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Research Cruise Proposal

GEOLOGICAL FRAMEWORK AND HYDROCARBON RESOURCE REASSESSMENT

OF THE BASS BASIN AND WEST TASMANIAN MARGIN

Project 9131-13  
BMR Fossil Fuels & Minerals Sub-program

Principal Investigators N.F. Exon & C.S. Lee

Schedule : March/April 1988

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1. Regional stratigraphy, unconformities and seismic sequences. After Hinz et al. (1986).
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### SUMMARY

It is planned to use Rig Seismic for one month during March-April 1988, in the Bass Basin and on the west Tasmanian margin, to carry out two projects :

1. Project 9131-13A : Deep crustal structure of the Bass Basin.
2. Project 9131-13B : Geological framework and hydrocarbon resource assessment of the west Tasmanian basins.

The first half of the cruise will be devoted to multichannel seismic surveying - 600 km in the Bass Basin and 1400 km on the west Tasmanian margin. The Bass Basin seismic survey is designed to test proposed models of basin formation, and the ship's airguns will be used as the source for land-based seismometers in Victoria and Tasmania (see Appendix 1) . The west Tasmanian seismic survey is designed to examine the King Island sub-basin of the Sorell Basin near Clam No. 1 well, to test the structure of the continental margin from the continental shelf to undoubted oceanic crust, and to provide a seismic tie through thick sedimentary basins on the west Tasmanian continental slope.

The latter half of the cruise will be devoted to geological sampling on the west Tasmanian margin. Some of the work will be the sampling of basement and older outcropping sequences (Mesozoic and Palaeogene) to provide control for seismic interpretation. Other aspects of the work will be the sampling of younger sequences in order to establish a model for Cainozoic sedimentation, the analysis of surface sediments to define areas of anomalous concentrations of thermogenic gas, and the measurement of near-surface heatflow and thermal conductivity as a means of establishing thermal flux.

The overall aim of the work is to better define the geology of the basins, and especially their history of rifting, stratigraphy, and petroleum potential.

### INTRODUCTION

BMR's Marine Division has been involved in three cruises on the west Tasmanian margin in recent years, two co-operative cruises with the Bundesanstalt fuer Geowissenschaften und Rohstoffe (BGR) using R.V. Sonne (Hinz et al., 1985, 1986), and one using R.V. Rig Seismic (Exon, Lee et al., 1987). These cruises provided 1000 km of regional multichannel seismic data on the west Tasmanian margin. They also provided 70 geological samples from the west Tasmanian margin, and 4 heatflow measurements. In 1982, BMR contracted Geophysical Services International (GSI) to carry out a multichannel seismic survey of the Bass Basin (BMR Survey 40), with regional seismic lines extending on either side of King Island, out to the abyssal plain. The Bass Basin results have been reported in a string of publications (Williamson et al., 1985, 1986, 1987b; Williamson and Pigram, 1986).

The forthcoming cruise of Rig Seismic (Project 9131-13) will build on these results and will consist of two elements :

- A. Deep basinal and crustal structure of the Bass Basin
- B. Geological framework and hydrocarbon resource assessment of the west Tasmanian basins.

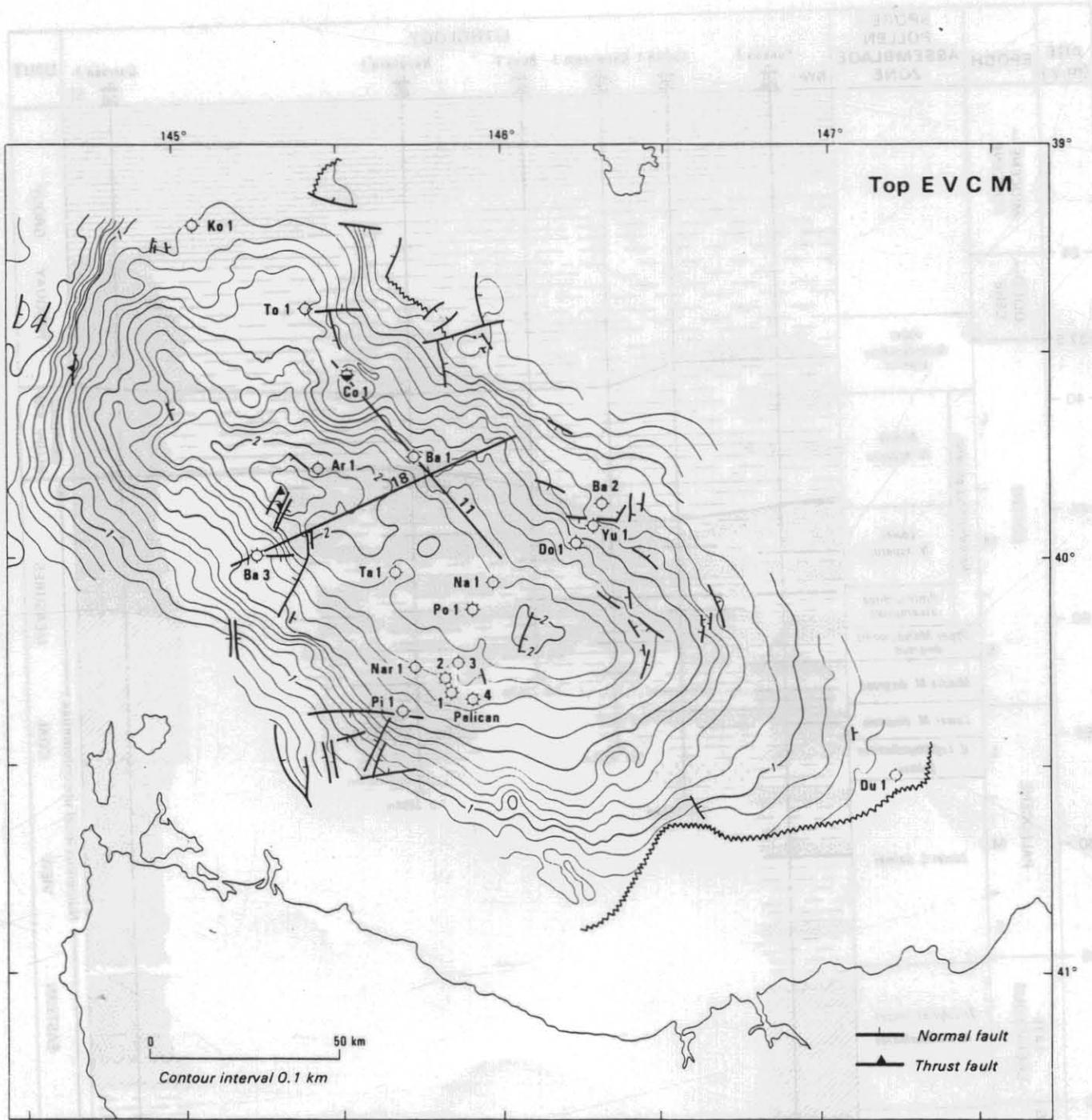
The cruise will consist of a multichannel seismic leg from Eden to Hobart, and a sampling leg from Hobart to Port Welshpool.

#### REGIONAL FRAMEWORK

The Otway, Bass, Gippsland and west Tasmanian Basins form a series of extensional basins along the southern margin of Australia, which developed in Late Jurassic and Early Cretaceous times before the breakup of East Gondwanaland (Robertson et al., 1978; Etheridge et al., 1984, 1985). These basins vary in character from predominantly rift-related in the Great Australian Bight, to mixed rift and wrench related in the Otway Basin, to predominantly wrench-related on the western margin of Tasmania. The abrupt terminations of most of the basins, and the accompanying offsets of the continental shelf, can be attributed to the development of major transform or transfer faults.

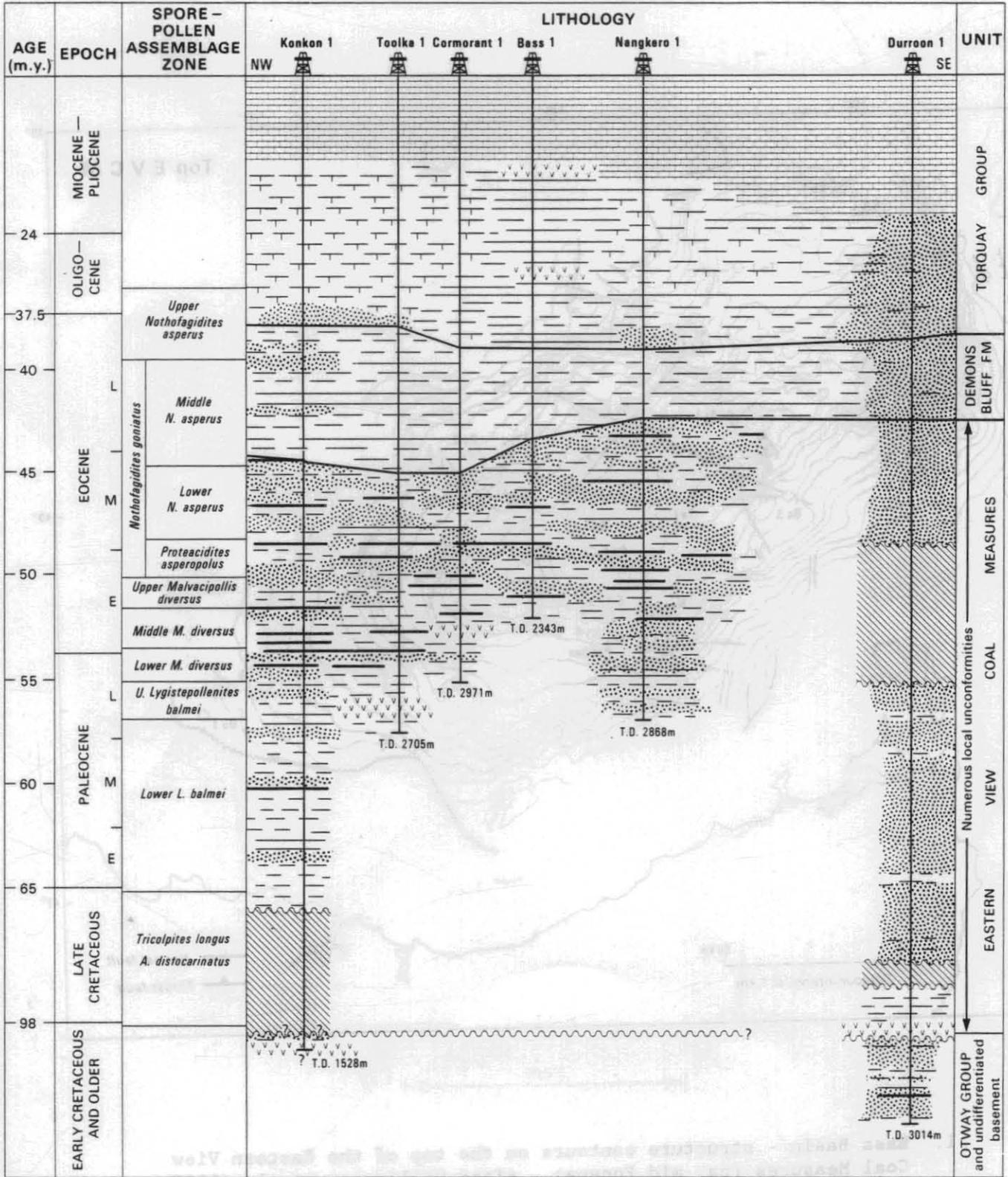
The intracratonic Bass Basin (Fig. 1) formed by extensional tectonics during the Late Jurassic to Early Cretaceous (Williamson et al., 1985). The stratigraphy is summarized in Figure 2. The basin contains up to 7 km of non-marine sediments of (?) Late Jurassic to late Eocene age and up to 3.5 km of upper 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. Seismic reflection studies (Williamson et al., 1987b) show that significant structural and stratigraphic prospects for petroleum exploration occur at Paleocene, Cretaceous, and probably Jurassic levels. Source rock studies combined with depositional models suggest that suitable source and reservoir rocks occur in the Upper Cretaceous to Paleocene non-marine sequences. Organic maturation studies suggest that mature levels for petroleum generation are 3-5 km deep, which generally corresponds to Upper Cretaceous to Paleocene sediments. The best potential for petroleum discoveries appears to be at mature levels within the Upper Cretaceous to Paleocene Eastern View Coal Measures (EVCN) (Williamson et al., 1985, 1986, 1987b.)

Etheridge et al. (1985), during interpretation of high-quality seismic reflection data from the Bass Basin, recognised the existence of major Early Cretaceous extensional normal faults segmented by contemporaneous transfer faults. 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. There are three major normal faults, with trends of 290° to 300° - one along each margin and one near the centre of the basin. The transfer faults are vertical and trend 020° to 030° (Fig. 3). They are predominantly right-lateral offset, giving rise to the northwesterly trend of the basin. The normal faults and associated tilt-block edges have had a major influence on structural evolution in



1. Bass Basin - structure contours on the top of the Eastern View Coal Measures (ca. mid Eocene). After Williamson et al. (1987b).

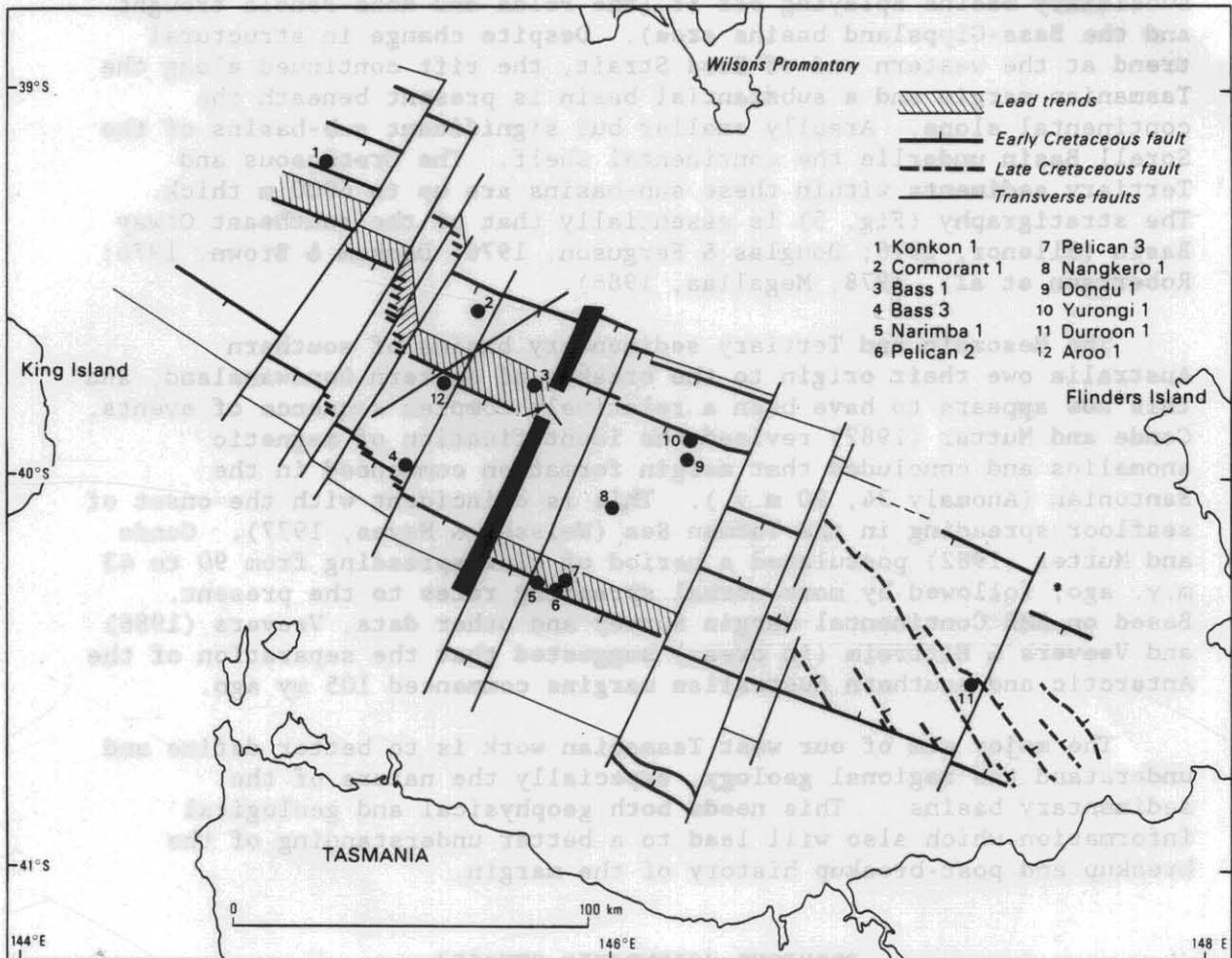
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- Limestone
- Siltstone, mudstone
- Sandstone
- Volcanics
- Marl
- Shale
- Coal
- Hiatus

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2. Bass Basin stratigraphy. After Williamson et al. (1985).



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3. 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 et al. (1985).

the overlying hydrocarbon-prospective EVC. The aim of our Bass Basin multichannel seismic program is to test the hypothesis that transfer faults are traceable right across the basin, and to map deep structure in order to better understand how the basin developed.

To the southwest, the western margin of Tasmania (Fig. 4) forms the eastern end of the band of extensional basins which developed as a precursor to formation of the southern margin of the Australian continent (Hinz et al., 1986). These related basins initially formed a complex rift system which extended for more than 1500 km, with subsidiary basins splaying off it (the Polda and Robe-Penola troughs and the Bass-Gippsland basins area). Despite change in structural trend at the western end of Bass Strait, the rift continued along the Tasmanian margin and a substantial basin is present beneath the continental slope. Areally smaller but significant sub-basins of the Sorell Basin underlie the continental shelf. The Cretaceous and Tertiary sediments within these sub-basins are up to 6000 m thick. The stratigraphy (Fig. 5) is essentially that of the southeast Otway Basin (Ellenor, 1976; Douglas & Ferguson, 1976; Denham & Brown, 1976; Robertson et al., 1978, Megallaa, 1986).

The Mesozoic and Tertiary sedimentary basins of southern Australia owe their origin to the breakup of eastern Gondwanaland, and this now appears to have been a relatively complex sequence of events. Cande and Mutter (1982) revised the identification of magnetic anomalies and concluded that margin formation commenced in the Santonian (Anomaly 34, 90 m.y.). This is coincident with the onset of seafloor spreading in the Tasman Sea (Weissel & Hayes, 1977). Cande and Mutter (1982) postulated a period of slow spreading from 90 to 43 m.y. ago, followed by more normal spreading rates to the present. Based on BMR Continental Margin Survey and other data, Veevers (1986) and Veevers & Eittreim (in press) suggested that the separation of the Antarctic and southern Australian margins commenced 105 my ago.

The major aim of our west Tasmanian work is to better define and understand the regional geology, especially the nature of the sedimentary basins. This needs both geophysical and geological information which also will lead to a better understanding of the breakup and post-breakup history of the margin.

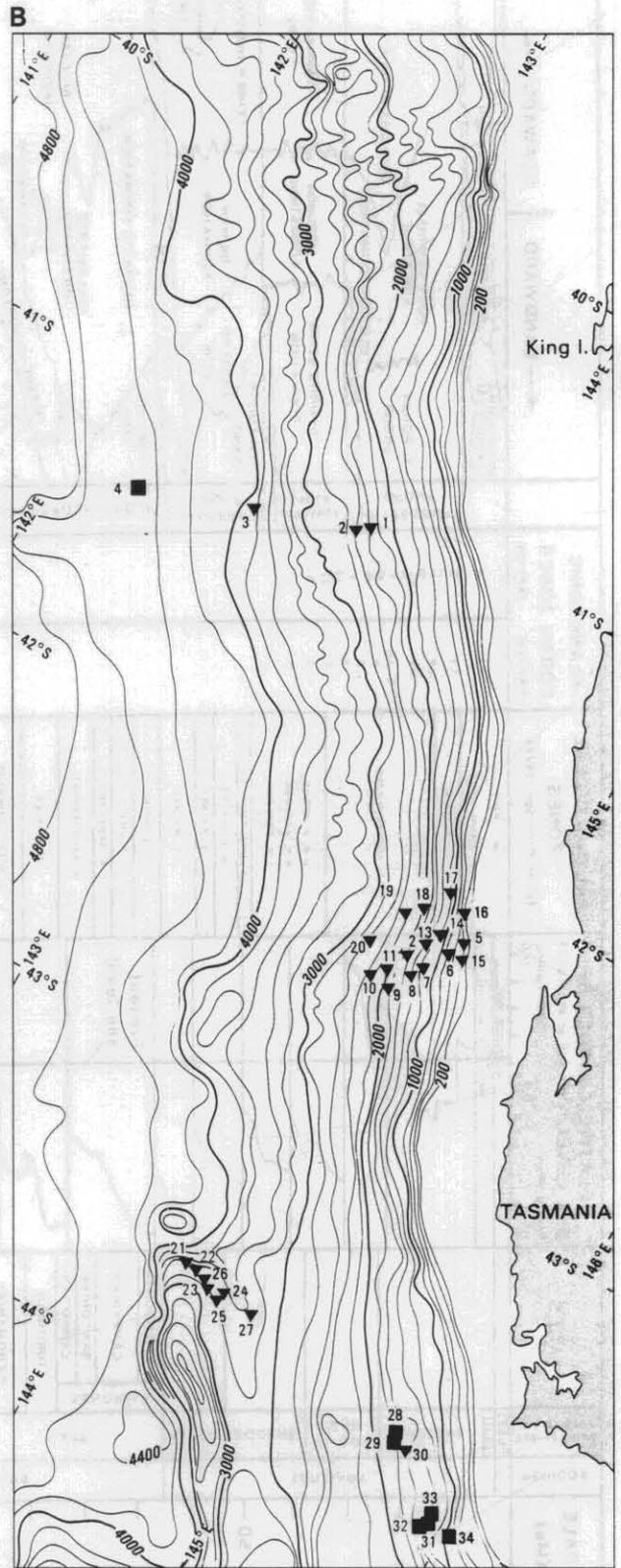
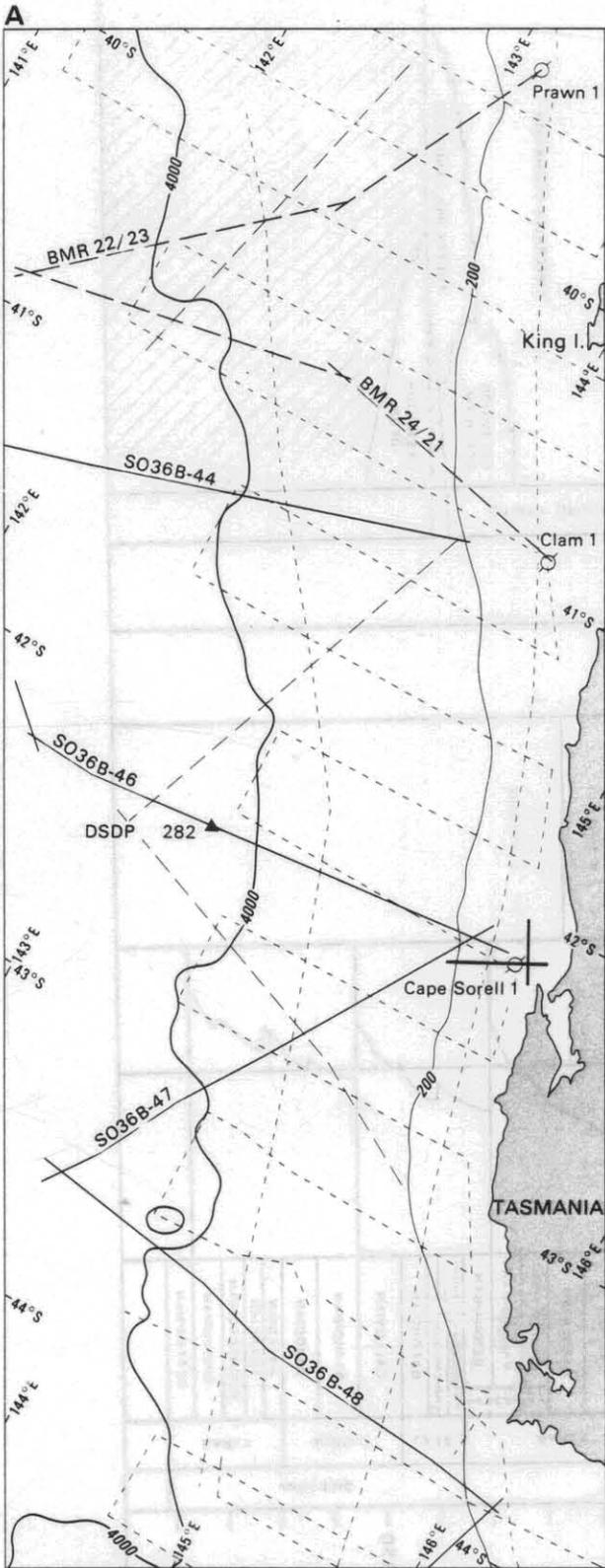
#### PREVIOUS SCIENTIFIC STUDIES

Neither the Bass Basin nor the Sorell Basin have any worthwhile onshore exposure, so relevant previous studies are virtually confined to geophysical and sampling cruises and offshore drilling.

The first regional seismic survey that included the two basins was the 1972 BMR Continental Margin Survey. This sparker survey extended from the shelf to the abyssal plain, with a line spacing of about 35 km, and was the basis of a report on the Australian southern margin by Willcox (1978).

In 1973, BMR recorded about 1000 km of low-energy reflection profiles over the west Tasmanian shelf from M.V. Sprightly. These profiles gave penetration of up to half a second (two-way time), and

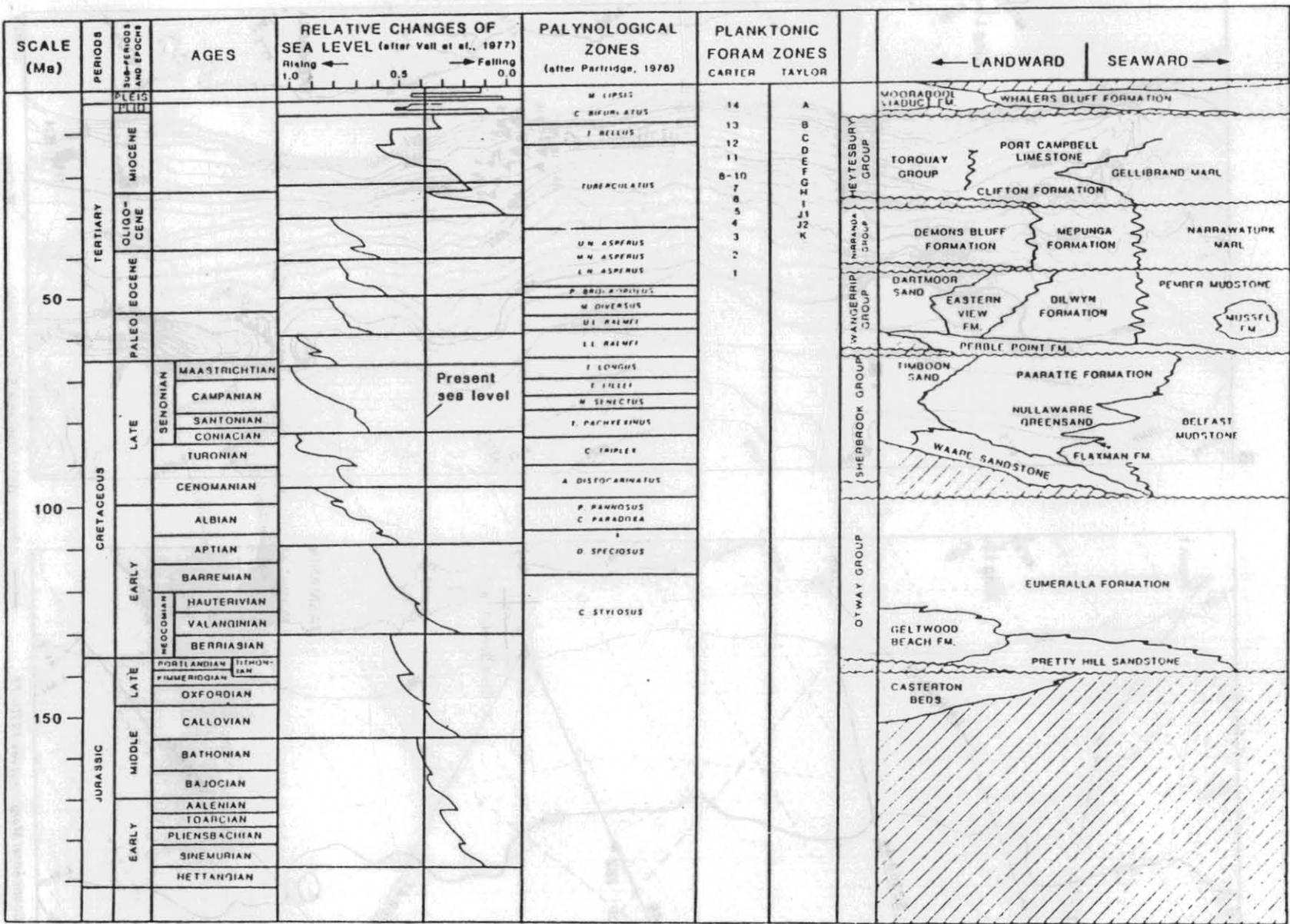
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- - - BMR Continental Margin survey 1970-73      — Amoco 'West Tasmania Basin' survey      ▼ Core  
 - - - Shell 'Petrel' survey      — BGR 'Sonne' Cruise SO-36, 1985      ■ Dredge  
 - - - BMR Bass Strait survey

4. Regional multichannel seismic tracks and drill sites off west Tasmania, bathymetry and Sonne sampling sites. After Hinz et al. (1986).

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5. Regional stratigraphy of the Otway Basin, much of which applies in the Sorell Basin off west Tasmania. (After Megallaa (1986)).

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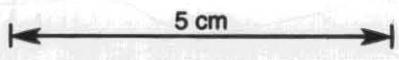
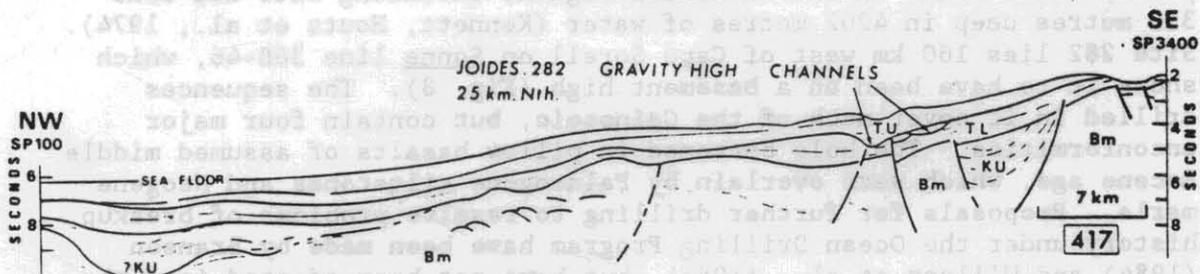
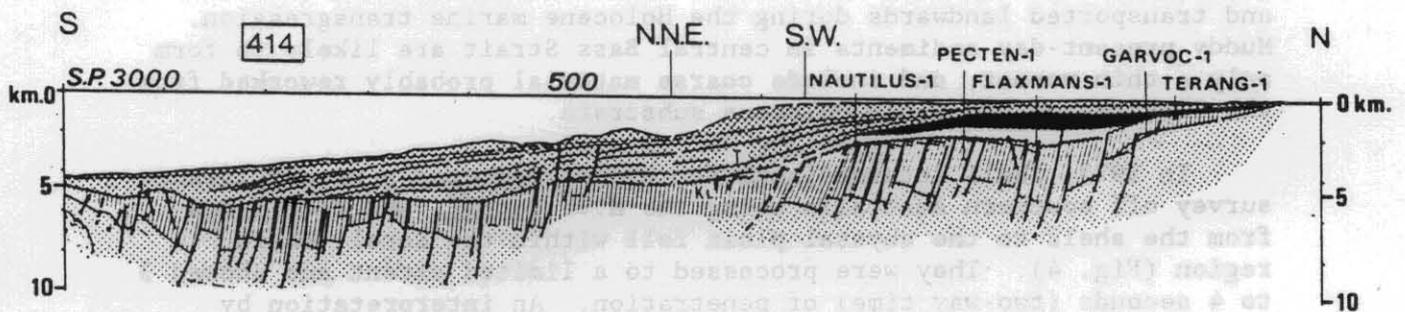
showed that gentle faulting, uplift and erosion occurred during the late Miocene, and that Pliocene to Quaternary sediments unconformably overlie Miocene and older rocks (Jones & Holdgate, 1980). Much of the shelf consists of Miocene outcrop or subcrop below a veneer of younger sediments. Superficial sediments sampled on the same cruise showed that off western Tasmania the inner shelf consists of quartz sand with some shell debris, and the outer shelf of medium to coarse grained bryozoal sand and gravel (Jones & Davies, 1983). The shelf sands are mainly relict from times of lower sea level. Phosphate was recovered in several dredge hauls, the highest values (<4%) being found between West Point and Rupert Point.

Jones & Davies (1983) reported that quartz-rich sands with variable amounts of shell debris occur on the rises flanking the central Bass Strait basin. They are essentially modern deposits derived in the main from Pleistocene nearshore sand bodies reworked and transported landwards during the Holocene marine transgression. Muddy present-day sediments in central Bass Strait are likely to form only a thin veneer, and include coarse material probably reworked from the Pleistocene and early Holocene substrate.

In 1973, Shell International Petroleum conducted a reconnaissance survey off southern Australia using the M.V. Petrel, and four lines from the shelf to the abyssal plain fell within the Sorell Basin region (Fig. 4). They were processed to a limited extent and showed 3 to 4 seconds (two-way time) of penetration. An interpretation by Bouef & Doust (1975) provided the first regional review of the deepwater parts of the region. Two west Tasmanian profiles, showing their interpretation, are illustrated in Figure 6.

Leg 29 of the Deep Sea Drilling Program (DSDP) drilled four partly cored holes in the Tasmanian region, including site 282 some 310 metres deep in 4202 metres of water (Kennett, Houtz et al., 1974). Site 282 lies 160 km west of Cape Sorell on Sonne line 36B-46, which shows it to have been on a basement high (Fig. 8). The sequences drilled in it cover much of the Cainozoic, but contain four major unconformities. The hole bottomed in pillow basalts of assumed middle Eocene age, which were overlain by Palaeogene siltstones and Neogene marls. Proposals for further drilling to resolve problems of breakup history under the Ocean Drilling Program have been made by Branson (1984) and Willcox et al. (1985), but have not been adopted into the current program.

Bouef & Doust (1975) showed that the Otway Basin and the west Tasmanian region was a passive margin, with a thick wedge of sediments that they indicated was bounded by oceanic crust on the edge of the abyssal plain. Beneath the continental rise, block-faulted continental basement was recognized. They stated: "The sedimentary wedge which overlies the block-faulted and collapsed continental basement is subdivided by unconformities into: (a) a continental Lower Cretaceous unit and a fluvio-deltaic unit of Upper Cretaceous-Danian age which are taken to represent rift valley stages of deposition controlled by extensional tectonics and (b) a post-breakup sequence of Tertiary units representing regional collapse and out-building of the shelf. The Upper Cretaceous sequence is missing along much of the continental edge where Tertiary sediments appear to rest directly on the Lower Cretaceous unit. Our



6. Interpreted line drawings of Shell Petrel seismic sections N414 and N417 off King Island and Cape Sorell, after Bouef & Doust (1975). Locations in Figure 12.

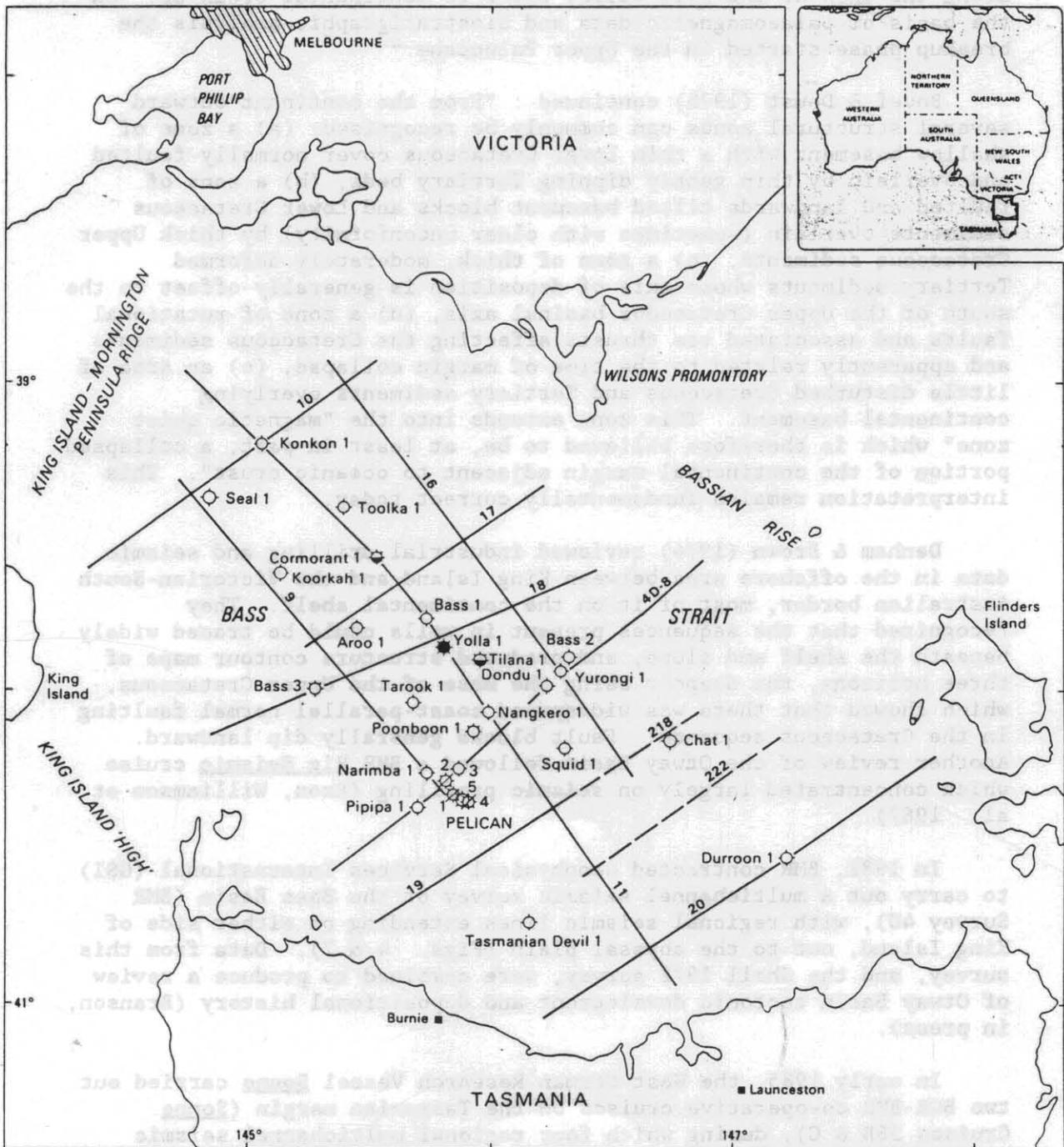
interpretation suggests that a prolonged period of uplift took place along the axis of the rift valley prior to continental break-up. On the basis of palaeomagnetic data and biostratigraphic analysis the breakup phase started in the Upper Paleocene."

Bouef & Doust (1975) continued : "From the continent outward several structural zones can commonly be recognised: (a) a zone of shallow basement with a thin Lower Cretaceous cover normally faulted and overlain by thin gently dipping Tertiary beds, (b) a zone of faulted and landwards tilted basement blocks and Lower Cretaceous sediments overlain (sometimes with clear unconformity) by thick Upper Cretaceous sediments, (c) a zone of thick, moderately deformed Tertiary sediments whose axis of deposition is generally offset to the south of the Upper Cretaceous basinal axis, (d) a zone of rotational faults and associated toe thrusts affecting the Cretaceous sediments and apparently related to the time of margin collapse, (e) an area of little disturbed Cretaceous and Tertiary sediments overlying continental basement. This zone extends into the "magnetic quiet zone" which is therefore believed to be, at least in part, a collapsed portion of the continental margin adjacent to oceanic crust". This interpretation remains fundamentally correct today.

Denham & Brown (1976) reviewed industrial drilling and seismic data in the offshore area between King Island and the Victorian-South Australian border, most of it on the continental shelf. They recognized that the sequences present in wells could be traced widely beneath the shelf and slope, and produced structure contour maps of three horizons, the deepest being the base of the Upper Cretaceous, which showed that there was widespread coast-parallel normal faulting in the Cretaceous sequence. Fault blocks generally dip landward. Another review of the Otway Basin followed a BMR Rig Seismic cruise which concentrated largely on seismic profiling (Exon, Williamson et al. 1987).

In 1982, BMR contracted Geophysical Services International (GSI) to carry out a multichannel seismic survey of the Bass Basin (BMR Survey 40), with regional seismic lines extending on either side of King Island, out to the abyssal plain (Figs. 4 & 7). Data from this survey, and the Shell 1972 survey, were combined to produce a review of Otway Basin tectonic development and depositional history (Branson, in press).

In early 1985, the West German Research Vessel Sonne carried out two BGR-BMR co-operative cruises on the Tasmanian margin (Sonne Cruises 36B & C), during which four regional multichannel seismic lines and several short tie lines (1000 km long in all) were recorded off west Tasmania, and 34 sampling stations occupied (Fig. 4). A detailed cruise report was provided by Hinz et al. (1985). An interpretation of these seismic lines (Figs. 8 and 9), combined with those of a 1982 BMR line and an Amoco line (Figs. 10 & 11), showed that up to 5 seconds (two-way time) of section is present and that up to 14 unconformities can be identified (Table 1 and Hinz et al., 1986). Sampling and well data indicated that unconformity U3 represented the regional Oligocene unconformity, U9 the basal Tertiary unconformity, and U12 the basal Upper Cretaceous unconformity. The relatively thin Tertiary sequences consist essentially of Neogene carbonates and Palaeogene terrigenous sediments. The Upper Cretaceous



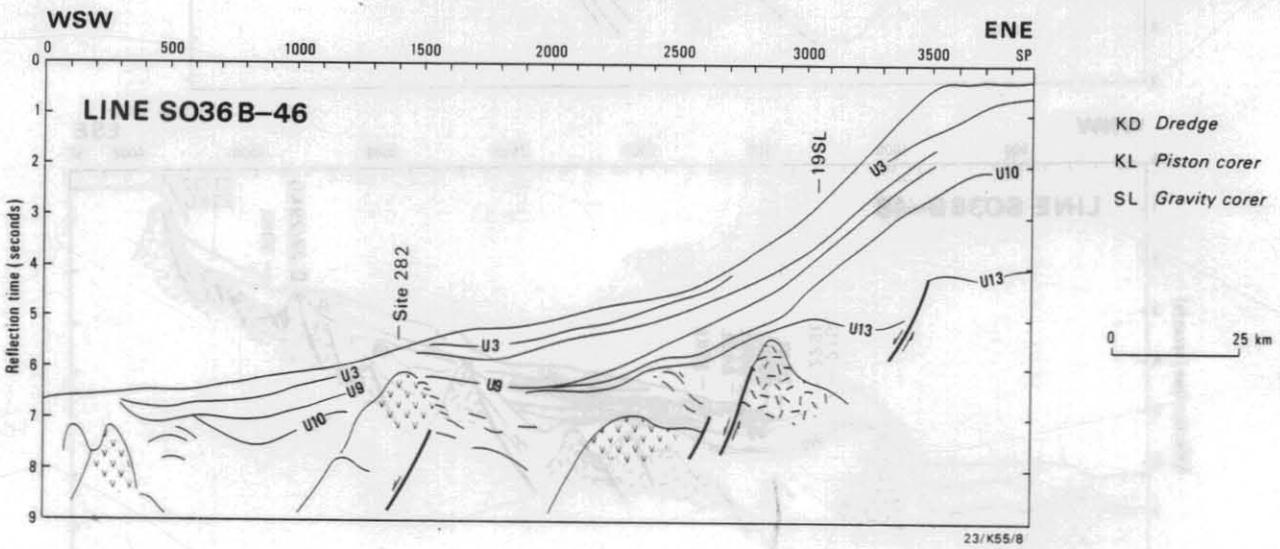
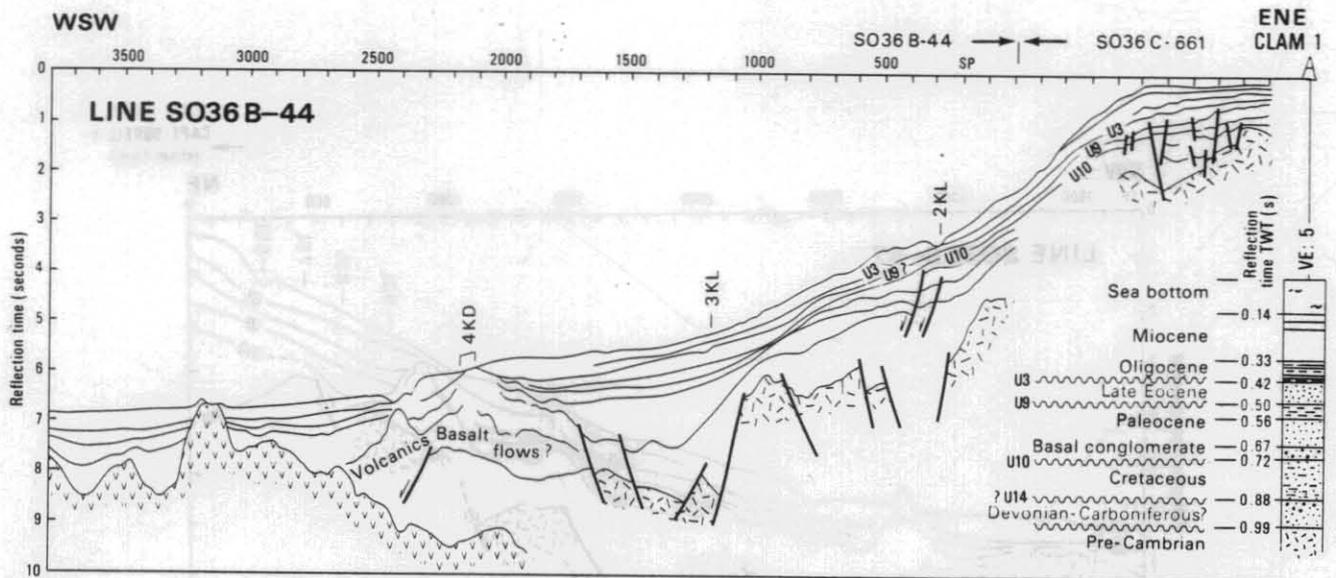
0 100 km

11 — BMR 1982 seismic line  
 218 — Hematite Pty Ltd seismic line

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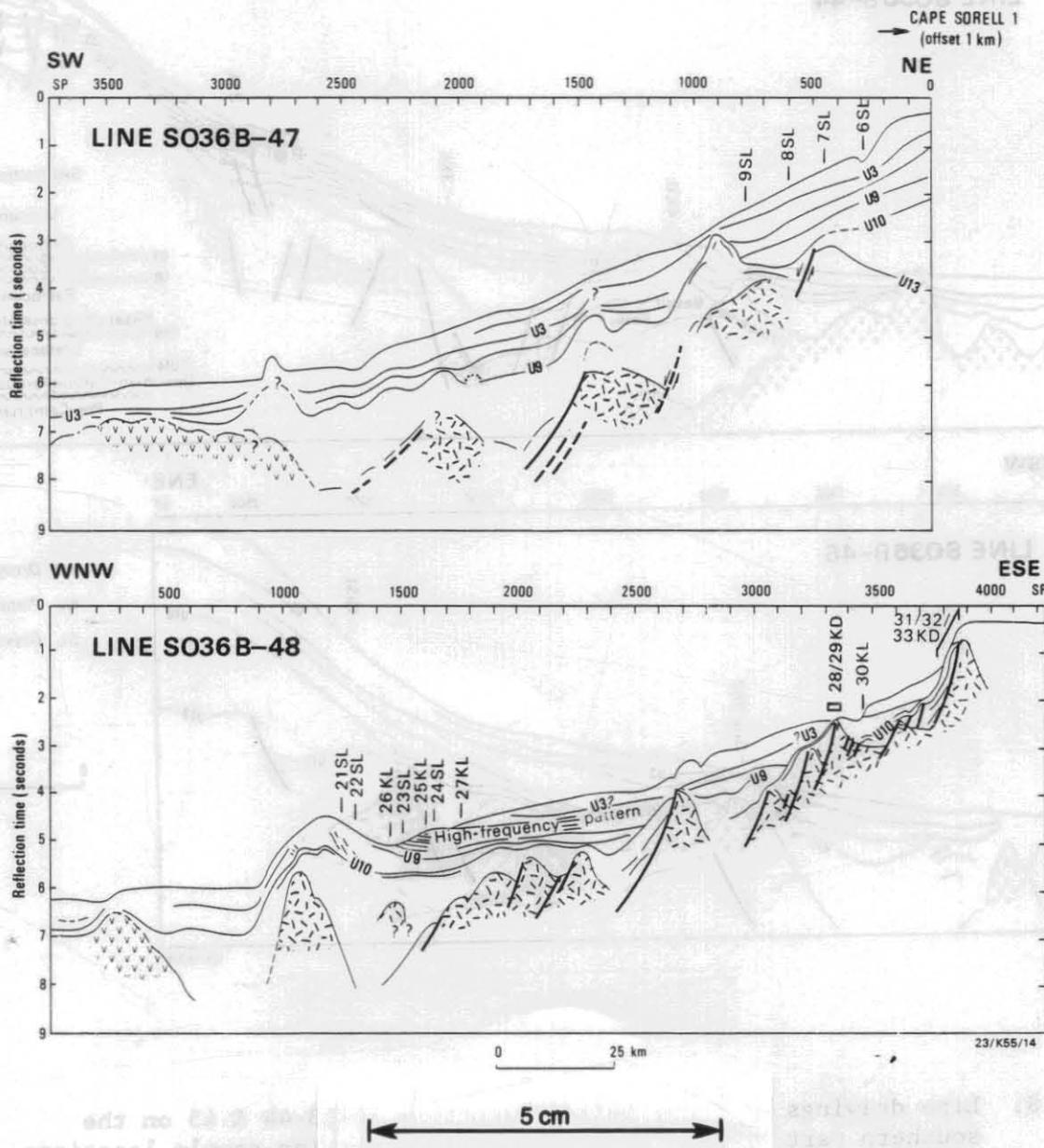
- Well, dry abandoned
- ⊙ Well, with show of gas, abandoned
- ⊛ Well, gas discovery
- ⊛ Well, with show of oil and gas, abandoned
- ⊛ Well, oil and gas discovery
- ⊛ Gas well, abandoned

7. 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.



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8. Line drawings of Sonne seismic sections SO36B-44 & 45 on the southern part of west Tasmanian margin, showing sample locations (see Fig. 4). After Hinz et al. (1986).

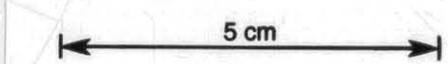


9. Line drawings of Sonne seismic sections S036B-47 & 48 on the southern part of the west Tasmanian margin, showing sample locations (see Fig. 4). After Hinz et al. (1986).

Table 1. Regional stratigraphy, unconformities and seismic sequences. After Hinz et al. (1986).

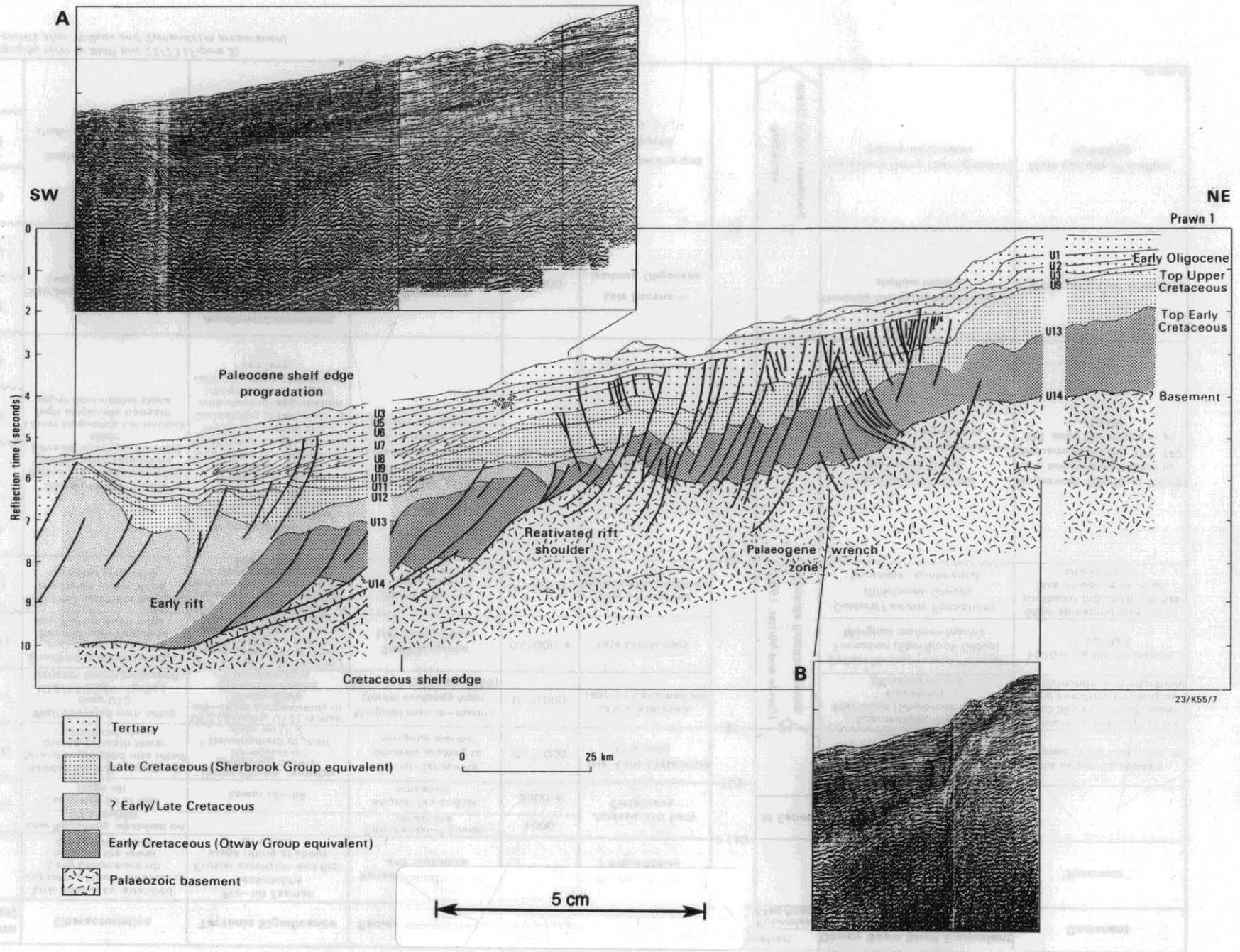
Unconform (Sequence)	Characteristics	Tectonic Significance	Facies Interpretation	Approx Thickness (m)	Proposed Age Identification			Otway Basin Shelf Equivalent and Unconformities	Comment	
					Stratigraphic	m. y.	Equivalent Mag Anom			
U14	Low frequency, stratified and folded Floors Jurassic or Early Cretaceous rift beneath the lower continental slope	Pre-rift Tasman Geosyncline Crustal extension and first stage rifting at about U14 time	Varied metasediments and volcanics	Unknown	Palaeozoic and ? Precambrian			"Basement"		
S(13-14)	Low frequency, stratified on rift shoulder Contorted fill in first stage rift	Lower rift-fill	Continental-? fluvial, lacustrine Alluvial fan and/or volcanics	1000 3000 +	Jurassic and Early Cretaceous	140 105	M Series	Casterton Beds and Otway Group Non-marine clastics and volcanogenic sediments		
U13	Bedded fill in first stage rift Now incorporated into tilted blocks beneath lower continental slope	Upper rift-fill, probably preceding marine transgression ? Development of shelf edge on U12	Fluvial-lacustrine possibly grading to marginal marine	0-?1000	"late" Early Cretaceous (? Albian)	95		Probably time equivalent to Eumerella Formation (Otway Gp) Continental environments with volcanism	This sequence appears confined to the first stage rift	
U12	Well stratified with onlap onto U12 U12/13 block-faulted beneath continental shelf	U12 (possibly U13) is main rift-onset unconformity in Otway Basin S(11-12) marine transgression	Marginal marine-marine (foram evidence from Ribis and Aphorpe, 1969)	0-?1000	Late Cretaceous (approx Cenomanian)	34	Slow spreading episode (Cande and Mutter, 1982)	Approximate Waarre Formation (Sherbrook Group) equivalent Shoreline facies	Wrenching and uplift of the tilted blocks beneath lower slope commenced (Willcox and Symonds, in preparation)	
S(11-12)									Belfast Mudstone and Flaxman Formation (Sherbrook Group) Marginal marine-marine	1570m Belfast Mudstone in Voluta 1
U11	Stratified sediment wedge with onlap onto U11 Basal channelling land ward of old shelf edge	U11 eustatic lowstand in ? Coniacian (Vail et al., 1977) S(10-11) basin transgr restricted by blocks below lower continental slope	Shallow marine (restricted basin)	0-1000 +	Late Cretaceous					
S(10-11)										
U10	Stratified sediment wedging out below lower slope Downlap onto U10	U9 and U10 relative falls in sea level U9-slowing or termination of movement of tilted blocks beneath lower slope	Shallow marine (regressive)	0-500 +	Late Cretaceous (approx Maastrichtian)	29		Curdies/Paratte Formations (Sherbrook Group) Shoreline-continental	Slow spreading episode in southeast Indian Ocean has less influence on outer Otway Basin	
S(8-9)										
U8	S(5-6) to S(8-9) are distinctive, high frequency, downlapping sequences beneath lower continental slope	A period of minimal subsidence in the outer Otway Basin due to contact between Australian and Antarctic plates in Tasmanian region Sedimentation influenced by elevated blocks beneath lower continental slope	Shelf clastics, grading into fine grained progradational wedges at palaeoshelf-edge (largely terrigenous)	200-1500	Paleocene-Middle Eocene			Age equivalent of the Wangarrup Group Shallow marine → shoreface → continental (regressive)	Sequences S(5-6) to S(8-9) are believed equivalent to depositional cycles TP1, TP2, TE1 and ?TE2 of Vail et al. (1977)	
U7	Lower frequency, continuous, high amplitude beneath upper continental slope	Outbuilding of fine clastics with minimal aggradation Unconformities largely reflect eustatic changes in sea level								
S(6-7)										
U6										
S(5-6)										
U5	Stratified, onlapping S(3-4) extends across outer tilted blocks	Accelerated movement along Australian-Antarctic plate boundary Major wrenching and development of flower structures in southeast Otway Basin and western margin of Tasmania	Shallow marine (largely terrigenous)	0-800	Late Eocene-earliest Oligocene	42		Nirranda Group (transgressive) - shallow marine	? Minor volcanism at U5 time	
S(4-5)										
U4										
S(3-4)										
U3	Stratified, channelled, shelf-edge progradation	U3 is widespread Early Oligocene unconformity marking clearance of Australian and Antarctic plates and establishment of open marine conditions	Shelf - open marine (largely carbonate)	0-600	Late Oligocene and Neogene	35		Heytesbury Group (transgressive) marine carbonates	Main episode of seafloor spreading	
S(2-3)										
U2										
S(1-2)										
U1										

\* For stratigraphy refer to BMR line 22/23 (Figure 3)  
Tectonic events after Willcox and Symonds (in preparation)



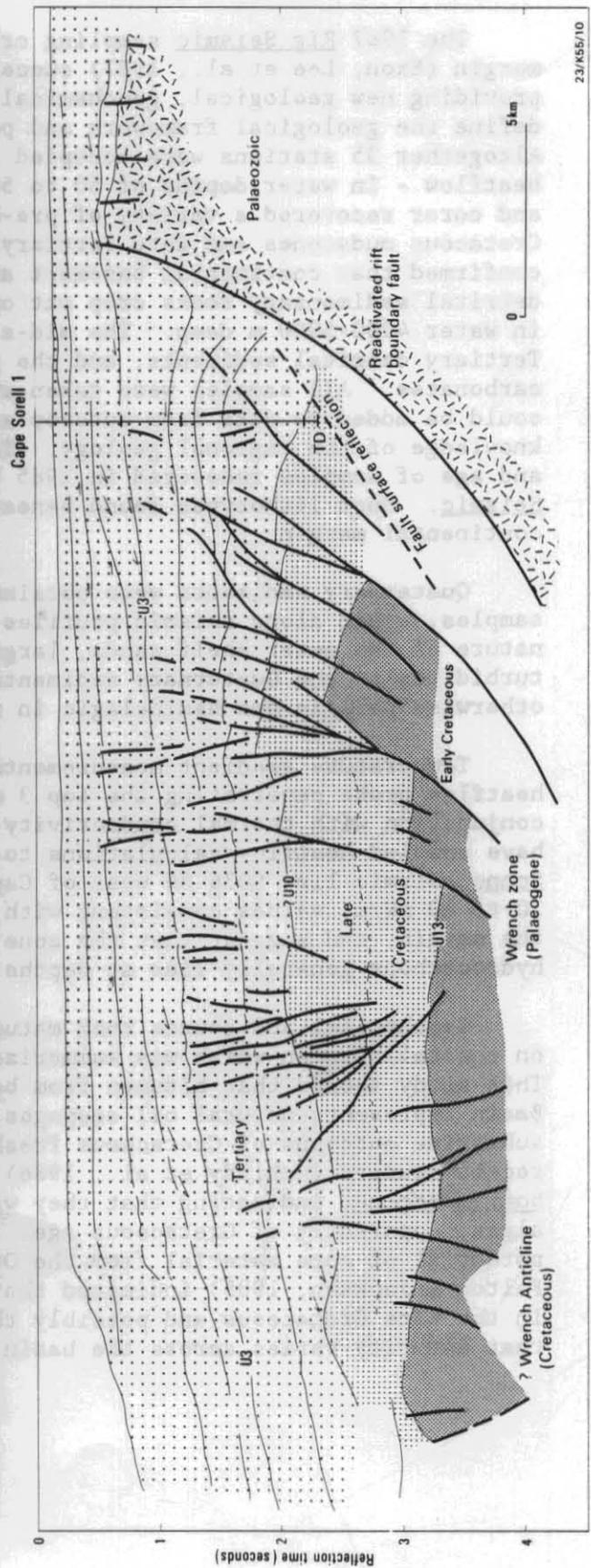
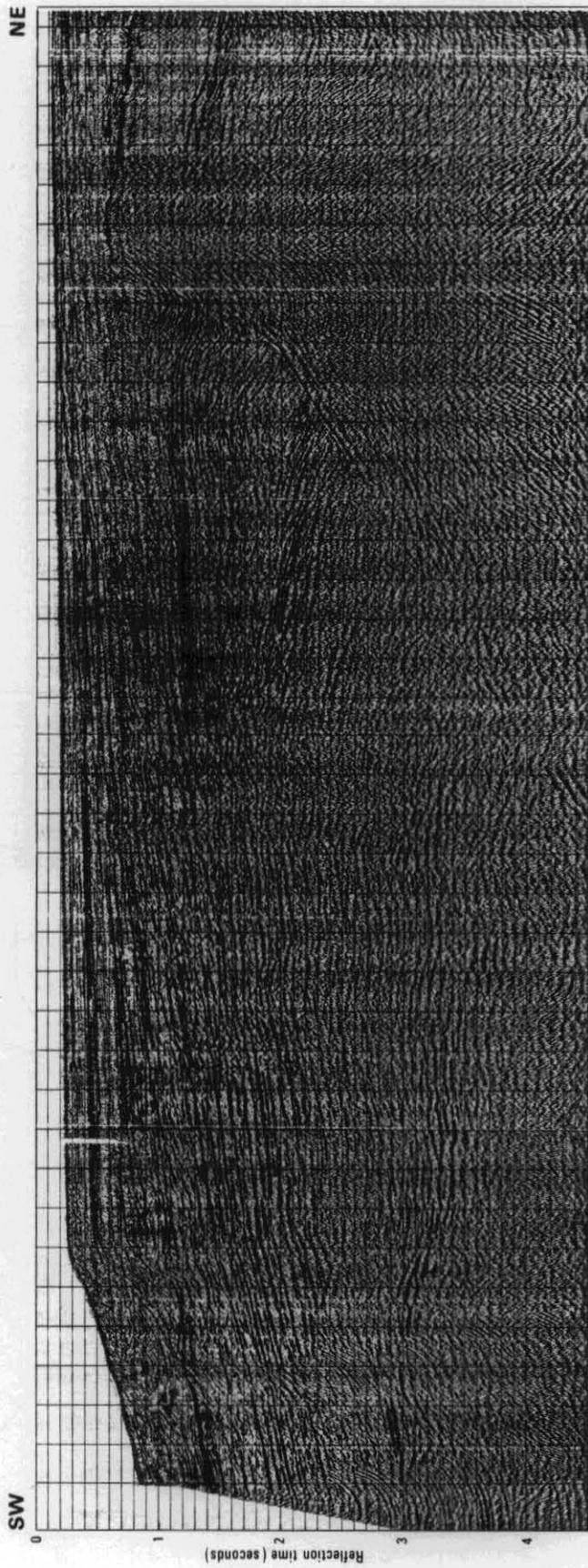
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10. Interpretation of BMR seismic profile 40-22/23, tied tentatively to Prawn No. 1 well. Location shown in Figure 4. After Hinz et al. (1986).

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11. Interpretation of Amoco seismic profile W88-82 through Cape Sorell No. 1. After Hinz et al. (1986).

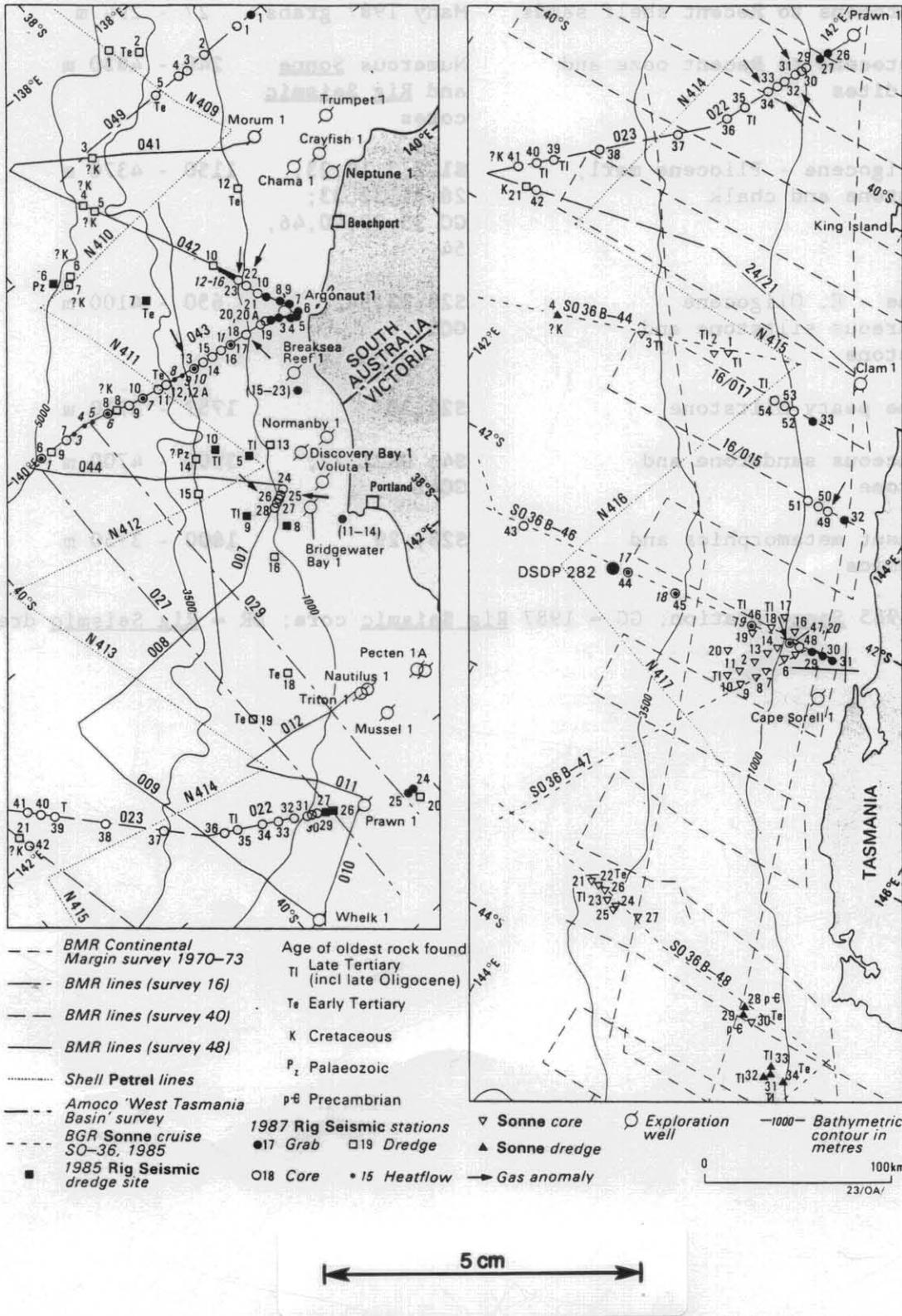
sequence appeared to subcrop along the foot of the continental slope, along with continental basement which was sampled at three stations.

The 1987 Rig Seismic sampling cruise over the west Tasmanian margin (Exon, Lee et al., 1987) succeeded in its overall aim of providing new geological, geochemical and heatflow data to better define the geological framework and petroleum potential of the region. Altogether 35 stations were occupied - 3 dredge, 25 core, 8 grab and 4 heatflow - in water depths of 50 to 5000 m (Fig. 12; Table 2). Dredge and corer recovered a variety of pre-Quaternary rocks and sediments, Cretaceous mudstones and Late Tertiary carbonates. These results confirmed that continental basement and Early and Late Cretaceous detrital sedimentary rocks crop out on the lowermost continental slope in water 4000-5000 m deep. The mid-slope is characterized by Early Tertiary detrital sediments, and the upper slope by Late Tertiary carbonates. All samples were taken along seismic profiles, and so could be added to data from outcrop and shelf wells to help refine knowledge of the regional geology. Table 2 summarises the character and age of samples recovered in 1985 by Sonne, and in 1987 by Rig Seismic. Most lithotypes found beneath the shelf are present on the continental margin.

Quaternary sediments were obtained in most cores and grab samples, again along seismic profiles. Grab sampling established the nature of the outer shelf sands, largely bryozoal, which provide turbidites to the Quaternary sediments on the continental slope, otherwise pelagic and hemipelagic in nature.

Temperature gradient measurements at 4 stations, made by a heatflow probe penetrating the top 3 metres of sediment, in conjunction with thermal conductivity measurements on sediment cores, have enabled heatflow calculations to be made. These measurements, on Sonne seismic line S036-46 west of Cape Sorell No. 1 well, vary from 20 to 40 mW/m, values consistent with the accepted breakup history of the margin, and suggest that the zone of thermal maturation of hydrocarbons generally lies at depths of 2-4 km.

Geochemical and source rock maturity studies commenced with work on coastal bitumen which was summarized by McKirdy & Horvath (1976). This study showed that bitumen from beaches along the western Otway Basin represents natural oil seepages, believed to be derived from submarine outcrops of Cretaceous freshwater and paralic rocks. More recent studies (McKirdy et al., 1986) show that the oils contain botryococcane, indicating that they were derived from lacustrine green algae, apparently of Cretaceous age. Studies of the source-rock potential of core material from the Otway Basin (Jackson et al., 1983; Felton & Jackson, 1985) indicated that the best source rocks might be in the Late Cretaceous and possibly the Early Tertiary sequences, and that maturity varies across the basin.



12. Maps showing regional seismic grid and Rig Seismic and Sonne sampling and heatflow stations, Otway Basin and west Tasmanian margin.

TABLE 2 : CHARACTER AND AGE OF SAMPLES : SONNE & RIG SEISMIC CRUISES

<u>Sequence</u>	<u>Stations</u>	<u>Depth Range</u>
Pleistocene to Recent shelf sands	Many 1987 grabs	27 - 294 m
Pleistocene to Recent ooze and turbidites	Numerous <u>Sonne</u> and <u>Rig Seismic</u> cores	240 - 4830 m
L. Oligocene - Pliocene marl, limestone and chalk	S1,2,3,19,23, 26,31,32,33; GC 35,39,40,46, 54	1150 - 4370 m
Eocene - E. Oligocene calcareous siltstone and limestone	S29,32,34; GC5	650 - 4100 m
Eocene peaty siltstone	S22,30	1757 - 3710 m
Cretaceous sandstone and mudstone	S4; DR21,22; GC42	3900 - 4700 m
Basement metamorphics and volcanics	S28, 29	1800 - 3750 m

S - 1985 Sonne station; GC - 1987 Rig Seismic core; DR - Rig Seismic dredge



SI  
 This figure shows the locations of the Sonne and Rig Seismic stations and the depth contours of the study area. The map is oriented vertically and shows a series of dashed lines representing depth contours. Numerous small circles and lines indicate the locations of various sampling stations, including Sonne stations (S) and Rig Seismic stations (GC, DR). The map is overlaid with a grid of latitude and longitude lines.

On the west Tasmanian margin, DSDP site 282 on the abyssal plain (Fig. 4) contained a sequence of organic-rich Eocene silty clays with considerable source rock potential (Hunt, 1975a). In Cape Sorell No. 1 (Amoco, 1982) extensive traces of oil were found in the latest Cretaceous/earliest Paleocene. A shipboard study of 27 Sonne cores (Hinz et al., 1985) indicated that wet gas of thermogenic origin is abundant in surface sediments on the west Tasmanian margin, indicating the presence of mature source rocks. Similar results were obtained by Exxon, Lee et al. (1987).

#### PETROLEUM EXPLORATION

The geology and petroleum potential of the Bass Basin have been discussed by Weeks & Hopkins (1967), Richards & Hopkins (1969), Robinson (1974), Brown (1976), Robertson et al. (1978), Williamson et al. (1985, 1986, 1987b), and Williamson & Pigram (1986). Fifteen petroleum exploration wells, including two appraisal wells, were drilled by a Hematite/Esso partnership between 1965 and 1973 (Fig. 3). 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.

Nicholas et al. (1981) carried out a source rock study of the Bass Basin after the first round of exploration, with emphasis on the Eastern View Coal Measures. Geochemical analyses were carried out on 29 core samples from 11 wells. Vitrinite reflectance determinations, and geothermal gradients suggested that, with the exception of Cormorant No. 1, none of the wells is deep enough to have penetrated a mature source rock section. The deeper wells in the basin centre, and wells on the southwest flank in the vicinity of the Pelican field, appeared to have been terminated just above the zone of initial hydrocarbon generation. The analytical results for samples from the Eastern View Coal Measures indicate a good source potential for the Paleocene to Early Eocene section, both in the deep basin and on the flanks, and a fair to good potential for the overlying Early to Late Eocene section. Kerogen type was determined microscopically in samples from four wells: Bass No. 3, Aroo No. 1, Poonboon No. 1, and Cormorant No. 1. The samples were found to contain predominantly gas-prone kerogen, in keeping with the interpreted delta-plain depositional environment, although minor, more oil-prone kerogen was also detected. The study confirmed the occurrence of potential source rocks throughout the Eastern View Coal Measures, but indicated that the best potential is in its Paleocene to early Eocene lower part.

The lack of shallow exploration success in the first phase of exploration in the Bass 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's Division of Marine Geosciences and Petroleum Geology. This study, which began in 1982, incorporated well data, 4,500 km of modern multichannel seismic data and seismostratigraphic, 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, 1987b). 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. 2). 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. 1).

The only significant published account of the petroleum potential of the west Tasmanian margin is that of Hinz et al. (1986), on which we draw extensively. The west Tasmanian shelf is between 20 and 70 km wide (Fig. 4) and company data (especially that of Esso and Amoco) show that substantial sediment thicknesses are present in several sub-basins of the Sorell Basin between King Island and Macquarie Harbour. Up to 6000 m of Cretaceous and Tertiary sediments underlie the continental slope and seem to provide a vast 'kitchen area' for hydrocarbon generation.

The sequence immediately above basement generally appears to be Early Cretaceous, although about 220 m of Palaeozoic strata overlie Precambrian basement in Clam No. 1. A thick Late Cretaceous sequence is inferred at the site of Cape Sorell No. 1 (Fig. 11) and seismic data show a total Cretaceous thickness of 4000-5000 m in the main depocentres.

A marked mid-Oligocene unconformity (U3) extends throughout the region (Figs. 10 & 11). The overlying late Oligocene to Miocene marls and shallow marine carbonates, although only 740 m thick in Clam No. 1, reach a maximum of 1400 m on seismic data. Pliocene and younger oozes and sands, which overlie the Miocene limestones, are generally very thin.

Significant hydrocarbon traps are believed to be present in the Sorell Basin. However the structural complexity created by rifting and wrenching in both the Late Cretaceous and Eocene makes the location of drillsites a difficult task. For example, Cape Sorell No. 1 was sited on a relatively young (Palaeogene) rollover on the downthrown block of a major normal fault. Hinz et al.'s (1986) reinterpretation of Amoco Line W-81-12 (Fig. 11), which extends through the drillsite, indicates that although the normal fault marks the boundary of the original rift, it has been reactivated (?reversed) and strong wrenching has affected the sediment pile. An outer wrench anticline of Late Cretaceous age underlies the continental shelf break, and a major ?Eocene wrench zone occupies the area westward of the boundary fault. Complex fault structures extend upwards to the mid-Oligocene unconformity (U3). A huge sediment pile of largely Paleocene age was deposited locally in the Cape Sorell sub-basin, as a result of strike slip movement. If the well had been sited a few kilometres to the southwest it may have been in a more favourable structural location, intersecting the central uplifted blocks of a "flower structure".

Studies of the concentration and composition of hydrocarbons in surface sediments in the west Tasmanian area by Hinz et al. (1985, 1986) and Exon, Lee et al. (1987) are indicative of active source units and show that hydrocarbons of thermogenic origin are currently being generated just west of the shelf break. Migration paths and entrapment beneath the continental shelf, as demonstrated by the traces of free oil encountered in Cape Sorell No. 1, can be hypothesized. The distribution appears to be strongly influenced by fault-directed migration. Without either additional geochemical well control data or stable isotope evidence, the identification of the hydrocarbon source rocks is highly speculative. The early/mid-Eocene has demonstrated source rock qualities, and although in most areas it is at relatively shallow depth, examples from the offshore Otway Basin indicate that maturation can occur in Palaeogene sediments 1500 to 2000 m deep, with the 'oil window' between 2000 m and 4000 m (Felton & Jackson, 1985). However the Cretaceous units, with their suitable burial depth and thickness, are more attractive as hydrocarbon source rocks.

#### OBJECTIVES AND BACKGROUND

The overall aim of this project is to build on the results of the 1982 GSI cruise in Bass Strait, and the 1985 Sonne and 1987 Rig Seismic cruises on the west Tasmanian margin, in order to better define the geological history of the Bass Basin and the west Tasmanian margin. The more detailed objectives and a discussion of them are outlined below :

##### Bass Basin

1. To define the deep structure of sediments and underlying basement, along transects perpendicular to the presumed extensional fabric and parallel to presumed transfer faults (Fig. 3); and to determine the early rifting pattern and evolution of the basin.
2. To study continental crustal kinematics; to evaluate tectonic models of basin evolution; and to evaluate the geothermal consequences of such models in relation to the history of hydrocarbon generation and migration.
3. To test the tectonic model of the Bass Basin proposed by Etheridge et al. (1985), involving transfer faults and deep detachments.

The Bass Basin is the location of some petroleum exploration effort, and a better knowledge of the deep structure and development of the basin is expected to assist in future exploration by allowing new structural/stratigraphic play concepts to be formed. The seismic data will be among the first acquired with the purpose of defining basin-wide structural geometry to test extension and detachment models of rifting.

The project forms one component of a multi-faceted BMR investigation of southeast Australian basins and continental margins. The Tasman, Gippsland, Otway and Sorell basins represent a tectonically-related suite of oceanic, continental margin, and

intracratonic basins, which may have related structural evolutions. Similar deep crustal seismic data will be acquired in the Tasman Sea in Project 9131-11, the Gippsland Basin in Project 9131-12, and the west Tasmania margin in this Project 9131-13B. The data will enable us to compare and contrast the nature of basin formation in the Gippsland, Bass and Sorell basins.

Planning of the present project relies heavily on data collected during the 1982 BMR cruise carried out by GSI, and the deep seismic data to be acquired will complement those earlier multichannel seismic data.

#### West Tasmanian Margin

1. To better determine the structure, stratigraphy and evolution of the west Tasmanian margin, making use of the semi-detailed grid of good quality company data on the continental shelf, and regional data elsewhere.
2. To assess the tectonic history of the continental margin and its relationship to Antarctica and the South Tasman Rise.
3. To better assess the petroleum potential of the region, in particular of the sub-basins of the Sorell Basin : south of King Island, off Sandy Cape, and off Cape Sorell (Fig. 14).

This program is the logical continuation and completion of earlier BMR Otway Basin and west Tasmanian programs :

- . Project 1C.03 - Geological and resource framework of Otway Basin, making use of 1985 Rig Seismic multichannel seismic survey of Otway Basin, and 1985 Sonne multichannel seismic and sampling cruises off west Tasmania margin. Results were reported primarily in papers in the PESA volume covering the 1985 southeast Australian petroleum conference, and the 1987 APEA Journal.
- . Project 1C.09 - Stratigraphy, depositional environments and petroleum maturation history of the Otway Basin, making use of 1987 Rig Seismic sampling results from the west Tasmanian margin. Work is continuing, but initial results were presented at BMR's 1987 Otway Symposium, and in BMR Record 1987/11.

The data available on the west Tasmanian margin (Figs. 4 & 12) include :

- . A regional seismic data set extending into deep water, including multichannel Shell Petrel (1973), Sonne (1985) and BMR Bass Strait data (1982), and BMR six-channel Continental Margin Survey data (1973).
- . About 1500 km of Esso 24 channel regional seismic data on the west Tasmanian shelf, recorded in 1969 and 1970.
- . About 800 km of Amoco 96 channel detailed seismic data, in the Cape Sorell Sub-basin, recorded in 1981.

- . Seventy-four geological sampling stations occupied by Sonne and Rig Seismic in 1985 and 1987.
- . About 40 surface sediment cores analysed for thermogenic gas.
- . Four heatflow stations on Sonne seismic line S0-46.

### CRUISE PLAN

#### Timetable

Total cruise, Eden to Port Welshpool = 28 days, starting 23 March, 1988.

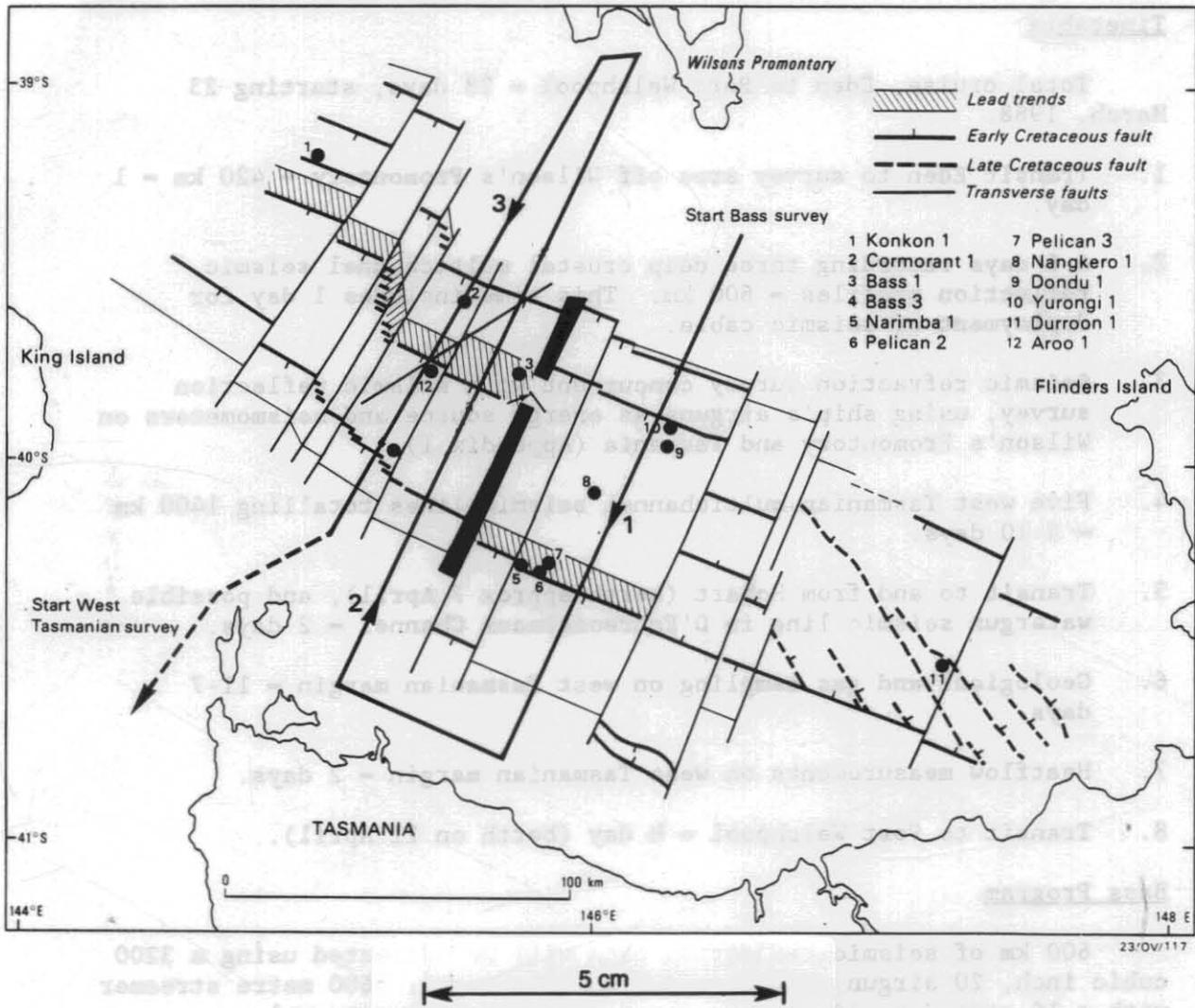
1. Transit Eden to survey area off Wilson's Promontory = 420 km = 1 day.
2. 4-6 days recording three deep crustal multichannel seismic reflection profiles = 600 km. This time includes 1 day for deployment of seismic cable.
3. Seismic refraction survey concurrent with seismic reflection survey, using ship's airguns as energy source and seismometers on Wilson's Promontory and Tasmania (Appendix 1).
4. Five west Tasmanian multichannel seismic lines totalling 1400 km = 8-10 days.
5. Transit to and from Hobart (berth approx 7 April), and possible watergun seismic line in D'Entrecasteaux Channel = 2 days.
6. Geological and gas sampling on west Tasmanian margin = 11-7 days.
7. Heatflow measurements on west Tasmanian margin = 2 days.
8. Transit to Port Welshpool = ½ day (berth on 21 April).

#### Bass Program

600 km of seismic reflection data will be collected using a 3200 cubic inch, 20 airgun source, and a 96/90 channel, 3600 metre streamer with a 16 second record length and 2/4 ms sampling interval. Indicative line locations are shown in Figure 13. Sonobuoy and onshore seismometer experiments, by Monash University, are planned to coincide with the seismic reflection data collection.

#### West Tasmanian Program

1. The multichannel seismic program, using the same system as in the Bass program, will consist of five lines (Fig. 14) :
  - A. Three regional lines to augment the existing company data set in the King Island sub-basin.



13. Map showing proposed deep structural seismic lines in the Bass Basin under Project 9131-13A, and their relationship to basin-forming structures.



- B. Two long lines examining the deep crustal structure and sedimentary section between the west Tasmanian shelf and the young oceanic crust on the abyssal plain. These lines will fill a major data gap which hampers understanding of the development of the margin.
  - C. A long, deepwater strike-line to tie BMR, Shell and Sonne data in an area where the sedimentary sequence is several thousand metres thick and the slope is not great. This line will be essentially complementary to company regional strike-lines on the shelf. It will greatly assist in determining the nature of the west Tasmanian strike-slip basins.
2. The sampling stations will be placed on new and pre-existing multichannel seismic lines, and will fall into four categories :
- A. Dredge stations aimed at ground-truthing seismic interpretations of Mesozoic and older outcrops.
  - B. Core stations aimed at ground-truthing seismically interpreted Tertiary sequences.
  - C. Core stations, largely vibrocore stations on the continental shelf, aimed at headspace gas analysis of sediments, which would be complementary to previous work on the continental slope. These will provide important extrapolated information about the abundance and nature of deep-seated hydrocarbons.
  - D. Grab stations to provide surface sediments on the shelf, and as a preliminary check before vibrocoring.
  - E. Heatflow stations, aimed at determining existing thermal gradients on the margin, as one parameter in establishing geothermal gradients through time.

The maximum number of stations anticipated are 20 dredge, 40 conventional cores, 5 box cores, 20 vibrocores, 20 grabs, 20 heatflow.

#### PERSONNEL AND EQUIPMENT

##### Personnel

The tentative personnel assignments are as follows. The letters in brackets refer to the leg on which personnel who are one leg only will participate.

Chief scientists :

N.F. Exon  
C.S. Lee

Sedimentologists/geochemists :

A. Felton (B) Wollongong University  
 P. Baillie (B) Tasmanian Mines Department  
 B. Thomas Flinders University, Adelaide  
 T. Hamilton (B) Flinders University, Adelaide

Geophysicists :

N. Johnston  
 G. Heal  
 G. Bernadel (A)  
 C. Collins (A) BMR Petrology & Geochemistry Division

Palaeontologist :

S. Shafik (B)

Technical officers :

J. Bedford  
 P. Davis  
 J. Kossatz  
 C. Lawson  
 H. Reynolds  
 J. Stuart  
 L. Miller  
 G. Burren  
 G. Jennings  
 R. Schuler  
 P. Walker  
 GSI technician (A)  
 Field hand

Equipment

- A. Multichannel seismic system with two gun strings.
- B. Standard underway geophysics : gravity, magnetics, and bathymetry.
- C. Rock dredges, piston, box and gravity corers; vibrocorer and grab for shelf work.
- D. Heatflow probe and conductivity measuring equipment.
- E. Equipment to allow shipboard canning of sediment for shore-based analysis.
- F. Core splitting equipment, microscopes, X-ray and photographic gear.

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## APPENDIX 1 : ON-SHORE REFRACTION RECORDING

by

C. Collins, BMR

Objectives

In order to test and develop models for the formation of the Bass Basin, an improved understanding of the deep structural elements must be obtained. In particular, to test an extensional model for the formation of the basin, the presence of detachment faults, transfer faults and any crustal thinning must be identified.

Vertical profiling may not unequivocally resolve these deeper features, and long-offset seismic refraction/wide-angle reflection data recorded coincidentally would 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 in any case provide additional data beyond the location of the profiling.

The refraction data will yield the velocity structure of the crust beneath the basin and its margins. This velocity data will assist the interpretation of the coincident vertical data, 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 temperatures.

This experiment will test the feasibility of on-shore recording of an air-gun source of 3200 cu. in. capacity in the noisy environment of Bass Strait, and result in the development of acquisition and processing techniques to collect and enhance such data. Development of a novel recording system to record near-continuous digital data over the period of the cruise is already well advanced. The techniques developed will be used in future experiments where on-shore recording of marine seismic sources may be used to enhance the interpretation of deep structure, and tie off-shore structures to land-based data.

Operations

Digital recorders will be located on Wilson's Promontory and northwest Tasmania, at both ends of one of the northeast-southwest traverses, giving a reversed refraction traverse of at least 220 km length. As much data as possible will be recorded from the other traverses. Other recorders may be deployed on land to extend the range of this traverse and provide additional data at different offsets and azimuths.

The digital recorders have been developed to record the air-guns semi-continuously 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 than 6 seconds.

The noise level is expected to be high on recordings made near and within Bass Strait, 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.