Bureau of Mineral Resources, Geology & Geophysics

RECORD

Record 1989/12

Preliminary Postcruise Report : BMR Cruise 78

R.V. RIG SEISMIC GEOPHYSICAL AND GEOLOGICAL RESEARCH CRUISE OFF WESTERN AND SOUTHEASTERN TASMANIA

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

Co-chief scientists N.F. Exon, C.S. Lee & P.J. Hill

Division of Marine Geosciences & Petroleum Geology

Record 1989/12

Preliminary Postcruise Report : BMR Cruise 78

RIG SEISMIC GEOPHYSICAL AND GEOLOGICAL RESEARCH CRUISE OFF WESTERN AND SOUTHEASTERN TASMANIA

Co-chief Scientists
N.F. Exon, C.S. Lee & P.J. Hill

Scientific staff
P.W. Baillie[1], G. Bernadel, E.A. Felton, T. Graham,
T. Hamilton[2], G. Heal, N. Johnston, J. Needham, S. Shafik
B. Thomas[2]

Technical support staff
G. Burren, E. Chudyk, N. Clark, P. Davis, C. Dyke, J. Kossatz,
C. Lawson, L. Miller, H. Reynolds, R. Schuler, J. Stuart,
P. Walker, J. Vickery[3]

1. Tasmanian Mines Department, Hobart
2. Flinders University of South Australia, Adelaide
3. Geophysical Services International, Perth.

CONTENTS

Appendices

Figures

Tables

SUMMARY

R/V Rig Seismic carried out BMR research cruise 78 on the Tasmanian margin from 24 March to 18 April, 1988. The first half of the cruise was devoted to multichannel seismic surveying - 1750 km on the west Tasmanian margin and 265 km off southeast Tasmania. The west Tasmanian seismic survey examined the King Island and Strahan Sub-basins of the Sorell Basin, tested the structure of the continental margin from the continental shelf to undoubted oceanic crust, and provided a key seismic tie through the thick sedimentary basin on the west Tasmanian continental slope. The southeast Tasmanian seismic survey examined the Palaeozoic sequences near Bruny Island on which oil seeps are known.

The latter half of the cruise was devoted to geological sampling on the west Tasmanian margin. Twelve stations were designed to sample basement and older outcropping sequences (Mesozoic and Palaeogene) to provide control for seismic interpretation. Younger sequences were cored at 37 stations in order firstly, to establish a model for Cainozoic sedimentation, and secondly, to allow the analysis of surface sediments to define areas of anomalous concentrations of thermogenic gas. Near-surface thermal gradient and thermal conductivity were measured at 10 stations as a means of establishing thermal flux.

The work will enable us to better define the geology of the basins, and especially their history of rifting, their stratigraphy, and their petroleum potential.

INTRODUCTION

BMR's Marine Division has been involved in four previous 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 two using R.V. Rig Seismic (Exon, Williamson et al., 1987; Exon, Lee et al., 1987). These cruises provided 1000 km of regional multichannel seismic data on the west Tasmanian margin, 70 geological samples, 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 present cruise (BMR Cruise 78) was designed to build on the earlier results. Its major aim was to better define and understand the regional geology, especially the nature of the sedimentary basins. This needed both geophysical and geological information, which also will lead to a better understanding of the breakup and post-breakup history of the margin.

The ship sailed from Eden on 24 March, 1988, and berthed in Portland on 18 April. There was an exchange of personnel in Hobart on 5 April, with P.J. Hill, G. Bernadel, J. Kossatz, J. Needham and J. Vickery disembarking, and C.S. Lee, P. Baillie, N. Clark, E.A. Felton, T. Graham, T. Hamilton and S. Shafik embarking.

Acknowledgements

The technical and scientific staff all performed excellently. Special mention must be made of Norm Johnston in charge of systems, Lindsay Miller in charge of electronics, Peter Walker in charge of mechanical equipment, and Jenny Stuart in charge of science operations, and Peter Davis in charge of gas geochemistry.

The skill of the Rig Seismic crew was vital to the success of the cruise:

Master	:	H. Foreman
Chief Officer	:	D. Harvey
Second Officer	:	R. Hardinge
Chief Engineer	:	J. Scott
Second Engineer	:	P. Pittiglio
Electrician	:	B. Knox
EA/Seaman	:	K. Halliday
AB	:	L. Luscombe
AB	:	D. Kane
AB	:	J. Kemp
Ch Steward/Cook	:	H. Dekker
Cook	:	G. Conley
Steward	:	J. Caminiti
Steward/Seaman	:	S. O'Rourke

The introductory chapters of this Record were prepared largely by Exon, with important elements of the "Regional Framework" written by Baillie and Thomas, and of "Petroleum Exploration" by Baillie. The "West Tasmanian geophysical results" was written by Exon, Hill and Lee, and "Bruny Island geophysical results" was prepared by Hill. "West Tasmanian geological results" was written by Exon, Felton, Baillie, Thomas, Graham and Hamilton, "Hydrocarbons in seafloor sediments off west Tasmania" by Exon and D.T. Heggie, and "West Tasmanian heatflow survey" by Lee. The chapter on calcareous nannofossils was written by Shafik, the chapter on shipboard geophysical systems by Johnston and Heal, and the chapter on geological equipment by Graham.

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 (Deighton, Falvey & Taylor, 1976; Robertson et al., 1978; Davidson, 1980; Etheridge et al., 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 western margin of Tasmania (Fig. 1) forms the southeastern end of the band of extensional basins which developed as a precursor to formation of the southern margin of the Australian continent (Hinz

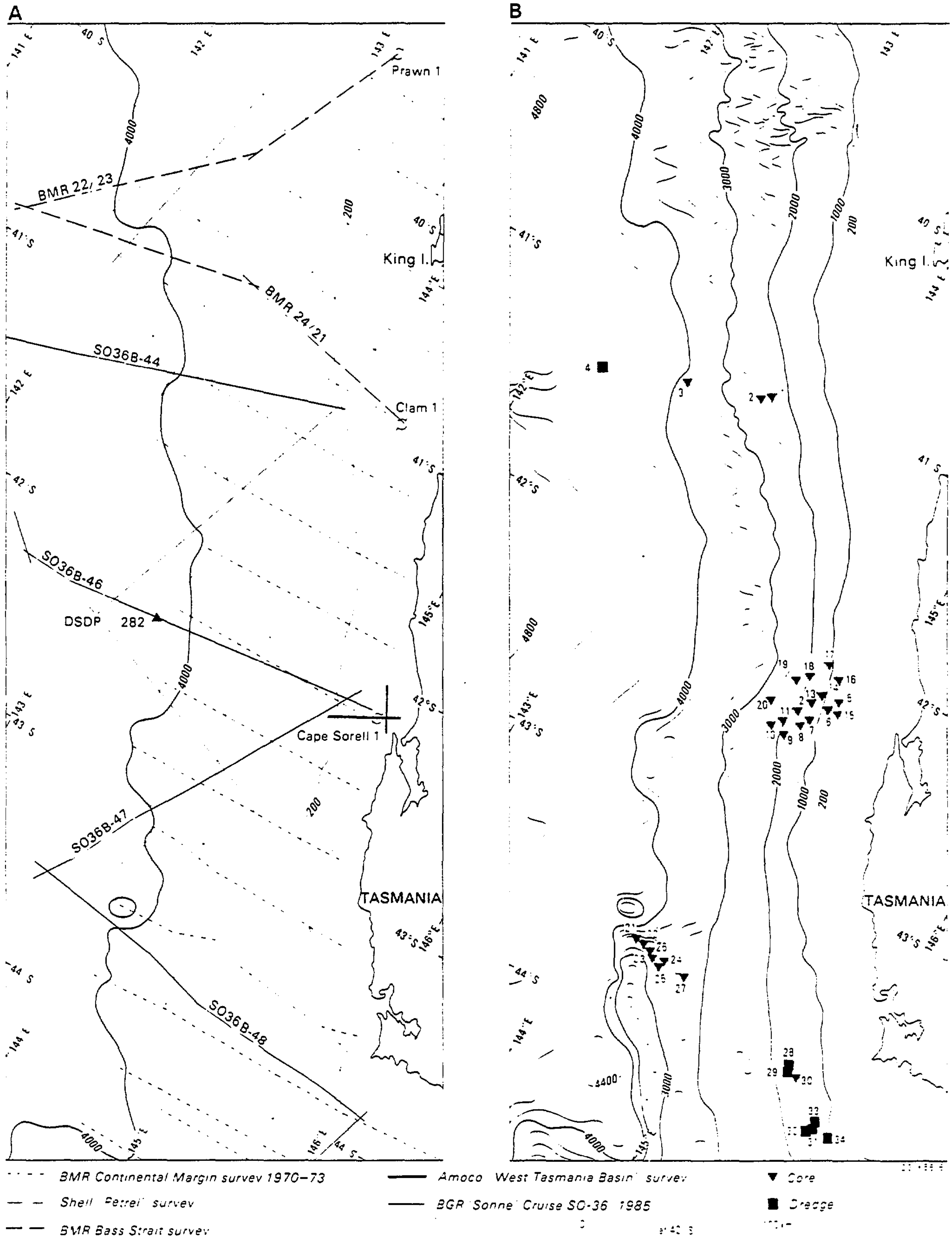


Figure 1. Regional multichannel seismic tracks and drill sites off west Tasmania, bathymetry and Sonne sampling sites. After Hinz et al. (1986).

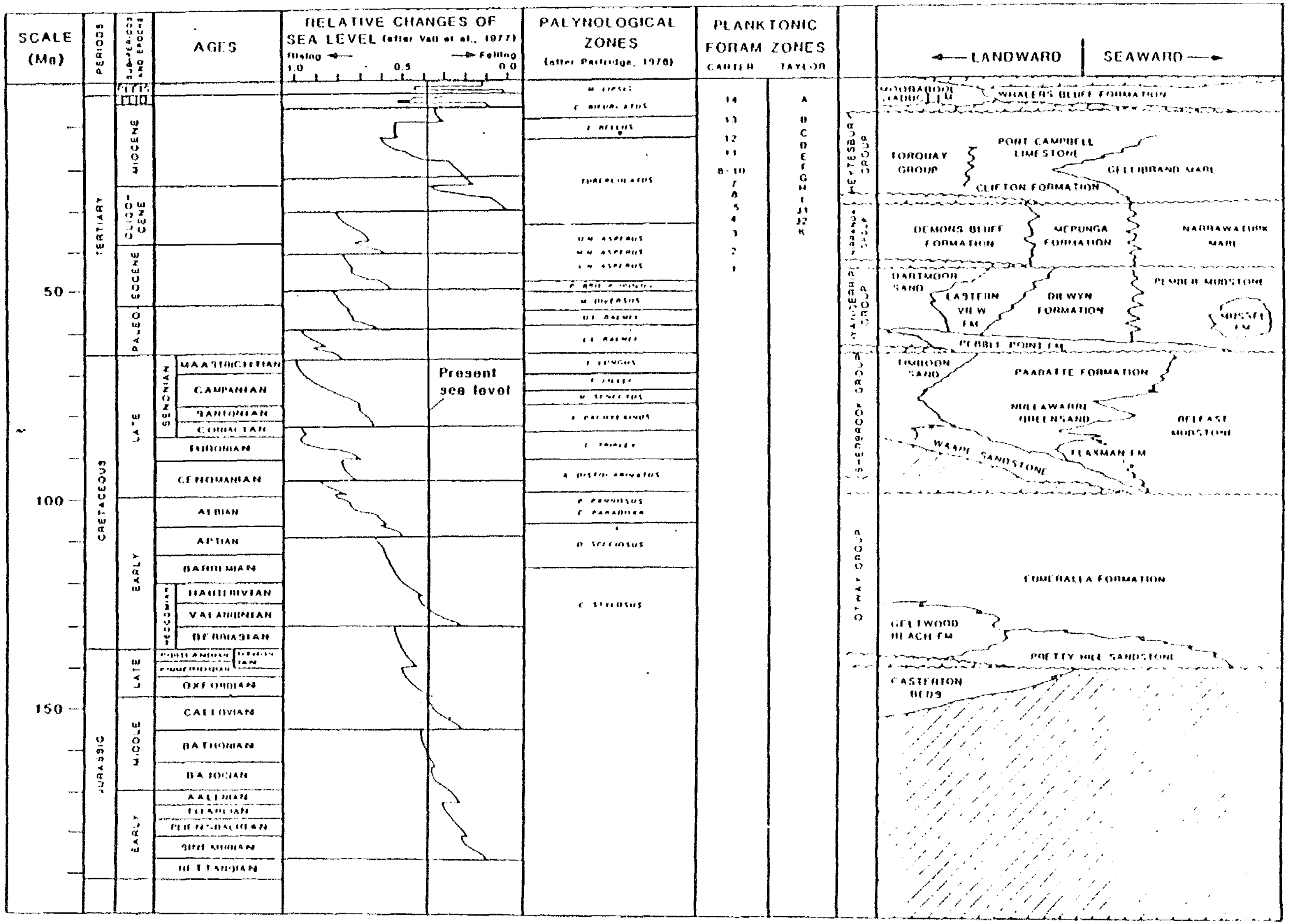


Figure 2. Regional stratigraphy of the Otway Basin, much of which applies in the Sorell Basin off west Tasmania. After Megallaa (1986).

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 a 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 small but significant sub-basins of the Sorell Basin underlie the continental shelf; Cretaceous and Tertiary sediments within these sub-basins are up to 6000 m thick. The stratigraphy is similar to that of the southeast Otway Basin (Fig. 2) (Ellenor, 1976; Douglas & Ferguson, 1976; Denham & Brown, 1976; Robertson et al., 1978, Megallaa, 1986), but has not been formally established.

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 & Mutter (1982) revised Weissel & Hayes (1972) 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. Using 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 m.y. ago.

Revised basin nomenclature

Structural nomenclature for the west Tasmanian continental margin has been rather confused in the past, largely because of the lack of sufficient data to properly define the structural units. Information from the previous _Sonne_ cruises, the 1985 and 1987 _Rig Seismic_ cruises, and the present cruise, have provided sufficient data to better define the structural elements which make up the margin. The distribution of the various units is shown in Figure 3.

The margin of western Tasmania, part of the continental margin of southern Australia, is known as the Sorell Basin and is separated from the Otway Basin to the north by a ridge of shallow basement which extends in a southwesterly direction from King Island (Fig. 3). Although, in general, the geological development of the two basins is similar, important differences including significant strike-slip faulting, do occur in the history of the Sorell Basin.

Three local depocentres of significant sediment thickness (greater than 4 km) are present in the Sorell Basin (Fig. 3), and are here termed the King Island, Sandy Cape and Strahan Sub-basins (the latter formerly known as the Cape Sorell Basin) These sub-basins are developed on the continental shelf and separated by basement highs. Limited stratigraphic control for the sub-basins, and indeed the Sorell Basin as whole, is provided by 2 petroleum exploration wells: Clam No. 1 was drilled near the margin of the King Island Sub-basin, and Cape Sorell No. 1 was drilled near the landward margin of the Strahan Sub-basin. Little detailed information is available for the Sandy Cape Sub-basin.

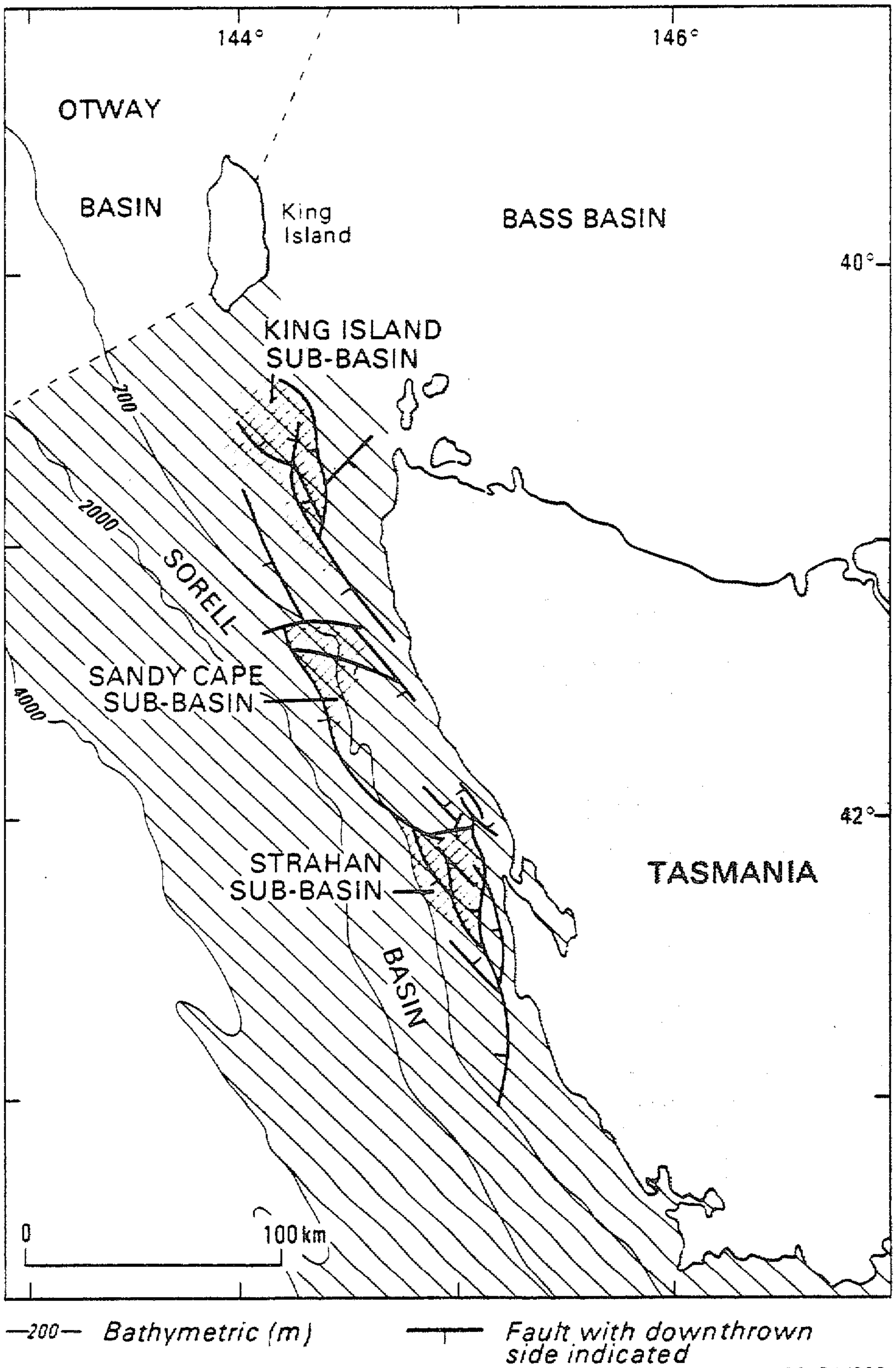


Figure 3. The Sorell Basin and its sub-basins.

Strahan Sub-basin

The Strahan Sub-basin underlies the West Tasmanian continental shelf, off Macquarie Harbour, in water depths mostly less than 200 m (Fig. 3). The basin is about 50 km long and 25 km wide, and trends NNW-SSE parallel to the Tasmanian coast.

Seismic coverage includes a semi-detailed seismic survey carried out by Amoco in 1981, which produced a 4 km data grid. The Amoco Cape Sorell No. 1 well was located on one of these profiles and reached latest Cretaceous strata at 3130 m and total depth at 3528 m; the thick underlying sedimentary section is considered to consist of Late and Early Cretaceous sequences.

A recent study by B. Thomas and J.B. Willcox has shown that the maximum sedimentary thickness is found in the northern part of the basin, where seismic records indicate that there is at least 4.5 sec (two-way time; about 6000 m) of sedimentary cover over acoustic basement. Basement is taken to be Palaeozoic strata equivalent to those outcropping in the Cape Sorell area. The Strahan Sub-basin is structurally controlled on its northern edge by a southerly throwing E-W fault, and on its eastern edge by oceanward throwing NW-SE and N-S bounding faults. These major faults are responsible for the landward tilting of the Palaeozoic basement. The Strahan Sub-basin is therefore a typical half-graben and its basement gently rises up to the south and the west where it forms an almost continuous ridge separating the basin from the continental slope.

Tilting and fracturing of the basement occurred in several stages, from the latest Jurassic/Early Cretaceous to the Paleocene, and is associated with N-S wrench movements widened by N-S "flower structure" zones through the sedimentary cover.

An Oligocene erosional surface and unconformity marks the end of the tectonic activity in the graben, and the beginning of the sag phase of the West Tasmanian margin which was accompanied by the development of prograding wedges on the shelf. It coincides also with a sedimentological boundary between predominantly detrital lithofacies in the Mesozoic and Early Tertiary, and biogenic carbonates from Oligocene to Recent times.

PREVIOUS SCIENTIFIC STUDIES

The Sorell Basin has no worthwhile onshore exposure, except for the 500 m thick early Eocene semi-lithified sands, gravels and lignites of the Macquarie Harbour Reds (Baillie, Bacon & Morgan, 1986). Other relevant previous studies are confined to geophysical and sampling cruises and offshore drilling. The first regional seismic survey that included the basin 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 showed that gentle faulting, uplift and erosion occurred during the late Miocene, and that Pliocene to Quaternary sediments unconformably overlie Miocene and older rocks in places (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.

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. 1). 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 a regional review of the deepwater parts of the region. Two west Tasmanian profiles, showing their interpretation, are illustrated in Figure 4.

Bouef & Doust (1975) showed that the Otway Basin and the west Tasmanian region formed part of 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 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

Unconform (Sequence)	Characteristics	Tectonic Significance	Facies Interpretation	Approx Thickness (m)	Proposed Age Identification: Stratigraphic	m.y.	Equivalent Mag Anom	Otway Basin Shelf Equivalent and Unconformities	Comment
	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"
U14						? 140			
S(13–14)	Low frequency, stratified on rift shoulder		Continental–? fluvial, lacustrine	1000	Jurassic and Early Cretaceous		M Series	Casterton Beds and Otway Group Non-marine clastics and volcanogenic sediments	
	Contorted fill in first stage rift	Lower rift-fill	Alluvial fan and/or volcanics	3000 +					
U13						105			
S(12–13)	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)			Probably time equivalent to Eumerella Formation (Otway Gp) Continental environments with volcanism	This sequence appears confined to the first stage rift
U12						95	34		
S(11–12)	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 Apthorpe, 1969)	0–?1000	Late Cretaceous (approx Cenomanian)		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)
U11									
S(10–11)	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			Belfast Mudstone and Flaxman Formation (Sherbrook Group) Marginal marine–marine	1570 m Belfast Mudstone in Voluta 1
U10									
S(9–10)	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)			Curdies/Paaratte Formations (Sherbrook Group) Shoreline–continental	Slow spreading episode in southeast Indian Ocean has less influence on outer Otway Basin
U9						65	29		
S(8–9), U8, S(7–8), U7, S(6–7), U6, S(5–6)	S(5–6) to S(8–9) are distinctive, high frequency, downlapping sequences beneath lower continental slope Lower frequency, continuous, high amplitude beneath upper 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 Outbuilding of fine clastics with minimal aggradation Unconformities largely reflect eustatic changes in sea level	Shelf clastics, grading into fine grained progradational wedges at palaeoshelf-edge (largely terrigenous)	200–1500	Paleocene—Middle Eocene		?	Age equivalent of the Wangerrip 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)
U5						42	18	? ?	
S(4–5), U4, S(3–4)	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			Nirranda Group (transgressive) — shallow marine	? Minor volcanism at U5 time
U3						35	13		
S(2–3), U2, S(1–2), U1	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		Southeast Indian Ocean spreading	Heytesbury Group (transgressive) marine carbonates	Main episode of seafloor spreading

23 K55 15

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

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

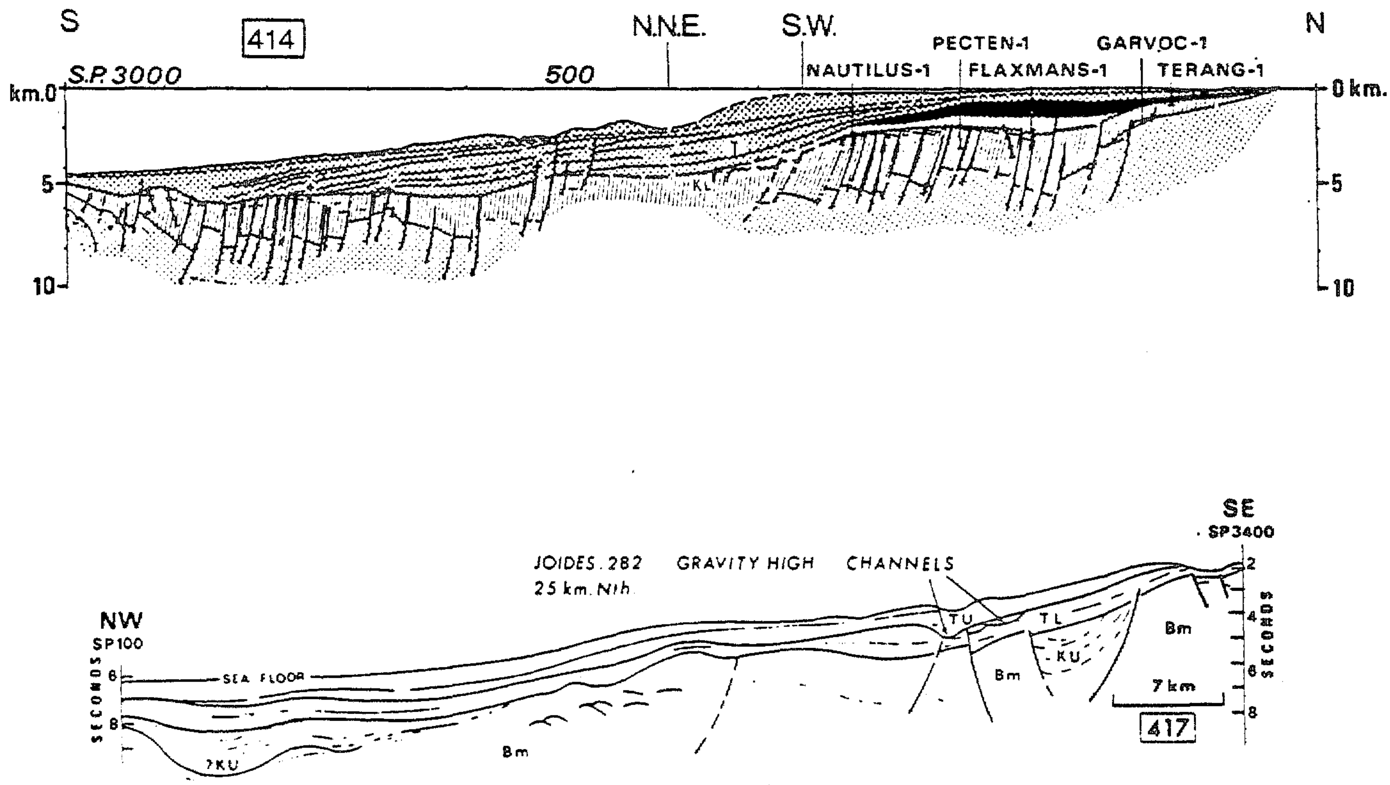


Figure 4. Interpreted line drawings of Shell Petrel seismic sections N414 and N417 off King Island and Cape Sorell, after Bouef & Doust (1975). Locations in Figure 12.

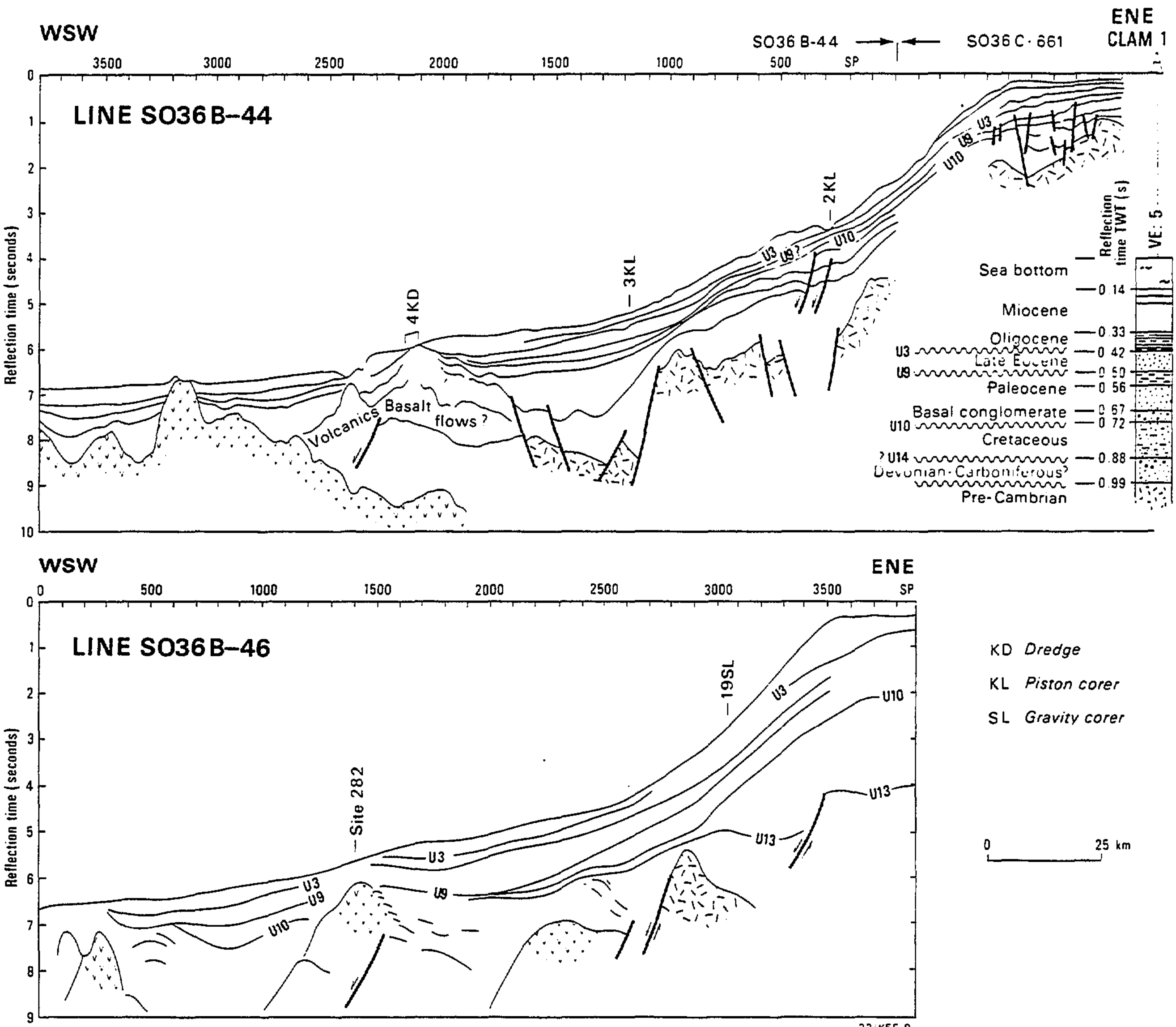


Figure 5. Line drawings of <u>Sonne</u> seismic sections SO36B-44 & 45 on the southern part of west Tasmanian margin, showing sample locations (see Fig. 1). After Hinz et al. (1986).

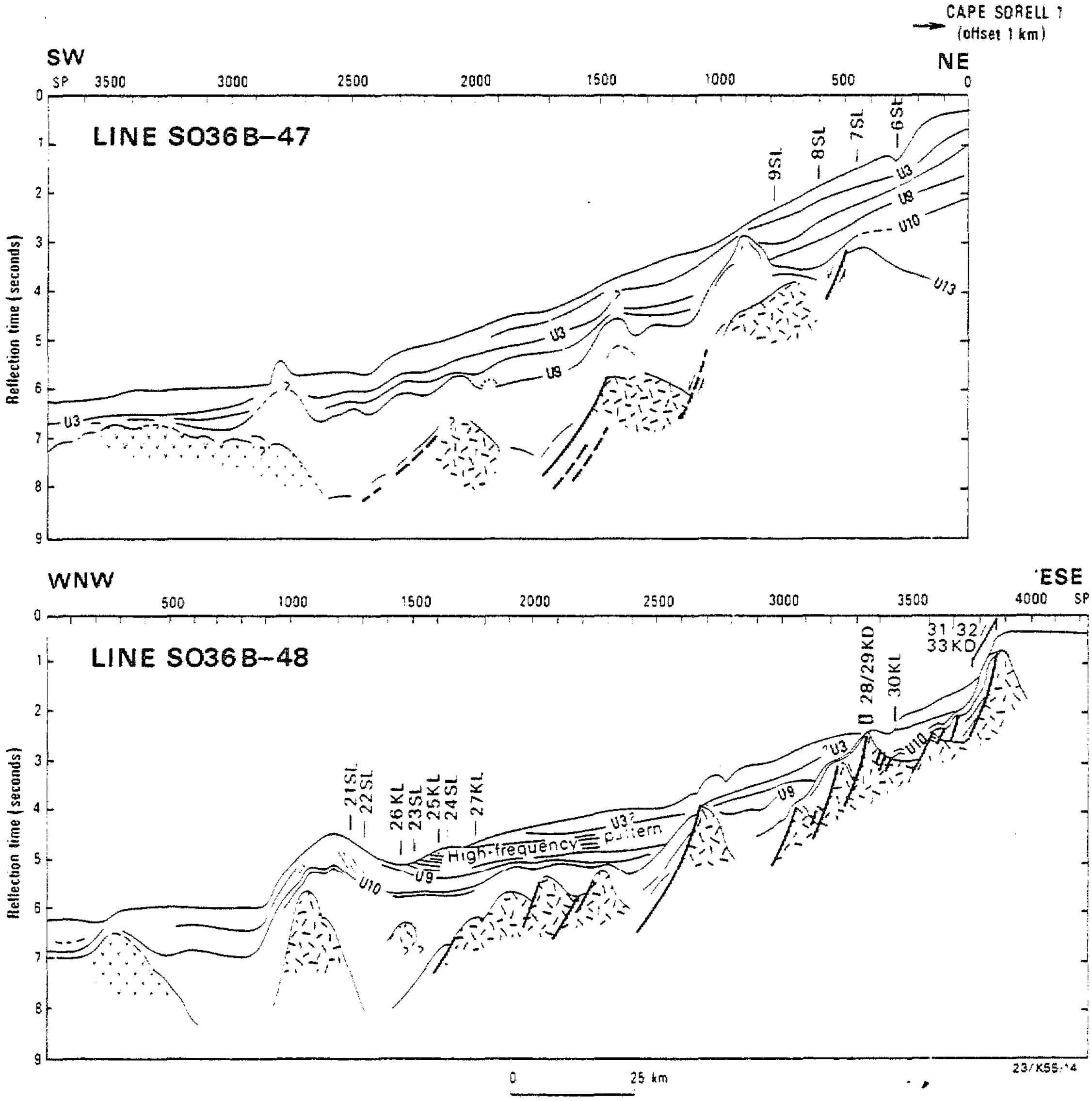


Figure 6. Line drawings of Sonne seismic sections SO36B-47 & 48 on the southern part of the west Tasmanian margin, showing sample locations (see Fig. 1). After Hinz et al. (1986).

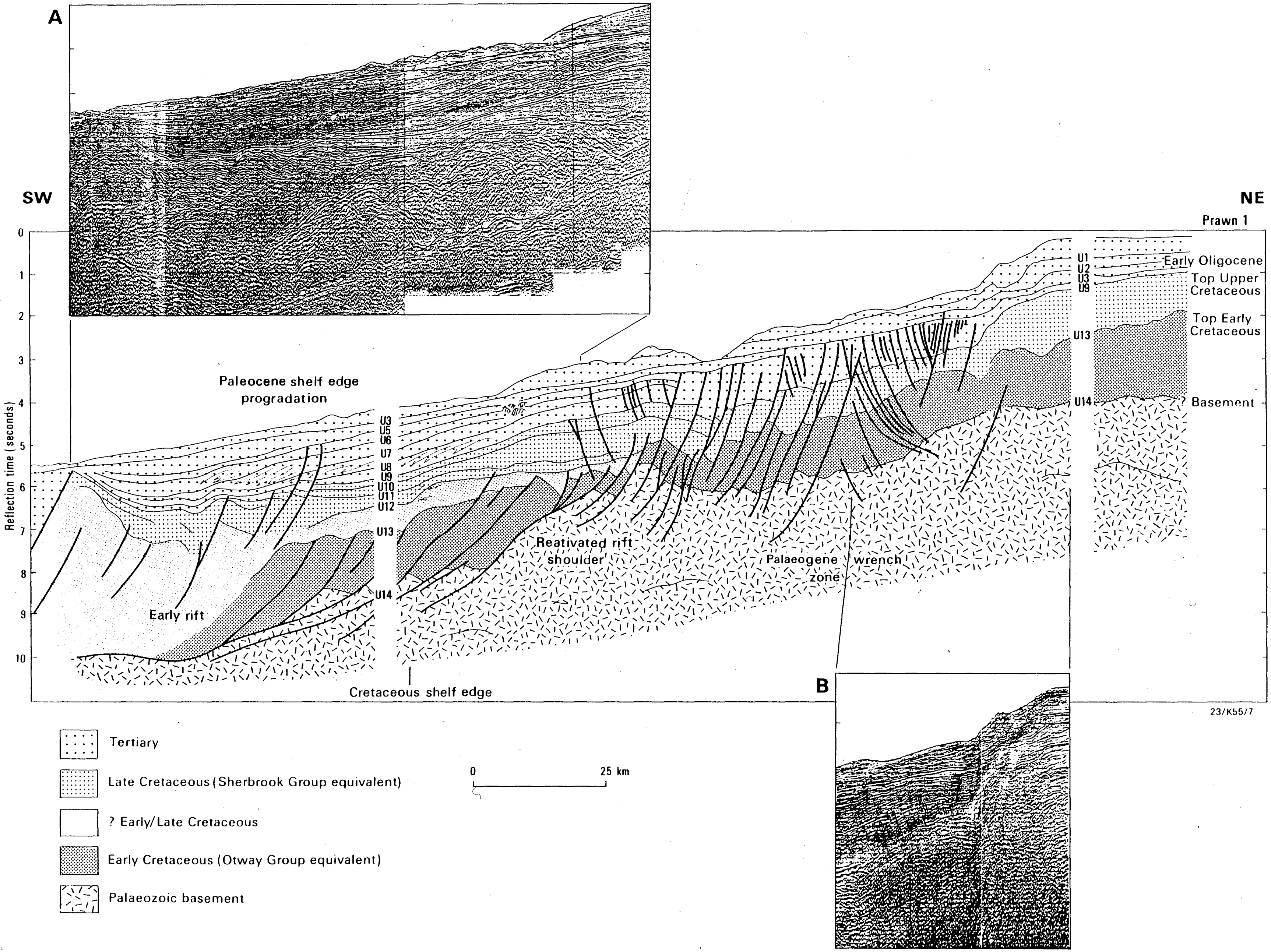


Figure 7. Interpretation of BMR seismic profile 40-22/23, tied tentatively to Prawn No. 1 well. Location shown in Figure 1. After Hinz et al. (1986).

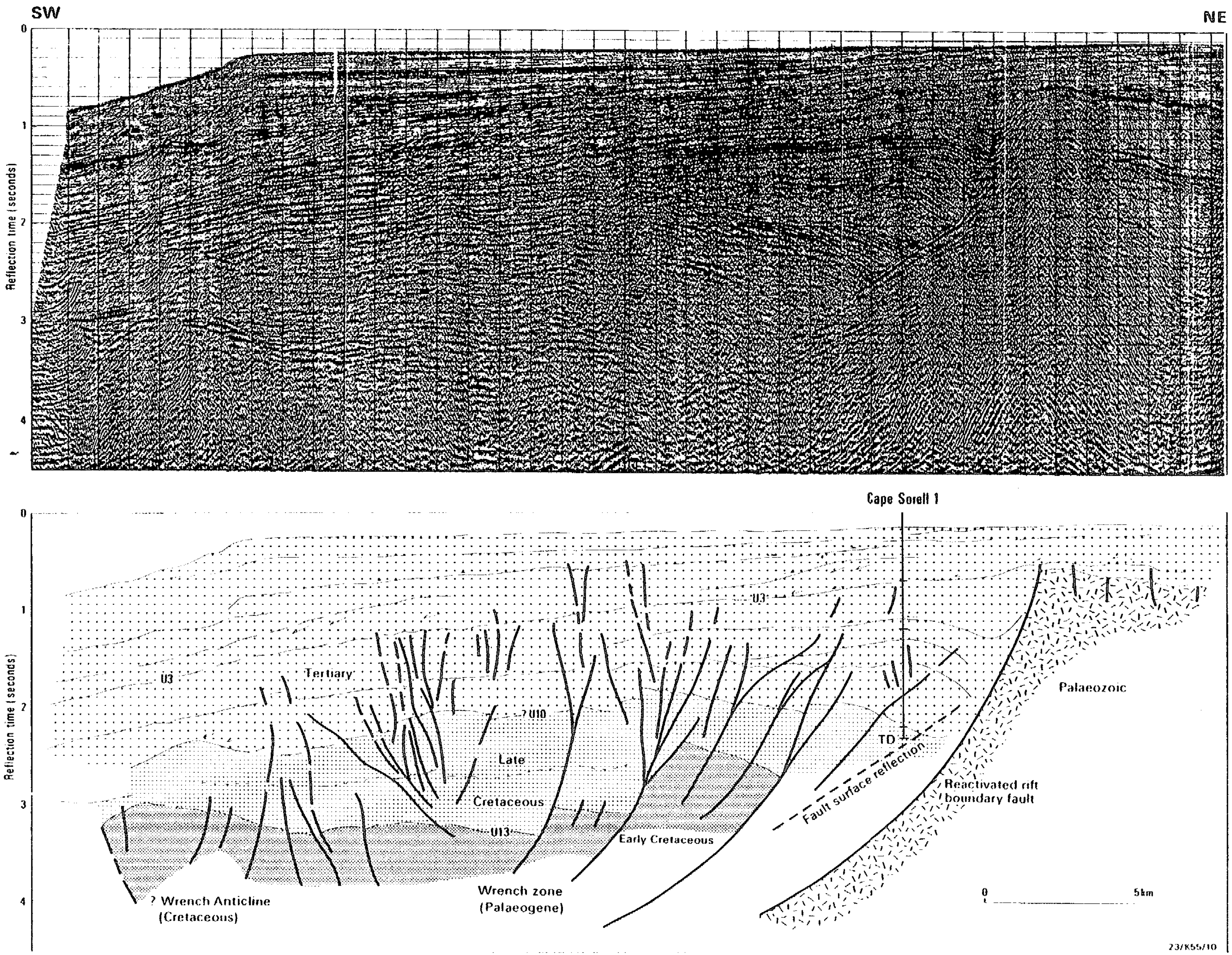


Figure 8. Interpretation of Amoco seismic profile W88-82 through Cape Sorell No. 1. After Hinz et al. (1986).

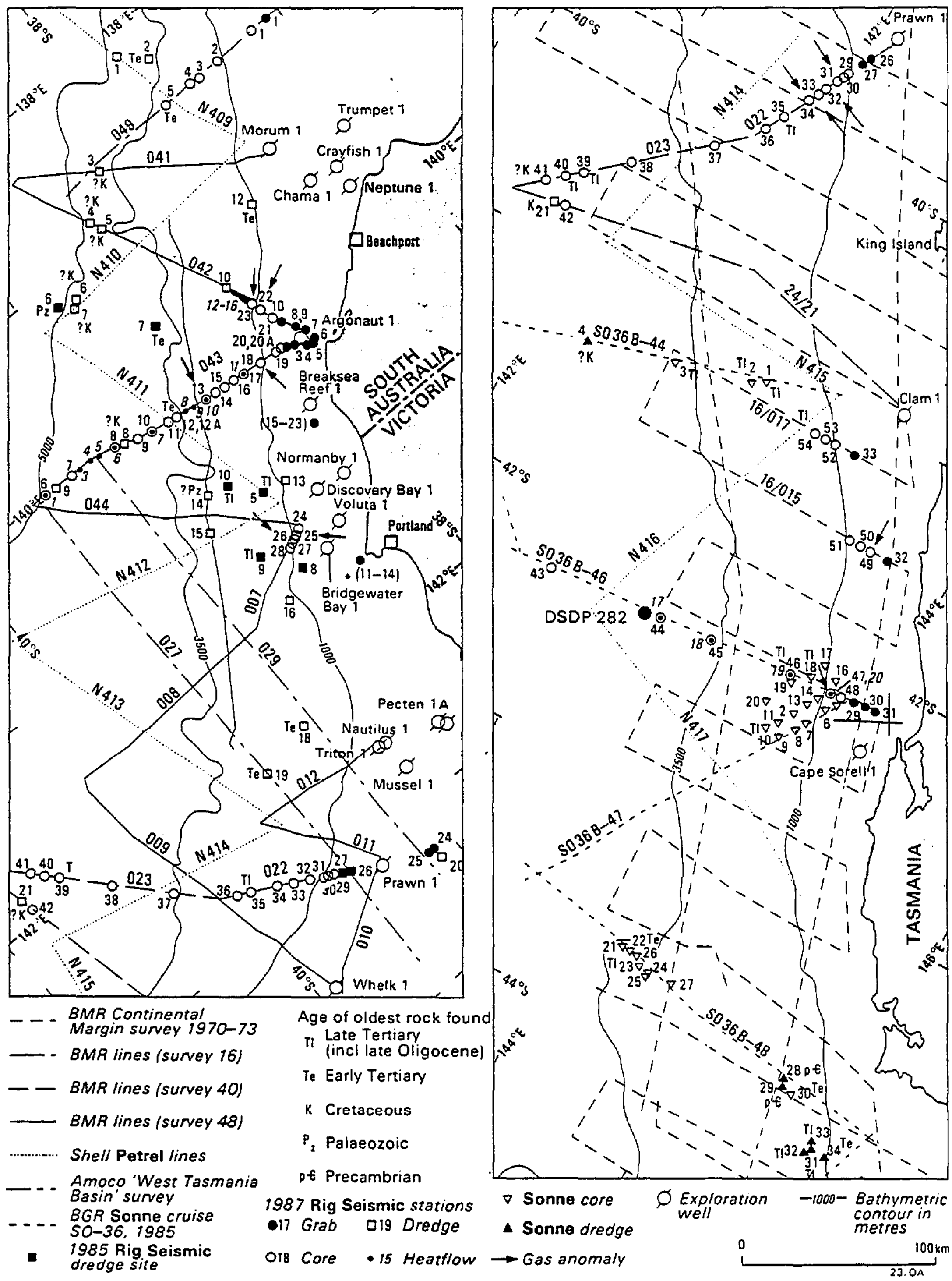


Figure 9. Maps showing regional seismic grid and Rig Seismic and Sonne sampling and heatflow stations, Otway Basin and west Tasmanian margin.

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 (BMR Survey 48; Exon, Williamson et al., 1987; 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 (Fig. 1). 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 (altogether 1000 km long) were recorded off west Tasmania, and 34 sampling stations occupied (Fig. 1). A detailed cruise report was provided by Hinz et al. (1985). An interpretation of these seismic lines (Figs. 5 and 6), combined with those of a 1982 BMR line and an Amoco line (Figs. 7 & 8), 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 generally relatively thin Tertiary sequences consist essentially of Neogene carbonates and Palaeogene terrigenous sediments. The Upper Cretaceous sequence appears 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 Otway Basin and west Tasmanian margin (BMR Survey 67; Exon, Lee et al., 1987, 1989; Haggie et al., 1988) 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 on the west Tasmanian margin - 3 dredge, 25 core, 8 grab and 4 heatflow - in water depths of 50 to 5000 m (Fig. 9; 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

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

Sequence	Stations	Depth Range
Pleistocene to Recent shelf sands	Many 1987 grabs	27 - 294 m
Pleistocene to Recent ooze and turbidites	Numerous Sonne and Rig Seismic 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 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, enabled heatflow calculations to be made. These measurements, on Sonne seismic line SO36-46 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.

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 on the continental rise 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 (Figs. 1 & 6). 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 were made by Branson (1984) and Willcox, Branson & Exon (1985), but have not been adopted into the current program.

DSDP site 282 (Fig. 1) contained a sequence of organic-rich Eocene silty clays with considerable source rock potential (Hunt, 1975). 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 (Whiticar et al., 1985) showed that wet gas of thermogenic origin is abundant in surface sediments on the west Tasmanian margin, indicating that mature source rocks are present. Similar results were obtained by Exon, Lee et al. (1987, 1989).

Geochemical and source rock maturity studies had 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, 1987) 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.

Since 1984, Conga Oil Pty Ltd has had an interest in the Bruny Island/D'Entrecasteaux region of southern Tasmania, and has used gravity and magnetic data, in conjunction with limited reflection seismic data, to help define the subsurface structure of that part of the Tasmanian Basin, and to predict rock types at depth (Leaman, 1987).

Permian and Triassic sedimentary rocks of the Parmeener Super-Group and intrusive Jurassic dolerites blanket most of the region to a depth of one kilometre or more, and are cut by very complex fault structures (Berry & Banks, 1985). Beneath a regional unconformity lies a suite of Cambrian to Middle Devonian sedimentary rocks, including Ordovician carbonates and Silurian sandstones and shales.

Oil seeps have been recorded on Bruny Island and in D'Entrecasteaux Channel, and these oils have been matched geochemically with hydrocarbons in trace amounts in outcrop samples of Ordovician limestone (Leaman, 1987; Volkman, 1988). Thus it seems highly likely that oil has been generated in Ordovician sequences beneath the main unconformity, and has leaked to the surface through the overlying Permo-Triassic sandstones and shales.

The aim of our Bruny Island seismic work (Fig. 22) was to help establish the regional structure at and below the main unconformity.

PETROLEUM EXPLORATION

Baillie (1986) reported that portions of the west Tasmanian continental margin have been held under permit at various times since the 1960's: T/2P (Magellan); T/8P (Esso); T/10P (Magellan); T/12P (Amoco); T/17P (Van Diemans Land Resources); T/20P (Van Diemans Land Resources). Several seismic surveys have been undertaken by exploration companies, and include:

(1) Tasman-Bass Strait Marine Seismic Survey (Magellan, 1969).
(2) Esso T69A Survey (Esso, 1969).
(3) Esso T70A Survey (Esso, 1970a).
(4) Marine seismic Survey T70C (Esso, 1970).
(5) EE-68 Marine Seismic and Magnetic Survey (Esso, 1968).
(6) Amoco 1981 Seismic and Magnetic Survey (Amoco, 1981).
(7) Marine Seismic Survey OMQ81 (VDL, 1981).
(8) Marine Seismic Survey OMQ82A (VDL, 1982).
(9) Otway/King (Esso, 1964-1974).
(10) Shell "Petrel" survey (Shell, 1974).

The western margin of Tasmania contains the Sorell Basin, which extends from the shelf to the lower continental slope. The three sub-basins on the shelf, King Island, Sandy Cape and Strahan, are separated by basement highs.

Baillie (1986) noted that the most important west Tasmanian well for correlative purposes is Prawn No. A1, north of King Island in the Otway Basin, which was drilled by Esso/Hematite in 1968 and penetrated the following sequence (Culp, 1967):

Depth below msl (m)	Description
81 - 725	Carbonate sequence: marl, limestone, calcareous sandstone (Miocene - Oligocene Heytesbury Group).
725 - 766	Marl (Late Eocene Nirranda Group).
766 - 1238	Dominantly sand sequence (Eocene-Paleocene Wangerrip Group)

1238 - 2917	Interbedded sandstone, mudstone, calcareous sandstone and conglomerate (Late Cretaceous Sherbrook Group).
2917 - 3166	Lithic sandstone sequence (Early Cretaceous Otway Group).

Stratigraphic control for the King Island Sub-basin (Baillie, 1986) is provided by Esso Clam No. 1 well, which encountered the following succession:

Depth below msl (m)	Description
102 - 387	Carbonate sequence: limestone, marl, mudstone (Miocene - Oligocene Heytesbury Group correlate).
387 - 513	Quartz sandstone.
513 - 925	Interbedded sandstone and mudstone sequence with basal conglomerate (Paleocene - Late Cretaceous Wangerrip Group correlate.
925 - 1462	Sandstone, mudstone with basal ferruginous sequence (Late Cretaceous Sherbrook Group correlate).
1462 - 1592	?Palaeozoic/Late Proterozoic basement.

Baillie (1986) noted that the Strahan Sub-basin has a shallow onshore extension known as the Macquarie Harbour Graben which contains sedimentary infill having a thickness of approximately 500 m immediately west of Strahan (Baillie & Corbett, 1985). The oldest known sediments exposed onshore are Eocene in age and were deposited in a marginal marine environment (Forsyth, in Baillie & Corbett, 1985). An unconformity is present between the Eocene sediments and overlying Plio-Pleistocene sediments. The Cape Sorell No.1 well, drilled by Amoco Australia Petroleum Company in 1982, was located about 13 km north-west of Cape Sorell, and shows a remarkable thickening of the Tertiary sequence seawards. The results were outlined by Amoco (1982) and Hughes et al. (1983). The sequence penetrated was:

Depth below msl (m)	Description
94 - 412	Carbonate sequence: limestone, sandstone, mudstone, minor dolomite (Miocene - Oligocene Heytesbury Group correlate).
412 - 1759	Dominantly sandstone, minor mudstone, limestone (Middle - Early Eocene).
1759 - 3528	Interbedded sandstone, siltstone, conglomerate, with minor coal and tuff (Paleocene to 3130 m; Late Cretaceous below that)

The thick Eocene section contains glauconite, dinoflagellates, and foraminifera, indicating that the depositional environment was marine. Rare arenaceous forams are present in parts of the Paleocene section (Amoco, 1982).

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. 1) and company data (especially that of Esso and Amoco) show that substantial sediment thicknesses are present in the 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. In Clam No. 1, Lunt (1969) described 220 m of "red beds" above Palaeozoic/Precambrian basement as of probable Devonian age. However, they are more likely to be Late Cretaceous (Baillie, 1986). A thick Late Cretaceous sequence is inferred at the site of Cape Sorell No. 1 (Fig. 8).

A marked mid-Oligocene unconformity (U3) extends throughout the region (Figs. 7 & 8). 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 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 NNW-trending normal fault. J.B. Willcox's reinterpretation of Amoco Line W-81-12 (Hinz et al., 1986; Fig. 7), 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) show that hydrocarbons of thermogenic origin are currently being generated just west of the shelf break. Migration 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 migration up faults. Without either additional geochemical well control data or stable isotope evidence, the identification of the nature of hydrocarbon source rocks is highly speculative. The early/mid-Eocene has demonstrated source rock qualities, and although in most areas it is relatively shallow, 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, 1987). However the Cretaceous units, with their suitable burial depth and thickness,

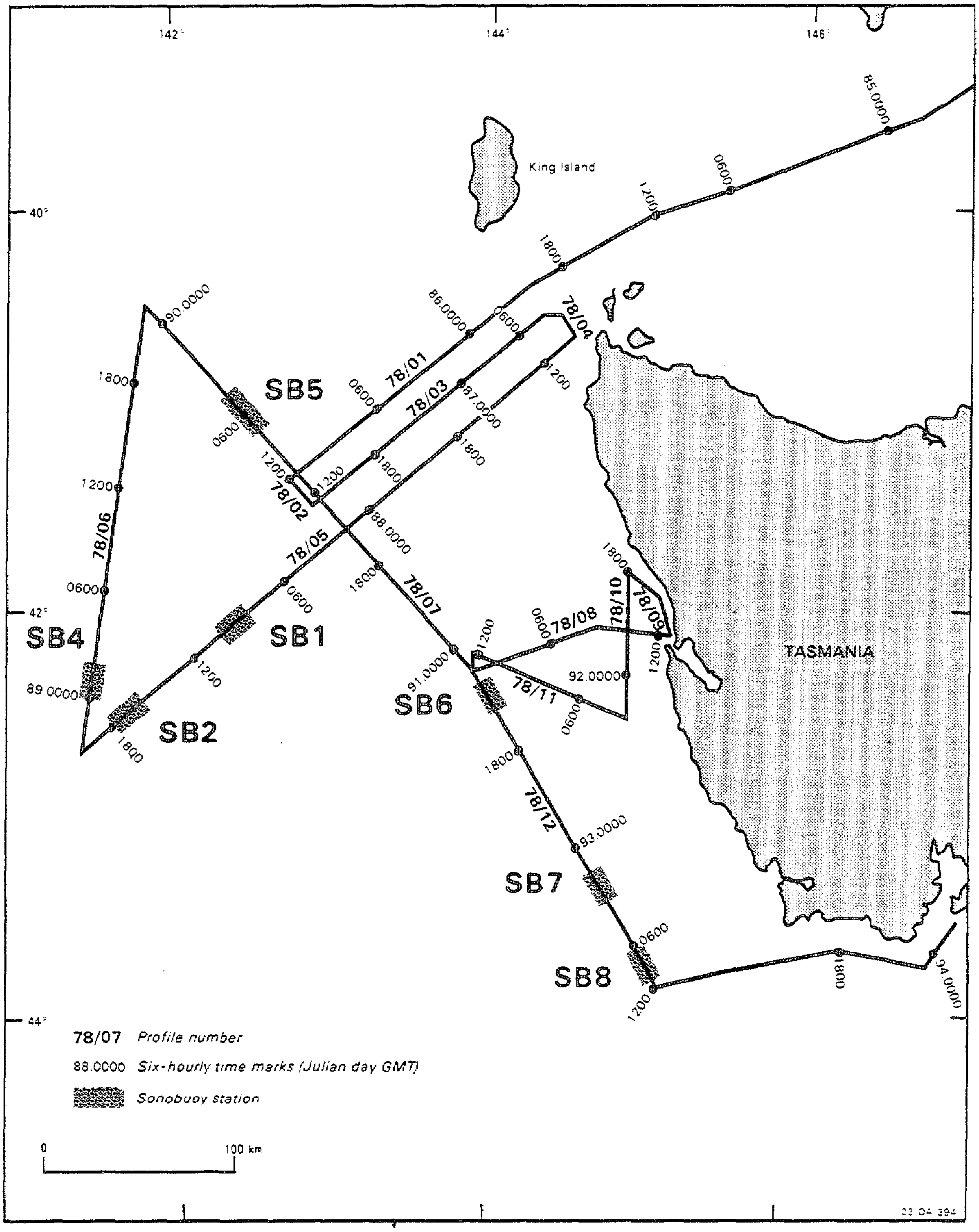
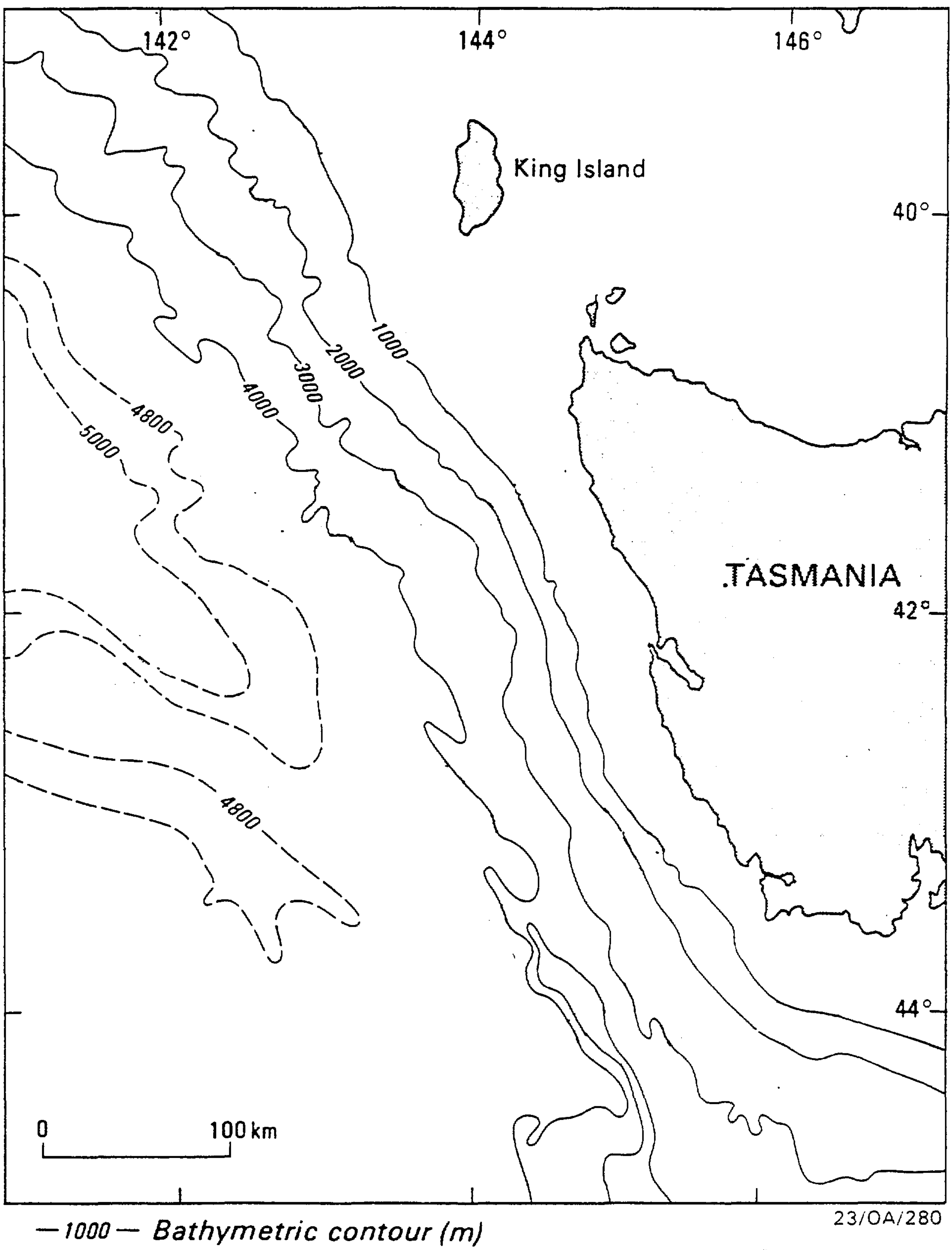


Figure 10. Track map showing west Tasmanian geophysical leg of BMR Cruise 78, including sonobuoy locations.

Figure 11. Bathymetry of west Tasmanian margin incorporating results of BMR Cruises 67 and 78.



are more attractive as hydrocarbon source rocks.

Early exploration off southeast Tasmania included a seismic survey (Amoco, 1971), which indicated that sedimentary section was limited in Storm Bay and further east. Petroleum exploration in the Bruny Island region of the Tasmanian Basin around Hobart is at the preliminary stage (Leaman, 1987; Volkman, 1988), but Conga Oil Pty. Ltd. holds an exploration permit, and believes it has established the existence of source rocks, escaping petroleum, good seal conditions and a geological history supporting oil generation and preservation.

WEST TASMANIAN GEOPHYSICAL RESULTS

Bathymetry

A new bathymetric map was compiled at a scale of 1:1,000,000, using GEBCO data, and the results of BMR surveys 40, 47, 67 and 78, and Sonne survey 36. This was then reduced to produce Figure 11. The region clearly falls into several natural physiographic regions : the continental shelf, a steep upper slope, a rather gentle lower slope, and an abyssal plain cut by northwesterly trending ridges and troughs. The lower slope is complicated off southern Tasmania by a major depression which separates Tasmania from the South Tasman Rise, and by buried northwesterly trending fault blocks. The latter dip landward and are truncated on the seaward side by major faults that have formed spectacular scarps.

The continental shelf is relatively broad around King Island (more than 50 km) and narrower along the west Tasmanian coast (less than 50 km). Detailed bathymetric maps at 1:250,000 scale, produced by NATMAP and showing contours out to 300 m, indicate that the edge of the shelf is at about 170 m, very close to the 200 m contour shown in Figure 11. They also indicate that bedrock structure clearly affects the sea bed configuration along this wave and current swept shelf. Parts of the NATMAP maps are shown in Figure 34 over the Sandy Cape Sub-basin and Figure 37 over the Strahan Sub-basin. The "scarp and dip-slope topography" in Miocene limestone at the surface, noted by Jones & Holdgate (1980) from sparker seismic records, is apparent in these maps. Major faults mapped by Esso (1969) are reflected in the surface topography in many cases (see especially Fig. 34). Further south, trends in the basement rocks strongly influence the shelf bathymetry.

The upper slope is fairly steep, around 5 degrees along the Tasmania coast. It extends from 170 to 1200 m off King Island, 170-2500 m off Sandy Cape, and 170-2000 m off South West Cape. North of Cape Sorell, it is cut by numerous small canyons. These canyons generally extend from the shelf edge to 3000 m and then peter out. The long mid-slope profiles 78/07 and 78/12 show little evidence of canyons (Figs. 16 & 18).

The lower slope extends to 4800 m, and is very gentle in the north. Dips average 2 degrees, and are only half that below 3800 m. In the south the gentle dip of the lower slope is upset by massive fault-blocks in Cretaceous sediments. These en-echelon blocks strike northwest (Fig. 11), dip landward, and are buried on the landward side by younger sediment (Fig. 13). Their outer edges are fault scarps with dips of 10-20° and heights of up to 1600 m, and their buried inner sides form terraces. Their tops lie in water depths of 2000-3400 m.

The southern fault blocks are truncated about 150 km south and southwest of South West Cape, by a west-northwest trending depression, which has axial depths deepening westward, from 3000 m at 146°E to 4600 at 144°E. This depression marks the separation of Tasmania from the South Tasman Rise, and must be fault-controlled.

The abyssal plain is covered by broad basement ridges and swales; these have thick sediment cover near the foot of the slope, but are current-swept and very rough further from land (Fig. 12). These structures have at total relief of about 500 m, and trend northwest, a trend which is also seen in satellite altimetry data (Royer, 1987), and which aligns neatly with the northwest trending fault blocks in the continental slope. They appear to consist of oceanic basalt, and either represent a spreading fabric aligned northwest, or are long blocks bounded by transform faults.

Reflection seismic survey

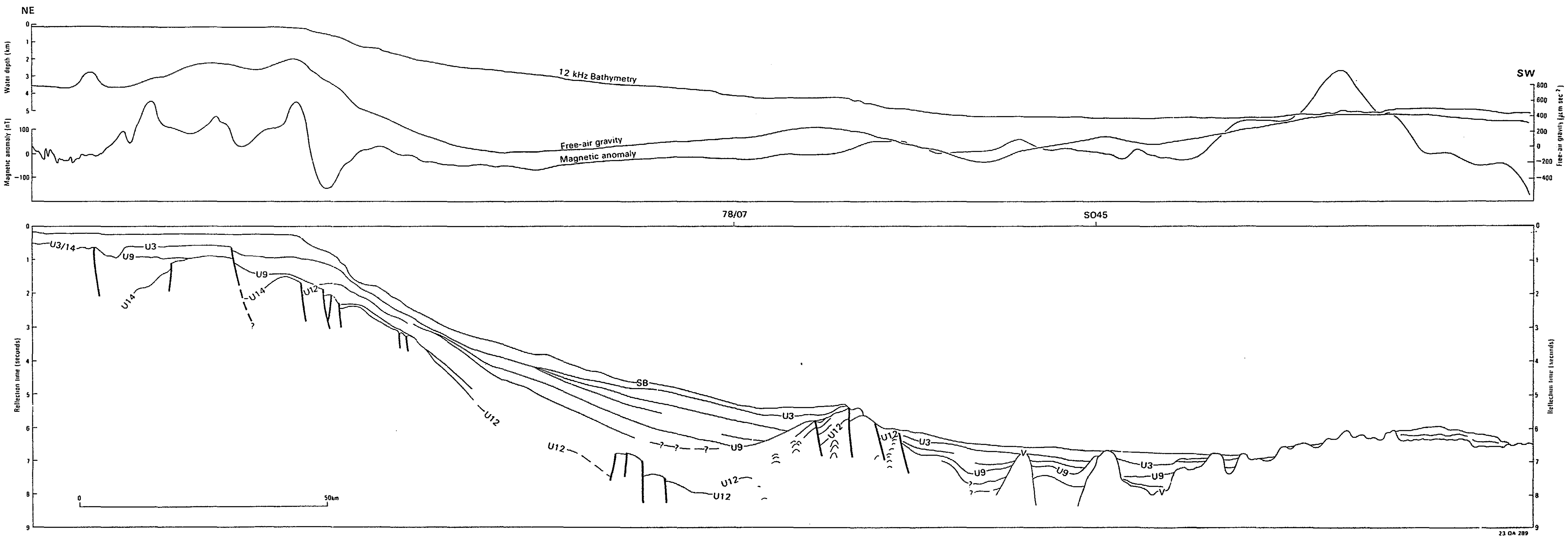
The west Tasmanian geophysical survey in the Sorell Basin went smoothly, and 48 multichannel seismic reflection data were recorded on the entire survey of 1750 km (Fig. 10). The survey was shot at 5 knots using a 1200 m cable. The seismic source was a single gun array of 10 guns with a capacity of 1600 cubic inches.

The shipboard monitor records were recorded on the second channel, which lay about 290 m behind the vessel, and 255 m behind the gun array. The monitors show several seconds of penetration in deep water, but on the shelf hard Miocene carbonates on the surface led to ringing which tends to obscure deep reflections. Further seismic data processing will be needed.

Preliminary interpretations of three key profiles, 78/05, 78/07 and 78/12, using the shipboard monitors, illustrate the character of the margin. The four key unconformities (U3 = Oligocene, U9 = top Cretaceous, U12 = top Lower Cretaceous, and U14 = top basement) could be identified from well and seismic ties. Profile 78/05 extends from the northwest Tasmanian shelf near Clam No. 1 well southwestward to the abyssal plain (Fig. 10), and is illustrated in Figure 12. The monitor records show about two seconds of penetration on the shelf, and up to three seconds in deeper water. On the shelf, small basins with a fill of Cretaceous and Cainozoic sediment lie between basement blocks which have a magnetic signature. Near the shelf edge are a number of major faults which are probably listic and on which basement (U14) and Lower Cretaceous (U12) blocks have been rotated (detail in Fig. 13). The magnetic data suggest that the outermost basement block lies landward of 87.1600. The Lower Cretaceous lies relatively shallow oceanward to 87.1900 and the overlying sequences, although continuous, are thin. Beyond 87.1900 the depth of the Lower Cretaceous surface below sea bed increases, and it can no longer be recognised between 87.2030 and 87.2200.

The Neogene SB-U3 sequence maintains a fairly constant thickness of 0.2-0.3 s, but the Palaeogene U3-U9 and Upper Cretaceous

Figure 12. Seismic interpretation of monitor record, and bathymetric, gravity and magnetic profiles, along Profile 78/05 from the shelf to the abyssal plain. Location in Figure 10.



R8901202

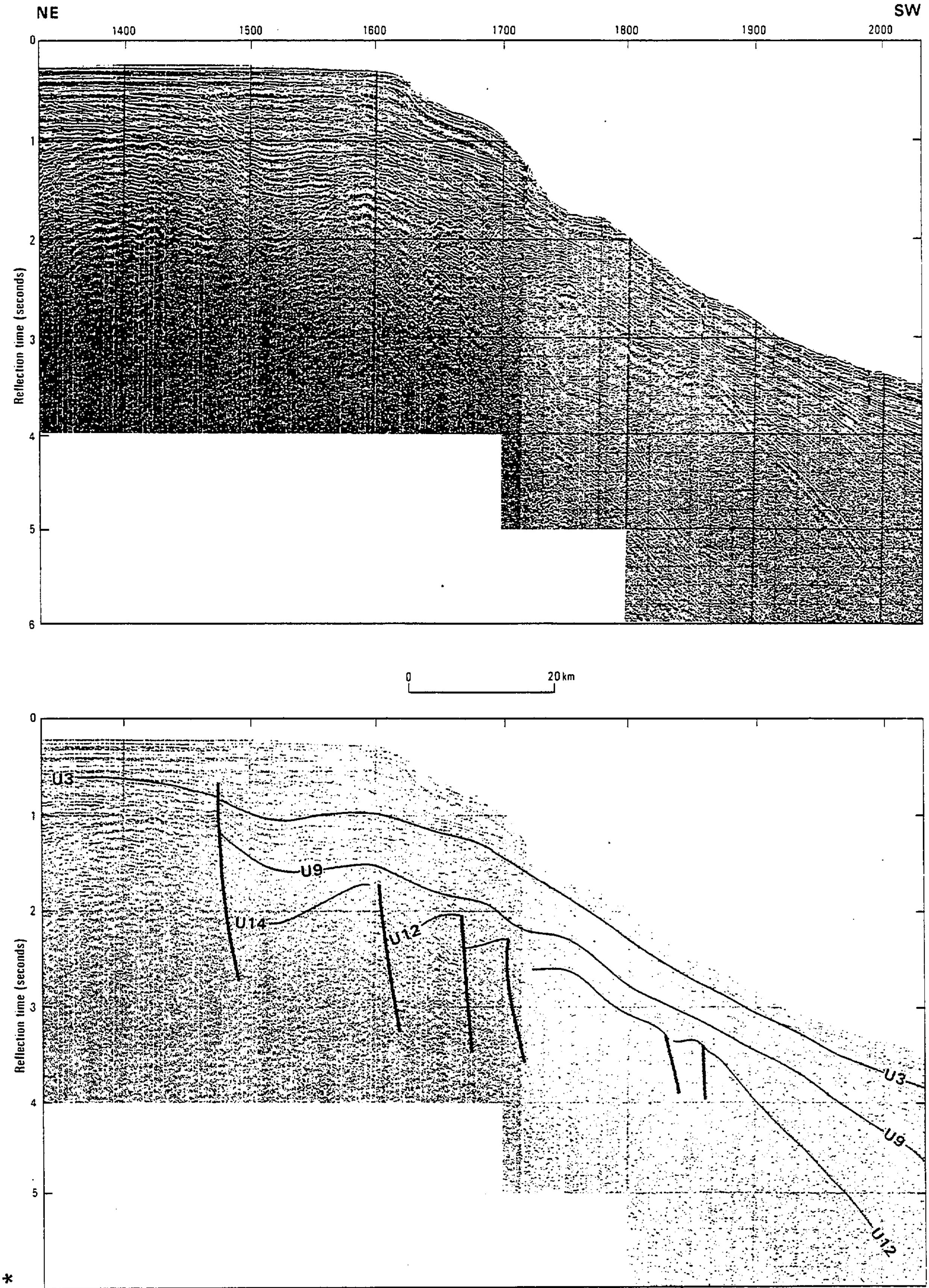


Figure 13. Monitor record of outer shelf part of seismic profile 78/05, showing basement and Cretaceous fault blocks.

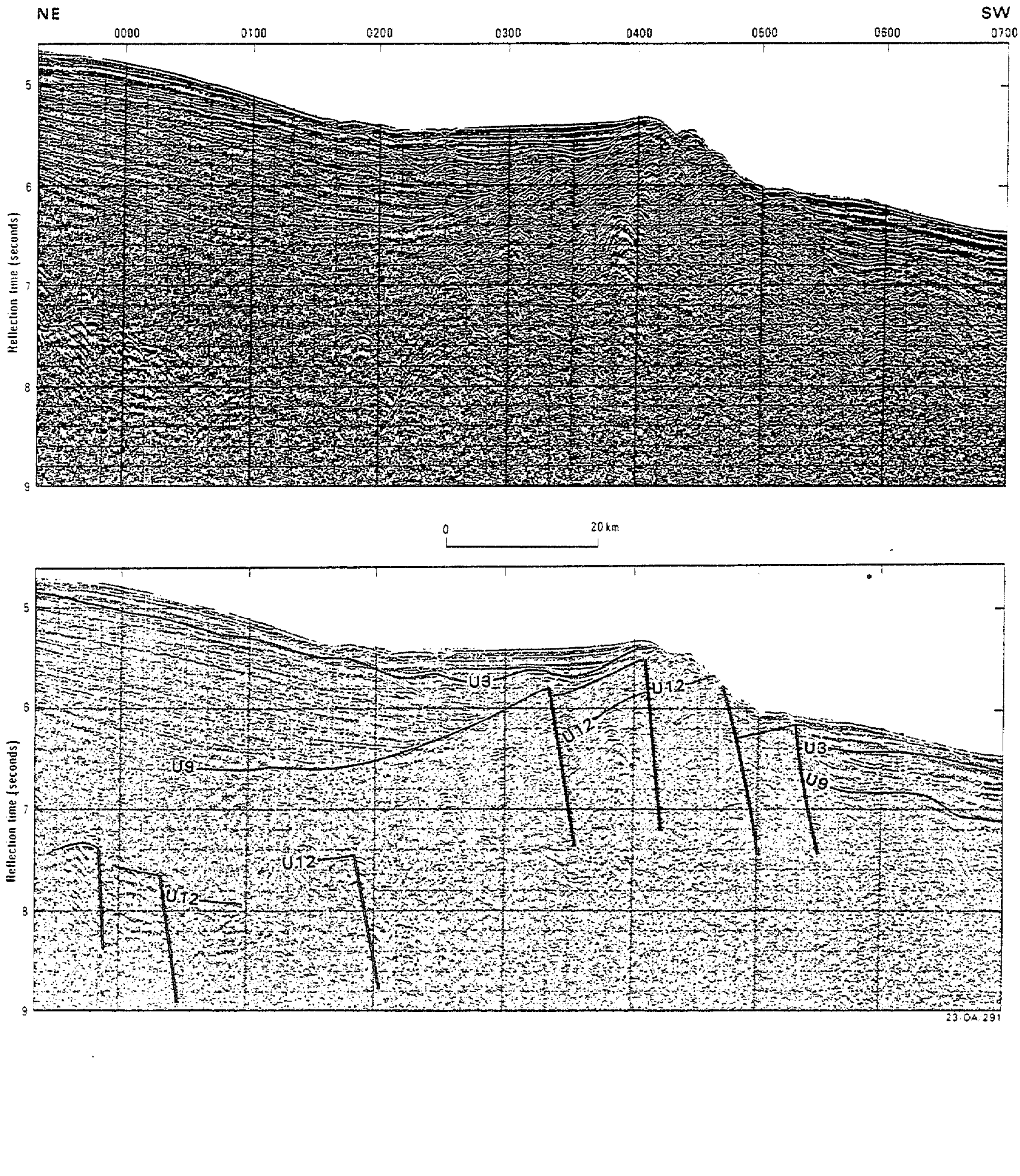


Figure 14. Monitor record of part of seismic profile 78/05, showing onlap of Tertiary sequences against Cretaceous block.

Figure 15. Monitor record of part of seismic profile 78/05, showing the transitional zone between continental and oceanic crust.

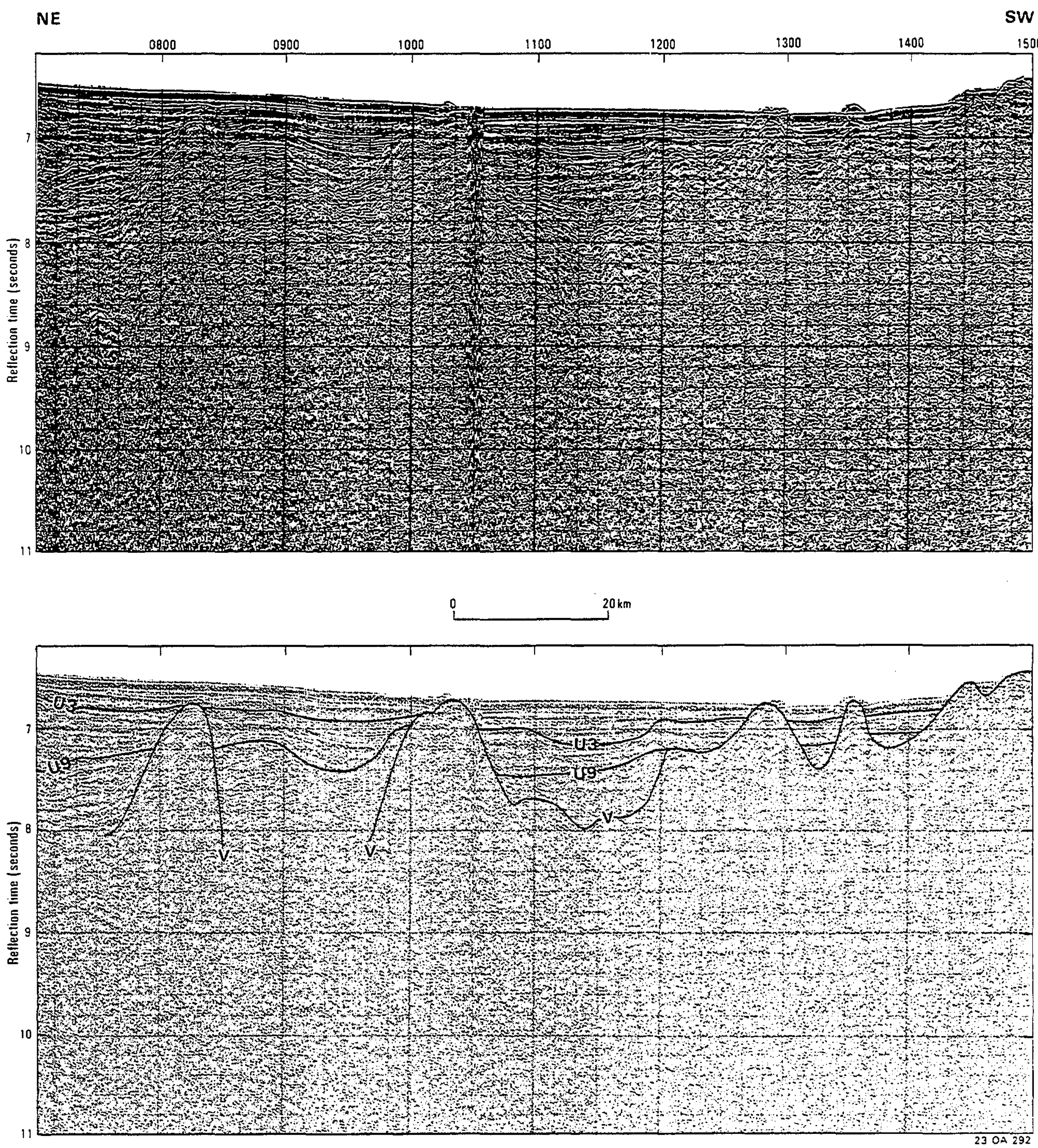


Figure 16. Seismic interpretation of monitor record, and bathymetric, gravity and magnetic profiles, along mid-slope Profile 78/07. Location in Figure 10.

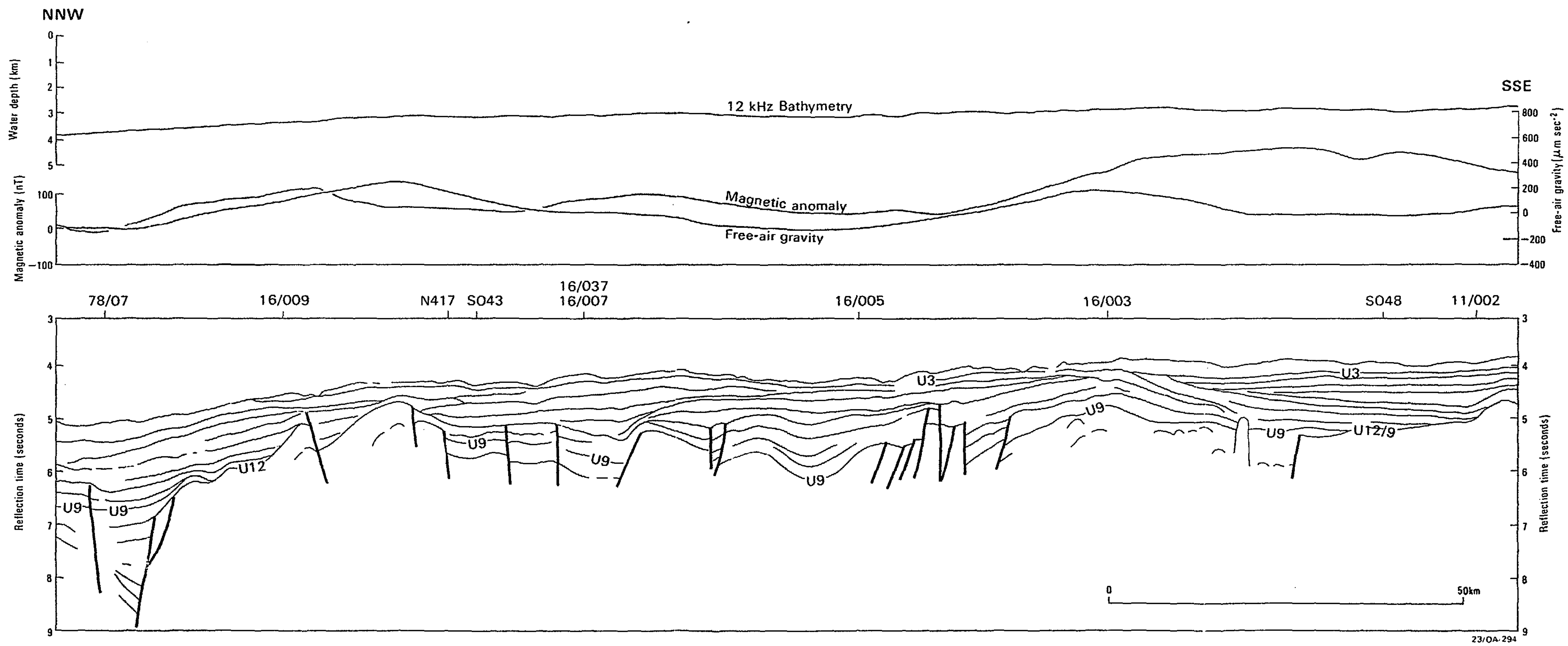
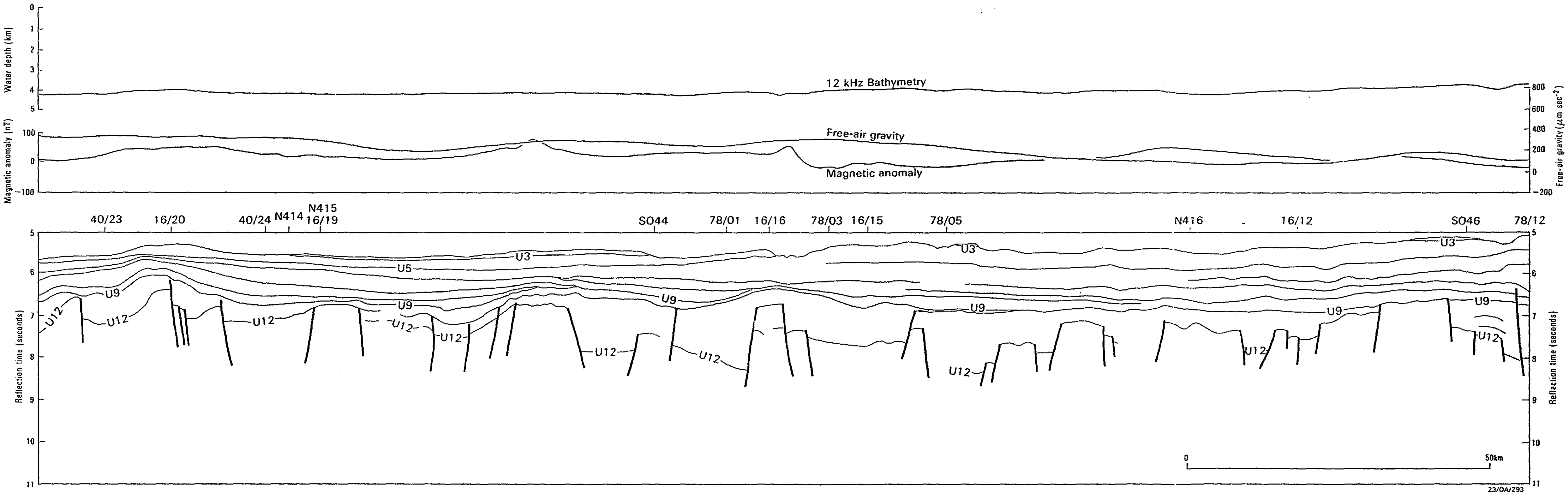


Figure 17. Seismic interpretation of monitor record, and bathymetric, gravity and magnetic profiles, along mid-slope Profile 78/12. Location in Figure 10.



U9-U12 sequences thicken remarkably downslope toward a depocentre around 88.0000. The Palaeogene sequence is characterized by a series of sequences which prograde oceanward, and onlap the U9 unconformity where it rises toward several high blocks at the foot of the slope between 88.0100 and 0430 (detail in Fig. 14). Similar prograding sequences are also visible in the Upper Cretaceous sequence beneath U9. The maximum thickness of the Palaeogene sequence is 1.7s, and of the Upper Cretaceous sequence is 1.5 s.

The Lower Cretaceous sequence (beneath U12) is sporadically visible between 87.2230 and 88.0530. It is cut by steeply dipping faults, and rises to form a high on the lower slope between 88.0330 and 0530. This high consists of landward tilted blocks cut by listic faults, and the magnetic data suggest that the high is reversely magnetized. The Lower Cretaceous is not visible beyond the outermost tilted block. The Upper Cretaceous sequence (U9-U12) is also cut by the faults, but they do not appear to extend higher than U9. The Upper Cretaceous sequence rises in concert with the Lower Cretaceous sequence, and thins greatly onto the high.

On the abyssal plain, beyond the high at the foot of the lower slope, basement reappears in the form of diapir-like bodies with little or no magnetic signature. These bodies are surrounded by fill up to 1.5s thick which appears to include sediments as old as Late Cretaceous. Beyond 88.1000 the bodies form continuous basement, which rises toward the sea bed (Fig. 15) and reaches it at 88.1300. From there it has a strong magnetic signature and appears to consist of diffracting oceanic basement in a current-swept ridge trending northwest.

Seismic profiles 78/07 and 78/12 form a continuous mid-slope tie line trending northwest (Fig. 10). Profile 78/07 (Fig. 16) shows penetration of up to 3s on the monitor, and the top of the Lower Cretaceous is commonly visible (U12). The Lower Cretaceous is extensively faulted by what appear to be normal faults, into horsts, grabens, tilt blocks and half-grabens. The Upper Cretaceous sequence (U9-U12) is also cut by these faults but they seldom displace its top (U9). The Upper Cretaceous sequence fills in between the Lower Cretaceous blocks and buries all but a few of them. There are major highs at 90.0000, 90.0700, 90.1200 and 91.0000, and some of these may possibly be related to transfer faults normal to the profile.

In general, on Profile 78/07 most of the Neogene sequence (SB-U3) is missing. The Palaeogene sequence averages 1s in thickness and contains prograding sediment wedges which tend to build away from the major highs. The Upper Cretaceous sequence is generally 0.5s thick, but thickens spectacularly in some grabens and half-grabens to as much as 1.5s (especially 90.0800-90.1700). Two fault blocks, those at 90.0700 and 90.1130, have some magnetic expression, but overall there is little change along the magnetic profile.

Profile 78/12 continues Profile 78/07 to the south-southeast, and is fairly similar in character (Fig. 17). Again the Lower Cretaceous (U12 and older) is cut by what appear to be normal faults, and horsts, grabens, tilt-blocks and half-grabens are characteristic. There is a spectacular rift at 91.1300 with 2s of section beneath the U9 unconformity (Figs 17 & 18). There are major highs at 91.1700 and 91.0300; the first involves the Lower Cretaceous sequence, but the

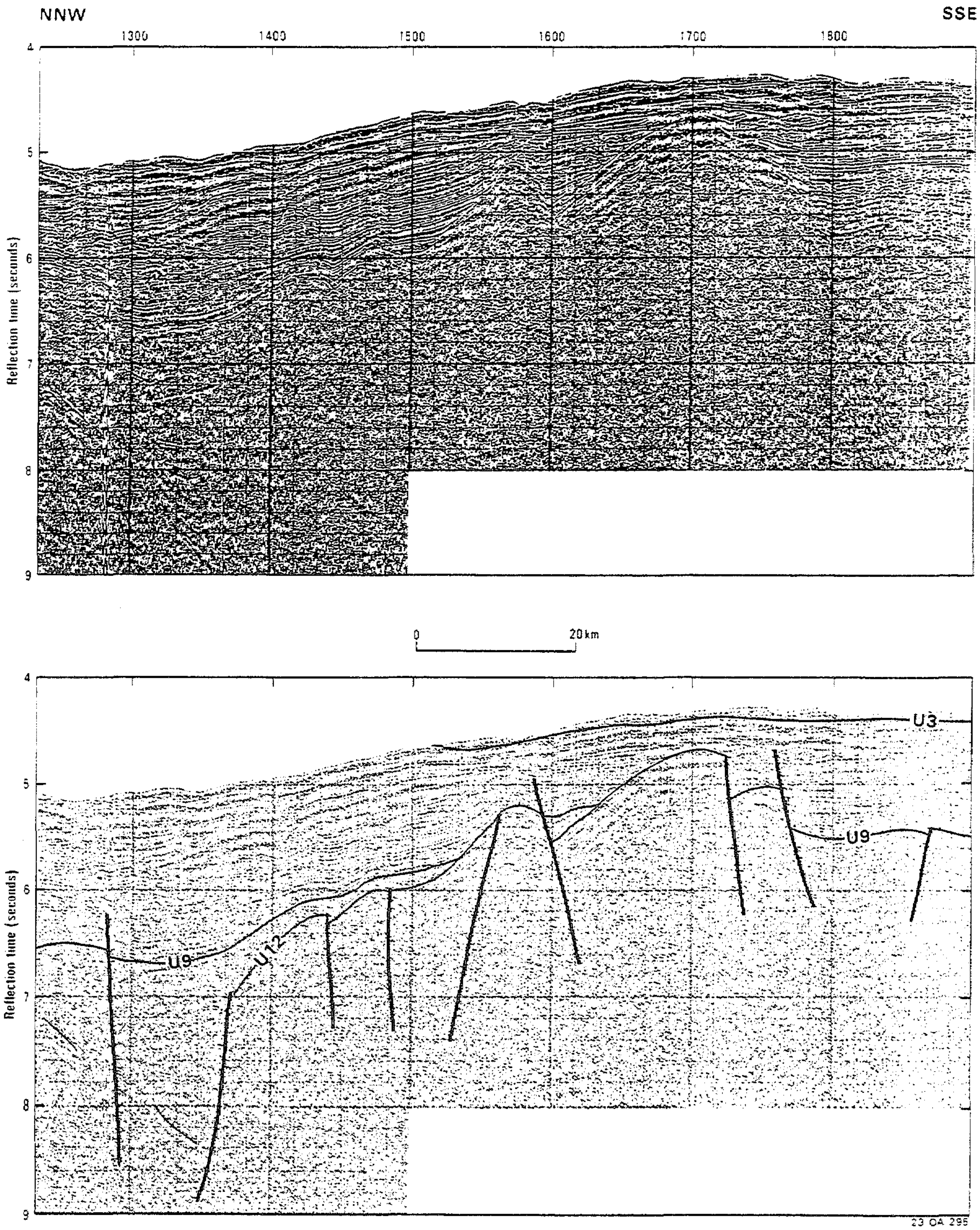


Figure 18. Monitor record of part of seismic profile 78/12, showing deep rift on mid slope.

second may be underlain by igneous basement, there being a magnetic high extending from it to the southeastern end of the profile. The Upper Cretaceous (U9-U12) fills between the Lower Cretaceous high blocks, but is generally apparently thinner (<0.5s) than on profile 78/07. The Palaeogene sequence (U3-U9) averages 1s in thickness, and is considerably thicker in places. Prograding units are marked and are particularly obvious on the flanks of the major highs. The Neogene sequence (SB-U3) is generally thin or absent, but is 0.2-0.3s thick on the southern part of the line.

Overall, the new seismic profiles confirm that the Sorell Basin is tectonically complex, and that there are thick Cretaceous and Palaeogene sequences in much of it. It is known that listic, strike-slip and normal faulting all played a role in its structural development. The new profiles, when processed, will provide key tie lines which should enable the entire data set to be analysed, and the basin's geological history to be elucidated.

Refraction seismic survey

Refraction and wide-angle reflection data were obtained from 7 sonobuoys off the west Tasmanian coast (Fig. 10). The sonobuoys were sited over extended continental crust of the mid-lower continental slope (SB5, SB6, SB7 and SB8), on oceanic crust just beyond the continent/ocean boundary (SB2 and SB4), and on transitional crust (SB1).

The sonobuoys used were of military type AN/SSQ-57A, set for 8 hour transmission and a hydrophone depth of 19 metres. The data were digitally recorded on channel 49 of the seismic acquisition system at 8 second record length, and displayed on one of the self-serve seismic monitors. Acquisition was in conjunction with routine reflection shooting using the 10-gun tuned array as source, and a shot interval of 50 metres. Table 3 provides sonobuoy details and survey information.

Figures 19 and 20 show examples of shipboard monitor records over extended continental crust (SB5) and oceanic crust (SB4), respectively. A preliminary analysis and geological interpretation of the sonobuoy data has been completed, with results tabulated in Table 4. For the analysis, a simple horizontally stratified velocity section has been assumed.

Results for SB1 are not included in Table 4, since its analysis is complicated by high relief on the deepest reflector visible in the reflection monitor records. Seismic 'basement' lies at depths of 0.6-1.5s (two-way time = twt) below seafloor, with block faulting possibly responsble for the relief. It has a refraction velocity of approximately 3940 m/s, suggesting a lithology of (oceanic) basalt or of sediments equivalent to the Otway Group.

The crustal velocity structure derived from the sonobuoys is depicted in Figure 21. The results are compatible with the findings of other studies conducted along the southern margin of Australia (eg. Hawkins & others, 1965; Talwani & others, 1979; Exon, Williamson & others, 1987). The velocity/depth profiles of SB5-SB8 (extended continental crust) are closely similar, and contrast with the profiles for SB2 & SB4 (oceanic crust), which portray high velocity just

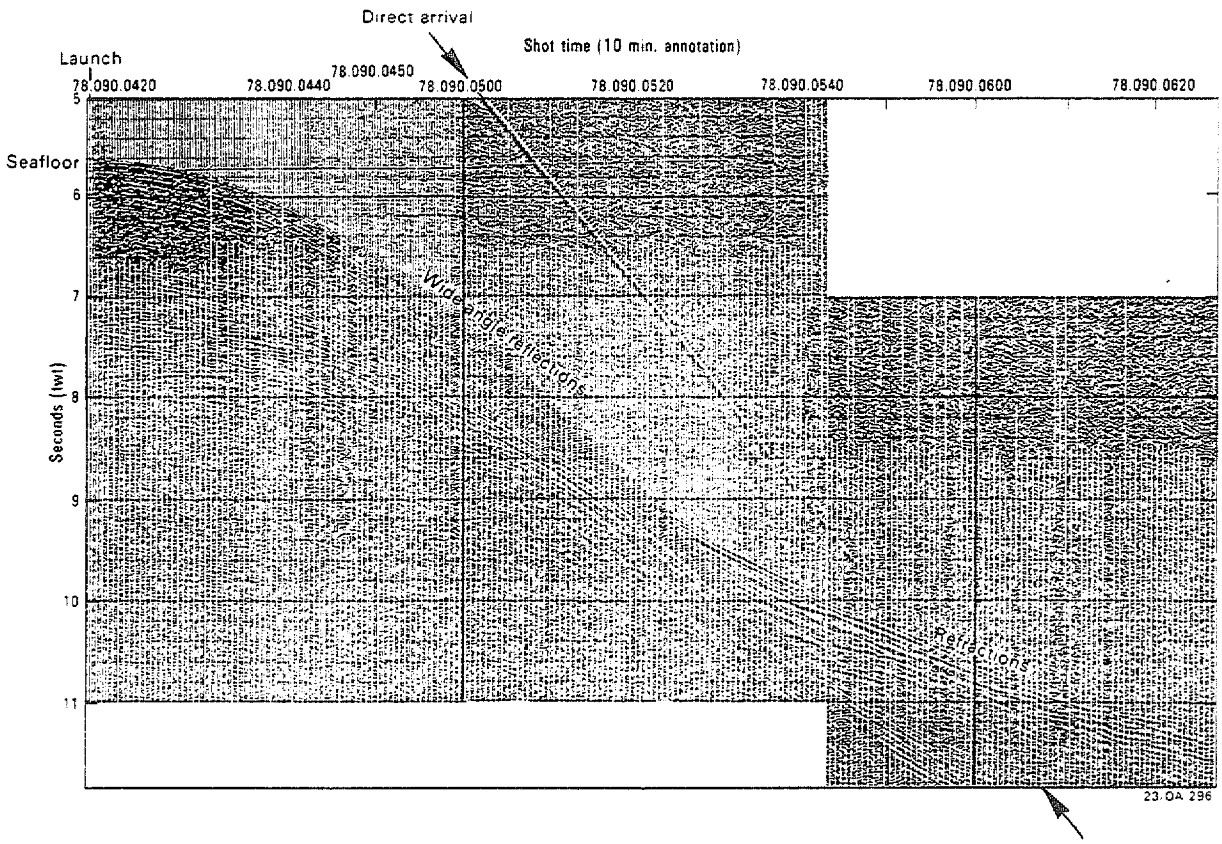


Figure 19. Sonobuoy record SB5, over continental crust on Profile 78/07. Location in Figure 10.

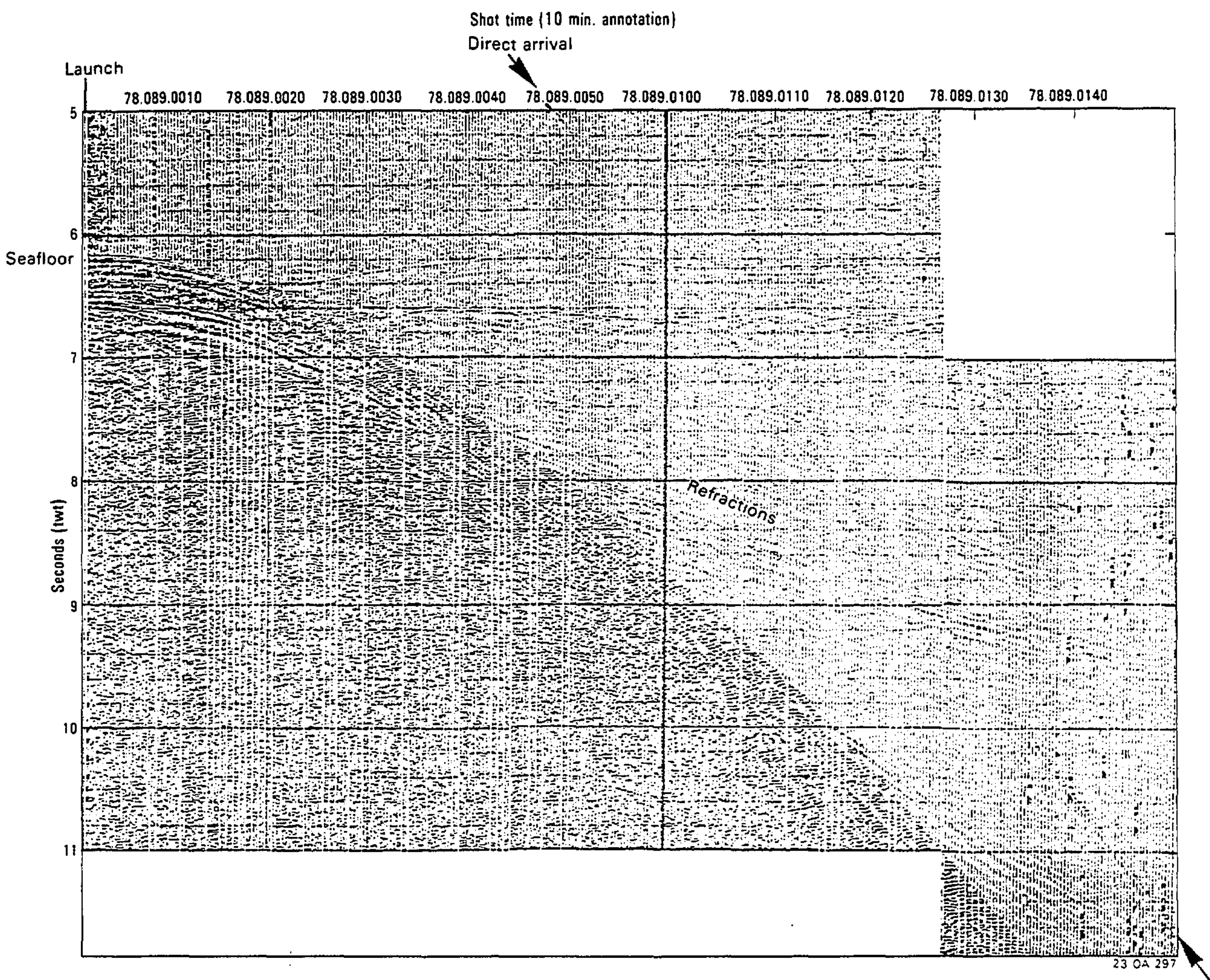


Figure 20. Sonobuoy record SB4, over oceanic crust on Profile 78/06. Location in Figure 10.

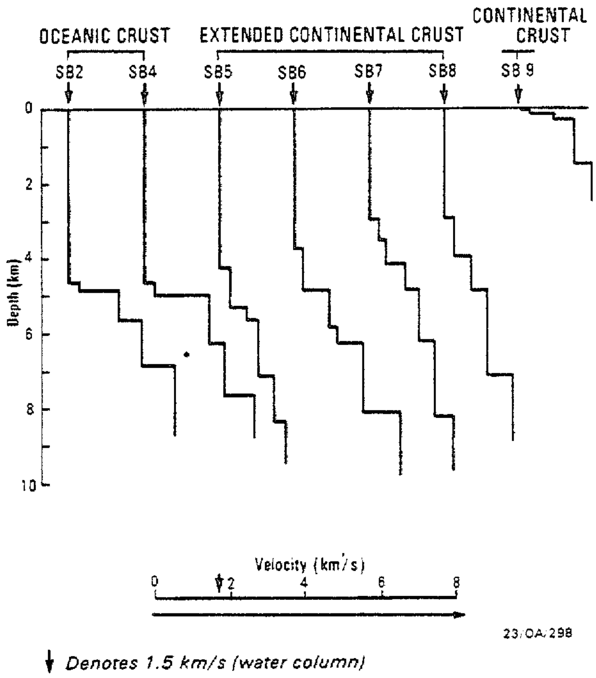


Figure 21. Crustal velocity structure from sonobuoy data recorded on BMR Cruise 78. Locations in Figure 10.

beneath the sea-bed and relatively rapid increase of velocity with depth.

No mantle events (refraction velocity greater than 8.0 km/s) could be discerned with certainty in the monitor records. Processing of the digital sonobuoy data is expected to result in considerably improved record quality, and enhancement of deep crustal events such as mantle refractions and wide-angle reflections.

Magnetic and gravity survey

Profile 78/01 to 78/04 & NE half of 78/05 (King Island Sub-Basin)

The magnetic field over the continental shelf is moderately anomalous, with anomalies typically 1-5 km across and of amplitude about 200 nT. The magnetic anomalies commonly coincide with local gravity highs of 10-15 mGal. High-standing faulted Proterozoic/Palaeozoic basement blocks and possible volcanic intrusions are believed to be responsible for many of the anomalies. Magnetic anomalies of very short-wavelength, though low amplitude, were recorded along profile 78/04 and at the extreme northeastern ends of profiles 78/03 and 78/05 (Figs. 10 & 12), signifying that volcanics or Proterozoic/Palaeozoic basement lie at shallow depth. A broad 20 mGal gravity low between 85.1400 and 85.1815 suggests the presence of a sediment-filled trough or graben.

A prominent magnetic anomaly of about 400 nT amplitude was recorded at or close to the shelf break on lines 78/01, 78/03 and 78/05. This anomaly appears to be the expression of a major crustal boundary, with basement blocks downthrown to the southwest, and it probably marks the head fault of the marginal rift system. On profile 78/01 the main magnetic anomaly is about 8 km back from the shelf edge, suggesting that a major cross-cutting structure such as a transfer fault may lie between this profile and profile 78/03. A detailed aeromagnetic survey would be needed to delineate the basin structure.

The gravity field decreased rapidly across the shelf edge by about 90 mGal. The decrease, from a gravity ridge above the outer shelf to a subdued gravity low over the mid-lower continental slope, represents the 'edge effect' typical of continental margins (Symonds & Willcox, 1976), and arises from the opposing effects of increased water depth and crustal thinning on the free-air anomaly as the margin is crossed. The increased sedimentary section beneath the continental slope, estimated from the seismic data to be in excess of 3 seconds (twt), must also contribute to the decrease in gravity field.

Profiles 78/05 (SW half) & 78/06 (Oceanic crust and continent-ocean boundary)

The south-western end of profile 78/05 (Fig. 12) and the southern end of profile 78/06 extend over oceanic crust as evidenced by thin (0-300 m) sediment cover, rough basement topography and high amplitude (300 nT) magnetic anomalies. The transition to oceanic crust is also accompanied by a 20-30 mGal increase in free-air gravity, attributed largely to a 450 m rise in seafloor and considerable reduction in sediment thickness.

Evidence from magnetic, gravity and seismic data places the Continent-Ocean Boundary (COB) at least as far landward as 88.1200 on profile 78/05 and 89.0400 on profile 78/06, though it is possible that oceanic crust could extend farther landward to 88.0730 (78/05) and 89.0730 (78/06). The oceanic magnetic pattern appears to follow a northwest trend in line with a major bathymetric high (Fig. 11). Along that part of profile 78/06 which crosses crust which is clearly oceanic in character, the recorded magnetic anomalies are tentatively correlated with magnetic anomalies 30-32 (65-71 m.y.b.p.).

A number of acoustic basement highs with relief of about 2 km (sub-bottom) are visible in the seismic profiles over the deep bathymetric basin at the foot of the continental slope. Along profile 78/06 such highs are located at 89.0530, 89.0700 and 89.1230, and project several hundred metres above the generally flat-lying basin floor. Two 'basement' highs are present on profile 78/05 (Figs 12 & 15), at 88.0815 and 88.1015. The first of these lies several hundred metres below seafloor, while the second appears to project just above seafloor. The highs on both lines have both magnetic and gravity expression : 50-150 nT magnetic anomalies and 10-20 mGal positive gravity anomalies. This suggests they are either volcanic in composition or that they represent tilted Precambrian basement blocks.

The break in submarine slope at 88.0400 (78/05) probably correlates with a similar feature on profile 78/06 at 89.1730. On profile 78/06 this break in slope coincides with an underlying 20 km wide structural high of rotated Cretaceous blocks. A gravity high of about 15 mGal is located over this zone, while the magnetic field is moderately anomalous but of long wavelength. Diffractions, which generally appear at depth in the seismic section, may represent volcanic intrusions which are too narrow to be resolved in the magnetic profile because of their depth (5-6 km below sea level).

The deep gravity lows located just seaward of the structural highs at 88.0720 (78/05) and 89.1500 (78/06), delineate a 20-25 km wide graben with substantial sediment fill. The combination of a gravity high above the break in slope and a gravity low below this break suggests that a deep-water 'edge effect' may be involved with the inference that the bathymetric anomaly may coincide with a crustal discontinuity across which substantial seaward thinning of the crust has occurred.

Profile 78/07 (Sub-basins on the lower slope)

The gravity and magnetic fields along this profile on the lower slope (Fig. 10) undulate gently at long wavelength. The absence of major anomalous features in the potential fields is attributed to the fact that this line roughly parallels the continental margin and is essentially a strike line; the only major cross-cutting structures expected are transfer faults.

The long-wavelength variations in the gravity profile mainly appear to reflect slight changes in water depth. The U12 surface is strongly faulted, but this faulting is not reflected to any significant extent in the magnetic and gravity profiles. Hence depth to basement is probably fairly uniform.

Magnetic anomalies of about 50 nT and moderate wavelength, at

90.0700 and 90.1220, may be due to volcanics in the section. The anomaly at 90.1220 is above a section of seafloor dissected by erosion. The seafloor erosion and possible intrusion of volcanics may be related to the same structural control.

Profile 78/12 (Sub-basins on the lower slope)

This line is a continuation of profile 78/07 to the SSE (Figs. 10 & 17). Apart from some thinning of the Tertiary section, no major changes in stratigraphic or structural character are evident in the seismic profile. As for profile 78/07, the magnetic and gravity profiles undulate at long wavelength, but the amplitudes of the variations are higher along profile 78/12.

Broad gravity highs of about 20 mGal amplitude reflect structural highs at the U9-U12 level at 92.1700 and 93.0300. The very broad magnetic high (150 nT) extending from 93.0130 to the end of the line may indicate a lithological change in underlying basement.

Profiles 78/08 to 78/11 (Strahan Sub-basin)

A large 90 mGal continental 'edge effect' gravity anomaly is present on profiles 78/08 and 78/10-11, and extends from the outer shelf to the lower continental slope. As on profiles 78/01, 78/03 and 78/05 to the north, the anomaly consists of a high over the outer shelf decreasing to a broad, deep low over the slope. The gravity and magnetic profiles over the continental slope are mainly of long wavelength, signifying deep basement. However, coincident local gravity and magnetic highs at 92.0600 (78/11) indicate an elevated basement block.

Cape Sorell No. 1 well (at about 91.1140 on Line 78/08) is within a 25 mGal gravity low, which suggests a local thickening of the sedimentary section. However, about 3 km to the east the presence of short-wavelength, large amplitude (300 nT) magnetic anomalies, and an abrupt increase in gravity field, mark the sub-basin's eastern boundary fault, across which basement shallows to about 500 m depth.

A broad gravity low centred between the middle and the northern end of profile 78/09 appears to be associated with only minor thickening of the sedimentary section. This could be explained either by less dense basement northeast of the Macquarie Harbour lineament or by a structure off to the side of the profile. The gravity and magnetic data suggest that the thickest section is located at about 91.1610 - a thickness of at least 1.5 s (twt) is indicated here from the seismic monitor records.

A very shallow basement block, about 10-km wide along the profile, between 91.1950 and 91.2050, is delineated by a band of high amplitude (1000 nT), short wavelength magnetic anomalies and a steep-sided 25 mGal gravity high.

Elevated basement blocks are also interpreted to underlie the outer edge of the continental shelf near the intersection of profiles 78/10 and 78/11. The basement highs are indicated by short-wavelength magnetic anomalies of up to 150 nT amplitude, as well as local gravity highs. The tops of the blocks are located at about 92.0130 and 92.0230/92.0300 (same block crossed twice during turn), and from inspection of the seismic monitor records they appear to lie at a depth of about 500 m.

BRUNY ISLAND GEOPHYSICAL RESULTS

Reflection seismic survey

The seismic reflection data in southeast Tasmania were shot in two separate parts using different seismic cable configurations. Profiles 78/14-17 (see Fig. 22) were surveyed with a cable configuration identical to that employed off west Tasmania, i.e. 1200 m active section with 25 m hydrophone groups (48 channels). For operations in the more confined and relatively shallow areas of D'Entrecasteaux Channel (78/18), the overall cable length was shortened by reducing the active section to 600 m and using only one 50 m stretch section at the front of the cable instead of the three used earlier in the cruise. Forty-eight recording channels were retained by changing to 12.5 m hydrophone groups. Profiles 78/14-17 were shot with the 10-gun tuned array, while most of profile 78/18 was shot with an 80 cubic inch water-gun. For part of profile 78/18, at the southern end of D'Entrecasteaux Channel (between 95.0300 and 95.0550), the seismic source was changed back to the air-gun array in an attempt to improve penetration. A shot interval of 25 m (nominal) was adopted for the entire southeast Tasmania survey, giving 24-fold coverage along profiles 78/14-17 and 12-fold coverage along profile 78/18.

The reflection data visible in the monitor records are, predictably, not of high quality. Apart from the usual problems encountered when operating in shallow water, such as reverberations and multiples, interpretability is further reduced by geological complexity and the widespread high-velocity dolerite sheets at shallow depth. With the water-gun source the monitor records show reflection events down to about 1 second (twt), while with the airgun array reflections are visible down to about 2.5 seconds (twt) in places. Typical monitor record quality is illustrated in Figure 23 by a section from the northern end of profile 78/17 in Storm Bay, which compares favourably with the seismic data recorded by Amoco (1971). Processing will produce a significant improvement in seismic data quality.

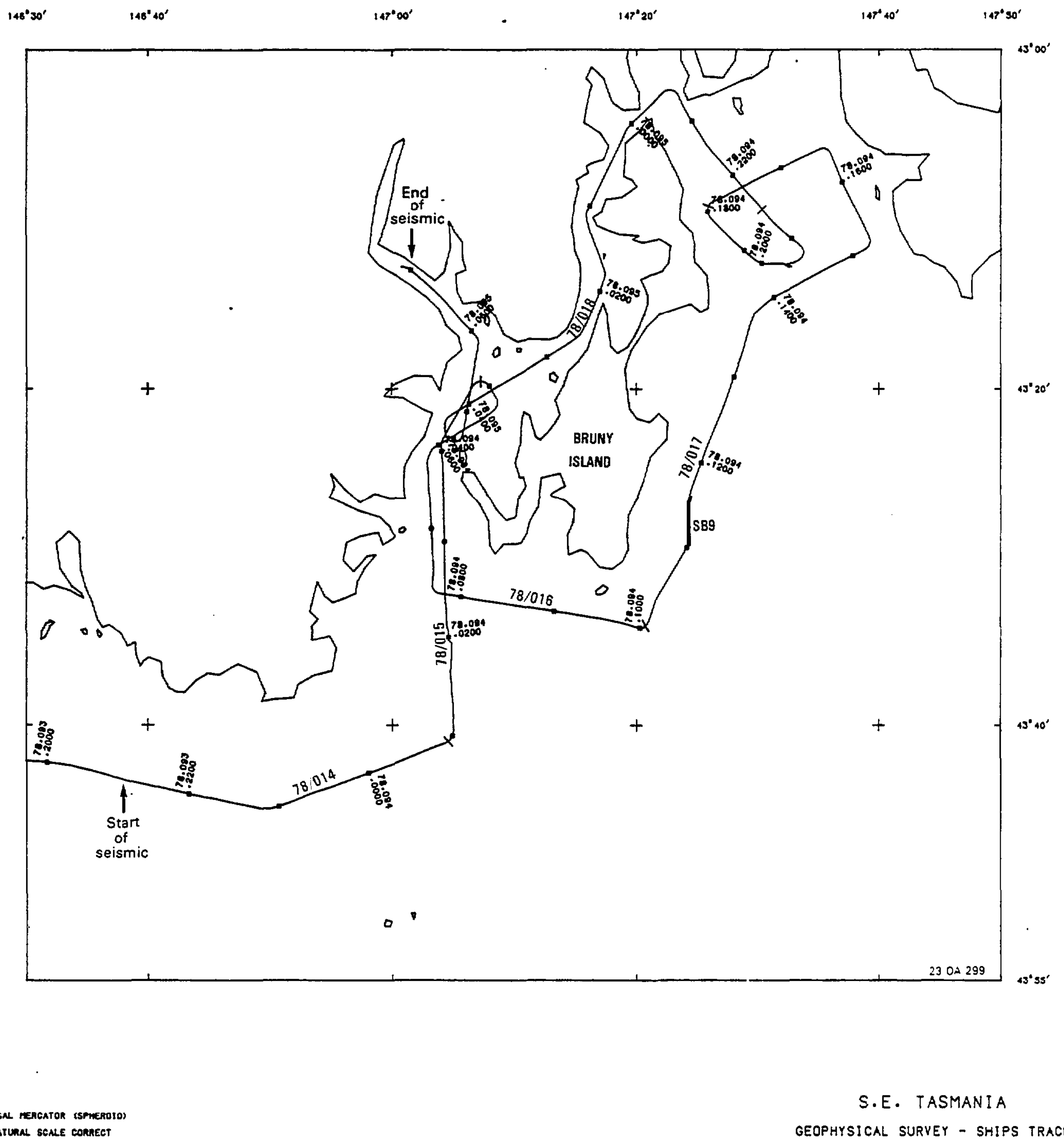
It would be premature to attempt a detailed interpretation based on the monitor records, particularly since the offshore geology is virtually unknown apart from what can be extrapolated from onshore surface mapping and bore holes.

Several basins which appear to be Tertiary in age are well defined in the monitor data, however, and are briefly discussed below.

(i) Between 93.2350 and 94.0025 (line 78/014) ?Tertiary sediments thicken into a basin 0.8-1.0 seconds (twt) deep.

(ii) A ?Tertiary trough 1.0 second (twt) deep at 94.0120 (line 78/15) extends between 94.0110 and 94.0135.

Figure 22. Track map showing Bruny Island geophysical leg of BMR Cruise 78, including location of sonobuoy 9.



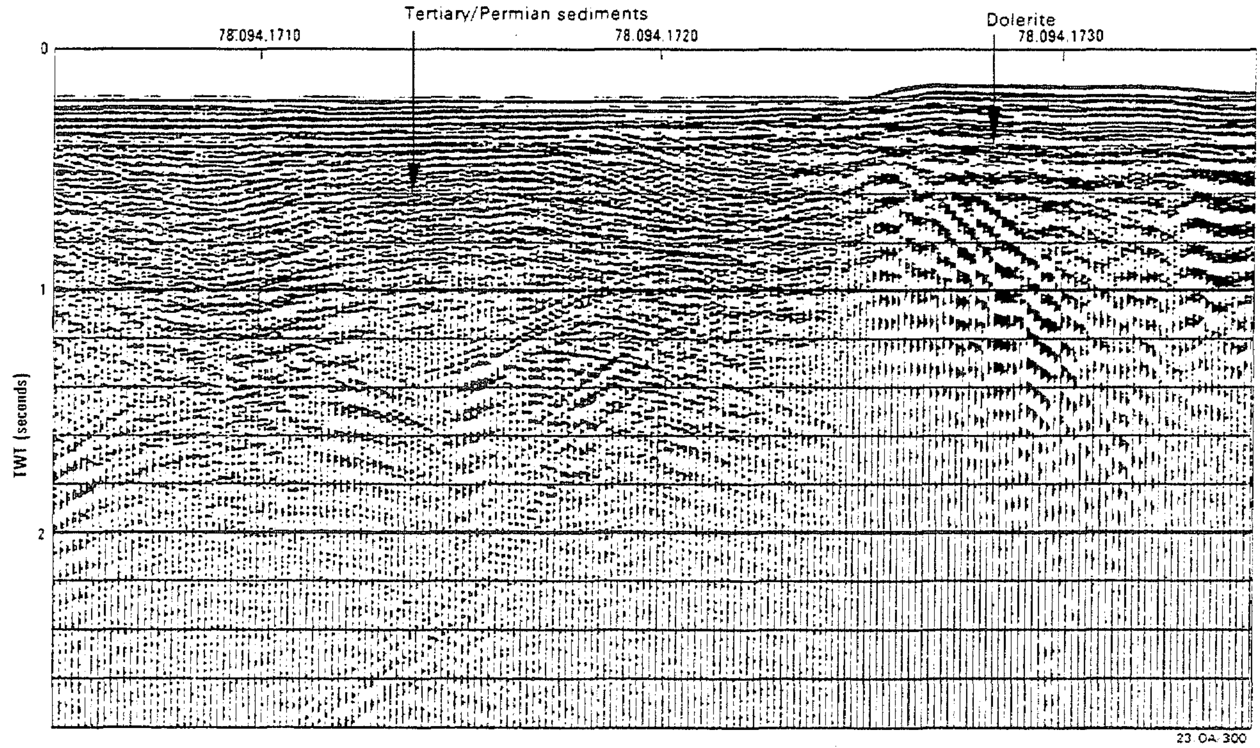


Figure 23. Monitor record of reflection seismic data from Profile 78/17 in Storm Bay near Bruny Island. Shows Jurassic dolerite and Phanerozoic sedimentary rocks. Location in Figure 22.

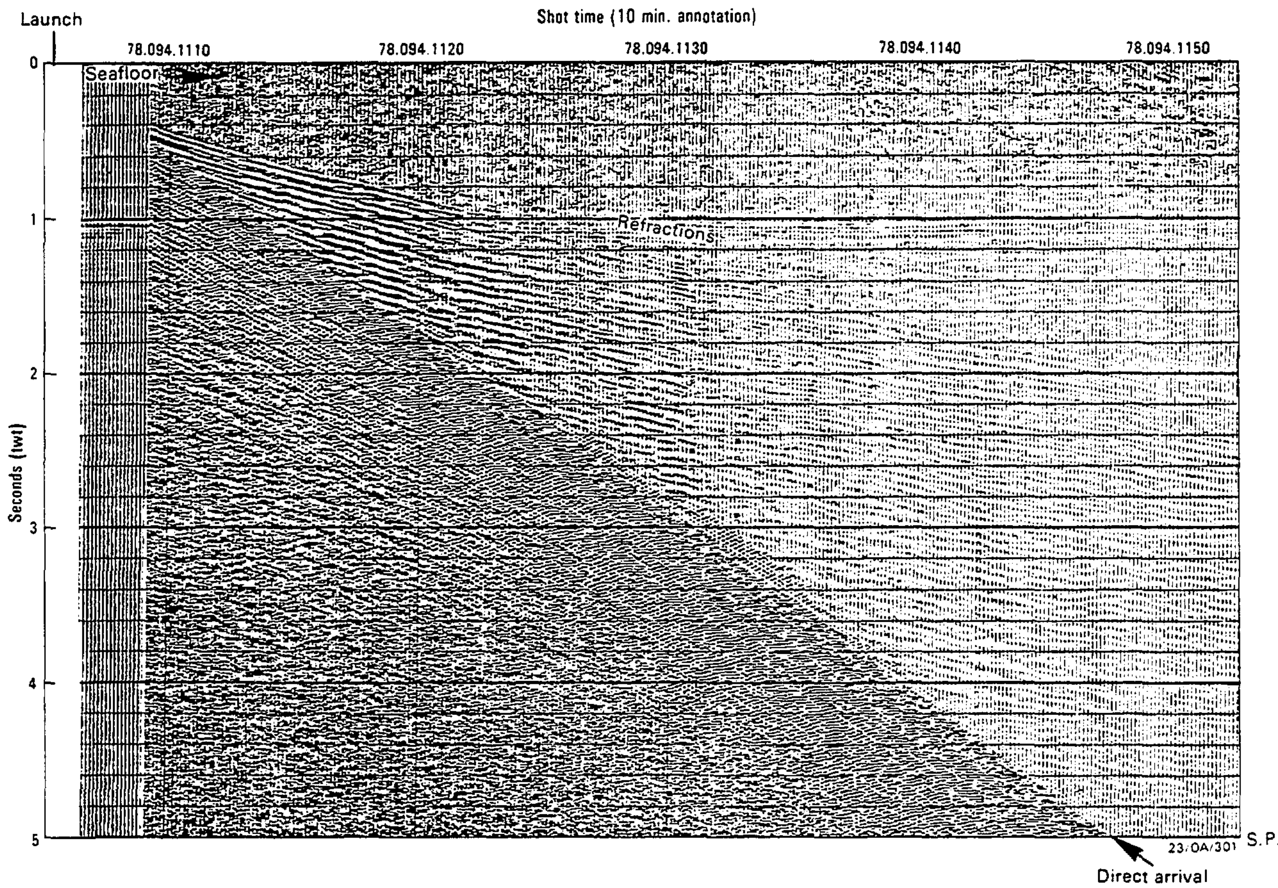


Figure 24. Sonobuoy record SB9, over continental crust on Profile 78/17, east of Bruny Island. Location in Figure 22.

(iii) A NNW trending ?Tertiary sediment trough about 2 km wide is seen at 94.1405 and 94.1720 on profile 78/17, and appears to be fault bounded to the west against a dolerite sheet (Fig. 23). The trough also appears at 94.2140, 94.2247 and 94.2338 on line 78/18. It deepens from about 0.6 seconds (twt) where crossed near the northern entrance to D'Entrecasteaux Channel to 1.0 seconds (twt) at the southernmost crossing in Storm Bay.

The sediment trough on profile 78/17 is probably part of the Derwent Graben, a north-northwest trending structure developed by Jurassic and ?early Tertiary normal faulting and further deepened by fluviatile erosion. Tertiary sedimentary rocks have been proved to a depth of 180 m at Sandy Bay, while a thickness in excess of 600 m is inferred offshore from Taroona (Leaman, 1972; Leaman 1976; Farmer, 1979).

Refraction seismic survey

Sonobuoy SB9 was deployed off the east coast of Bruny Island (Fig. 22) during the reflection survey, to establish the velocity structure of the upper crust. Sonobuoy information and launch particulars are provided in Table 3. As in the case of the other sonobuoy experiments (off the West Tasmanian coast), the seismic source used was the 10-gun tuned array. However, for SB9 the shot interval was 25 m (nominal) and record length 5 seconds.

The SB9 sonobuoy monitor record is reproduced in Figure 24. Strong, 3340-4310 m/s refractions originating from shallow depth are prominent in the record, and are believed to be produced by travel paths through underlying (?fractured) dolerite and/or Palaeozoic sediments. A higher velocity (5360 m/s) refraction event seen at longer offsets may represent arrivals from Precambrian basement. Table 4 and Figure 21 show the results of preliminary analysis and interpretation of SB9.

During the Bruny Island reflection survey it was noted that refractions (cf. the direct wave and reflections) were frequently the first arrivals at far and middle hydrophone groups. This was particularly common during operations with the longer 1200 m active section cable. These early refractions result from the shallow water depth (15-120 m) and the high-velocity rocks (dolerite/Palaeozoic sediments) exposed on the seafloor or high in the sub-bottom. Such refraction data provide useful supplementary information for geological interpretation.

Velocity analysis of shallow, high-velocity refractions recorded over two areas off southern Bruny Island yielded a velocity range of 4850-5100 m/s. The associated highly anomalous magnetic field and the onshore geology suggest that the refractors are almost certainly dolerite.

Magnetic and gravity survey

Gravity coverage was obtained along all profiles in southeast Tasmania. Because the towed magnetometer sensor was in danger in water shallower than 30-40 m, it was not deployed during work in

TABLE 3 : SONOBUOY DATA

Sonobuoy No.	Serial No.	Radio Transmission Channel	Launch Time (ddd.hhmm)	Line No.	Water Depth (m)	Launch Location/ Remarks	
SB1	09594	30	088.0825	78/005	4950	42°00.5'S	142°25.9'E
SB2	09553	28	088.1550	78/005	4650	42°27.0'S	142°45.3'E
SB3	01070	25	088.2347	78/006	-	Failed (?sank on deployment)	
SB4	09571	30	089.0002	78/006	4650	42°24.2'S	141°26.6'E
SB5	05723	31	090.0417	78/007	4270	40°55.0'S	142°19.7'E
SB6	10328	31	092.1331	78/012	3790	42°21.3'S	143°56.0'E
SB7	05547	26	093.0106	78/012	3000	43°16.8'S	144°40.1'E
SB8	01774	25	093.0604	78/012	2930	43°39.9'S	144°58.9'E
SB9	11500	31	094.1105	78/017	70	43°29.1'S	147°24.2'E

TABLE 4. PRELIMINARY SONOBUOY ANALYSIS AND INTERPRETATION

Sonobuoy No.	Layer No.	Velocity (m/s)	Depth bsl (m)	Thickness (m)	Interpretation
SB2	1	1500	0	4650	Water column.
	2	2000*	4650	180	Pelagic, hemipelagic sediments (post mid-Cretaceous)
	3	4160	4830	810	Upper oceanic crustal layer (basalt).
	4	5330	5640	1220	Upper-mid oceanic crust (gabbro).
	5	7020	6860	-	Main oceanic crustal layer.
SB4	1	1500	0	4650	Water column.
	2	2000*	4650	340	Pelagic, hemi-pelagic sediments (post mid-Cretaceous).
	3	4960	4990	1250	Upper oceanic crustal layer (basalt)
	4	5670	6240	1420	Upper-mid oceanic crust (gabbro)
	5	7370	7660	-	Main oceanic crustal layer.
SB5	1	1500	0	4650	Water column.
	2	2000*	4270	1060	Tertiary sediments.
	3	2930	5330	310	Upper Cretaceous sediments.
	4	3590	5640	1500	Lower Cretaceous sediments.
	5	4400	7140	1210	?Palaeozoic unit.
	6	5020	8350	-	Precambrian basement.
SB6	1	1500	0	3790	Water column.
	2	2000*	3790	1110	Tertiary sediments.
	3	3340	4900	970	Cretaceous sediments.
	4	3800	5870	390	Lower Cretaceous sediments.
	5	5090	6260	1870	Precambrian basement.
	6	7100	8130	-	Main crustal layer.
SB7	1	1500	0	3000	Water column.
	2	2000*	3000	560	Tertiary sediments.
	3	2300	3560	630	Early Tertiary sediments.
	4	3380	4190	670	Cretaceous sediments.
	5	4150	4860	1340	?Lower Cretaceous sediments
	6	4810	6200	2000	?Palaeozoic unit.
	7	6000	8200	-	Precambrian basement.
SB8	1	1500	0	2930	Water column.
	2	2000*	2930	1040	Tertiary sediments.
	3	2950	3970	860	Early Tertiary/Upper Cretaceous sediments.
	4	3730	4830	2330	Lower Cretaceous sediments.
	5	5170	7160	-	Precambrian basement.

Table 4 (continued)

Sonobuoy No.	Layer No.	Velocity (m/s)	Depth bsl (m)	Thickness (m)	Interpretation
SB9	1	1500	0	70	Water column.
	2	2000*	70	130	Tertiary sediments.
	3	3340	200	170	Upper part dolerite sill/Permian sediments.
	4	4310	370	1140	Dolerite/Ordovician sediments.
	5	5360	1510	-	Precambrian basement.

*assumed velocity.

D'Entreasteaux Channel and the northern area of Storm Bay. Magnetic coverage was limited to parts of profiles 78/14-17, and amounted to about 50% of the total line length surveyed in the area.

Profile 78/14

The ?Tertiary basin defined by reflection seismic data towards the eastern end of this profile appears as a 10 mGal low in the gravity profile. The magnetic anomaly profile shows high amplitude variations (to 550 nT) at short to medium wavelength, suggesting that these anomalies are derived from sources at or below the unconformity at the base of the ?Tertiary sediments. The sub-unconformity rocks may comprise Jurassic dolerites or Cambrian volcanics. The abrupt change in magnetic amplitude at about 93.2350 and 94.0045 points to the likely presence of major structural discontinuities.

Profile 78/15-16

A gravity low of about 15 mGal is centred at 94.0150 on profile 78/15 and extends from the start of the profile (94.0100) to about 94.0215. This section of line is also characterized by a more subdued magnetic profile with increased wavelength, which tends to confirm that it is underlain by a thickened sedimentary section. The ?Tertiary trough identified in the seismic data at 94.0120 would be part of this inferred sediment pile.

Beyond 94.0215 the amplitude of the magnetic anomalies increases and wavelength decreases. North of 94.0300 amplitudes exceed 600 nT. Thus the southern entrance to D'Entrecasteaux Channel is clearly underlain by dolerites at shallow depth.

Short-wavelength, high amplitude (400 nT) magnetic anomalies were also recorded south of Tasman Head on the southernmost Bruny Island, at the end of profile 78/16, and are accompanied by an increase in gravity of about 15 mGal. Tasman Head and the adjacent islands (The Friars) consist entirely of Jurassic dolerite. The potential field data and the recording of high-velocity refractions confirm that the dolerite extends offshore as a thick sheet.

Profile 78/17

The linear section of profile east of Bruny Island, between the start of the profile (94.1000) and 94.1400, is magnetically anomalous along its length, with anomalies mainly of 100-250 nT amplitude and fairly short wavelength. Dolerite probably lies within 500 m of the surface along most of the line.

20 mGal gravity lows at 94.1405 and 94.1715 mark crossings of the ?Tertiary sediment trough identified in the seismic monitor records and interpreted as possible Derwent Graben fill. High amplitude, short-wavelength magnetic anomalies at about 94.1350, located just west of the southernmost crossing of the trough, indicate dolerite at shallow depth.

Profile 78/18

The ?Tertiary sediment trough is seen on this line as 10-20 mGal lows at 94.2005, 94.2135, 94.2245 and 94.2335. The gravity profiles down the D'Entrecasteaux Channel and up the Huon River show minor variations of about 5 mGal, but there are no major excursions indicative of large lateral density contrasts in the upper crust.

WEST TASMANIAN GEOLOGICAL RESULTS

The geological sampling program was designed to complement those of Hinz et al. (1985, 1986) and Exon, Lee et al. (1987, 1989), and was marked by the good performance of the equipment. The number of stations occupied, and the number of stations at which the main objective was attained (in brackets) are listed below:

Dredges 10(4)
Piston cores 5(4)
Gravity cores 23(14)
Vibrocores 4(0)
Box cores 6(4)
Grabs 9(9)

The ship's tracks are shown in Figure 25. The locations of all stations are shown in Figures 26, 32 and 34. The results of laboratory studies of material from cores taken on this and earlier cruises are summarized in Exon, Stratton, Reynolds & Tindall (1989).

Dredge samples

At all stations except one a large chain bag dredge was used, with a solid bridle, weights 200 m ahead of the dredge, and a small pipe dredge behind. Dredge 7 used a 7 tonne shear pin which broke, but fortunately the safety strap held.

Dredges 1 to 9 were on the continental slope southwest of Tasmania (Fig. 26) and were aimed at continental and oceanic basement and Cretaceous sedimentary rocks, exposed in fault scarps with dips of $10\text{-}15^{\circ}$. The results are summarized in Table 5, which indicates that dredges 1, 3 and 7 recovered only Quaternary material. Dredge 2 recovered quartz muscovite schist and phyllite showing multiple deformation, of probable Proterozoic age.

Dredge 4 recovered very thick Mn crusts (25 cm) forming on large nodules (Fig. 27), and we assume that the combination formed on a hard pre-Tertiary substrate, none of which was recovered. Dredges 5 and 6 recovered semi-indurated sandstone, siltstone and mudstone, which seismic correlations suggest are of Late Cretaceous age. A mudstone from Dredge 6 contained Santonian palynomorphs, and was a marginal marine deposit (Appendix 6).

Dredge 8 was aimed at a pre-Tertiary bathymetric high on the continental shelf off southwest Tasmania (Fig. 26) but the pipe dredge being used became hooked and was lost. Dredge 9 was run across two scarps of oceanic basalt on the abyssal plain at the outer end of seismic line 78/05 (Fig. 26), but the scarps proved to be blanketed in ooze. However, a fragment of grey mudstone contained Paleocene palynomorphs, and was deposited in restricted marine conditions (Appendix 6).

TABLE 5: DREDGE STATIONS

Station	Latitude	Longitude	Water Depth (m)	Seismic Profile	Recovery (Hard Rock)	Description or Comments
DR01	44°09.5'	146°02.5'	1820	11/009	None	About 10 kg greenish grey Quarternary foram ooze in pipe dredge; 1 piece (1 cm) dark greenish grey ? metasiltstone with laminae, possible volcanic.
DR02	44°09.4' 44°09.5'	146°03' 146°03.5'	1650- 1550	11/009	200 kg metamorphic rocks	Quartz muscovite schist , dark grey phyllite; probably Proterozoic. Quaternary grey foram nanno ooze in pipe dredge, with small fragments of metamorphics.
DR03	44°10.2'	145°20.5'	3000	11/009	None	Quaternary light olive grey foram nanno ooze with arenaceous forams, fine worm burrows, ophiuroids, 1 piece basalt.
DR04	44°09.0' 44°08.8'	144°46.8 144°47.6	2800- 2600	11/009	200 kg	Manganese nodules, 4 cm to 15 cm diameter manganese crusts to 25cm thick.
DR05	44°10.2' 44°08.8'	144°41.7' 144°43.8'	3730- 3050	11/900	1 kg	Semi-indurated medium grey siltstone/ mudstone with manganese crust (1mm to 4 mm). Quaternary light olive grey nanno foram ooze with fragments of manganese crust, in pipe dredge.
DR06	43°36.2'	144°11.8'	3915- 3760	S048	One pebble	Dark greenish grey Santonian indurated mudstone. Quarternary ooze.
DR07	43°10.4' 43°09.4' 43°08.9'	145°10.7' 145°11.7' 145°12.3'	1200 730 630	16/005	None Shear pin broken on chain bag dredge	In pipe dredge A. Quaternary pale olive fine to course calcareous sand. B. Light olive grey foram ooze, slightly consolidated. C. Sticky greyish white foram nanno ooze, chalky. D. Fraction (>2 mm): bryozoa, gastropods, pteropods, corals, bivalves, larger forams, echinoid spines, calcareous lumps.
DR08	45°50.2'	145°07.2'	120		None	Large pipe dredge deployed; lost.
DR09	42°50.0'	143°49.7'			None	In pipe dredge: A. Quarternary greyish orange (10YR/ 7/4 foram nanno ooze B. 0.5 kg nannofossil-free, brownish grey (5yr4/1) Paleocene silty clay-stone C. Granules of semi-lithified sandstone
DR10	42°22.2' 42°22.6'	141°52.8' 141°50.5'	4970 4820	78/005	None	Brown mud (?from deeper location). Grey mud (?from shallower location).

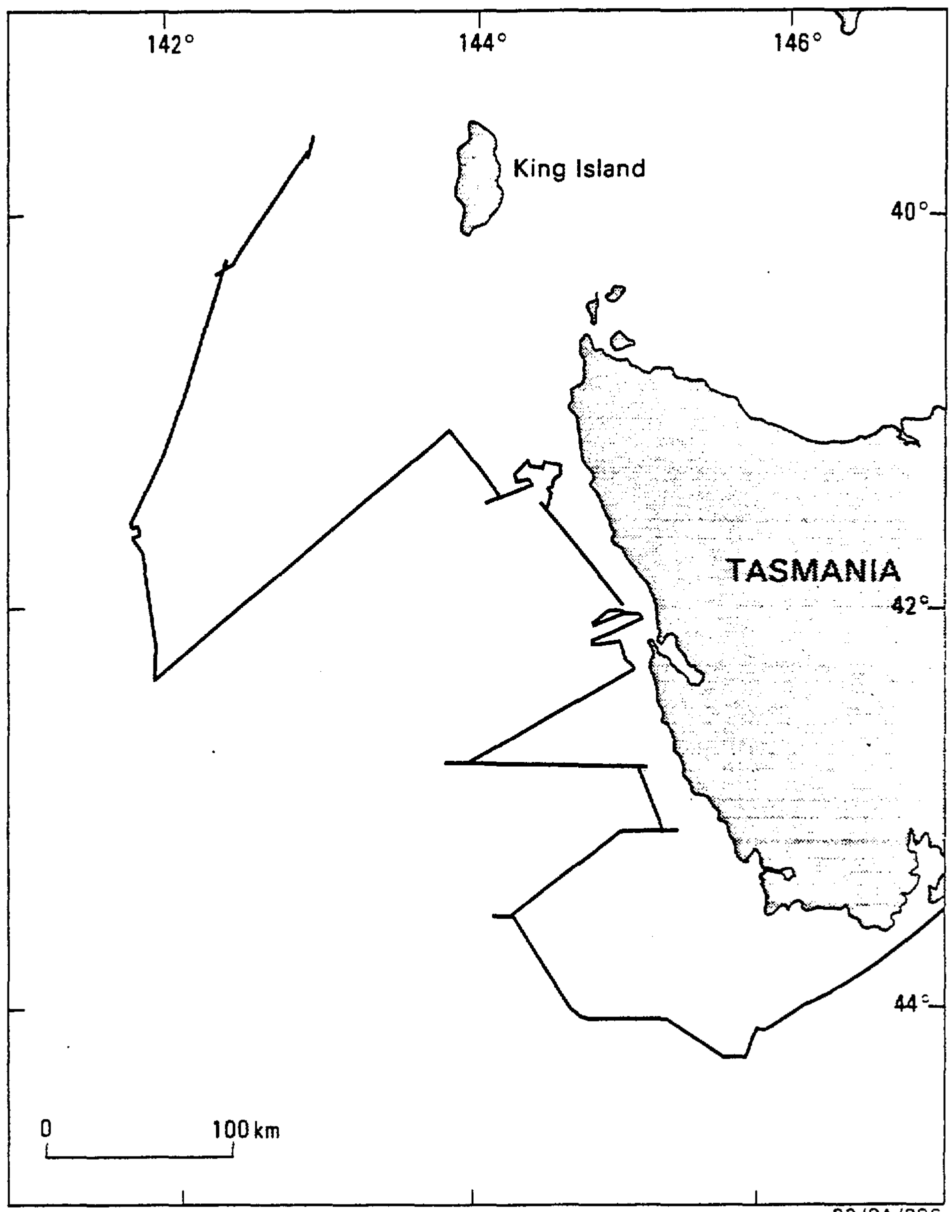
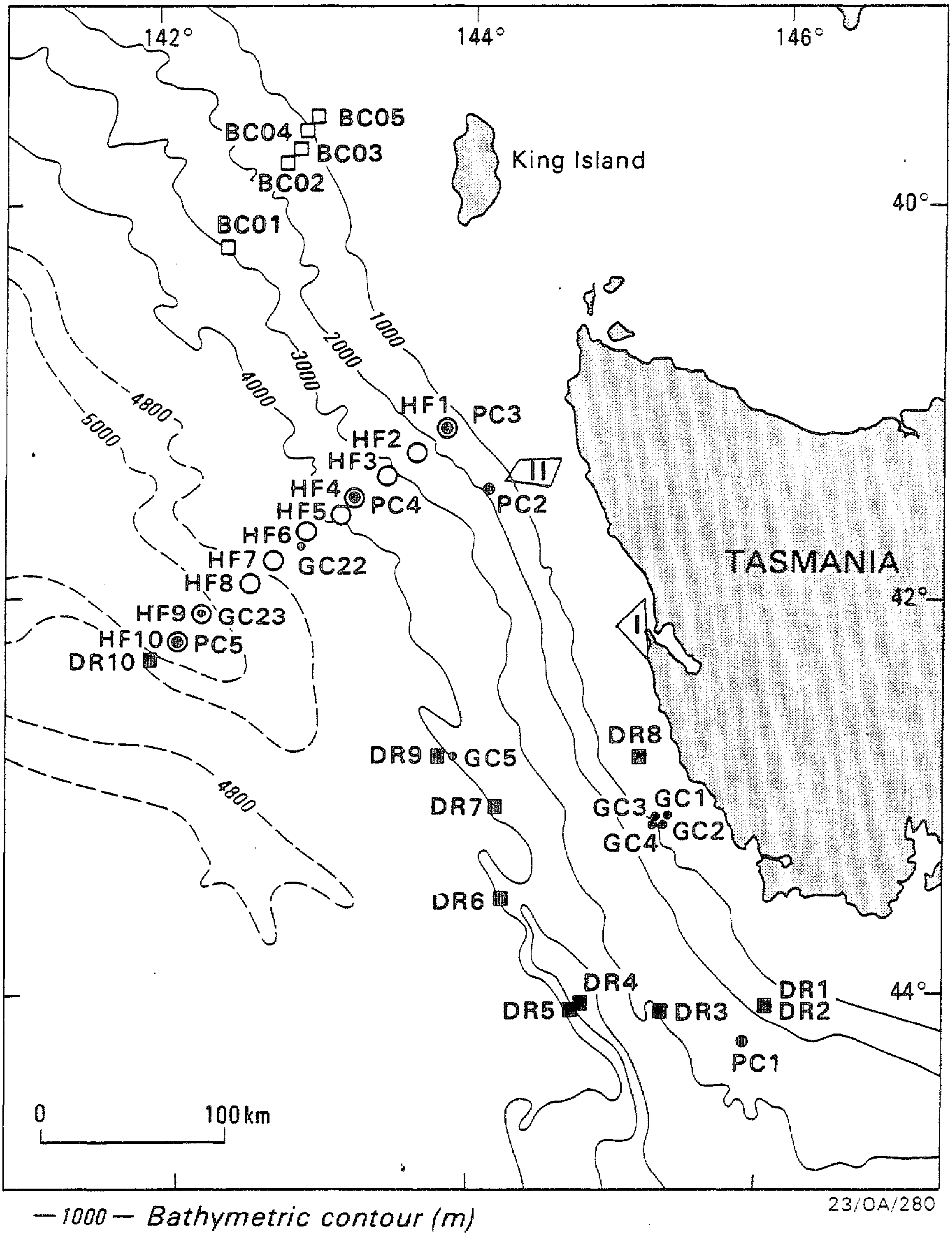
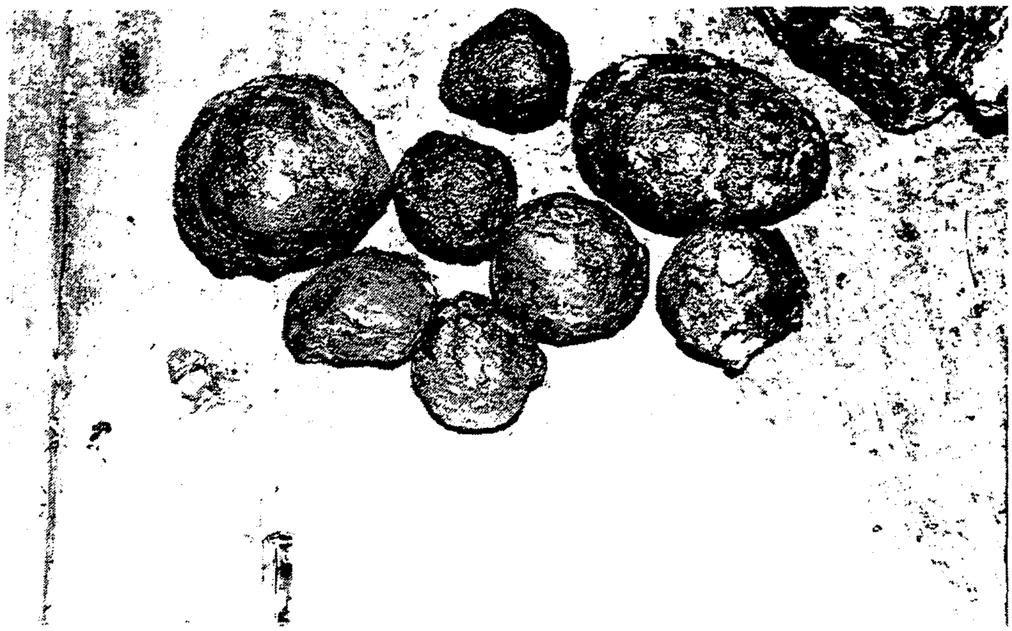


Figure 25. Map showing ship tracks for west Tasmanian geological leg.

Figure 26. Map relating sampling and heatflow stations for west Tasmanian geological leg to bathymetry.





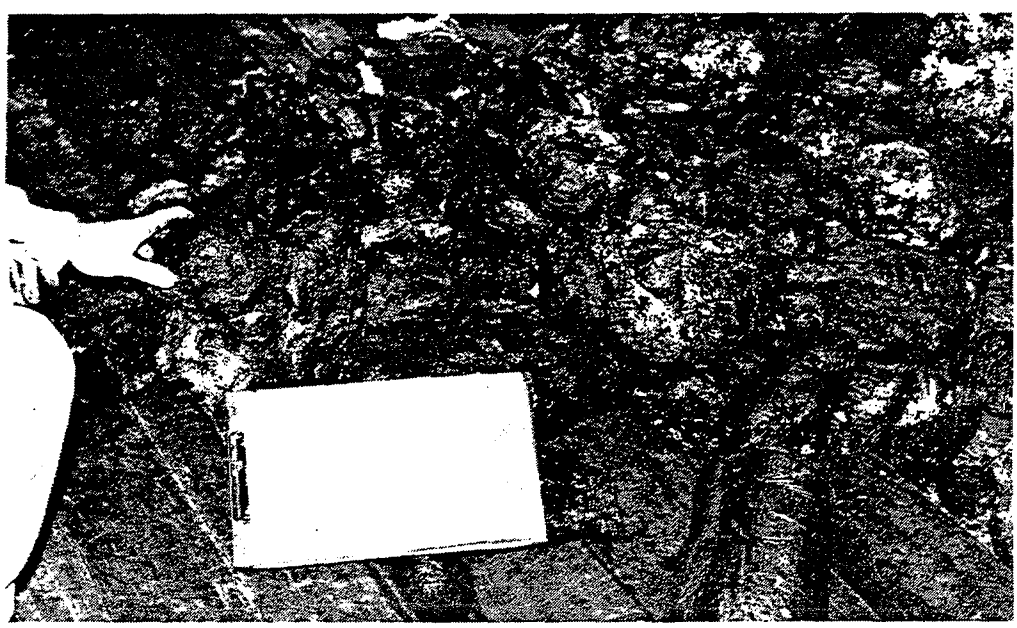


Figure 27. Photograph of extraordinarily large ferromanganese nodules (10-15 cm diameter) dredged at station DR4 on steep slope in water of 2600-2800 m depth, 130 km west-southwest of South West Cape (Fig. 26).

TABLE 6: REGIONAL CORE STATIONS

Station	Latitude (S)	Longitude (E)	Water depth (m)	Seismic profile	Recovery (cm)	Description or comments
GRAVITY CORES						
GC01	43°9.9'	145°17.2'	307	16/005	282	Quaternary bryozoah shall hash; pink is above 23 cm, grey green below.
GC02	43°10.9'	145°15.9	478	16/005	2	Coarse shelly sand.
GC03	43°08.9'	145°12.1'	643	16/005	20	Bryozoal ooze: greyish orange above 12 cm, bluish grey below. Early to mid Miocene at base.
GC04B	43°09.8'	145°12.4'	793	16/005	383	Quaternary olive grey bioclastic sandy mud.
GC05	42°50.1'	143°51.1'	3530	16/007	60	Quaternary pale orange nanno foram ooze above early Eocene brownish black semi-plastic mud.
GC22	41°45.3'	142°50.5'	3970	78/05	730	Light olive, light grey and light brown interbedded foram nanno ooze, chalky toward base. Quaternary.
GC23	42°09.2'	142°12.5'	5014	78/05	-	Pipe bent. Probably hit turbidite sand.
PISTON CORES						
PC01A	44°19.9'	145°53.0'	2270	Sonne 49	539	Interbedded light grey and greenish grey foram nanno ooze and foram sand turbidites. Quaternary.
PC02	41°30.0'	144°06.2'	1703	16/15	633	Not split on board as palaeomagnetic core. Mid to late Miocene at base.
PC03	41°06.9'	143°50.0'	1265	78/05	494	Dusky yellow green foram nanno ooze beneath 6 cm of light olive gray muddy foram sand. Quaternary
PC04	41°30.3'	143°13.6'	3560	78/05	738	Greenish grey and light olive gray foram nanno ooze with three thin turbidite sands. Qua ternary.
PC05	42°14.3'	142°04.8'	5029	78/05	-	Pipe bent. Probably hit turbidite sand.

TABLE 7: SANDY CAPE SUB-BASIN GRAVITY CORE STATIONS

Station	Latitude (S)	Longitude (E)	Water depth (m)	Seismic profile	Recovery (cm)	Description or comments
GC06	(41°30')	(144°27')	325		385	30 cm brown bryozoal shell hash above yellow green foram nanno ooze. Quaternary.
GC07	(41°30')	(144°24')	516		373	Olive gray sandy foram nanno ooze.
GC08	41°28. 0'	144°28.0'	118		40	Bryozoal shell hash on (chips of) early to mid Miocene limestone.
GC09	41°26.0'	144°26.3'	131		10	Bryozoal shall hash on (chips of) brown Miocene calcarenite.
GC10	41°23.0'	144°30.0'	127		5	Bryozoal shell hash.
GC11	41°22.0'	144°33.1'	111		5	Bryozoal shell hass.
GC12	41°19.7'	144°33.8'	119		2	Bryozoal shell hash.
GC13	41°20.1'	144°30.0'	131		20	Consolidated muddy bryozoal shell hash. Early to mid Miocene at base.
GC14	41°19.1'	144°27.2'	144		1	Bryozoal shell hash.
GC15	41°21.4'	144°26.0'	159		1	Bryozoal shell hash.
GC16	41°21.0'	144°24.0'	293		378	40 cm yellow to pale olive bioclastic sand, above yellow green calcareous silty mud containing Terebratulids. Qua ternary.
GC17	41°18.0'	144°20.0'	111		1	Bryozoal shell hash.
GC18	41°23.1'	144°14.0'	814		410	15 cm yellowish gray foram nanno ooze, above olive gray calcareous silty mud. Quaternary.
GC19	41°24.8'	144°15.1'	910		394	37 cm pale yellow fine bioclastic sand, above light olive gray calcareous silty mud. Quaternary.
GC20	41°24.0'	144°18.6'	641		20	Sandy bioclastic ooze. Quaternary.
GC20A	41°23.8'	144°18.6'	638		-	
GC21	41°24.6'	144°21.7'	436		114	9 cm light olive gray bioclastic sand, above olive gray foram nanno ooze. Quaternary.

TABLE 8: STRAHAN SUB-BASIN SAMPLING

Station	Latitude (S)	Longitude (E)	Water depth (m)	Recovery	Description or comments
GS1	42°20.1'	145°3.2'	94	Full	Bryozoal shell hash.
VC1	42°20.0'	145°3.2'	94	Negligible	" " "
VC1A	42°20.0'	144°3.1'	95	5 cm	" " "
GS2	42°14.3'	144°59.0'	133	Small	" " "
GS3	42°12.7'	144°57.9'	140	Small	" " "
VC2	42°11.4'	144°53.6'	155	none	" " "
GS4	42°10.2'	144°56.2'	135	Full	" " "
GS5	42°10.9'	144°54.8'	142	None	" " "
GS6	42°11.1'	144°53.6'	153	1/2 grab	Bryozoal sand.
GS7	42°12.0'	144°51.7'	159	1/3 grab	Muddy shelly sand.
VC3	42°12.4'	144°51.8'	159	None	Lost core barrel
GS8	42°03.9'	145°00.9'	93	1/2 grab	Sandy bryozoal hash with quartz grains.
VC4	42°03.9'	145°00.9'	93	None	Electrical fault in corer.
GS9	41°25.0'	144°22.9'	400	Full	Bryozoal shell hash.

NB GS = Van Veen grab station
VC = 3.5 m vibrocorer station.

TABLE 9: BOX CORE STATIONS WEST OF KING ISLAND

Station	Latitude (S)	Longitude (E)	Water depth (m)	Seismic profile	Recovery (cm)	Description or comments
BC01	40°13.7'	142°25.2'	3057	40/20-23	-	Triggered and ooze on frame.
BC02	39°47.0'	142°48.8'	1642	40/20-23	19	Light greenish gray foram nanno ooze.
BC03	39°42.8'	142°53.1'	1303	40/20-23	5	Greenish gray nanno foram ooze.
BC04	39°37.4'	142°56.3'	1026	40/20-23	5	Light olive gray foram nanno ooze.
BC05	39°34.0'	142°59.5'	306	40/20-23	-	Did not trigger.
BC05A	39°33.8'	142°59.9'	295	40/20-23	26	Greenish gray muddy bryozoal sand.

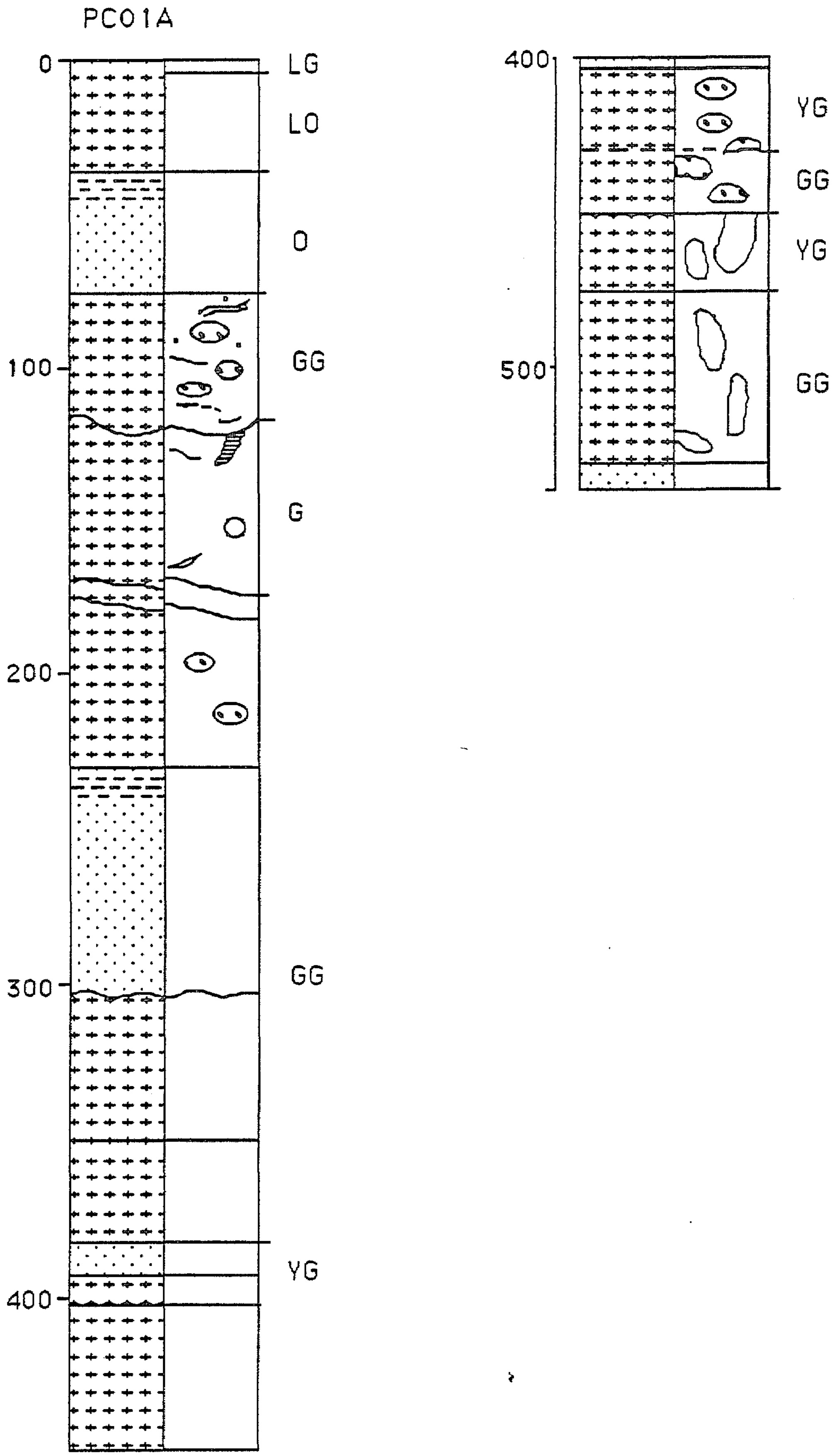
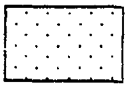
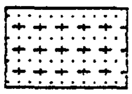
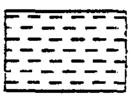
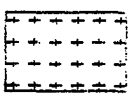
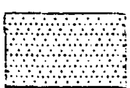


Figure 28. Lithological log of piston core PC01A from a depth of 2200 m south of Tasmania. Location in Figure 26.

KEY

Lithology

	Bioclastic sand
	Intermixed bioclastic sand and mud/ooze
	Calcareous silty mud
	Foram nanno ooze
	Silty foram ooze

Colours

g	Green
GY	Greenish yellow
Y	Yellow
G	Grey
O	Olive
GG	Greenish grey
YG	Yellow grey
L	Light
/	Mottles

Figure 29. Lithological key to all core logs.

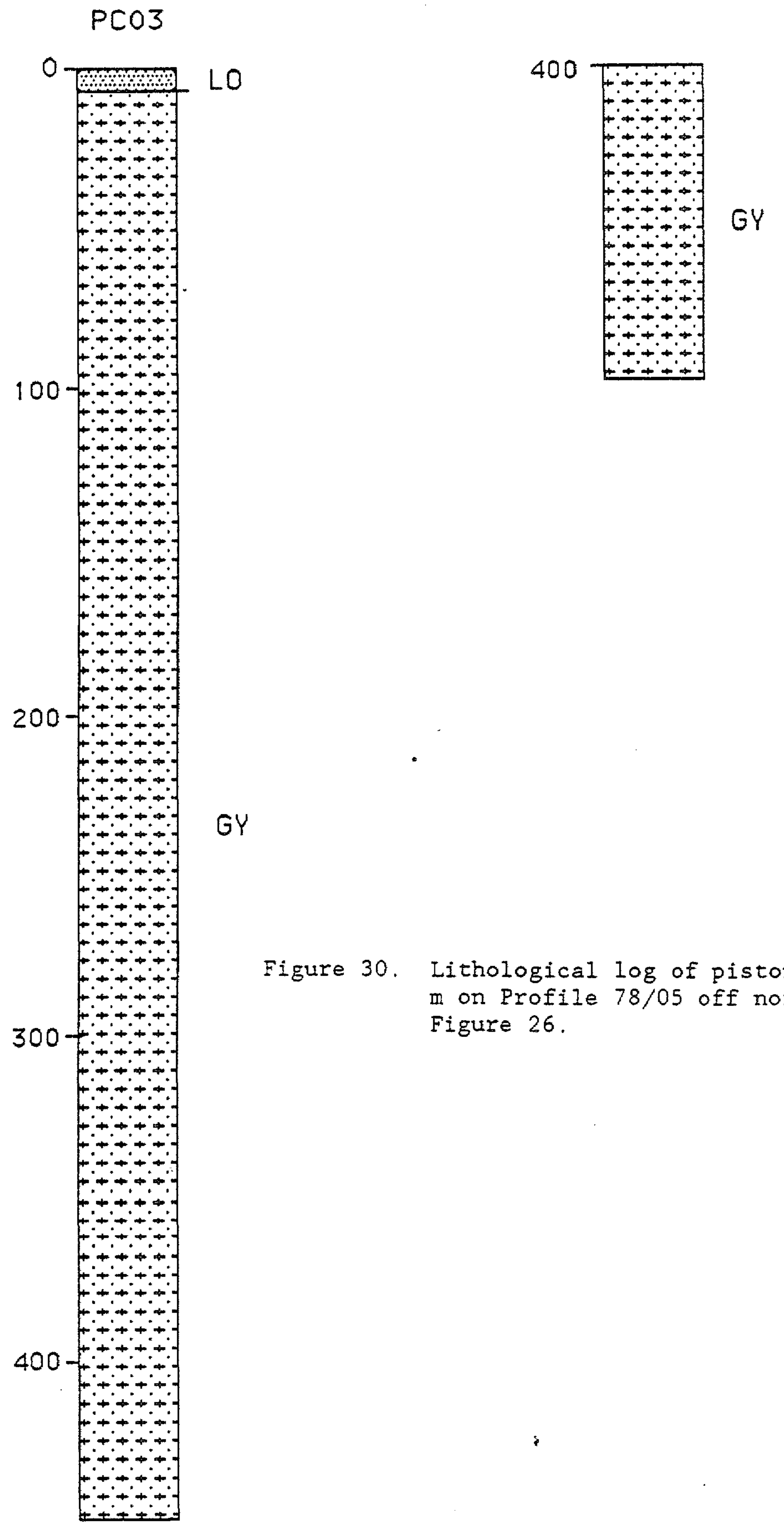


Figure 30. Lithological log of piston core PC03, from a depth of 12[illegible] m on Profile 78/05 off northwestern Tasmania. Location in Figure 26.

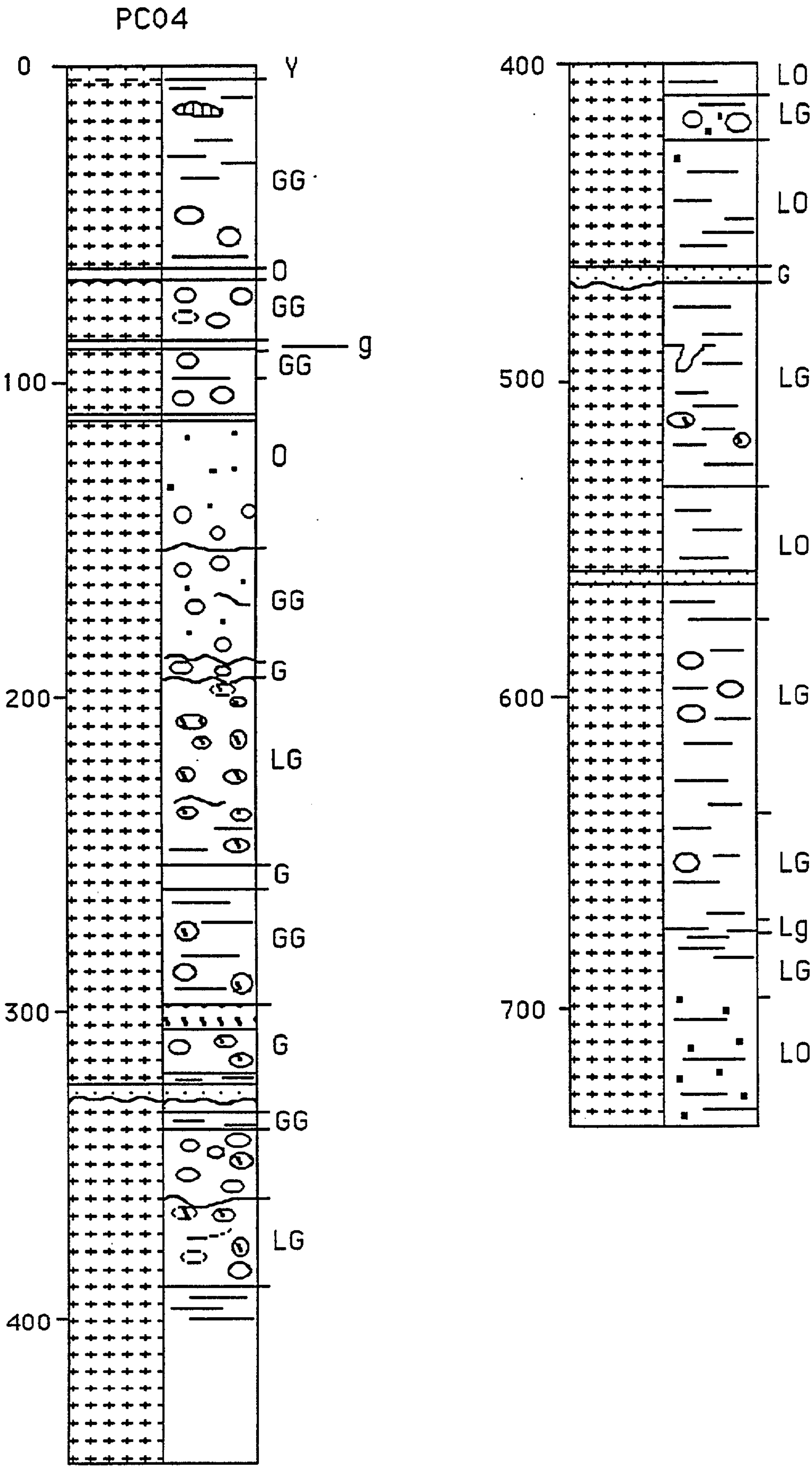


Figure 31. Lithological log of piston core PC04 from a depth of 3560 m on Profile 78/05 off northwestern Tasmania. Location in Figure 26.

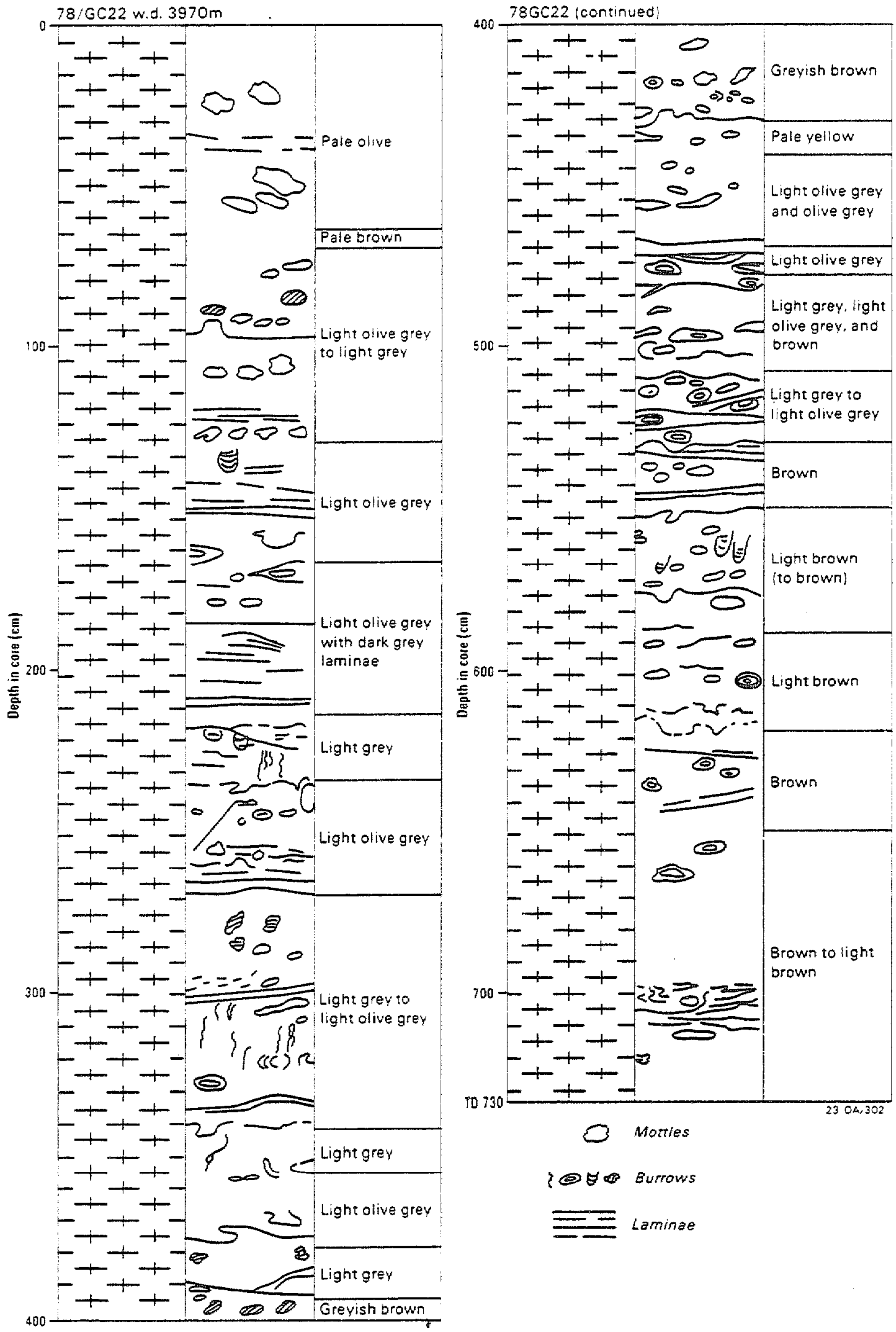


Figure 32. Lithological log of gravity core GC22 from a depth of 3968 m on Profile 78/05 off northwestern Tasmania. Location in Figure 26. Alternation of olive/gray sequences and brown sequences suggests alternation of reducing and oxidizing conditions caused by fluctuations in top of Antarctic Bottom Water.

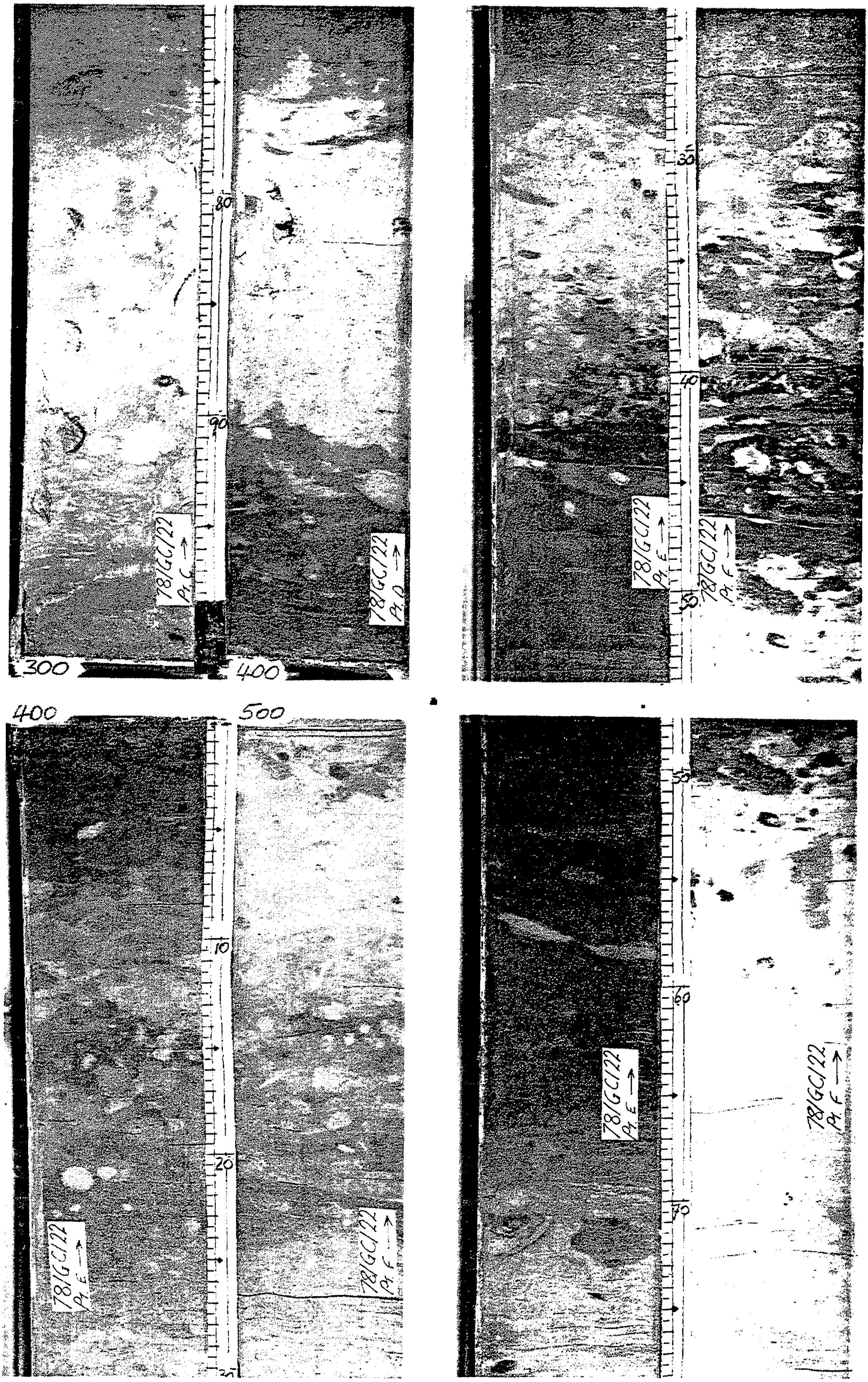


Figure 33. Photographs of gravity core GC22; log shown in Figure 32.

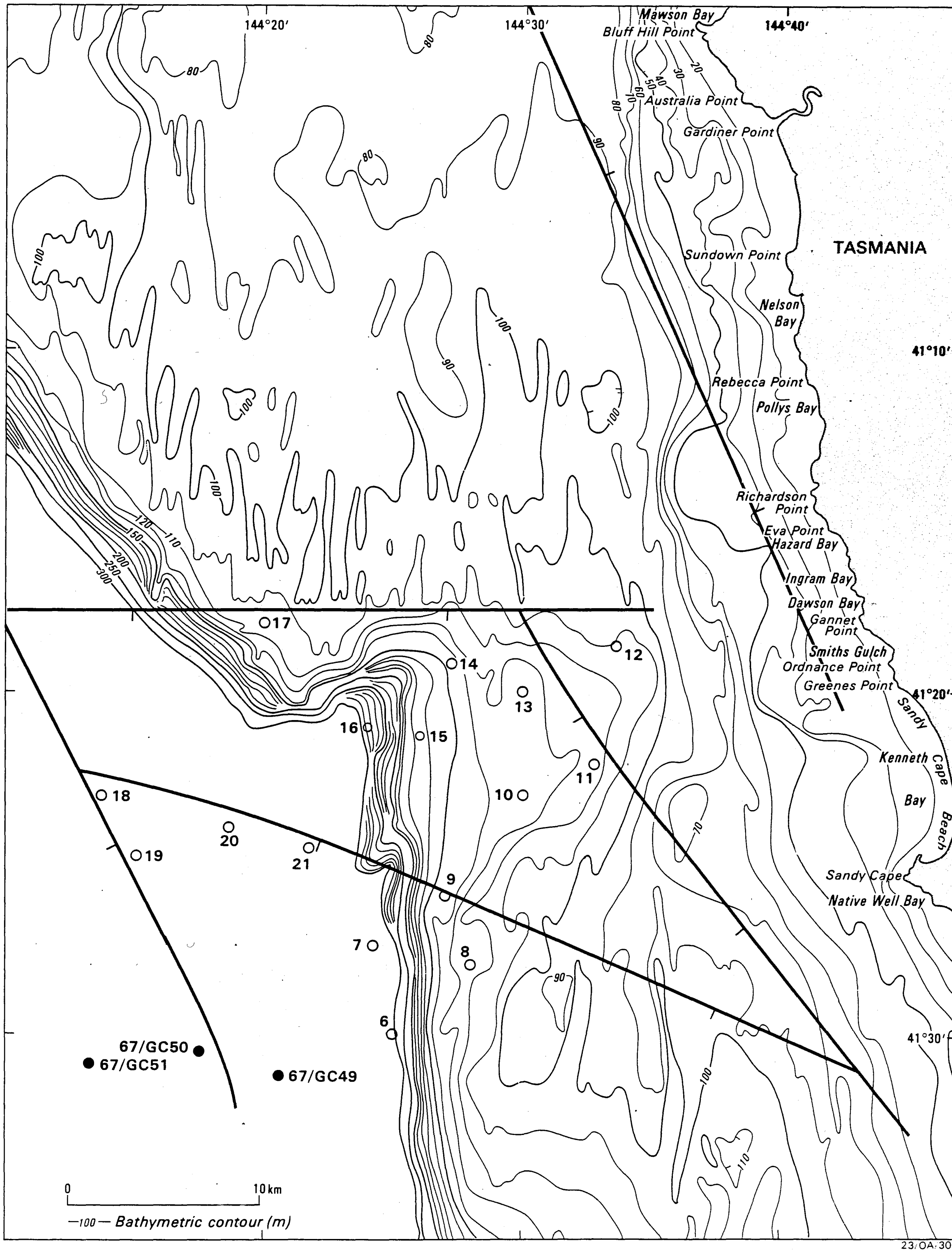


Figure 34. Map showing location of samples taken in the Sandy Cape sub-basin.

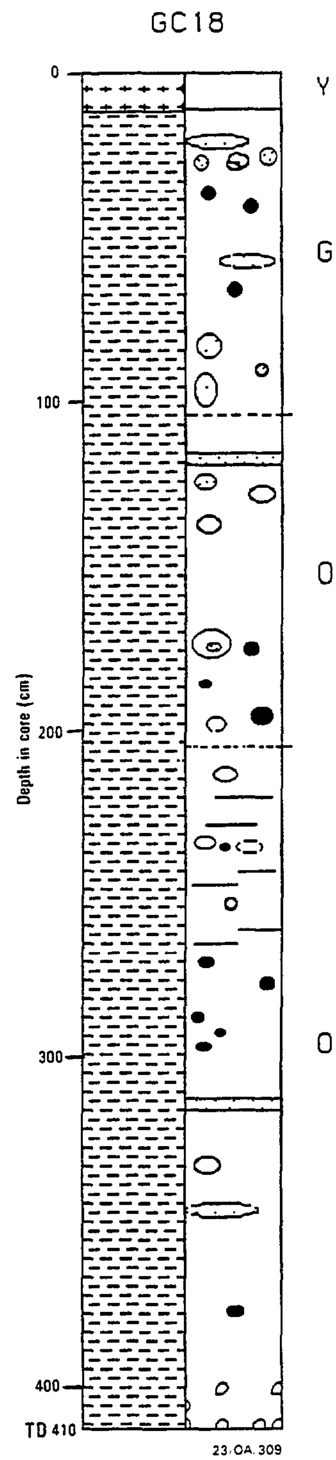


Figure 35. Lithological log of gravity core GC18 taken from the upper slope in the Sandy Cape Sub-basin from a depth of 814 m.

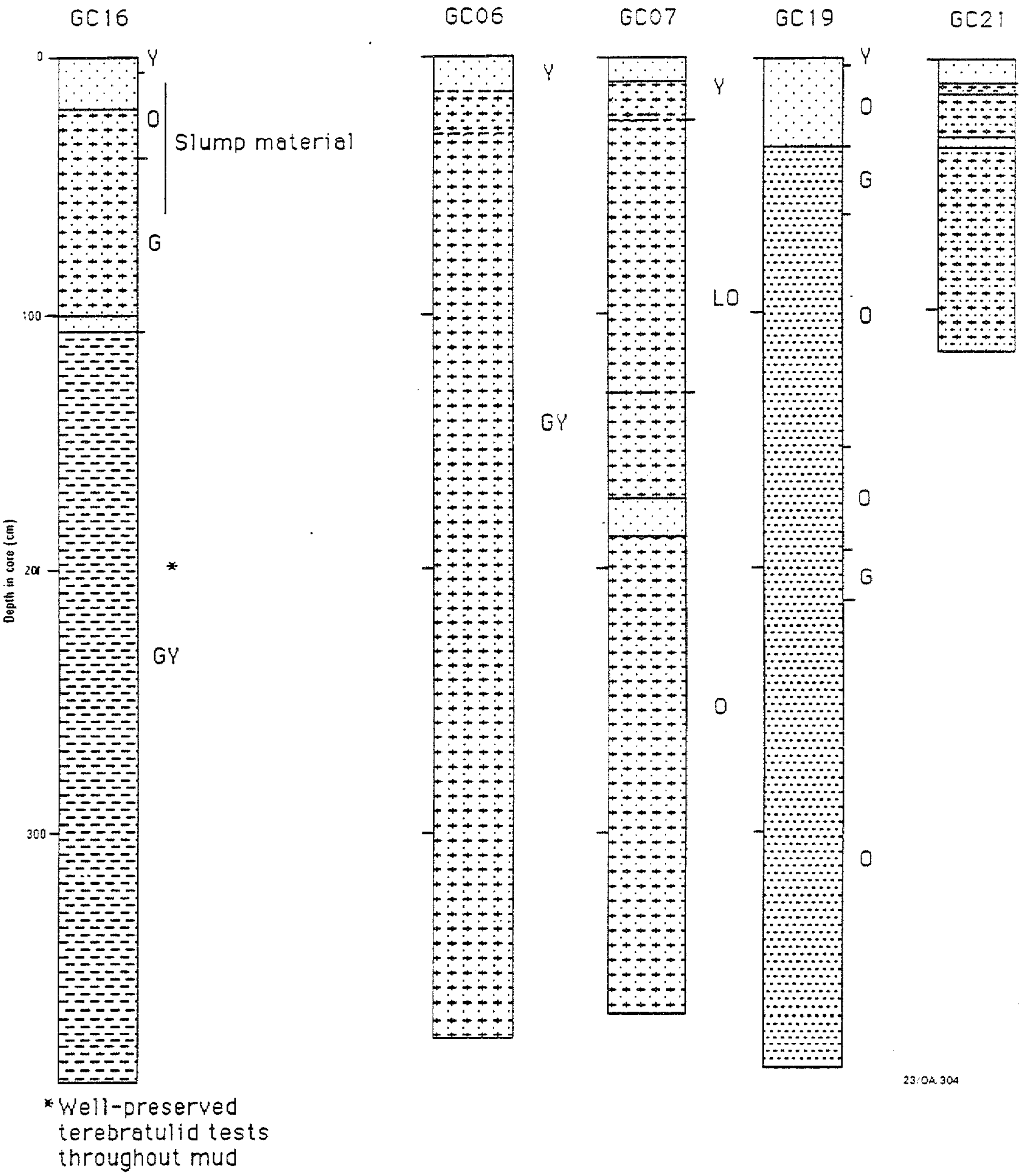


Figure 36. Lithological logs of gravity cores taken in Sandy Cape Sub-basin.

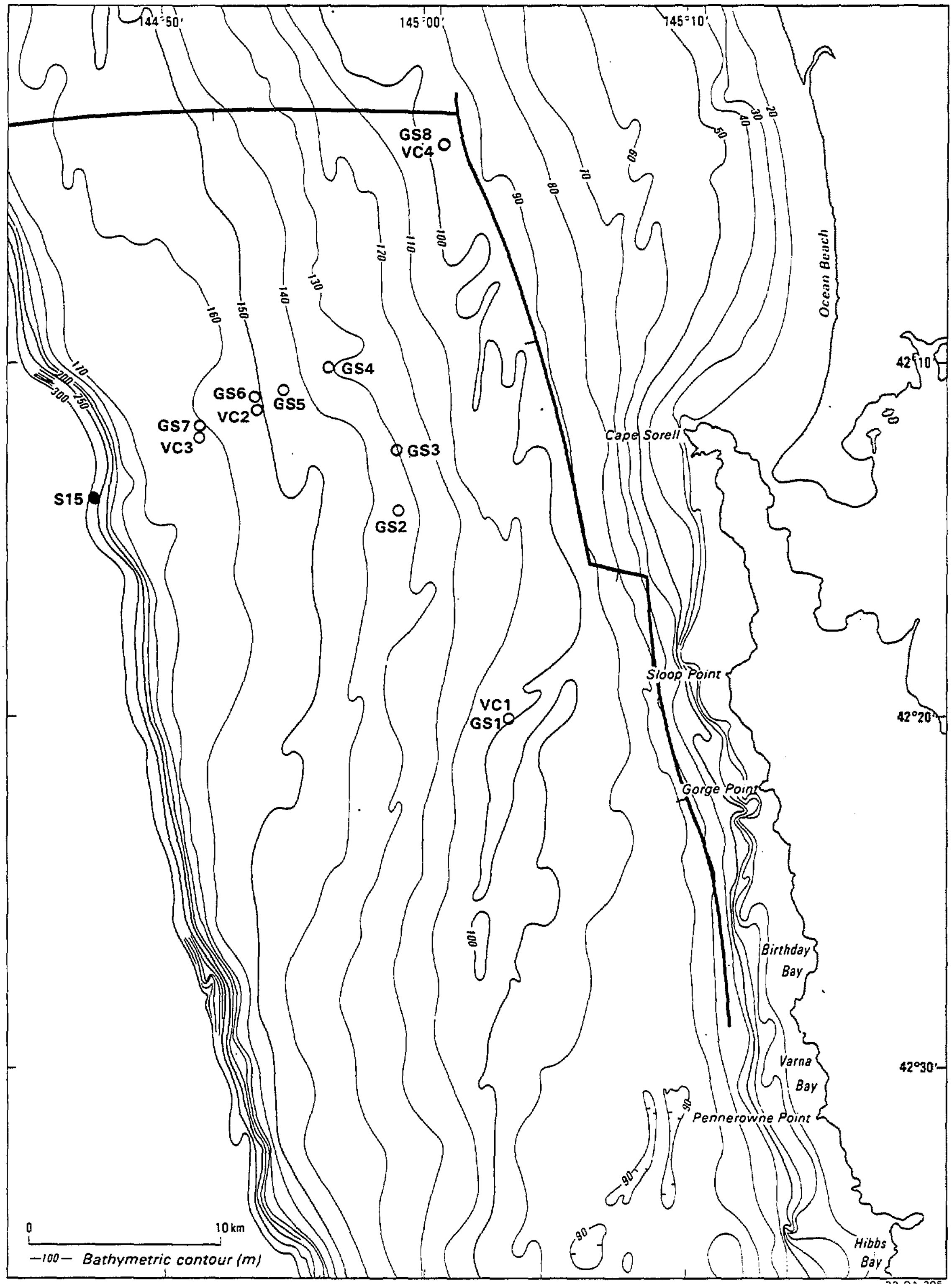


Figure 37. Map showing location of samples in the Strahan Sub-basin.

Core samples

Coring was attempted at 38 stations: along regional seismic lines (Fig. 26) in the Strahan Sub-basin (Fig. 32) and the Sandy Cape Sub-basin (Fig. 34), and on the upper continental slope west of King Island (Fig. 26). Results are summarized in Tables 6, 7 and 9. They were taken for a variety of purposes, using whatever equipment was appropriate:

1. To sample older sequences identified on seismic profiles

2. To provide material for thermal conductivity measurements needed for the heatflow profile (78/05)

3. To provide material for gas sampling, especially in the Strahan and Sandy Cape sub-basins

4. To provide material for Quaternary magnetostratigraphy (PC02)

5. To provide material for radiochemical studies west of King Island (BC1-5).

Equipment used included gravity and piston corers producing cores 90 mm in diameter, a stainless steel piston corer producing cores 50 mm in diameter, a 3.5 m vibrocorer, a medium sized box corer, and a van Veen grab. Maximum core recovery was 7.4 m for the large piston corer, 7.3 m for the large gravity corer, 6.3 m for the small piston corer and 26 cm for the box corer. Cores were split aboard the ship for initial lithological description, nannofossil studies (Appendix 4) and gas sampling.

Cores were divided into one metre lengths using a hand saw, and then split using a frame mounted power saw. Cores were labelled with a cruise number (78), a site number (eg. GC02), a core interval (e.g. 100-134 cm) and a core letter designating the sequence of the sections. In addition red tape was secured around the lower half of each section. Cores were stored in their liners in plastic bags at a temperature of 4 degrees C.

Cored material was described by lithological unit, following the sediment classification of the DSDP (after JOIDES 1974), and colour variations were matched against a Munsell colour chart. The positions of nannofossil, gas and smear slide samples were recorded on the log. Representative cores are illustrated in Figures 28, 30, 31, 32, 35 and 36, and a lithological key forms Figure 29. Only cores PC02, GC03, GC08 and GC13 contained nannofossils older than Plio-Pleistocene (Table 6). Early Eocene palynomorphs were recovered from GC05 (Appendix 6).

Core PC01A, from a water depth of 2200 m off southern Tasmania, consists of Quaternary light gray, greenish gray and olive gray pelagic foram nanno ooze and nanno foram ooze, with interbeds of graded, similarly coloured foram sand (Fig. 28) containing some bryozoan and echinoid fragments. The foram sand normally has an erosional base and is believed to be turbidite. Some beds are extensively burrowed and mottled, and little bedding is preserved.

Core PC03, from a water depth of 1265 m off northwest Tasmania, consists of hemipelagic, dusky yellow green, Quaternary, silty foram nanno ooze with some shelly fragments (some in defined layers), overlain by a veneer of light olive gray muddy foram sand (Fig. 30), which probably represents reworking by currents.

Core PC04, from a water depth of 3560 m off northwest Tasmania, consists almost entirely of Quaternary pelagic gray, greenish gray and olive gray foram nanno ooze, with three thin dark gray, pyritic, foram sand turbidite beds (Fig. 31). Mottles, pyritic filled burrows, and pyrite blebs are very common, but bioturbation has been less intense than in the shallower water cores PC01A and PC03, and bedding laminae are moderately well preserved in some beds. Green clayey material forms thin horizons at 64, 89, 329, 673 and 679 cm, and this may represent altered glass, like that seen in other cores in the region (Exon, Lee et al., 1987).

Core GC22, from a water depth of 3968 m off northwest Tasmania, consists of Quaternary foram nanno ooze, with gray, olive gray and olive tones interbedded with brown tones (Fig. 32). The sequence is dominantly gray and olive to 395 cm, mixed gray, olive gray and brown to 530 cm, and light brown and brown below 530 cm. It is believed that this change, from brownish oxidized sediments to grayish reduced sediments, is most likely caused by a deepening of the top of the oxygen-rich Antarctic Bottom Water (ABW) with time. Within the bottom water conditions are oxidizing, whereas above it conditions are reducing. The top of the ABW generally corresponds to the lysocline (where calcite starts to dissolve) in the South Pacific (Seibold & Berger, 1982). The sediments in core GC22 are extensively bioturbated, with four types of burrows as well as general mottling, but bedding laminations are preserved in places (Fig. 33).

In the Sandy Cape Sub-basin off northwest Tasmania, sixteen core stations were occupied in water depths of 111-910 m (Fig. 34; Table 7). At many stations coarse bryozoal shell hash limited penetration to 20 cm or less, but six cores of more than 350 cm length were obtained (Figs. 35 & 36). Miocene carbonates were present at the base of cores GC08, GC09 and GC13, indicating how shallow is the Quaternary cover. Core GC 18, from a water depth of 814 m, is a typical deepwater, Quaternary hemipelagic core (Fig. 35). It consists almost entirely of olive gray and olive, calcareous silty mud with abundant foraminifera and calcareous nannoplankton, overlain by 15 cm of yellowish gray foram nanno ooze. There is only slight evidence of bedding laminations because of extensive bioturbation evidenced by open and closed burrows and colour mottling.

A series of Quaternary cores in the Sandy Cape Sub-basin are illustrated in Figure 36. The shallowest long core (GC16) came from 293 m, and the deepest (GC19) from 910 m. In all these cores there is a thin layer of yellowish, bioclastic foram-rich sand at the surface, with greenish, grayish or olive sediment beneath. In all except the deepest core (GC19), the material underlying the surface sand is intermixed bioclastic sand and mud or hemipelagic ooze. Calcareous silty mud is at depth in GC16, and beneath the surface sand in GC19. Thin bioclastic sands in several cores are probably turbidites.

All the Sandy Cape Sub-basin cores appear to be extensively bioturbated, with mottling and burrowing very evident in the finer grained material. Bryozoan and other shell debris is a major component of the sandy sediment, which contains almost no coarse terrigenous material.

The yellowish green, calcareous silty mud below 103 cm in core GC16 is most unusual in that, firstly, it is hardly mottled and, secondly, it contains a monospecific macrofauna of articulated chitinous terebratulids. Calcareous fossils such as foraminifera are generally absent. Although pyrite is not readily apparent, it is believed that reducing conditions in the mud inhibited bioturbation and dissolved any calcareous organisms, leaving the in situ terebratulids intact. Above 103 cm in this core, the olive gray bioclastic sand contains bivalves, pteropods, foraminifera and algal lumps, and is heavily bioturbated, signalling a major change in depositional environment (mass transport of sand?).

Box cores were taken at four stations in water depths of 295-1642 m west of King Island (Table 8). They returned up to 26 cm of sediment, largely foram nanno ooze, but with muddy bryozoal sand at the shallowest station.

Miocene geology

Lithified brown limestone of Miocene age occurs extensively in the Sorell Basin, where it commonly crops out on the sea floor or lies beneath a very thin cover of winnowed bryozoal hash (see also Jones & Holdgate, 1980). The succession, which has a thickness of 285 m at Clam No. 1 well and 318 m at Cape Sorell No. 1, has been correlated with the Port Campbell Limestone of the Miocene-Oligocene Heytesbury Group in the Otway Basin (Jones & Holdgate, 1980; Baillie, 1986).

Grab sampling and echo-sounder profiling carried out during the present cruise in the Strahan and Sandy Cape Sub-basins have confirmed that the unit forms most of the sea floor of the continental shelf in those areas and is terminated sharply at the shelf edge.

Echo-sounder profiles indicate the common presence of irregularities on the surface of the limestone (Fig. 38); relief of the irregularities is of the order of 1-5 m. These irregularities are interpreted as being palaeokarst, which developed during colder climatic phases of the Pleistocene when the sea was up to 150 m below its present level. Differential erosion of the limestone was also noted by Jones & Holdgate (1980) who stated that Late Miocene and Pleistocene erosion of the gently-dipping Miocene strata resulted in the formation of "scarp and dip-slope topography".

The seafloor of the Strahan Sub-basin, off the Ocean Beach/Trial Harbour region, deepens gently and regularly in a westerly direction to a water depth of approximately 150 m. Figure 39 shows onshore/offshore topographic profiles constructed along E-W lines through Queenstown and Strahan.

Onshore, a prominent seaward-sloping surface in this part of western Tasmania is known as the Henty Surface which, although having a complicated Cainozoic history, lies in part on Eocene sediments and hence is predominantly of post-Eocene age (Ballie & Corbett, 1985).

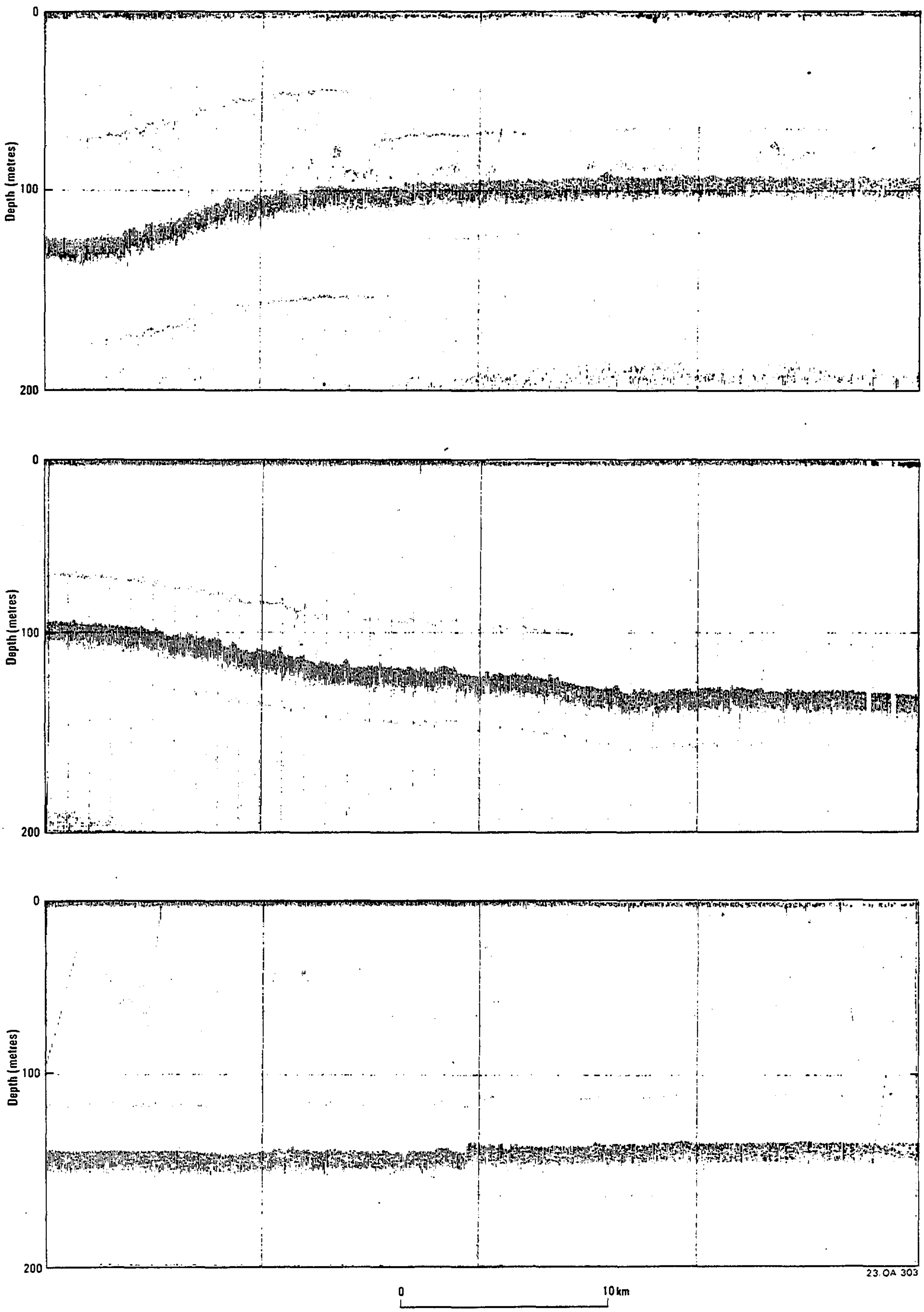


Figure 38. Echosounder profiles from the Strahan Sub-basin showing the development of karst features in outcropping Miocene limestone.

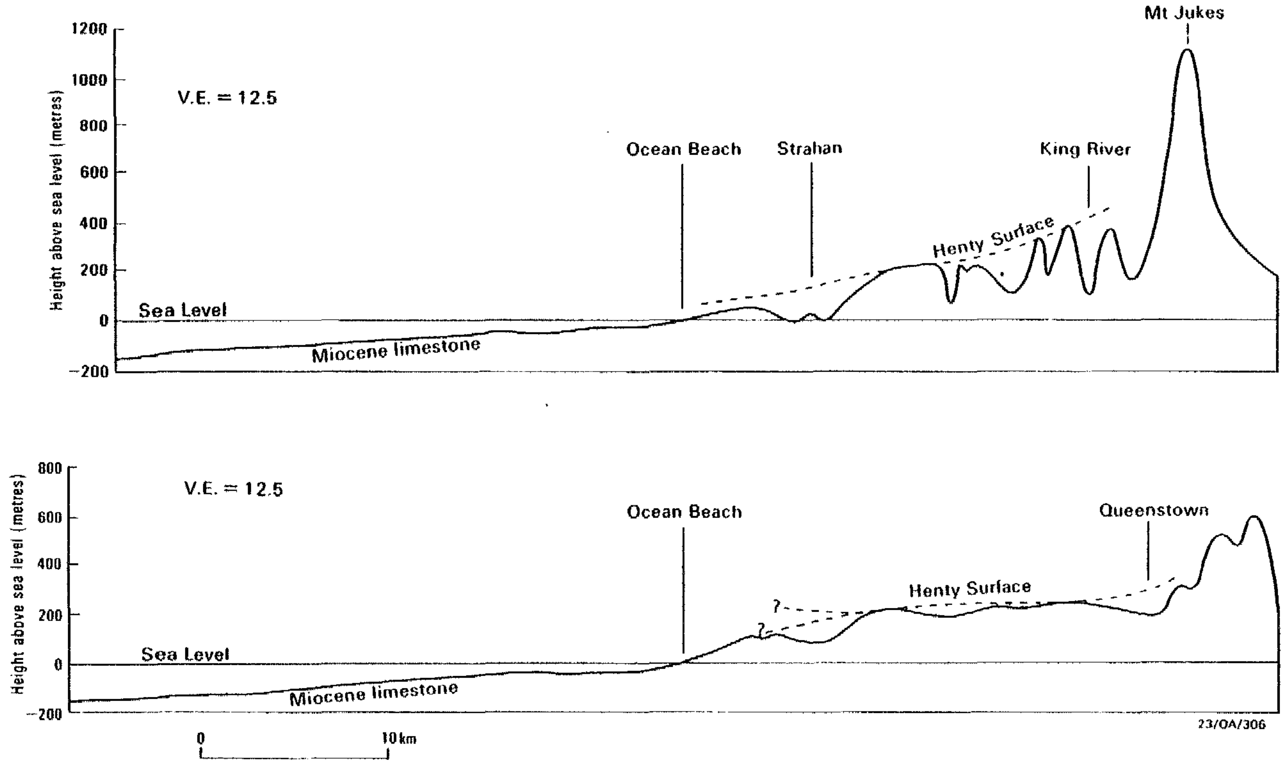


Figure 39. Onshore/offshore east-west topographic profiles through Queenstown and Strahan, showing the Henty Surface onshore and the seabed (top of Miocene limestone) offshore.

Figure 39 clearly depicts this surface occurring below heights of 400 m, and possibly continuing offshore into the region consisting of Miocene limestone. However, as the top of the limestone apparently truncates an imaginary seaward extension of the surface (Fig. 39) it is more likely that the limestone sequence is younger than the Henty Surface. As no marine fossils have been found on the surface (Banks et al., 1977), it is probable that the present limits of the limestone on the continental shelf represent the limit of the Miocene transgression. An alternative is that the Henty Surface was cut at the peak of the transgression and was essentially an erosional rather than depositional surface; in that case any veneer of Miocene marine sediments would have been removed by later erosion of the upwarped Henty Surface.

CALCAREOUS NANNOFOSSILS FROM WEST TASMANIAN MARGIN, RIG SEISMIC CRUISE 78

by Samir Shafik

Introduction

The global distribution of Cainozoic calcareous nannofossils, based on already published work (e.g. Perch-Nielsen, 1985), indicates a decrease in their diversity polewards. Most of the index taxa used in subdividing sections at mid to low latitudes are either absent or extremely rare at higher latitudes. The attendant result is that biostratigraphic subdivisions at high latitudes are usually much broader. Plate tectonic studies of the Australian-Antarctica region suggest that the west Tasmanian margin lay at high latitudes during the Late Cainozoic, so broad biostragraphic subdivisions are to be expected.

Calcareous nannofossil assemblages

Dredge samples

Dredging at ten stations (Fig. 26) resulted in the recovery of mostly soft oozes in all the pipe dredges, the chain bag dredge often being without sediments. Results are summarized in Table 5.

Quaternary nannofossils were identified from the oozes at Stations 78DR02, 03, 04, 05, 06, 07, 09 and 10. Preservation is generally moderate, and reworking from essentially Mid to Late Tertiary sources did not present a problem. The Quaternary assemblages at these stations are similar, being essentially composed of **Coccolithus pelagicus**, **Calcidiscus leptoporus**, **Helicosphaera kamptneri/wallichi** and small Gephyrocapsa spp.. **Gephyrocapsa caribbeanica** was encountered in 78DR02, 78DR03, 78DR09 and 78DR10, whereas **G. oceanica** was identified in 78DR06A and 78DR09. The determination of **Emiliania huxleyi** in most of the assemblages must wait onshore examination, using a scanning electron microscope.

Samples 78DR5B, 78DR6B and 78DR9B1 contained no nannofossils, and their age could not be determined.

Gravity cores

Recovered sediments bearing calcareous nannofossils are early Miocene, mid Miocene, Plio-Pleistocene or Quaternary in age. Sediments barren of calcareous nannofossils were recovered in the lower part of 78GC05. Stations are located in Figure 26, and core results are summarized in Tables 6 and 7.

Plio-Pleistocene to Holocene sections are represented by several gravity cores, namely 78GC01A, 78GC04B, 78GC04B, 78GC05, 78GC06, 78GC16, 78GC18, 78GC19, 78GC20, 788GC20A, 78GC21 and 78GC22.

The poorly preserved calcareous nannofossils in the core catcher of 78GC08 include **Calcidiscus leptoporus**, **C. macintyrei**, **Coccolithus pelagicus**, **Reticulofenestra antarctica**, **R. gelida**, **Helicosphaera kamptneri**, **Sphenolithus abies**, **S. moriformis** and **Pontosphaera** sp. The absence of discoasters suggests cold surface waters, and makes precise biostratigraphic assignment difficult. The assemblage is Late Cainozoic in age, probably mid Miocene; **Sphenolithus moriformis** is reworked.

The index species **Sphenolithus heteromorphus**, suggesting early to mid Miocene age, was encountered in several assemblages. Several of these occurrences are due to reworking into Quaternary sediments, e.g. 78GC18 (160-161 cm). **In situ** occurrences of **S. heteromorphus** were recorded in the assemblages recovered from 78GC03 and 78GC13. The assemblages of 78GC03 included **Cyclicargolithus floridanus**, **C. abisectus**, **Coccolithus pelagicus**, **Braarudosphaera bigelowii**, **Pontosphaera multipora**, **Helicosphaera obliqua**, **H. euphratis**, **H.** sp., **Coronocyclus nitescens**, **Discoaster deflandrei** and one specimen of **Discoaster druggii**.

The assemblages of 78GC13 are similar to those of 78DR03. They include **Braarudospaera bigelowii**, **Micrantholithus pinguis**, **Sphenolithus moriformis**, **Cyclicargolithus floridanus**, **Discoaster deflandrei**, **Helicosphaera kamptneri**, **H. euphratis**, **H. obliqua**, **Calcidiscus leptoporus** and **Reticulofenestra** sp., in addition to **Sphenolithus heteromorphus**.

The absence of the key species Helicosphaera ampliaperta from the assemblages of both 78GC03 and 78GC13 suggests an early rather than a mid Miocene age.

Piston cores

The piston cores are located in Figure 26, and several are illustrated (Figs. 28, 30, 31). Except for 78PC02, the piston cores recovered only Quaternary sediments. This is indicated by the presence of **Gephyrocapsa oceanica** and related forms in 78PC01, 78PC03 and 78PC04. Other taxa found in these cores included **Calcidiscus leptoporus**, **Coccolithus pelagicus**, **Helicosphaera kamptneri** and several small species of **Gephyrocapsa**, including the unbarred **G. dorinicoides**. **Braarudosphaera bigelowii** and **Gephyrocapsa caribbeanica** were encountered in the assemblage in the core catcher of 78GC03.

The assemblage in the 78PC02 core catcher included **Calcidiscus macintyrei**, **C. leptoporus**, **Cyclicargolithus abisectus**, **C. floridanus**, **Discoaster loeblichii**, **D. intercalaris**, **D. variabilis**, **Helicosphaera kamptneri**, **?H. rhomba**, **Pontosphaera multipora**, **Reticulofenestra pseudoumbilica**, **Sphenolithus moriformis** and **S. abies**. A mid to late Miocene age is suggested.

Discussion

These results add little to the results from the samples taken from the west Tasmanian margin by Rig Seismic in 1987 (Shafik, 1987). **Pseudoemiliania lacunosa** and **Helicosphaera sellii** are absent from most of the Quaternary sections sampled. The highest occurrences of these taxa have been used to subdivide the Pleistocene (Gartner, 1977). Similarly the highest occurrences of several slender discoasters, such as **Discoaster pentaradiatus** and D. **broweri** have been used to subdivide the later part of the Pliocene (e.g. Martini, 1971; Bukry, 1973). These key taxa were not encountered in the Plio-Pleistocene sections sampled. Therefore, fine biostratigraphic resolution could not be achieved.

The age-diagnostic species **Sphenolithus heteromorphus** evidently has a wide geographic distribution in the southeast Australian region. Besides its presence in two localities (Stations 78GC3 and 78GC13) along the west Tasmanian margin, I have noted its present in several sections in Victoria (e.g. Sorrento Bore, unpublished data) and in the offshore Otway Basin. In none of these occurrences does S. **heteromorphus** occur in association with the equally age-diagnostic **Helicosphaera ampliaperta**, whose earliest occurrence has been used to indicate the lower/middle Miocene boundary (see, e.g. Martini, 1971). It is difficult to determine whether the absence of H. **ampliaperta** is true absence or just an ecological exclusion. In the absence of other independent evidence (e.g. based of associated foraminiferids), the early Miocene age for these occurrences is adopted.

HYDROCARBONS IN SEAFLOOR SEDIMENTS OFF WEST TASMANIA

Introduction

Hydrocarbon gases (C1-C4) and heavier volatile hydrocarbons (C5-C7) are common in young marine sediments. They have two possible origins - biogenic or thermogenic - and in both cases methane is invariably dominant. Biogenic gas is formed by the action of microbes on shallowly buried sediments, while thermogenic gas is produced at depths of a kilometre or more by the action of heat on buried organic matter.

This is the third study of hydrocarbon concentrations in cores taken in young sediments in the Sorell Basin off west Tasmania. The first results came from a 1985 cruise of R.V. Sonne, and were reported by Hinz et al. (1985, 1986). Fifty-five samples from 27 cores were degassed aboard ship in a vacuum/acid apparatus, a technique which strips porewater and adsorbed gas. Gas yield and molecular composition were measured with a gas chromatograph. Thermogenic gas proved to be widespread and was quite wet (C2-C4/C1-C4 x 100% generally exceeded 5%). The higher gas values, of up to 1363 ppb (by weight) came from the northern west Tasmanian margin, on the upper continental slope. The sampling was concentrated in the deepwater parts of the King Island and Strahan (then called Cape Sorell) Sub-basins, and indicated the presence of mature petroleum source rocks at depth.

The second study of hydrocarbon gases in cores was carried out on a 1987 cruise of R.V. Rig Seismic by D.M. McKirdy and D.T. Heggie (in Exon, Lee & others, 1987; Heggie at al., 1988). The degassing technique was less rigorous than that applied on the Sonne cruise, and released gases in the sediment porewater but not those adsorbed to minerals. Again gas yield and molecular composition were measured aboard ship, with a gas chromatograph. Results were provided in microlitres/litre wet sediment, rather than in ppb by weight. Thus, the results were not directly comparable to the earlier ones. Twenty-three samples from eleven cores on the continental slope off northwest Tasmania were analysed, and confirmed that there was thermogenic gas in the Strahan Sub-basin and indicated that there was thermogenic gas in the Sandy Cape Sub-basin.

On the present cruise the same degassing technique was used aboard ship by P. Davis as that described by McKirdy and Heggie for the 1987 Rig Seismic cruise. However, the cans of gas were frozen aboard ship, and analysed by C. Tindall on the next cruise, up to a month after they were taken.

The intention had been to take most samples in shallow water cores, to see whether the thermogenic gas anomalies identified on the continental slope on the previous cruises could be traced onto the continental shelf. A vibrocorer was especially designed for this purpose, but the widespread presence of hard Miocene limestones right at the surface generally prevented penetration. Thus all cores were taken in water depths of more than 150 m, by other coring devices. Most samples came from depths of 100-700 cm in gravity and piston cores, but a number came from depths of less than 50 cm in short gravity cores and box cores. The sediments samples varied from carbonate sands to oozes (Tables 6, 7 and 8).

Recognition of Thermogenic Hydrocarbons

The compositional parameters used to distinguish light hydrocarbons of mainly thermogenic origin from solely biogenic gas were:

1)	C1/C2+C3	< 500	(Bernard & others, 1976)
2)	C2/C2:1	> 1	(Kvenvolden & others, 1981)
3)	C3/C3:1	> 3	(McKirdy & Heggie, in Exon, Lee & others, 1987)

Their effectiveness is based on the fact that contemporary bacterial activity in marine sediments produces mainly methane, resulting in very high C1/C2+C3 ratios (>1000), and minor but significant amounts of ethene (C2:1) and propene (C3:1) which are not components of thermogenic gas.

Two other parameters were used as maturity indicators:

4)	i-C4/n-C4	< 1	(Monnier & others, 1983; Alexander & others, 1983)
5)	i-C5/n-C5	< 4	(Hunt, 1984).

The values specified correspond to the principal phase of thermogenic hydrocarbon generation.

Results

The results of all hydrocarbon measurements are listed in Table 10, and the locations of all cores are shown in Figures 26, 34 and 37. Cores GC01 and GC04 came from the upper slope off southwestern Tasmania, and cores GC05, GC22 and PC04 all came from the lower slope off western Tasmania. Box cores BC2-4 came from the upper slope west of King Island. The largest group of cores, GC06-GC21, came from the upper slope and outer shelf in the Sandy Cape Sub-basin, and PC03 came from the upper slope in the King Island Sub-basin.

TABLE 10 : HYDROCARBONS IN SURFACE SEDIMENTS OFF WEST TASMANIA, BMR CRUISE 78

Core	Seismic line	Water depth (metres)	Depth in Core (cm)	C1	Total C1-C4	Total C1-C5	C6 & heavier	Wet gas (%)	C1 / C2+C3	C2 / C2:1	C3 / C3:1	i-C4 / n-C4	1-C5 / n-C5
				Micro-litres per litre wet sediments									
GC01	16/05	307	240-262	0.403	0.48	0.59	1.008	15.24	6.6	0.18	0.12	0.25	0.44
GC04B	16/05	803	325-335	2.623	2.88	2.91	0.397	8.79	11.56	1.05	2.10	0.31	0.65
GC04B	16/05	803	351-361	3.921	4.62	4.67	0.026	15.19	6.02	0.96	3.58	0.28	0.51
GC05	16/07	3530	16-26	0.184	0.20	0.28	0.461	7.14	13.01	1.06	2.92	-	0.17
GC06	-	325	357-367	6.641	7.44	7.54	0.332	10.8	9.12	1.39	3.06	0.26	0.27
GC06	-	325	337-347	7.353	8.15	8.27	0.071	9.84	10.11	1.50	3.16	0.26	0.21
GC07	-	516	315-325	10.740	10.84	10.84	0.037	0.89	124.19	1.05	2.47	0.31	0.62
GC07	-	516	345-355	25.432	26.12	26.18	0.118	2.62	41.96	0.88	2.27	0.33	0.43
GC15	-	159	C/CATCHER	0.537	0.6	0.68	0.366	10.99	9.04	1.93	1.84	1.15	0.13
GC16	-	293	10-20	2.022	2.61	2.79	0.527	22.58	3.89	0.84	1.89	0.24	0.19
GC16	-	293	30-40	2.351	2.77	2.83	0.102	15.20	6.29	0.65	1.93	0.25	0.24
GC18	-	814	350-360	4.575	5.4	5.51	0.040	15.25	6.13	1.51	4.05	0.26	0.24
GC19	-	910	344-354	17.990	18.18	18.26	3.255	1.04	102.66	1.65	2.21	0.28	0.25
GC19	-	910	374-384	13.177	13.39	13.46	1.515	1.61	65.78	1.98	4.17	0.3	0.07
GC20	-	641	0-20	2.387	2.54	2.69	2.249	17.86	0.35	0.73	0.35	0.17	2.387
GC21	-	436	60-70	1.164	1.31	1.42	0.176	11.17	9.01	0.57	0.52	0.27	0.08
GC21	-	436	80-90	0.754	0.83	0.86	0.147	9.05	11.36	0.91	0.35	0.31	0.16
GC22	78/05	3970	680-690	0.994	1.0	1.0	-	0.73	196.8	0.79	0.2	0.11	-
GC22	78/05	3970	707-717	0.755	0.76	0.76	-	0.78	127.00	0.28	0.09	-	-
PC03	78/05	1265	10-20	5.165	5.56	5.70	1.706	7.06	14.61	1.02	2.83	0.26	0.17
PC03	78/05	1265	30-40	15.442	16.28	16.43	0.478	5.14	20.53	1.12	3.34	0.26	0.34
PC04	78/05	3560	700-710	3.58	3.79	3.79	1.167	4.17	26.1	0.1	0.15	0.28	1.42
PC04	78/05	3560	719-729	3.057	3.21	3.24	10.623	4.89	22.57	0.09	0.24	0.3	0.73
BC2	40/20-23	1642	-	0.831	0.89	0.98	0.051	6.20	18.11	0.14	0.44	0.35	0.03
BC3	40/20-23	1303		0.571	0.64	0.71	0.041	10.22	10.74	0.15	0.44	0.33	0.10
BC4	40/20-23	1026		0.477	0.58	0.67	0.302	17.31	5.56	0.14	0.35	0.36	0.14

GC = gravity core, PC = piston core, BC = box core, Wet gas % $= \frac{C2\text{-}C4}{C1\text{-}C4} \times 100$

TABLE 11. HYRDOCARBONS IN SURFACE SEDIMENTS, SANDY CAPE SUB-BASIN

Core	Depth in core	Water depth (m)	Total hydrocarbons microlitres/litre	C1	Total C1-C4	Wet gas (%)	Hydrocarbon anomalies
67/GC51	37- 57	1557	1.182	0.60	0.63	3.6	?
	77- 97		3.820	1.97	2.02	2.6	?
67GC50A	76- 96	1081	2.094	1.07	1.11	3.4	?
	116-136		1.242	0.59	0.66	10.3	?
78/GC19	344-354	910	21.52	17.99	21.52	1.0	Yes
	374-384		14.98	13.17	14.98	1.6	Yes
67/GC49	174-194	838	5.810	3.03	3.08	1.5	Yes
	224-244		0.997	0.49	0.53	6.5	?
	264-284		1.668	0.84	0.88	4.6	?
78/GC18	350-360	814	5.55	4.57	5.40	15.3	Yes
78/GC07	315-325	516	10.88	10.74	10.84	0.9	Yes
	345-355		26.30	25.43	26.12	2.6	Yes
78/GC06	337-347	325	8.34	7.35	8.15	9.8	Yes
	357-367		7.87	6.64	7.44	10.8	Yes
78/GC16	10- 20	293	3.32	2.02	2.61	22.6	Little penetration
	30- 40	293	2.93	2.35	2.77	15.2	Little penetration
78/GC15	c/c	159	1.05	0.54	0.60	11.0	Little penetration

The results show that gas was abundant in many upper slope and outer shelf cores, but was present only in trace amounts in two of the three lower slope cores, and in the box cores (which probably did not penetrate deeply enough to be satisfactory tests). The parameters for recognition of thermogenic hydrocarbons suggest that there were anomalies in GC04B and possibly GC05 taken off southwest Tasmania, and PC03 taken in the King Island Sub-basin (Fig. 26). The maturity indicators (i-C4/n-C4 & i-C5/n-C5) suggest that thermogenic hydrocarbons in these cores came from mature hydrocarbon sources. The data also indicate that a number of cores from the Sandy Cape Sub-basin, GC06, GC07, GC18 and GC19, from water depths of 325 m to 910 m (Fig. 34), also contain anomalous concentrations of thermogenic hydrocarbons derived from mature sources. Half the sub-basin cores examined were anomalous, in fact all those where penetration of the surface sediments exceeded 100 cm. These results indicate that the Sandy Cape Sub-basin is potentially prospective for hydrocarbons in the sense that it contains mature source rocks which are generating (or have generated) hydrocarbons.

The anomalous samples contain 2.6-25 microlitre/litre C1, and 2.9-26 microlitre/litre C1-C5. Wet gas percentages exceed 5% in many samples, even in some which do not appear anomalous otherwise, and the maximum of 22% is very high indeed. Values of C6 and heavier volatile hydrocarbons were generally less than 1 microlitre/litre, but anomalous values of 1-10 microlitres/litre occur in five cores in a variety of geological settings and water depths. It is possible that these represent thermogenic hydrocarbons which have had long residence times in the surface sediments and have been biodegraded.

Summary of west Tasmanian results

All three reconnaissance studies (*Sonne* 1985; *Rig Seismic* 1987 & 1988) have shown that thermogenic hydrocarbons are being generated in the deep basins off west Tasmania. Work has been concentrated largely in the Strahan and Sandy Cape Sub-basins. For results from the Strahan Sub-basin, which was not examined in the present study, see Hinz et al. (1985, 1986) and Exon & Willcox (1987).

The results in the Sandy Cape Sub-basin, from three 1987 cores (BMR Cruise 67) and seven 1988 cores (BMR Cruise 78), are summarized in Table 11, listed by water depth. They show that total hydrocarbon values are 1-26 microlitres/litre and exceed 5 microlitres/litre in eight of 17 samples. Wet gas makes up 1-22% of total gas, and exceeds 5% in eight of 17 samples (not entirely the same 8 that had high total hydrocarbon values).

On the basis of all the results so far, we conclude that thermogenic hydrocarbons are being generated from mature source rocks in the three main sub-basins of the Sorell Basin - King Island, Sandy Cape and Strahan- and elsewhere. This is clearly a positive factor in the assessment of the petroleum potential of the Sorell Basin.

WEST TASMANIAN HEATFLOW SURVEY

Introduction

The heatflow survey in the west Tasmanian cruise was aiming to examine the present-day heatflow distribution along this complex rifted margin and to carry out a regional geohistory analysis. One heatflow transect (BMR 78/05) was carried out in an E-W direction across the west Tasmanian margin from south of the King Island Sub-basin to the abyssal plain (Fig. 26). The heatflow results of this cruise have been combined with previous heatflow data (the estimated heatflow value from Cape Sorell well and the measured heatflow values from BMR cruise 67) to discuss the regional geothermal structure.

Thermal Gradient Measurements

Thermal gradient measurements were attempted at ten stations (Fig. 26) along the multichannel seismic line BMR 78/05, using the Nichiyu Giken NTS-11 heatflow system. This system contains a microprocessor which can be utilized for up to 15 hours of continuous 30 second sampling rate, eight thermistors which are evenly spaced on a 3-m expendable lance, and a PC for data handling and processing. A more detailed description of the NTS-11 heatflow system can be found in Liu et al (1987).

During the survey, we have used a BMR-designed Bullard type thermistor lance. This lance is different from the conventional Bullard type lance. One difference is that the thermistors are mounted on the outriggers attached spirally along the lance, as for an Ewing (corer) type lance. The other is that the lance has 3 vanes mounted on the outside to protect the thermistors during deployment and to increase the weight during the penetration. This type of lance has the advantage of less bending. The treatment to correct this bending was much easier than for the conventional lance. A pogo technique for thermal gradient measurement was carried out during this cruise. The procedure was as follows:

- descending
- stabilize at 100 m above seafloor for 5 minutes
- first entry fro 10 minutes
- stabilize at 100 m above seafloor for 5 minutes
- second entry for 10 minutes
- stabilize at 100 m above seafloor for 5 minutes
- third entry for 10 minutes
- back on board

The heatflow probe penetrated three times at each station. These multiple penetrations have shown the data to be repeatable and thus increased our confidence in data reliability (Fig. 40). Due to the number of reliable thermistors being reduced eventually to two,

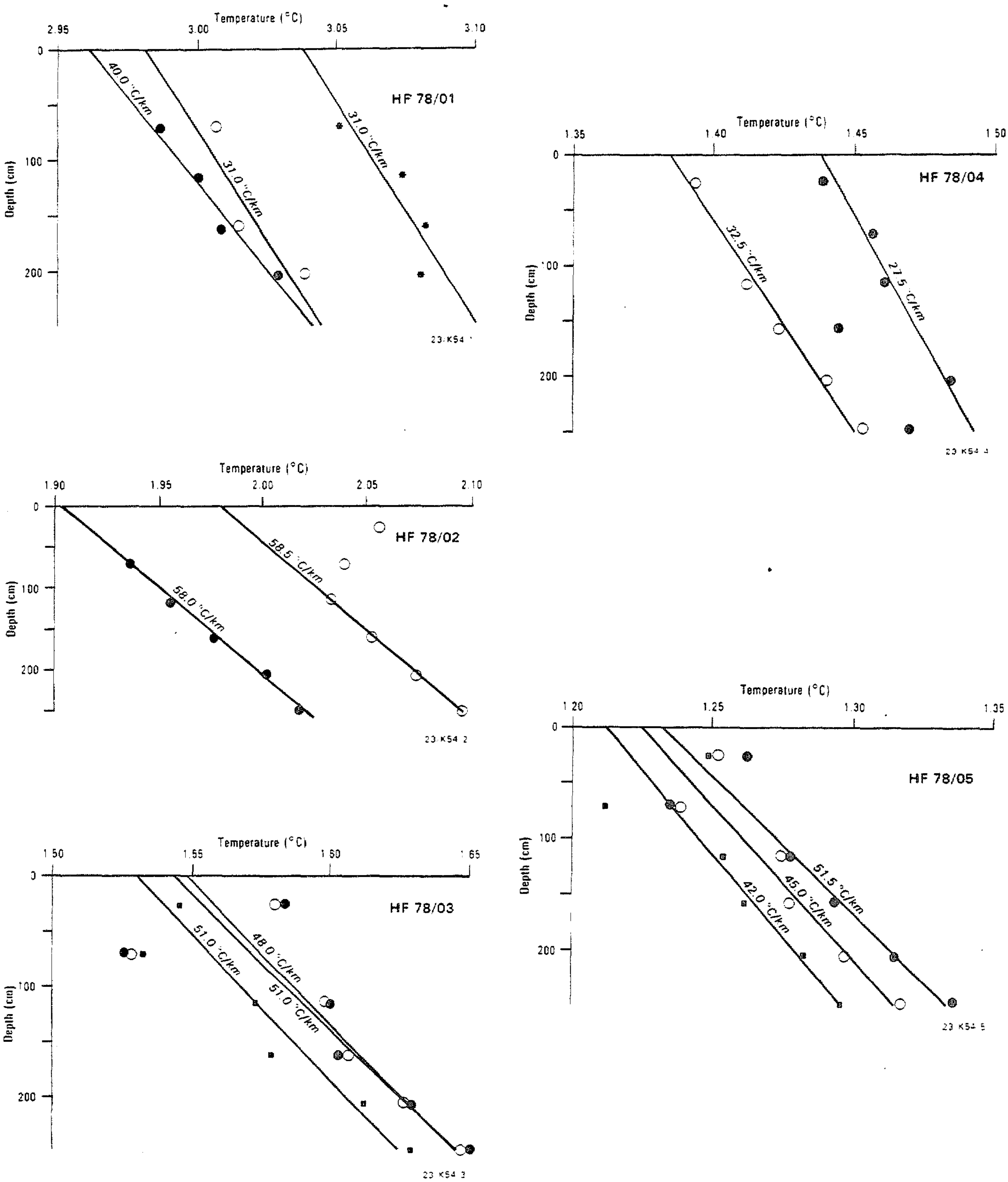


Figure 40. Conductivity measurements in sediment cores along seismic profile 78/05.

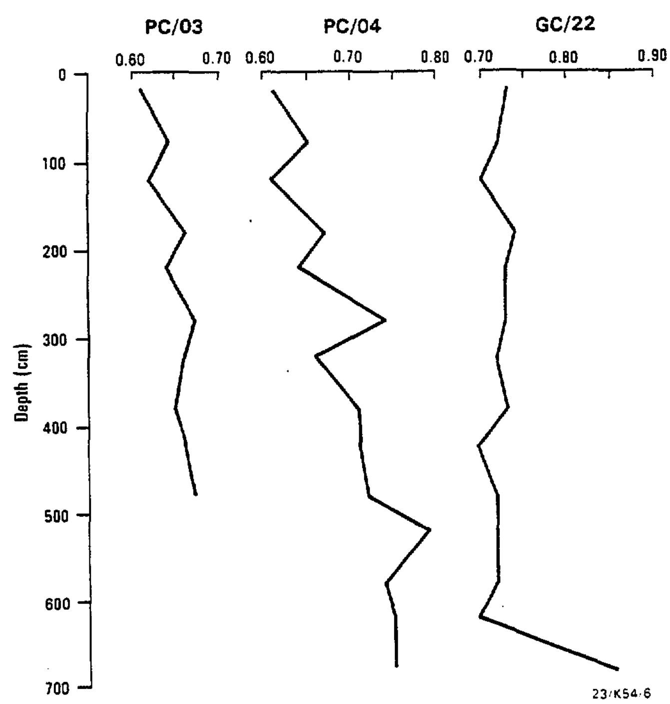


Figure 41. Thermal gradients from heatflow stations 78/01-78/05, along seismic profile 78/05.

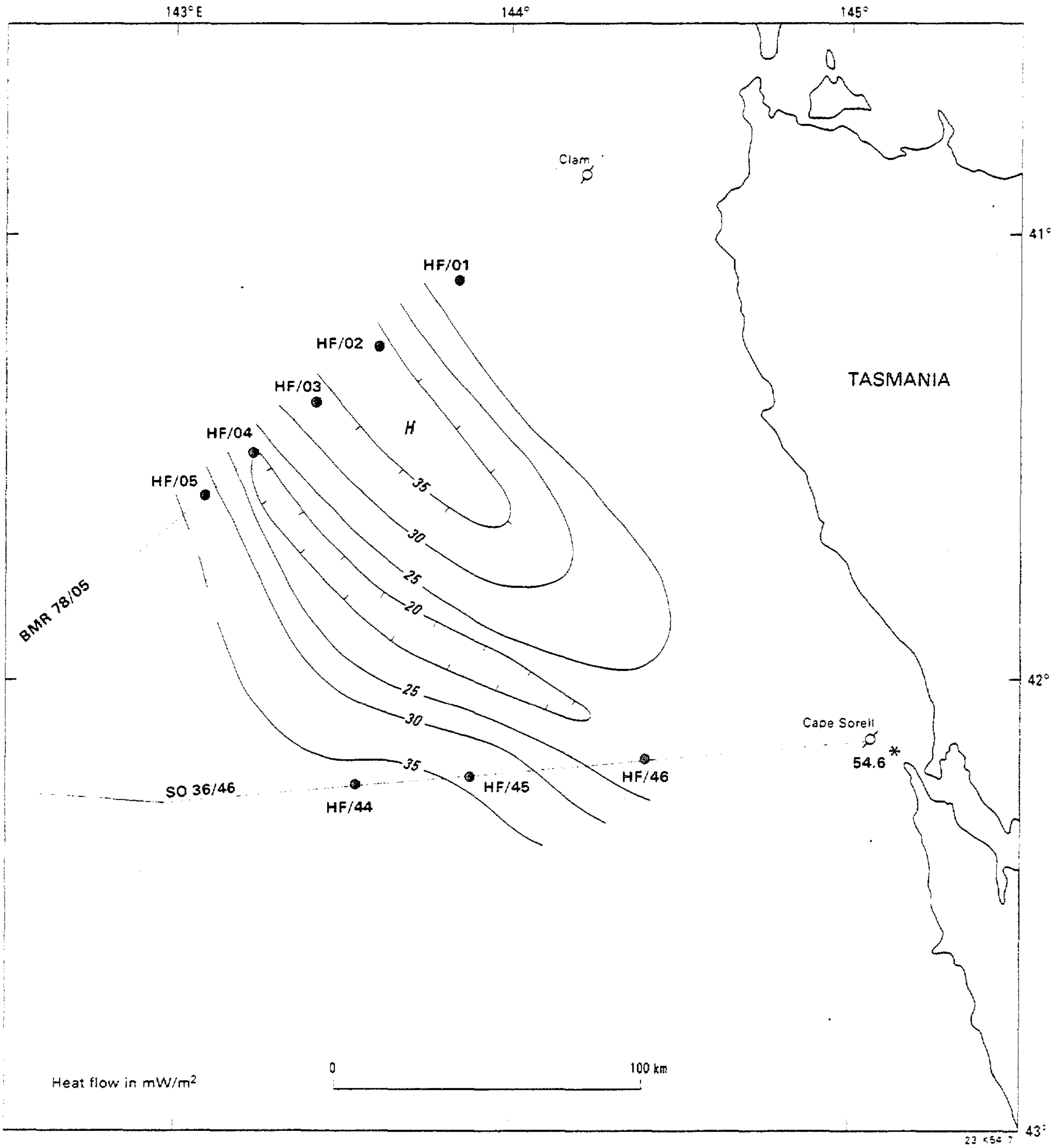


Figure 42. Heatflow map derived from stations occupied on BMR cruises 67 (HF/44-HF/46) and 78 (HF/01-HF/05).

TABLE 12 PRELIMINARY HEATFLOW VALUES FROM WEST TASMANIA CRUISE

Station	Latitude	Longitude	Depth (m)	Sen	TG (°C/Km)	core	Cond. (W/m.k)	HF (mW/m²)
HF/01	41°7.0'	143°49.4'	1320	5	31.0	PC/03	0.65	20.15
				5	40.0	PC/03	0.65	26.00
				5	31/0	PC/03	0.65	26.00
				AVERAGE HEATFLOW = 22.10 + 2.92				
HF/02	41°16.1'	143°35.8'	2540	5	58.5	PC/03	0.65	38.02
				5	58.0	PC/03	0.65	37.70
				AVERAGE HEATFLOW = 37.86 + 0.16				
HF/03	41°23.1'	143°24.6'	3127	7	47.5	PC/04	0.67	31.82
				7	48.0	PC/04	0.67	32.16
				7	51.0	PC/04	0.67	34.17
				AVERAGE HEATFLOW + 32.71 + 1.17				
HF/04	41°30.5'	143°13.6'	3569	7	32.5	PC/04	0.67	21.77
				7	27.5	PC/04	0.67	18.42
				AVERAGE HEATFLOW = 20.09 + 1.67				
HF/05	41°35.8'	143°5.5'	3950	4	51.5	PC/04	0.67	34.50
				4	42.0	PC/04	0.67	28.14
				6	45.0	PC/04	0.67	30.15
				AVERAGE HEATFLOW = 30.93 + 3.00				

and the angle of tilts being as high as 40 degrees, stations 6-10 have failed to obtain useful data. We lost 5 thermistors at station HF/10.

Thermal Conductivity Measurements

Thermal conductivity measurements on the sediment cores were determined with a BMR-constructed needle probe, using the thermal transient technique pioneered by von Herzen and Maxwell (1959). Two piston cores and one gravity core were used for this measurement, ranging from 5 to 7 m in length (Fig. 41). These cores were either taken at the heatflow station, or on the same tectonic structure within a distance of less than 20 km, thus ensuring that the values were relevant. A measurement was made in every representative lithology, and/or 40 to 50 cm apart, after cores have been equilibrated at room temperature for at least 24 hours.

The thermal conductivity values from three cores showed relatively little variation and were in the range of 0.60 - 0.85 W/m.k (Fig. 41). In general, the mean conductivity values increase from 0.65 in shallow water to 0.75 in deep water. This trend is different from the results of an Otway Basin heatflow survey (Exon, Lee et al, 1987).

Results

Primary heatflow values obtained, by multiplying the thermal gradient with the thermal conductiavity, are shown in Table 12. We have not applied denvironmental correction to the shipboard measurements; generally an increase of 10-15% is anticipated (Ben-Avraham and von Herzen, 1987). The preliminary heatflow results can be addressed as follows:

1. The average heatflow throughout the west Tasmanian margin survey area is about 30mW/sq.m. This is relatively low as compared with the values from the Otway Basin (Exon, Lee et al., 1987). This difference may be caused by different sedimentation rates and tectonic setting.

2. A heatflow contour map (Fig. 42) from two Tasmanian transects has shown that an area of low heatflow (20mW/sq.m) is associated with the zone of changing tectonic setting in both seismic lines BMR 78/05 and Sonne 36/46. Further study will be needed to examine the thermal convection cell in relationship to deep crustal structure.

3. The estimated heatfow value from the bottom hole temperature of Cape Sorell well is 54.6mW/sq. m. This is higher than any heatflow values that we have measured on the west Tasmanian margin. Future study on the other wells (Clam, Whelk and Prawn) will help us better understand the thermal maturation history of the west Tasmanian margin.

SHIPBOARD GEOPHYSICAL SYSTEMS AND PERFORMANCE

NON-SEISMIC SYSTEMS RESULTS

The non-seismic data acquisition system (DAS) ran for the entire cruise with no break in data collection.

Navigation

Positioning of the ship is derived from three largely independent systems; Global Positioning System (GPS), dead reckoning with updates from the Transit Satellite System, and radio navigation using Hifix. All on-board navigation is done within the WGS72 coordinate system, as this is the system used by the Transit Satellites. The GPS has been using WGS84 since January 1987 but, as the difference from WGS72 is only of the order of a metre, no conversion of the GPS positions is warranted.

Global Positioning System

A Magnavox T-Set receiver gives continuous absolute positioning within about 20 metres r.m.s. under optimum conditions. However, the system is in the experimental stage with only 7 of the proposed 24 satellites in orbit. Positioning is generally possible for some 8 hours a day but this can be extended to 12 hours in the two-satellite mode by using an atomic frequency standard. Success depends entirely upon an acceptable frequency bias between the satellite transmissions and the standard being determined during the previous period of three to four satellite visibility. Considerable uncertainty is involved with the use of two satellites. Experimentation with the system in port has shown that the two-satellite system is unreliable, giving position errors which compound the longer the system operates on two satellites. It is still not clear whether this is due to the Magnavox software, which is a new version (2.9), or due to an inaccuracy in the ship's rubidium standard. However, during periods of three and four satellites no appreciable change in frequency bias was detected, which tends to indicate that the atomic standard is relatively stable in output even if it is inaccurate.

During the geological sampling portion of the cruise, the GPS running on two satellites produced results that were unacceptable. As a result of this the clock-aiding facility in the T-Set was turned off. This restricted GPS navigation to those periods where 3 or 4 satellites were visible and reduced the use of the GPS system to about 8 hours a day.

Dead Reckoning System

Two independent systems, incorporating gyro compass, dual-axis sonar-doppler log and Transit satnav receiver, provided basic dead reckoning for periods when the other systems proved inadequate. The primary dead reckoning system of Robertson gyro, Magnavox MX6100 sonar-doppler and MX1107RS satnav receiver provides the best available positioning of this type. A lower grade system of Robertson gyro, Raytheon DSN450 sonar-doppler and MX1142 satnav receiver is used as the backup.

Both systems have problems in rough weather or when heading into the sea, due to air being trapped under the hull and blanking the transmission of all sonar systems. A small paddle wheel log has proven to be useful in bad weather, as it is not affected by the under-bottom turbulence to the same extent as the sonar-dopplers. This is mainly due to the fact that it can be lowered further beneath the hull than the sonar-dopplers.

The paddle log failed (93:0300 GMT), with the problem believed to be a jammed or lost paddle wheel. In general, the sonar-dopplers operated extremely well for most of the seismic leg, with the majority of the dead reckoned positions being in close proximity to the satellite fixes. However, there were stages during the geological portion of the cruise where, in deep water and rough weather, the dead reckoned positions were up to one nautical mile from the satellite fix positions.

Hifix

A Decca Hifix radio navigation system was operated for the entire cruise with varying results. 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 standards. During this cruise three shore stations were slaved to their own Rubidium standard, and the shipboard receiver was slaved to its own atomic standard. The system was operational up to ranges of 800 kilometres during the geological sampling portion of the cruise. The positions derived from the chain were excellent and tests done during periods when GPS and Hifix was operational showed that the Hifix positions were within 60-80 metres of GPS positions for the majority of the time. The co-ordinates of the Hifix shore stations are given in Appendix 1.

Hifix use during the seismic leg of the cruise was minimal. Problems with equipment failure, long range, atmospheric conditions and the position of Tasmania in relation to the ship and the shore stations, all contributed to prevent use of the Hifix for extended periods. The lack of radio navigation during the seismic leg was compensated by the excellent quality of the sonar-dopplers during this period. The radio navigation did improve for the geological leg, with the Hifix being used consistently in the period from about 1200 LMT to 2200 LMT. Atmospheric conditions did, on occasion, prevent the use of Hifix during the late afternoon and evening.

Bathymetry

During the seismic leg of the cruise, the 12 kHz echo sounder was used. The digital depth data obtained were of high quality and will require minimal editing and processing.

Both the 3.5 kHz and 12 kHz echo sounders were used in the geological sampling leg. The 12 kHz echo sounder produced good results, only missing data when the ship's speed was high during transits from sample sites. The 3.5 kHz echo sounder was used to provide an indication of sea floor and near subsurface lithology around sample sites. While some seafloor lithology information was derived from the 3.5 kHz echo sounder, it produced little or no penetration into the near subsurface. The use of the 3.5 kHz echo sounder was kept to a minimum, as it sometimes swamped the signal transmissions from the sonar-dopplers.

After the cruise it was found that all transducers were heavily encrusted with marine growth, and this must have affected the echosounders' performance.

Magnetics

Single channel magnetic data were obtained along all seismic lines except those in the shallow water of Storm Bay, the D'Entrecasteaux Channel and Huon River. The magnetic data for most of the seismic leg had noise levels of the order of 2 to 4 nT.

Gravity

Gravity data were obtained using the Bodenseewerke KSS-31 Gravity Meter. The system failed, due to problems with the battery back-up power supply, while the vessel was moored at Eden. It was possible to restart the system, let it settle and perform a gravity tie before departure from Eden. The system failed once during the seismic leg (87:0500 GMT) with the cause again suspected to be related to the battery back-up power supply. The system automatically caged the gravity meter after this failure. A restart was performed on the gravity system, with consistent gravity values being recorded by 87:0600 GMT. Due to problems with the Worden gravity meter, it was not possible to perform a gravity tie while the ship was docked in Hobart.

A list of the channel allocations for the non-seismic data for the Tasmania Cruise (#78) is given in Appendix 2.

SEISMIC DATA ACQUISITION SYSTEM

Cable

Two different cable configurations were used for this cruise. The initial part of the cruise used the 1200 metre Teledyne cable configured for 48 channels, with 25 m group interval. The second part of the cruise used a 600 metre cable configured for 48 channels with 12.5 metre group length. Details of the two cable configurations are given in Appendix 3.

he cable was towed with a nominal depth of 10 metres and 5 metres, for each section of the cruise respectively. Performance of the cable varied but was generally with ▪ 2 metres of the nominal depth. Cable noise was measured at the start of the survey and found to be around the 10 to 20 microvolt level.

Seismic Source

The first section of the cruise used a single gun array. It consists of fourteen 160 cu in guns, arranged in four groups. One gun in each group is a spare, and at a given time, ten guns are used. Thus the total capacity of each array is 1600 cu in. The guns are operated at 2000 psi. The airguns were towed at 10 metres depth, and the arrays were towed 30 metres behind the ship. Gun array performance was monitored closely. In general, no more than one gun in the gun array was allowed to fall beneath full performance before the array was repaired. As two gun arrays were available, no time was lost due to repairs to an array.

The section of the cruise in the D'Entrecasteaux Channel generally used an 80 cu inch water gun, towed at a depth of 5 metres. However, in the less conjested area between the northern D'Entrecasteaux Channel and the Huon River, an array of six airguns was used.

Gun Controller System

The guns were controlled by the PUSSY guns controller system which both hardware and software designed and developed at BMR. The system is designed to fire the airguns 30 milliseconds after the shot pulse is sent from the computer. The shot sensors at each gun measure the actual fire time and send this back to the computer. The fire error is the difference between the actual fire time and the designated fire time. The PUSSY software averages the fire error over ten shots. The averaged fire error is used to adjust the fire time of each gun independently. Thus, variations in gun performance of a period longer than 10 shots can be corrected. The system worked consistently well during the cruise, the only problems being related to transmission errors which occasionally occurred between the gun controller and the computer.

The shot firing was generated by the seismic acquisition system based on a fixed nominal ship speed. Typically this was 5.0 knots on this cruise, giving a firing interval of 19 seconds when the array was used and 9.5 seconds when the water gun was used.

Amplifier/Filter System

The signal from the seismic cable was taken through the SMF-1 amplifier filter system which was designed and built at BMR. The high cut filter was set at 128 Hz to provide suitable anti-alias filering. The low cut was set to 6 Hz to minimise low frequency noise generated from the cable. This setting was selected from previous experience.

The amplifier system is a constant gain system and is set to maximise the signal being sent to the analogue to digital converter without overdriving. The gain was adjusted depending upon water depth, but, since most of this cruise was recorded in water depths greater than 400 metres, the highest gain setting was used most frequently.

Analogue to Digital Converter

The amplified, filtered data were digitised using a PHOENIX model DAS 6000 A/D converter. This is a fixed gain converter which outputs data to a maximum precision of 14 bits plus sign. The least significant bit is set if the converter overdrives, giving a total of 15 bits plus sign. This is presented to the computer as a 16 bit 2's complement integer.

Acquisition Computer System

The seismic data acquisition is controlled using a HP minicomputer and various peripherals for receiving and saving the data. The software is known as MUSIC (Multichannel Seismic Computer) and has been developed at BMR using a very highly modified BCS operating system. The system configuration used on this cruise was as follows:

Computer

HP1000 E-Series with 2 megabytes memory and I/O extender.

Tape Transports

Two HP7970 tape drives were used. These write data on standard 0.5 inch magnetic tape in 1600 bpi phase encoded format.

Log Devices

The recording was logged and monitored using EPSON MX100 dot matrix printers as follows:
Shot Logger : Logs each shot and tape, reports data analyses at regular intervals.
Gun Logger: Reports output from Gun Controller for each shot.
Fast Monitor: Plots channel 2 of each shot to give a continuous record of the first three seconds of each line recorded.
Slow Monitor: Plots the same data as the fast monitor, but at one quarter the paper speed, giving a much more compressed section.
Cycling Monitor: Plots a channel incrementally from successive shots, cycling through all channels over 53 shots (48 data, 5 auxiliary).
Self-Serve: This monitor is configurable, but usually shows the first six seconds of data, or is set to display sonobuoy data when that is being recorded.

Visual Monitors

The MUSIC system presents a number of visual monitors which the operator observes to maintain data acquisition quality. These include a multiplexed channel display which is output while the data are being received, and shows the activity on all channels simultaneously, displays of single traces, signal levels and cable performance.

Data Format

The seismic data were recorded in BMR SEG-Y.

GEOLOGICAL EQUIPMENT PERFORMANCE

Dredging

Deployment of the dredge has now become a simple and routine procedure, facilitated by recent modifications such as that allowing the removal of the core cradle cone, the rounded stern plate with integral roller, and the use of stainless steel bolt clamps and an air rattle gun. A new shear mechanism tried during this cruise was designed primarily to overcome the past difficulty with removing distorted shear pins. However, it also achieved the auxilary benefits of a substantial reduction in size and weight, and the use of shear pins which can be quickly manufactured from a standard production steel bar. This mechanism proved highly successful.

Piston Coring

Further refinement of the deployment procedure of the piston corer designed "in house" took place early in the cruise and an instruction manual was produced. It appears that we have now moved beyond the steep part of the learning curve. With the new deck facilities (ie overhead crane, dispensing racks, modified cradle and hero platform), it has become feasible to do repetitive deployments of p to 10 m barrel length with relative ease and safety. The present turn-around time of about 2-2½ hours could be reduced to less than 1½ hours as more people become familiar with the operation. During the cruise the piston corer was successfully deployed with a record 11.3 m barrel. It became obvious, after the corer triggered in the water column at its first deployment, that the minimum trigger weight must be equivalent to one of the long solid bar weights used for dredging.

Vibrocoring

A new 3.5 m vibrocore frame was trialled during this cruise. This frame is deployed from the helicopter deck via an extended ship's crane using a new hydraulic winch. Two winches were used, one for the stress cable, and another for the electric cable. Initial trials at the 'eleventh hour' in Eden encountered winch teething problems and power supply failure. Both problems were rectified during the mid-cruise Hobart visit.

The vibrocorer was successfully deployed and activated during light sea conditions in the Sorell Basin. The trial, however, remains inconclusive with regard to core recovery because there was hard limestone right at the sea floor.

Dynamic Positioning System

The vibrocoring operation was greatly assisted by the ship's dynamic positioning (DP) system working on a taut wire. Both the DP and taut wire systems were overhauled in Eden, and now appear to be viable for operations. A trial of the deeper water Simrad transponder, inputting to the DP System, proved unsuccessful due to the failure of the Simrad to track. This may have been due to fouling, which was to be removed in Portland.

Coring winch

The main winch program was lost during the cruise, and it came as a surprise to all concerned to learn from the supplier that the entire program is reliant on a battery which had gone flat! Operations were able to continue because of an alternative "wire length out" and "winch speed" system developed by J. Pittar prior to the cruise.

Box coring

The box-corer appears to have suffered again from its perennial problem of insufficient weight to allow full penetration of the box.

General

It is gratifying to observe that a great variety of operations are now carried out in a systematic and repeatable fashion, without heavy physical lifting and with a high regard for safety. The benefits of recent efforts to: a. organise storage of equipment and parts, b. keep a comprehensive list of spare parts, c. standardise procedures such as core labelling and d. promote tidyness in the workplace, were obvious in this cruise. The efforts of all technicians involved in geological operations during cruise 78 are to be commended.

CONCLUSIONS

R/V Rig Seismic successfully carried out a 21 day geophysical/geological cruise on the western and southeastern margins of Tasmania in early 1988.

The first part of the program consisted of 1750 km of multichannel seismic, magnetic and gravity profiling, and sonobuoy refraction surveying, off west Tasmania (Fig. 10). The work included a regional profile from the shelf to the abyssal plain, and a mid-slope tie line right along the western margin of Tasmania. Other profiles revealed details of the King Island and Strahan Sub-basins and the abyssal plain. The seismic system employed a single 1600 cubic inch airgun array and a 48 channel, 1200 m seismic cable.

The monitors indicate that data quality was good; they showed penetration of at least 2 seconds (twt) on the shelf and 3 seconds on the continental slope. The monitor records reveal that continental basement and assumed Early Cretaceous sedimentary rocks are near the surface beneath the outermost shelf and the outermost continental slope above the abyssal plain, but that elsewhere there are thick Late Cretaceous and Early Tertiary sequences of the Sorell Basin (3 seconds or more thick in places). Three important sub-basins on the continental shelf (Fig. 3) have formed in response to strike-slip faulting: King Island, Sandy Cape and Strahan (formerly Cape Sorell). These basins contain more than 3 seconds of section, are very complex tectonically, and have considerable petroleum potential.

The magnetic and gravity data, in conjunction with seismic reflection and refraction data, reveal that there is a transitional zone about 50 km wide on the abyssal plain between the foot of the slope (which is on continental crust) and undoubted oceanic crust. This zone is cut by diapir-like bodies with little magnetic expression.

The second part of the program involved 265 km of geophysical profiling in the D'Entrecasteaux Channel/Bruny Island region off southeast Tasmania (Fig. 25). Part of this program used the same seismic system as off west Tasmania, but part utilised a less powerful system because of the danger of working in confined, shallow waterways (single watergun or 6 gun array, and 48 channel, 600 m seismic cable). The stratigraphic sequence in the region consists of 1-2 seconds (twt) of Permo-Triassic sediments, cut by massive Jurassic dolerite sills and incised by stream channels filled with Tertiary sediments, and unconformably overlying shallowly dipping Paleozoic rocks.

The dolerite sills obscured most information on the monitor records, and only full processing will enable any reasonable seismic interpretation to be carried out. Nevertheless, in places the watergun source gave visible penetration of 1 second, and the airgun array of 2.5 seconds. Several troughs of possibly Tertiary strata up to 1 second thick were visible on the monitors, the main trough being part of the Derwent Graben.

The final part of the cruise consisted of sampling on the west Tasmanian margin (Figs. 26, 34, & 37) which was complementary to that of Hinz et al. (1985) and Exon, Lee et al. (1987). Altogether 12 dredge stations, 37 core stations, 9 grab stations and 10 heatflow stations were occupied. Schistose sandstone of probably Proterozoic age was recovered at one station (DR02), probably Cretaceous sediments at two stations (DR05, DR06), very large manganese nodules and thick crusts at one station (DR04), probably Palaeogene sediments at two stations (GC05, DR09), and pre-Quaternary Neogene sediments at four stations (PC02, GC08, GC09, GC13). Most stations were on seismic profiles, so the results can be used to help establish an integrated geological history of the margin.

Twenty-eight of the above stations were designed to obtain unconsolidated material for gas analyses, like those reported by Exon, Lee et al. (1987). Many were in the Strahan and Sandy Cape Sub-basins, and we had hoped to adequately sample these two shelf sub-basins to review petroleum prospectivity. However, hard Miocene limestones close to the surface greatly reduced the planned sampling program. Altogether 16 cores were sampled for gas, but many of these were in deeper water. The samples from the Sandy Cape Sub-basin are the first strong indication that thermogenic hydrocarbons are being generated widely there.

Ten heatflow stations were occupied on BMR seismic profile 78/05 on the continental slope and abyssal plain (Fig. 26). Five stations gave thermal gradients. Conductivity was measured on three cores from the same locations, allowing heatflow to be calculated. In general, the mean heatflow value on the west Tasmanian margin is about 30mW/sq.m, lower than in the Otway Basin (Exon, Lee et al., 1987).

Overall, the geophysical and geological results obtained, together with pre-existing data, will enable a full study of the geological framework and petroleum potential of the west Tasmanian margin to be carried out. The more limited southeast Tasmanian geophysical data will be useful in assessing the petroleum prospects of the D'Entrecasteaux/Bruny region.

REFERENCES

AMOCO, 1971, Cape Pillar marine seismic survey, Tasmania tenement T11/P. Final Report (unpubl.).

AMOCO, 1981, Cape Sorell Basin seismic survey (unpubl.).

AMOCO, 1982, Cape Sorell No. 1 well completion report (unpubl.).

BAILLIE, P.W., 1986, Geology and exploration history of the west Tasmanian continental margin. Tasmania Department of Mines Unpublished Report 1986/47, 7 p.

BAILLIE, P.W., & CORBETT, K.D., 1985, Geological Atlas 1:50,000 Series. Sheet 57 (7913N), Strahan. Explanatory Report Geological Survey Tasmania.

BAILLIE, P.W., BACON, C.A., & MORGAN, R., 1986, Geological observations on the Macquarie Harbour Beds at Coal Head, Western Tasmania. Tasmania Department of Mines Unpublished Report 1986/73, 4p.

BANKS, M.R., COLHOUN, E.A., & CHICK, N.K., 1977, A reconnaissance of the geomorphology of central western Tasmania, in Banks, M.R. & Kirkpatrick, J.B. (eds). LANDSCAPE AND MAN: 29-54. Royal Society of Tasmania, Hobart.

BEN-AVRAHAM, Z., & VON HERZEN, R.P., 1987, Heatflow and continental breakup: the Gulf of Elat (Aqaba), Journal Geophysical Research, 1407-1416.

BERRY, R.F., & BANKS, M.R., 1985, Striations on minor faults and the structure of the Parmeener Super-Group near Hobart, Tasmania. Papers and Proceedings of the Royal Society of Tasmania 119, 23-29.

BMR, 1982, Data : Bass Strait Survey, cruise 40.

BOUEF, M.G., & DOUST, H., 1975, Structure and development of the southern margin of Australia. APEA Journal 15(1), 33-43.

BRANSON, J.C., 1984, Northwest Tasmanian margin in Site proposals for scientific drilling in the Australasian region. Consortium of Ocean Geosciences Publication No. 2, 58-71.

BRANSON, J.C., in press, The Otway Basin : Petroleum exploration. Special Publication Victoria Department of Industry, South Australian Department of Mines and Energy, Bureau of Mineral Resources, and Tasmanian Department of Mines.

BUKRY, D., 1973, Low-latitude coccolith biostratigraphic zonation. In Edgar, N.T., Saunders, J.B. & others, Initial Reports of Deep Sea Drilling Project, Washington (U.S. Government Printing Office), 13, 685-703.

CANDE, S.C., & MUTTER, J.C., 1982, A revised identification of the oldest seafloor spreading anomaly between Australia and Antarctica. Earth and Planetary Science Letters, 58, 151-160.

CULP, B.L., 1967, Esso Prawn No. A1 well completion report (unpubl.).

DAVIDSON, J.K., 1980, Rotational displacements in southeastern Australia and their influences on hydrocarbon occurrence. Tectonophysics, 63, 139-153.

DEIGHTON, I., FALVEY, D.A., & TAYLOR, D.J., 1976, Depositional environments and geotectonic framework: southern Australian continental margin. APEA Journal 16(1):25-36.

DENHAM, J.I., & BROWN, B.R., 1976, A new look at the Otway Basin. APEA Journal 16(1), 91-98.

DOUGLAS, J.G. & FERGUSON, J.A. (eds), 1976, Geology of Victoria. Geological Society Special Publication 5, 152-163.

ELLENOR, D.W., 1976, Otway Basin. In: Leslie, R.B., Evans, H.J., & Wangerrip, C.L. (Editors), Economic Geology of Australia and Papua New Guinea, 3. Petroleum, AIMM Monograph Series 7, Parkville, Victoria.

ESSO, 1968, Tasmania EE-68 marine seismic and magnetic survey. Final Subsidy Report (BMR File 68/3013) (unpubl.).

ESSO, 1969, West Tasmania T69A marine seismic and magnetic survey final report. Bureau Mineral Resources File, 69/3000 (unpubl.).

ESSO, 1970a, West Tasmania T70A marine seismic and magnetic survey. Final Subsidy Report (BMR File 70/7) (unpubl.).

ESSO, 1970b, West Tasmania T70C marine seismic and magnetic survey. Final Subsidy Report (BMR File) (unpubl.).

ETHERIDGE, M.A., BRANSON, J.C., and STUART-SMITH 1985, Extensional basin-forming structures in Bass Strait and their importance for hydrocarbon exploration : APEA Journal, 25(1), 344-361.

EXON, N.F., & WILLCOX, J.B., 1985, Hydrocarbon indications off western Tasmania. BMR Research Newsletter 3, 20.

EXON, N.F., WILLIAMSON, P.E. & Shipboard Party, 1987, Rig Seismic Research Cruise 3, Otway Basin, June/July 1985. BMR Cruise Report 279, 48 p.

EXON, N.F., LEE, C.S. & Shipboard Party, 1987, Rig Seismic Research Cruise 1987 : Otway Basin and West Tasmania sampling. Bureau Mineral Resources Record, 1987/11, 143 p.

EXON, N.F., LEE, C.S. & Shipboard Party, 1989, Bureau of Mineral Resources Research Cruise 67 : Otway Basin and west Tasmanian sampling. Bureau Mineral REsources Report 285.

EXON, NF., STRATTON, J., REYNOLDS, H. & TINDALL, C., 1989, Sedimentological analyses from deepsea cores taken off southwest Victoria, and western and southern Victoria. Bureau Mineral Resources Record 1989/5.

FARMER, N., 1979, Geological Atlas 1:250,000 series. Sheet SK-55/8 Hobart. Explanatory Report, Geological Survey of Tasmania.

FELTON, E.A., & JACKSON, K.S., 1987, Hydrocarbon generation in the Otway Basin, Australia. BMR Journal of Australian Geology & Geophysics 10, 213-224.

GARTNER, S. Jr, 1977, Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. Marine Micropaleontology, 2, 1-25.

HAWKINS, L.V., HENNION, J.F., NAFE, J.E., & DOYLE, H.A., 1965, Marine seismic refraction studies on the continental margin south of Australia, Deep Sea Research, 12, 479-495.

HEGGIE, D., MCKIRDY, D., EXON, N. & LEE C.S., 1988, Hydrocarbon gases, heat-flow and the development of the offshore Otway Basin. PESA (Petroleum Exploration Society Australia) Journal 13, 32-42.

HINZ, K., & SHIPBOARD PARTY, 1985, Geophysical, geological and geochemical studies off west Tasmania and on the South Tasman Rise. Bundesanstalt fuer Geowissenschaften und Rohstoffe Cruise Report. Cruise SO36(2), 220 p.

HINZ, K., WILLCOX, J.B., WHITICAR, M., KUDRASS, H.R., EXON, N.F., & FEARY, D.A., 1986, The West Tasmanian margin: an underrated petroleum province? In R.C. Glenie (Ed): Second Southeastern Australia Oil Exploration Symposium, Petroleum Exploration Society of Australia, 395-410.

HUGHES, G.W., SEYMOUR, W.P., VAROL, O. & CHOW, Y.C., 1983, The biostratigraphy of the Amoco Australia Petroleum Co. Cape Sorell-1 well, offshore west Tasmania, Australia. Robertson Research (Singapore) Private Limited Report 1176 (unpubl.).

HUNT, J.M., 1975, Hydrocarbon studies. In Initial Reports of the Deep Sea Drilling Project 31. US Government Printing Office, Washington, D.C. 901-904.

JACKSON, K.S., FORMAN, D.J., FELTON, E.A., NICHOLAS, E. & DENARDI, R. 1983, Geochemical and organic microscopy data from Australia's petroleum source rocks. Bureau Mineral Resources Report 240; BMR Microform MF180.

JONES, H.A., & DAVIES, P.J., 1983, Superficial sediments of the Tasmanian continental shelf and part of Bass Strait. Bureau of Mineral Resources Bulletin 218, 25 p.

JONES, H.A., & HOLDGATE, G.R., 1980, Shallow structure and Late Cainozoic geological history of western Bass Strait and the west Tasmanian Shelf. BMR Journal Australian Geology & Geophysics 5, 87-93.

KENNETT, J.P., HOUTZ, R.E., et al., 1974, Initial Reports of the Deep Sea Drilling Project 29. US Government Printing Office, Washington, D.C..

LEAMAN, D.E., 1972, Gravity survey of the Hobart district. Bulletin of the Geological Survey of Tasmania 52.

LEAMAN, D.E., 1976, Geological atlas 1:50,000 series. Zone 7. Sheet 82 (8312s) Hobart. Explanatory Report, Geological Survey of Tasmania.

LEAMAN, D.E., 1987, Conga Oil current exploration status : Project D'Entrecasteaux, south east Tasmania. Conga Oil Ltd Unpublished Report 33 p.

LIU, Y.S.B., CHOI, D.R., STAGG, H.M.J., & SWIFT, M., 1987, Marine heatflow System - instrumentation and technique. Bureau Mineral Resources Record 1987/47.

LUNT, C.K., 1969, Esso Clam No. 1 well completion report (unpubl.).

McKIRDY, D.M., COX, R.E., VOLKMANN, J.K., & HOWELL, V.J., 1986, Botryococcane in a new class of Australian non-marine crude oils. Nature 320, 57-59.

McKIRDY, D.M., & HORVATH, Z., 1976, Geochemistry and significance of coastral bitumen from southern and northern Australia. APEA Journal 16(1), 123-135.

MARTINI, E., 1971, Standard Tertiary and Quaternary calcareous nannoplankton zonation. In FARINACCI, A. ((ed.), Proceedings of the 2nd Planktonic Conference, Roma, 1971, 2, 739-785.

MEGALLAA, M., 1986, Tectonic development of Victoria's Otway Basin - a seismic interpretation. In : Glenie, R.C. (editor), Second Southeastern Australia Oil Exploration Symposium, Petroleum Exploration Society of Australia, 201-218.

PERCH-NIELSEN, K., 1985, Cenozoic calcareous nannofossils. In Bolli, H.M., Saunders, J.B. & Perch-Nielsen, K. (Eds.), Plankton Stratigraphy, Cambridge (Cambridge University Press), 1985, 427-554.

ROBERTSON, C.S., CRONK, D.K., MAYNE, S.J., & TOWNSEND, D.G., 1978, A review of petroleum exploration and prospects in the Otway Basin region. Bureau of Mineral Resources Record 1978/91, 49 p.

ROYER, J.Y., 1987, Evolution of the eastern Indian Ocean : new constraints from satellite altimetry data. University of Texas Paleoceanographic Mapping Project Progress Report 29-1287 (unpubl.).

SEIBOLD, E., & BERGER, W., 1982 - The sea floor : an introduction to marine geology Springer Verlag, Berlin. 288 p.

SHAFIK, S., 1987, Tertiary nannofossils from offshore Otway Basin and off west Tasmania. BMR Record 1987/11, 67-101.

SYMONDS, P.A. & WILLCOX, J.B., 1976, The gravity field of offshore Australia. BMR Journal of Australian Geology & Geophysics, 1, 303-314.

TALWANI, M., MUTTER, J.C., HOUTZ, R. & KONIG, M., 1979, The crustal structure and evolution of the area underlying the magnetic quiet zone on the margin south of Australia, in, Geological and Geophysical Investigations of continental margins, J.S. Watkins L. Montadert and P.W. Kickerson (eds.); American Assoc. Petrol. Geol. Memoir 29, 151-175.

VEEVERS, J.J., 1986, Breakup of Australia and Antarctica estimated as mid-Cretaceous (95±5 Ma) from magnetic and seismic data at the continental margin. Earth & Planetary Science Letters 77, 91-99.

VEEVERS, J.J., & EITTREIM, S.L., in press, Reconstruction of Antarctica and Australia at breakup (95±5 Ma) and before rifting (160 Ma) : Australian Journal of Earth Sciences.

VOLKMAN, J.K., 1988, Hydrocarbons in Ordovician limestone from Queenstown and Lune River, Tasmania. CSIRO Marine Laboratories Unpublished Report 39 p.

VON HERZEN, R.P. & MAXWELL, A.E., 1959, The measurement of thermal conductivity of deep-sea sediment by a needle-probe method, Journal Geophysical Research, 64, 1557-1563.

WEISSEL, J.K. & HAYES, D.E., 1972, The Australian-Antarctic discordance : new results and implications. Journal Geophysical Research, 79 (17), 2579-2587.

WEISSEL, J.K., & HAYES, D.E., 1977, Evolution of the Tasman Sea reappraised. Earth and Planetary Science Letters, 36, 77-84.

WHITICAR, M.J., BERNER, U., POGGENBURG, J. & TOSTMANN, H., 1985, Shipboard report of geochemical surface exploration off western Tasmania and on the South Tasman Rise. In : Hinz, K. & Shipboard Party, 1985. Geophysical, geological and geochemical studies off West Tasmania and on the South Tasman Rise. Bundesanstalt fuer Geowissenschaften und Rohstoffe Report. Cruise SO36(2), 141-171.

WILLCOX, J.B., 1978, The Great Australian Bight : a regional interpretation of gravity, magnetic and seismic data from the Continental Margin Survey. Bureau of Mineral Resources, Australia, Report, 201, 65 p.

WILLCOX, J.B., BRANSON, J.C. & EXON, N.F., 1985, A proposal for ODP-drilling on the Australian continental margin in the Otway Basin/west Tasmania Region. Bureau of Mineral Resources Record 1985/43, 9 p.

WILLIAMSON, P.E., O'BRIEN, G.W., SWIFT, M.G., FELTON, E.A., SCHERL, A.S., EXON, N.F., LOCK, J., & FALVEY, D.A., 1987, Hydrocarbon potential of the offshore Otway Basin. APEA Journal 27(1), 173-194.

APPENDIX 1 : HIFIX SHORE STATION COORDINATES

Station	Australian Geodetic	WGS72
Ewan Ponds	S 38 02.541 E 140 49.533	S 38 02.456 E 140 49.607
Peterborough	S 38 33.883 E 142 46.776	S 38 33.797 E 142 46.849
Barwon Heads	S 38 17.191 E 144 25.207	S 38 17.103 E 144 25.279

Barwon Heads off air Monday 11 April.
Shifted to Cape Jaffa and on air Thursday 14 April.

Cape Jaffa	S 36 58.900 E 139 42.060	S 36 58.815 E 139 42.134

APPENDIX 2 : NON-SEISMIC DATA CHANNELS

The following is a list of the channel allocations for the non-seismic data for the Tasmania cruise (#78).

Main Data

The main data are saved on magnetic tape every 60 seconds in blocks of 128 x 6 floating point words.

1 - Clock (Survey and Day Number)
2 - Acquisition time (GMT) from 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 no. 1
9 - Magnetometer no. 2
10 - Depth no. 1; 3.5 kHz
11 - Depth no. 2; 12 kHz
12 - F/A Magnavox sonar-doppler (3920.4 counts/nm)
13 - P/S Magnavox sonar-doppler (3920.4 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 (approx 7000 counts/nm)
17 - not used
18 - Instrument room gyro (degrees)
19 - Bridge gyro (degrees)
20 - Gyro compass differences
21 - not used
22 - not used
23 - not used
24 - not used
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 - 40 - not used
41 - T-SET ; number of satellites and satellite numbers in constellation
42 - T-SET time (GMT seconds)
43 - T-SET Dilution of Precision
44 - T-SET latitude (radians)
45 - T-SET longitude (radians)
46 - T-SET height above geoid (metres)
47 - T-SET speed (knots x 10)
48 - T-SET course (degrees X 10)
49 - T-SET frequency bias
50 - T-SET GMT (.HHMMSS)
51 - Latitude, calc. from Magnavox Sonar-Doppler & A.B. gyro
52 - Longitude, calc. from Magnavox Sonar-Dopper & A.B. grro
53 - Speed calc. from Magnavox sonar doppler & A.B. gyro

54 - Course calc. from Magnavox sonar doppler & A.B. gyro
55 - Latitude, calc. from Raytheon Sonar-Doppler & bridge gyro
56 - Longitude, calc. from Raytheon Sonar-Doppler & bridge gyro
57 - Speed calc. from Raytheon sonar doppler & bridge gyro
58 - Course calc. from Raytheon sonar doppler & bridge gyro
59 - Latitude, calc. from paddle log & A.B. gyro
60 - Longitude, calc. from paddle log & A.B. gyro
61 - Speed calc. from paddle log
62 - Course calc. from A.B. gyro
63 - Latitude, radio-nav
64 - Longitude, radio-nav
65 - Speed from radio-nav
66 - Course from radio-nav
67 - GMT from Magnavox MX1107 sat nav (secs)
68 - Dead Reckoned Time from MX1107 (secs)
69 - Latitude (radians) MX1107
70 - Longitude (radians) MX1107
71 - Speed (knots) MX1107
72 - Heading (degrees) MX1107
73 - GMT from Magnavox MX1142 sat nav
74 - Dead Reckoned Time from MX1142
75 - Latitude (radians) MX1142
76 - Longitude (radians) MX1142
77 - Speed (knots) MX1142
78 - Heading (degrees) MX1142
79 - Gravity (mGal * 100)
80 - ACX (m/s/s * 10000)
81 - ACY (m/s/s * 10000)
82 - Sea state (N/A)
83 - AGRF magnetic anomaly no. 1
84 - AGRF magnetic anomaly no. 2
85 - Magnetics difference (gradiometer)
86 - Seismic shot time HHMMSS
87 - Seismic shot point number
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)

The T-SET channel 41, which holds the number and numbers of the satellites in the current constellation, has data packed as follows. The units of the value in the channel gives the number of satellites 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 it becomes available. The data from each navigator is in a similar format, each being identified by the first word.

1 - 1107 or 1142
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 (naut 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 satellite 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 (2 F.P. words) identify the block, 702, and the start time of the block

APPENDIX 3: DETAILS OF SEISMIC CABLE CONFIGURATIONS

West Tasmania

Distance from front of active 1 (m)	Section type
	Tow leader
-154	Stretch
-104	Stretch
-54	Stretch
-4	Adaptor 96 > 48
-2	WB/DT # 1
0	Active # 1
100	Active # 2
200	DT # 2
202	Active # 3
302	Active # 3
402	DT # 3
404	Active # 5
504	Active # 6
604	WB/DT # 4
606	Active # 7
706	Active # 8
806	DT # 5
808	Active # 9
908	Active # 10
1008	DT # 6
1010	Active # 11
1110	Active # 12
1210	WB/DT # 7
1212	Stretch
1262	Tail Rope
~ 1462	Tail Buoy

The offset from the rear of the ship to the first active is given in the seismic log book for each cable configuration and is also entered in data trace headers on the magnetic tapes.

D'Entrecasteaux Channel

Distance from front of active 1(m)	Section type
	Tow leader
-52	Stretch
-2	WB/DT # 1
0	Active # 1

100	Active # 2
200	DT # 2
302	Active # 4
402	DT # 3
404	Active # 5
504	Active # 6
606	Stretch
656	Tail Rope
~856	Tail Buoy

APPENDIX 4 : SMEAR SLIDE DESCRIPTIONS - WEST TASMANIA BMR CRUISE 78.

by
E. Anne Felton

78/PC01A 30 cm.

Abundant: large foraminifera (globigerinid-type); echinoid plate fragments, bryozoan fragments.
Rare: echinoid spine fragments, sponge spicules, brown mineral grains, ?molluscan shell fragments, carbonate mud (?nannofossils).

150 cm.

Abundant: large and small globigerinid forams, bryozoan fragments.
Minor: echinoid spine and plate fragments, Textularia-type forams, brown and green (?glauconite) mineral grains, nannofossil mud.

350 cm

Abundant: large and small globigerinid forams, sand-size bryozoan fragments, nannofossil mud, very fine bryozoan, shell and echinoid debris.
Rare: sponge spicules.

397 cm

Abundant: large and small globigerinid forams as for 350 cm; other components as for 350 cm, but nannofossil mud less abundant.
Rare: Textularia-type forams.

78/PC04 325 cm

Abundant: large forams (globigerinid and Textularia-type forams), sand-size bryozoan debris, echinoid spine fragments, mineral/rock grains.

465 cm

Very similar to 325 cm sample.

78/GC05 38 cm

Abundant: terrigenous mud with fine sand-size debris of bryozoans, brown and green mineral grains, opaque grains, some rounded (possible pyrite framboids or pyritic casts of forams); minor questionable wood fragments.

45 cm

Similar to 38 cm sample but mineral grains less abundant and slightly coarser.

51 cm

Similar to 38 cm sample, but sand-size grains smaller and less abundant.

78/GC21 107 cm

Abundant: coarse sand-size sponge spicules, globigerinid forams, mineral and rock grains, echinoid plate and sponge fragments, shell fragments.
Common: nannofossil mud.

78/GC07 51 cm

Abundant: coarse sand-size spicules, large globigerinid-type forams, echinoid spine and plate fragments, rock/mineral grains.
Common : nannofossil mud, Textularia-type forams, small globigerinid forams, bryozoan debris.

151 cm

Similar to 51 cm sample: includes common bryozoan debris and rare green (?glauconite) grains.

251 cm

Similar to 51 cm sample in nature of coarse sand fraction; rock and mineral fragments less abundant, common intermixed nannofossil mud.

301 cm

Abundant: coarse sand-size spicules, forams (globigerinid and fusulinid types), echinoid spines and plates, nanno-fossil mud; rock and molluscan shell fragments.
Common : bryozoan debris.
Rare : green (?glauconite) grains.

373 cm

Similar to 301 cm sample.

Summary of 78/GC07 suite (5 samples).

The sample suite from 78/GC07 is similar throughout: coarse sand-size carbonate fragments, forams and mineral fragments are present in approximately equal proportions, along with varying amounts of nannofossil mud. Rock/mineral fragments are tabular to equant in shape, and angular, indicating minimal transport and rapid deposition. Size sorting (in the coarse fraction) is good but overall size distribution is bimodal.

APPENDIX 5: THIN SECTION DESCRIPTIONS - WEST TASMANIA BMR CRUISE 78.

by

E. Anne Felton

78/DR02A(1): Quartz-muscovite (-biotite) schist

Quartz and rare plagioclase (? oligoclase) up to 1 mm diameter form porphyroblasts in a groundmass of granulated quartz, muscovite and redbrown biotite. Porphyroblasts have an 'eye' texture, with the ends being granulated during deformation of the rock. Two foliations are present; porphyroblasts are being rotated into the second foliation from an orientation with long axes parallel to first.

Fabric is that of a metamorphic tectonite. Minor opaques are present. Identification of groundmass minerals is difficult due to thick section (second order interference colours in quartz) but epidote may be present.

On the basis of composition and texture, a porphyritic felsic volcanic or poorly sorted quartz arenite are suggested as possible precursors of this tectonite.

78/DR02A(2): Quartz-muscovite (-biotite) schist.

This sample is slightly more weathered than in (1) but is similar in composition and texture. The differentiated layering (mica-rich and quartz-rich) forming the tectonite fabric is better developed in this sample. Biotite is greenish-brown in colour.

Thick section.

78/DR02B: Crenulated quartz-muscovite schist

The rock consists almost entirely of granulated quartz and muscovite, with common scattered opaques. Occasional quartz porphyroblasts to 0.5mm are almost completely granulated. The rock is strongly foliated with a closely spaced differentiated layering and crenulated (two S surfaces). The crenulation cleavage planes are subparallel and slightly wavy.

A possible precursor is a finegrained quartz arenite.

Thick section.

78/DR05A(1): Bioturbated siltstone

Rock consists of very fine quartz silt and clay. Texture is quite even, with a well-sorted quartz fraction; occasional patches lack quartz. These patches are round to elongated and probably represent burrows. No lamination is present.

The rock is uniformly brown in colour and contains much finely disseminated organic matter.

Complete mixing by bioturbation is inferred.

78/DR05A(2): Bioturbated siltstone

This sample is similar to (1) above, but contains coarser silt grains and fewer burrows. Iron staining along a network of small fractures is present on one side of the thin section.

APPENDIX 6 : PALYNOLOGICAL ANALYSIS OF SAMPLES FROM THE OFFSHORE OTWAY BASIN AND WEST TASMANIAN MARGIN

M.K. Macphail

Consultant palynologist, 20 Abbey Street, Gladesville, NSW 2111

INTRODUCTION

In 1985, the Division of Marine Sciences and Petroleum Geology, Bureau of Mineral Resources, Canberra, commenced a program aimed at increasing knowledge of the geology and resource potential of the offshore Otway Basin and continental shelf and slope off western Tasmanian. This research program included extensive sampling of rocks and soft sediments on the sea-floor [Hinz et al., 1986; Exon, Lee et al., 1989; Exon, Lee & Hill, this volume].

Thirteen samples of mud and hard rock, recovered by dredge and piston coring during BMR surveys (67 & 78) and processed by BMR, as listed in Table 1, were examined for spore-pollen and dinoflagellates.

TABLE 1 : STATION DATA FOR PALYNOLOGICAL SAMPLES

A. 1987 BMR Cruise 67 : Otway Basin/West Tasmania

67 DR3/1 (MFP 8868). Dredge at 38°14.3'S, 138°37.2'E, 4000-4500m. Dark brownish grey indurated siltstone. Half of dredge haul.

67 DR3/2A (MFP 8869). Dredge at 38°14.3'S, 138°37.2'E, WD4000-4500m. Dark brown plastic mud of silt size. Common in dredge haul.

67 DR4/2A (MFP 8870). Dredge at 38°25.5'S, 138°51.0'E, WD4050-4700 m. Laminated, burrowed medium grey-brown mudstone. Minor in dredge haul.

67 DR6/A (MFP 8866). Dredge at 38°46.0'S, 139.9.0'E, WD4450-4660 m. Black non-fissile mudstone. Small pieces in dredge haul.

67-DR8 (MFP8865). Dredge at 39°02.0'S, 140°02.0'E, WD4050-4350 m. Dark brown mud and soft mudstone. Limited quantity in small dredge haul.

67 DR21/2 (MFP8872). Dredge at 40°50.0'S, 141°47.5'E, WD4155-4580 m. Thinly well-bedded, fine-grained carbonaceous micaceous clayey sandstone with mudclasts and clay lenses. Minor part of moderate dredge haul.

67 DR22/2 (MFP8871). Dredge at 42° 41.35'S, 143°43.2'E, WD3900-4200 m. Tough dark grey mud. Most of small recovery of semilithified material.

67GC 09CC (MFP8867). Core at 38°57.1'S, 146°06.6'E, WD3615 m, Core catcher, at 203-213 cm depth, of firm brown mud.

67GC 12CC (MFP 8864). Core at 38°42.6'S, 140°07.1'E, WD3150 m.

B. 1988 BMR Cruise 78 : West Tasmania

78GC 05A (MFP 9125). Core at 42°50.1 'S, 143°51.1'E, WD3530 m.
Grey mudstone at 48 cm in core.

78GC 05/CC (MFP 9126). Core at 42° 50.1'S, 143° 51.5'E, WD 3530 m.
Dark grey mudstone in core catcher at 50-60 cm depth. (Same core as 78GC 05A).

78DR 06A (MFP 9124). Dredge at 43°36.2'S, 144°11.8'E, WD 3760-3915 m. Dark grey mudstone.

78DR 09B (MFP9123). Dredge at 42° 50.0'S, 143°49.7'E, WD 3700-4370 m. Grey mudstone.

Yields and preservation were adequate to good, but the confidence of many age-determinations was reduced by either or both reworking [see Geological Comments] and poor slide preparation [see Biostratigraphic Comments].

Palynological age-determinations and interpreted palaeoenvironments of deposition are summarized below (Table 2). Full interpretative data for each sample are given in Annex 1.

TABLE 2 : SUMMARY OF RESULTS

SAMPLE	AGE	ZONE SPORE-POLLEN	ZONE DINOFLAGELLATE	ENVIRONMENT
67GC12CC	Middle Eocene	Lower N. asperus	T. pandus	open marine
67DR08	Late Santonian-Early Campanian	Upper T. apoxyexinus	N. aceras	restricted-open marine
67DR06A	Early Eocene	Lower M. diversus	-	marginal marine
67GC09CC	Middle Eocene?	Lower N. asperus?	T. pandus	marginal marine
67DR3/1	Campanian	T. lilliei	O. porifera Int.	marginal marine
67DR03/2	Early Eocene	P. asperopolus	W. edwardsii?	marginal marine
67DR04/2A	Campanian	T. lilliei	I. korojongense	marginal marine
67DR22/2	Maastrichtian	Upper T. longus	M. druggii	restricted-marginal marine
67DR21/2	Maastrichtian	Lower T. longus	-	marginal marine
78DR09B	Paleocene	Lower L. balmei	E. crassitabulata	restricted marine
78DR06A	Santonian	T. apoxyexinus	O. porifera Int.	marginal marine
78GC05A	Early Eocene	Lower M. diversus	-	marginal marine
78GC05CC	Early Eocene	Upper M. diversus	-	marginal marine

GEOLOGICAL COMMENTS

1. All samples were deposited in marine-influenced depositional environments, ranging from marginal to fully open marine.

2. The oldest sample recorded [78 DR 06A] is Santonian, T. apoxyexinus Zone, similar in age to the earliest recorded marine influence in the Gippsland Basin [Macphail, 1984; Marshall, 1988]. The depositional environment [marginal marine] interpreted for this and the other Late Cretaceous samples examined in this report are broadly consistent with Late Cretaceous shoreline developments [Frakes et al., 1987] and patterns of sedimentation [Deighton et al., 1976] during the Late Cretaceous evolution of the Southern Ocean.

   Irrespective of the dinoflagellate yield, it is noted that all of the Early Tertiary samples contained abundant spore-pollen, a characteristic of marginal marine palynofloras. This implies that the sediments were, in fact, deposited in near-shore or lagoonal environments and therefore that these localities have since undergone massive subsidence since the Early Tertiary. The only unequivocal Middle Tertiary sample [67 GC 12 CC] yielded a diverse dinoflagellate assemblage indicative of open marine conditions.

3. Several samples contained distinctive dinoflagellate assemblages which should allow the rock units to be correlated with sections/marine transgressions elsewhere, particularly in the Otway and Gippsland Basins. These are (i) 67 GC 12 CC [ms T. pandus Zone]; 67 DR 08 [Paaratte Fm, Whelk-1, Otway Basin]; 67 DR 03/2 [W. edwardsii/W. thompsonae Zone]; 67 DR 22/2 [M. druggii Zone]; and 67 DR 21/2 [? Haumuri Bluff section, N.Z.].

4. A comparision of spore-pollen assemblages analysed here, and those of equivalent age in the Gippsland Basin, reveals both qualitative and quantitative differences. The former is most clearly expressed in the Tertiary samples, most of which contain species or varieties which are not recorded in the Gippsland Basin. This probably reflects increasing regionalization of the Southern Australian flora and vegetation during the Tertiary. Examples of quantitative differences, chiefly expressed in the relative abundance of the more common species found in both basins, are the sparsity of Lygistepollenites balmei and Gambierina rudata in Late Paleocene and Maastrichtian assemblages from Otway/west Tasmanian margin.

   The point is of geologic as well as biogeographic interest, since it underscores the need for caution when applying spore-pollen zonation criteria from one basin to another. Dinoflagellate floras are less provincial and thus are a more reliable basis for inter-basin comparisons.

BIOSTRATIGRAPHIC COMMENTS

A. Zonation

The sparse range data published by Harris (1971), pre-date the extensive drilling of the Bass Strait Basins and the revisions of planktonic foraminiferal zonation schema widely used to tie palynological zones to the geologic time scale.

Accordingly, zone and age-determinations have been made using criteria proposed by Stover & Partridge (1973), Helby *et al*. (1987), and unpublished observations made on Gippsland and Otway Basin wells drilled by Esso Australia Ltd. The informal subdivision of the *T. longus* Zone proposed by Macphail (1983: see Helby et al., ibid p.58) is followed here. Zone names have not been altered to conform with nomenclatural changes to nominate species such as *Tricolpites longus* [now *Forcipites longus*: see Dettman & Jarzen, 1988].

A recurrent problem with marine-influenced facies is reworking of older palynomorphs into younger sediments. Moreover, where depositional rates are very low, a condensed section will develop, e.g. at the base of a highstand systems tract. In such units, it is not uncommon for species whose ranges do not overlap in geologic time to occur in the same sample, or for the geologic age of a sediment based on spore- pollen to differ [usually be older] from the age indicated by dinoflagellates.

The approach adopted here is to base age-determination on dinoflagellates when these indicate a younger date than do the spore-pollen, e.g. samples 67 GC 12 CC and 67 GC 09 CC [both yielding Middle Eocene dinoflagellates and Early Eocene spore-pollen assemblages]. It is noted that the age- determination may reflect the latest episode of *in situ* reworking rather than any accumulation of additional clastic sediments. The converse situation, where spore-pollen indicates an age that is younger than do the dinoflagellates, has to be decided on an individual basis. Where the dinoflagellate flora is substantially older than the spore- pollen flora [usually Late Cretaceous versus Eocene], reworking of the dinoflagellates almost certainly has occurred. Where no great disparity in age exists, a condensed section is indicated, e.g. sample 67 DR 06A. The one exception in this report is sample 78 DR 09B, dated as Paleocene despite the occurrence of the Middle-Late Tertiary species *Nothofagidites falcatus*. Here, contamination or minor bioturbation is proposed.

Interpretation of Palaeoenvironments

The reconstruction of depositional conditions using palynology depends on the presence/absence of marine dinoflagellate species and subjective estimates of (i) the absolute concentration of palynomorphs in the rock sample (ii) the relative abundance of spore-pollen and dinoflagellates, and (iii) the diversity of dinoflagellate species. Algal species diagnostic of freshwater lacustrine conditions were not recorded.

The criteria broadly adopted here are:

(a) Open marine - dinoflagellates diverse and very abundant relative to spore-pollen [often wind-pollinated pollen and water-transported spore types].

(b) Restricted marine - dinoflagellates diverse, approximately equal in abundance relative to spore-pollen.

(c) Marginal marine - dinoflagellates sparse relative to spore-pollen or, if abundant, then 1-3 species present only.

Processing

The majority of strew-mounts contained very abundant plant macerals, mostly ranging from less than 1 micron to less than 100 microns in diameter, but usually clumped with spore-pollen into larger aggregrates.

This has reduced the confidence of the age-determinations since many palynomorphs were too obscured by structured organic matter to be identified - leading to an incomplete analysis of species present. Good concentration and dispersal of palynomorphs within a strew-mount is critical when the index species are small [less than 20 microns], e.g. the Early-Middle Eocene dinoflagellate genus Tritonites.

REFERENCES

DETTMAN, M.E. & JARZEN, D.M. (1988), Angiosperm pollen from uppermost Cretaceous strata of southeastern Australia and the Antarctic Peninsula. Memoir Association Australasian Palaeontologists, 5, 217-237.

DEIGHTON, I., FALVEY, D.A. & TAYLOR, D.J. (1976), Depositional environments and geotectonic framework: Southern Australian continental margin. APEA Journal 16, 25-36.

EXON, N.F., LEE, C.S., & Shipboard Party (1989), Bureau of Mineral Resources Research Cruise 67 : Otway basin and west Tasmania sampling. Bureau of Mineral Resources Report 285.

FRAKES, L.A. & OTHERS (1987). Australian Cretaceous shorelines, stage by stage. Palaeogeography, Palaeoclimatology, Palaeoecology 59, 31-48.

HARRIS, W.K. (1971), Tertiary stratigraphic palynology, Otway Basin. In Wopfner, H. & Douglas, J.G. (Eds.). THE OTWAY BASIN OF SOUTHEASTERN AUSTRALIA. Special Bulletin geological Survey. South Australia & Victoria, pp.67-87.

HELBY, R., MORGAN, R. & PARTRIDGE, A.D. (1987). A palynological zonation of the Australian Mesozoic. Memoir Association Australasian Palaeontologists, 4, 1-94.

HINZ, K. & OTHERS (1986), The west Tasmanian margin: an under-rated petroleum province?. In: Glenie, R.C. (Ed.) : SECOND SOUTH-EASTERN AUSTRALIA OIL EXPLORATION SYMPOSIUM, Melbourne. Petroleum Exploration Society of Australia, pp. 395-409.

MACPHAIL, M.K. (1983), Revision of the *T. longus* Zone based on analyses from Hapuku-1 and Pilotfish-1A wells. Esso Australia Ltd. Palaeontological Report 1983/19B.

MACPHAIL, M.K. (1984), Freshwater and marginal marine rocks of *T. apoxyexinus* Zone (Santonian) age in the Tuna-4 well, Gippsland Basin. Esso Australia Ltd. Palaeontological Report 1984/5 [unpubl.].

MARSHALL, N.G. (1988), A Santonian dinoflagellate assemblage from the Gippsland Basin, southeastern Australia. Memoir Association Australasian Palaeontologists, 5, 195-215.

PARTRIDGE, A.D. (1976), The geological expression of eustacy in the Early Tertiary of the Gippsland Basin. APEA Journal 16(1), 73-79.

STOVER, L.E. & PARTRIDGE, A.D. (1973), Tertiary and Late Cretaceous spores and pollen from the Gippsland Basin, Southeastern Australia. Proceedings Royal Society Victoria, 85, 237-286.

ANNEX 1 : INTERPRETATIVE DATA FOR ALL SAMPLES

CLIENT ID: N. Exon, BMR   DATE: 7/2/89   RECORD NO: 01

1. BASIN: Otway   WELL/LOCALITY: offshore WLT 3504

2. SAMPLE NO: 67 GC 12 CC   TYPE: core catcher   DEPTH: sea-floor WD 3150m
   LITHOLOGY: carb. mudstone   YIELD: high   PRESERVATION: good
   STREW MOUNT CODE: MFP 8864   NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE:	Middle Eocene	
ZONE [SPORE-POLLEN]:	Lower *N. asperus*	CONFID. RATING:* 2
ZONE [DINOFLAGELLATE]	*T. pandus* (informal)	CONFID. RATING:* 0

INDEX SPP: *Tritonites pandus*, *T. tricornus*

4. AGE RANGE

MAXIMUM AGE: Foram Zone P.14   based on: *T. Pandus*, absence of *T. spinosus*

MINIMUM AGE: Foram Zone P.10   based on: *T. tricornus*, absence of *T. asteris*

5. RECYCLED SPP: *Isabelidinium korojongense* [Late Cretaceous], *Veryhachium* sp [Mesozoic]

6. PALAEOENVIRONMENT: Open marine

7. REFERENCES: Marshall, N.G. & Partridge, A.D. (1988). *Mem. Ass. Australas. Palaeontols.*, 5: 239-257.

8. COMMENTS: The date is wholly based on the presence/absence of *Tritonites* spp. The associated spore-pollen is Early Eocene, Upper *M. diversus*-*P. asperopolus* Zone in age, based on *Deflandrea truncata*, *Myrtaceidites tenuis* and *Tricolporites leuros*. This indicates that the sample is a condensed sequence, probably coeval with the Gurnard Formation in Marlin Field wells and the middle section of the Turrum Formation in the central Marlin Channel, Gippsland Basin. *Tritonites pandus* occurs at 392.5m, and *T. tricornus* at 422.1 & 435.3m in Whelk-1, Otway Basin [see Marshall & Partridge *ibid*, pp. 241-242.]

* Note : Based on the Esso system of confidence ratings in which the highest rating is 0 and the lowest, for conventional core, SWC and outcrop, is 2.

CLIENT ID: N. Exon; BMR DATE: 7/2/89 RECORD NO: 02

1. BASIN: Otway WELL/LOCALITY: offshore WLT 3505

2. SAMPLE NO: OT 67 DR 08 TYPE: dredge DEPTH: sea-floor WD 4050+m
LITHOLOGY: mud/mudstone YIELD: high PRESERVATION: good
STREW MOUNT CODE: MFP 8865 NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE:	Late Santonian-Early Campanian		
ZONE [SPORE-POLLEN]:	Upper *T. apoxyexinus*	CONFID. RATING:	2
ZONE [DINOFLAGELLATE]	*N. aceras*	CONFID. RATING:	1

INDEX SPP: *T. apoxyexinus*, *Forcipites spp.*, *T. confessus*, *Camarozonosporites bullatus*, *Phimopollenites pannosus*, *Isabelidinium cretaceum*, *Nelsoniella truncata*, *Heterosphaeridium heterocanthum*, *Odontochitona porifera* [common]

4. AGE RANGE

MAXIMUM AGE: latest Santonian earliest Campanian — based on: *N. tuberculata*, *O. porifera* to

MINIMUM AGE: middle-late Campanian — based on: *Stereisporites regium* ms. *Phimopollenites pannosus*

5. RECYCLED SPP: Mostly Early Cretaceous spp., including *Dictyotosporites speciosus*, *Dictyophyllidites crenatus*.

6. PALAEOENVIRONMENT: Open to restricted marine

7. REFERENCES: Helby, R., Morgan, R. & Partridge, A.D. (1987) p.66. *Mem. Ass. Australas. Palaeontols.*, 4: 1-94

8. COMMENTS: Dinoflagellate spp. dominate the sample, particularly *Odontochitona porifera* and *Heterosphaeridium heterocanthum*. Although neither *Nothofagidites* nor *Xenikoon australis* were recorded, the sample may be lowermost *N. senectus* Zone. The reference section of the *N. aceras* Zone is Whelk-1 1096-1208m [Paaratte Formation].

CLIENT ID: N. Exon, BMR　　DATE: 7/2/89　　RECORD NO: 03

1. BASIN: Otway　　WELL/LOCALITY: offshore WLT 3505

2. SAMPLE NO: OT 67 DR 06A　　TYPE: dredge　　DEPTH: sea-floor WD 4450+m
LITHOLOGY: black mudstone　　YIELD: high　　PRESERVATION: good
STREW MOUNT CODE: MFP 8866　　NO. OF MOUNTS WORKED: 1

3. AGE DETERMINATION

GEOLOGIC AGE:	Early Eocene	
ZONE [SPORE-POLLEN]:	Lower M. diversus	CONFID. RATING: 2
ZONE [DINOFLAGELLATE]	-	CONFID. RATING: -

INDEX SPP: Cyathidites gigantis, Camarozonosporites bullatus, Intratriporopollenites notabilis, Deflandrea obliquipes, Cordosphaeridium inodes [freq.],

4. AGE RANGE

MAXIMUM AGE: Late Paleocene　　based on: L. balmei, G. rudata, C. gigantis, P. incurvatus, A. obscurus
MINIMUM AGE: Early Eocene　　based on: C. gigantis, D. obliquipes

5. RECYCLED SPP: Odontochitona porifera. Possible recycled spp. are L. balmei, G.rudata; probable recycled spp. include Tetracolporites verrucosus, Isabelidinium cf bakeri and an undescribed Alisocysta sp.

6. PALAEOENVIRONMENT: Marginal marine.

7. REFERENCES:

8. COMMENTS: It is possible that this sample represents a condensed section rather than an Early Eocene sediment containing reworked Late Paleocene spp.

CLIENT ID: N. Exon, BMR DATE: 7/2/89 RECORD NO: 04

1. BASIN: Otway WELL/LOCALITY: offshore WLT 3506

2. SAMPLE NO: 67 GC 09 CC TYPE: core catcher DEPTH: sea-floor WD 3615m
LITHOLOGY: YIELD: high PRESERVATION: poor
STREW MOUNT CODE: MFP 8867 NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE: Middle Eocene or Campanian reworked during the Middle Eocene

ZONE [SPORE-POLLEN]: Lower N. asperus (T. lilliei] CONFID. RATING: 2
ZONE [DINOFLAGELLATE] T.pandus (informal)[I.koroj.] CONFID. RATING: 2

INDEX SPP: Anacolosidites rotundus ms, Tritonites tricornus [Tricolporites lilliei, Isabelidinium korojongense]

4. AGE RANGE

MAXIMUM AGE: T. lilliei based on: T. lilliei, I. korojongense

MINIMUM AGE: Lower N. asperus based on: T. tricornus

5. RECYCLED SPP: Nelsoniella cf tuberculata, Heterosphaeridium heterocanthum Gambierina spp., Myrtaceidites tenuis, Cyatheacidites tectifera, Ornamentifera sentosa, Tetracolporites verrucosus

6. PALAEOENVIRONMENT: Marginal marine.

7. REFERENCES:

8. COMMENTS: This sample contains a diverse palynoflora, dominated by spore-pollen taxa which include index spp. from the Late Cretaceous, I. korojongense Zone, Paleocene, L. balmei Zone and Early Eocene, Upper M. diversus-P. asperopolus Zone. Either extensive reworking or a highly condensed sequence is suggested.

CLIENT ID: N. Exon, BMR DATE: 7/2/89 RECORD NO: 05

1. BASIN: Otway WELL/LOCALITY: offshore WLT 3506

2. SAMPLE NO: OT 67 DR 3/1 TYPE: dredge DEPTH: sea-floor WD 4000+m
LITHOLOGY: siltstone YIELD: high PRESERVATION: fair
STREW MOUNT CODE: MFP 8868 NO. OF MOUNTS WORKED: 1

3. AGE DETERMINATION

GEOLOGIC AGE:	Campanian	
ZONE [SPORE-POLLEN]:	T. lilliei	CONFID. RATING: 2
ZONE [DINOFLAGELLATE]	O. porifera Interval	CONFID. RATING: 1

INDEX SPP: Tricolporites lilliei, Triporopollenites megasectilis ms, Tetracolporites verrucosus, Stereisporites regium ms, Grapnelispora sp. nov., Ornamentifera sentosa, Odontochitona porifera.

4. AGE RANGE

MAXIMUM AGE: Maastrichtian based on: T. verrucosus, Grapnelispora sp.

MINIMUM AGE: Campanian based on: T. lilliei, T. megasectilis ms

5. RECYCLED SPP: Early Cretaceous spp. such as Dictyotosporites speciosus, Classopollis sp. Cyatheacidites tectifera may be reworked.

6. PALAEOENVIRONMENT: Marginal marine.

7. REFERENCES:

8. COMMENTS: The confidence of the age-determination is reduced by the presence of Tricolpites phillipii and Cyatheacidites tectifera. The former species first appears in the T. longus Zone and the latter may range no higher than the T. apoxyexinus Zone.

CLIENT ID: N. Exon, BMR DATE: 7/2/89 RECORD NO: 06

1. BASIN: Otway WELL/LOCALITY: offshore WLT 3507

2. SAMPLE NO: OT 67 DR 03/2A TYPE: dredge DEPTH: sea-floor WD 4000+m
LITHOLOGY: silt mud YIELD: high PRESERVATION: good
STREW MOUNT CODE: MFP 8869 NO. OF MOUNTS WORKED: 1

3. AGE DETERMINATION

GEOLOGIC AGE:	Early Eocene	
ZONE [SPORE-POLLEN]:	P. asperopolus	CONFID. RATING: 1
ZONE [DINOFLAGELLATE]	W. edwardsii?	CONFID. RATING: 2

INDEX SPP: Myrtaceidites tenuis [abundant], Tricolporites leuros, Proteacidites pachypolus [freq.], P. ornatus, Intratriporopollenites notabilis, Wilsonidinium spp., Kisselovia sp. nov.

4. AGE RANGE

MAXIMUM AGE:	Upper M. diversus	based on:	Wilsonidinium, Kisselovia spp. M. tenuis, P. pachypolus
MINIMUM AGE:	P. asperopolus	based on:	T. leuros, P. ornatus, I. notabilis

5. RECYCLED SPP: Lygistepollenites balmei, Gambierina rudata, Deflandrea truncata

6. PALAEOENVIRONMENT: Marginal marine.

7. REFERENCES: Wilson, G.J. (1967) N.Z. J. Botany, 5: 469-97.
Partridge, A.D. (1976) APEA J., 16: 73-79.

8. COMMENTS: The Wilsonidinium (al. Wetzeliella) spp. in this sample more closely resemble the N.Z. species W. tabulatum and W. articulata than any described Australian spp. The Kisselovia sp. is distinct from any described species, but is likely to be contemporary with K. edwardsii and K. thompsonae/coleothrypta.

CLIENT ID: N. Exon, BMR DATE: 7/2/89 RECORD NO: 07

1. BASIN: Otway WELL/LOCALITY: offshore WLT 3507m

2. SAMPLE NO: OT 67 DR 04/2A TYPE: dredge DEPTH: sea-floor WD 4050+m
LITHOLOGY: lam., burrowed mudstone YIELD: low PRESERVATION: poor
STREW MOUNT CODE: MFP 8870 NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE: Campanian
ZONE [SPORE-POLLEN]: *T. lilliei* CONFID. RATING: 1
ZONE [DINOFLAGELLATE] *I. korojongense* CONFID. RATING: 0

INDEX SPP: *Tricolporites lilliei*, *Tricolpites waiparensis*, *Proteacidites wahooensis* ms, *Isabelidinium pellucidum*

4. AGE RANGE

MAXIMUM AGE: Campanian based on: *T. lilliei*, *I. pellucidum*

MINIMUM AGE: Maastrichtian based on: *I. pellucidum*

5. RECYCLED SPP: none noted

6. PALAEOENVIRONMENT: Marginal marine.

7. REFERENCES:

8. COMMENTS: The negligible recovery of dinoflagellates is consistent with deposition in a low energy environment subject to a low degree of marine influence.

CLIENT ID: N. Exon, BMR   DATE: 7/2/89   RECORD NO: 08

1. BASIN: Otway   WELL/LOCALITY: offshore WLT 3508

2. SAMPLE NO: OT 67 DR 22/2   TYPE: dredge   DEPTH: sea-floor WD 3900+m
LITHOLOGY: similith. mud   YIELD: high   PRESERVATION: fair
STREW MOUNT CODE: MFP 8871   NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE:	Maastrichtian	
ZONE [SPORE-POLLEN]:	Upper *T. longus*	CONFID. RATING: 1
ZONE [DINOFLAGELLATE]	*M. druggii*	CONFID. RATING: 0

INDEX SPP: *Ornamentifera sentosa*, *Tricolporites lilliei*, *Stereisporites* (*Tripunctisporis*) sp., *Mamumiella druggii* [abundant].

4. AGE RANGE

MAXIMUM AGE: Upper *T. longus*   based on: *M. druggii*, *Stereisporites* (*Tripunctisporis*) sp.

MINIMUM AGE: as above   based on: as above

5. RECYCLED SPP: *Isabelidinium ponticum*?

6. PALAEOENVIRONMENT: Restricted marginal marine

7. REFERENCES:

8. COMMENTS: Despite the abundance of *M. druggii*, other dinoflagellate species are rare, indicating a restricted/marginal rather than open marine depositional environment. Analogous modern dinoflagellate 'blooms' occur at the mouths of rivers entering estuaries or in restricted seaways such as the Red Sea.

Based on Gippsland Basin seismic stratigraphy, the sample is likely to come from a condensed section close to, but below, the Cretaceous/Tertiary boundary.

CLIENT ID: N. Exon, BMR DATE: 7/2/89 RECORD NO: 09

1. BASIN: Otway WELL/LOCALITY: offshore WLT 3508

2. SAMPLE NO: OT 67 DR 21/2 TYPE: dredge DEPTH: sea-floor WD 4155+m
LITHOLOGY: lam., carb., ss. YIELD: low PRESERVATION: good
STREW MOUNT CODE: MFP 8872 NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE:	Maastrichtian	
ZONE [SPORE-POLLEN]:	Lower T. longus	CONFID. RATING: 2
ZONE [DINOFLAGELLATE]	-	CONFID. RATING: -

INDEX SPP: Forcipites sabulosus, Triporopollenites sectilis, Gambierina spp. [freq.], Odontochitona spinosa [freq.], I. cf fenestrata ms

4. AGE RANGE

MAXIMUM AGE: Campanian based on: T. sectilis

MINIMUM AGE: Maastrichtian based on: F. sabulosus, O. spinosa

5. RECYCLED SPP: Early Cretaceous spp. including Dictyotosporites complex, D. speciosus.

6. PALAEOENVIRONMENT: Marginal marine

7. REFERENCES: Wilson, G.J. (1984). N.Z. J. Botany, 22: 549-556

8. COMMENTS: The age-determination is based on Wilson ibid, who has recorded a population of O. spinosa in Maastrichtian sediments in New Zealand, and Forcipites sabulosus, which ranges no higher than the Lower T. longus zone. The similarity of the assemblage to that described by Wilson is reinforced by the occurrence of a Microdinium sp. cf M. cassiculatum.

As with sample OT 67 DR 04/2A [Campanian], the marine-influence, at the time of deposition of this sediment in a low energy environment, was slight.

CLIENT ID: N. Exon, BMR | DATE: 7/2/89 | RECORD NO: 10

1. BASIN: Otway — WELL/LOCALITY: offshore WLT 3530.

2. SAMPLE NO: 78 DR 09B — TYPE: dredge — DEPTH: sea-floor WD 3700+m
LITHOLOGY: grey mudstone — YIELD: high — PRESERVATION: fair
STREW MOUNT CODE: MFP 9123 — NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE:	Paleocene	
ZONE [SPORE-POLLEN]:	Lower L. balmei	CONFID. RATING: 1
ZONE [DINOFLAGELLATE]	E. crassitabulata	CONFID. RATING: 0

INDEX SPP: Eisenackia crassitabulata, Paleocystodinium golzowense, Deflanderea medcalfii/dartmooria, Glaphracysta retiintexta Haloragacidites harrisii, Tetracolporites multistrixus ms

4. AGE RANGE

MAXIMUM AGE: Early Paleocene — based on: E. crassitabulata

MINIMUM AGE: Late Paleocene — based on: Lygistepollenites balmei, Gambierina rudata.

5. RECYCLED SPP: taeniate bisaccate [Permian]

6. PALAEOENVIRONMENT: Restricted marine based on the relative abundance of spore-pollen [very high] to dinoflagellates [high].

7. REFERENCES:

8. COMMENTS: A single specimen of the Middle Eocene-Pliocene species Nothofagidites falcatus was recorded. This is more likely to be a contaminant [introduced via bioturbation?] than indicating any significant reworking of a Paleocene sediment during the Late Tertiary.

CLIENT ID: N. Exon, BMR   DATE: 7/2/89   RECORD NO: 11

1. BASIN: Otway   **WELL/LOCALITY**: offshore WLT 3530

2. SAMPLE NO: 78 DR 06A   TYPE: dredge   DEPTH: sea-floor WD 3760+m
LITHOLOGY: grey mudstone   YIELD: low   PRESERVATION: fair
STREW MOUNT CODE: MFP 9124   NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE:	Santonian	
ZONE [SPORE-POLLEN]:	*T. apoxyexinus*	CONFID. RATING: 2
ZONE [DINOFLAGELLATE]	*O. porifera*	CONFID. RATING: 1

INDEX SPP: *Cyatheacidites tectifera*, *Forcipites* cf *stipulatus*, *Amosopollis cruciformis* [freq.], *Odontochitona porifera*, **Chatangiella tripartita*, *Heterosphaeridium heterocanthum*

4. AGE RANGE

MAXIMUM AGE:	Santonian	based on:	*C. tectifera*, *O. porifera*, **C. tripartita*
MINIMUM AGE:	Campanian	based on:	possible occurrence of *Isabelidinium korojongense*

5. RECYCLED SPP: none noted

6. PALAEOENVIRONMENT: Marginal marine

7. REFERENCES:

8. COMMENTS: *Some uncertainty exists about the identification of *Chatangiella tripartita*. The majority of specimens are intermediate between this species and *Isabelidium korojongense*.
The presence of *Cyatheacidites tectifera* is more consistent with a Santonian rather than a Campanian date, as is a possible specimen of *Hoegisporis* and the absence of distinctive Late Cretaceous *Proteacidites*, *Tricolpites* and *Tricolporites* spp.

CLIENT ID: N. Exon, BMR   DATE: 7/2/89   RECORD NO: 12

1. BASIN: Otway   WELL/LOCALITY: offshore WLT 3531

2. SAMPLE NO: 78 GC 05A   TYPE: core catcher   DEPTH: sea-floor WD 3530m.
LITHOLOGY: grey mudstone   YIELD: high   PRESERVATION: fair
STREW MOUNT CODE: MFP 9125   NO. OF MOUNTS WORKED: 2

3. AGE DETERMINATION

GEOLOGIC AGE:	Early Eocene	
ZONE [SPORE-POLLEN]:	Lower *M. diversus*	CONFID. RATING: 2
ZONE [DINOFLAGELLATE]	-	CONFID. RATING: -

INDEX SPP: *Deflandrea dartmooria*, *Cyathidites gigantis*, *Bysmapollis emaciatus*, *Proteacidites grandis* [freq.].

4. AGE RANGE

MAXIMUM AGE: Late Paleocene   based on: *Lygistepollenites balmei*, *Proteacidites incurvatus*

MINIMUM AGE: Early Eocene   based on: *C. gigantis*, *D. dartmooria*

5. RECYCLED SPP: Late Cretaceous spp. including *Appendicisporites distocarinatus*; Early Cretaceous spp. including *Pilosisporites notensis*, *Trilobosporites tribotrys* and *Dictyotosporites speciosus*; and Permo-Triassic taxa including *Plicatpollenites* spp.

6. PALAEOENVIRONMENT: Marginal marine.

7. REFERENCES:

8. COMMENTS: The dinoflagellate flora includes *Samlandia reticulifera*, a species ranging up to [restricted to?] the Late Eocene. What weight should be attached to this record is unclear since no other Middle-Late Eocene dinoflagellate species were recorded.

The Early Eocene, Lower *M. diversus* Zone age for this core sample is inconsistent with an Upper *M. diversus* Zone age for sediments some 2 cm lower in the same core. The samples may have been mis-labelled, or there may have been contamination of the lowermost material (in the core catcher) during withdrawal from the sediment.

CLIENT ID: N. Exon, BMR   DATE: 7/2/89   RECORD NO: 13

1. BASIN: Otway   WELL/LOCALITY: offshore WLT 3531

2. SAMPLE NO: 78 GC 05 CC   TYPE: core catcher   DEPTH: sea-floor WD 3530m 3530m
LITHOLOGY: grey mudstone   YIELD: low   PRESERVATION: poor
STREW MOUNT CODE: MFP 9126   NO. OF MOUNTS WORKED: 1

3. AGE DETERMINATION

GEOLOGIC AGE: Early Eocene
ZONE [SPORE-POLLEN]: Upper M. diversus   CONFID. RATING: 2
ZONE [DINOFLAGELLATE] -   CONFID. RATING: -

INDEX SPP: Deflandrea flounderensis, D. truncata, Dryptopollenites semilunatus

4. AGE RANGE

MAXIMUM AGE: Paleocene   based on: Proteacidites grandis, Palaeocystodinium golzowense
MINIMUM AGE: Early Eocene   based on: D. truncata

5. RECYCLED SPP: Dictyotosporites speciosus

6. PALAEOENVIRONMENT: Marginal marine

7. REFERENCES:

8. COMMENTS: Sample badly under-oxidized, leading to clumping and obscuring of virtually all of the palynomorphs by plant macerals. No comprehensive listing of the species present was possible. As noted under comments on sample 78 GC 054, the age-determination is inconsistent with an apparently reliable Lower M. diversus Zone age for sediments some 2cm higher in the same core.