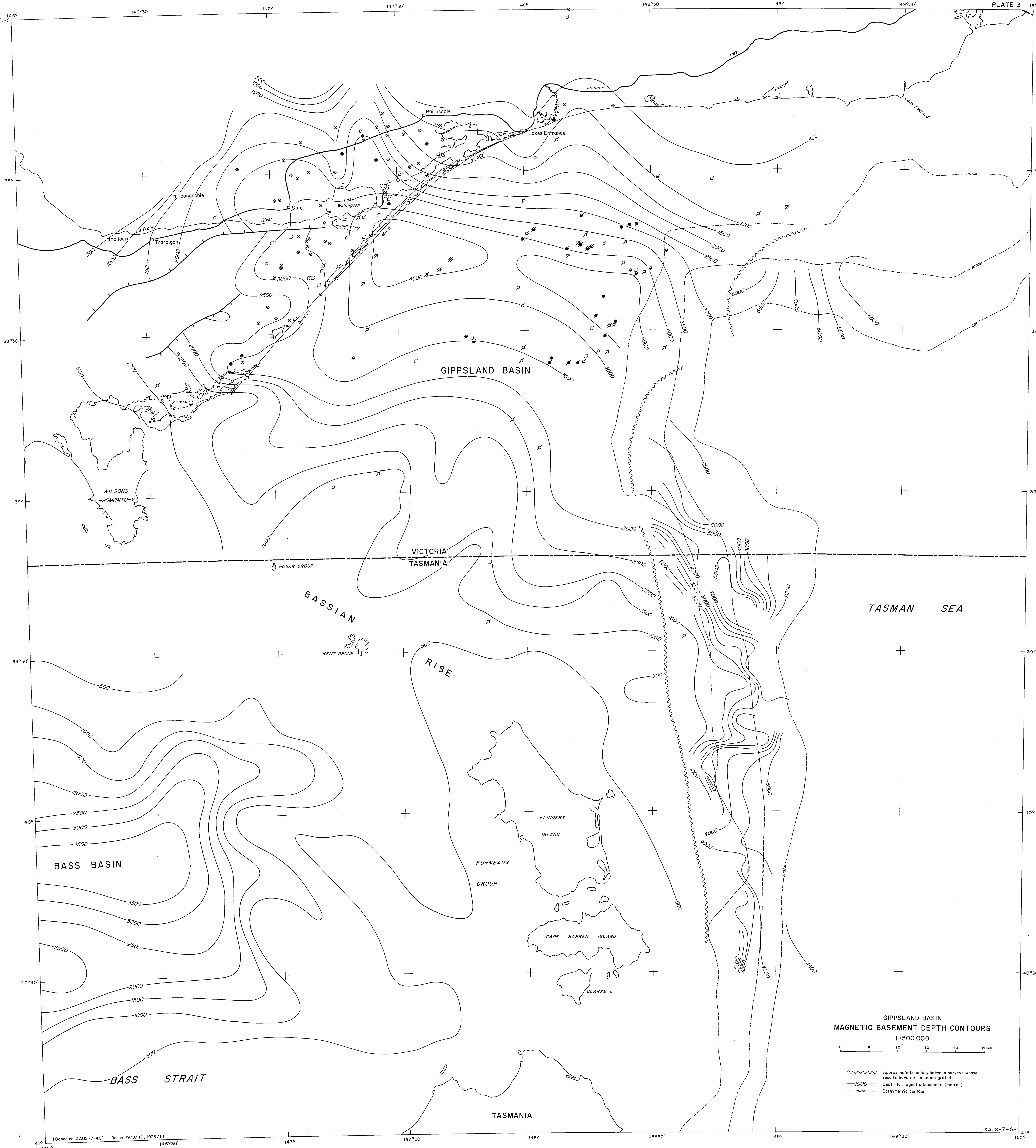


PLATE 2
GIPPSLAND BASIN
MAGNETIC SURVEY AND LINE LOCATIONS
1:500 000
0 10 20 30 40 50km
LEGEND
1 Area covered by Gippsland Basin airborne survey
2 Bass Strait — Encounter Bay airborne survey
3 East Gippsland Basin survey
4 Gippsland G69A survey
5 Tasman — Bass Strait survey
6 Gippsland G71A survey
7 Shell Deepwater Scientific survey
8 BMR Continental Margin survey
The identifying numbers on this Plate also refer to Appendix 2.
1
GIPPSLAND BASIN
(BMR, 1951–52 AND 1956)
(N-S flight lines, spacing 1·6km)
2
BASS STRAIT-ENCOUNTER BAY
(HAEMATITE, 1960–61)
(NW-SE flight lines, spacing 2–10km)
Bairnsdale
Lakes Entrance
Toongabbie
Sale
Lake Wellington
Yallourn
Traralgon
La Trobe
River
NINETY MILE BEACH
PRINCES HWY
Cape Everard
WILSONS PROMONTORY
HOGAN GROUP
KENT GROUP
VICTORIA
TASMANIA
TASMAN SEA
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
BASS STRAIT
TASMANIA
(Based on XAUS-7-46)
Record 1978/111
XAUS-7-61A

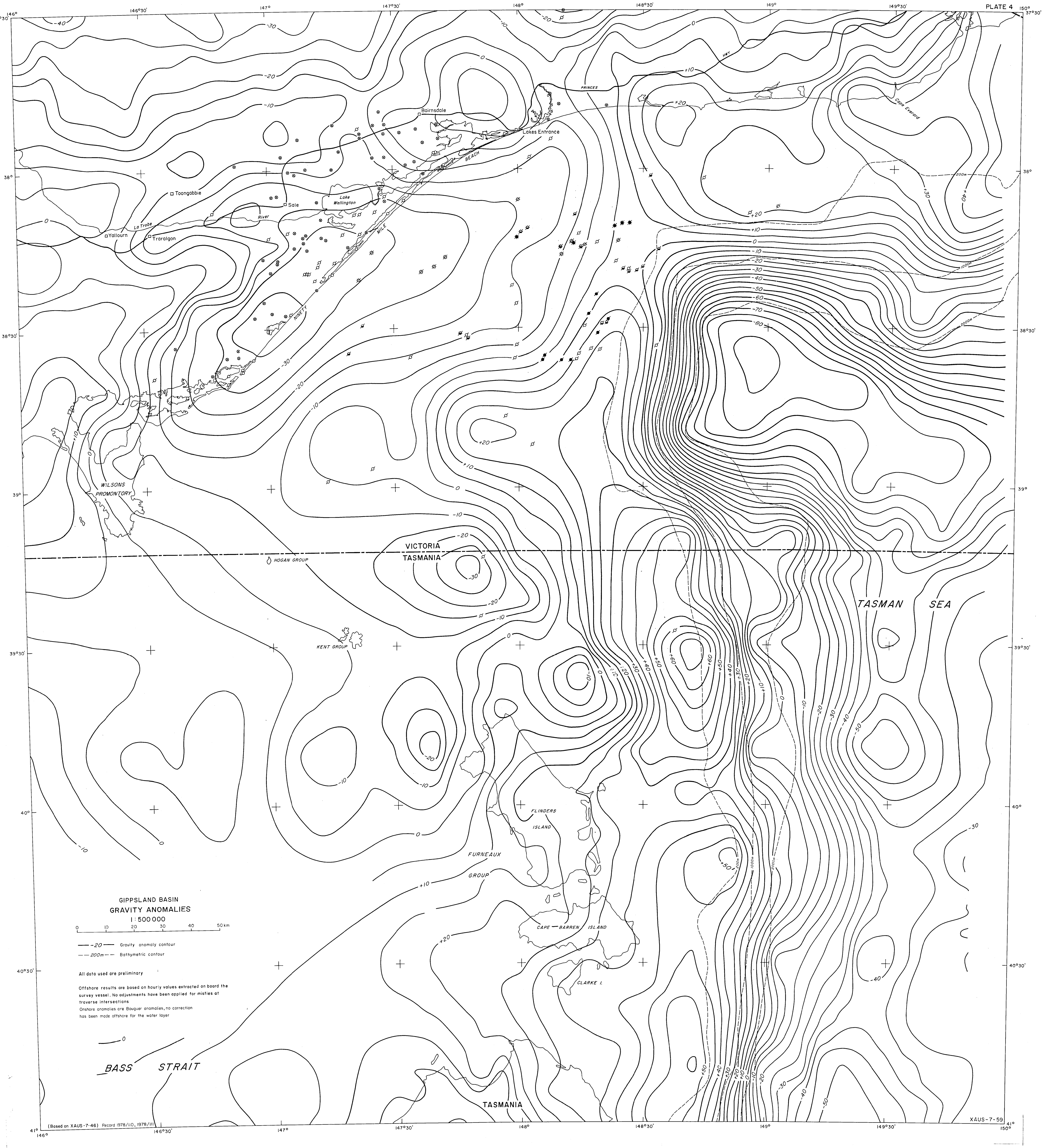


GIPPSLAND BASIN
MAGNETIC BASEMENT DEPTH CONTOURS
1:500 000

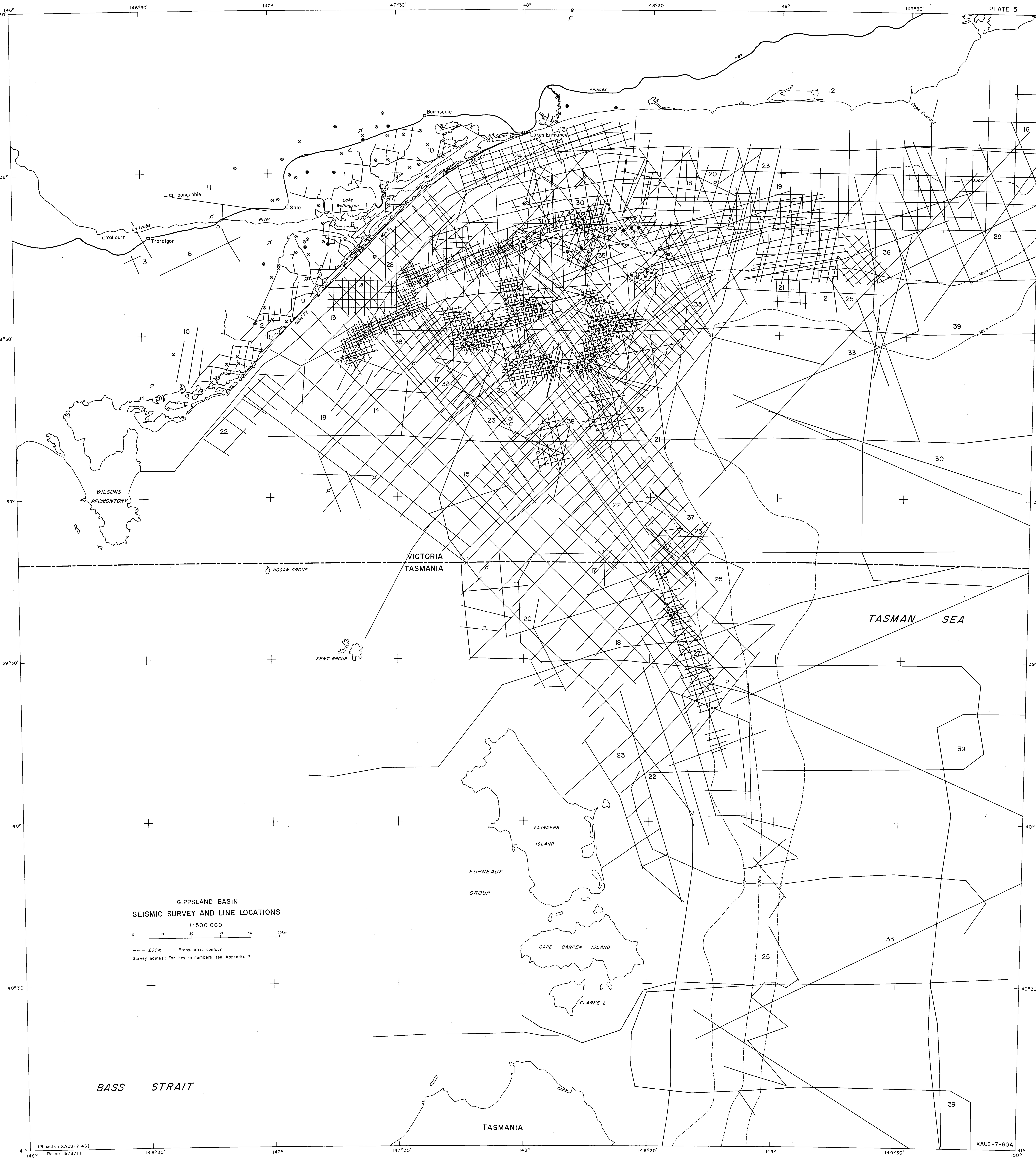
(Based on XAUS-7-46) Record 1978/110, 1978/111

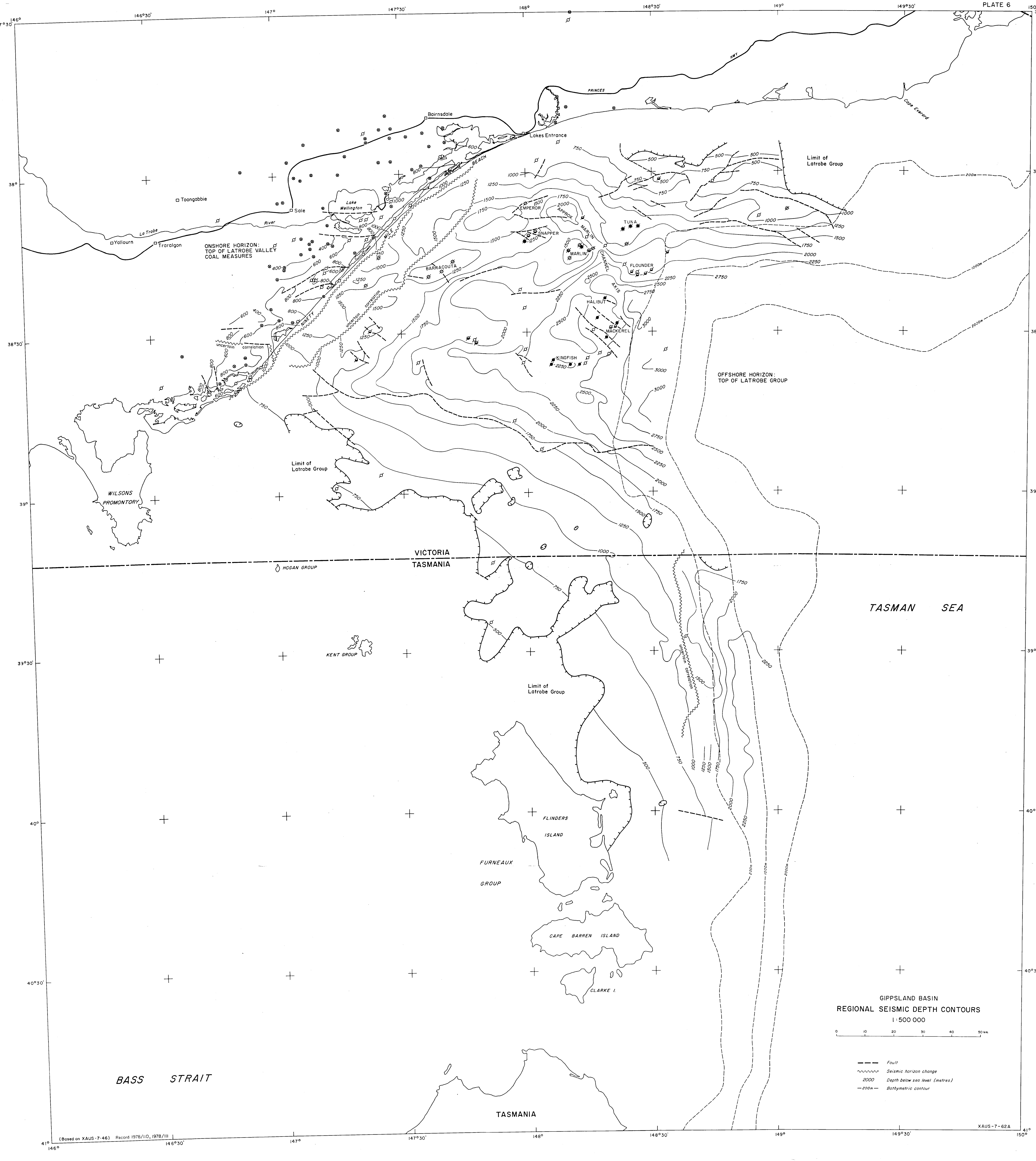
XAUS-7-58

PLATE 4



GIPPSLAND BASIN
GRAVITY ANOMALIES
1:500 000
0 10 20 30 40 50 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
Bairnsdale
Lakes Entrance
Toongabbie
Sale
Lake Wellington
La Trobe
River
Yallourn
Traralgon
NINETY MILE BEACH
PRINCES HWY
Cape Everard
WILSONS PROMONTORY
VICTORIA
TASMANIA
HOGAN GROUP
KENT GROUP
TASMAN SEA
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
BASS STRAIT
TASMANIA
146° 146°30' 147° 147°30' 148° 148°30' 149° 149°30' 150°
37°30' 38° 38°30' 39° 39°30' 40° 40°30' 41°
(Based on XAUS-7-46) Record 1978/110, 1978/111
XAUS-7-59


GIPPSLAND BASIN
SEISMIC SURVEY AND LINE LOCATIONS
1:500 000
0 10 20 30 40 50km
--- 200m --- Bathymetric contour
Survey names: For key to numbers see Appendix 2
(Based on XAUS-7-46)
Record 1978/111
XAUS-7-60A
VICTORIA
TASMANIA
TASMAN SEA
BASS STRAIT
WILSONS PROMONTORY
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
KENT GROUP
HOGAN GROUP
Bairnsdale
Lakes Entrance
Sale
Toongabbie
Yallourn
Traralgon
Lake Wellington
La Trobe River
PRINCES HWY
NINETY MILE BEACH
Cape Everard
146°
146°30'
147°
147°30'
148°
148°30'
149°
149°30'
150°
37°30'
38°
38°30'
39°
39°30'
40°
40°30'
41°



GIPPSLAND BASIN
REGIONAL SEISMIC DEPTH CONTOURS
1:500 000
Fault
Seismic horizon change
Depth below sea level (metres)
Bathymetric contour
ONSHORE HORIZON: TOP OF LATROBE VALLEY COAL MEASURES
OFFSHORE HORIZON: TOP OF LATROBE GROUP
Limit of Latrobe Group
Bairnsdale
Lakes Entrance
Sale
Toongabbie
Yallourn
Traralgon
Lake Wellington
La Trobe River
PRINCES HWY
Cape Everard
NINETY MILE BEACH
EMPEROR
SNAPPER
MARLIN
TUNA
FLOUNDER
BARRACOUTA
HALIBUT
MACKEREL
KINGFISH
APPROX MARLIN CHANNEL AXIS
uncertain correlation
WILSONS PROMONTORY
HOGAN GROUP
KENT GROUP
VICTORIA
TASMANIA
TASMAN SEA
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
BASS STRAIT
(Based on XAUS-7-46) Record 1978/110, 1978/111
XAUS-7-62A