BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

BMR RECORD 1988/18

DEEP STRUCTURE OF THE GIPPSLAND AND BASS BASINS
(PROJECT 9131.12B)

- RESEARCH CRUISE PROPOSAL -

by

J.B. Willcox, J.B. Colwell and A.M.G. Moore

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CONTENTS

SUMMARY

Petroleum exploration within the Gippsland Basin has been focussed on major anticlines at the Early Tertiary "top Latrobe" unconformity, and to a much lesser extent on "intra-Latrobe" traps. Little information exists on the petroleum potential deep within the basin. Similarly, in the adjacent Bass Basin, most of the exploration effort has been concentrated at or near the top of the Latrobe Group equivalent, the Eastern View Coal Measures.

Analysis of regional seismic data collected by BMR in 1982 suggests that the Bass and Gippsland Basins were initiated by NNE-SSW lithospheric extension, probably in the Early Cretaceous. A reactivation of these basin-forming extensional structures, particularly transfer faults, may have had a significant influence on petroleum migration and accumulation higher in the stratigraphic section.

It is proposed here that the R/V Rig Seismic undertake a 29-day research cruise over the Gippsland and Bass Basins in late 1988. This cruise should result in the acquisition of approximately 2400 km (1600 km Gippsland, 800 km Bass) of high-quality, 96-channel seismic reflection data together with ship-shore seismic refraction data. The cruise aims to:

(i) improve definition of the deep structure of the Gippsland and Bass Basins using basin-wide deep seismic (12+ seconds) transects,

(ii) evaluate models for basin evolution

(iii) develop concepts for petroleum migration and entrapment from the regional data and by analogy with the similar basins, worldwide, and

(iv) through the provision of regional seismic data assist the petroleum industry in carrying out seismic correlations.

The cruise is one of a number of studies by BMR of the structure, stratigraphy, evolution and resource potential of offshore basins along Australia's southeastern margin.

INTRODUCTION

Although the Gippsland Basin, Australia's principal liquid petroleum province, has been extensively explored during the last twenty five years (see Figs. 1 and 2), little information has been obtained about deep structures within the basin. This is primarily because of the concentration of exploration activity at the relatively shallow "top Latrobe Group" levels and the dispersion of seismic energy caused by extensive Tertiary coal measures and channels. Likewise, exploration activity in the Bass Basin has been concentrated at the top of the basin's Latrobe Group equivalent, the Eastern View Coal Measures (Fig. 3).

In 1982, BMR undertook a regional survey of Bass Strait aimed at the deeper parts of the Otway, Bass and Gippsland Basins. This survey (shot by GSI), when combined with selected company data, suggested that the three Bass Strait basins were initiated by north-northeast to south-southwest lithospheric extension, largely during the Early Cretaceous (Etheridge & others, 1985; Figs 4 and 5). The extensional stage was followed by a Late Cretaceous to Pliocene thermal subsidence stage and, in the case of the Gippsland Basin, by a late stage of tectonic overprinting (Fig. 6). The work also suggested that many of the Gippsland Basin's compressional structures, which contain oil and gas, were controlled by a reactivation of major early normal and tranfer faults (Etheridge & others, op. cit.).

The main aims of the proposed study (<u>Rig Seimsic</u> Research Cruise 23/Survey 83) are (i) to better define the deep structure of the Gippsland and Bass Basins and so to assist future exploration by providing new information on potential "deep" structural and stratigraphic plays; (ii) to evaluate tectonic models of the basins' evolution (e.g. Etheridge & others 1985 model involving transfer faults and deep detachments) and to evaluate the geothermal consequences of such models in relation to the history of hydrocarbon generation and migration; and (iii) through the provision of regional seismic data in the Gippsland Basin, assist companies in carrying out seismic correlations within the basin.

During the study it is proposed that approximately 2400 km (1600 km Gippsland, 800 km Bass) of high-quality 96-channel seismic reflection data together with ship-shore seismic refraction data be collected (Figs. 7 & 8). These data will complement data collected aboard the <u>Rig Seismic</u> over the eastern part of the Gippsland Basin in 1987 (Cruise 13; Colwell & others, 1987) and over the adjacent Otway-West Tasmania margins in early 1988 (Cruise 18; Exon & Lee, 1988).

GEOLOGICAL SETTING

The Gippsland and Bass Basins are the eastern-most of a series of extensional basins present along the southern margin of Australia.

Offshore Gippsland Basin

The geology, regional setting, and evolution of the offshore Gippsland Basin have been discussed by numerous authors, including Weeks & Hopkins (1967), Hocking (1972), Gunn (1975), Threlfall & others (1976), Partridge (1976), Robertson & others (1978b), Smith (1982), Willcox (1984), Davidson & others (1984), Stainforth (1984), Etheridge & others (1985), Bodard & others (1986), Thompson (1986) and Clark & Thomas (1988). Although its early history is unclear, the basin forms the eastern extremity of a complex rift system which extended along the southern margin of Australia during the Jurassic and Early Cretaceous as a precursor to the post-Mid Cretaceous seafloor spreading between Australia and Antarctica. It may also be partly a "failed arm" of a triradial rift or another feature associated with the Late Cretaceous (anomaly 33) to Eocene (anomaly 24) separation of Australia from the Lord Howe Rise and New Zealand i.e. development of the Tasman Basin (Weissel & Hayes, 1977; Shaw, 1978, 1979; Jongsma & Mutter, 1978 ; Roeser & others, 1985; Fig. 9).

The basin is largely surrounded by Paleozoic rocks of the Tasman Geosyncline (Geological Society of Australia, 1971). Up to 3500 m of greywacke, sand, shale, and minor coal of the Strzelecki Group were deposited in interlocking alluvial-fan and alluvial-plain complexes during the Late Jurassic to Early Cretaceous infra-rift and syn-rift stages of the basin (sometimes referred to as the Strzelecki Basin). These were followed during the Late Cretaceous and Eocene by deposition of up to 5000 m of predominantly fluvio-deltaic sand, shale, and coal of the Latrobe Group (Figs. 10-12). Deposition of these rocks was initially accompanied by volcanism that moved westwards with time. The volcanism was most common in the central basin deep, and was associated with basement fault blocks. During the Eocene, the upper surface of the Latrobe Group was eroded and several large-scale channels of various ages (see Figs. 10-12) developed, most likely associated with low stands of sea level.

Marine conditions were established over the basin in the Early Oligocene, although there is evidence of shallow-marine conditions and westerly prograding shorelines prior to this, particularly in the east (e.g., top Latrobe barrier sands and Gurnard Formation). Sediment type changed from the mainly coarse-grained clastics of the Latrobe Group to calcareous shale and marl of the Lakes Entrance Formation. The marine shale was mainly deposited in a narrow wedge around the basin margins with only a thin veneer being laid down in the basin centre. During the late Early Eocene a drop in sea level caused erosion of the shale on the margins, over structural "highs" and perhaps in the youngest of the Eocene channels. With a renewed rise in sea level deposition of shale and marl continued into the Early Miocene onlapping structural "highs" and the basin margins, and providing a good regional seal.

During the Miocene, the Lakes Entrance Formation shales and marls were gradually replaced by the bryozoan limestones and marls of the Gippsland Limestone which form much of the present-day shelf and slope. A series of submarine channels were cut into the Miocene surface of the Gippsland Limestone prior to the deposition of up to 350 m of marine calcarenite of Pliocene and Recent age (Fig. 10). In general, fill in the channel heads consists of a coarse-grained mixture of skeletal fragments and sand, whereas in the middle and distal parts of the channels it is predominantly micritic limestone of low porosity. These latter rocks cause considerable problems for seismic interpretation.

Tectonically, the Gippsland Basin has undergone several major phases of deformation. Two structural styles appear to be present: (i) commonly poorly-defined, basin-forming, normal rotational, and transfer faults active principally during extention and basin subsidence (Early Cretaceous to Early Eocene; Fig. 13); and (ii) en echelon anticlines and shear faults generated by compression during the Late Eocene-Early Oligocene and Middle-Late Miocene, and possibly related to a reactivation of major early normal and transfer faults (Threlfall & others, 1976; Etheridge & others, 1985; Thompson, 1985; Fig. 14). Many of the anticlinal structures contain large hydrocarbon accumulations within coarse clastics at the top of the Latrobe Group. Although intra-Latrobe targets have been increasingly explored in recent years, most hydrocarbon discoveries to date have been made at the top of the Latrobe Group within the "central deep".

Recently, it has been suggested that the unconformity which is widely interpreted as separating the Latrobe and Strzelecki Groups may be an intra-Latrobe feature (Lowry, 1987). This raises the possibility that the prospective Latrobe Group may extend to greater depths within the basin than previously thought, particularly in areas transitional between the "central deep" and flanking "platforms".

<u>Bass Basin</u>

Aspects of the geology and petroleum potential of the intracratonic Bass Basin (Fig. 15) have been discussed by Weeks & Hopkins (1967), Richards & Hopkins (1969), Robinson (1974), Brown (1976), Robertson & others (1978a), Smith (1986), Williamson & others (1985, 1986, 1987) and Williamson & Pigram (1986). Like the adjacent Gippsland Basin, the basin appears to have formed by extensional tectonics during the Late Jurassic to Early Cretaceous. It contains up to 7 km of non-marine sediments of (?) Late Jurassic to late Eocene age and up to 3.5 km of Upper Eocene to Holocene marine sediments (Fig. 16). Cainozoic volcanics occur in places. Sedimentation in the basin was dominated initially by Cretaceous flood-plain, alluvial-fan, and lacustrine deposition, then Late Cretaceous and early Tertiary flood-plain deposition, and finally, Cenozoic shallow marine deposition.

Although the Bass Basin is not to date a petroleum producer (unlike the Gippsland Basin), seismic reflection studies (Williamson and others, 1987) suggest that significant structural and stratigraphic prospects for petroleum exploration occur at Paleocene, Cretaceous, and probably Jurassic levels. Source rock studies combined with depositional models indicate that suitable source and reservoir rocks probably occur in the Upper Cretaceous to Paleocene non-marine sequences. Overall, the best potential for petroleum discoveries appears to be at mature levels within the Upper Cretaceous to Paleocene Eastern View Coal Measures (EVCM) (Williamson and others 1985, 1986, 1987).

Major Early Cretaceous extensional normal faults segmented by contemporaneous tranfser faults appear to underlie the basin (Etheridge and others, 1984, 1985; Fig. 17). The normal faults, which initiated the development of the basin, are rotational, have low to moderate dips, and were produced by 60-80% horizontal extension of the crust beneath the basin. The transfer faults are vertical and trend 020° to 030° (Fig. 5) similar to those in the Gippsland Basin. They are predominantly right-lateral offset, giving rise to the northwesterly trend of the basin.

EXISTING DATA BASE

Gippsland Basin

Since 1962 when the first seismic data were shot in the basin, over 70,000 km of seismic data have been collected (see Appendix 5) and over 140 exploration and appraisal wells drilled (Brown, 1986; Figs. 1 and 2). Most of the seismic data have been shot in the shallow-water part of the basin on tight grids over the main oil and gas producing structures.

In addition to the company data, data has also been acquired by BMR. In 1982, 810 km of 48-fold, 96-channel seismic was shot using a Geophysical Service International vessel, and in 1987 2185 km of 24-fold, 48-channel seismic was acquired aboard the RV Rig Seismic over the eastern margin of the basin and adjacent Tasman Sea (Fig. 1). In both cases lines were placed to fill in gaps in the regional seismic network.

Bass Basin

Fifteen petroleum exploration wells, including two appraisal wells were drilled by a Hematite/Esso partnership in the Bass Basin between 1965 and 1973 (Fig. 5). Hematite drilled a further two exploration wells in 1974 and a third appraisal well in 1979. The Pelican gas/condensate accumulation was the most significant discovery of that period, but other significant hydrocarbon shows were recorded in Bass No. 3 and Cormorant No. 1.

The lack of shallow exploration success in the first phase of exploration in the basin highlighted the differences between it and the major oil-producing Gippsland Basin, and led to a comprehensive study of the stratigraphy, structure, and petroleum potential of the Bass Basin by BMR. This study, which began in 1982, incorporated well data, 4,500 km of modern multichannel seismic data and seismo-stratigraphic, source rock, structural, and geohistory studies to generate a geological overview of the basin, particularly below the well-explored Eocene levels. Parts of this study were reported by Etheridge et al. (1984, 1985), Williamson and Pigram (1986), and Williamson et al. (1985, 1986, 1987). The results of this study suggest that the Bass Basin has good potential for generation and entrapment of petroleum, particularly at the rarely explored Paleocene and Upper Cretaceous levels (Fig. 16). Since mid-1984, an additional 8 wells have been drilled in a second phase of exploration in the basin, of which three (Yolla 1, Tilana 1, and Pelican 5) have encountered hydrocarbons (Fig. 17).

CRUISE OBJECTIVES

Objectives of <u>Rig Seismic</u> cruise 23 are:

- To test and develop models for the formation of the Gippsland and Bass Basins by obtaining an improved understanding of their deep structure. In particular, to test an extensional model for formation of the basins, the direction of extension (currently believed to be 027°), and the presence of detachment faults and transfer faults.

- To determine the degree of crustal thinning associated with formation of the basins as well as the velocity structure of the crust beneath the basins and their margins, and allow positive identification of boundaries such as the Moho. Velocities constrain the petrological interpretation of crustal and upper-mantle layers, and by comparison with adjacent regions may point to changes in physical conditions at depth such as temperature.

- To compare and contrast the deep structure of the Gippsland and Bass Basins and with extensional basins in general.

In addition, the following objectives are more closely related to hydrocarbon exploration in the Gippsland Basin:

- To provide industry with a grid of regional seismic profiles within the Gippsland basin, with a depth of penetration sufficient to determine any relationships between deep structure and hydrocarbon production. To obviate the problem of individual companies obtaining regional data beyond their lease boundaries.

- To tie seismic profiles to key wells in the basin in order to identify formation tops, velocity variations and facies variations.

- If operational time permits, to study the relationship of the southeastern margin of the basin to the basin proper. In this area, the basin trends appear to be more closely related to the Tasman Sea margin.

- To make a regional study of the key seismic horizons, isopachs and facies variations throughout the basin.

CRUISE PLAN

The cruise is tentatively scheduled for 29 days in the period from mid October to mid December 1988.

Seismic Reflection Work

(A) Gippsland Basin

It is proposed to record eight regional lines (A-H on Figs. 7, 18, 19 and 20) across the strike of the basin, and two tie-lines (I and J) along strike, within the basin depocentre. A further line (K) is planned to cross the southeastern margin of the basin (Figs 7, 19 and 20) supplementing data collected aboard Rig Seismic on the basin's eastern margin in 1987. Total coverage, excluding positioning and 'link lines', is 1644 km.

The planned cross-strike ('dip') lines trend 027°, parallel to the presumed direction of extension, and extend beyond the limits of the Latrobe Group and the basin-boundary faults. The nominal line-spacing is approximately 15 km; however, this has been modified in many areas to enable effective well-ties, avoid production platforms, and to position lines within extensional compartments between presumed transfer faults. Details of the lines and way points are given in Appendix 1.

(B) Bass Basin

It is planned to record four dip lines (lines L-N&P) across the main basin forming structures (Figs 8 and 21). The lines will cross four of the major fault-bounded compartments mapped by Etheridge & others (1984, 1985). In addition, one tie line (O) will be run. Total coverage within the basin, excluding link lines is 789 km.

Reflection Profiling Cable Geometry

The seismic cable geometry to be selected for the Gippsland/Bass cruise is dependent on the scientific objectives and a number of practical considerations. The main factors are:

- cable length should be sufficient to give significant moveout on deep reflections, thereby creating an opportunity for maximum attenuation of multiples.
- cable length should be such that a towing spread of about 4 knots can be achieved, and the cable should be controllable in the relatively large currents that are anticipated.
- high multiplicity data is desirable for noise cancellation, and in view of the objective to profile deep basin-forming structures, multiplicity is generally more desirable than short CDP spacing.
- CDP spacing will influence resolution in the upper prospective part of the section.
- record lengths should be of the order of 12 + seconds.
- the sampling interval should preferably be 2 millisecs; however, a 4 millisec interval is acceptable (Nyquist frequency = 125 Hz).

(i) Cable limitations:

Length = 1200 - 4400 metres
Groups = 12.5, 25, 37.5, 50 metres
Max. length for 4 kt tow speed = 3600 metres
Total channels = 117 (96 reflection data)
Samples = 468,000 per record
Maximum sample throughput = 58,000 per second.

(ii) Most suitable geometries and recording configurations:

Type 1 : 3600 m   72 ch   50 m group
Type 2 : 3600 m   48 ch   25 m group
Type 3 : 3600 m   96 ch   37.5 m group

Type	Fold	CDP	Shot Spacing (m)	Sample Interval ms
1	72	25	11.2	2
	36	50	22.4	4
2	48	12.5	5.6	2
(Front)	24	25	11.2	2
	12	50	22.4	4
(Back)	48	25	11.2	2
	24	50	22.4	4
	12	100	44.8	8
3	96	18.8	8.4	2
	48	37.5	16.8	4
	24	75	33.6	8

(iii) Conclusion:

It is concluded that the cruise objectives can best be achieved by use of a 3600m, 96-channel, 37.5 m-group cable, used with 48-fold recording and a 4 millisec sampling interval to give a record length of up to 16 seconds.

On-Shore Refraction Recording

Vertical profiling may not unequivocally resolve the deeper features, and long-offset seismic refraction/wide-angle reflection data recorded coincidentally will provide additional information to constrain the vertical data. It may also be the only source of information on the lower crust and upper mantle beneath the basin, and will be in any case providing additional data beyond the location of the profiling.

Refraction Operations

Digital instruments to record the ship's 3200 cubic inch airgun source will be located in Gippsland and on Deal Island at the ends of Line 'E', and on Wilson's Promontory and northwest Tasmania of the ends of Line 'M' giving reversed refraction traverses of greater than 200 km length. As much data as possible will be recorded from the other lines. Other recorders may be deployed on land to extend the range of the refraction traverse and provide additional data at different offsets and azimuths.

Digital recorders have been developed to record the air-guns semi-continously while the ship completes each traverse. The data will be recorded continuously for a duration exceeding 10 minutes and then dumped to disc and later archived to tape. New duty cycles are initiated automatically with dwell times of less then 6 seconds.

The noise level is expected to high and development of processing techniques to enhance the signal-to-noise ratio may require a major effort. The large number of shots recorded at each recording site, and close shot spacing, will allow various stacking procedures to be applied.

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FIGURES

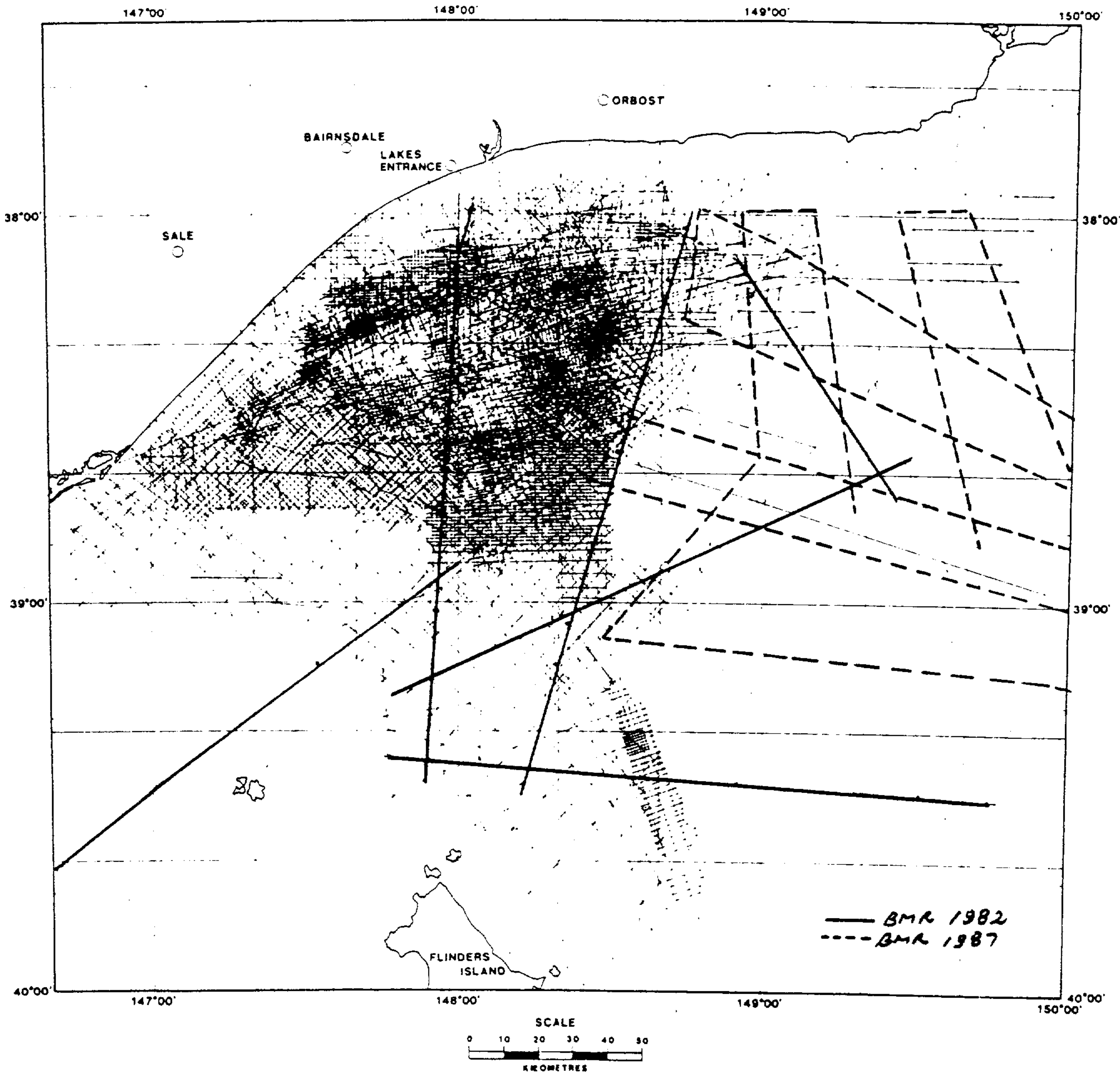

Figure 1. Seismic line density within the Gippsland Basin showing most lines shot between 1962 and 1987 (after Brown, 1986). BMR's 1982 and 1987 lines are highlighted.

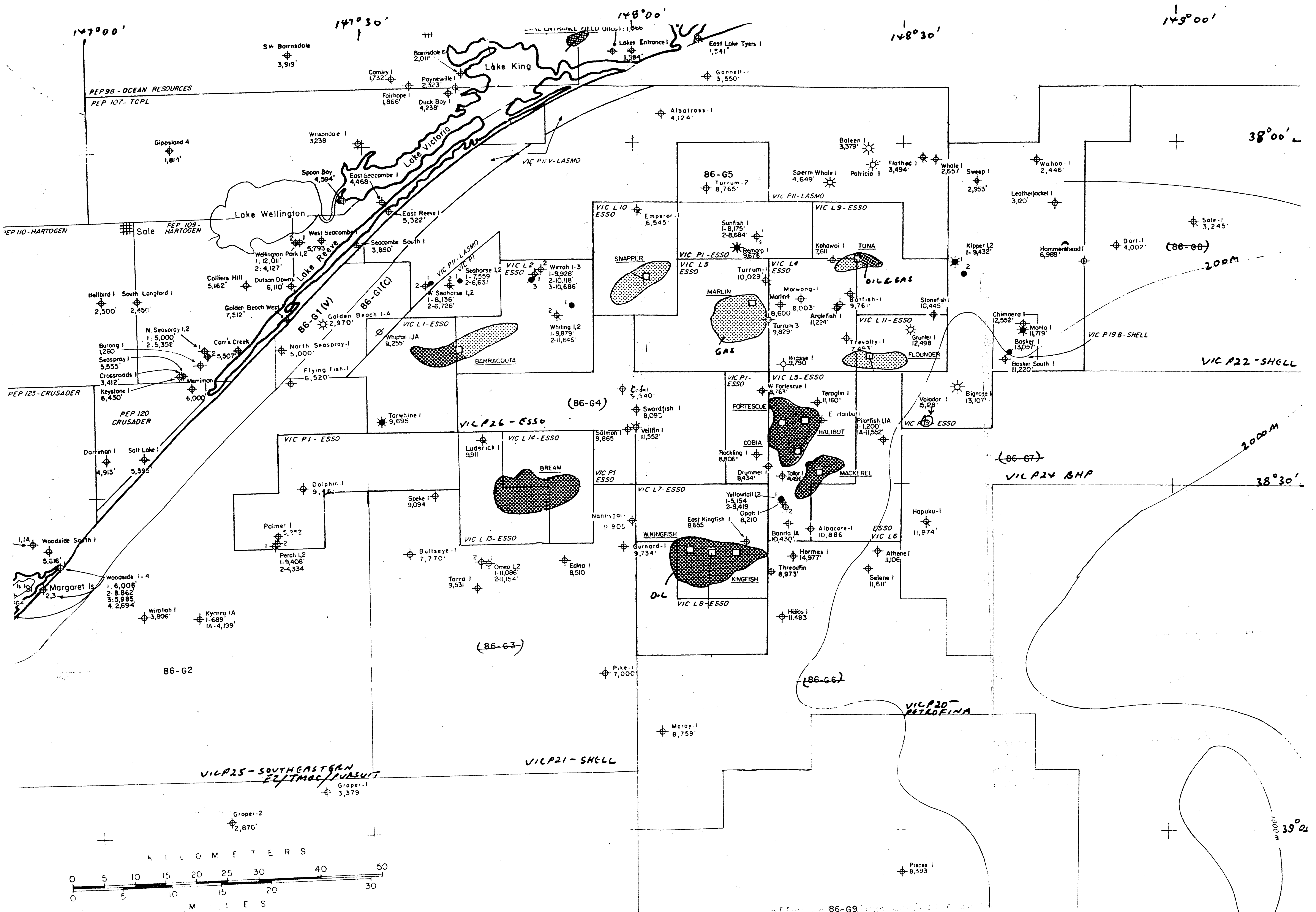

Figure 2. Location of petroleum exploration wells, oil and gas fields, and lease areas within the Gippsland Basin.

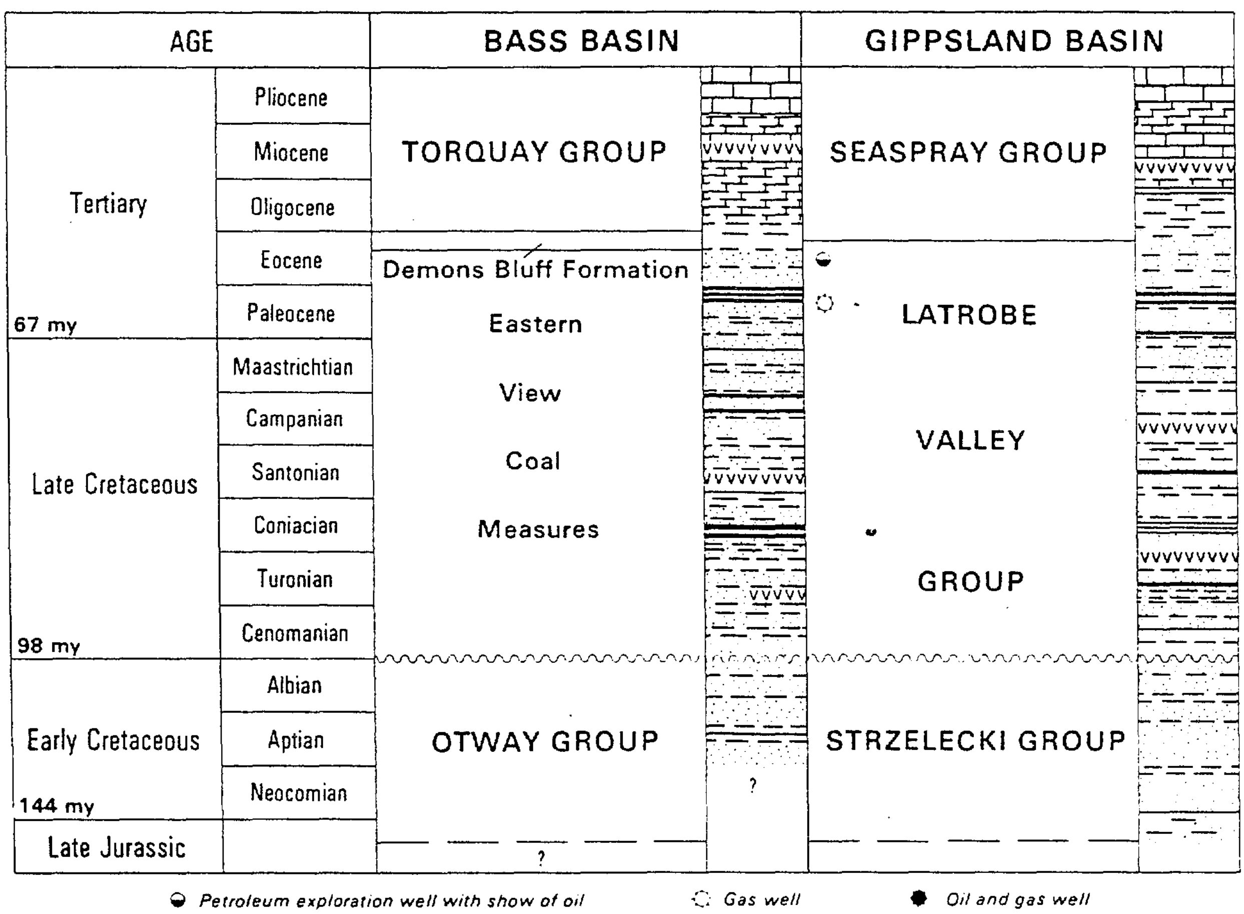

Figure 3. Comparative stratigraphy of the Bass and Gippsland Basins.

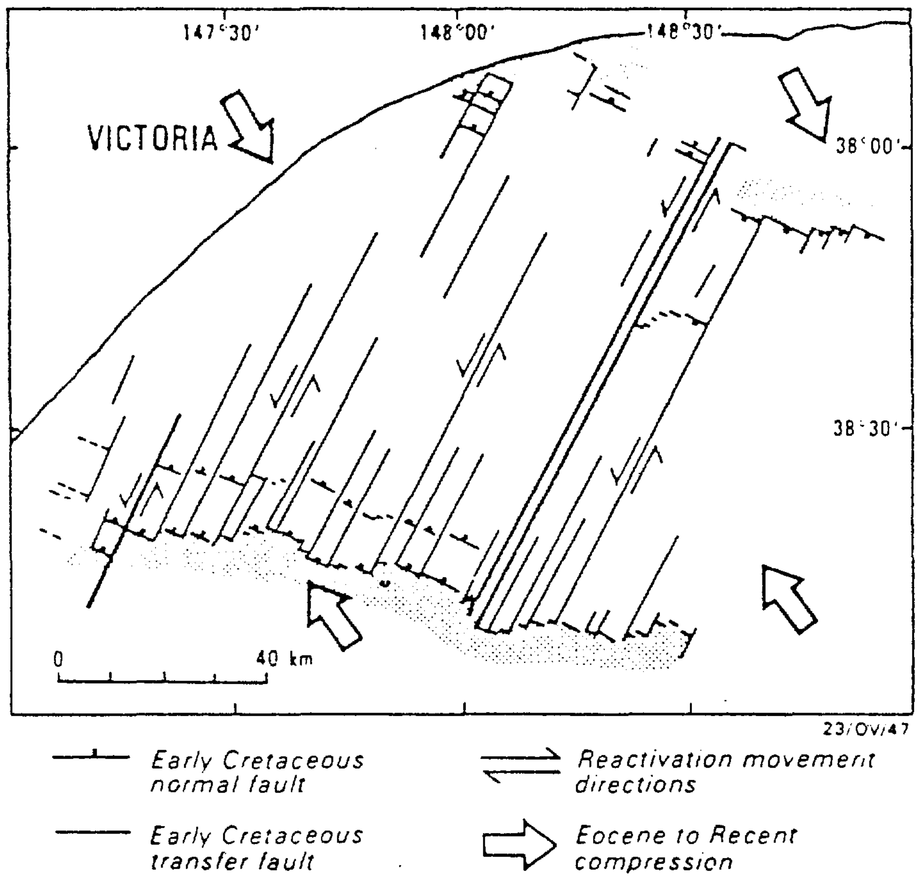

Figure 4. Map of Early Cretaceous structures within the Gippsland Basin showing how Tertiary northwest-southeast compression gives rise to left-lateral wrench reactivation of transfer faults, and oblique reverse reactivation of normal faults (after Etheridge & others, 1985).

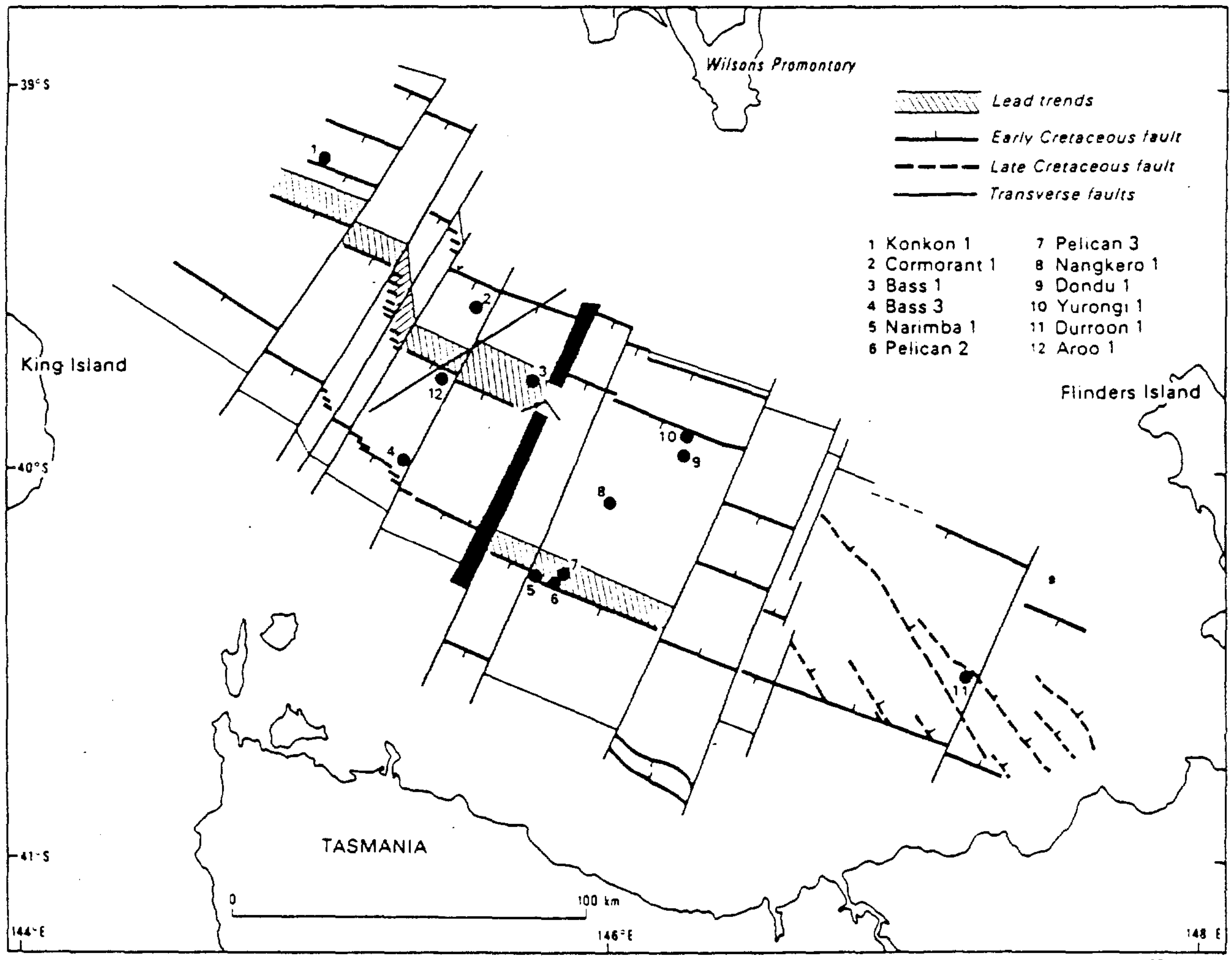

Figure 5. Basin-forming structures in the Bass Basin, showing the extent of the mid-basin Early Cretaceous tilt blocks and the location of pre-1985 exploration wells. After Etheridge & others (1984, 1985)

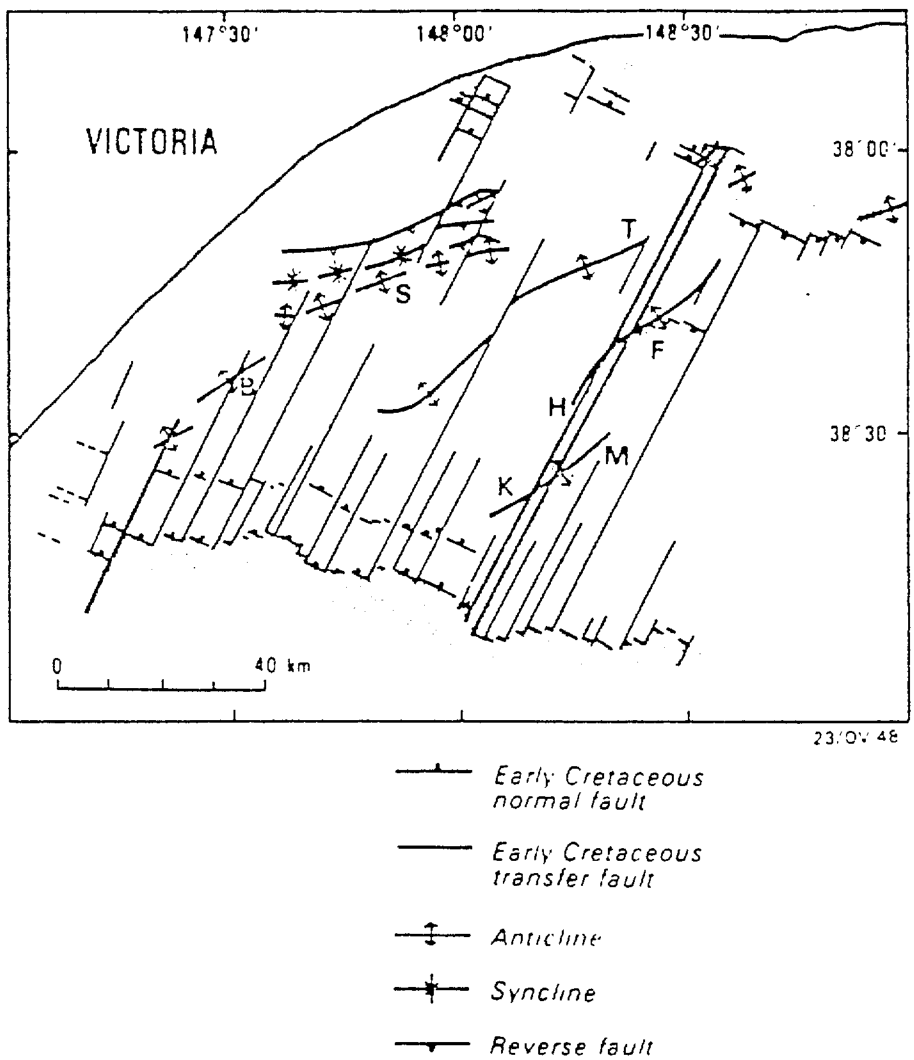

Figure 6. Map of Late Tertiary compressional structures within the Gippsland Basin (most of them hydrocarbon reservoirs) superimposed on the Early Cretaceous extensional structures (after Etheridge & others, 1985)

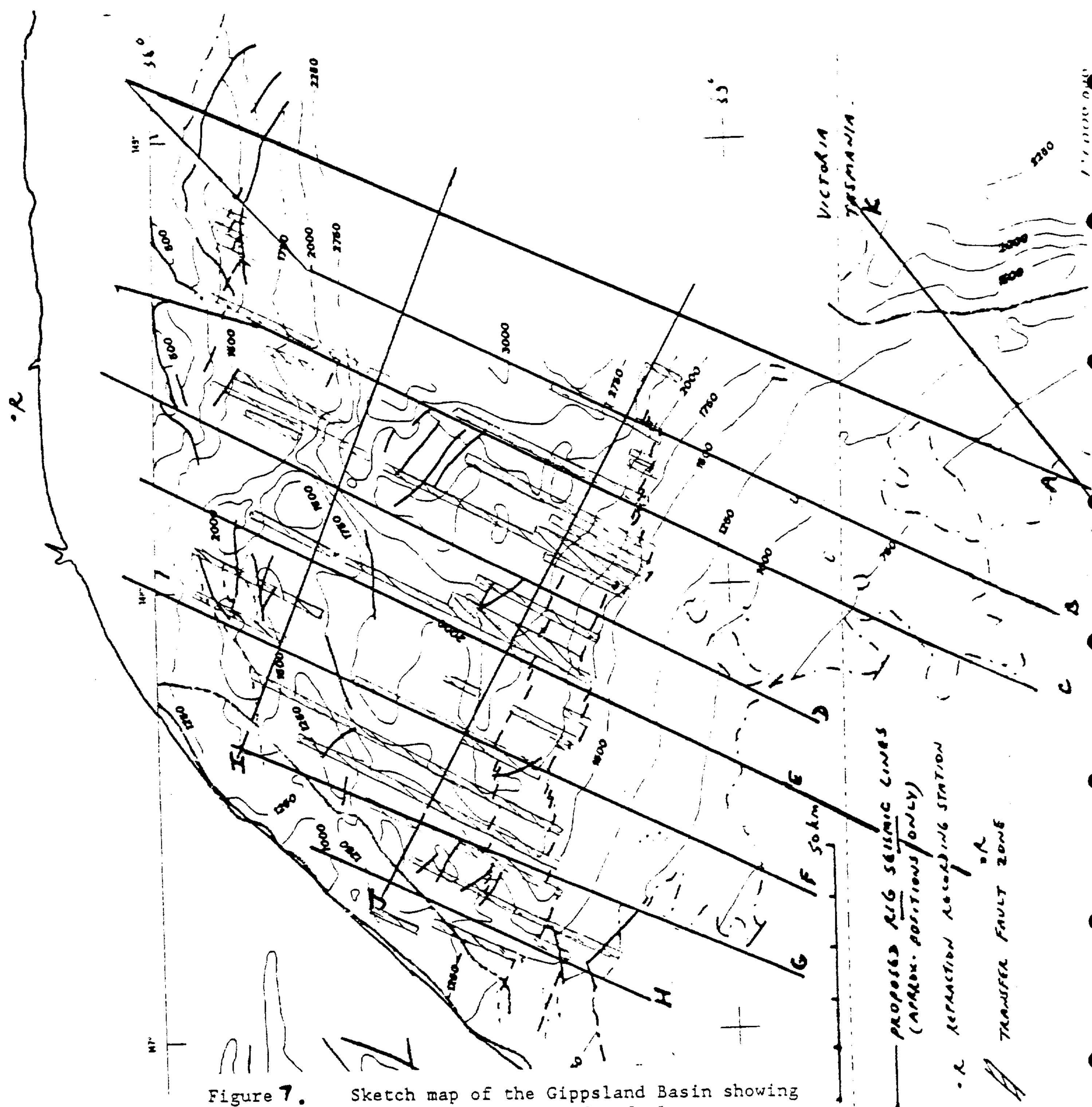

Figure 7. Sketch map of the Gippsland Basin showing the location of transfer fault zones (after Etheridge & others, 1985) and proposed Rig Seismic lines.

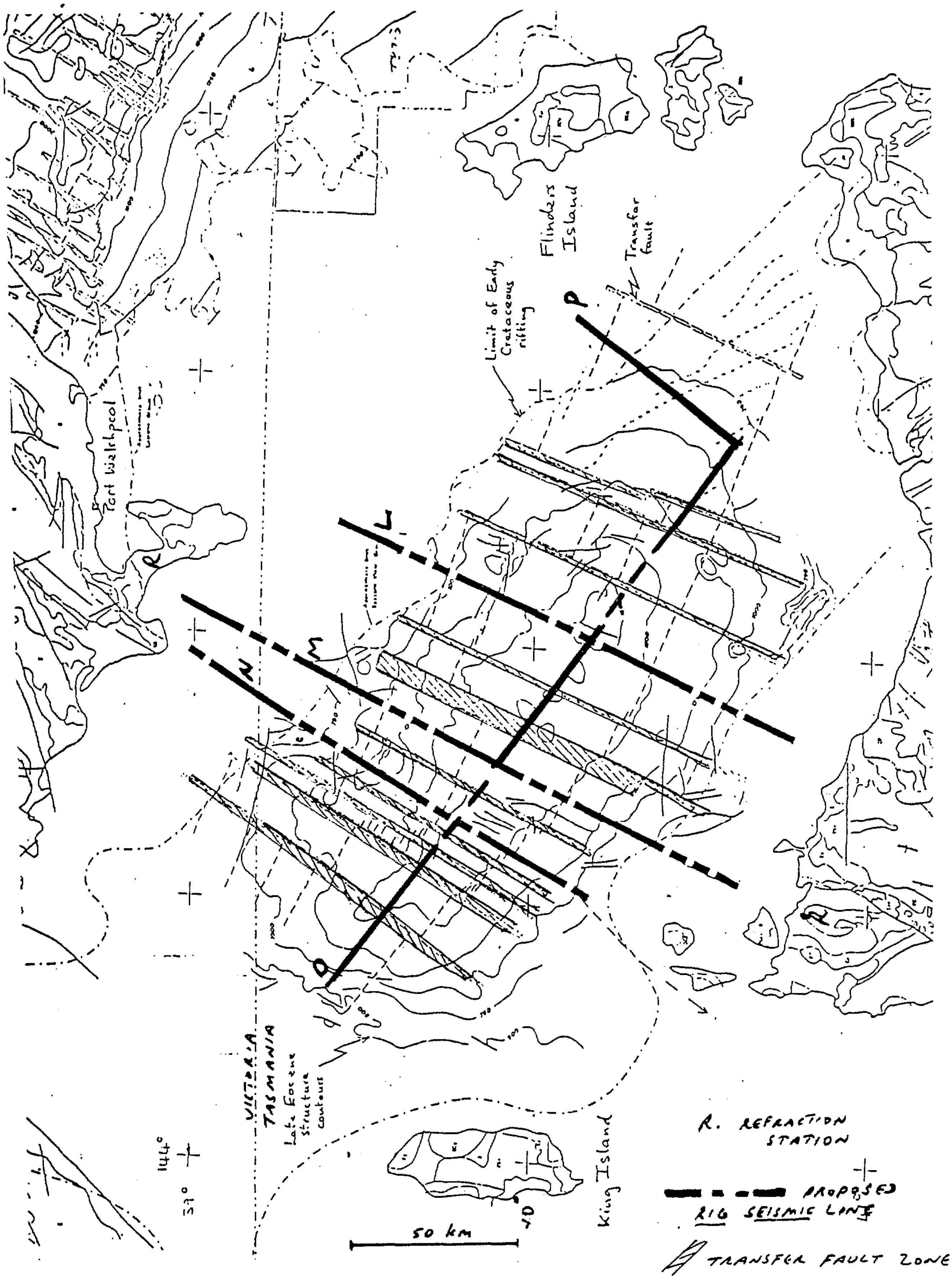

Figure 8. Sketch map of the Bass Basin showing location of transfer fault zones (after Etheridge & others, 1984, 1985) and proposed Rig Seismic lines.

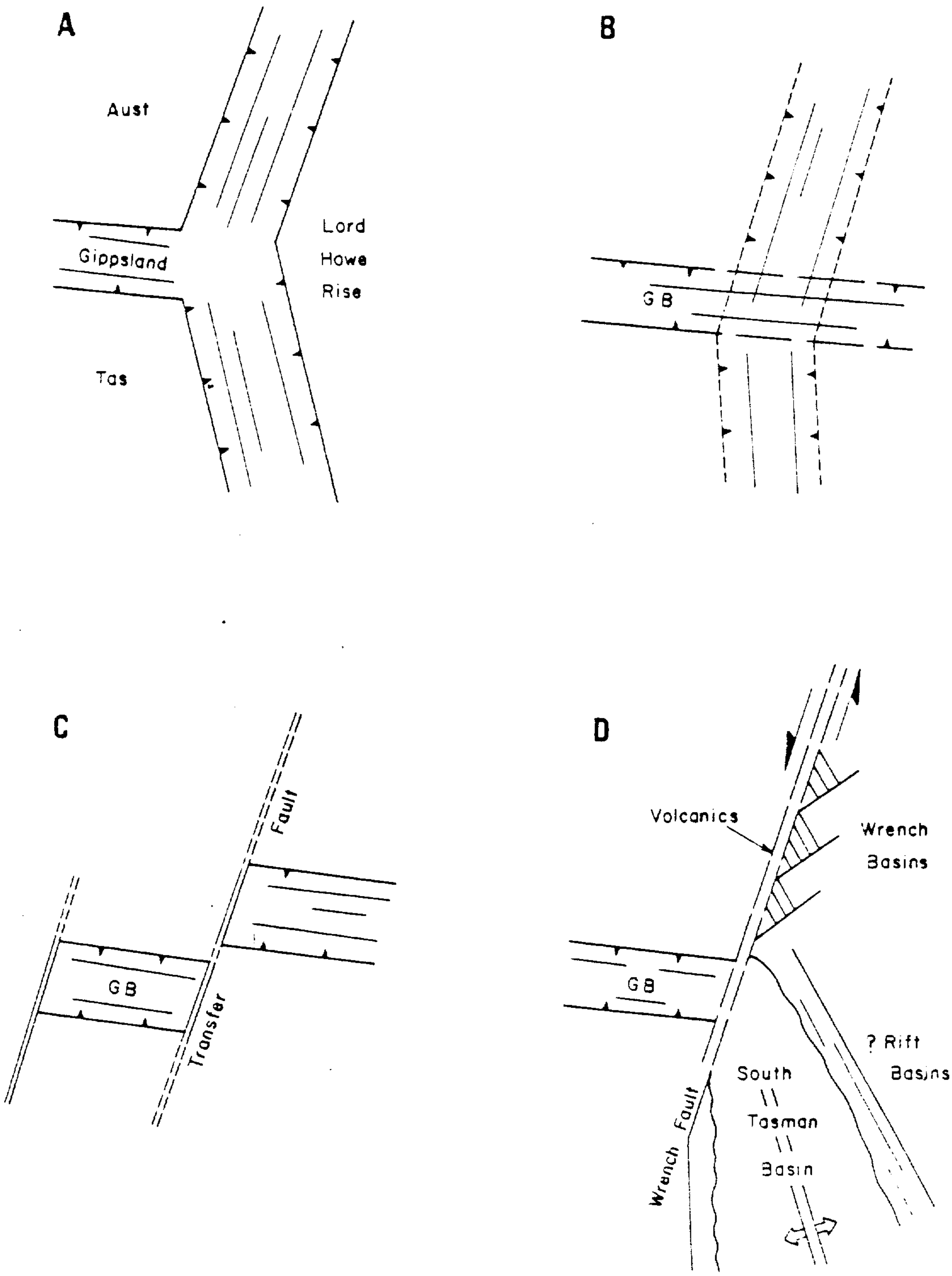

Figure 9. Models for the evolution of the Tasman Sea (after Roeser & others, 1985). A, bifurcating rift; B, rift overprint; C, basin offset along transfer fault; D, wrench-basin development.

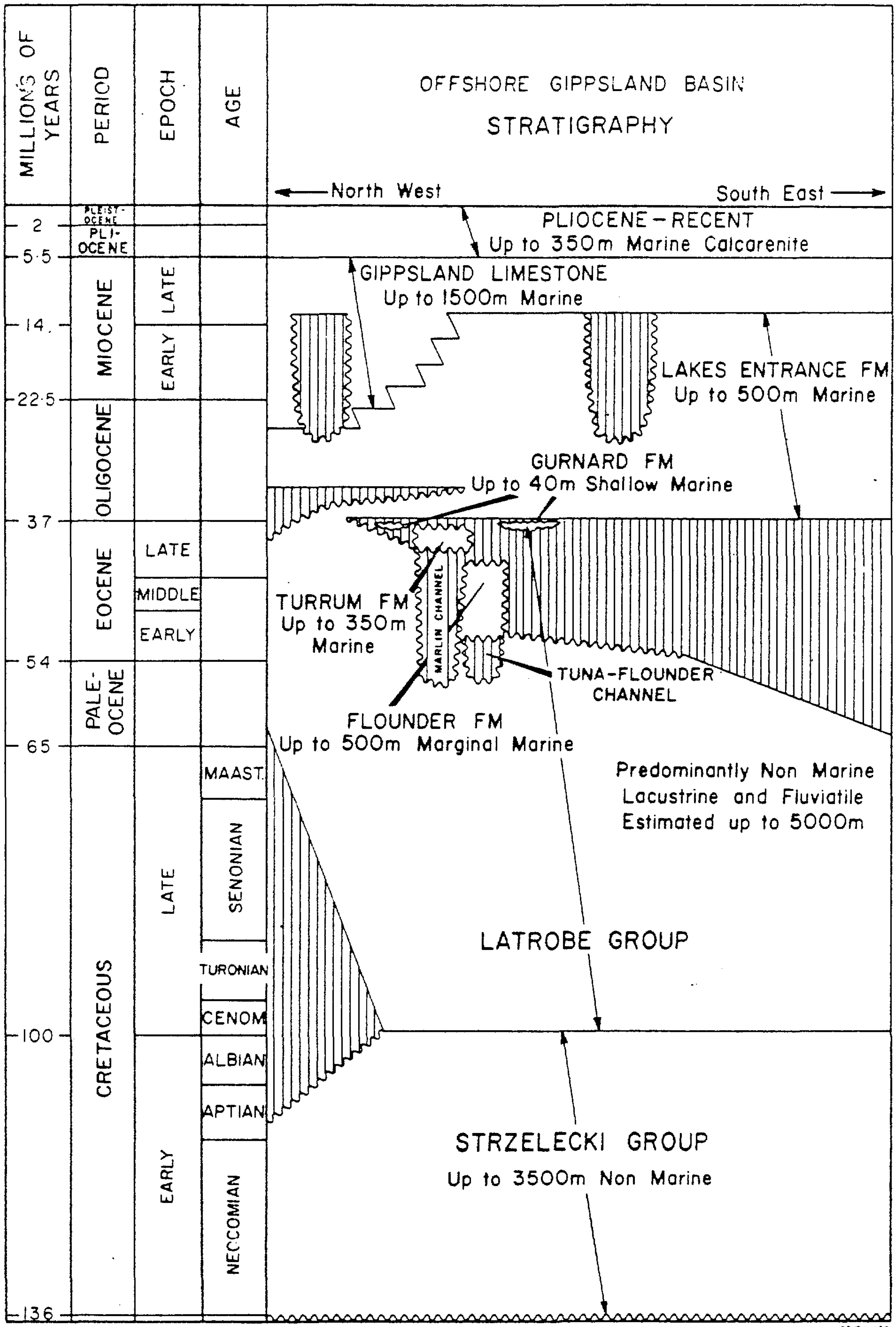

Figure 10. Stratigraphy of the offshore Gippsland Basin (after Threlfall & others, 1976).

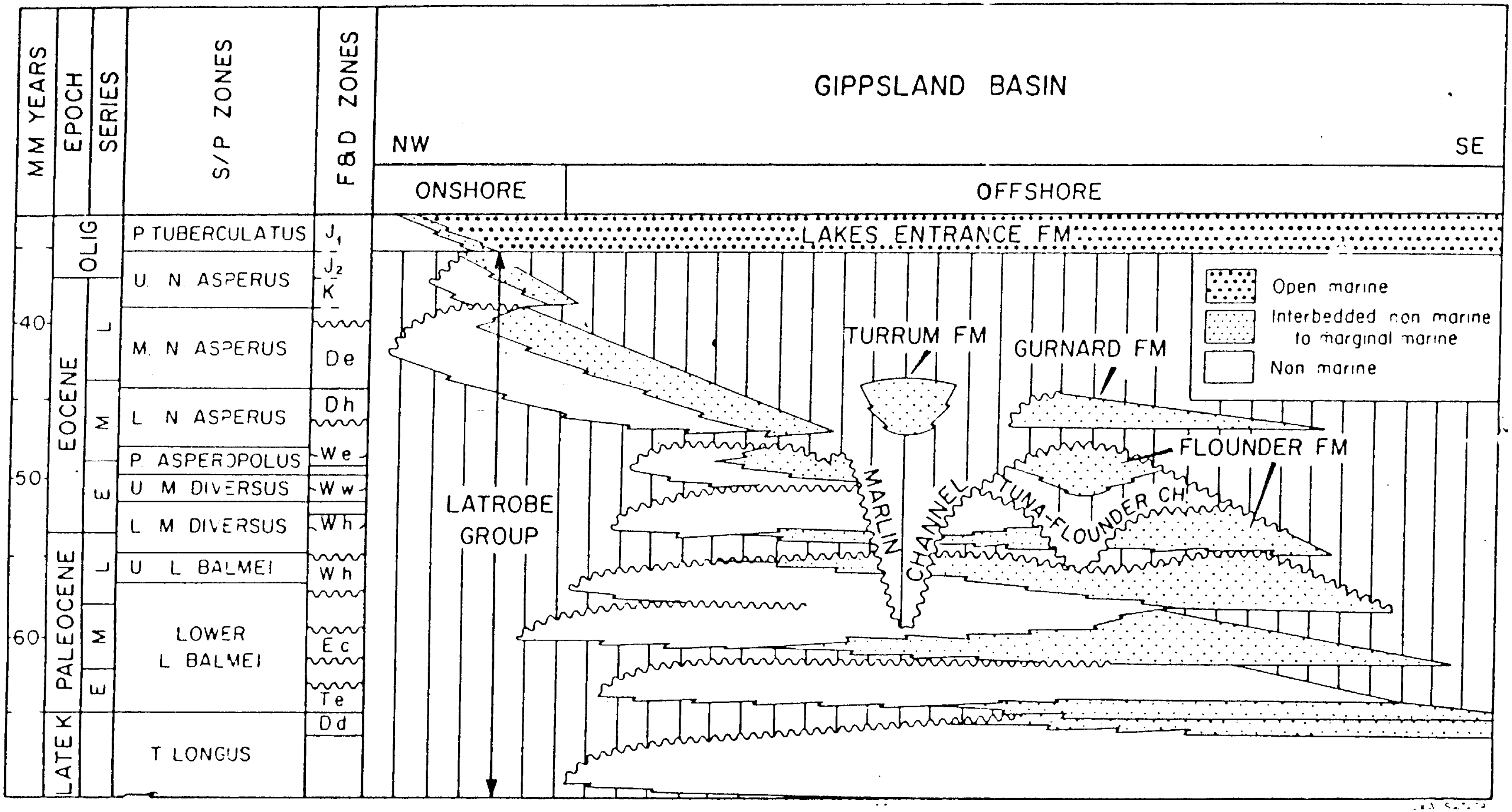

Figure 11. Chronographic section across the Gippsland Basin (after Partridge, 1976).

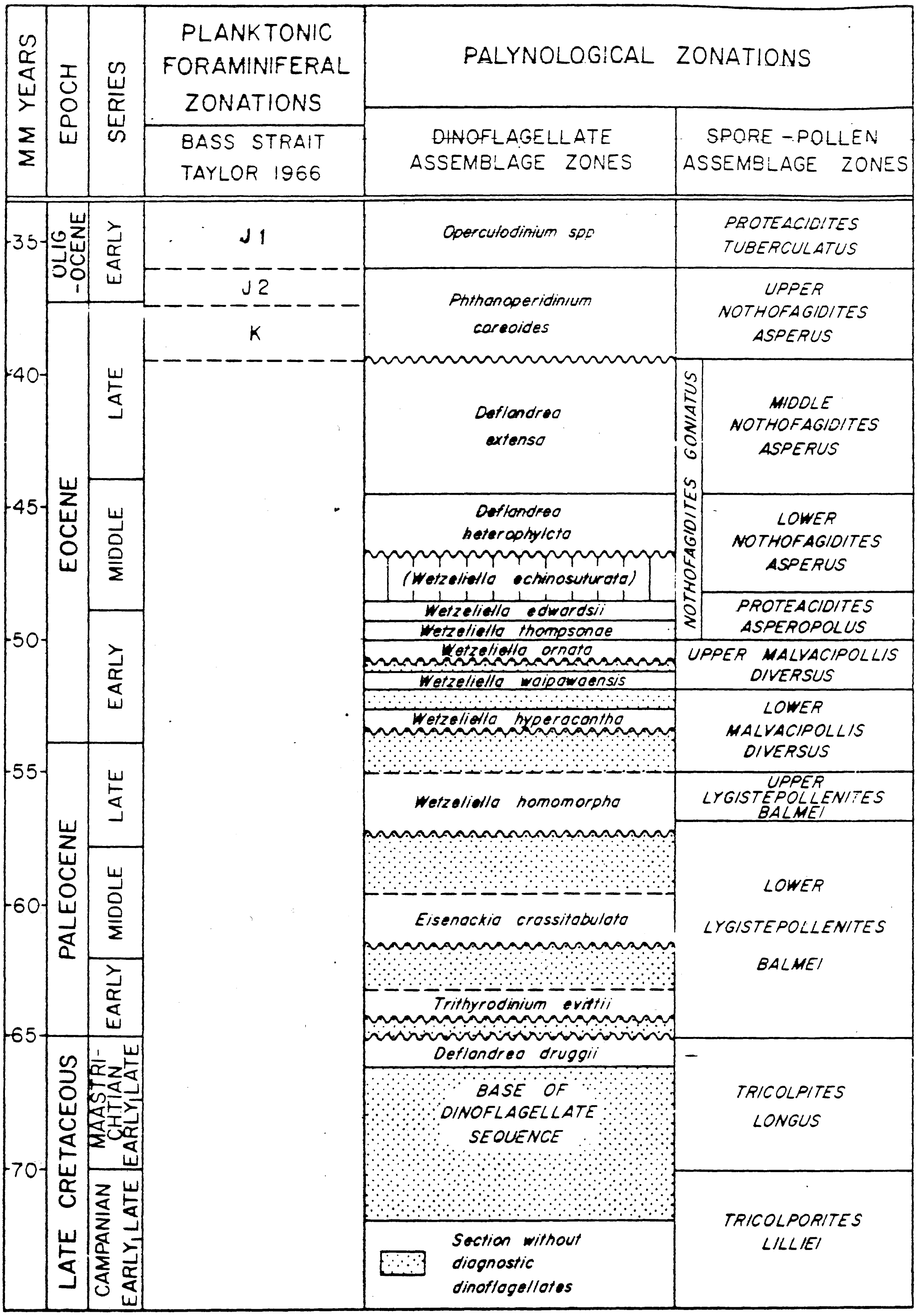

Figure 12. Correlation of planktonic foraminiferal and palynological zonations of the Gippsland Basin with the geological time scale (after Partridge, 1976).

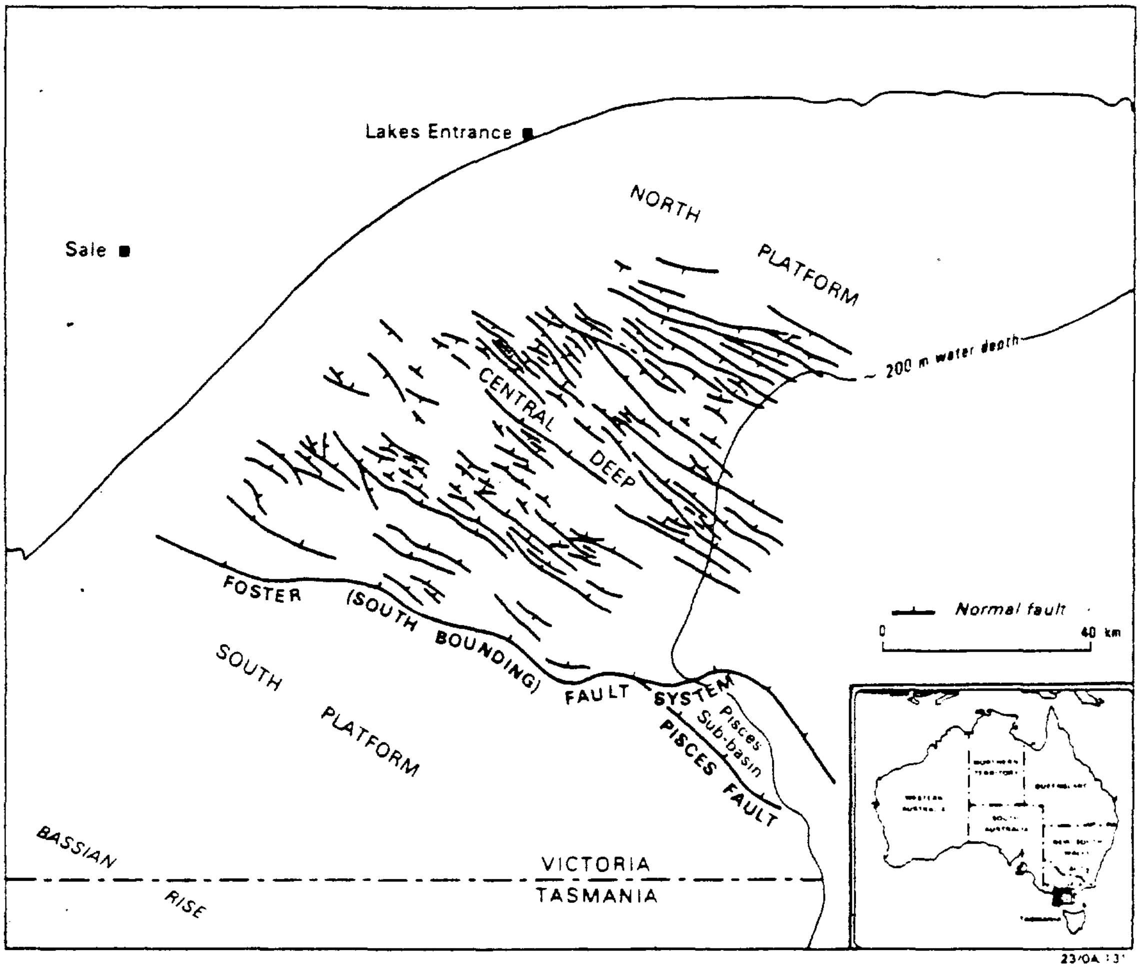

Figure 13. Basin forming normal fault pattern, Gippsland Basin (after Threlfall & others, 1976). The faults probably consist in part of short northwest trending fault segments bounded by basin-wide north-northeast trending transfer faults (Etheridge & others, 1985).

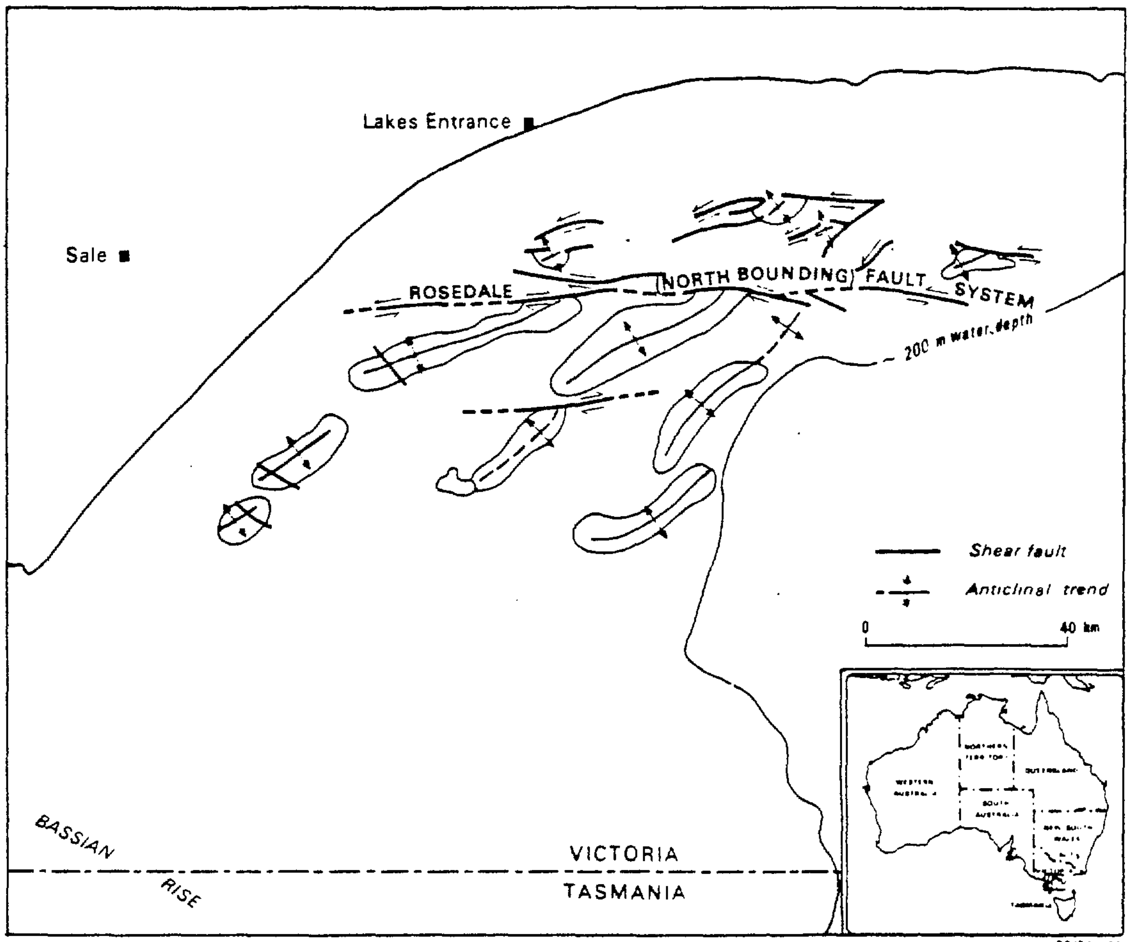

Figure 14. En echelon fold patterns and related shear faults, Gippsland Basin (after Threlfall & others, 1976).

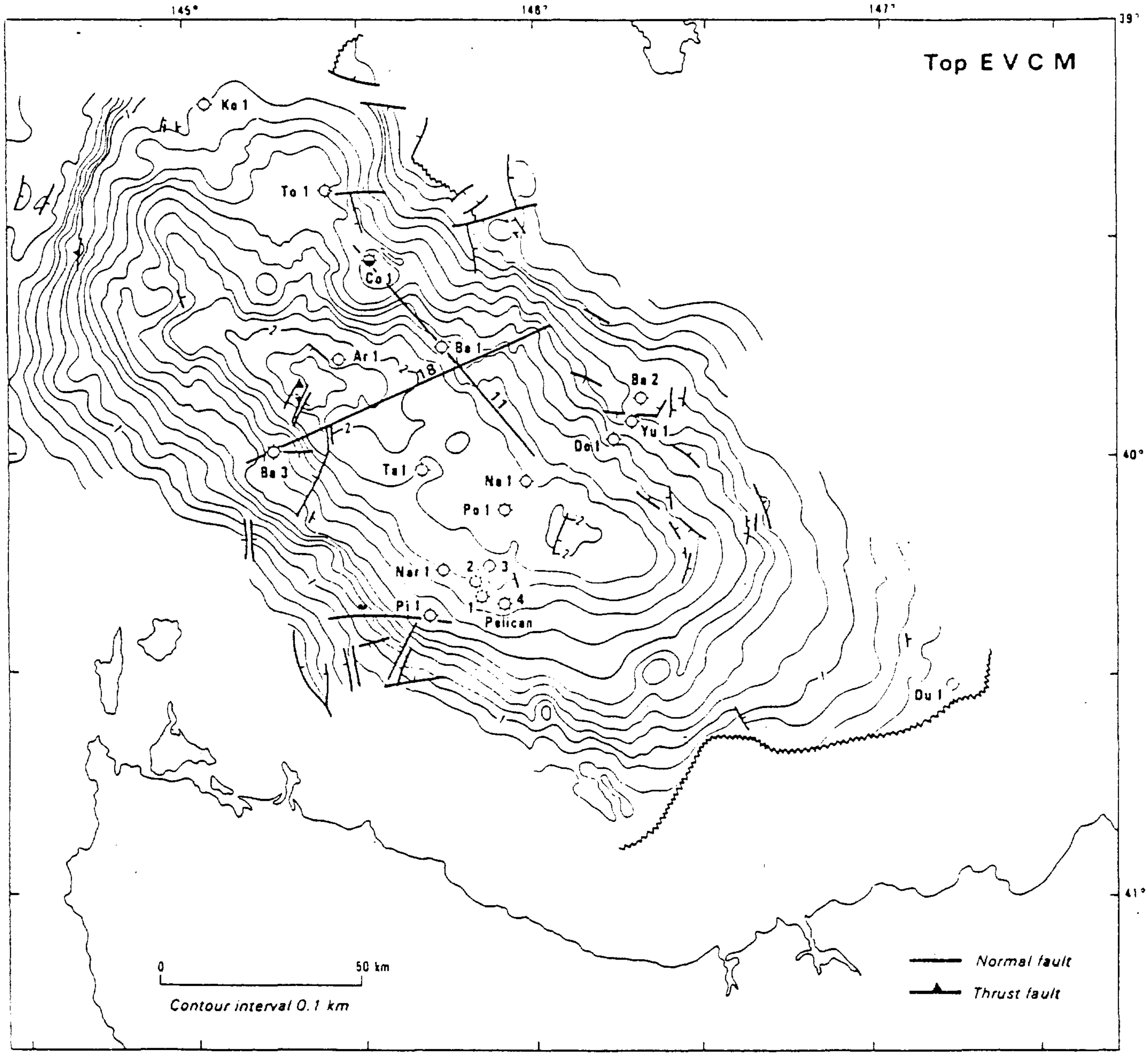

Figure 15. Bass Basin - structure contours on the top of the Eastern View Coal Measures (ca. mid Eocene). After Williamson & others. (1987).

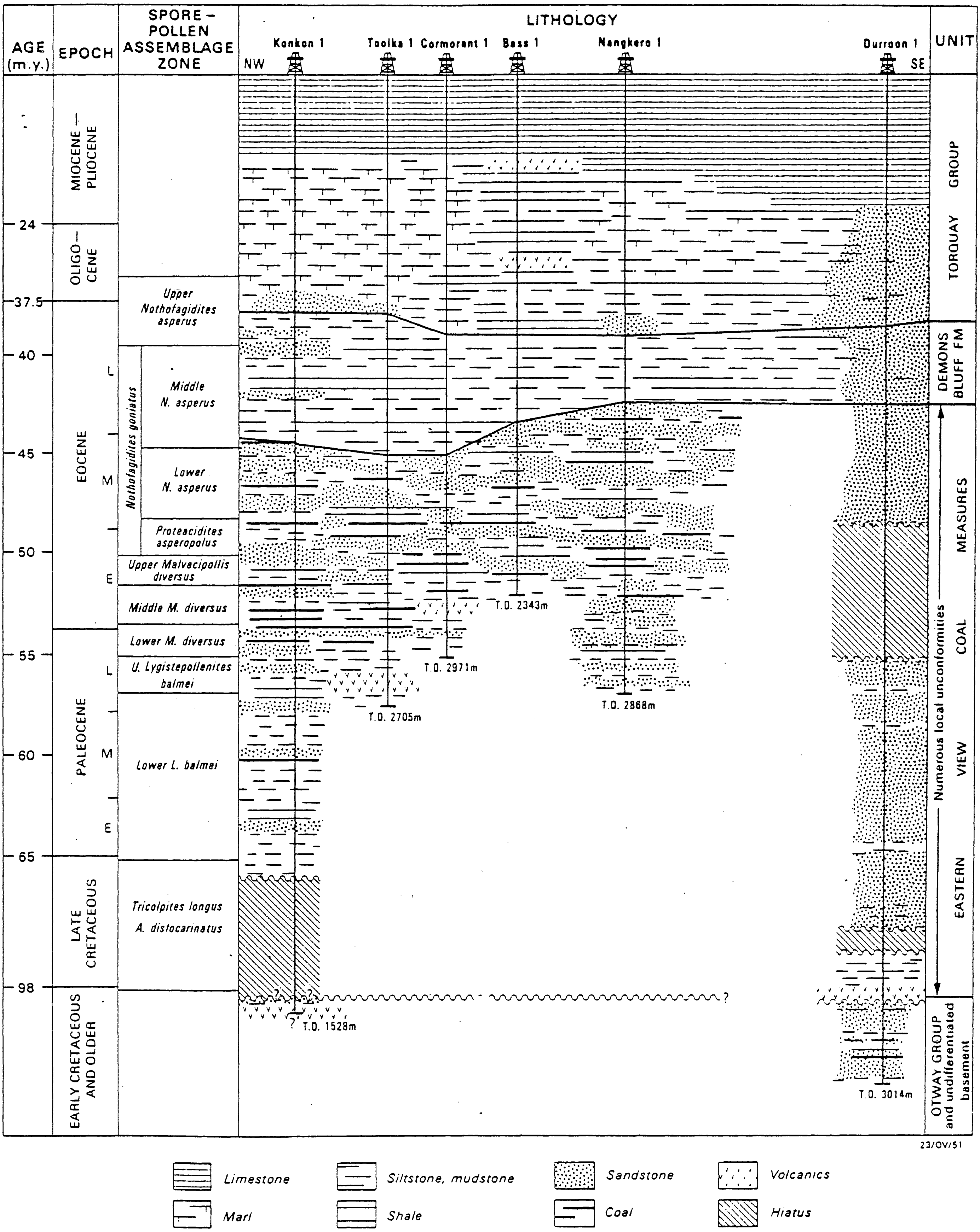

Figure 16. Bass Basin stratigraphy. After Williamson & others (1985).

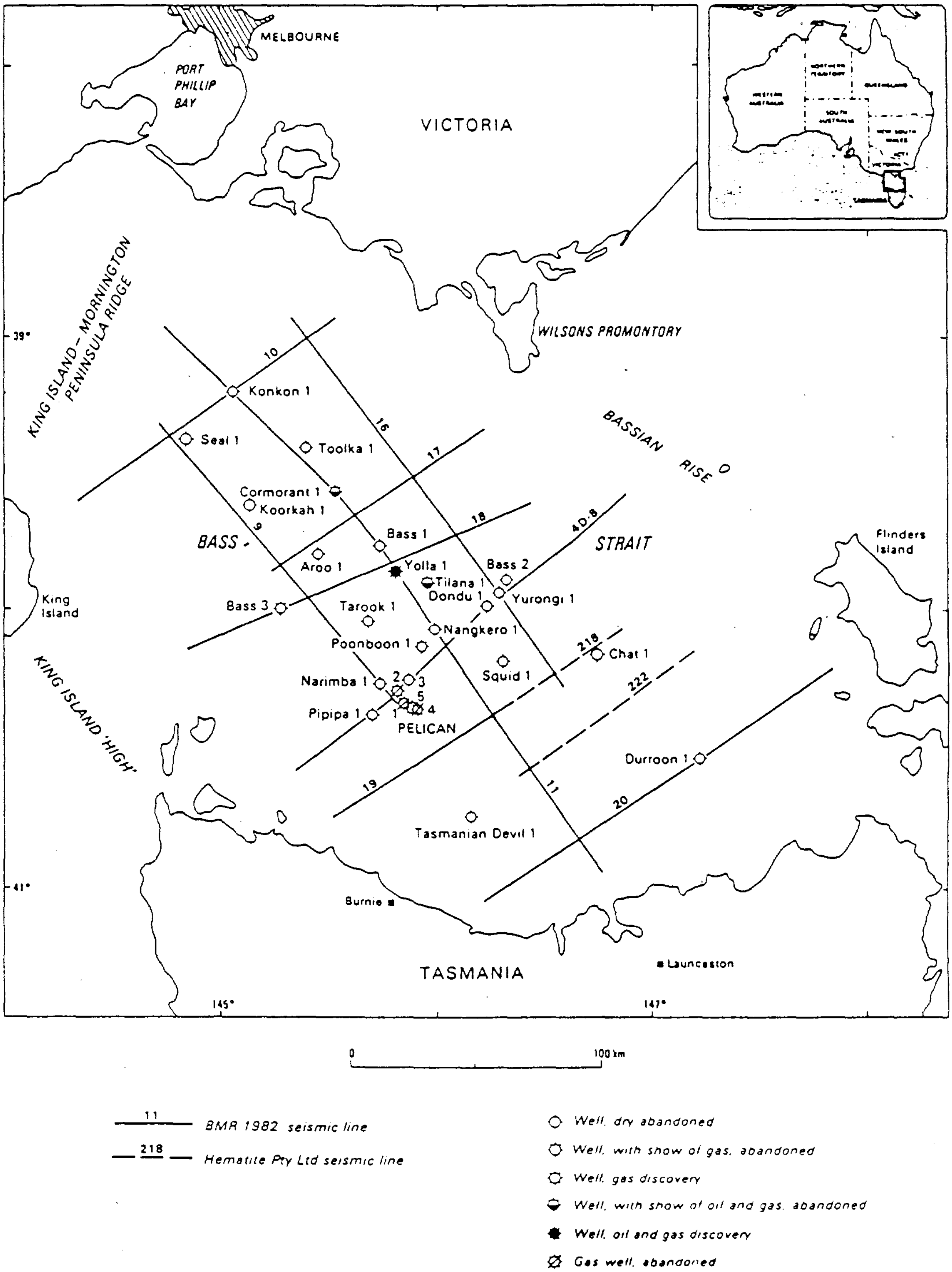

Figure 17. Bass Basin, showing location of BMR 1982 seismic survey run by GSI and reprocessed Hematite Pty seismic lines. Water depths are 30 to 90 m.

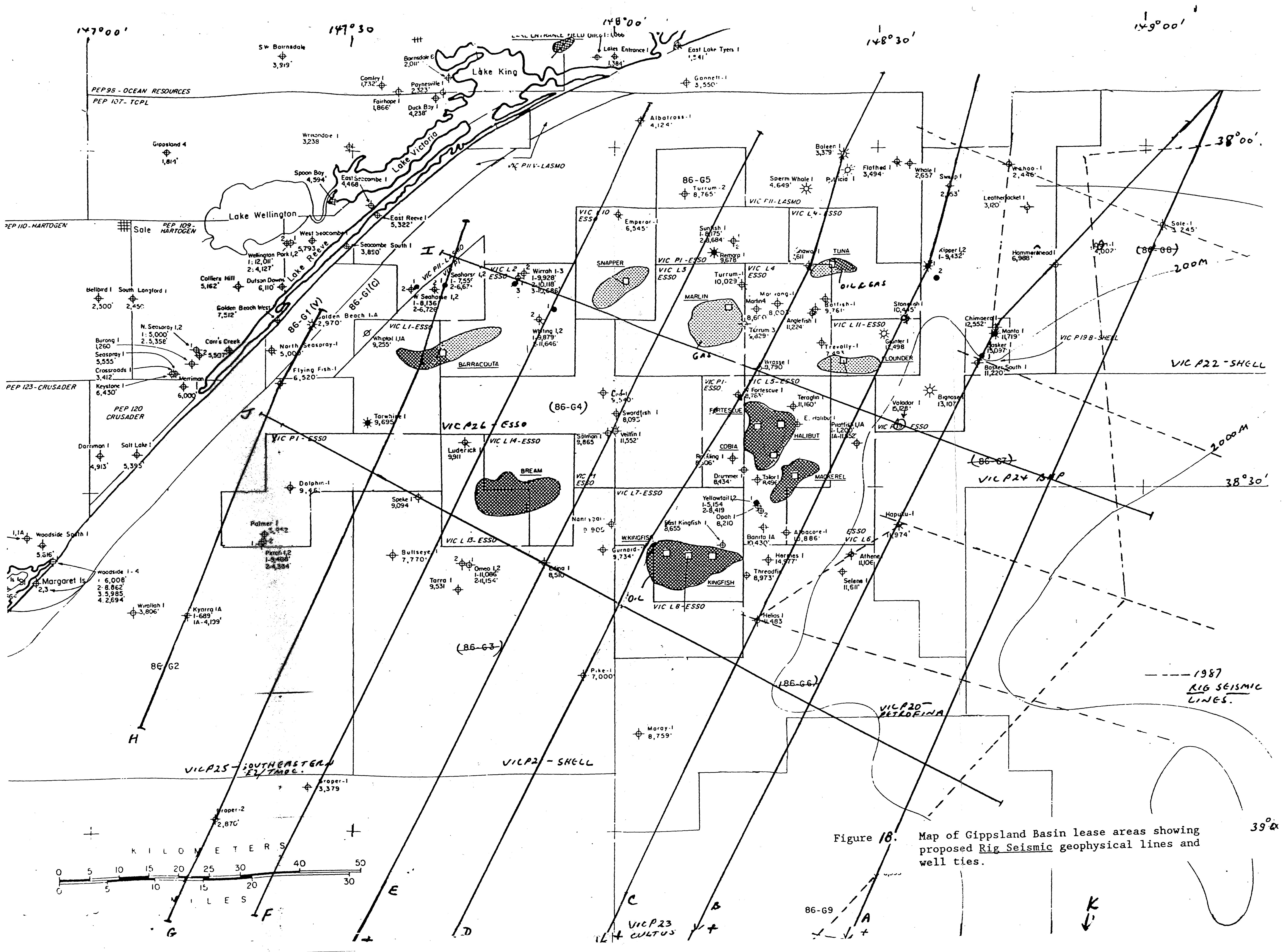

Figure 18. Map of Gippsland Basin lease areas showing proposed Rig Seismic geophysical lines and well ties.

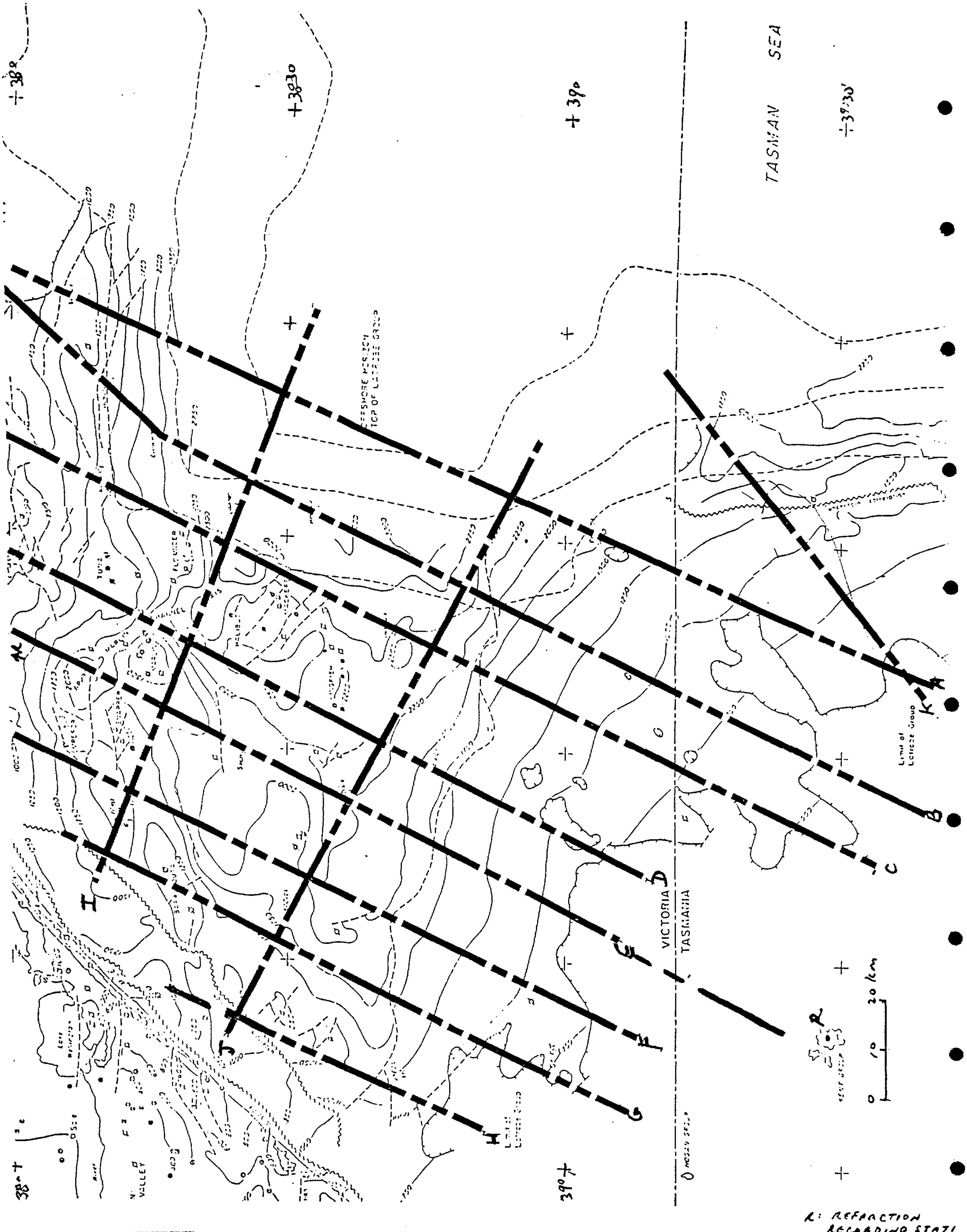

Figure 19. Structural map of the Gippsland Basin (after Robertson & others, 1978b) showing proposed Rig Seismic lines.

APPENDIX 1 - DETAILS OF LINES AND WAY POINTS

WAY POINT	LAT. °(S)	LONG. °(E)	LINE	WELL TIE	LENGTH KM (nmi)	LINE LENGTH KM (nmi)
Gippsland Basin						
W.P. 1	39° 10.4'	148° 57.0'		-		
			K		78.9 (42.6)	
W.P. 2	39° 36.0'	148° 13.0'		-		'K' : 78:9 (42.6)
			A		65.2 (35.1)	
W.P. 3	39° 03.599'	148° 30.708'		Pisces - 1		
			A		114.3 (61.7)	
W.P. 4	38° 07.017'	149° 02.067'		Sole - 1		
			A		17.2 (9.3)	
W.P. 5	37° 58.5'	149° 06.8'		-		'A': 196.7 (106.2)
			B		33.2 (17.9)	
W.P. 6	38° 10.570'	148° 49.988'		Hammerhead - 1		
			B		13.9 (7.5)	
W.P. 7	38° 15.939'	148° 43.319'		Chimaera - 1		
			B		5.1 (2.7)	
W.P. 8	38° 18.442'	148° 41.887'		Basker - 1		
			B		30.5 (16.5)	
W.P. 9	38° 33.334'	148° 32.938'		Hapuku - 1		
			B		118.9 (64.5)	
W.P. 10	39° 31.9'	147° 58.7'		-		"B": 201.6 (108.8)
					22.5 (12.1)	
W.P. 11	39° 33.9'	147° 43.2'		-		
			C		108.0 (58.3)	

W.P. 12	38° 41.674'	148° 16.568'		Helios - 1		
			C		55.2 (29.8)	
W.P. 13	38° 15.036'	148° 33.579'		Stone fish - 1		
			C		8.2 (4.4)	
W.P. 14	38° 10.600'	148° 35.783'		Kipper - 1		
			C		40.2 (21.7)	
W.P. 15	37° 52.5'	148° 16.8'		-		"C": 211.6 (114.2)
					23.8 (12.8)	
W.P. 16	37° 52.5'	148° 30.5'		-		
			D		14.8 (8.0)	
W.P. 17	38° 00.610'	148° 26.140'		Baleen - 1		
			D		20.7 (11.2)	
W.P. 18	38° 11.350'	148° 22.134'		Tuna - 4		
			D		17.1 (9.2)	
W.P. 19	38° 19.462'	148° 16.519'		Wrasse - 1		
			D		6.4 (3.5)	
W.P. 20	38° 22.472'	148° 14.323'		Fortescue - 1		
			D		27.2 (14.7)	
W.P. 21	38° 35.0'	148° 03.5'		-		
			D		23.8 (12.9)	
W.P. 22	38° 46.484'	147° 57.012'		Pike - 1		
			D		46.1 (24.9)	
W.P. 23	39° 08.8'	147° 42.8'		-		"D": 156.1 (84.3)
					46.7 (25.1)	
W.P. 24	39° 25.0'	147° 17.9'		-		
			E		103.1 (55.6)	
W.P. 25	38° 36.376'	147° 52.699'		Edina - 1		
			E		23.6 (12.7)	
W.P. 26	38° 25.040'	148° 00.140'		Veilfin - 1		
			E		57.1 (30.8)	

W.P. 27	37° 56.8'	148° 15.8'		-		"E" : 183.8 (99.2)
					17.1 (9.2)	
W.P. 28	37° 54.7'	148° 04.4'		-		
			F		5.4 (2.9)	
W.P. 29	37° 57.500'	148° 03.300'		Albatross - 1		
			F		34.4 (18.6)	
W.P. 30	38° 14.196'	147° 53.016		Whiting - 1		
			F		109.1 (58.9)	
W.P. 31	39° 07.4'	147° 20.7'		-		"F" : 148.9 (80.4)
					15.4 (8.3)	
W.P. 32	39° 06.2'	147° 10.1'		-		
			G		15.1 (8.2)	
W.P. 33	38° 58.667'	147° 14.2'		Groper - 2		
			G		80.1 (43.2)	
W.P. 34	38° 19.317'	147° 37.05'		Barracouta - 3		
			G		14.8 (8.0)	
W.P. 35	38° 11.799'	147° 40.372'		Seahorse - 1		
			G		14.0 (7.6)	
W.P. 36	38° 04.8'	147° 44.0'		-		"G" : 124.0 (67.0)
					9.0 (4.8)	
W.P. 37	38° 08.6'	147° 40.2'		-		
			I		13.7 (7.4)	
W.P. 38	38° 11.372'	147° 48.952'		Wirrah - 1		
			I		42.8 (23.1)	
W.P. 39	38° 19.462'	148° 16.519'		Wrasse - 1		
			I		25.9 (14.0)	
W.P. 40	38° 25.472'	148° 32.612'		Volador - 1		
			I		43.0 (23.2)	
W.P. 41	38° 34,3'	149° 00'		-		"I" : 125.4 (67.7)
					45.2 (24.4)	

W.P. 42	38° 57.0'	148° 48.5'		-		
			J		89.2 (48.1)	
W.P. 43	38° 36.376'	147° 52.699'		Edina - 1		
			J		24.9 (13.4)	
W.P. 44	38° 30.577'	147° 37.196'		Speke - 1		
			J		29.0 (15.6)	
W.P. 45	38° 23.5'	147° 19.4'		-		"J": 143.1 (77.2)
					21.0 (11.3)	
W.P. 46	38° 13.6'	147° 26.4'		-		
			H		3.8 (2.1)	
W.P. 47	38° 15.5'	147° 25.335'		Golden Beach 1A		
			H		11.1 (6.0)	
W.P. 48	38° 20.863'	147° 21.87'		Flying Fish - 1		
			H		40.2 (21.7)	
W.P. 49	38° 40.876'	147° 11.204'		Kyarra - 1A		
			H		18.9 (10.2)	
W.P. 50	38° 50.0'	147° 05.3'		-		"H": 74.0 (40.0)

Total Gippsland Basin lines (A-K): 1644 (888)

Total link lines : 204 (110)

<u>Bass Basin</u>

W.P. 51	39° 34.5'	146° 27.0'				-
			L		41.9 (22.6)	
W.P. 52	39° 55.499'	146° 15.981'		Yurongi - 1		
			L		109.1 (58.9)	
W.P. 53	40° 50.0'	145° 46.7'		-		"L": 151.0 (81.5)
					58.5 (31.6)	
W.P. 54	40° 35.0'	145° 10.0'		-		

			M		180.5 (97.4)	
W.P. 55	39° 06.0'	146° 01.5'		-		"M": 180.5 (97.4)
					16.6 (9.0)	
W.P. 56	39° 07.0'	145° 50.0'		-		
			N		57.2 (30.9)	
W.P. 57	39° 34.380'	145° 31.595'		Cormorant - 1		
			N		88.2 (47.6)	
W.P. 58	40° 16.0'	145° 01.5'		-		"N": 145.4 (78.5)
					110.8 (59.8)	
W.P. 59	39° 23.0'	144° 25.5'		-		
			O		230.5 (124.4)	"O": 230.5 (124.5)
W.P. 60	40° 36.5'	146° 36.5'		-		
			P		82.0 (44.3)	"P": 82.0 (44.3)
W.P. 61	40° 05.0'	147° 18.0'		-		

Total Bass Basin lines (L-P): 789 (426)

Total link lines : 186 (100)

Appendix 2. List of Geophysical Equipment.

Seismic System

Streamer 3600 m Teledyne hydrophone analogue streamer: standard configuration 96 x 37.5 m groups;

- -10 hydrophones per 12.5 metre group
- -~15 µV noise; maximum ambient at 5 knots
- -Syntron RCL-2 individually adressable cable levellers

Source array
- -52.4/73.4 litre (3200/4480 cubic inch), 28-element tuned Texas Instruments airgun array
- -Teledyne gun signature phones, gun depth sensors, and I/O SS-8 shot sensors
- -4 x Price A-300 compressors, each rated at 300 scfm @ 2000 psi

Recording
- -BMR designed and built seismic acquisition system based on Hewlett-Packard minicomputers
- -96-channel digitally controlled preamp/filters
  - -low-cut 6,12,24,48 Hz; 18 dB/octave
  - -high-cut 256,128,64 Hz; 72 dB/octave
- -bit accuracy
  - -12 bit floating point with 4 bit dynamic range
  - -15 bit integer card
- - 6250 bpi tape drives
- -data read after write in demultiplexed SEG-Y format
- -2 ms sampling interval with 96 channels, maximum 10 s shot rate, and 6 s record length
- -streamer noise, leakage, and individual group QC
- -source array timing QC
- -recording oscillator and 4 seismic monitor QC

Seismic Refraction System

- -Reftek sonobuoy receiver
- -Reftek 2 sonobuoys
- -Yaesu sonobuoy receiver
- -Spartan SSQ-57 sonobuoys

Bathymetric Systems

- -Raytheon deep-sea echo-sounder; 2 kW maximum output at 3.5 kHz
- -Raytheon deep-sea echo-sounder; 2 kW maximum output at 12 kHz

Magnetometer System

- -2 x Geometrics G801/803 proton precession magnetometers; may be used as standard single-sensor cable or in horizontal gradiometer configuration
- -Geometrics G803 proton precession magnetometer; single sensor cable

Navigation Systems

GPS Navigation System
- Magnavox T-Set GPS navigator

Prime Transit System
- Magnavox MX1107RS dual channel satellite receiver
- Magnavox MX610D dual-axis sonar doppler speed log
- Robertson gyro-compass

Secondary Transit System
- Magnavox MX1142 single channel satellite receiver
- Raytheon DSN450 dual-axis sonal doppler speed log
- Robertson gyro-compass

Radio Navigation
- Decca HIFIX-6

Data Acquisition System

- data acquisition system built around Hewlett-Packard 2113 E-Series minicomputer, with tape drives, disc drives, 12" and 36" plotters, line printers, and interactive terminals

APPENDIX 3. SCIENTIFIC AND TECHNICAL CREW

J.B. Willcox	Co-chief scientist
J.B. Colwell	Co-chief scientist
R. Whitworth	Systems specialist
C. Penney	Systems specialist
P. Napier	Scientist/Observor
A. Moore	Scientist/Observor
C. Collins	Scientist/Observor
K. Revill	Science Technician
G. Saunders	Science Technician
J. Bedford	Science Technician
I. Roach	Science Technician
C. Tindall	Science Technician
D. Pryce	Science Technician
J. Pittar	Electronics Technician
D. Holdway	Electronics Technician
P. Walker	Mechanical Technician
P. Harris	Mechanical Technician
G.S.I.	Airgun specialist
Fieldhand	
Fieldhand	
20	

APPENDIX 4. WELL DATA (TIES)

WELL NAME	OPERATOR	LEGSLN.	T.D. (m)	T.D. DATE
Gippsland Basin				
Albatross 1	Endeavour Oil Co Ltd	PSLA	1255	15-JUL-70
Baleen 1	Hudbay Oil (Aust) Ltd	PSLA	1030	30-NOV-81
Barracouta 3	Esso Explor and Prod Aust Ltd	PSLA	2942	08-SEP-69
Basker 1	Shell Development (Aust) P/L	PSLA	3991	12-JUN-83
Chimaera 1	Shell Development (Aust) P/L	PSLA	3826	14-MAY-84
Edina 1	Aust Aquitaine Petroleum	PSLA	2594	26-OCT-82
Flying Fish 1	NSW Oil and Gas Co	PSLA	1987	27-NOV-71
Fortescue 1	Esso Explor and Prod Aust Ltd	PSLA	2691	16-JUN-78
Golden Beach 1A	Barkley Oil Co P/L	PSLA	2937	17-JUL-67
Groper 2	Esso Explor and Prod Aust Ltd	PSSA	875	21-SEP-69
Hammerhead 1	Shell Development (Aust) P/L	PSLA	2130	23-JUN-82
Hapuku 1	Esso Explor and Prod Aust Ltd	PSLA	3650	11-AUG-75
Helios 1	Phillips	PSLA	3500	06-DEC-82
Kipper 1	Esso Explor and Prod Aust Ltd	PSLA	2875	29-MAR-86
Kyarra 1A	Aust Aquitaine Petroleum	PSLA	1280	23-FEB-83
Pike 1	Esso Explor and Prod Aust Ltd	PSLA	2134	25-JUL-73
Pisces 1	Union Texas Petroleum Corp	PSLA	2580	08-MAY-82
Seahorse 1	Esso Explor and Prod Aust Ltd	PSLA	2304	02-SEP-78
Sole 1	Shell Development (Aust) P/L	PSLA	1128.7	05-FEB-73
Speke 1	Aust Aquitaine Petroleum	PSLA	2772	05-JUL-84
Tuna 4	Esso Explor and Prod Aust Ltd	PSLA	3321	08-JUL-84

Appendix 4 (cont.)

WELL NAME	OPERATOR	LEGSLN.	T.D. (m)	T.D. DATE
Veilfin 1	Esso Explor and Prod Aust Ltd	PSLA	3521	30-MAR-84
Volador 1	Shell Development (Aust) P/L	PSLA	4611	24-MAR-83
Whiting 1	Esso Explor and Prod Aust Ltd	PSLA	3011	05-APR-83
Wirrah 1	Esso Explor and Prod Aust Ltd	PSLA	3026	18-NOV-82
Wrasse 1	Esso Explor and Prod Aust Ltd	PSLA	2984	20-NOV-83

Bass Basin

Cormorant 1	Esso/Hematite	PSLA	2971	9-JUL-70
Yurongi 1	Esso/Hematite	PSSA	2429	13-JUL-73

APPENDIX 5. LIST OF MARINE SEISMIC SURVEYS, GIPPSLAND BASIN.

Marine seismic surveys

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

Marine seismic surveys

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

Marine seismic surveys

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

Title	PEDIN #	Survey name	PSLA #	Operator
VIC				
	S38101	MSI-80 Scientific Inves. Mar S	81/33	Magnet Metals Pet
	S38501	G-GSI-85B Scientific Marine S	85/14	GSI
VIC/L01				
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38202	G82B Extension Marine Seismic	82/31	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L01				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L02				
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38302	G82D Marine Seismic	82/60	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L02				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L03				
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38205	G82C Turrum 3D Marine Seismic	82/36	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L03				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L04				
	S37301	G73A Marine Seismic	73/14	ESSO
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38205	G82C Turrum 3D Marine Seismic	82/36	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L04				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L05				
	S37301	G73A Marine Seismic	73/14	ESSO
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L05				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L06				
	S37301	G73A Marine Seismic	73/14	ESSO
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L06				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L07				
	S37301	G73A Marine Seismic	73/14	ESSO
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L07				
	S37401	G74A Marine Seismic	74/15	ESSO

Title	PEDIN #	Survey name	PSLA #	Operator
VIC/L08				
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
VIC/L08				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L09				
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L09				
	S37401	G74A Marine Seismic	74/15	ESSO
VIC/L10				
	S37401	G74A Marine Seismic	74/15	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/L11				
	S37401	G74A Marine Seismic	74/15	ESSO
	S37601	G76A Marine Seismic	76/10	ESSO
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
VIC/L12				
	S37601	G76A Marine Seismic	76/10	ESSO
VIC/P01				
	S06904	G69B Marine Seismic	69/03	ESSO
	S07101	G71A Marine Seismic	71/05	ESSO
	S37004	G70A Marine Seismic	70/03	ESSO
	S37101	G71B Marine Seismic	71/06	ESSO
	S37201	G72A Marine Seismic	72/14	ESSO
	S37301	G73A Marine Seismic	73/14	ESSO
	S37303	G73B Marine Seismic	73/15	ESSO
	S37401	G74A Marine Seismic	74/15	ESSO
	S37601	G76A Marine Seismic	76/10	ESSO
	S37701	G77A Marine Seismic	77/15	Hematite Pet
	S38004	G80A and Extension Marine S	79/22	Hematite Pet
	S38106	G81A Marine Seismic	81/14	Hematite Pet
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38202	G82B Extension Marine Seismic	82/31	ESSO
	S38402	G84A Marine Seismic	84/26	ESSO
VIC/P02				
	S06904	G69B Marine Seismic	69/03	ESSO
	S07101	G71A Marine Seismic	71/05	ESSO
	S37101	G71B Marine Seismic	71/06	ESSO
	S37201	G72A Marine Seismic	72/14	ESSO
	S37301	G73A Marine Seismic	73/14	ESSO
	S37401	G74A Marine Seismic	74/15	ESSO
	S37601	G76A Marine Seismic	76/10	ESSO
VIC/P03				
	S36901	Tasman-Bass Strait Marine S	69/11	Magellan
VIC/P04				
	S06801	East Gippsland Marine SM	68/01	Magellan
	S36901	Tasman-Bass Strait Marine S	69/11	Magellan
VIC/P06				
	S06901	B69B Marine Seismic	69/01	ESSO
	S07105	B71A Marine Seismic & Magnetic	71/04	ESSO
	S07204	B72A Marine Seismic	72/12	ESSO
	S07403	H.O. 4 Marine Seismic	74/20	Hematite Pet

Title	PEDIN #	Survey name	PSLA #	Operator
VIC/P07				
	S07403	H.O. 4 Marine Seismic	74/20	Hematite Pet
VIC/P08				
	S36902	Offshore Lakes Entrance Mar S	69/07	Endeavour Oil
	S37001	Seaspray Marine Seismic	70/09	Endeavour Oil
VIC/P09				
	S06801	East Gippsland Marine SM	68/01	Magellan
	S37003	Gippsland Basin Marine SM	70/10	Shell
	S37302	1973 Marine Seismic	73/19	Shell
VIC/P10				
	S37002	Portland Marine Exper. Seismic	70/14	Shell
	S37501	Princetown Marine SM	75/01	Interstate Oil
VIC/P11				
	S38001	GB79 Marine Seismic	79/23	Beach Pet
	S38104	GB81 Marine Seismic	81/02	Beach Pet
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38203	GH-82A Marine Seismic	82/10	Hudbay Oil
	S38301	GH-83A Marine Seismic	83/07	Hudbay Oil
	S38502	GL-85B (Tambo) Marine Seismic	85/19	Lasmo
VIC/P12				
	S38003	GC-80 Marine Seismic	80/12	Cultus Pacific
	S38110	GC-82 Marine Seismic	82/02	Cultus Pacific
	S38111	CP-81A Marine Seismic Magnetic	81/18	Cultus Pacific
	S38303	GUT-83A Marine SM	83/10	Union Texas Aust
VIC/P13				
	S38006	GBS 80 Marine Seismic	80/01	Bass Strait Oil & Gas
	S38105	GBS 81 Marine Seismic	81/13	Bass Strait Oil & Gas
	S38107	GA-81A Marine Seismic	81/60	Aust Aquitaine
VIC/P14				
	S38002	OP 80 Marine SGM	80/44	Phillips
	S38204	OP 82A Marine Seismic	82/20	Phillips
	S38207	OP 82B Marine Seismic	82/54	Phillips
VIC/P15				
	S38005	Otway (O80A) Marine Seismic	80/40	ESSO
	S38102	Otway OE 81 A Marine SM	81/01	ESSO
VIC/P16				
	S38103	OMO 81 Marine Seismic	81/03	Oil & Mineral Quest
	S38304	OMQ 82 Marine Seismic	82/29	Bass Strait Oil & Gas
VIC/P17				
	S38107	GA-81A Marine Seismic	81/60	Aust Aquitaine
	S38206	GA82B Marine Seismic	82/38	Aust Aquitaine
	S38305	GA-83A Marine Seismic	83/21	Aust Aquitaine
	S38401	GA84A Marine Seismic	84/17	Aust Aquitaine
VIC/P18				
	S38108	GP-81A Marine Seismic	81/64	Phillips
VIC/P19				
	S38109	GS-81A Marine Seismic	81/59	Shell
	S38201	G82A,G82B 3D Marine Seismic	82/30	ESSO
	S38208	GS-82A Marine Seismic	82/53	Shell

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Title	PEDIN #	Survey name	PSLA #	Operator
T/13P				
	S78001	Flinders 1980 Marine Seismic	80/13	Otter Expl
	S78207	UT-82A Marine Seismic	82/58	Otter Expl
	S78301	GUT-83 P Marine SM	83/11	Union Texas Aust


SCALE 1 : 250 000
5 0 5 10 15 20 25
KILOMETRES
A. M. G. ZONE 55
142 E
144 E
146 E
148 E
150 E
38 S
40 S
42 S
BUREAU OF MINERAL RESOURCES
SHEET 1
PROPOSED RIG SEISMIC LINE
INTERPRETATION BY :
DATE :
DRAWING NO. :
TRANSFER FAULT ZONE
TRANSFER FAULT ZONE
CLAM 1
21-5-A
TASMANIAN DEVIL
PELICAN
HAMMERHEAD
TILAPIA 1
SQUID
WHAT 1
145°00'
145°45'
146°00'
146°15'
146°30'
147°00'

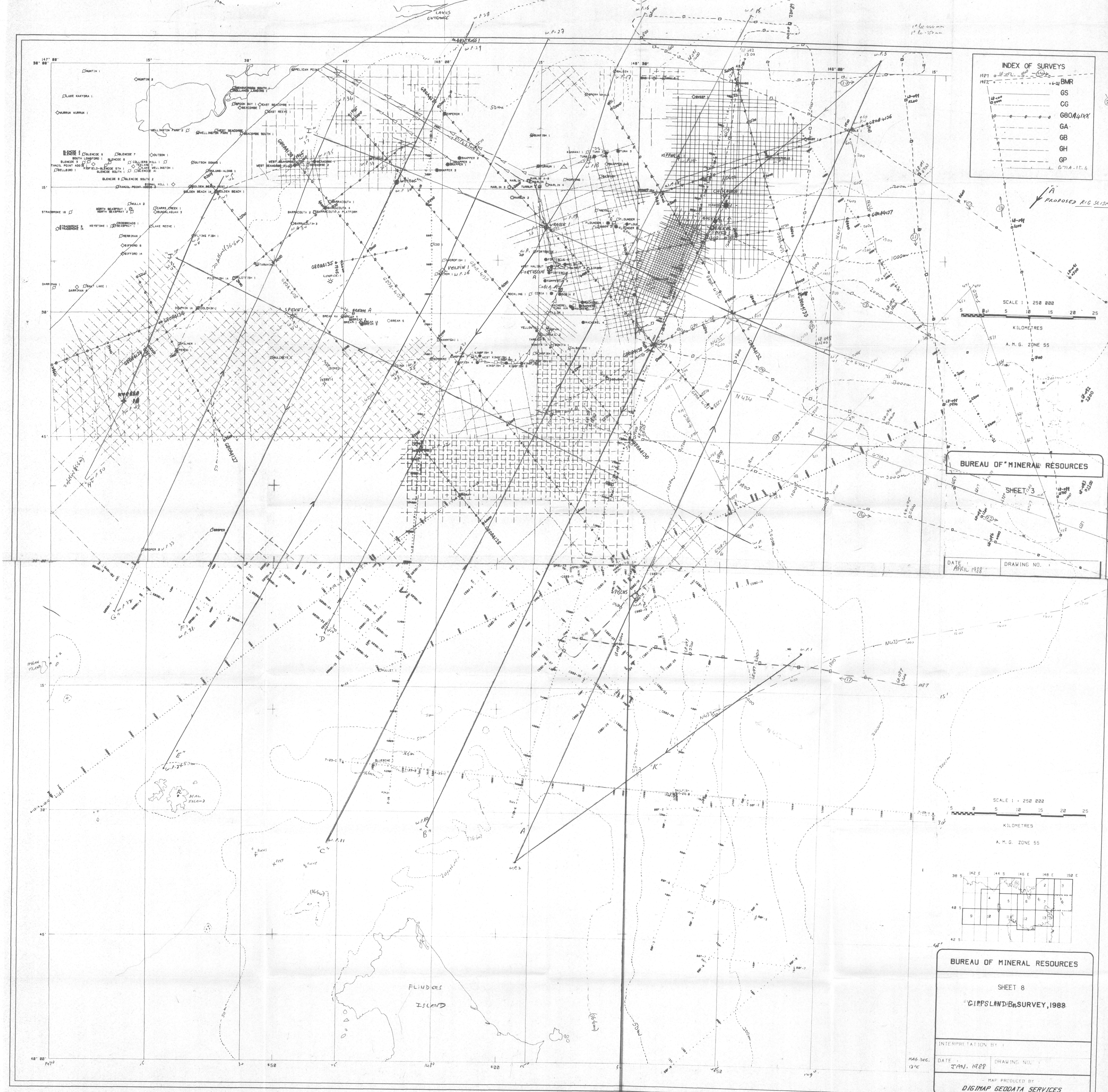

Figure 20. Track map, Gippsland Basin.
To accompany Record 88/18.