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

OPERATIONAL REPORT FOR SURVEY 90

by

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SUMMARY

The Gippsland Basin accounts for the majority of petroleum production in Australia. Petroleum exploration within the Gippsland Basin has been mainly focussed on major anticlines formed by compressional reactivation of previous normal fault systems and erosion at the Early Tertiary "top Latrobe" unconformity. To a much lesser extent exploration has investigated "intra-Latrobe" traps. Prior to this study no modern regional and deep-crustal seismic reflection data existed to investigate the structural development of the basin and 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, and no prior regional deep-crustal seismic reflection data were available.

Analysis of regional seismic data collected by BMR in 1982 led Etheridge et al. (1985) to suggest that the Bass and Gippsland Basins were formed by NNE-SSW lithospheric extension, probably in the Early Cretaceous; and that a reactivation of these basin-forming extensional structures, particularly transfer faults orthogonal to the rift faults, may have had a significant influence on petroleum migration and accumulation higher in the stratigraphic section. Williamson et al. (in press), building on detailed mapping in the Otway and Bass Basins, suggest that an earlier phase of NNW-SSE Lower Cretaceous rifting also occurred throughout Bass Strait.

This operational report describes the second of two cruises undertaken in the Gippsland/ Bass region. It is presented in the same format and draws somewhat upon the report of the first cruise, BMR marine survey 89, in November - December 1988 (Willcox and Colwell, 1989), which began the study and collected two of the eleven traverses in the Gippsland Basin. The second cruise in March - April 1989 completed the data acquisition in the Gippsland Basin and collected two of the proposed lines in the Bass Basin. The cruise aimed to:

- (i) improve definition of the deep structure of the Gippsland and Bass Basins using basin-wide deep seismic (14 seconds) transects,
- (ii) develop 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.

This second cruise (Survey 90) was broken into four parts:

- (i) Equipment testing involving the measurement of drift on a HIfix radio navigation system, and testing and utilisation of IFP electronics for the deep recording objectives of the program,

(ii) Recording of approximately 1300 km of regional deep-crustal seismic reflection profiles in the Gippsland Basin (14s records, 52.4 litre air-gun array).

(iii) Recording of 300 km of regional deep-crustal seismic reflection profiles in the Bass Basin (14s records, 52.4 litre air-gun array).

(iv) Recording of associated refraction records at nine onshore locations on the margins of the Gippsland and Bass Basins.

INTRODUCTION

Although the Gippsland basin, Australia's principal liquid petroleum province, has been extensively explored during the last twenty five years (see Figs. 1, 2 and 3) 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 within the Latrobe Group. 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. 4) and coals within that Group also disperse seismic energy making collection of deeper data difficult.

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), along with selected company data, were reviewed by Etheridge and others (1985), who suggested a working model in which the three Bass Strait basins were initiated by north-northeast to south-southwest lithospheric extension, largely during the Early Cretaceous (Figs 5 and 6). The data from the survey and industry data were interpreted by Williamson and others (1985, 1987, 1988) for the Bass Basin and features of the resulting map at top Otway Group (Fig. 7) show some correspondence to elements of the model. 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. 8). These authors 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 current study (Rig Seismic Surveys 82 & 90) is designed (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), to develop other models if required, 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 two cruise study it is proposed that approximately 2500 - 3500 km of high-quality 96-channel seismic reflection data together with ship-shore seismic refraction data be collected (Figs. 9 & 10). These data will complement data collected aboard the Rig Seismic over the eastern part of the Gippsland Basin in 1987 (Colwell & others, 1987), over the adjacent Otway-West Tasmania margins in early 1988 (Exon & Lee 1988) and over the whole Otway margin (Exon and Williamson, 1987).

This report outlines the operations for Cruise 2 (Survey 90) which departed from Melbourne on 14th March 1989 and finished in Newcastle on 12th April 1989.

GEOLOGICAL SETTING

Offshore Gippsland Basin

The geology, regional setting, and evolution of the offshore Gippsland Basin, Australia's most prolific oil and gas province, 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), Clark & Thomas (1988) and Rahmanian & others (in press). 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 (Weissel & Hayes, 1977; Shaw,1978, 1979; Jongsma & Mutter, 1978 ; Roeser & others, 1985).

Except for its eastern flank the basin is 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. 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 developed.

Marine conditions were established over the basin in the Early Oligocene, although shallow-marine conditions and westerly prograding shorelines existed prior to this in places, 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 Oligocene 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. All of these major structures have now been drilled forcing explorationists to concentrate on fault dependent and combined structural/stratigraphic traps.

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 accommodarion faults active principally during extention and basin subsidence (Early Cretaceous to Early Eocene) 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 accommodation faults (Threlfall & others, 1976; Etheridge & others, 1985; Thompson, 1985). Many of the anticlinal structures contain large hydrocarbon accumulations within coarse clastics at the top of the Latrobe Group.

Recently, Lowry (1987, 1988) has suggested that the unconformity which is widely interpreted on the northern margin of the basin 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 have been discussed by Weeks & Hopkins (1967), Richards & Hopkins (1969), Robinson (1974), Brown (1976), Robertson & others (1978a), Moore & others (1984), Smith (1986), Williamson & others (1985, 1986, 1987, 1988) 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. 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, seismic reflection studies (Williamson and others, 1987, 1988) suggest that significant structural and stratigraphic prospects for petroleum exploration occur at Paleocene, Cretaceous, and possibly 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), and within the basal Otway Group on the basin margins. The latter play is similar to that in the equivalent Pretty Formation of the Otway Basin (Williamson and others, 1987, 1988).

Broad delineation of the deep structure in this basin suggested to Etheridge and others (1984, 1985) that major Early Createous extensional normal faults segmented by contemporaneous transfer faults under lie the central and northwestern parts of the basin (Fig. 6). Detailed mapping at various levels within the basin by Williamson and others (1987, 1988; Fig. 7) shows greater complexity but includes features that could correspond to some elements of the above analysis.

CRUISE OBJECTIVES

The objectives of the Gippsland/Bass program 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 the latest extensional model for formation of the basins (Etheridge and others, 1984), the direction of extension is believed to be 027 degrees, and detachment faults and transfer faults are defined.
- 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.
- To make a regional study of the key seismic horizons, isopachs and facies variations throughout the basin.

CRUISE PLAN

Seismic Reflection Work Planned for Cruises 82 and 90

Gippsland Basin:

It was proposed to record eight regional lines (Fig. 9) across the strike of the basin, and two or three tie-lines along strike, within the basin depocentre. A further line was planned to cross the southeastern margin of the basin supplementing data collected aboard Rig Seismic on the basin's eastern margin in 1987. Total coverage planned for the Gippsland Basin, excluding positioning and 'link lines', was about 1650 km.

The planned cross-strike ('dip') lines trend 027 degrees parallel to the postulated direction of extension, and extend beyond the limits of the Latrobe Group and the basin-boundary faults. The nominal line-spacing was approximately 15 km; however, this was modified in many areas to enable effective well-ties, avoid production platforms, and to position lines within extensional compartments between postulated transfer faults.

Bass Basin:

It was planned to record four dip lines across the main basin forming structures (Fig. 10). The lines were to cross four of the major fault-bounded compartments interpreted by Etheridge & others (1984, 1985). In addition, one WNW - ESE tie-line was to be run along the central axis of the basin. Total coverage within the basin, excluding link lines, was to be about 800 km.

Reflection Cable Geometry and Recording Parameters:

The recording geometry and parameters were discussed at length in Willcox & others (1988). It was concluded that the cruise objectives could ideally be met by use of a 3600m, 96-channel, 37.5m-group cable, used for 48-fold recording with a 2 or 4 millisec sampling interval to give a record length of up to 16 seconds. During Cruise 90 record lengths of 14 seconds were achieved with a sampling interval of 4 milliseconds. These were judged adequate to meet cruise objectives. In all other respects cable geometry and recording parameters were those considered ideal.

Onshore Refraction Recording

As vertical reflection profiling may not unequivocally resolve the deeper structure under the basins, we planned to record long-offset seismic refraction/wide-angle reflection data concurrently with the conventional reflection program. This was expected to provide information on the lower crust and upper mantle, both below and beyond the boundaries of the survey.

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

Digital recorders were developed to record the air-guns semi-continously while the ship completed each traverse.

The noise level was expected to be high, and development of special processing techniques to enhance the signal-to-noise would be undertaken. The large number of shots recorded at each recording site, and close shot spacing, would allow various stacking procedures to be applied.

OPERATIONS

The work carried out during the cruise accomplished most of the cruise plan. The Gippsland Basin operation added nine regional seismic reflection lines to the two collected during Cruise 82, completing that program. The Bass Basin operation collected two lines and was shortened to 300 kms, because of time lost from waiting on weather in order to achieve low noise levels during the Gippsland component, and cable reconstruction after it was cut by a Chinese bulk carrier. Details of the equipment, cable configuration, shooting and recording parameters, seismic lines and waypoints are given as Appendices 1 to 6, respectively. An abridged seismic log is given as Appendix 7.

During the early part of the cruise time was taken up with the final testing of equipment needed to meet the requirements of precision navigation (particularly over well sites) and deep seismic recording. This testing included:

- Measurement of the 'drift' on three HIFIX stations installed on the Victorian coast, by comparing responses from HIFIX and miniranger stations.
- Complete inflation of the seismic streamer with SOL-T (cable fluid) and accurate leading, in order to induce positive boyancy and minimise noise levels.
- Completion of successful testing and installation of new IFP (instantaneous floating point) instrumentation. This reduced instrumental noise levels by an order of magnitude.

At the end of the cruise a tie was made to HIFIX and miniranger stations on the Victorian coast to help resolve drift by the atomic standards in the HIFIX system during the time of the cruise.

SYSTEMS PERFORMANCE

Non-seismic

The non-seismic data acquisition system (DAS) ran for the duration of the cruise with 4 short breaks in data collection. These 4 breaks, caused by memory parity error computer crashes, resulted in a total of 35 minutes of non-seismic data not being recorded over the cruise length of 28 days.

Navigation

Positioning of the ship is derived from three independent systems; NavStar Global Positioning System (GPS), dead reckoning with updates from the U.S. Navy Navigation Satellite System (commonly known as the Transit Satellite System), and radio navigation using Decca Hifix 6 and Motorola Miniranger III. Hifix and miniranger locations are given as Appendix 8.

NavStar Global Positioning System

The onboard Magnavox T-Set receiver using the GPS coarse/acquisition (C/A) code gives continuous absolute positioning within 35 metres rms under optimum conditions.

However, the system is in the experimental stage with only six of a proposed 18 satellites in functioning orbit. Limited satellite visibility results in GPS positioning being possible for approximately 7 hours per day. This period can be extended to 10 hours in the two satellite mode by using an atomic frequency standard. The success of two satellite mode depends entirely upon an acceptable frequency bias between the satellite transmissions and the atomic standard being determined during the previous period of three to four satellite visibility.

Experimentation with the GPS receiver while berthed has shown two satellite positioning to be unreliable. Investigation prior to this cruise in Port Melbourne has shown the onboard rubidium standard 5 MHz signal used to clock aid the GPS receiver suffers with interference. Strong inductive forces acting on the connections between the rubidium standard and the GPS receiver seriously affect the 5 MHz reference signal going into the GPS receiver and thus utility in two-satellite mode.

Apart from the problem outlined above, the GPS receiver worked well during the cruise. The satellite constellation was subject to experimentation with the GPS control segment more frequently than usual during the final fortnight of the cruise. This resulted in an occassional slight reduction in the period of visibility of 3 or 4 satellites.

Dead Reckoning System

Two independent systems incorporating gyro compass, dual axis sonar-doppler and Transit satnav receiver provide basic dead reckoning for periods where the other navigation systems prove inadequate. The primary dead reckoning system of SGBrown gyro, Magnavox MX610D sonar-doppler and MX1107RS dual channel satnav receiver provides one of the best available positioning systems of this type. A lower grade system of Robertson gyro, Raytheon DSN450 sonar-doppler and MX1142 single channel satnav receiver is used as a backup.

The sonar-doppler systems performed well for the majority of the cruise with most dead reckoned positions being within 0.2 nautical miles from Transit satellite fix positions. The velocity determinations from the sonar-doppler systems deteriorated during the period of rough weather encounterd in the Gippsland Basin, but the ship was not recording seismic at that time and radio navigation provided good positioning in that interval. The sonar doppler systems operated in bottom lock mode for most of the survey except in the deep water of the extreme east of the Gippsland segment.

Hifix

A Decca Hifix 6 radio navigation chain was operated for the entire cruise with consistent results. The locations of the stations are given in Appendix 8. BMR Marine has been experimenting for some time to extend the effective range of the

Hifix system by operating it in circular mode with all stations slaved to their own rubidium atomic standard. During this cruise, four shore stations plus the shipboard receiver were slaved to their own rubidium atomic standard.

The drift rate of the individual Hifix stations rubidium standards affected the positions derived from the Hifix chain during the cruise. Due to operational constraints it was not possible for the ship to remain stationary and observe all rubidium standard drifts over an extended period. In order to determine the rubidium standard drift rate, software was developed prior to the cruise that compared observed Hifix ranges to theoretical ranges from GPS or Miniranger derived positions. Although such a comparison must include error in the GPS/Miniranger derived position, the calculated drift rates were moderately consistent.

The observed drift rates were entered into the navigation computer so the calculated Hifix position had drift compensation included.It appeared from comparison of Hifix positions and Transit sat fix positions that the drift rates had subtle variation at night, possibly due to the diurnal variation in magnetic field intensity. Poor Miniranger reception precluded the accurate calculation of drift rates observed at night.

The variations in drift rates at night, however, caused the calculated Hifix position to slowly diverge from the true position. When four satellite GPS coverage resumed the following day, the Hifix position was of the order of 0.1 nautical miles out. The Hifix position would be strapped back using offset adjustment to the 4 satellite GPS position or Miniranger position if available and then be allowed to slowly diverge across the next 24 hours.

The reception of the Hifix shore station transmissions was excellent, with at least 2 shore stations being received at all times. The Hifix station at Seaspray was not needed for positioning in the Gippsland segment. The stations at Golden Beach, Woodside Beach and Lake Tyers were selected on the 3 channel Hifix receiver onboard the ship for all of the Gippsland program performed after GMT day 78.

Once seismic operations had ceased in the Gippsland Basin, the Hifix transmitters at Seaspray and Dalray Beach were relocated to Phillip Island and Cape Liptrap. The drift values of the rubidium standards used for compensation were kept the same when the transmitters were moved to the Bass Basin sites. Observations of the drift rates at the transmitters that were moved indicated very erratic drift rates for the Phillip Island transmitter. The drift rates of the stations at Cape Liptrap and Lake Tyers remained fairly consistent.

Miniranger

A four code Miniranger system was installed on board the ship for the cruise. The system was set up with the four Miniranger transponders placed adjacent to the Hifix shore stations (Appendix 8). The objectives of running the Miniranger chain were to allow precise positioning in near shore areas, provide a means of recovering Hifix range lanes, and examining Hifix atomic standard drift rates.

System tests performed with the Miniranger while berthed at Port Melbourne revealed offsets with two of the transponders used. The presence of large steel sheds adjacent to the ship while berthed suggested the possibility of interference with radio wave propagation, and so no attempt was made to determine the size of the offsets while berthed. In order to calculate offsets, the four Miniranger transponders were set up together on a test site near Golden Beach. From a period of observations (077:0400 to 077:0800) using the transponder ranges, offsets of minus 10 metres for the code 2 transponder and plus 50 metres for the code 3 transponder were calculated.

The reception of the Miniranger shore transponders was extremely poor througout the survey. Thorough testing of the Miniranger equipment on the ship did not reveal any faults, and it appeared the poor reception was largely a function of atmospheric interference and possible alignment and height problems of the transponders onshore while in Gippsland. When the transponders were relocated to Phillip Island and Cape Liptrap for the Bass segment, the reception remained poor.

In an attempt to accurately determine the offsets in the Miniranger system, a further calibration was attempted when the ship docked in Newcastle. The transponders were set up a distance of 2313.5 metres from the ship (distance determined using laser electronic distance measuring equipment), and the ranges returned from the transponders recorded every 10 seconds over a period of 2 hours.

The ranges observed during this period of observation were highly variable. The code 1 transponder returned an average range of 2292 metres with an rms of 7 metres. The code 2 transponder returned an average range of 2285 metres but was very noisy, with an rms of 28 metres. To test if these offsets and noise were inside the ship receiver unit or the shore transponders, the codes of the shore transponders were swapped. This switch made no difference to the results on the code 1 transponder, although the code 2 transponder slightly decreased its average to 2280 meters and the code 2 rms dropped to 11 metres.

Tests with the code 3 and code 4 transponders returned average ranges of 2336 metres for code 3 and 2291 metres for code 4. The rms noise levels of the ranges measured were 20 metres for code 3 and 13 metres for code 4. Similar values were recorded when the codes of the transponders were swapped.

The ranges returned during this calibration check indicate that code 1 had an offset of -20 metres, code 2 had an offset of approximately -31 metres, code 3 has a consistent offset of +23 metres and code 4 has an offset around -21 metres. The noise levels observed during the calibration were far above those often quoted when using Miniranger systems (1 in 10000). The reasons why the Miniranger results obtained in Newcastle were so noisy are unclear but the problem possibly lies with the modifications performed on the receiver to allow the 2 code receiver to get ranges from 4 codes.

Bathymetry

Bathymetric data was obtained from a Raytheon 12 KHz echo sounder. This echo sounder was modified prior to the cruise to operate in "pinger" mode instead of correlator mode. These modifications resulted in the echo sounder operating in pinger mode, but all digital depth data obtained on the modified 12 KHz system suffered from a constant 48.3 metre offset.

Sub bottom profiling was attempted using a Raytheon 3.5 KHz echo sounder. The penetration achieved with this system was disappointing. The system was of use in providing a second independent water depth.

Gravity

Gravity data was obtained using a Bodenseewerk KSS-31 Gravity metersensor. The processed gravity data should have an accuracy of approx. 0.5 milligal. Gravity and other non-seismic data channels are detailed in Appendix 9.

Seimic

Software

The need to have a 37.5 m shot interval and the longest possible record length necessitated modifications to the seismic system software prior to the cruise to increase the possible cycle time. A number of changes were made both to decrease the time required by some software routines and to improve the seismic displays and to further aid the operator in monitoring the system.

The software which reads the Syntron bird controller was further modified and now reads depths and wing angles from 22 birds in up to 180 msec. The new gun controller software, implemented on the previous Gippsland Basin cruise, was further modified to monitor autofires of the airguns. The software controlling the storage CRO display and the Epson seismic monitors was updated to display instantaneous floating point (IFP) -recorded data in integer form. To simplify system testing the amplifier testing was brought under computer control and to aid the system operator in quickly determining faults a number of error flags were incorporated such as magnetic tape off-line, parity error. These flags now appear as messages on the operator console. Some unused and redundant routines were removed to provide space for the modifications.

All the software modifications worked well and with a shot interval of 18.2 seconds, 14 second records with a sampling rate of 4 milliseconds were recorded with no cycle time problems. The data recording and display took on average 3.5 sec.

Hardware

The survey was conducted using the new E.S.U. designed and developed Instantaneous Floating Point card (I.F.P.) in the Pheonix 6000 series high level analogue data acquisition system. The I.F.P. card was developed to increase the dynamic range of the Marine Seismic system from 90db to 120 db. The I.F.P. card replaces the Integer Analogue to Digital card in the Pheonix. The I.F.P. card was tested under survey conditions and the total noise level figures on the Seismic Data acquisition system was within the required specifications and comparable to that of a digital cable. Data acquired from the I.F.P. card was sent to Canberra for further analysis.

Only minor problems occurred with the seismic cable and gun arrays. The depth controllers gave excellent results. Channel 40 was affected by low frequency noise, possibly from the adjacent depth controller. Channel 82 showed reversed polarity for the entire survey. Channels 27 and 88 were dead for the entire survey and other channels became excessively noisy during the survey, namely channels 15,73 and 75.

On day 087 a ship passed two miles astern of Rig Seismic and severed the cable. All of the cable was retreived however one active section and one bird were destroyed. The four active sections on the severed part of the cable attached to the tailbouy sank approximately 100m. These may have been damaged and were replaced. The remainder of the survey was carried out with 21 depth controllers.

The gun arrays performed very well during extremely good weather and not much time was lost in maintenance under these conditions. All gun sensors were tested and operational prior to the survey, however the starboard array sensors gave problems with starboard sensors 2 and 4 dead by completion of the survey. The gun depth transducers appeared to calibrate correctly on deck but when deployed gave erroneous readings. Rope length to floating bouys attached to the gun chain indicated, however, that gun depths were approximately 10m.

REFRACTION RECORDING

The refraction study of the Gippsland and Bass Basins was undertaken jointly by BMR and the Department of Earth Sciences, Monash University. Seismic recorders were deployed on land to record long offset wide-angle reflection and refraction data using the Rig Seismic's airgun array as the energy source. The objective of the study was to provide information which, when combined with the reflection profiling, would promote a better understanding of the tectonic history of these basins. This includes information on the deep structures and velocities beneath the basins and their margins, the average total thickness of the basin sediments, the crustal thickness, and the relationship between the crustal structure of Victoria and Tasmania.

Recording Equipment

Six BMR analogue recorders were run continuously during the survey. A digital recorder from Monash University was operational for selected lines only. The analogue recorders were four-channel FM tape recording systems with a maximum continuous recording period of 16 days. The output from a single Willmore Mk II seismometer with a natural frequency of 1.5 Hz was filtered 4-100 Hz and recorded at two gain levels. Also recorded were a coded clock signal and radio time signals derived from the VLF Omega Navigation broadcast.

The digital recorder was developed at Monash University, and is based on a portable PC/AT with a 20 megabyte hard disc and analogue-to-digital converter. The seismometer, filters and amplifier were similar to the analogue recorders. The signal was digitized with a sample interval of either 10 or 20 msec. Accurate timing was maintained by reference to the Omega radio time signals. Data was transferred from the disc to a tape streamer periodically.

Energy Source

The Rig Seismic's 3200 cubic inch (52.4 litre) airgun array operating at 2000 psi was used as the energy source during the normal profiling operations. The firing rate was either 18.2 or 19.2 seconds, with a ship speed of 4.0 or 3.8 knots respectively, giving a shot interval of 37.5 metres. The shot times were obtained in Universal Time by synchronising the ship's Data Acquisition System clock with Omega radio time signals.

Location of Onshore Stations.

During the Gippsland cruise analogue recorders were operated continuously at four locations in Victoria: Wilson's Promontory, Stradbroke West, Toongabbie, and 20 km north of Orbost (Appendix 10).
A digital recorder was deployed on Deal Island during part of Line 2 and during Line 7. During the Bass cruise, six analogue recorders were operational at Wilson's Promontory, Stradbroke West, Toongabbie, Mirboo, Cape Liptrap, and Cape Paterson. A digital recorder was deployed at Stanley, northwest Tasmania. Thus potentially all shots in the Gippsland and Bass Basins were recorded by land stations.

Sonobuoys

Seven sonobuoys were deployed in the Gippsland Basin and three in the Bass Basin (Appendix 11). All were REF-TEK-2 sonobuoys with delayed (approximately 25 minutes) hydrophone deployment to 60 feet. The signal was received on board ship by a Yaesu VHF/UHF receiver. They provide velocity data at shallow to intermediate depths along the traverses to supplement the deep velocity data from the shore stations, and provide some constraints on traverses that were not reversed. Good first arrivals were observed on average to about 40 km, with a maximum of over 60 km. Wide-angle reflections from a deep boundary, possibly the Moho, were recorded by the latter sonobuoy

ACKNOWLEDGEMENTS

We acknowledge the co-operation and assistance of Henry Foreman (Master) and the crew of the Rig Seismic during this cruise. A list of ship's crew and scientific staff is given as Appendix 12.

Co-operative arrangements with the School of Earth Sciences, Monash University, enabled successful completion of the refraction experiment.

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APPENDIX 1: List of Geophysical Equipment

<u>Seismic System</u>

Streamer: 3600m Teledyne hydrophone analogue streamer configured as 96 x 37.5m groups.
- 30 hydrophones per 37.5m group
- 5V/bar sensitivity
- ~15 microvolts noise; maximum ambient at 5 knots
- Syntron RCL-3 individually adressed cable levellers

Source Array:
- 52.4/73.4 litre (3200/4480 cubic inch), 28-element tuned Texas Instruments air-gun array; 20 elements (3200 cubic inch) equally divided into two strings
- Teledyne gun signature phones, gun depth sensors, and I/O SS-8 shot sensors
- 4 x Price A - 300 compressors, each rated at 300scfm @ 2000 psi

Recording
- BMR designed and built seismic acquisition system based on Hewlett-Packard minicomputers
- 96 channel digitally controlled preamp/filters
- bit accuracy
  12 bit floating point with 4 bit dynamic accuracy
- 6250 bpi Telex tape drives
- data read after write in demultiplexed SEG-Y format
- 4 msec sampling with 96 channels
- streamer noise, leakage, and individual group QC
- source array timing QC
- recording oscillator and 4 seismic monitor QC

<u>Bathymetric System</u>
- Raytheon deep-sea echo-sounder; 2 kW output at 3.5 kHz

<u>Gravity Meter</u>
- Bodenseewerk Geosystem KSS - 31 marine gravity meter

<u>Navigation Systems</u>

GPS System - Magnavox T-Set GPS navigator

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

Secondary Transit System
- Magnavox MX1142 single channel satellite receiver
- Raytheon DSN450 dual-axis sonar doppler speed log
- Robertson gyrocompass

Radio Navigation
- Decca HIFIX-6
- Motorola miniranger

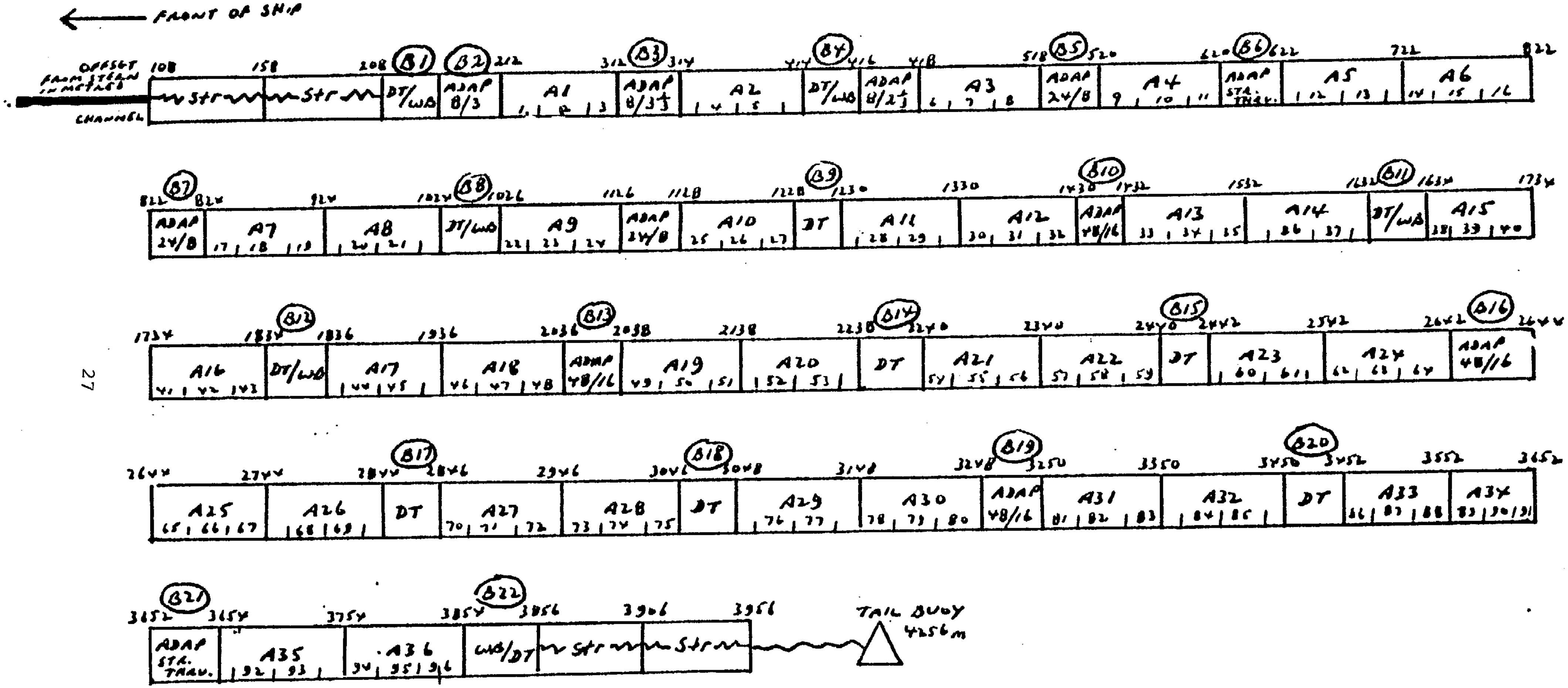
<u>Data Acquisition System</u>
- data acquisition system built around Hewlett-Packard 2117 F-Series minicomputer, with tape drives, disc drives, 12" and 36" plotters, line printers and interactive terminals

APPENDIX 2: Cable Configuration First Streamer

DES'	#	LEN	SERIAL	WEIGHTS KG BACK						FRONT	TOTAL KG	SOL-T ADDED	COMMENT
LEADER		108											
STRETCH		50											
STRETCH		50											
ADAPTOR		2	88/102										
DT & WB		2	88/026										BIRDS 1 & 2
ACTIVE	1	100	88/008	1.5	2.0	2.0	2.0	2.0	2.0	1.5	13.0	36	NEW SKIN
ADAPTOR		2	88/104										BIRD 3
ACTIVE	2	100	84/029	1.5	0.5	1.5	0.0	1.5	0.5	1.5	7.0	12	
ADAPTOR		2	88/113										BIRD 4
DT													
ACTIVE	3	100	84/006	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	20	
ADAPTOR		2	88/117										BIRD 5
ACTIVE	4	100	88/026	1.0	1.5	1.0	0.0	0.5	1.5	1.0	7.0	12	
ADAPTOR			88/041										BIRD 6
ACTIVE	5	100	88/035	1.0	1.5	1.5	0.0	1.5	1.5	1.0	8.0	16	
ACTIVE	6	100	86/007	1.0	1.5	1.5	0.0	1.5	1.5	1.0	8.0	16	
ADAPTOR		2	88/115										24>8
ACTIVE	7	100	86/002	1.0	1.5	1.5	0.0	1.5	1.5	1.0	9.0	20	
ACTIVE	8	100	83/104	0.5	0.5	1.0	1.5	1.0	1.5	0.5	6.5	20	
DT & WB		2	88/005										BIRD 8
ACTIVE	9	100	84/021	0.5	0.5	1.0	1.0	1.0	0.5	1.0	5.5	8	
ADAPTOR		2	88/116										
ACTIVE	10	100	84/028	0.5	1.0	1.0	1.0	1.0	1.0	1.0	6.5	12	
DT		2											BIRD 9
ACTIVE	11	100	88/001	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	16	
ACTIVE	12	100	88/004	1.5	2.0	1.5	1.5	1.5	1.5	1.5	11.0	20	
ADAPTOR		2	88/107										48>16 BIRD 10
ACTIVE	13	100	88/009	1.5	1.0	1.5	1.5	1.5	1.5	1.0	9.5	16	
ACTIVE	14	100	88/011	1.5	2.0	1.5	1.5	1.5	1.5	1.5	11.0	20	
DT & WB		2	034										BIRD 11
ACTIVE	15	100	88/010	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	16	
ACTIVE	16	100	88/007	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	16	
DT & WB		2	583-014-003										BIRD 12
ACTIVE	17	100	88/003	1.5	1.5	1.5	2.0	1.5	1.5	1.5	11.0	20	
ACTIVE	18	100	014-87	1.5	2.0	2.0	2.0	2.0	2.0	1.5	13.0	36	NEW SKIN
ADAPTOR		2	88/109										48>6 BIRD 13
ACTIVE	19	100	88/005	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	8	
ACTIVE	20	100	87/011	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	8	
DT		2	032										BIRD 14
ACTIVE	21	100	153-09	1.0	1.5	1.5	1.5	1.5	1.5	1.0	9.5	12	
ACTIVE	22	100	153-12	1.0	1.5	1.0	1.5	1.0	1.5	1.0	8.5	8	
DT		2	014										BIRD 15
ACTIVE	23	100	88/012	1.0	1.5	1.5	1.5	1.5	1.5	1.5	10.0	20	NEW SKIN
ACTIVE	24	100		1.0	1.0	1.5	1.5	1.5	1.0	1.0	8.5	8	
ADAPTOR		2	88/106										48>16 BIRD 16
ACTIVE	25	100	88/043	1.5	1.5	1.5	1.5	1.5	1.5	1.0	10.0	8	
ACTIVE	26	100	88/019	1.0	0.5	1.0	1.5	1.0	1.0	1.0	7.0	8	
DT		2	017										BIRD 17
ACTIVE	27	100	047-22	1.0	0.5	0.5	1.5	1.0	1.5	1.0	7.0	4	
ACTIVE	28	100	014-05	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.0	28	NEW SKIN
DT		2	036										BIRD 18
ACTIVE	29	100	88/001	1.5	1.5	2.5	2.5	2.5	2.0	1.5	15.0	8	
ACTIVE	30	100	84/041	1.5	2.0	2.0	2.0	2.0	2.0	2.0	13.5	4	
ADAPTOR		2	88/105										48>16 BIRD 19
ACTIVE	31	100	88/002	1.5	1.5	2.0	2.0	2.0	1.5	1.5	12.0	8	
ACTIVE	32	100	84/030	1.0	1.0	1.5	1.0	1.5	1.0	1.0	4.5	4	
DT		2	009										BIRD 20
ACTIVE	33	100	86/038	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
ACTIVE	34	100	84/018	2.0	1.0	2.0	2.0	2.0	1.0	1.5	11.5	4	
ADAPTOR		2	048										BIRD 21
ACTIVE	35	100	83/009	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	4	
ACTIVE	36	100	83/022	1.5	1.0	1.5	2.0	2.0	1.0	1.5	10.5	0	
DT & WB		2	028										BIRD 22
STRETCH		50											
STRETCH		50											
TAIL ROPE		300											

SURVEY 90 ... FIRST CABLE

96 CHANNEL, 3600m ACTIVE, 37.5m GROUPS



A1 : Active section (100m long)
Str : Stretch section (50m long)
ADAP: Adaptor section (2m long)
(B1) : Depth controller, bird
DT/WB: Depth transducer / waterbreak section (2m long)
DT : Depth transducer section (2m long)
TL : Tow leader.

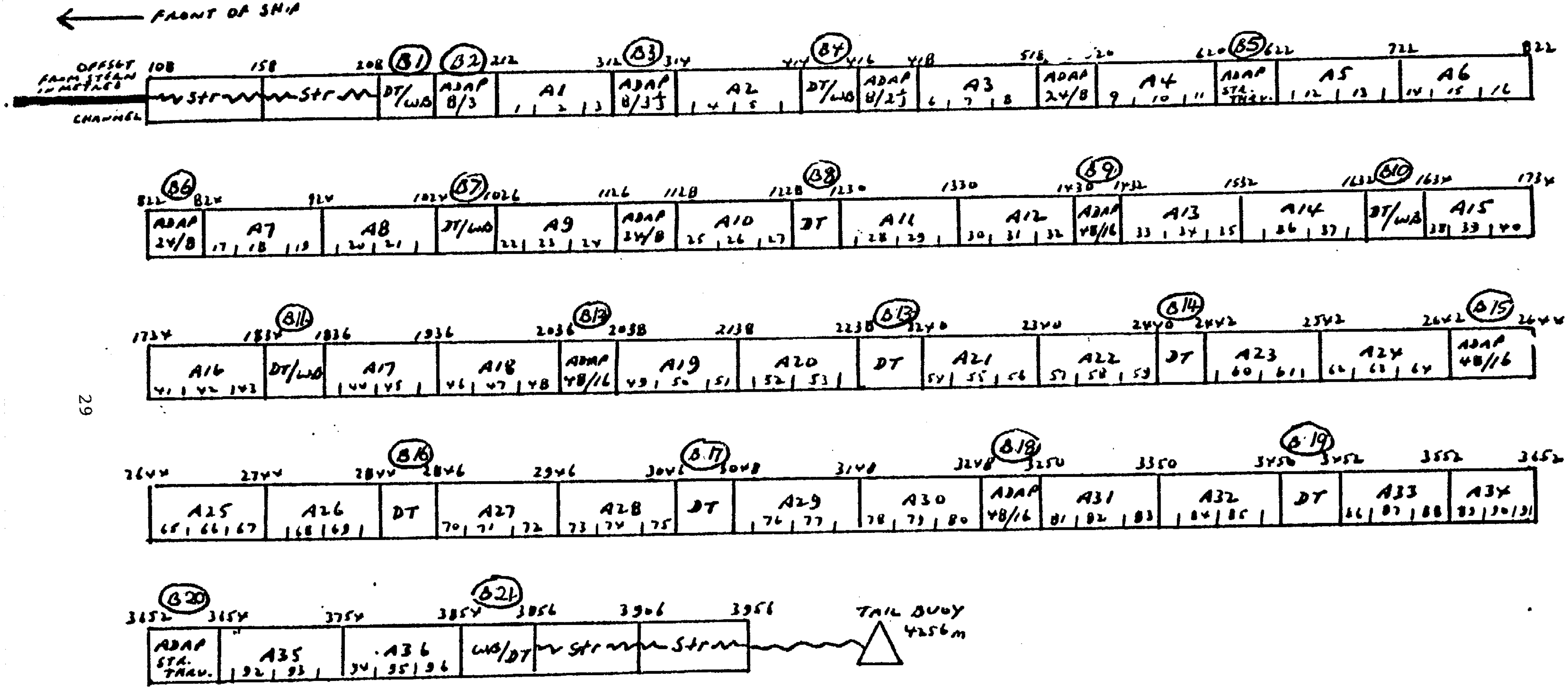
Offsets with 108m leader out over stern:
channel 1: 231m behind ship, 206m behind guns

APPENDIX 3: Cable Configuration Second Streamer

DES'	LEN #	SERIAL	WEIGHTS KG BACK						FRONT	TOTAL KG	SOL-T ADDED	COMMENT
LEADER	108											
STRETCH	50											
STRETCH	50											
ADAPTOR	2	88/102										
DT & WB	2	88/026										BIRDS 1 & 2
ACTIVE 1	100	88/008	1.5	2.0	2.0	2.0	2.0	2.0	1.5	13.0	0	NEW SKIN
ADAPTOR	2	88/104										BIRD 3
ACTIVE 2	100	84/029	1.5	0.5	1.5	0.0	1.5	0.5	1.5	7.0	0	
ADAPTOR	2	88/113										BIRD 4
DT	2											
ACTIVE 3	100	84/013	1.0	2.0	1.5	2.0	1.0	2.0	1.0	10.0	0	
ADAPTOR	2	88/117										
ACTIVE 4	100	88/026	1.0	1.5	1.0	0.0	0.5	1.5	1.0	7.0	0	
ADAPTOR		88/041										BIRD 5
ACTIVE 5	100	88/035	1.0	1.5	1.5	0.0	1.5	1.5	1.0	8.0	0	
ACTIVE 6	100	86/007	1.0	1.5	1.5	0.0	1.5	1.5	1.0	8.0	0	
ADAPTOR	2	88/115										24>8 BIRD 6
ACTIVE 7	100	86/002	1.0	1.5	1.5	0.0	1.5	1.5	1.0	9.0	0	
ACTIVE 8	100	83/104	0.5	0.5	1.0	1.5	1.0	1.5	0.5	6.5	0	
DT & WB	2	88/005										BIRD 7
ACTIVE 9	100	84/021	0.5	0.5	1.0	1.0	1.0	0.5	1.0	5.5	0	
ADAPTOR	2	88/116										
ACTIVE 10	100	84/028	0.5	1.0	1.0	1.0	1.0	1.0	1.0	6.5	0	
DT	2	SN/021										BIRD 8
ACTIVE 11	100	88/001	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
ACTIVE 12	100	88/004	1.5	2.0	1.5	1.5	1.5	1.5	1.5	11.0	0	
ADAPTOR	2	88/107										48>16 BIRD 9
ACTIVE 13	100	84/101	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
ACTIVE 14	100	88/011	1.5	2.0	1.5	1.5	1.5	1.5	1.5	11.0	0	
DT & WB	2	034										BIRD 10
ACTIVE 15	100	88/010	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
ACTIVE 16	100	88/007	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
DT & WB	2	583-014-003										BIRD 11
ACTIVE 17	100	88/003	1.5	1.5	1.5	2.0	1.5	1.5	1.5	11.0	0	
ACTIVE 18	100	014-87	1.5	2.0	2.0	2.0	2.0	2.0	1.5	13.0	0	NEW SKIN
ADAPTOR	2	88/109										48>6 BIRD 12
ACTIVE 19	100	88/005	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
ACTIVE 20	100	87/011	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
DT	2	032										BIRD 13
ACTIVE 21	100	153-09	1.0	1.5	1.5	1.5	1.5	1.5	1.0	9.5	0	
ACTIVE 22	100	153-12	1.0	1.5	1.0	1.5	1.0	1.5	1.0	8.5	0	
DT	2	014										BIRD 14
ACTIVE 23	100	88/104	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	NEW SKIN
ACTIVE 24	100		1.0	1.0	1.5	1.5	1.5	1.0	1.0	8.5	0	
ADAPTOR	2	88/106										48>16 BIRD 15
ACTIVE 25	100	88/043	1.5	1.5	1.5	1.5	1.5	1.5	1.0	10.0	0	
ACTIVE 26	100	88/019	1.0	0.5	1.0	1.5	1.0	1.0	1.0	7.0	0	
DT	2	017										BIRD 16
ACTIVE 27	100	88/102	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
ACTIVE 28	100	88/800	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	NEW SKIN
DT	2	036										BIRD 17
ACTIVE 29	100	88/001	1.5	1.5	2.5	2.5	2.5	2.0	1.5	15.0	0	
ACTIVE 30	100	84/041	1.5	2.0	2.0	2.0	2.0	2.0	2.0	13.5	0	
ADAPTOR	2	88/105										48>16 BIRD 18
ACTIVE 31	100	88/002	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
ACTIVE 32	100		1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	0	
DT	2	009										BIRD 19
ACTIVE 33	100	SN/103	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	4	
ACTIVE 34	100		1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	8	
ADAPTOR	2	048										BIRD 20
ACTIVE 35	100	88/006	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	4	
ACTIVE 36	100	88/009	1.5	1.5	1.5	1.5	1.5	1.5	1.5	10.5	4	
DT & WB	2	028										BIRD 21
STRETCH	50											
STRETCH	50											
TAIL ROPE	300											

SURVEY 90 - - - SECOND CABLE

96 CHANNEL, 3600m ACTIVE, 37.5m GROUPS



A1 : Active section (100m long)
Str : Stretch section (50m long)
ADAP: Adaptor section (2m long)
(B1) : Depth controller, bird
DT/WB: Depth transducer/waterbreak section (2m long)
DT : Depth transducer section (2m long)
TL : Tow leader

Offsets with 108m leader out over stern:
Channel 1: 231m behind ship, 206m behind guns

APPENDIX 4: Shooting and Recording Parameters

Source:	2 x 1600 cubic inch air-gun arrays
Shot Spacing:	37.5m
Shot Interval:	18.2 seconds at 4 knots, 19.2 seconds at 3.8 knots, 20.8 seconds at 3.5 knots
Cable length:	3600m active; 4200m to tail buoy
Group Interval:	37.5m
No. of Channels:	96
Near Offset:	229m behind stern; 204m behind guns
Far Offset:	3834m behind stern; 3809m behind guns
Cable Depth:	10m; line 90/025 15m
Recording Fold:	48
Record Length:	14 seconds
Sample Rate:	4 msec
Filter Settings:	8 Hz low cut; 64 Hz high cut
Amplifier Gain:	Pre-amplifiers 128; part line 90/004 64; line 90/017 256, IFP used for all lines
Field Tape Density:	6250 bpi
Tape Format:	SEG Y

APPENDIX 5: Seismic Line Details

LINE #	START TIME	STOP TIME	DATA COLLECTED		SEISMIC TAPES	LENGTH (NM)	MODE
(A) <u>Gippsland Basin:</u>							
90/002	90.077.1501	90.078.0820	48f,b,g		90/001-034	69	IFP
90/004a	90.078.1630	90.079.0750	"	"	90/035...	62	" "
90/004b	90.080.0230	90.080.0640	"	"	069	16	" "
90/005	90.080.0638	90.080.1824	"	"	90/070-088	48	" "
90/007	90.081.0356	90.082.0438	"	"	90/089-126	98	" "
90/009	90.082.1100	90.083.0209	"	"	90/127-149	60	" "
90/011	90.083.1619	90.084.0244	"	"	90/150-166	41	" "
90/013	90.084.1350	90.085.1013	"	"	90/167-199	80	" "
90/015	90.085.1415	90.086.0804	"	"	90/200-227	72	" "
90/017	90.086.1637	90.089.0654	"	"	90/228....	56	" "
90/017	90.088.1921	90.089.0720	"	"	268	48	" "
90/019	90.089.2037	90.089.2322	"	"	90/269-272	12	" "
90/019	90.093.1633	90.093.1756	"	"	90/273-274	6	" "
90/021	90.093.1756	90.094.0554	"	"	90/275-292	48	" "
90/023	90.094.1127	90.094.2200	"	"	90/293-308	42	" "
			Total reflection data: =			758 (NM)	
						1404 (KM)	
(B) <u>Bass Basin:</u>							
90/025	90.096.0631	90.097.1338	"	"	90/309-341	124	" "
90/027	90.097.1812	90.098.1833	"	"	90/342-373	96	" "
			Total reflection data: =			220 (NM)	
						407 (KM)	

Refraction experiments were conducted by Monash University during all of the above seismc lines and include bathymetric and gravity data but no magnetic data.

Notes: 48f = 48 fold seismic data.
b = bathymetric data.
g = gravity data.
IFP = instantaneous floating point mode.

APPENDIX 6: Way Points for Survey 90

The waypoints given below list the navigation parameters used. The break down is in terms of non seismic (transit) lines and seismic lines. The line numbers are navigation line numbers and are strictly sequential, the seismic line numbers are eqivalent to the navigation lines. This means that there are gaps in the seismic line numbers, corresponding to the transit (non seismic) lines. In some cases the start or end of line does not correspond directly to the waypoint, usually in the case where shallow water depths required that a line be broken early.

WP	#	LAT(°S)	LONG(°E)	WD	LENGTH	COMMENTS
1		37 49.390	144 56.340		-	PORT MELBOURNE
	1				210.0	TRANSIT TO GIPPS' AREA
2	2	38 15.454	147 25.404	19	-	SEISMIC
3	2	38 19.227	147 37.119	45	9.9	BARRACOUTA OIL WELL
4	2	38 24.950	148 00.208	65	19.0	VEILFIN AB'N WELL
5	2	38 33.244	148 33.006	384	27.0	HAPUKA AB'N WELL
6	2	38 38.300	148 51.800	2800	28.8	
	3				30.1	NON SEISMIC TRANSIT
7	4	38 10.000	149 05.000	180	-	SEISMIC
8	4	38 10.480	148 50.055	121	11.8	HAMMERHEAD AB'N WELL
9	4	38 10.510	148 35.850	95	11.2	KIPPER AB'N WELL
10	4	38 13.477	148 24.285	68	9.6	BATFISH AB'N WELL
11	4	38 12.077	148 14.751	58	7.6	TURRUM AB'N WELL
12	4	38 09.800	147 58.500	50	12.9	
13	4	38 11.282	147 49.020	49	7.7	WIRRAH AB'N WELL
14	4	38 13.000	147 38.401			EOL
15	5	38 25.600	147 19.400	26	23.2	FLYING FISH AB'N WELL
16	5	38 40.787	147 11.273	44	11.7	KYARRA AB'N WELL
17	5	38 50.000	147 05.300	40	-	
	6				37.5	NON SEISMIC TRANSIT
18	7	39 25.000	147 17.900	50	-	SEISMIC
19	7	38 36.286	147 52.768	69	55.6	EDINA AB'N WELL
20	7	38 24.950	148 00.208	65	12.7	VEILFIN AB'N WELL
21	7	37 56.800	148 15.800	40	30.8	
	8				25.0	NON SEISMIC TRANSIT
22	9	37 53.500	148 46.800	50	-	SEISMIC
23	9	38 10.510	148 35.850	95	19.1	KIPPER AB'N WELL
24	9	38 14.946	148 33.647	115	4.4	STONEFISH AB'N WELL
25	9	38 33.910	148 19.968	102	21.7	ALBACORE AB'N WELL
26	9	38 36.053	148 17.971	87	2.6	HERMES AB'N WELL
27	9	38 47.250	148 11.600		13.0	
	10				17.0	NON SEISMIC TRANSIT
28	11	38 31.000	148 06.700		-	SEISMIC
29	11	38 22.382	148 14.391	65	12.5	FORTESCUE 1 AB'N WELL
30	11	38 19.372	148 16.587	70	3.5	WRASSE AB'N WELL
31	11	38 11.260	148 22.202	59	9.2	TUNA A4 AB'N WELL
32	11	38 00.520	148 26.207	55	11.0	BALEEN SUSPENDED WELL
33	11	37 52.500	148 30.500	22	8.0	
	12				23.5	NON SEISMIC TRANSIT
34	13	37 54.700	148 04.400	18	-	SEISMIC
35	13	37 57.410	148 03.368	43	2.9	ALBATROSS AB'N WELL

36	13	38	14.106	147	53.084	53	18.6	WHITING WELL
37	13	38	31.260	147	47.952	58	17.6	BREAM-2 SUSPENDED WELL
38	13	38	38.530	147	42.206	63	2.0	TARRA AB'N WELL
39	13	39	07.400	147	20.700	45	11.8	
	14						9.0	NON SEISMIC TRANSIT
40	15	39	06.200	147	10.100	50	-	SEISMIC
41	15	38	58.578	147	14.270	59	15.1	GROPER 2 AB'N WELL
42	15	38	19.227	147	37.119	45	43.2	BARRACOUTA 3 AB'N WELL
43	15	38	15.500	147	39.000	38	4.1	
44	15	38	05.000	147	48.000	38	12.2	
	16						35.4	NON SEISMIC TRANSIT
45	17	38	23.500	147	19.400	19	-	SEISMIC
46	17	38	30.488	147	37.265	55	15.6	SPEKE 1 AB'N WELL
47	17	38	36.286	147	52.768	69	13.4	EDINA AB'N WELL
48	17	38	57.000	148	48.500	2400	48.1	
	18							NON SEISMIC TRANSIT
	19							NON SEISMIC TRANSIT
	20							NON SEISMIC TRANSIT
49	21	38	27.390	148	09.937		-	SEISMIC
50	21	38	35.000	148	03.500	77	14.7	
51	21	38	46.394	147	57.081	74	12.9	PIKE AB'N WELL
52	21	39	08.800	147	42.800	70	24.9	
	22						19.0	NON SEISMIC TRANSIT
53	23	39	03.000	148	02.500		-	SEISMIC
54	23	38	36.053	148	17.971	87	34.0	HERMES AB'N WELL
55	23	38	33.910	148	19.968	102	3.0	ALBACORE AB'N WELL
56	23	38	30.480	148	22.465		4.5	
	24						120.0	TRANSIT TO BASS AREA
57	25	39	06.500	146	01.500		-	SEISMIC
58	25	40	35.000	145	10.000		96.9	
	26						18.5	NON SEISMIC TRANSIT
59	27	40	16.000	145	02.000		-	SEISMIC
60	27	39	34.295	145	31.672		47.4	CORMORANT AB'N WELL
61	27	39	07.500	145	50.000		30.4	

* NOTE WP denotes way point number.
* NOTE # denotes navigation line number and seismic line number, if seimic acquisition was undertaken.
* NOTE LAT(itude) and LONG(itude) are degrees decimal minutes.
* NOTE WD denotes water depth in metres.
* NOTE LENGTH denotes the distance between the waypoint and the preceding waypoint in nautical mile. Except in the case where the waypoint is at the start of a seismic line.

APPENDIX 7. Condensed Seismic Desk Log

GIPPSLAND BASIN
****

077.1349	Cable is out, port gun array going out.
.1318	Started to shoot line 90/002, at sp 100
.1504	Stbd array on line for SP 426
.2257	System crash, last shot 1986
.2301	Rebooted at SP 2000
078.0420	System crash, last shot 3052
.0423	Rebooted at SP 3101
.0945	End of line 90/002, guns turned off, tests etc, last SP 3940
078.1028	Start acquisition line 90/004, at SP 103, tape 90/035
.1949	Sonobuoy approx 5.4 nm from start of line 4
078.0830	Guns being retrieved for repairs, 10 hour loop.
.1413	Resume shooting line 4 at SP 4034
.1638	Acquisition suspended after SP 4512
080.0231	Restart acquisition for line 4
.0658	Sonobuoy deployed
.0638	Suspend acquition after SP 2360, bringing in guns, End of line 90/004, last SP 5489, last tape 90/069
080.0638	Start of line 90/005, at SP 100, tape 90/070
.0658	Sonobuoy deployed
.1824	End of line 90/005, at SP 2429, tape 90/088
081.0356	Start line 90/007, at SP 2433, tape 90/089, tape header is line 5
.1104	Chan 97 used for sonobuoy at approx SP 1390
.1805	Deployed sonobuoy approx. 2.5 nm North of WP19, Edina well.
.0426	Stopped acquistion
081.0435	Tape 90/090 is line 7 with SP's starting at 100
082.0438	End of line 90/007, SP 4855, tape 90/126
082.1100	Start of line 90/009 at SP 100, tape 90/127
.1230	Tape 90/129 has tape header no 28
.1256	Tape 90/129 SP revert to 100 after SP 358
.2017	Sonobuoy deployed
083.0209	End of line 90/009 at SP 1138, tape 90/149
083.1619	Start of line 90/011, at SP 99, tape 90/150
.1635	System crash
.1641	Reboot at SP 200, use Sp 200 for start of line
084.0244	End of line 90/011, at SP 2190, tape 90/166
084.1350	Start of line 90/013, at SP 100, tape 90/167
.1754	Noist test SPs 903 to 913
.2358	System crash, last shot 2104
085.0001	Rebooted at SP 2200
085.1013	End of line 90/013, at SP 4215, tape 90/199
085.1415	Start of line 90/015, at SP 100, tape 90/200
.2350	Sonobuoy deployed
086.0804	End of line 90/015, at SP 3491, tape 90/227
086.1637	Start of line 90/017, at SP 100, tape 90/228
.1756	Cable set to 10m depth, feather angle 17 deg to port
.1803	Feather angle 3 deg to port
087.0655	End of cable run over by another ship, last 3 birds

	don't respond.
	Cable was cut at active section 32
088.1919	Rebuilt cable, cable 2 start amp test st SP 100
.1930	System crash
089.0114	Seismic gain set from128 to 256 at SP 1332
089.0720	End of line 90/017, at SP 2536, tape 90/268
089.1545	Seismic gain set from 256 to 128
089.2037	Start of line 90/019, at SP 80, tape 90/269
089.2241	End of line 90/019, at SP 598, tape 90/272 Line stopped due to bad weather. Bad weather for 3.75 days, no shooting
093.1633	Start of line 90/021, at SP 99, tape 90/273
094.0516	End of line 90/021, at SP 2435, tape 90/292
094.1127	Start of line 90/023, at SP 100, tape 90/293
.1135	Tests done, acquisition suspended, (waiting for guns to be deployed), after SP 130
.1145	Restart acquisition at SP 156 with all guns firing
.1430	Channel 73 is either dead or very low amlitude
094.2200	End of line 90/023, at SP 2159, tape 90/308

BASS BASIN
****

096.0631	Start of line 90/025, at SP 100, tape 90/309
.0850	System crash, cause unknown
.0918	System suspended after SP 57
.0930	Magnetometer cable caught in port gun array
.1611	Restart line 90/025 after untangling mag. cable from port guns. next SP was 700. feather angle 10 deg to port. Tail buoy dead astern as SP 761
097.0143	Deploy sonobuoy
097.1338	End of line 90/025, at SP 4411, tape 90/341
097.1812	Start of line 90/027, at SP 100, tape 90/342, SPs 101 - 103 lost.
.1909	Sonobuoy deployed
098.0845	System crash, caused by no access to drive 1, had problems restarting system, need to do a loop
.0857	Started acquisition, not recording untill we get back to where we were just before crash
.1257	Reshooting, first SP 3000
.1351	Sonobuoy finished
.1822	Note: acquisition suspended at 098.1822, SP4071, noise test
.1828	Tests restarted as tape drives were not writing during first test, SP 4096
098.1833	End of line 90/027, at SP 4109, tape 90/373

APPENDIX 8: Radio Navigation Shore Station Locations

Hifix Stations

Gippsland Segment

Station	AMG	WGS72
Dalray Beach	38 13.659 147 22.788 30 m	38 13.570 147 22.857 28 m
Lake Tyers	37 50.517 148 06.778 30 m	37 50.427 148 06.846 30 m
Seaspray	38 23.007 147 10.874 30 m	38 22.918 147 10.943 27 m
Woodside Beach	38 32.657 146 58.776 30 m	38 32.568 146 58.845 26 m

Bass Segment

Station	AMG	WGS72
Cape Liptrap	38 53.658 145 55.237 30 m	38 53.570 145 55.308 24 m
Phillip Island	38 31.284 145 12.792 30 m	38 31.196 145 12.863 24 m

Miniranger Stations

Gippsland Segment

Station	AMG	WGS72
Dalray Beach	38 13.622 147 22.788 20 m	38 13.573 147 22.857 18 m
Lake Tyers	37 50.517 148 06.778 20 m	37 50.427 148 06.846 20 m
Seaspray	38 23.013 147 10.868 20 m	38 22.924 147 10.937 17 m
Woodside Beach	38 32.661 146 58.774 20 m	38 32.572 146 58.843 16 m
Dalray Beach Test Site	38 19.276 147 15.769 29 m	38 19.187 147 15.838 26 m

Bass Segment

Station	AMG	WGS72
Phillip Island	38 31.291 145 12.786 20 m	38 31.203 145 12.860 14 m
Cape Liptrap	38 53.654 145 55.229 20 m	37 53.566 145 55.300 14 m

APPENDIX 9: Non-Seismic Data Channels

The following is a list of the channel allocations for the non-seismic data for the Gippsland/Bass II Cruise (#90).

MAIN DATA

The main data is saved on magnetic tape every 60 seconds in blocks of 128 x 6 floating words (ie: minute data for 128 channels with 10 second blocks).

1 - Clock (Survey and Day Number)
2 - Acquisition time (GMT) from internal computer clock
3 - Master clock time at acquisition
4 - Latitude, best estimate (radians)
5 - Longitude, best estimate (radians)
6 - Speed, best estimate (knots)
7 - Heading, best estimate (degrees)
8 - Magnetometer #1 (not used)
9 - Magnetometer #2 (not used)
10 - Depth #1; 3.5 KHz (metres)
11 - Depth #2; 12.5 KHz (metres) (affected by 48.3 m offset)
12 - F/A Magnavox sonar-doppler (4000.0 counts/nm)
13 - P/S Magnavox sonar-doppler (4000.0 counts/nm)
14 - F/A Raytheon sonar-doppler (193.5 counts/nm)
15 - P/S Raytheon sonar-doppler (193.5 counts/nm)
16 - Paddle log (7000 counts/nm) (not used)
17 - not used
18 - SGBrown Gyro Heading (degrees)
19 - Robertson Gyro Heading (degrees)
20 - Gyro compass differences (degrees)
21 - Miniranger Code 1 range (metres)
22 - Miniranger Code 2 range (metres)
23 - Miniranger Code 3 range (metres)
24 - Miniranger Code 4 range (metres)
25 - Hifix Fine A (centilanes)
26 - Hifix Fine B (centilanes)
27 - Hifix Fine C (centilanes)
28 - Hifix Coarse A (centilanes)
29 - Hifix Coarse B (centilanes)
30 - Hifix Coarse C (centilanes)
31 - 38 not used
39 - GPS north std dev (metres)
40 - GPS east std dev (metres)
41 - GPS satellite numbers
42 - GPS time (GMT seconds)
43 - GPS Dilution of Precision
44 - GPS latitude (radians)
45 - GPS longitude (radians)
46 - GPS height above geoid (metres)
47 - GPS speed (knots x 10)
48 - GPS course (degrees x 10)
49 - GPS frequency bias
50 - GPS GMT (.HHMMSS)

51 - Latitude from Magnavox sonar-doppler & SGBrown gyro
52 - Longitude from Magnavox sonar-doppler & SGBrown gyro
53 - Speed calc. from Magnavox sonar-doppler & SGBrown gyro
54 - Course calc. from Magnavox sonar-doppler & SGBrown gyro
55 - Latitude from Raytheon sonar-doppler & Robertson gyro
56 - Longitude from Raytheon sonar-doppler & Robertson gyro
57 - Speed calc. from Raytheon sonar-doppler & Robertson gyro
58 - Course calc. from Raytheon sonar-doppler & Robertson gyro
59 - Latitude calc. from paddle log & SGBrown gyro (not used)
60 - Longitude calc. from paddle log & SGBrown gyro (not used)
61 - Speed calc. from paddle log & SGBrown gyro (knots) (not used)
62 - Course calc. from padde log & SGBrown gyro (degrees) (not used
63 - Latitude, radio nav (radians)
64 - Longitude, radio nav (radians)
65 - Speed from radio nav (knots)
66 - Course from radio nav (degrees)
67 - GMT from Magnavox MX1107 satnav (seconds)
68 - Dead reckoned Time from MX1107 (seconds)
69 - Latitude (radians) MX1107
70 - Longitude (radians) MX1107
71 - Speed (knots) MX1107
72 - Heading (degrees) MX1107
73 - GMT from Magnavox MX1142 (seconds)
74 - Dead reckoned time from MX1142 (seconds)
75 - Latitude (radians) MX1142
76 - Longitude (radians) MX1142
77 - Speed (knots) MX1142
78 - Heading (degrees) MX1142
79 - Gravity (mGal x 100)
80 - ACX (metres/sec^2 x 10000)
81 - ACY (metres/sec^2 x 10000)
82 - Seastate (not used)
83 - AGRF magnetic anomaly #1
84 - AGRF magnetic anomaly #2
85 - Magnetics difference: gradiometer (not used)
86 - Seismic shot time (HHMMSS) (not used)
87 - Seismic shot point number (not used)
88 - Hifix A range 10 minute drift (centilanes)
89 - Hifix B range 10 minute drift (centilanes)
90 - Hifix C range 10 minute drift (centilanes)
91 - Hifix A range cumulative drift (centilanes)
92 - Hifix B range cumulative drift (centilanes)
93 - Hifix C range cumulative drift (centilanes)
94 - North Set and Drift applied to primary DR (rad/10 min)
95 - East Set and Drift applied to primary DR (rad/10 min)

The GPS channel 41, which holds the total number and the satellite numbers of the satellites in the current constellation, has data packed as follows; the units of value in the channel gives the number of satellites used, and the remainder gives a bit representation of the satellite number. For example; 1602 would imply 2 satellites (the units) leaving 160 which indicates satellites 5 and 7 (bits 5 and 7 on).

Transit Satellite Fixes

The Transit satellite fix information from both the MX1107 and the MX1142 are saved in blocks of 20 floating point words when the fix data becomes available. The data from each satnav is in a similar format, each being identified by the first word.

1 - 1107 or 1102
2 - Day number (1107) or date (1142)
3 - GMT
4 - Latitude (radians)
5 - Longitude (radians)
6 - Used Flag (0 = not used; 1 = used)
7 - Elevation (degrees)
8 - Iterations
9 - Doppler counts
10 - Distance from DR (nautical miles)
11 - Direction from DR (degrees)
12 - Satellite number
13 - Antenna height (metres)
14 - 20 - Doppler spread flags (1107 only)

The raw satellite data from the MX1107 transit receiver is saved every 2 minutes during each satellite pass as a block of 600 single words. These data are saved in the Magnavox 702 emulation mode. The first 4 words in each block identify the block, 702, and the start time of the block.

APPENDIX 10. Onshore Refraction Stations

No.	Location	Latitude	Longitude	Type	On	Off
1	Bonang Hwy	37 34.58	148 32.94	A	16/3	30/3
2	Toongabbie	38 04	146 36	A	16/3	09/4
3	Stradbroke	38 16.28	146 56.60	A	17/3	09/4
4	Wilson's Prom	39 07.76	146 23.97	A	17/3	09/4
5	Mirboo	38 28	146 12	A	31/3	09/4
6	Cape Liptrap	38 54	145 56	A	31/3	09/4
7	Cape Paterson	38 39	145 36	A	31/3	09/4
8	Deal Island	39 29.8	147 19.3	D	20/3	23/3
9	Stanley, Tas	40 46	145 17	D	06/4	08/4

Notes: i) Type A = Analogue recorder, D = Digital recorder

APPENDIX 11. Sonobuoys

No.	Line	Time Deployed d h m s	Latitude d m	Longitude d m	Ship's course	Duration h m	Range km
(A) Gippsland Basin							
1	2	77:20:15:09.4	38 25.14	148 01.00	ESE	4 45	35.2
2	4	78:19:50:36.4	38 09.98	148 58.29	W	6 49	50.6
3	5	80:06:56:50.6	38 13.46	147 36.84	SW	4 43	35.0
4	7	81:11:57:53.2	38 55.86	147 38.81	NNE	5 42	42.3
5	7	81:18:00:36.4	38 34.08	147 54.19	NNE	8 39	64.3
6	9	82:20:27:53.2	38 26.93	148 25.00	SSW	5 36	41.6
7	15	85:23:50:18.2	38 31.77	147 29.83	NNE	6 00	44.5
(B) Bass Basin							
1	25	97:01:43:07.2	39 45.58	145 38.73	SSW	9 07	58.3
2	27	97:19:09:23.6	40 12.33	145 04.63	NNE	13 31	100.3

APPENDIX 12: Crew List

<u>BMR</u>

P.E. Williamson	Co-chief scientist
M.G. Swift	Co-chief scientist
G. Heal	Scientist/Systems specialist
H. Miller	Scientist/Systems specialist
R. Whitworth	Scientist/Systems specialist (part of survey)
C. Collins	Scientist/observor
A. Constantine	Scientist/observor
S. Zhou	Scientist/observor
G. Saunders	Science technician
N. Clark	Science technician
P. Davis	Science technician
J. Mowat	Science technician (part of survey)
D. Hunter	Science technician
J. Kossatz	Science technician
T. McNamara	Science technician
J. Pittar	Electronics technician (part of survey)
J. Mangion	Electronics technician
D. Holdway	Electronics technician
P. Harris	Mechanical technician
J. Roberts	Mechanical technician
D. Hunter	Field Hand
A. Mellick	Field Hand

<u>DOT</u>

H. Foreman	Master
S. Johnson	Chief Engineer
D. Harvey	Chief Officer
P. Bain	Second Officer
T. Ireland	Second Engineer
P. Jiear	Electrician
L. Clarke	E.A./seaman
J. Fraser	A.B. 1
D. Kane	A.B. 2
J. Kemp	A.B. 3
B. Fowler	Chief steward/cook
D. Dunmall	Cook
J. Caminiti	Steward
M. Cumner	Steward/seaman

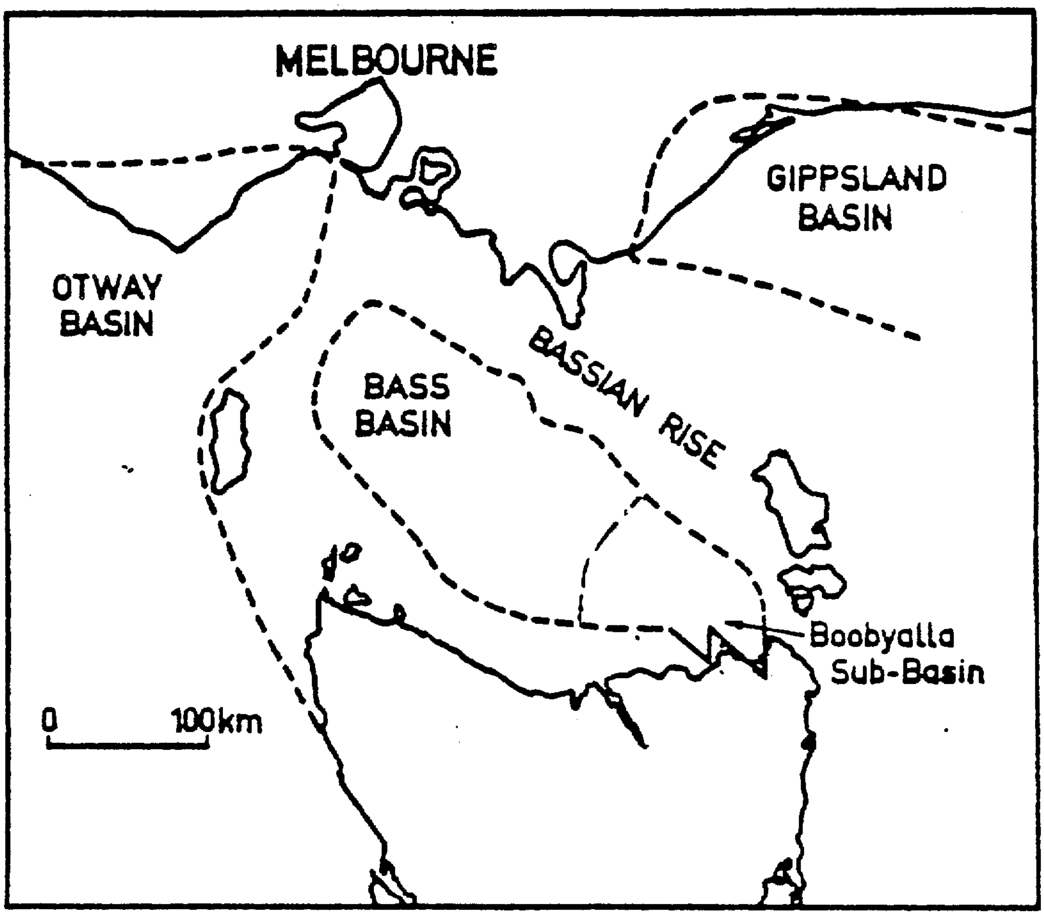


Figure 1. Locality map.

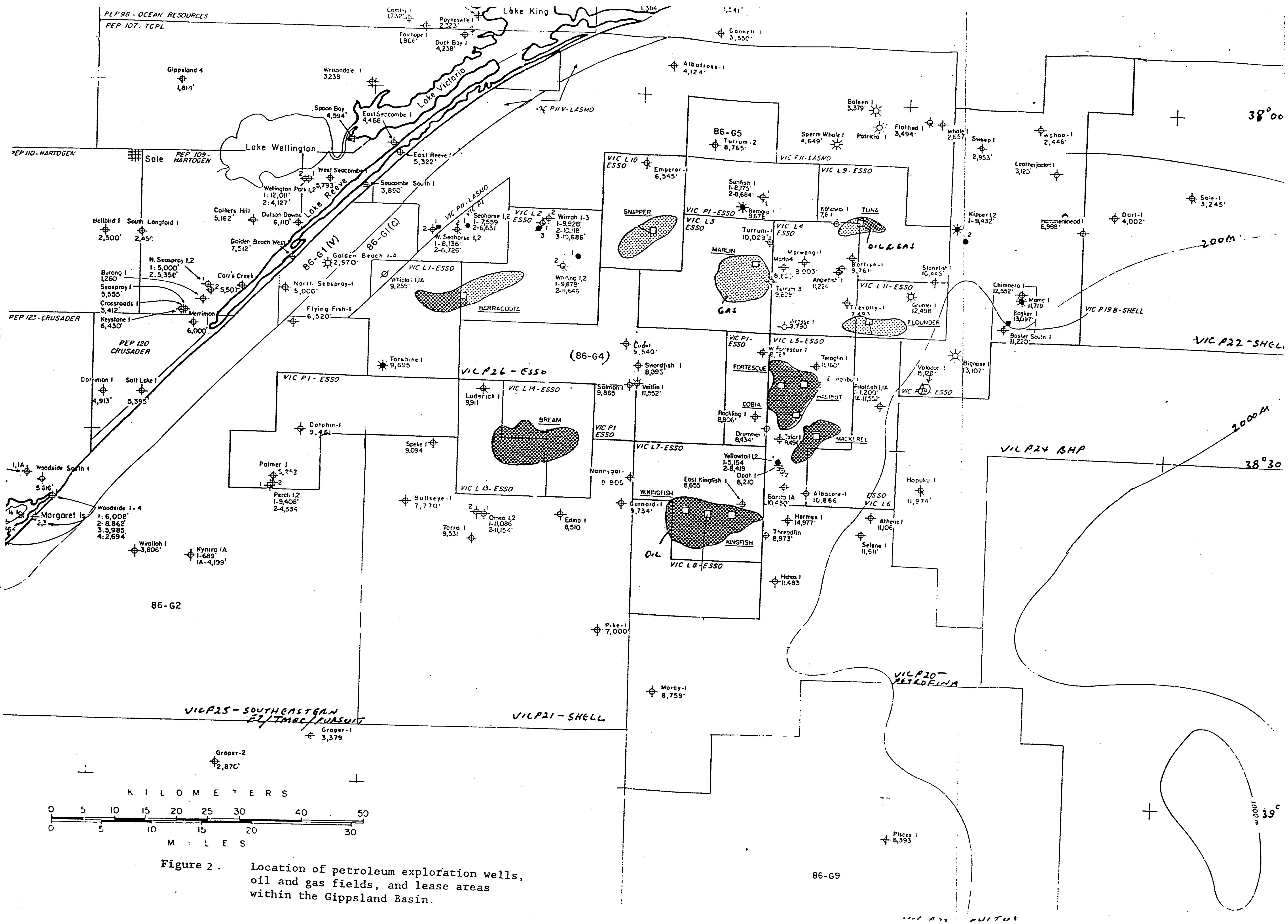


Figure 2. Location of petroleum exploration wells, oil and gas fields, and lease areas within the Gippsland Basin.

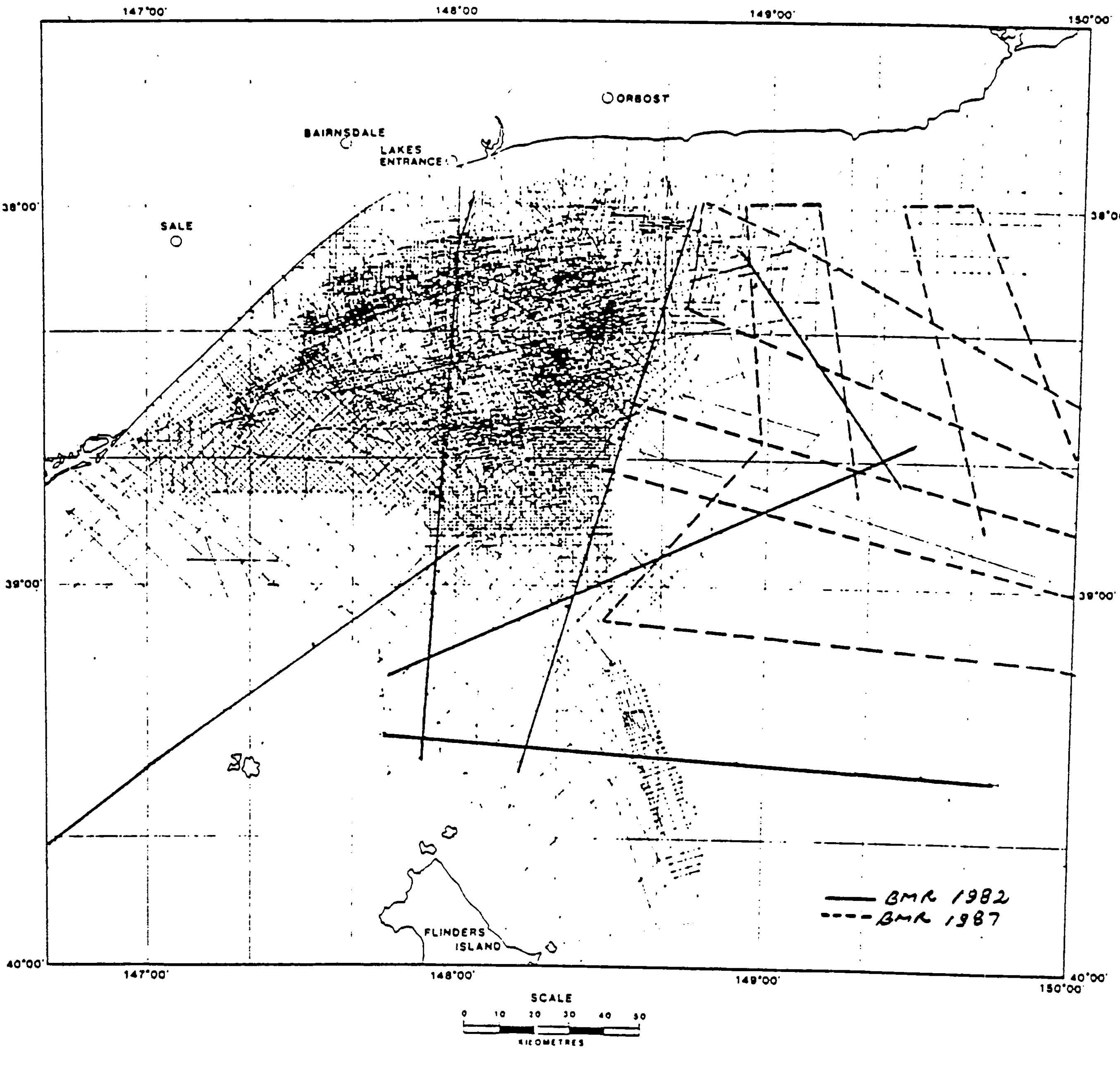


Figure 3. Seismic line density within the Gippsland Basin showing most lines shot between 1962 and 1987 (after Brown, 1986). BMR 1982 and 1987 lines are highlighted.

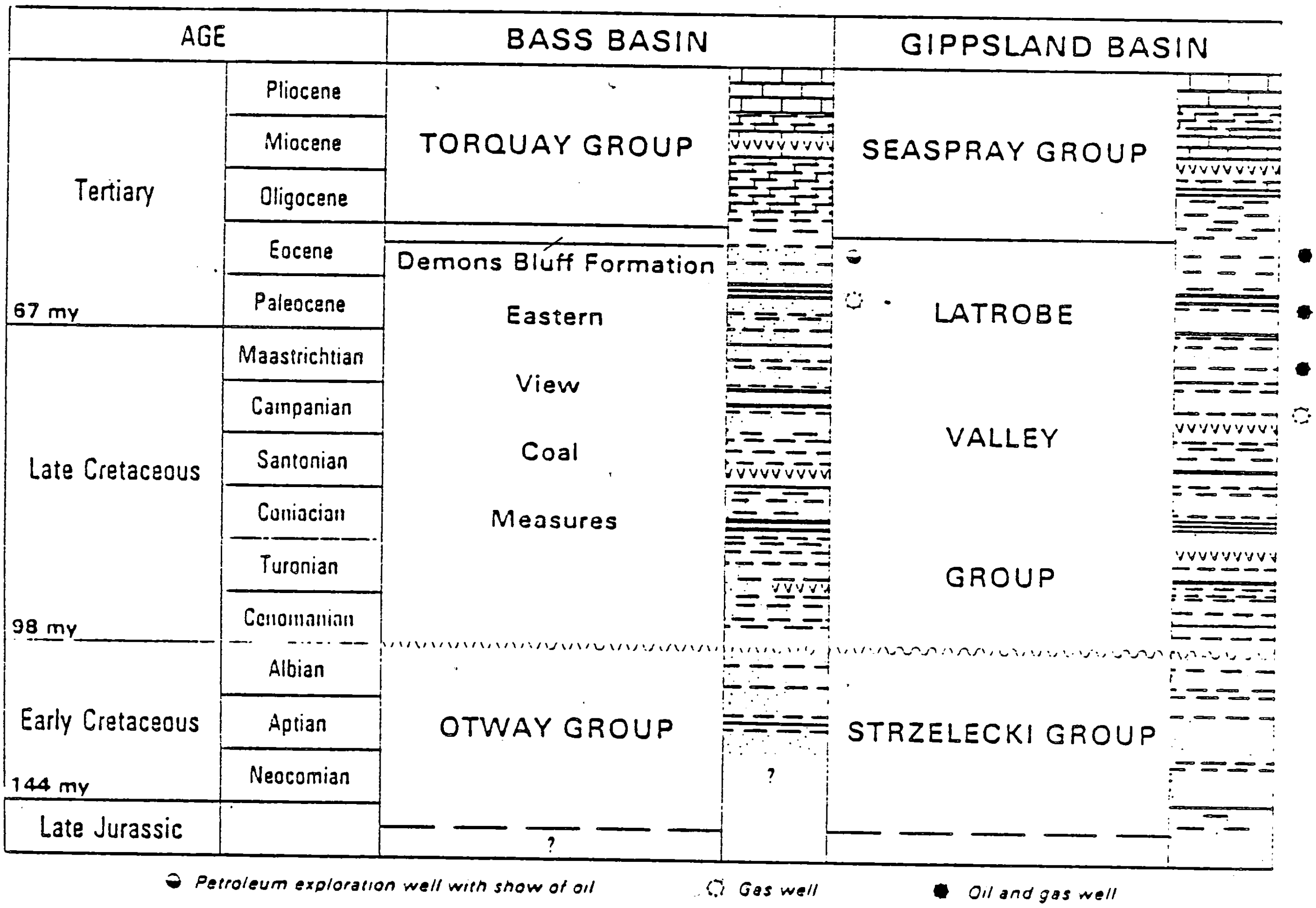


Figure 4. Comparative stratigraphy of the Bass and Gippsland Basins.

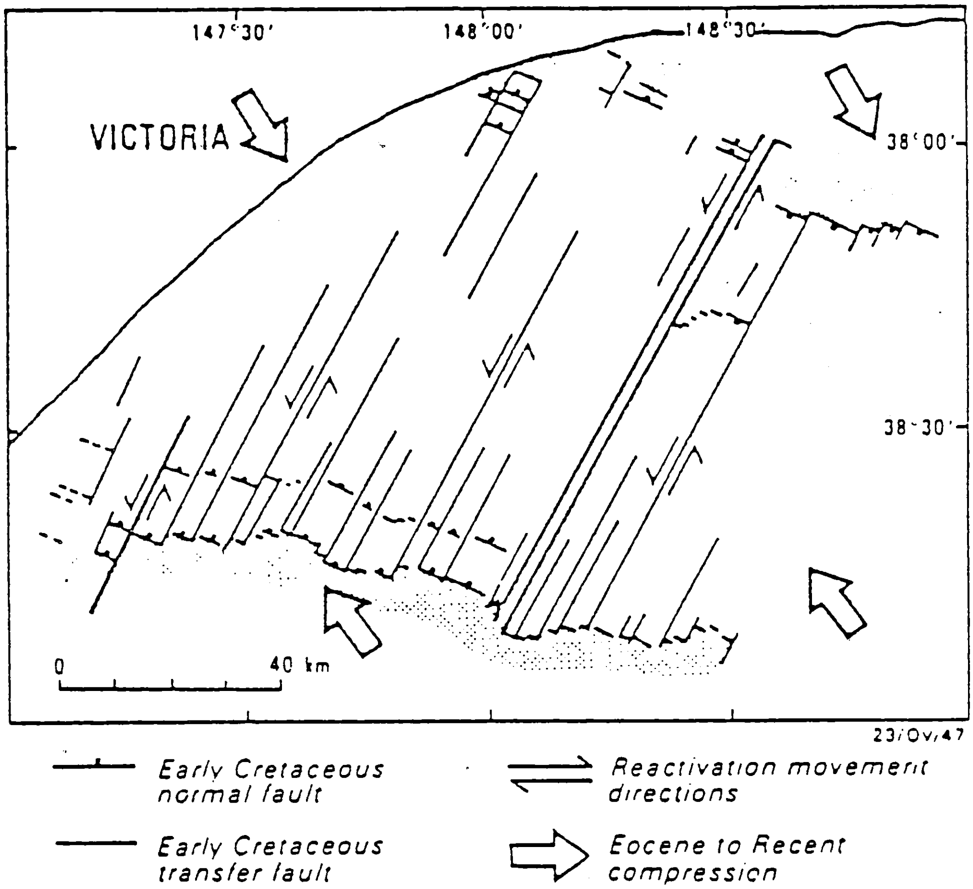


Figure 5. Map of Early Cretaceous structures within the Gippsland Basin showing how Tertiary northwest-southeast compression gives rise to left-lateral wrench reactivation of transfer faults, and oblique reverse reactivation of normal faults (after Etheridge & others, 1985).

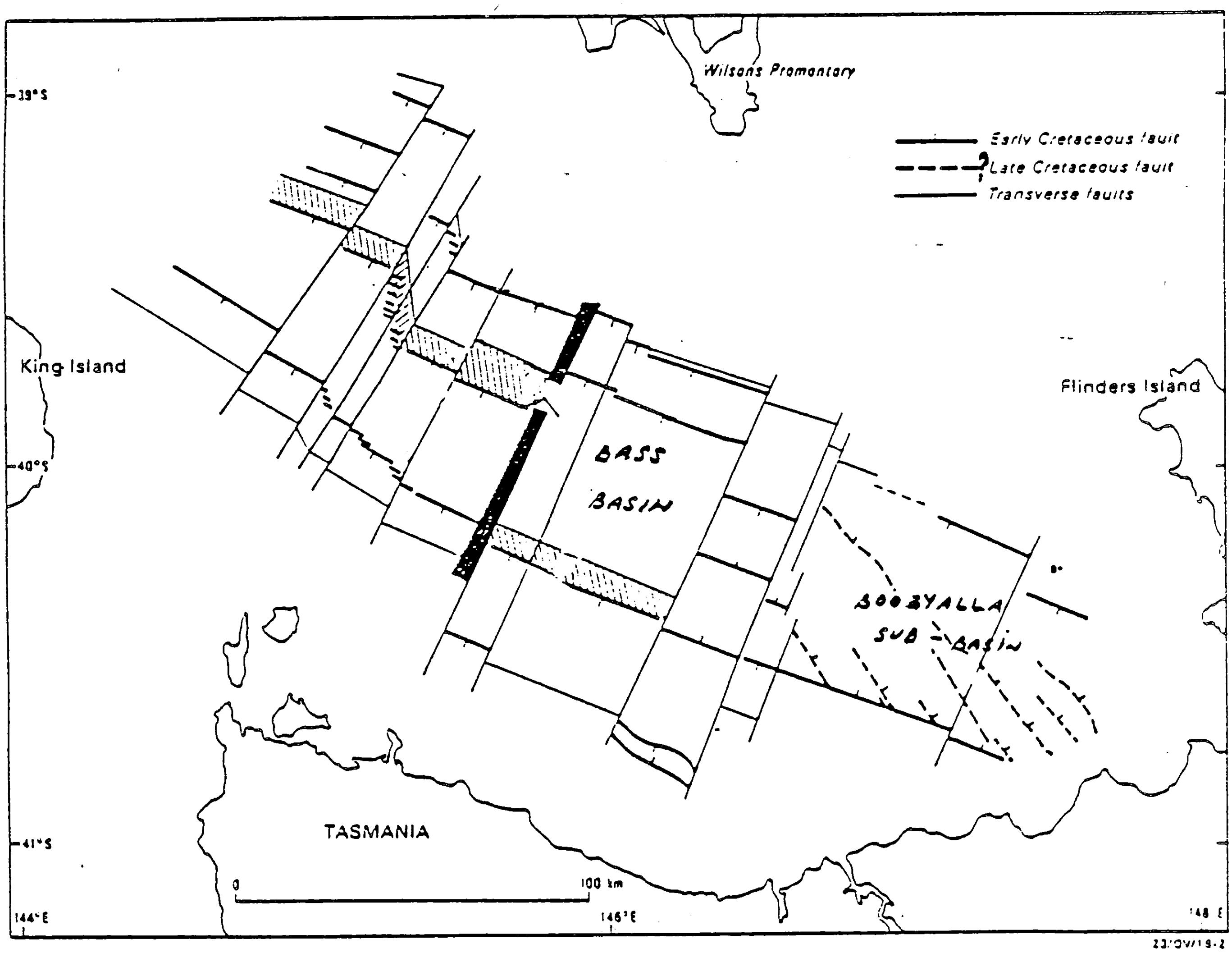


Figure 6. Basin-forming structures in the Bass Basin (after Etheridge & others, 1984, 1985).

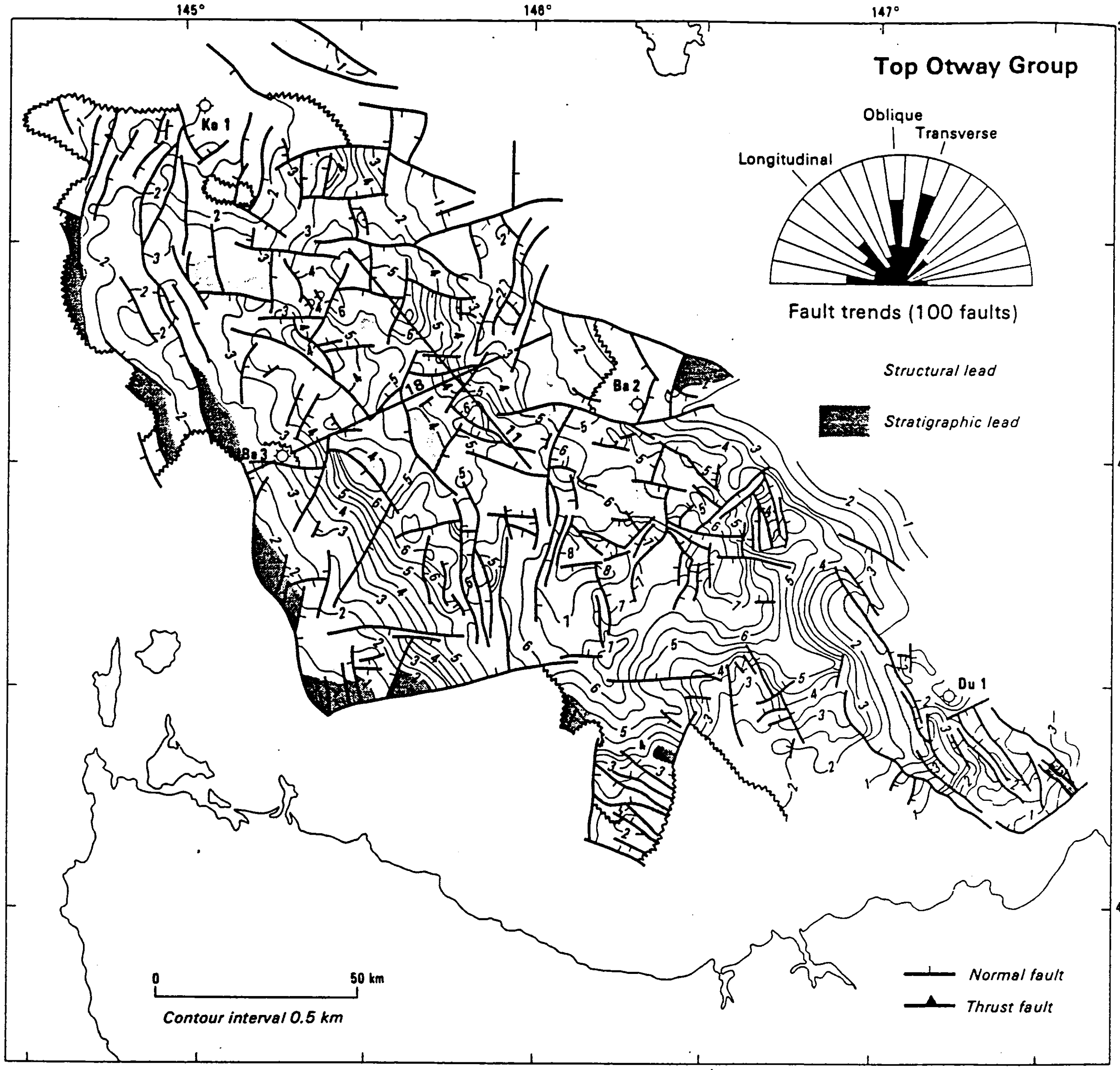


Figure 7. Structure map of top of Otway Group (middle Cretaceous rift unconformity) in the Bass Basin (from Williamson and others, 1985, 1987, 1988). Wells shown are those which penetrated the mapped level.

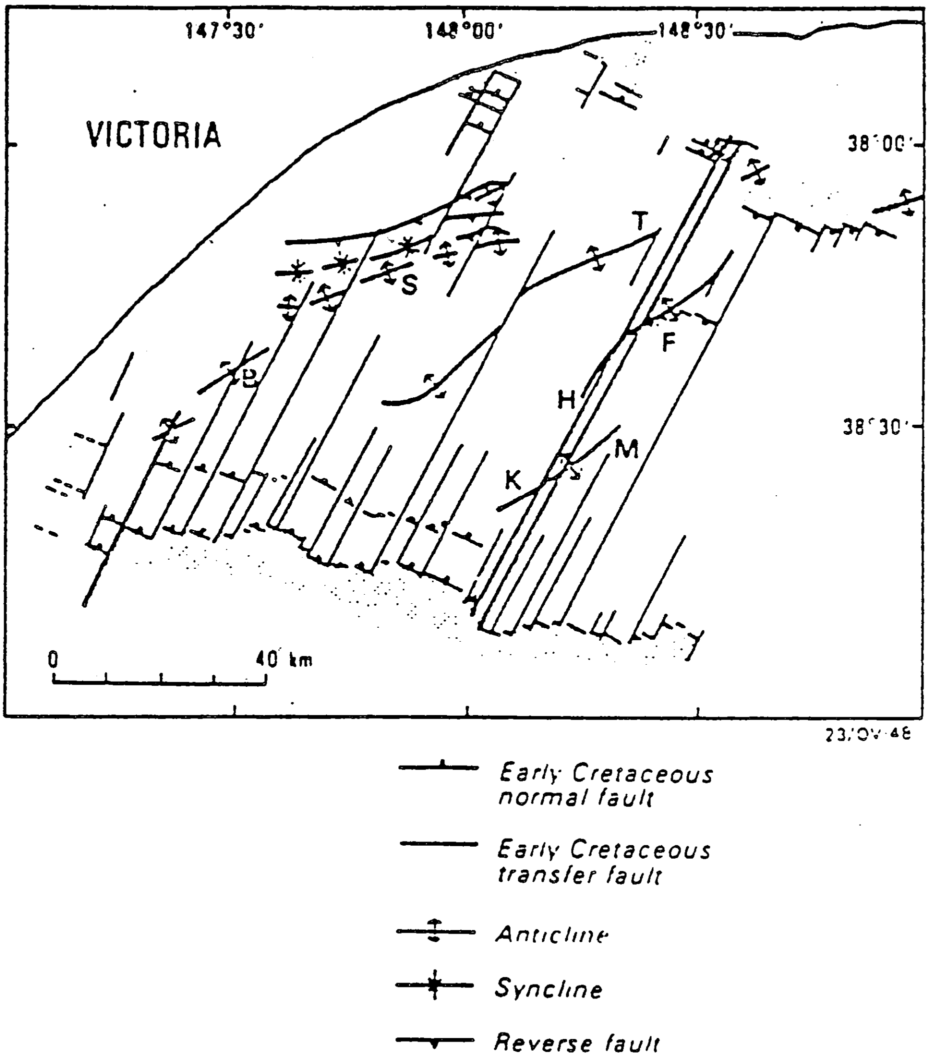


Figure 8. Map of Late Tertiary compressional structures within the Gippsland Basin superimposed on the Early Cretaceous extensional structure (after Etheridge & others, 1985).

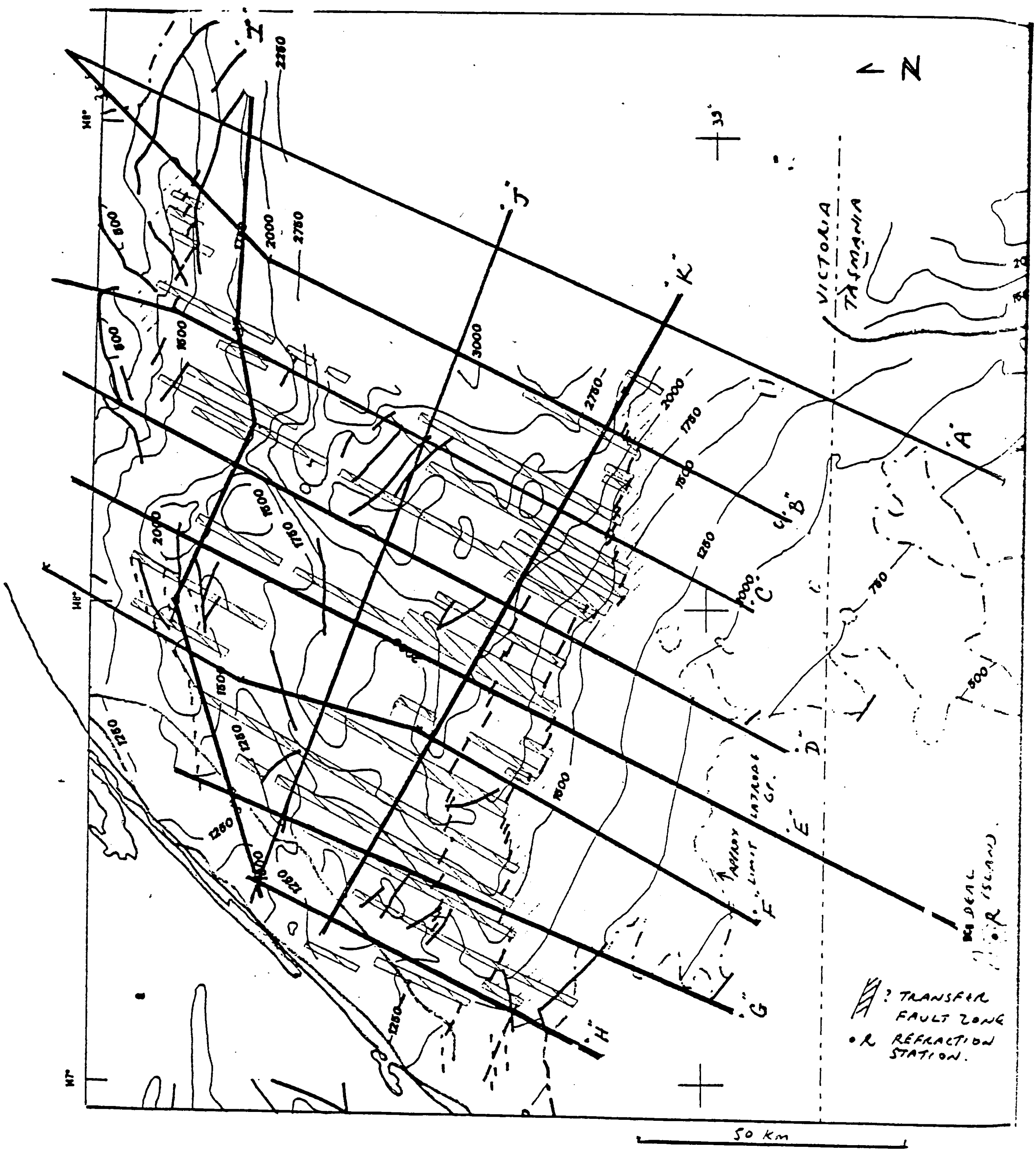


Figure 9. Sketch map of the Gippsland Basin showing location of transfer fault zones and Rig Seismic lines.

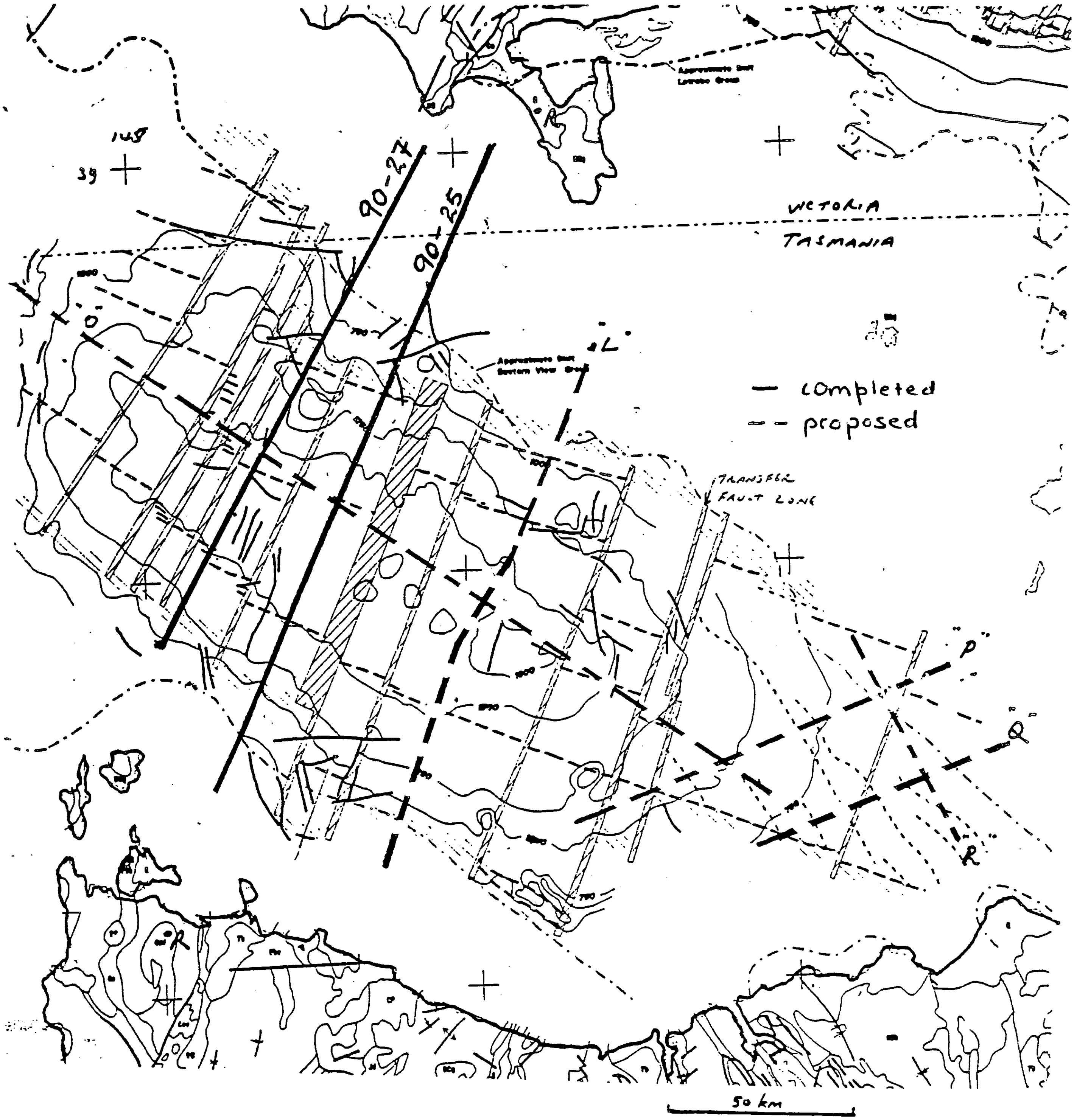
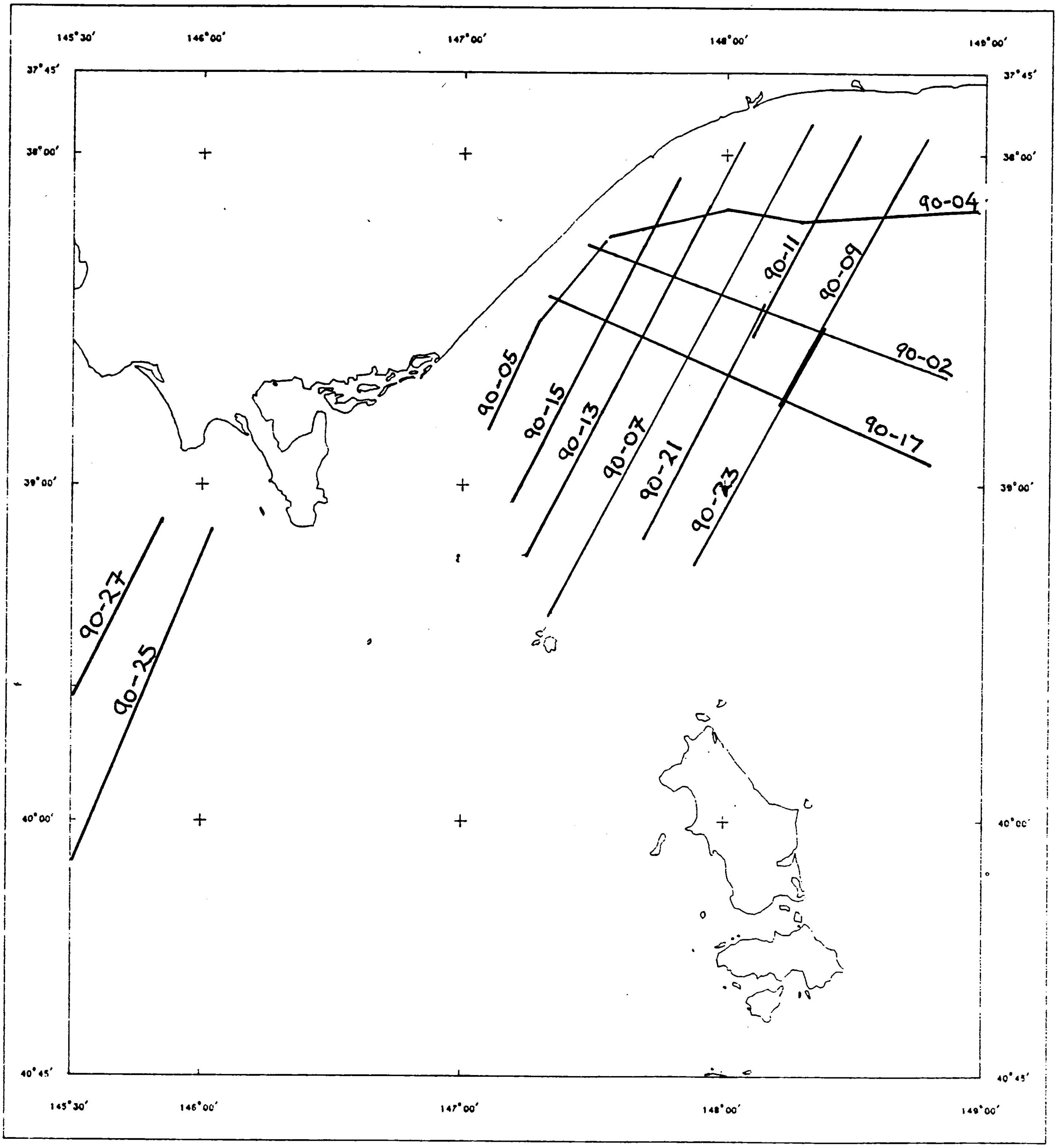


Figure 10. Sketch map of the Bass Basin showing location of transfer fault zones and completed and proposed *Rig Seismic* lines.

GIPPSLAND/BASS BASIN

SCALE 1:2000000

EDITION OF 1989/03/15



WORLD GEODETIC SYSTEM 1972
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

GIPPSLAND/BASS BASIN

Figure 11. Location of Survey 90 Gippsland Basin lines.

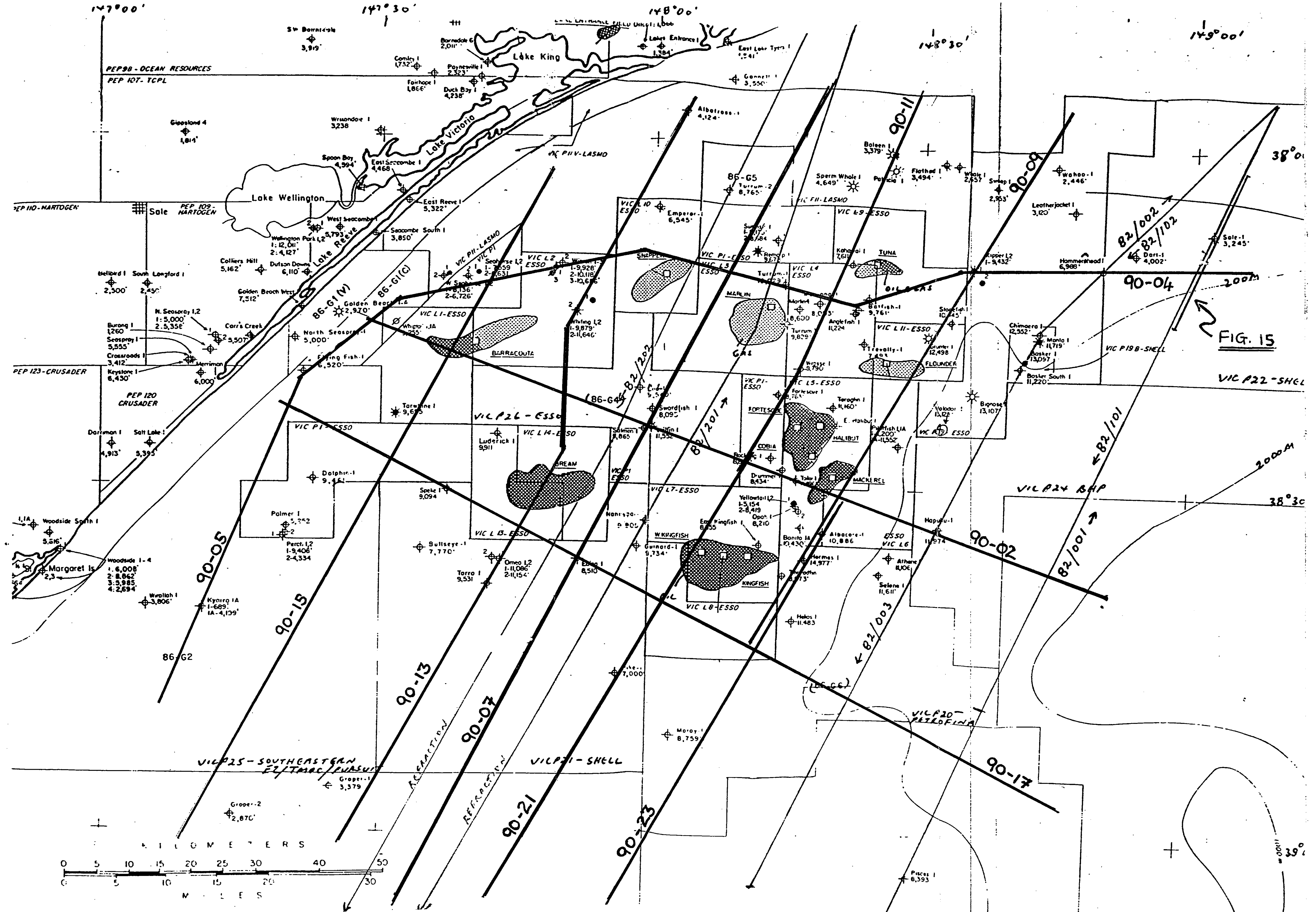
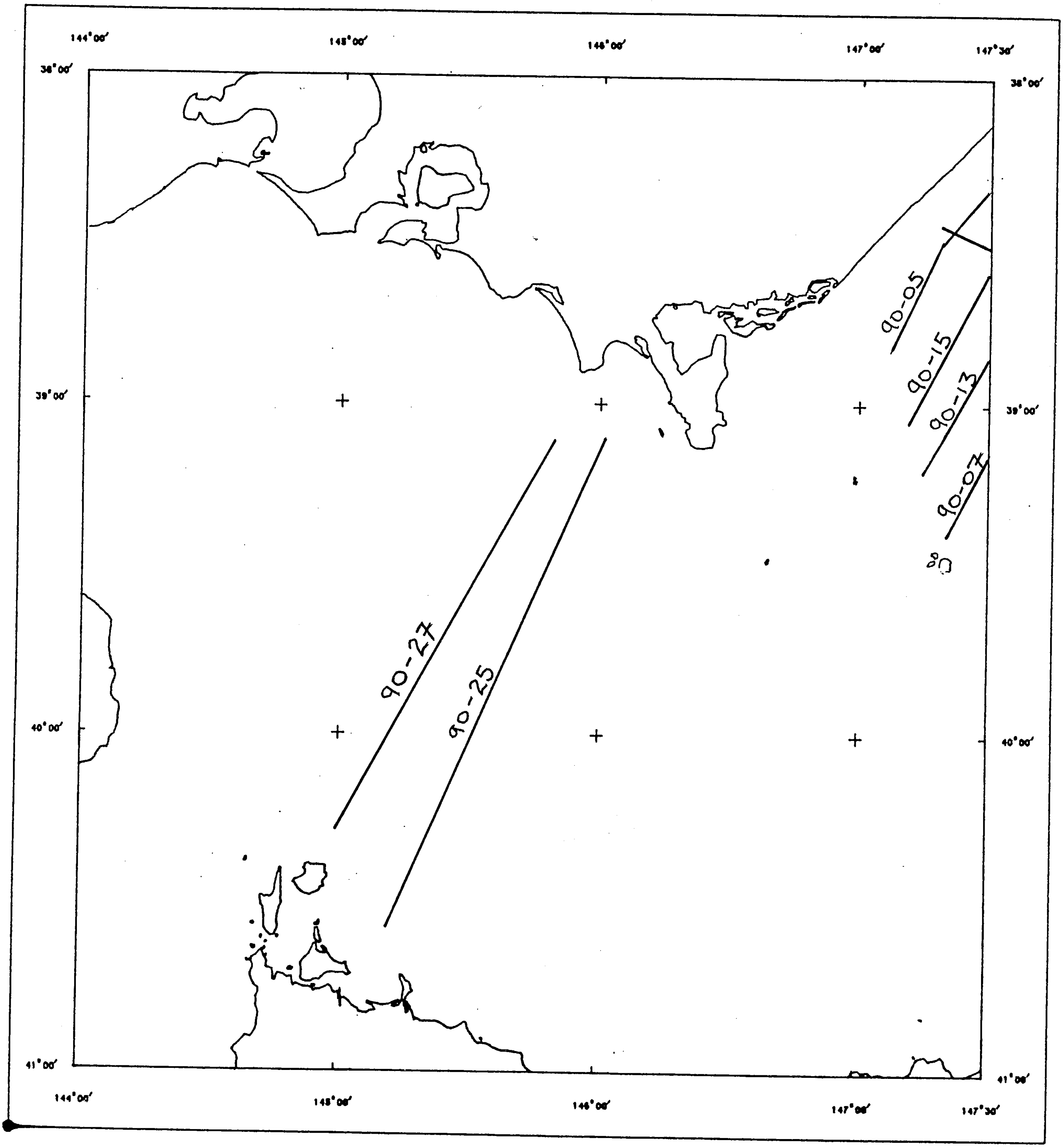


Figure 12. Location of Survey 90 and Survey 82 lines in relation to petroleum exploration wells, oil and gas fields and lease areas within the Gippsland Basin.

GIPPSLAND/BASS BASIN

SCALE 1:2000000

EDITION OF 1989/04/10



WORLD GEODETIC SYSTEM 1972
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

GIPPSLAND/BASS BASIN

Figure 13. Location of Survey 90 Bass Basin lines.

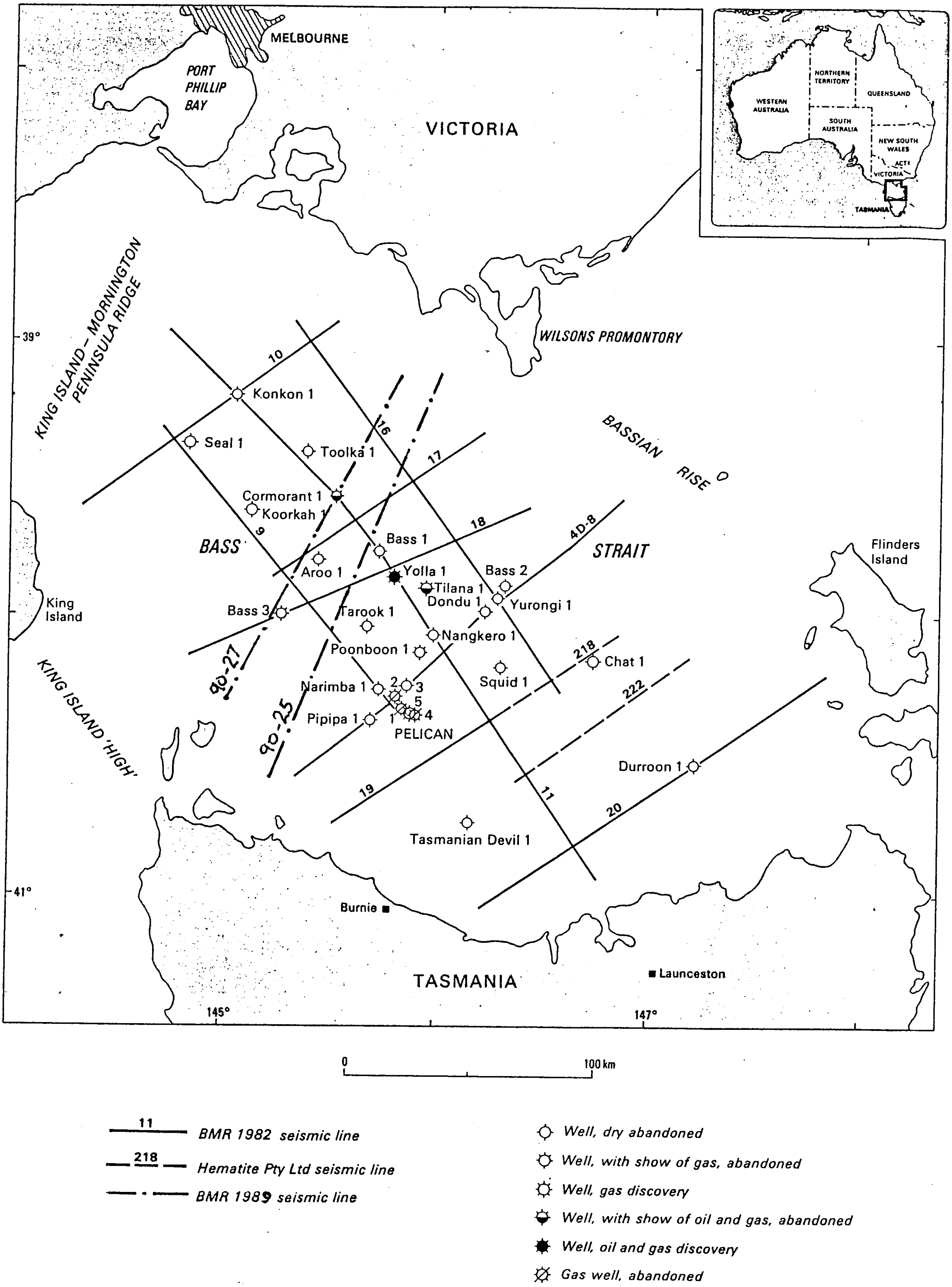


Figure 14. Location of Survey 90 Bass Basin lines in relation to petroleum exploration wells and 1982 Survey 40 lines.

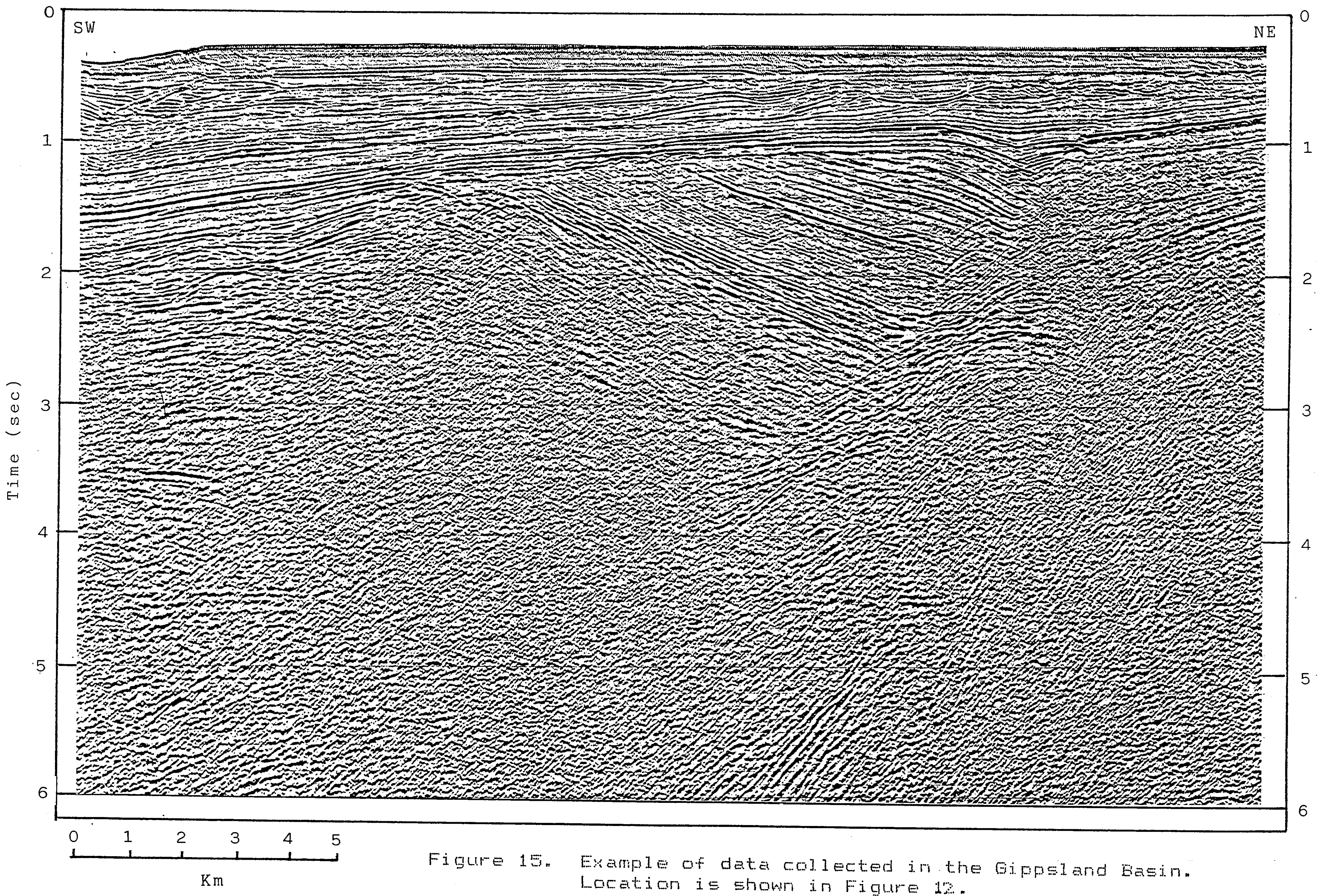


Figure 15. Example of data collected in the Gippsland Basin. Location is shown in Figure 12.