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THE GEOLOGY OF WESTERN TASMANIA AND ITS CONTINENTAL MARGIN - WITH PARTICULAR REFERENCE TO PETROLEUM POTENTIAL

FIELD EXCURSION HANDOUT
1989 APEA CONFERENCE, HOBART

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Australian Bureau of Mineral Resources
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FOREWORD

This BMR Record has been prepared for the 1989 APEA excursion to western Tasmania using numerous publications, open-file data, and preliminary maps made available from on-going projects within BMR. Many of the seismic interpretations and structural maps are currently being updated and refined: they are either in press or will be used by the authors in forthcoming publications. The Division of Marine Geosciences & Petroleum Geology (BMR) has current projects dealing with the west Tasmanian - Otway Basin continental margin and the Strahan Sub-basin, and a joint project with BGR (West Germany) for the South Tasman Rise. The contents of this record are not supposed to be anything but a preliminary account of the results of these projects.

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INTRODUCTION

The excursion will commence in Hobart, from where participants will be transported by air to Strahan on Macquarie Harbour in western Tasmania. The flight will take place over portions of the Southwest National Park, part of the World Heritage listed by UNESCO. The excursion will include a cruise on Macquarie Harbour examining Cainozoic sediments of the Macquarie Harbour Graben, a shallow onshore extension of the Sorell Basin which forms the continental margin of western Tasmania.

The cruise will continue up the Gordon River within the World Heritage area, where limestone sequences of Ordovician and Devonian age crop out beneath dense rainforest cover, a remnant of a formerly widespread Gondwana flora of Tertiary age.

Time permitting, Eocene rocks will be briefly examined near Strahan before the return trip is made to Hobart.

ONSHORE GEOLOGY (by Peter Baillie)

AN INTRODUCTION TO THE GEOLOGY OF TASMANIA

The flights to and from Strahan will enable participants to gain some appreciation of Tasmania's complex geology and geomorphology. The following account is summarised from various sources; a fully-referenced and comprehensive review and discussion may be found in the Geology and Mineral Resources of Tasmania (Burrett & Martin, 1989).

The oldest rocks in Tasmania occur within a core of folded and metamorphosed (Lower greenschist facies) Upper Proterozoic (about 1000 to 600 million years old) metasediments occurring from Port Davey in the far southwest northward to the Central Highlands. The relative resistance of interlayered quartzite and pelitic units within the succession, and the large-scale fold patterns in the rocks, have resulted in the formation of the broadly-arcuate mountain ranges and intervening valleys which characterise much of the southwest.

Other regions of Precambrian rocks occur throughout northwestern and northern Tasmania.

Cambrian rocks (about 600 to 500 Ma) occur as deep elongate basins which formed between and within the areas of Upper Proterozoic rocks. The basins collected sediment shed from the older regions and include siliciclastic, carbonate and basaltic/epiclastic successions. Recent work has indicated that Middle Cambrian serpentinised ultramafic rocks, which occur throughout western Tasmania, may be allochthonous (tectonically transported) relics of a forearc terrane which collided with, and was thrust over, passive continental margin sediments. Small but significant deposits of copper, nickel, osmiridium, chromium and asbestos occur within the serpentinites.

A little later, in Middle and Late Cambrian times, a belt of andesitic volcanoes formed near the western margin of the largest of the sedimentary basins (the Dundas "Trough"). The ensuing pile of lavas and associated epiclastic and sedimentary rocks is known as the Mount Read Volcanics, and contains economically important deposits of a number of minerals (including Au, Ag, Cu, Pb, Zn) throughout the belt. Currently-producing mines, within the Mount Read Volcanics include the Mt Lyell, Rosebery Que River and Hellyer mines, and the Henty gold prospect.

A period of strong basement uplift and erosion, accompanied by large fault movements and probably also by folding, followed the volcanic episode from the end of the Cambrian and continuing into the early Ordovician (about 500 to 480 Ma), when the volcanic deposits were buried by coarse siliciclastic sediments (Owen Conglomerate and correlates) as a series of alluvial fans and marginal marine deposits. These rocks, dominantly conglomerate, now form the spectacular peaks of the West Coast Range, including Mts Strahan, Sorell, Jukes, Owen, Lyell, Sedgwick, Murchison, Roland and the Black Bluff, Tyndall and Denison Ranges.

The Owen Conglomerate and its correlates are succeeded by the

Gordon Group, a dominantly peritidal carbonate succession spanning most of the Ordovician. This limestone succession is up to 2 km in thickness, and occurs widely throughout Tasmania west of a line joining the Tamar and Coal river valleys at localities including the Gordon and Olga rivers in western Tasmania, the Florentine Valley, Ida Bay in southeastern Tasmania, and Mole Creek in northern Tasmania where some of the more spectacular caves have been opened to tourists.

During Silurian and early Devonian times (about 440 to 380 Ma) much of the western half of Tasmania was covered by shallow seas in which deposits of sand, mud and carbonate accumulated.

A period of widespread folding and uplift (broadly correlated with the Tabberrabberan Orogeny of southeastern Australia) was followed by granite intrusion, during Late Devonian and Early Carboniferous times, into the folded sediments and volcanic rocks of the Early Palaeozoic and Upper Proterozoic successions. The formation of numerous mineral deposits took place in association with the granite intrusion, and they include the large tin deposits at Renison Bell and Mt Bischoff, tungsten deposits on King Island and the Kara deposits south of Burnie in northwestern Tasmania, tin-tungsten deposits at numerous localities in northern Tasmania, gold reefs at Beaconsfield and in northeastern Tasmania, and numerous Ag-Pb-Zn deposits on the west coast including the renowned Zeehan field.

Following a long period of erosion, extensive Upper Carboniferous and Lower Permian (about 300 to 270 Ma) glacigene successions were formed in Tasmania (and indeed throughout much of Gondwana). Likely depositional environments include fjords and small ice-shelves. These deposits are time-equivalents of the Cooper Basin hydrocarbon-producing successions.

Throughout the remainder of the Permian (about 270 to 250 Ma), Tasmania was the site of a small intracratonic basin in which glaciomarine and freshwater successions accumulated. Small, oil shale deposits in northern Tasmania (Tasmanites oil shale) probably resulted from local algal blooms.

Triassic rocks (about 250 to 215 Ma) in Tasmania are wholly freshwater in origin and include coal measure successions. Coal has been mined at a number of localities but today production is confined to the Fingal Valley in eastern Tasmania.

During the Jurassic Period, about 165 million years ago, large volumes of dolerite were formed as a result of stresses marking the beginning of the breakup of Gondwana. In Tasmania (and also in the then-adjacent north Victoria Land, Antarctica) the dolerite intrusions spread laterally within the flat-lying Permo-Triassic rocks as they neared the surface, and formed thick (up to 400-500 m), flat-lying sheets or sills, remnants of which cap many Tasmanian mountains and give the island much of its unique physiographic character. Such mountains include Mt Wellington, Ben Lomond and Cradle Mountain.

During the Early Cretaceous (about 150 to 100 Ma) extensional basins began to form around the margin of what is now Tasmania. The resultant basins include the Sorell Basin on the continental margin of western Tasmania, the intracratonic Bass Basin to the north, the unnamed continental margin of eastern Tasmania, and the southern portions of the Otway Basin west of King Island, and the Gippsland Basin east of Flinders Island.

The relationship of the larger basins to shallow onshore extensions of Tertiary age, including the Macquarie Harbour Graben, the Devonport-Port Sorell Sub-basin and the Tamar Trough, is not fully understood.

Movements associated with the late stage development of the basins and their onshore extensions during the Tertiary Period (70 to 2 Ma), together with volcanic activity which produced voluminous basalt lava flows filling troughs and river valleys, finally moulded Tasmania as we find it now. Fine detail was subsequently provided by the physiographic processes which acted during the Quaternary (the last two million years) - glacial and periglacial processes in highland areas, fluvial and aeolian processes in lower regions, and marine processes in coastal areas.

THE MACQUARIE HARBOUR GRABEN

The Sorell 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 sediments, which crop out extensively on the northeast side of Macquarie Harbour, are known as the Macquarie Harbour Beds and consist of a series of semi-consolidated sands and gravels, with bands of clay and lignite, extending from the mouth of the Henty River southwards through Macquarie Harbour to the Wanderer River (Scott, 1960).

Strahan Region

Two distinct microfloral assemblages are present in the Tertiary deposits at Strahan and indicate that the deposits are Eocene and Plio-Pleistocene in age (Forsyth in Baillie & Corbett, 1985).

At the old Mt Lyell Mining & Railway Co wharf immediately southwest of Strahan, well-consolidated and jointed, finely-laminated, thinly-bedded mudstone with abundant plant material and detrital resinite of Eocene age is overlain by a conglomerate-sandstone succession of Plio-Pleistocene age (Baillie & Corbett, 1985). The top of the underlying mudstone succession is leached and is probably a palaeosol.

Coal Head Region

Brown coal was noted on the northern shore of Macquarie Harbour in 1815 by Captain James Kelly, and coal was first reported in the vicinity of Coal Head by G.W. Evans in 1822 (Lempriere, 1842; Bacon inBaillie & Corbett, 1985), The coal, which occurs as thin beds less than 0.5 m in thickness, was mined by convicts sent to the infamous penal settlement at Sarah (Settlement) island which was occupied during the period 1822-33.

A brief description of the geology of the area is given by

Baillie et al. (1986). Two distinct facies are present:
(1) interbedded sandstone and siltstone with minor coal, and
(2) cross-bedded sandstone

Facies 1:
This facies included a variety of lithotypes which include coal, mudstone, siltstone, carbonaceous sandstone and cleaner, often cross-bedded sandstone. Bioturbation is often present, usually in the form of horizontal worm burrows. A continuum from clayey to sandy sediment types is present, and begins with sandy streaks in mud and passes into lenticular, wavy and flaser bedding.

Brown coal occurs as thin beds up to 500 mm in thickness. The coaly bands comprise brown coal and carbonaceous shale with occasional black lignitised wood lenses. Maceral analysis (mineral matter free) of a single specimen indicates that the coal consists of 92% vitrinite and 8% inertinite. The whole specimen contained 24% of minerals, including clay, quartz and pyrite.

The common bioturbation and the abundance of marine dinoflagellates in some beds, together with the presence of flaser bedding, indicate that this facies was deposited in a marginal marine environment such as a tidal flat.

Facies 2:
This facies overlies the previously described sequence, and forms prominent cliffs in the Coal Head area. The facies consists almost entirely of sandstone with large-scale trough cross-bedding (Facies of Miall, 1977). Beds with planar crossbeds are occasionally present. The sand is usually moderately well-sorted and medium-grained to coarse-grained.

The probable environment of deposition was a sandy braidplain in which deposition usually took place from dunes (lower flow regime)

Biostratigraphy:
Palynological analyses (Baillie et al., 1986) of samples from near Coal Head indicate that the sediments belong to the Malvacapollis diversus Zone of the Early Eocene, as they lack younger indicators, contain Tricolpites gilli (limiting them to the middle M. diversus Zone or older), and contain:

Anacolosidites acutullus
Kuylisporites waterbolkii
Lileacidites lanceolatus
Proteacidites clarus
P. kopiensis
P. leightonii
Spinozonocolpities prominatus

all of which limit them to the Middle M. diversus Zone or younger.

PALAEOZOIC ROCKS OF THE GORDON RIVER

Palaeozoic limestones have long been known to crop out as cliffs on the lower reaches of the Gordon River (e.g. Gould, 1866; Judd, 1908) where Ordovician limestone of the Gordon Group is faulted against clastic Eldon Group rocks (including limestone) of Lower Devonian age (Gee et al., 1969). A geological sketch map of the region is shown as Fig. 1.

Gordon Group

Ordovician limestone of the Gordon Group outcrops along the Gordon River, upstream from a point about one kilometre downstream of Eagle Creek (Fig 1). The limestone is a characteristically grey-blue rock consisting dominantly of micrite. Some dark brown dolomitised beds are present. Fossils are generally absent but an horizon of micaecous and calcareous siltstone from downstream of Eagle Creek has yielded middle or late Ordovician fossils (Gee et al., 1969).

Eldon Group

The Siluro-Devonian rocks of western Tasmania, which occupy the axial portions of major synclinoria through the region, are known as the Eldon Group.

The section along the Gordon River below Eagle Creek shows a succession of Eldon Group sandstone, limestone and mudstone of Early Devonian age (Gee at al, 1969). Total minimum thickness is a little over a kilometre and six lithological units are recognised:

Top		Maximum Thickness
D6	Mudstone	300 m
D5	Fine-grained sandstone	90 m
D4	Interbedded sandstone, siltstone and limestone	75 m
D3	Massive bioclastic limestone	24 m
D2	Interbedded sandstone, siltstone, mudstone and limestone	290 m
D1	Well-bedded quartz sandstone with minor siltstone	265 m
	Total	1044m

The crinoidal limestone is a very pure (metallurgical quality if found outside the World Heritage area), compact, massive, coarse-grained bioclastic limestone which contains well-rolled and poorly-preserved fragments of reef building corals.

Units D2, D3, D4 are correlated with similar rocks at Point Hibbs, on the coast some 45 km south of the entrance to Macquarie Harbour, and the whole sequence is the youngest known (Pragian) from the Tasmanian Devonian (Gee et al., 1969).

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WEST TASMANIAN CONTINENTAL MARGIN

(by J.B. Willcox, N.F. Exon, C.S. Lee, B. Thomas)

SORELL BASIN

General

The offshore margin of western Tasmania 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. Although 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.

We define the Sorell Basin as including all areas of thick Cretaceous and younger sediments which extend westward from the west coast of Tasmania, somewhat more than 100 km downslope to the edge of the abyssal plain at 4000-4500 m (Fig. 2). Three local depocentres of significant sediment thickness (greater than 4 km) are present in the Sorell Basin (Fig. 2), 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 is provided by 2 petroleum exploration wells: Clam No. 1 was drilled near the southern margin of the King Island Sub-basin, and Cape Sorell No. 1 was drilled near the landward margin of the Strahan Sub-basin. No subsurface geological information is available for the Sandy Cape Sub-basin.

The Otway, Bass, Gippsland and Sorell Basins form a series of extensional basins along southern Australia, which developed in Late Jurassic and Early Cretaceous times before the breakup of East Gondwanaland (Deighton, Falvey & Taylor, 1976; Robertson et al., 1978; 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 in the Sorell Basin. 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 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), using seafloor magnetic anomalies, concluded that margin formation commenced in the Santonian (Anomaly 34, 90 m.y.). 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. Veevers (1986) and Veevers & Eittreim (1988) suggested that the separation of the Antarctic and southern Australian margins commenced 105 m.y. ago.

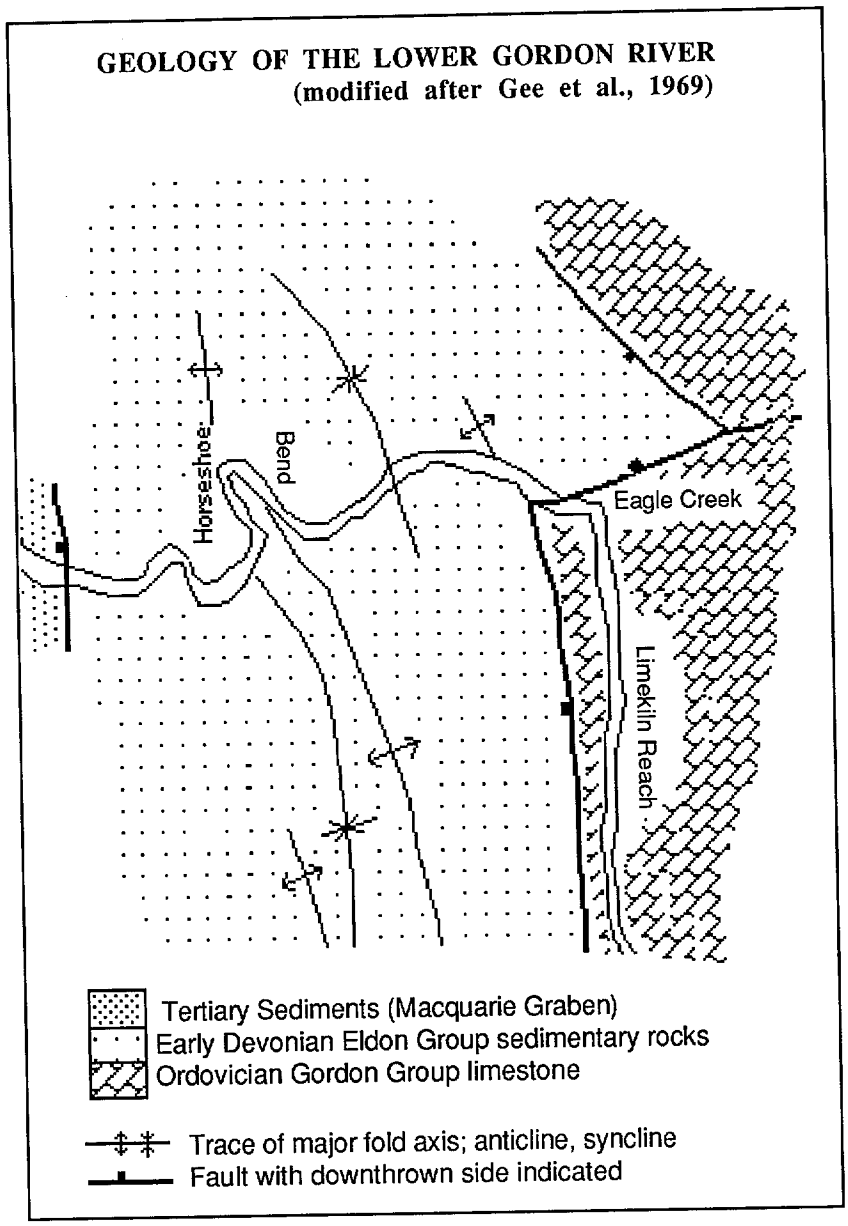

Fig. 1. Geology of the lower Gordon River.

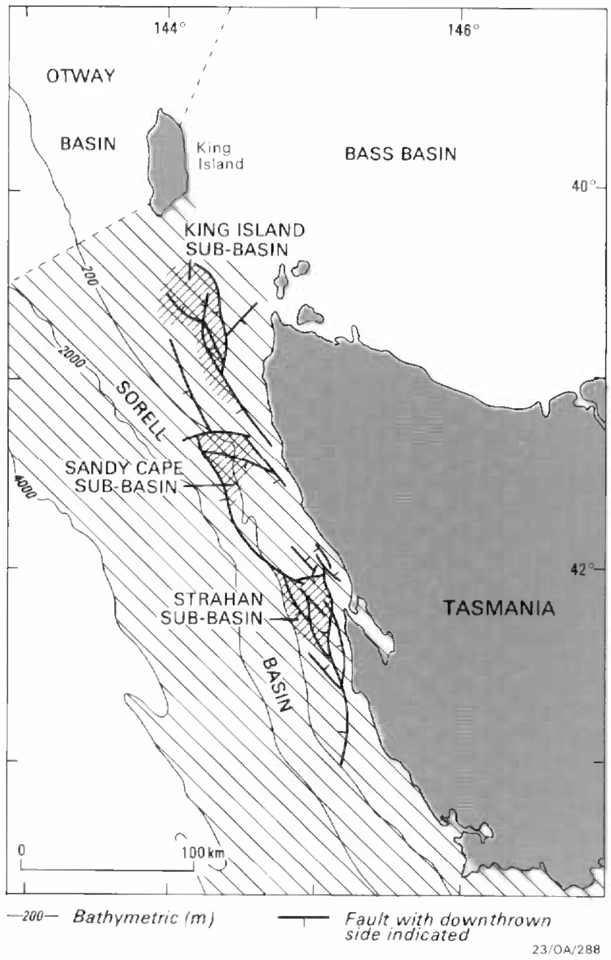

Fig. 2. Location map of the Sorell Basin and its sub-basins: King Island, Sandy Cape and Strahan sub-basins.

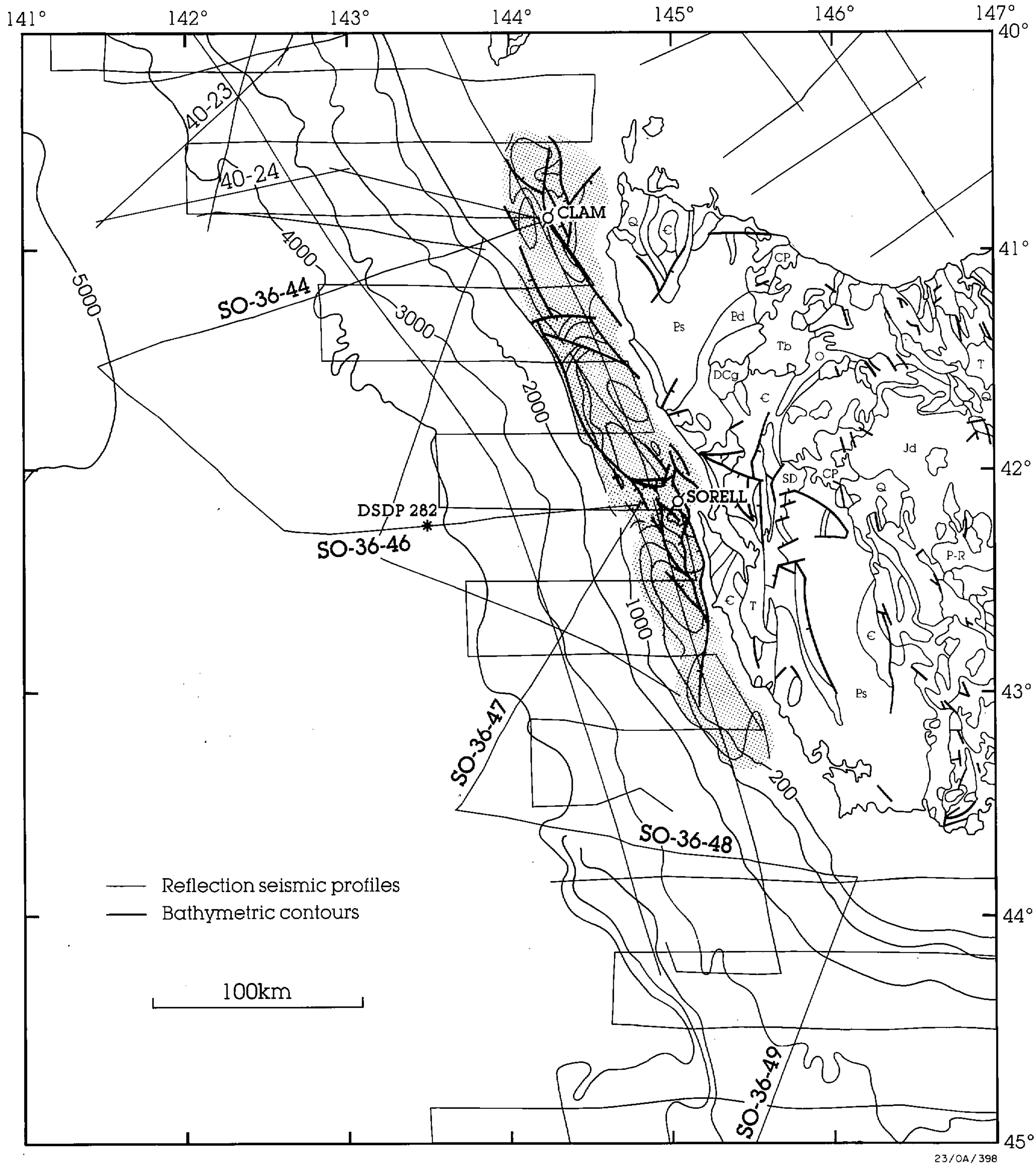

Fig. 3. Regional multichannel seismic tracks, and drill sites off west Tasmanian margin, showing onshore geology, offshore depth to basement (after Esso) and bathymetry.

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Scientific surveys

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 Beds (see ONSHORE GEOLOGY). Other relevant 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.

In 1973, BMR recorded about 1000 km of low-energy reflection profiles over the west Tasmanian shelf from MV Sprightly. These profiles showed that gentle faulting, uplift and erosion occurred during the late Miocene, and that younger 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 show that 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.

In 1973, Shell International Petroleum, using the MV Petrel, shot four lines from the shelf to the abyssal plain within the Sorell Basin region (Fig. 3). An interpretation by Bouef & Doust (1975) provided a regional review of the deepwater parts of the region. Denham & Brown (1976) reviewed industrial drilling and seismic data in the offshore area between King Island and the Victorian-South Australian Border. In 1982, BMR contracted Geophysical Services International (GSI), who shot two multichannel seismic (BMR Survey 40) lines extending on either side of King Island, out to the abyssal plain (Fig. 3).

In early 1985, the West German Research Vessel Sonne (Cruises SO-36B & C), shot four regional multichannel seismic lines and several short tie lines off west Tasmania, and occupied 34 sampling stations (Fig 4; Hinz et al., 1985). An interpretation of these seismic lines (Figs 5 and 6), combined with those of a 1982 BMR line (Fig. 7), 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 indicate that unconformity U3 represents the regional Oligocene unconformity, U9 the basal Tertiary unconformity, and U12 the basal Upper Cretaceous uncomformity. The generally relatively thin Tertiary sequences consist essentially of Neogene carbonates and Palaeogene terrigenous sediments. The Upper Cretaceous sequence appeared to subcrop along the foot of the continental slope, along with continental basement which was sampled at three stations.

A 1987 Rig Seismic sampling cruise (BMR Survey 67; Exon, Lee et al., 1987, 1989; Heggie et al., 1988) occupied 35 stations on the west Tasmanian margin - 3 dredge, 25 core, 8 grab and 4 heatflow - in water depths of 50 to 5000 m (Fig. 4; 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 Late Cretaceous detrital sedimentary rocks crop out on the lowermost continental slope in

Table 1. Correlation of seismic stratigraphic sequences with unconformities and tectonic events in the southeast Otway Basin and the west Tasmanian margin. After Hinz et al. (1986).

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 Eumeralla 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)	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)
U8									
S(7–8)									
U7									
S(6–7)									
U6									
S(5–6)									
U5						42	18	? ?	
S(4–5)	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
U4									
S(3–4)									
U3						35	13		
S(2–3)	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
U2									
S(1–2)									
U1									

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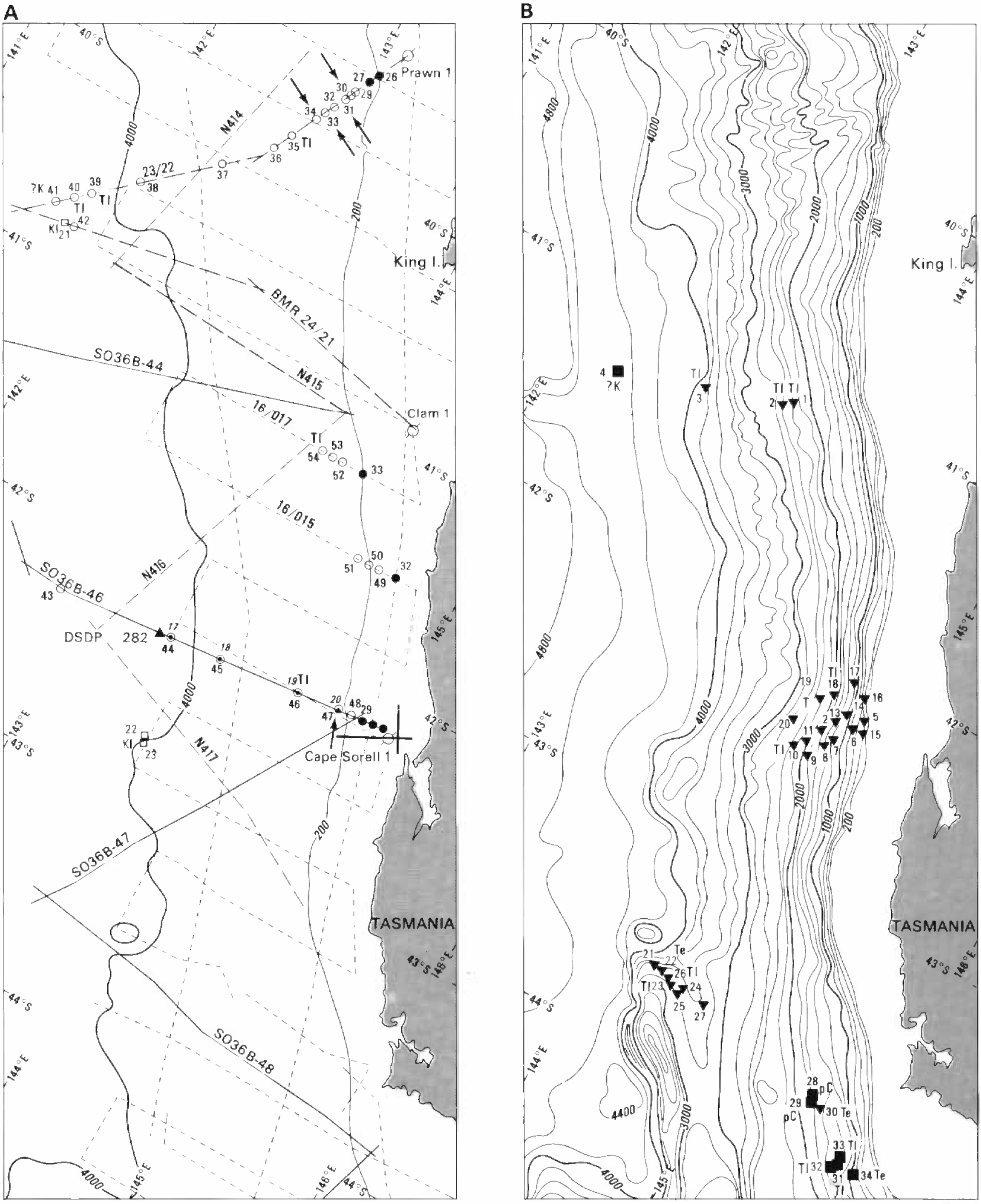
*For stratigraphy refer to BMR line 22/23 (Figure)
Tectonic events after Willcox and Symonds (in preparation)

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	27 Sonne and 53 Rig Seismic cores	240 - 4830 m
L. Oligocene - Pliocene marl, limestone, and chalk	S1,2,3,19,23,26,31 32,33; 1985/5,9,10; GC 35,39,40,46,54; DR10,12,14,18,19	1150 - 4370 m
Eocene - E. Oligocene calcareous siltstone and limestone	S29,32,34; 1985/7; GC5; DR2,10,12,18	650 - 4100 m
Middle Eocene peaty siltstone	S22,30; GC 12	1757 - 3710 m
Late Cretaceous sandstone and mudstone	S4; DR2,3,4,5,6,7, 21,22; GC 42	3900 - 4700 m
Basement metamorphics and volcanics	S28,29; 1985/6	1800 - 3750 m

NB : S = 1985 Sonne station; 1985 = 1985 Rig Seismic dredge; GC = 1987 Rig Seismic core; DR = 1987 Rig Seismic dredge

Fig. 4. Map of sampling and heatflow stations for 1985 Sonne and 1987 Rig Seismic west Tasmanian cruises, showing major gas anomalies in the surface sediments, petroleum exploration wells, key deepwater seismic lines and bathymetry.



- - - - BMR Continental Margin survey 1970–73
— — Shell 'Petrel' survey
— — BMR Bass Strait survey

1987 Rig Seismic stations
● 17 Grab
○ 18 Core
□ 19 Dredge
• 20 Heatflow
→ Gas anomaly

Amoco 'West Tasmania Basin' survey
BGR 'Sonne' Cruise SO-36, 1985

Age of oldest rock found
Tl Late Tertiary (incl late Oligocene)
Te Early Tertiary
Kl Late Cretaceous
Pz Palaeozoic
p€ Precambrian

0 at 42° S 100 km

▼ Sonne core
■ Sonne dredge

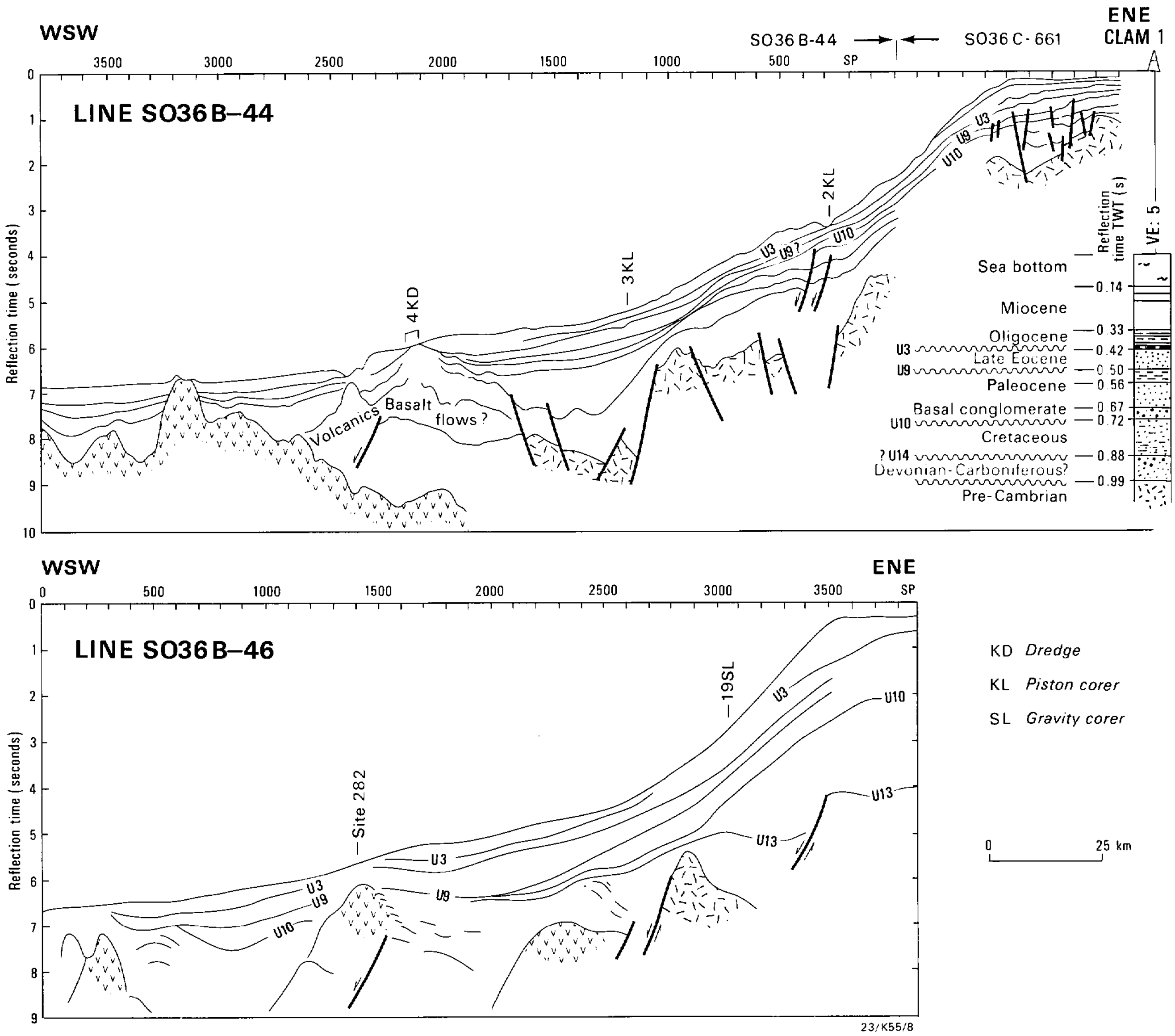


Fig. 5. Line interpretation of <u>Sonne</u> seismic sections SO36/44 & 46 on the west Tasmanian margin, showing sampling locations. After Hinz et al. (1986).

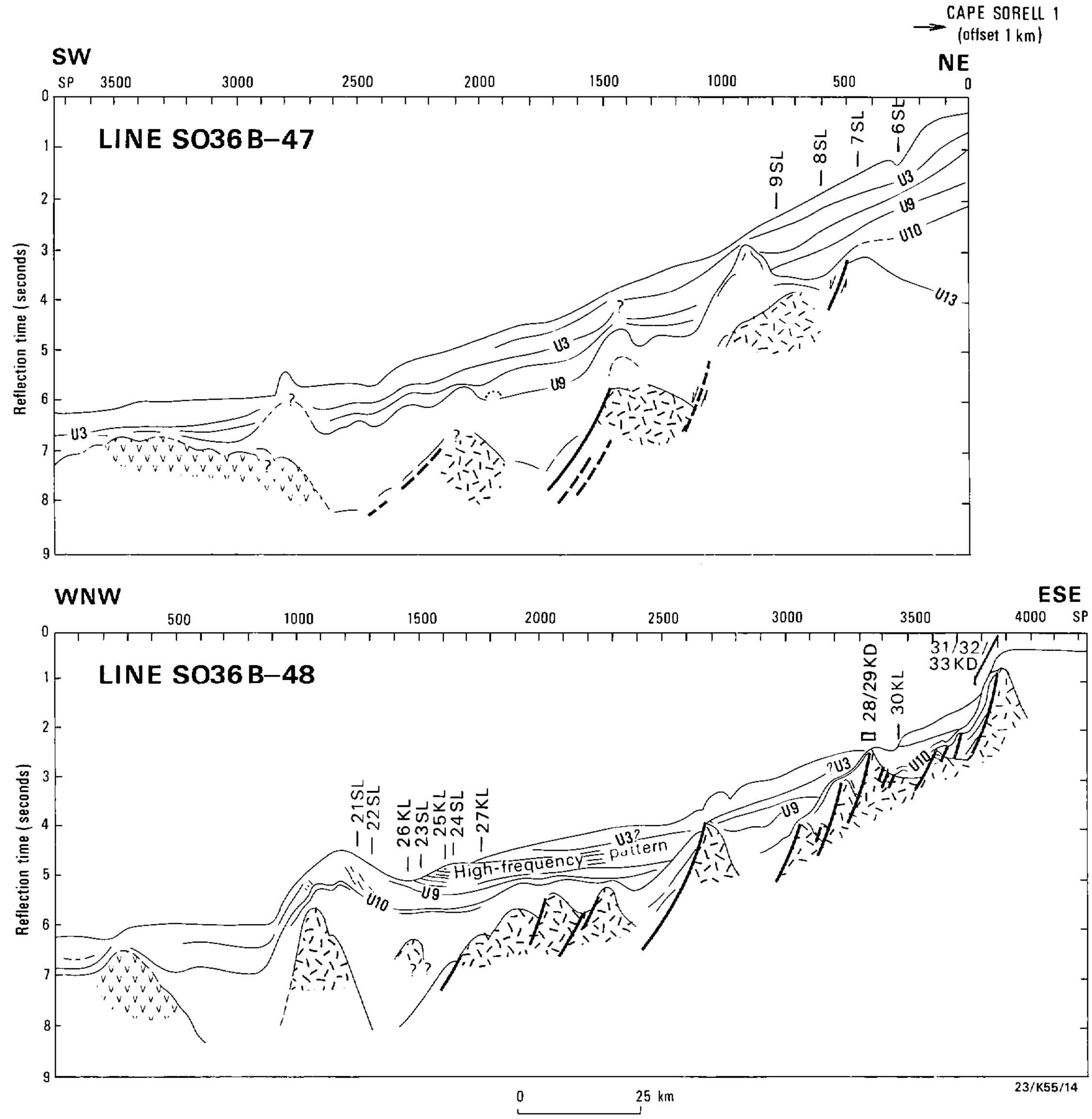


Fig. 6. Line interpretation of Sonne seismic sections SO36/47 & 48 on the west Tasmanian margin, showing sampling locations. After Hinz et al. (1986).

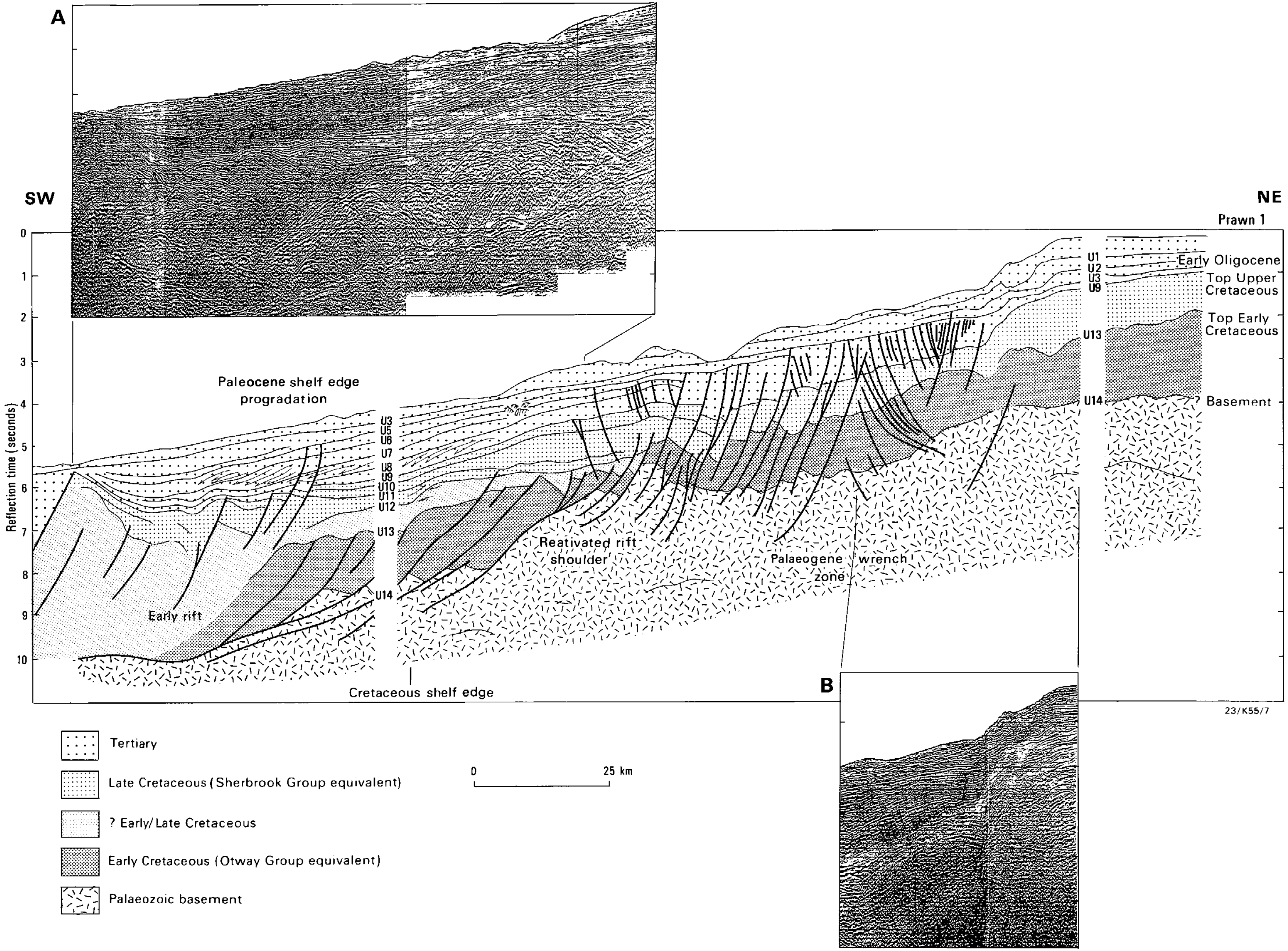


Fig. 7. Interpretation of BMR seismic profile 40-22/23, tied tentatively to Prawn No. 1 well. After J.B. Willcox, in Hinz et al. (1986).

water 4000-5000 m deep. The mid-slope is characterized by Early Tertiary detrital sediments, and the upper slope by Late Tertiary carbonates. 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, taken along seismic profiles. Grab sampling established the nature of the outer shelf sands, largely bryozoal, which provide turbidites to the Quaternary sediments on the continental slope, otherwise pelagic and hemipelagic in nature.

The 1988 Rig Seismic research cruise (BMR Survey 78) was entirely on the Tasmanian margin (Exon, Leed & Hill, 1989). Half of the cruise was devoted to multichannel seismic surveying - 1750 km on the west Tasmanian margin (Fig. 8). 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 latter half of the cruise was devoted to geological sampling (Fig. 9). 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 to further define the model for Cainozoic sedimentation, and to allow the analysis of surface sediments to define areas of anomalous concentrations of thermogenic gas. Measurements of near-surface thermal gradient and thermal conductivity were attempted at 10 stations as a means of establishing heat flow.

Leg 29 of the Deep Sea Drilling Program (DSDP) drilled 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. 3 & 5). 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.

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).

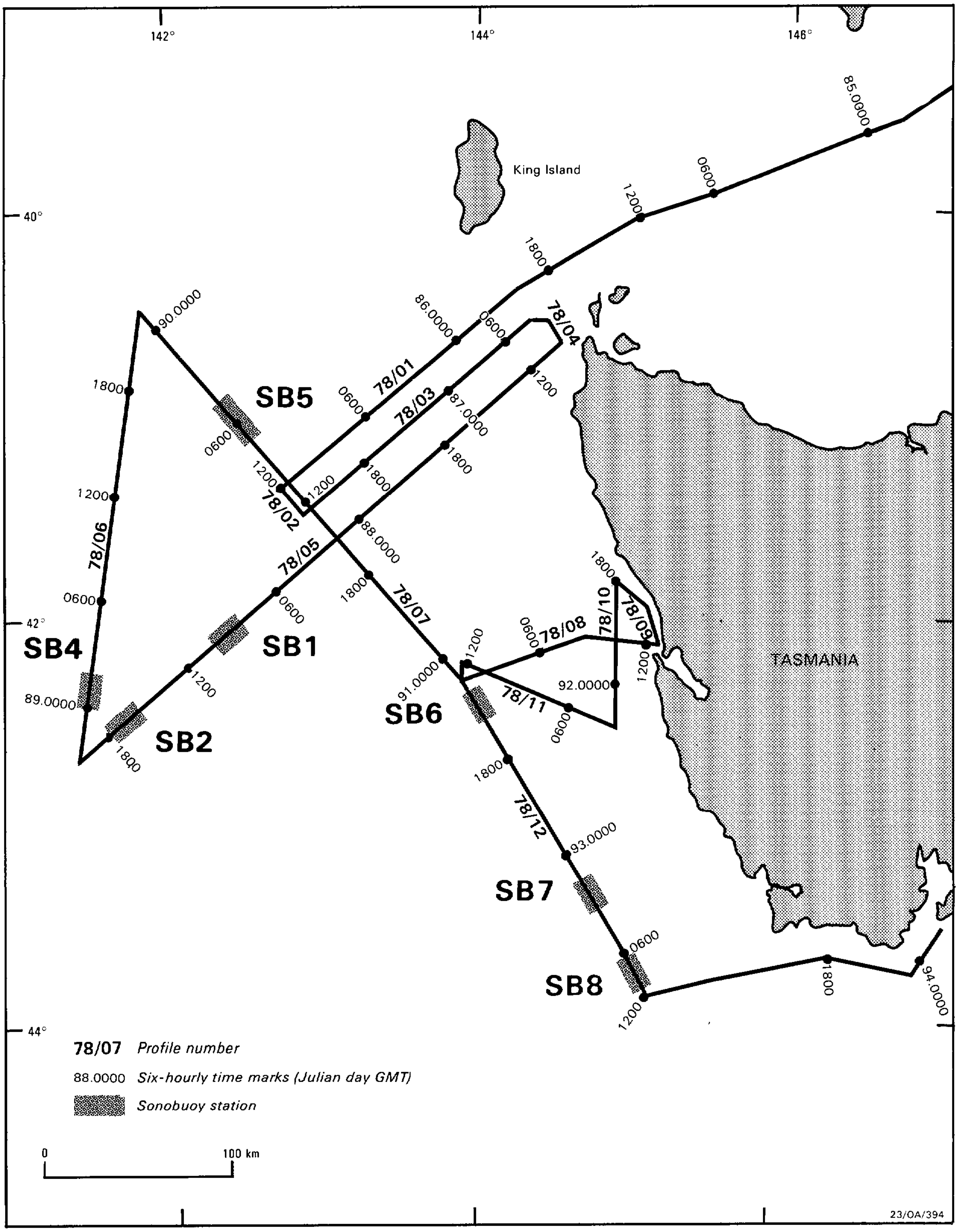


Fig. 8. Rig Seismic ship track map showing the west Tasmanian geophysical leg of BMR cruise 78, including sonobuoy stations.

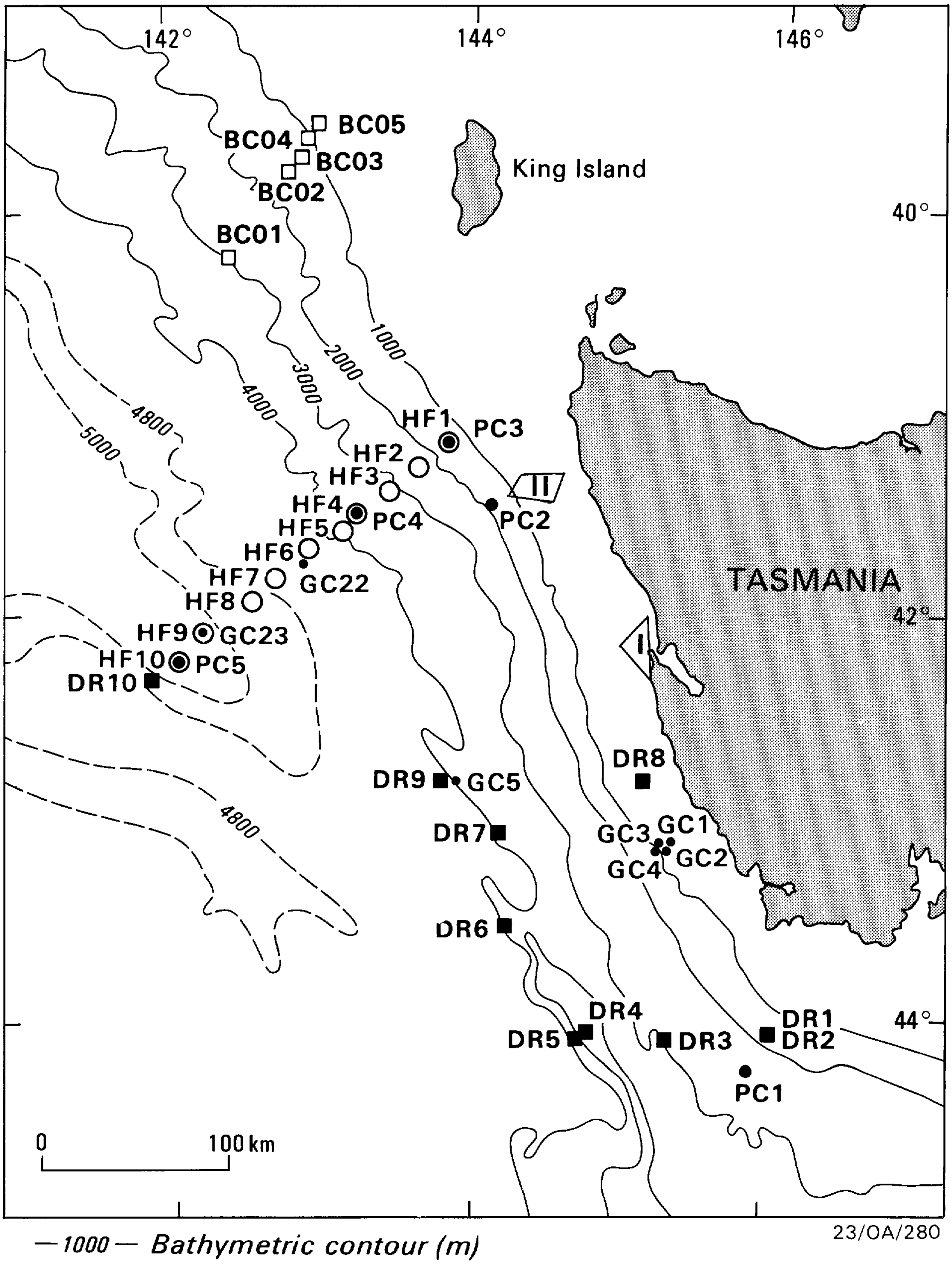


Fig. 9. Rig Seismic station map showing the west Tasmanian geological leg of BMR cruise 78.

(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 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 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 - Late Cretaceous Wangerrip Group correlate.
925 - 1462	Sandstone, mudstone with basal ferruginous sequence (?Late Cretaceous Sherbrook Group correlate).
1462 - 1592	?Palaeozoic/Late Proterozoic basement.

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, located about 13 km north-west of Cape Sorell, 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 (Figs. 3 & 4) 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.

Basin development

BMR is at present mapping the Sorell Basin at a regional scale , but no maps have yet been generated from that work. However, enough is known about the basin to provide a broad outline here.

Regional seismic data across the Basin indicate that it is an extensional basin which probably has been affected by two periods of strike-slip movements, creating 'transtensional' and 'transpressional' structures. Seaward-dipping normal faults, probably detaching on Palaeozoic basement, indicate less than 5% extension beneath the continental shelf and upper slope, and about 30% extension beneath the middle and lower slope. These areas of different extension are separated by a sub-branch of the detachment, with associated landward-dipping faults in places.

The basin was possibly initiated by left-lateral strike-slip movements (along a northwest to southeast trend) in the pre-Middle Jurassic, but developed as transtensional basins in the Early Cretaceous. A continuing strike-slip sense of movement appears to have created the uplift of tilt-blocks below the lower slope in the Late Cretaceous, and formed extensively faulted anticlines and 'squeezed blocks' below the upper slope in the Eocene and Early Oligocene. There is evidence that Tertiary structuring is associated with reactivation of the heads of sub-branches of the detachment.

The major depocentres in the basin are the three shelf sub-basins indicated in Figures 2 & 3, which are separated by areas of shallow basement, and the thick slope basin in deeper water. Several seismic profiles (Fig. 3) exemplify the regional configuration. The northernmost is BMR 40-22/23 (Fig. 7) which extends from Prawn No. A1 well, southwest almost to the abyssal plain. This shows major listric faults affecting the Early Cretaceous sequence, and Palaeogene wrench and normal faults. The thickest Cretaceous sequence is in the early rift, far from land, where there is 4 seconds (TWT) of section. This region has seen the uplift of large Cretaceous blocks, so that in places they crop out. The major Oligocene unconformity (U3) is virtually undeformed, although rotated down toward the ocean. Prograding deltaic Palaeogene sediments are common along the outer margin from west of King Island to off Southwest Cape. Sonne profile SO36B-44 (Fig. 5) and BMR profile 78-05 (Fig. 10) extend west and southwest of Clam No. 1 well, south of King Island to the abyssal plain.

The King Island Sub-basin, on the shelf, is controlled by basement faults, and contains up to 4000 m of section (Fig. 3). It is a half-graben about 40 kilometres wide deepening eastward to a high-angle ormal fault downthrown to north and west. There is a 'mid-basin arch' or rollover anticline near the southeastern side, where the thickness of the succession exceeds 3000 metres. The sub-basin appears to be a trans-tensional feature of similar age to the related Sandy Cape and Strahan sub-basins to the south-southeast and the Otway Basin to the north-west. Beyond a shelf edge high, basement drops away and basin fill is around 3 seconds (TWT) thick on the lower slope. BMR 78-05 indicates that continental crust extends at least to the abyssal plain, but where the oceanic crust begins is not easily defined.

Sonne profile SO36B-46, running west from Cape Sorell No. 1 well in the Strahan Sub-basin (Fig. 5), indicates that the sub-basin may contain 5s(TWT) of sediment, controlled by basement faults. Esso mapping (Fig. 3) suggests that the sediment pile, largely Cretaceous in age, is more than 4 km thick in places. Again, large basement blocks are visible beneath the slope, and there is a lower slope basin more than 3s(TWT) thick.

Sonne profiles SO36B-47 & 48 (Fig. 6) suggest that, although the same structural control prevails in the south, the sediment pile thins in that direction. Along SO36B-48, sediment fill seldom exceeds 2 seconds (TWT). The depth to basement map of the shelf sub-basins (Fig. 3), in conjunction with more detailed studies in the Strahan Sub-basin (see below), suggest that the Strahan and Sandy Cape Sub-basins first formed in the Late Jurassic/Early Cretaceous by SSE movement on a south-dipping detachment fault, along a landward strike-slip fault. In both sub-basins there is rapid thickening across these two faults, and slow thinning southward. Later movements have complicated matters.

The lower slope seismic lines, BMR 78-7 & 12, show how the basin changes parallel to the margin (Fig. 11). A common feature throughout is the large amount of block-faulting, some of which may be related to transfer faults normal to the Tasmanian margin. These faults strongly affect the Early Cretaceous sequence, but do not extend above unconformity U9 into the Tertiary, suggesting that this phase of faulting was synchronous with the one which formed the shelf basins. The Paleogene sequence is usually thick, and the Neogene sequence above U3 is thin to absent. This accords with the view that the margin subsided in the Oligocene,

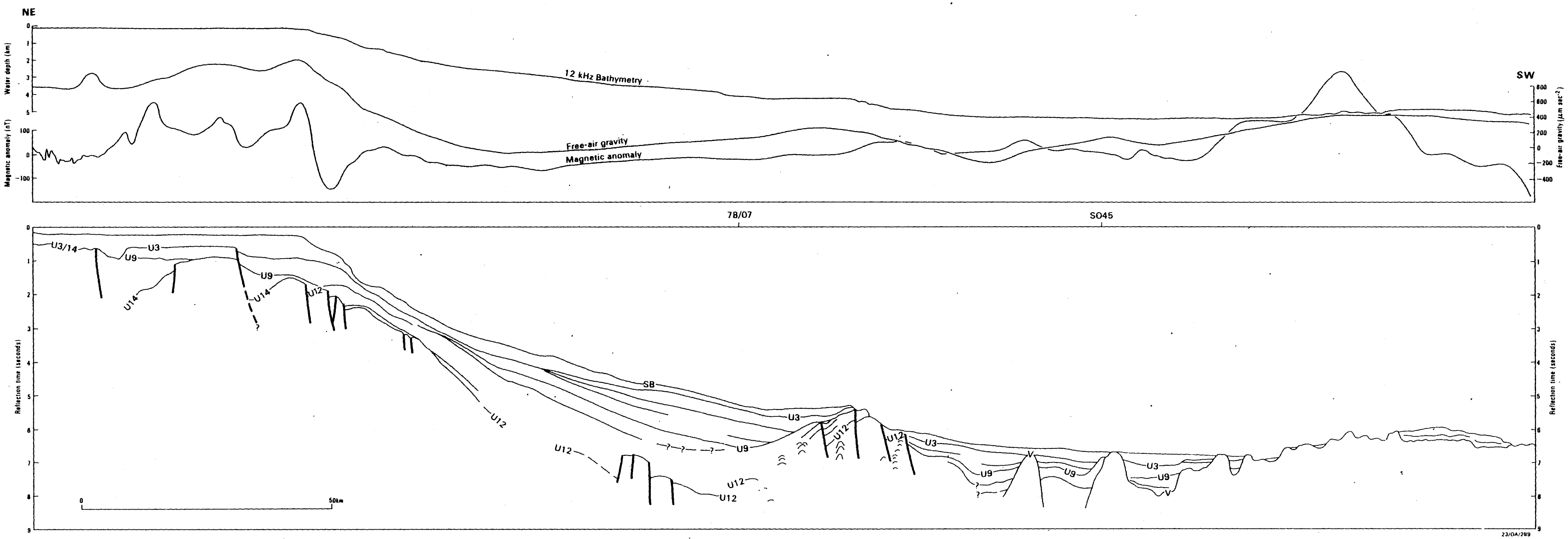


Fig. 10. Line interpretation of seismic monitor record, and bathymetry, gravity and magnetic profiles, along Rig Seismic line 78/05 on the west Tasmanian margin. After Exon et al. (1989).

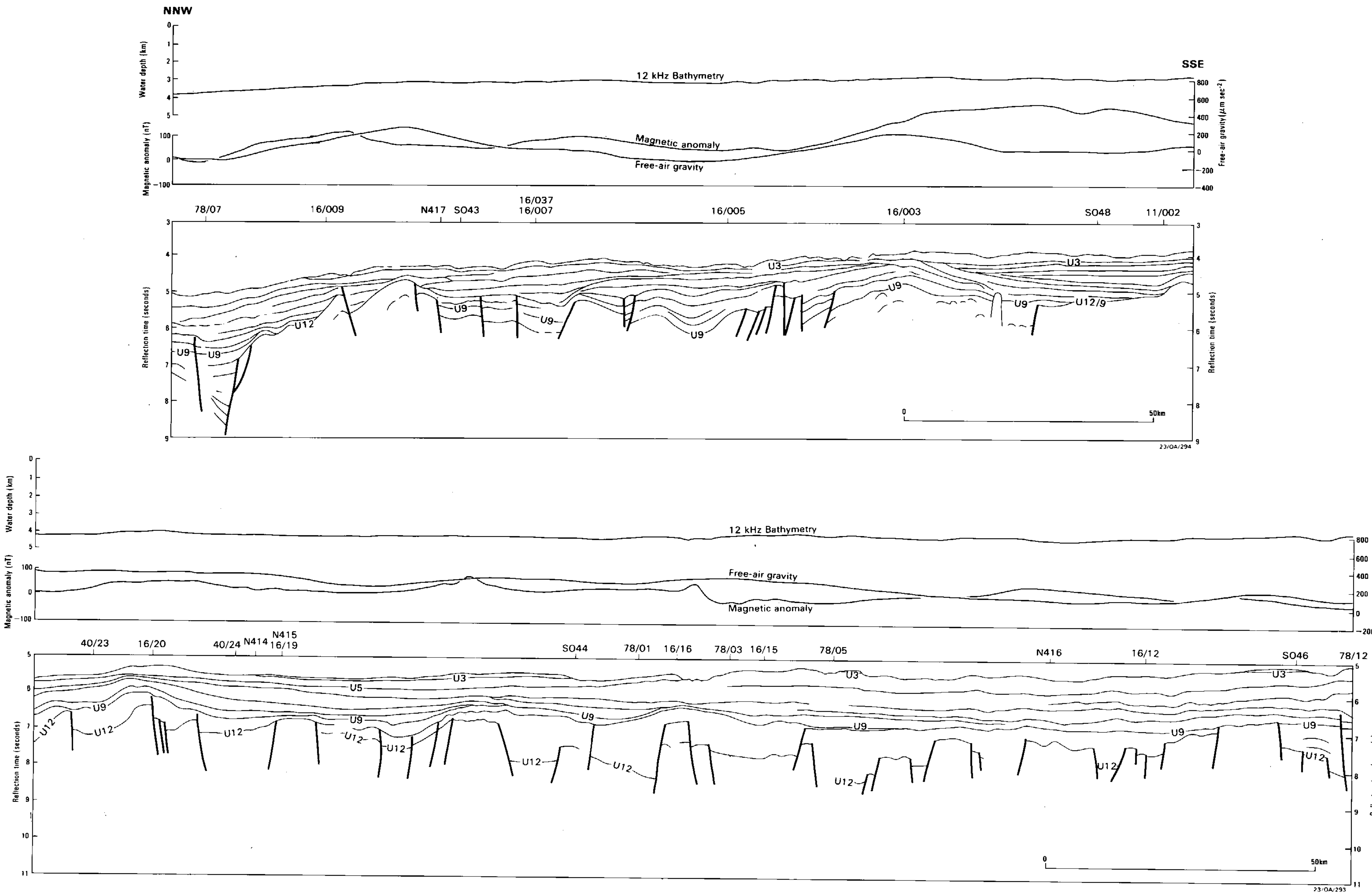


Fig. 11. Line interpretation of seismic monitor record, and bathymetry, gravity and magnetic profiles, along Rig Seismic lines 78/07 & 12 on the west Tasmanian margin. After Exon et al. (1989).

after fast spreading started, and sedimentation rates were much lower thereafter. Complex sedimentary patterns in the Palaeogene in the south may be related to the formation of delta lobes.

Heatflow surveys

Eight heatflow stations were successfully occupied during BMR Cruises 67 and 78 (Fig. 12) and the results are outlined by Exon, Lee et al (1987) and Exon, Lee & Hill (1988). Values were read in the surface sediments, from a 3 m lance on which thermistors formed outriggers. The preliminary heatflow results are listed in Table 3 and summarised below:

1. The average heatflow throughout the west Tasmanian margin survey area is about 30 mW/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. 12) from two Tasmanian transects has shown that an area of low heatflow (20 mW/sq. m) is associated with a zone of changing tectonic setting in 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 heatflow value from the bottom hole temperature of Cape Sorell well is 54.6 mW/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.

Overall, the results suggest that the heatflow and thermal gradient are high enough to generate petroleum from source rocks in the thick sedimentary sequences present in basinal areas.

Petroleum geochemistry

DSDP site 282 (Fig. 3) 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.

Studies of the concentration and composition of hydrocarbons in surface sediments of west Tasmania, by Hinz et al. (1985, 1986), Exon, Lee et al. (1987), and Exon, Lee & Hill (1989) show that hydrocarbons of thermogenic origin are currently being generated just west of the shelf break, especially in the Strahan and Sandy Cape sub-basins. No sampling on the shelf for hydrocarbons has been possible with the equipment available, because of the widespread Miocene limestone at or immediately below the surface.

Migration and entrapment beneath the continental shelf is demonstrated by the traces of free oil encountered in Cape Sorell No. 1. 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.

TABLE 3: PRELIMINARY HEATFLOW VALUES FROM WEST TASMANIA

Station	Latitude	Longitude	Depth (m)	Sen	TG (^{o}C/Km)	core	Cond. (W/m.k)	HF (mW/m^2)
78/HF/01	$41^{o}7.0'$	$143^{o}49.4'$	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				
78/HF/02	$41^{o}16.1'$	$143^{o}35.8'$	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				
78/HF/03	$41^{o}23.1'$	$143^{o}24.6'$	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				
78/HF/04	$41^{o}30.5'$	$143^{o}13.6'$	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				
78/HF/05	$41^{o}35.8'$	$143^{o}5.5'$	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				
67/HF/17	$42^{o}14.0$	$143^{o}32.0$	4100	7	54.5	GC/44	0.76	41.42
				5	44.0	GC/44	0.76	33.44
				AVERAGE HEATFLOW = 37.43 ± 2.99				
67/HF/18	$42^{o}14.0$	$143^{o}53.0$	3720	6	38.5	GC/45	0.82	31.57
				6	44.5	GC/45	0.82	36.49
				AVERAGE HEATFLOW = 34.03 ± 2.46				
67/HF/19	$42^{o}12.0$	$144^{o}25.0$	2340	5	25.5	GC/46	0.83	21.17

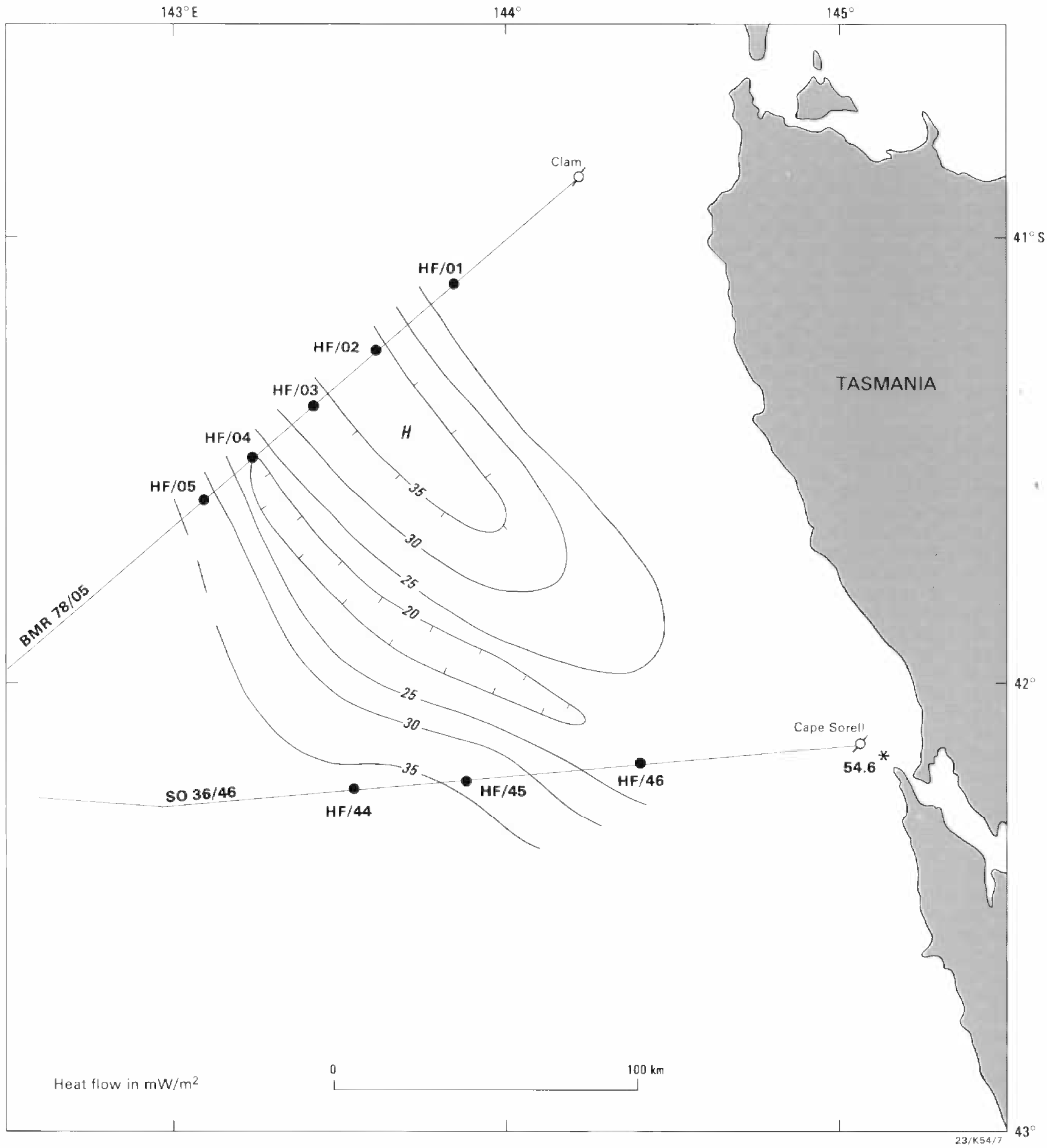


Fig. 12. Heatflow map derived from stations occupied on BMR cruises 67 (HF/44-46), 78 (HF/01-05) and estimated heatflow value from Cape Sorell well.

The early to 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, are more attractive as hydrocarbon source rocks.

STRAHAN SUB-BASIN

The Strahan Sub-basin was considered to be a wrench related structure by Willcox, Exon & Branson (1985). It is roughly a rhomb-shaped half-graben, about 50 km long and 25 km wide, trending NNW-SSE parallel to the west Tasmanian coast . Water depths are shelfal - being less than 200 m throughout, and less than 100 m over most of the basin.

Our knowledge of the structure and stratigraphy of the basin comes largely from the 2x4 km and 4x4 km seismic grid (Figure 13) and the Cape Sorell-1 exploration well (Figure 14) which reached TD at 3520 m in Paleocene - Late Cretaceous strata. Correlation of the Cretaceous units with those of the Otway Basin has been given by Hinz, Willcox & others (1985).

Structure

The Strahan Sub-basin is bounded on its northern and eastern edges respectively by fault systems which trend W-E and NNW-SSE (Figure 15) and downthrow the basement by up to 3000 or 4000 m. The eastern system appears to be composed largely of high-angle faults and is interpreted to be strike-slip or oblique-slip: the northern system is probably largely extensional. The basin is floored by one, or possibly two, major low angle tilt-blocks, the crests of which trend approximately W-E. The crests of these blocks appear to be offset by transfer faults running parallel to the eastern boundary of the basin, at about 144^0 55'E and possibly at 145^0 10'E. The gross configuration of the basin is of an NNW-SSE trending slot, comprising two W-E trending half-graben, and with the basement shallowing to the south and west from a northern depocentre. The basin boundary faults and the extensional faults bounding the tilt-blocks are considered to be a linked fault system responsible for the basin formation. This indicates that basin formation was fundamentally a product of strike-slip or oblique movement as shown conceptually in Figure 16. Consideration of the extensional tectonics of the Southern Margin as a whole indicates that the Strahan Sub-basin may have formed along a strike-slip zone which extended through the Otway Basin - west Tasmania region in ?Late Jurassic time (Willcox & Stagg, in press). Its formation would then have been contemporaneous with that of the Eyre Sub-basin and ?Great Australian Bight Basin which recent interpretation has shown to be the result of NW-SE extension.

Further structuring appears to have taken place in the Early Cretaceous, probably due to the same event which gave rise to the Gippsland Basin. However, of more significance are major zones of 'positive flower' / wrench-related structures which are

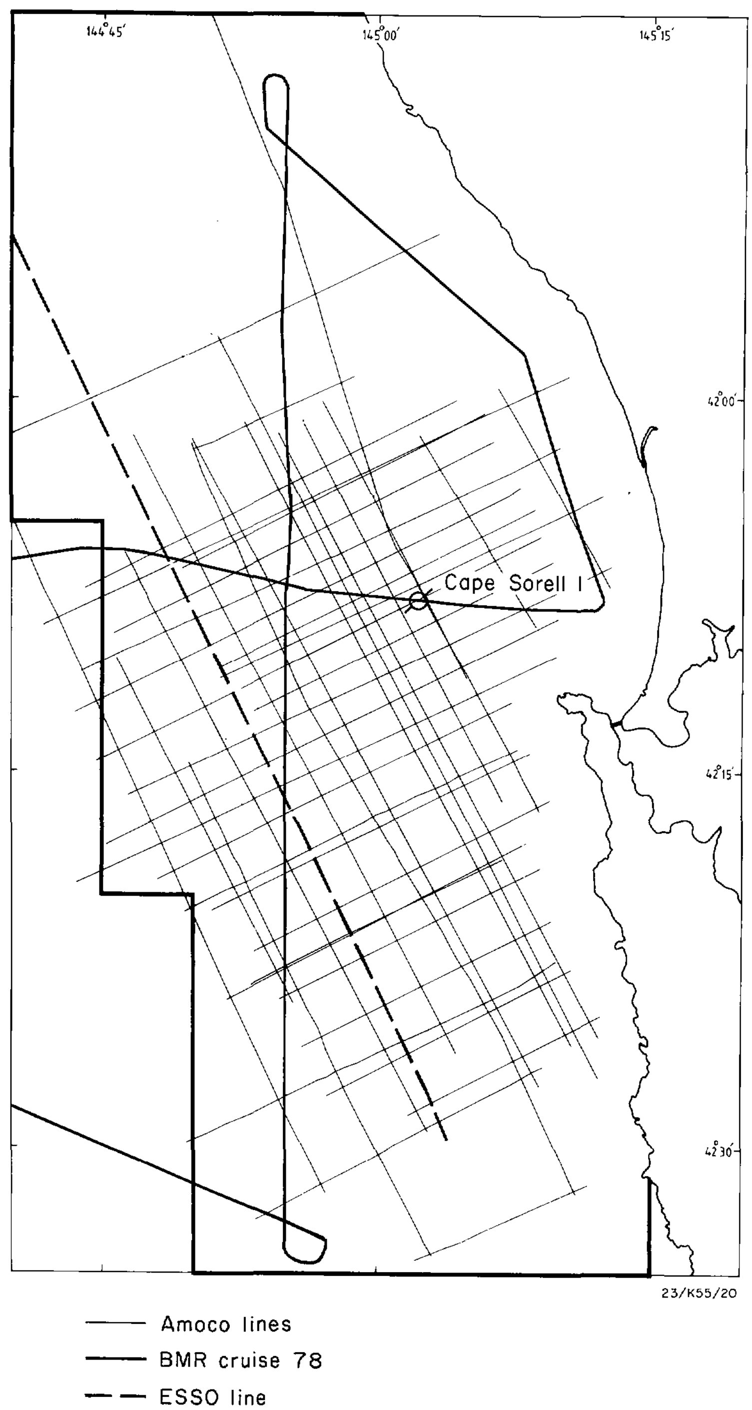


Fig. 13. Ship track map of the Strahan Sub-basin, including Amoco, Esso and BMR cruise 78 data.

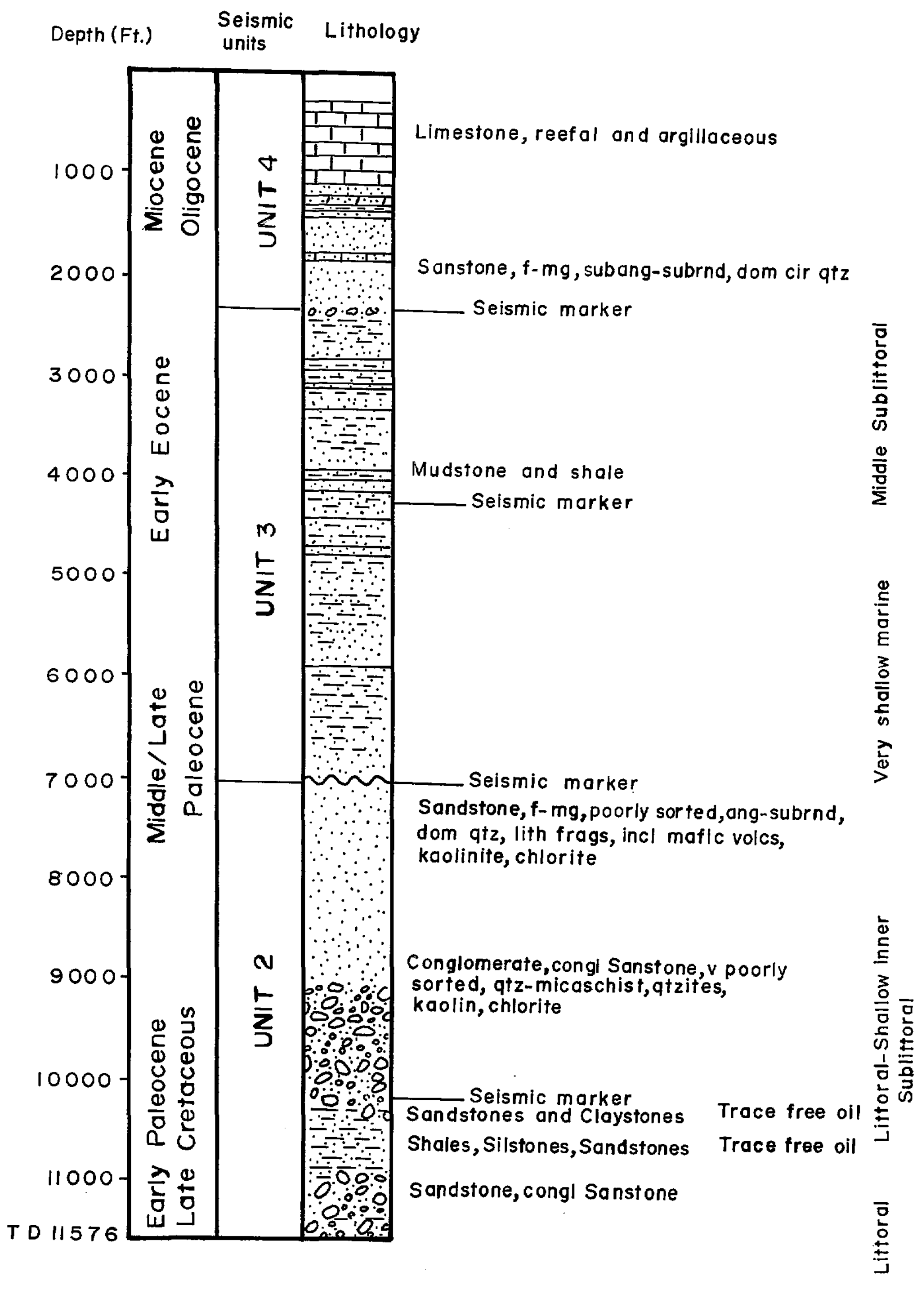


Fig. 14. Correlation of seismic unconformities and marker horizons with lithologies and ages of sequences penetrated in the Cape Sorell - 1 well in the Strahan Sub-basin.

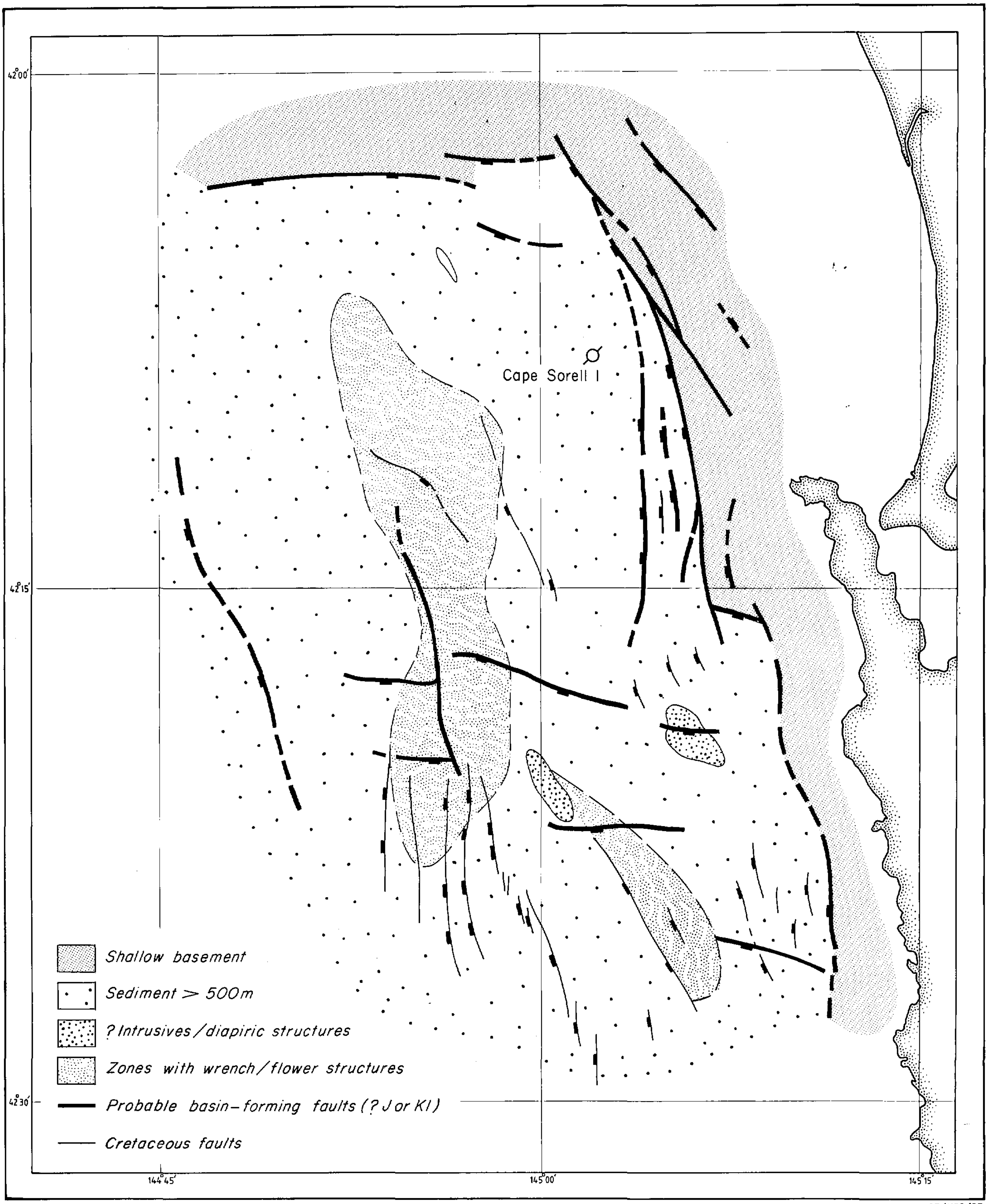


Fig. 15. Preliminary fault structure map. After Thomas & Willcox, in prep.

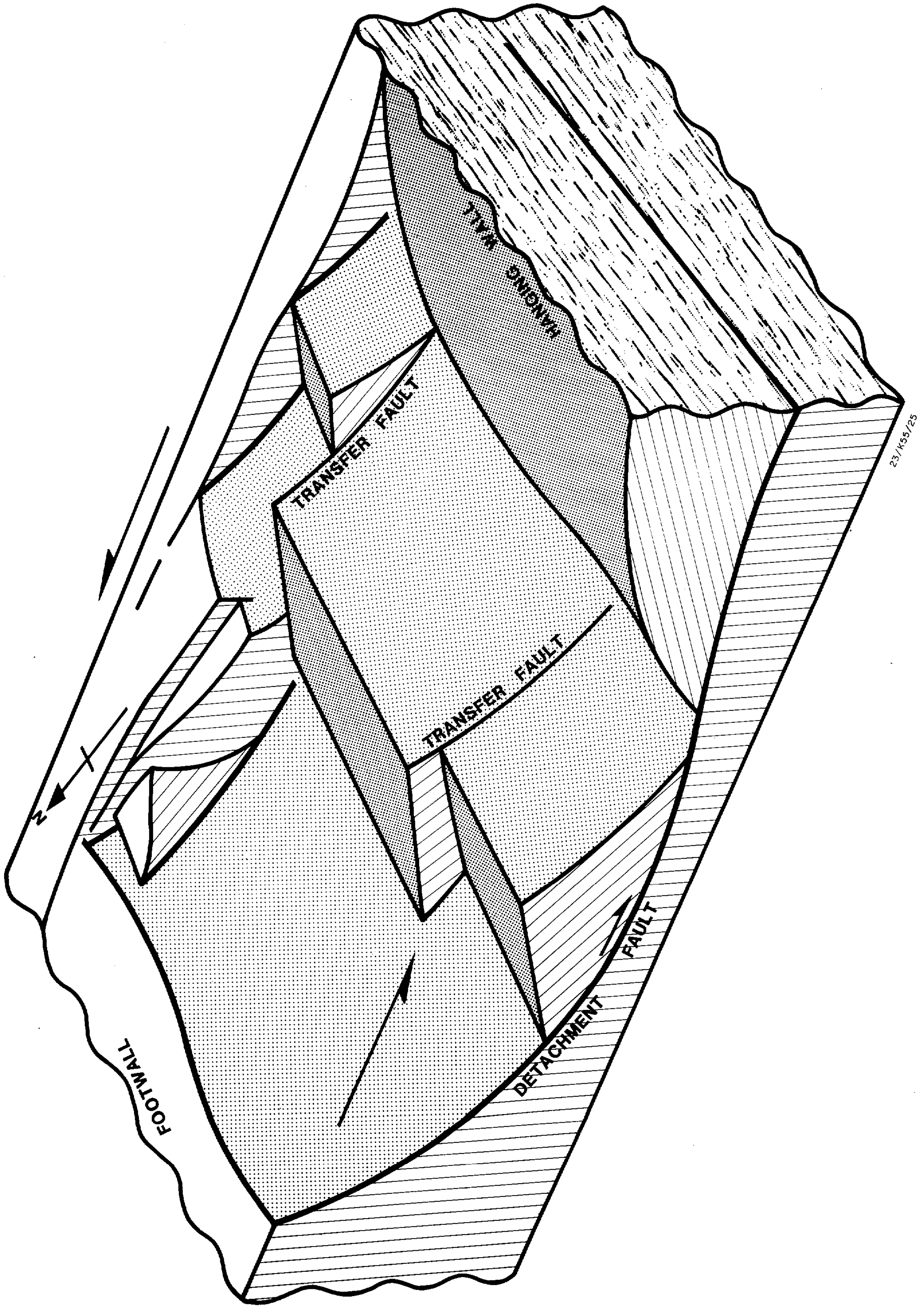


Fig. 16. Conceptual model for formation of the Strahan Sub-basin showing a linked-fault system and strike-slip origin. After J.B. Willcox.

interpreted to have developed from the Paleocene to the mid Oligocene (Figure 17). Faulting associated with these features terminates at the mid Oligocene unconformity: this strongly suggests that the structures are the result of interaction between the Australian and Antarctic Plates during seafloor spreading, a situation which would have continued until the mid Oligocene (that is, Anomaly 13 time or about 35 mA) when the plates cleared each other and when full oceanic circulation developed. The areas dominated by wrenching seem to overlie the postulated transfer faults, suggesting that they result from reactivation. The presence of these 'late structures' within the Strahan Sub-basin is a 'plus' for hydrocarbon exploration, since they could have given rise to traps at a time when potential source rocks were maturing.

Seismic mapping

The preliminary seismic maps were prepared by Bruno Thomas from the digitised data for prominant seismic horizons: namely,

- acoustic basement (Fig. 18)
- ?top Lower Cretaceous (not shown)
- approx. top Paleocene (Fig. 19)

Only the top Paleocene horizon was penetrated in the Cape Sorell - 1 well: the deeper horizons were dated from character correlations with the Otway Basin, and were mapped as part of a study of the basin-forming structures in the area.

Basement (Figures 15 & 18):
Over parts of the basin an acoustic basement can be recognised on the seismic sections. It is a low frequency event displaced by extensional faults. It is taken to represent rocks of the Palaeozoic continental basement of Tasmania - a part of the New England Geosyncline.

The Basement contour map clearly shows the steep, linear, northern and eastern boundaries of the basin and the crests of the easterly trending tilt-blocks which are the basin-forming structures (Figures 15 & 18). The contoured southern slopes of the tilt-blocks are the actual fault surfaces, whereas the northern slopes are the basement unconformity. The main depocentre of the basin is clearly in its northern half, where the reflection time to the basement unconformity is beyond 4.5 seconds twt (about 6000 km) which is the processed record length of the commercial seismic data.

The fault structural map (Figure 15) shows the position of possible transfer faults and their relationship to the flower structures / wrench zones which are important structures for the Paleocene - early Oligocene section (Figure 17).

Top Lower Cretaceous (not shown):
The top Lower Cretaceous map follows the broad features of the basement map but is generally smoother. This reflects onlap of the sequence onto the basement tilt-blocks in what appears to be a syn-rift relationship. The northern depocentre is again prominent at this horizon, indicating that basin extension continued throughout the Early Cretaceous. In fact, the seismic sections show that these faults continued to be active through the Late Cretaceous and into the earliest Paleocene.

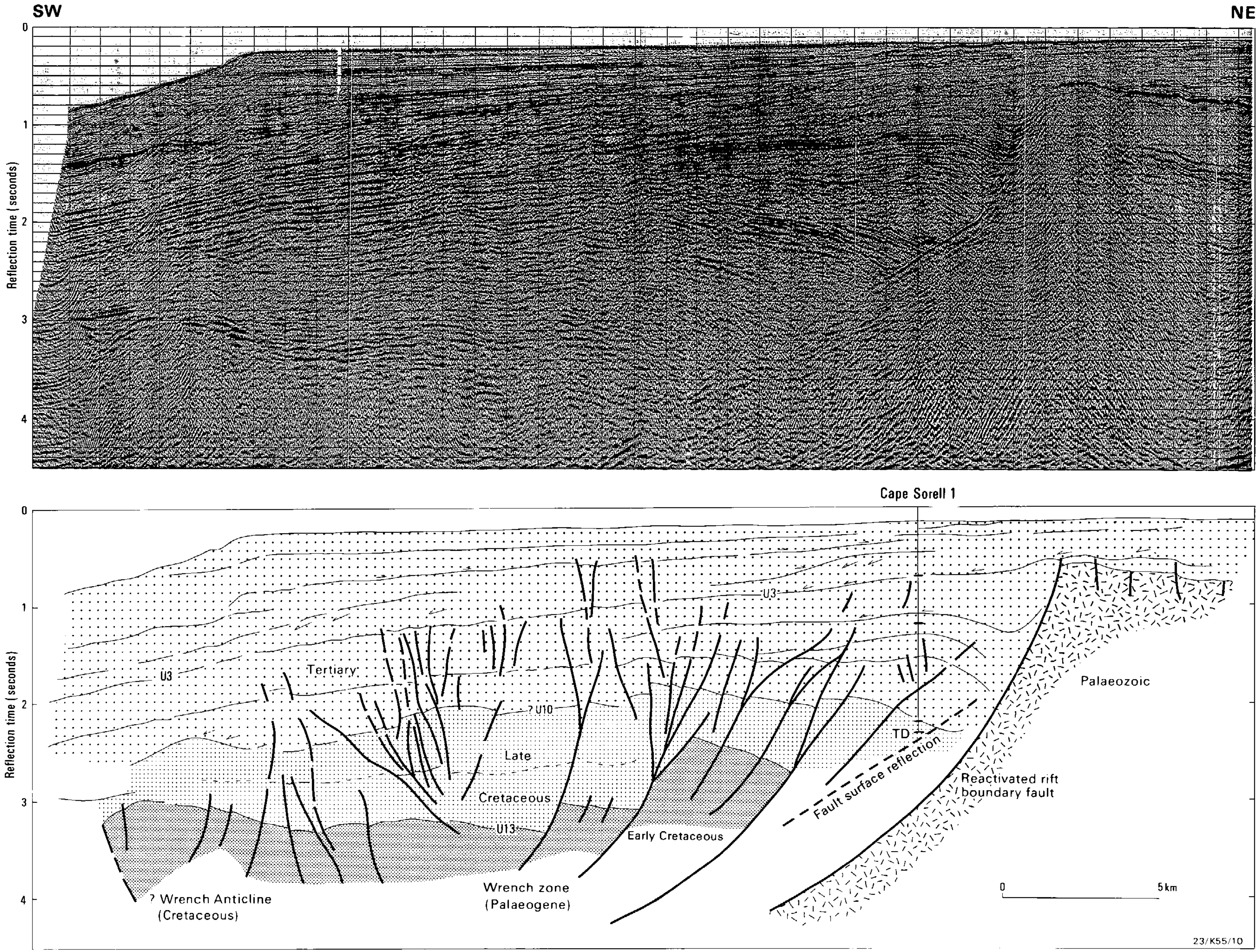


Fig. 17. Interpretation of Amoco seismic profile W-81-12 through the Cape Sorell - 1 well, showing wrench-related strucures. After J.B. Willcox, in Hinz et al. (1986).

Fig. 18. Preliminary depth to basement contour map of the Strahan Sub-basin. Two-way time in seconds. After Thomas & Willcox, in prep.

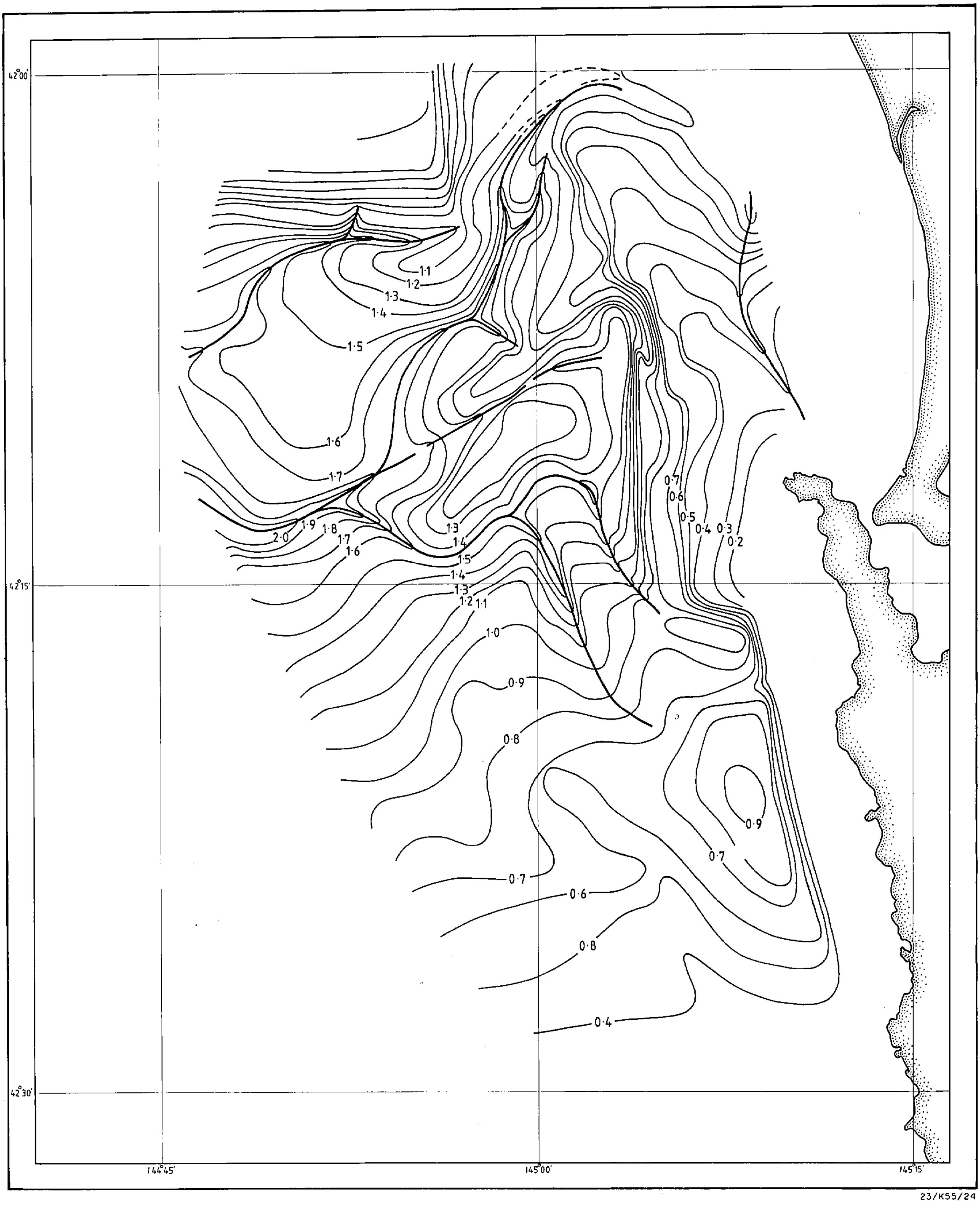


Fig. 19. Preliminary thickness map of the post-Paleocene section in the Strahan Sub-basin (essentially the structure of the top Paleocene erosion / channelling surface. Two-way time in seconds. After B. Thomas.

Top Paleocene (Figures 19 & 20):
The horizon near the top of the Paleocene (intersected in Cape Sorell - 1) is a strong erosional unconformity associated with the cutting of major canyons (up to 4000 m wide and 400 m deep; Figure 18) which discharge towards the present-day continental slope. This well-developed canyon system suggests that by the Paleocene the basin was draining westwards towards the active margin of the Australian Plate. It seems unlikely that this westward gradient was created by thermal sag of the continental margin, since the ridge crest would have been nearby at this time. The Australian and Antarctic Plates appear to have remained in stike-slip contact until the mid-Oligocene, as evidenced by the upward extent of wrench faults, hence the westward tilt must have resulted from differential uplift / depression of blocks within the wrench zone, or from a second phase of extension possibly synchronous with that which gave rise to the Gippsland Basin.

The map (Figure 19; actually post-Paleocene thickness) shows at least two closures at this level. For these closures to be viable traps, what are essentially topographic hills composed of sub-horizontal strata would need to be sealed by marine shales in the overlying section. The map also reflects the rollovers and flower structures which could create significant traps in the Eocene and early Oligocene sequences.

SANDY CAPE SUB-BASIN

Early Esso seismic work indicates that the Sandy Cape Sub-basin is fault-bounded to the north and east against basement, and pinches out against a rising basement surface to the south (Fig. 3). By analogy with the Strahan Sub-basin, the northern fault is probably listric and the eastern fault is probably of modified strike-slip origin. A large, southerly dipping fault probably represents the boundary between two major basement blocks.

Again by analogy with the Strahan Sub-basin, it is probable that the basin formed in the Late Jurassic or Early Cretaceous by strike-slip movements parallel to the present Tasmanian shore line, involving at least one major southerly dipping detachment fault, which forms the northern bounding fault. It contains more than 4000 m of section which is thickest in the west. This section is probably dominantly Early Cretacous non-marine sandstone and Late Cretaceous shallow marine detrital sediments, overlain by some Paleogene shallow marine detrital sediments, and Neogene shallow marine carbonates.

Seafloor hydrocarbons

Nine gas-sampling stations were occupied in the sub-basin during BMR Cruises 67 and 78, and technical details and results are provided in Exon, Lee et al (1989) and Exon, Lee & Hill (1989). The samples were taken from gravity cores, whose locations are shown in Fig. 21. The degassing techniques were those described by Heggie et al (1988).

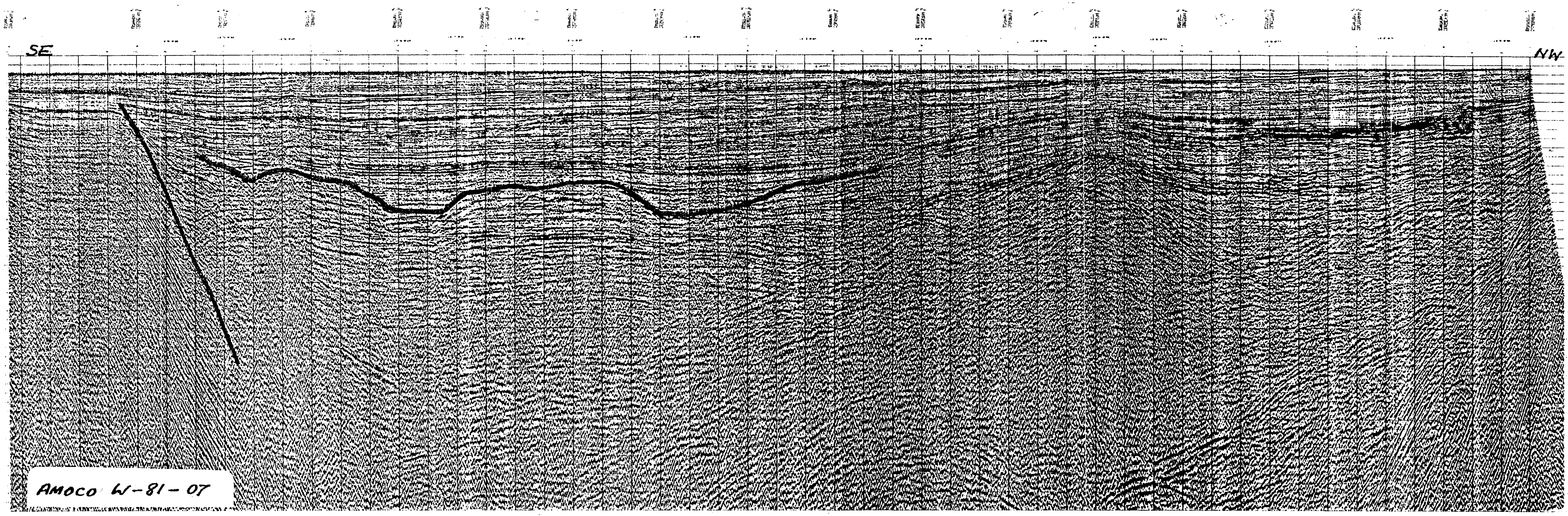
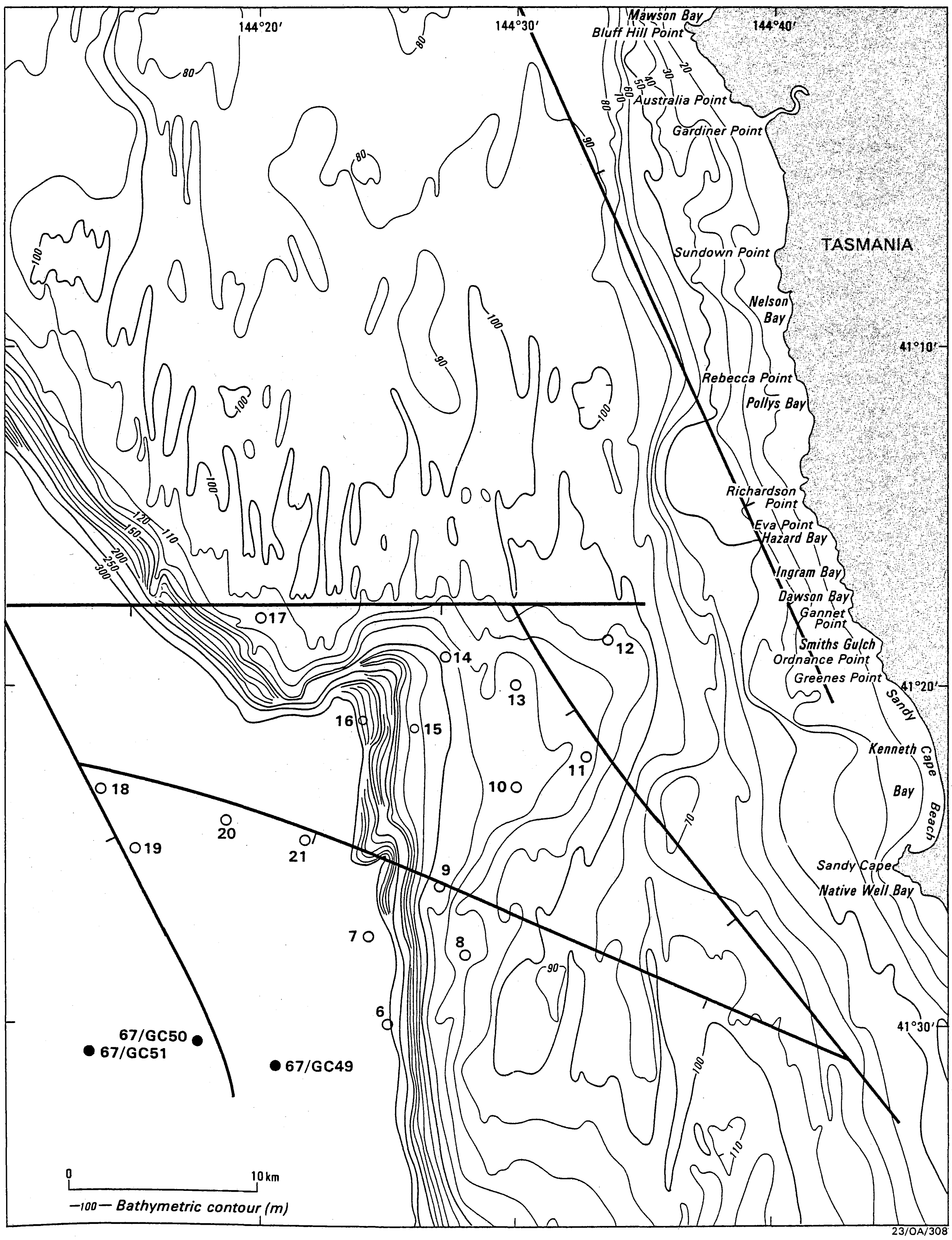


Fig. 20. Seismic profile showing the strong erosional unconformity and channelling of latest Paleocene age.

Fig. 21. Location map of geological sampling stations in the Sandy Cape Sub-basin. After Exon et al. (1989).



A summary of the results is given in Table 4. The data 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. 21), 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.

PETROLEUM POTENTIAL

Sediment and traps

Beneath the continental slope, the Sorell Basin comprises up to 6000 m of mainly Cretaceous and Tertiary sediments which seem to be providing a vast 'kitchen area' for the generation of hydrocarbons. Analogy and seismic ties with other Southern Margin basins suggest that the sediments overlying basement are probably Jurassic and Early Cretaceous: however, older sediments may be present in places, as shown by a 130 m section of Palaeozoic in Clam-1. On the continental shelf, in shallow water, the three depocentres - King Island, Sandy Cape and Strahan Sub-basins - contain estimated sediment thicknesses of 4000 to maybe 6000 m. If these sub-basins are of strike-slip origin, as predicted, the abrupt subsidence and/or elevation of individual fault-blocks which usually accompanies strike-slip movements, could be expected to have led to localised deposition of thick sequences during comparatively brief time spans. This appears to have been the situation in the Cape Sorell -1 area where an unusually thick Paleocene section was penetrated.

A mid-Oligocene unconformity (U3) extends throughout the region and separates predominantly detrital sediments below, from Neogene shallow marine carbonates above. In Clam-1 these carbonates are 740 m thick but reach an estimated maximum of 1400m on some seismic lines. The U3 unconformity marks the uppermost extent of nearly all faulting in the area and consequently the overlying carbonates should provide a regional seal at this level.

Potential hydrocarbon traps appear to be present in the sub-basins: they comprise -

. roll-overs and drape structures associated with the basin boundary faults and basin-forming tilt-blocks,

TABLE 4. 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

. major closures created by deep erosion in the Late Paleocene, draped and sealed by shallow marine mudstones,

. complex faulted anticlines (positive 'flower structures') formed largely in the Eocene and early Oligocene as a result of strike-slip plate motion between Australia and Antarctica.

The occurrence of late structuring in the basins (ie. Eocene/ Oligocene) has provided potential traps at a time when active migration of hydrocarbons was probably taking place.

Hydrocarbon generation

DSDP Site 282 (Figure 3) contained a sequence of organic-rich late Eocene silty clays with considerable source rock potential. Hunt (1975) reported that these sediments contain about 590 ppb Butane (C4) to Heptane (C7) by weight, a stong indication of hydrocarbon generation.

Extensive traces of oil were reported from the finer-grained portions of the earliest Paleocene/ latest Cretaceous towards the bottom of Cape Sorell -1. Although no significant oil zones were penetrated there is good evidence of source rock maturation in the well. Gas analysis towards the bottom of the hole revealed small quantities of Methane through Butane, and Methane shows were reported in the Oligocene/ Miocene limestones.

Whiticar & others (1985) measured gas yields and molecular composition from surface sediment samples in the Sorell Basin to test for the presence of thermogenic hydrocarbons. The highest yields were obtained from the upper continental slope, in the area about 25 km southwest of Cape Sorell -1 : the total C1-C5 yield was high by world standards, reaching a maximum of 1363 ppb (Figure 22). Although Methane was the major hydrocarbon present, the large C2-C5 proportion showed the gas to be wet, with a percentage wetness (sum C2-C4 / sum C1-C4 x 100) frequently around 40-45%, indicating a thermogenic source. Another measure of the of the biogenic / thermogenic origin of a gas is the 'Bernard Parameter' (ie C1 / (C2+C3)): gases of biogenic origin have Bernard Parameters of 5×10^2 to 1.0×10^5 or even higher; thermogenic gases typically have values less than 25. In the Cape Sorell area the Bernard Parameter was consistently around 1.7 units. Similar studies by Exon, Lee et al (1989) and Exon, Lee & Hill (1989) indicate that thermogenic gases are present elsewhere in the Sorell Basin (see, for example, SANDY CAPE SUB-BASIN).

The concentration and composition of hydrocarbons in the surface sediments of the west Tasmanian margin are indicative of active source units. The distribution appears to be strongly influenced by fault directed migration; the maximum yields occuring where basin-forming faults have been reactivated and extend to near the sea-bed, usually on the upper continental slope. The identification of the source rock units is highly specculative: the Early to mid-Eocene has demonstrated source rock qualities, and by analogy with the Otway Basin, maturation can occur in the

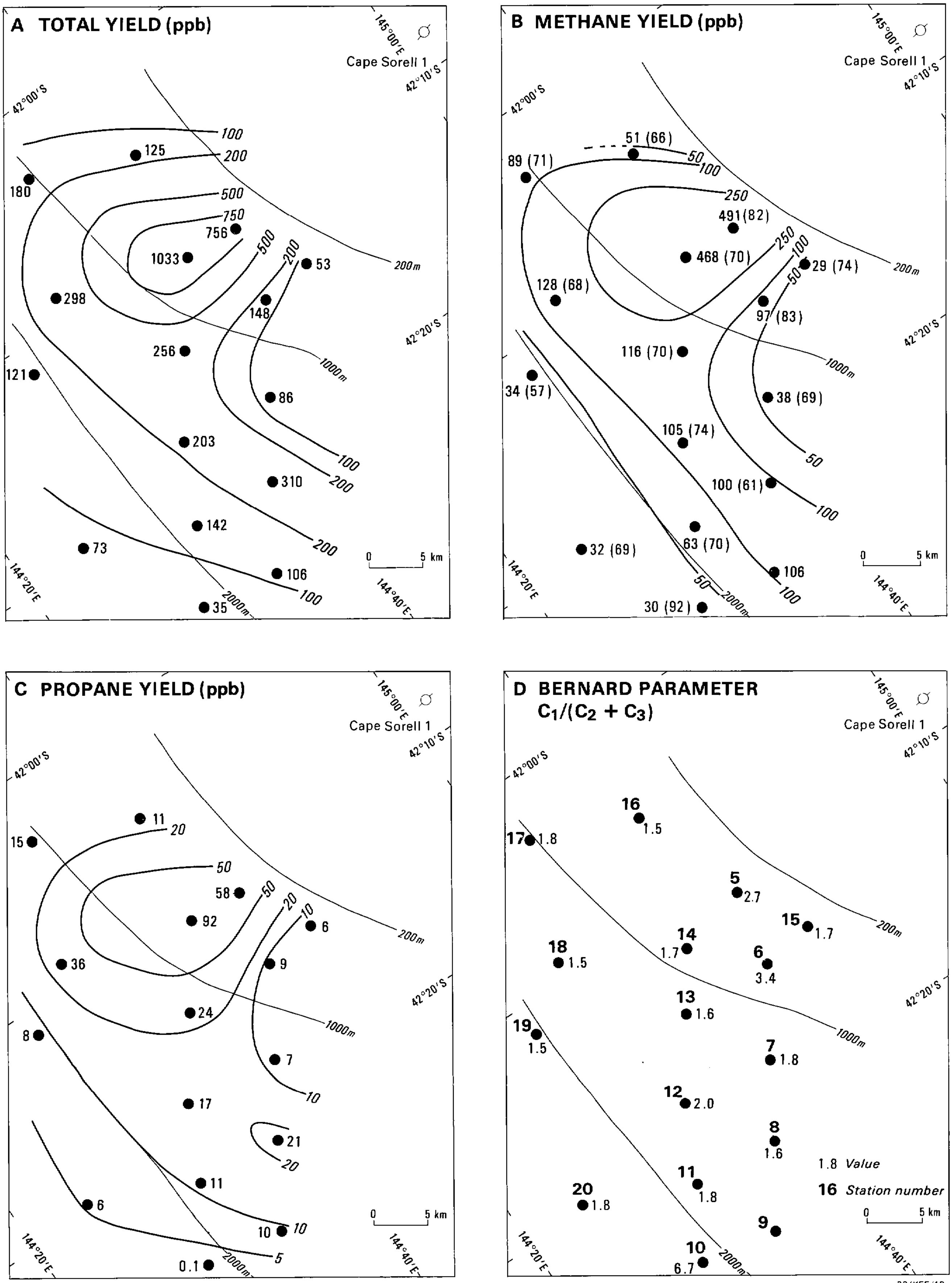


Fig. 22. Hydrocarbon yields from samples taken on the upper continental slope west of Cape Sorell - 1 well. After Whiticar et al. (1985).

Palaeogene sediments 1500 to 2000 m deep, with the 'oil window' between 2000 and 4000 m (Felton & Jackson, 1985). However, in the Sorell Basin the Cretaceous units with their suitable depth of burial could also provide an attractive source.

Maturation history

A cumulative subsidence curve for the Cape Sorell -1 exploration well (Figure 23) shows that, on the basis of vitrinite reflectance values of 0.7 and above, the early Paleocene and Late Cretaceous should now be mature for oil. This is consistent with the traces of free oil encountered in Late Cretaceous sandstones and siltstones in the well. However, the Late Cretaceous (Sherbrook Group equivalent) commenced passage into the oil window while wrench faulting was still proceeding, and thus some oil was probably lost along active fault conduits. Oil generated since the Oligocene would have has a reasonable chance of entrapment.

CONCLUSIONS

Seismic profiles indicate that up to 6000 m of sediment underlies the continental slope off western Tasmania and that relatively thick sediments also occur in the three strike-slip related sub-basins (King Island, Sandy Cape and Strahan) which underlie the continental shelf, in shallow water.

The potential of the area to generate hydrocarbons has been demonstrated by the high concentrations of thermogenic gases in surface sediment samples just west of the shelf break and the traces of free oil encountered in the Late Cretaceous / Paleocene in Cape Sorell -1 exploration well. Migration of hydrocarbons from the upper slope to the basins underlying the shelf could have taken place along fault conduits.

At this early stage the Strahan Sub-basin appears to have the greatest potential for hydrocarbons, in as much as it contains potential traps at several levels, possible marine source rocks, and a structural timing which would have allowed entrapment. The mapping of viable traps within the basin could be a painstaking task owing to the complexity of the wrench-related structures and, in places, a lack of seismic continuity.

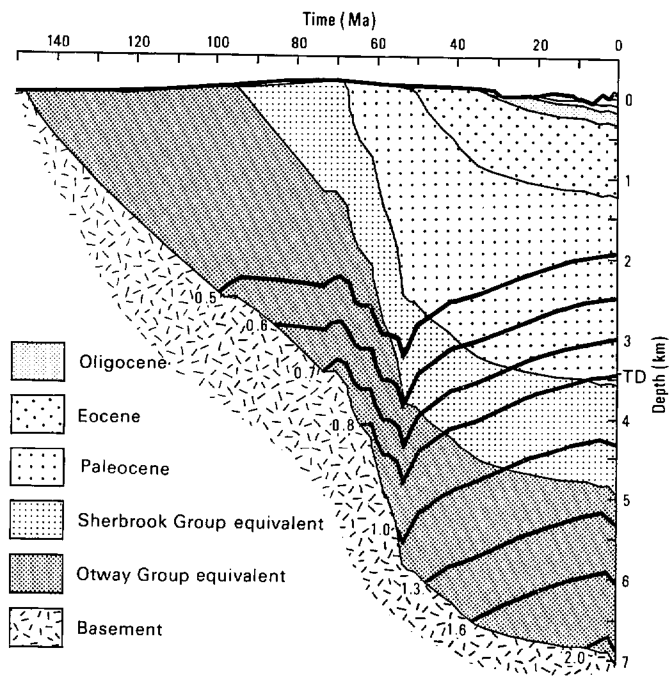


Fig. 23. Cumulative subsidence curve for Cape Sorell - 1 well, with constant heatflow of 1.3 HFU. After Hinz et al. (1986).

SOUTH TASMAN RISE (by J.B. Willcox)

The South Tasman Rise (STR) covers an area of 140 000 km^2 and lies in water depths ranging from about 800 to 3000 m or more (Figure 24). It is encompassed by Australia's Legal Continental Shelf, with approximately 70% of the Rise extending beyond an Exclusive Economic Zone (EEZ or 200 nautical miles; Symonds & Willcox, in press). The geology of the STR is of interest in relation to that of the Otway Basin - Sorell Basin region and sheds light on the extension/ breakup history of the Southern Margin in general. Although substantial basins are present on the STR, its remoteness and water depth are not conducive to petroleum exploration in the forseeable future.

A continental origin for the STR is deduced from its location in plate tectonic reconstructions, the drilling results at DSDP Site 281 (Figure 24) and its relatively quiet gravity and magnetic signature. At the drillsite, basement is composed of Palaeozoic mica-shist overlain by a basal angular agglomerate (Kennett & others, 1973): this agglomerate is overlain by Late Eocene to Oligocene detrital sediments deposited in a shallow marine, deepening to marine, environment. Miocene to Holocene ooze was penetrated above the Late Eocene to Oligocene unconformity which is widespread in the Tasman and Coral Seas. More recently, Neogene sediments were sampled during the 1985 *R/V Sonne* research cruise in the region (Hinz & others, 1985).

An interpretation of the widely-spaced *Sonne* seismic profiles and old BMR sparker data indicates that many of the seismic sequences identified in the Otway - Sorell Basins are apparently also present in the STR basins. The characteristics and tectonic significance of these sequences have been discussed by Hinz, Willcox & others (1986; Figure 7 & Table 1).

Structurally, the STR consists of a central triangular core of Palaeozoic basement, flanked on all sides by sedimentary basins (Figure 25; map by Willcox, Figure 26). The basement is extensively planated and its surface is continuous with the Late Eocene to Oligocene unconformity which extends across the area. A large extensional basin appears to occupy the southwest: it contains up to 6000 m of sediment-fill in many places, although volcanics are present within the synrift sequence. Another basin is developed in the northeast, along the margin opposite the East Tasman Plateau, but its origins are less clear. The stratigraphy and structure of these basins is consistent with their having a common origin with the Otway - Sorell Basins. The preliminary mapping indicates that major dislocations occur within the structure of the basins, and that these may represent the locations of transfer faults which probably have a NNE-trend, similar to that postulated in the Gippsland, Bass and Otway Basins (Etheridge & others, 1986).

The western half of the Rise is characterised by northerly-trending 'slivers' of basement, and intervening 'V-shaped' basins, which appear to have been created by transtensional movement in the Eocene and earliest Oligocene. Wrench faults extend through the sedimentary section up to the prominent Oligocene unconformity, and the western margin of the Rise is a

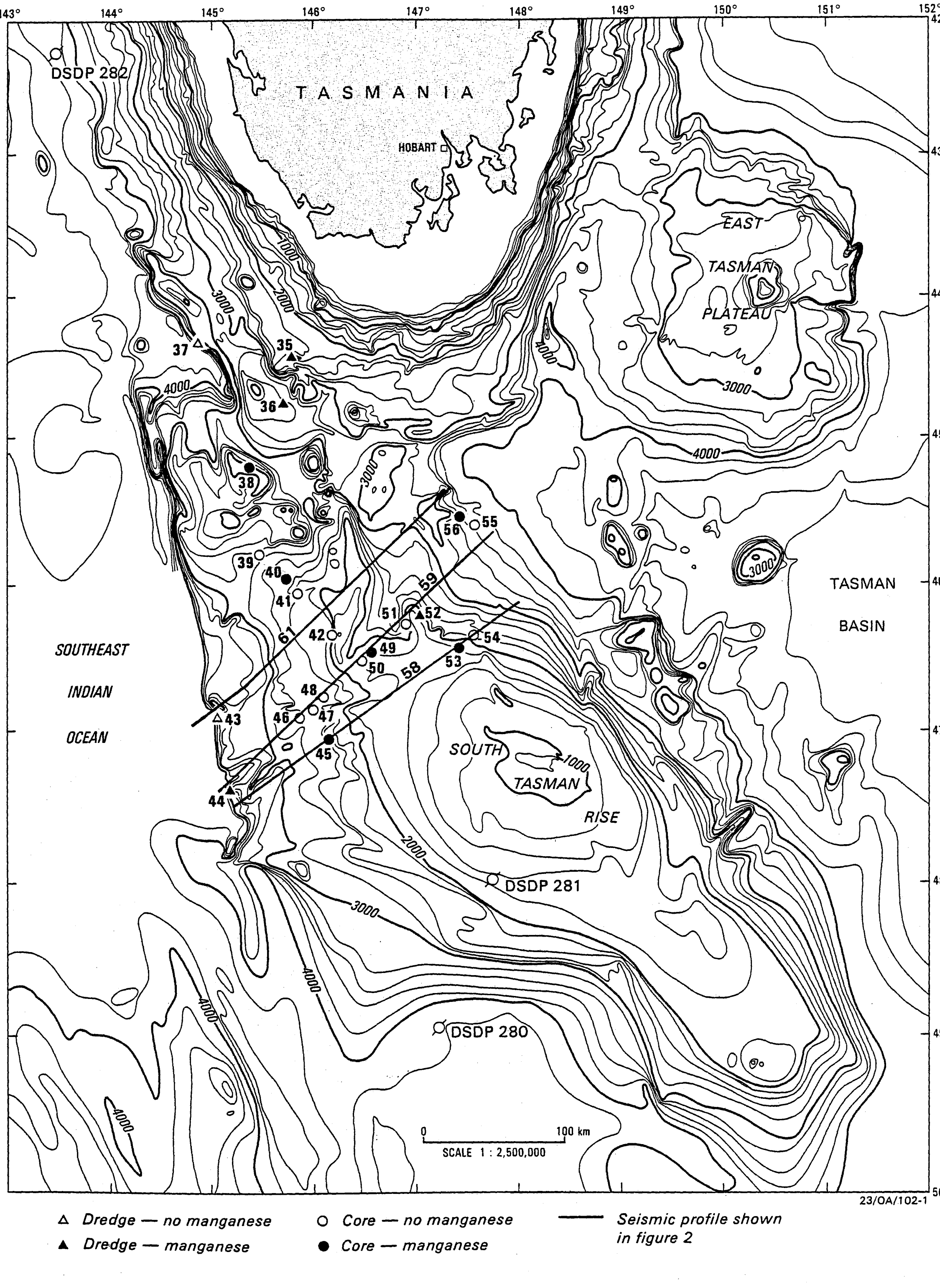


Fig. 24. The South Tasman Rise region off southeast Australia, showing sampling stations, key seismic profiles and bathymetry from Sonne cruise 36. After Bolton et al. (1988).

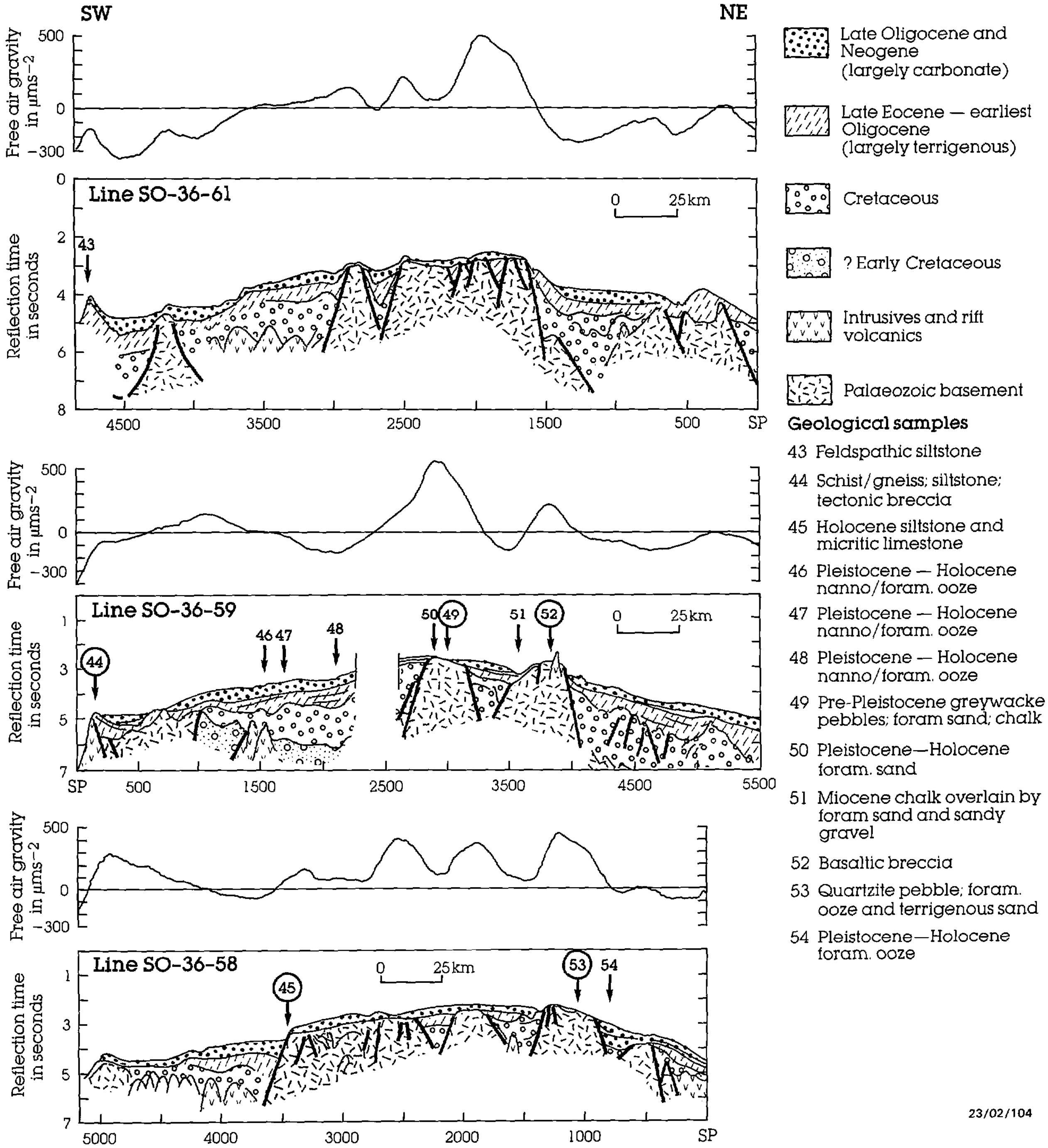


Fig. 25. Line interpretation of Sonne seismic profiles SO-36-61, SO-36-59 and SO-36-58, showing free-air gravity and sampling stations. After Willcox (1986).

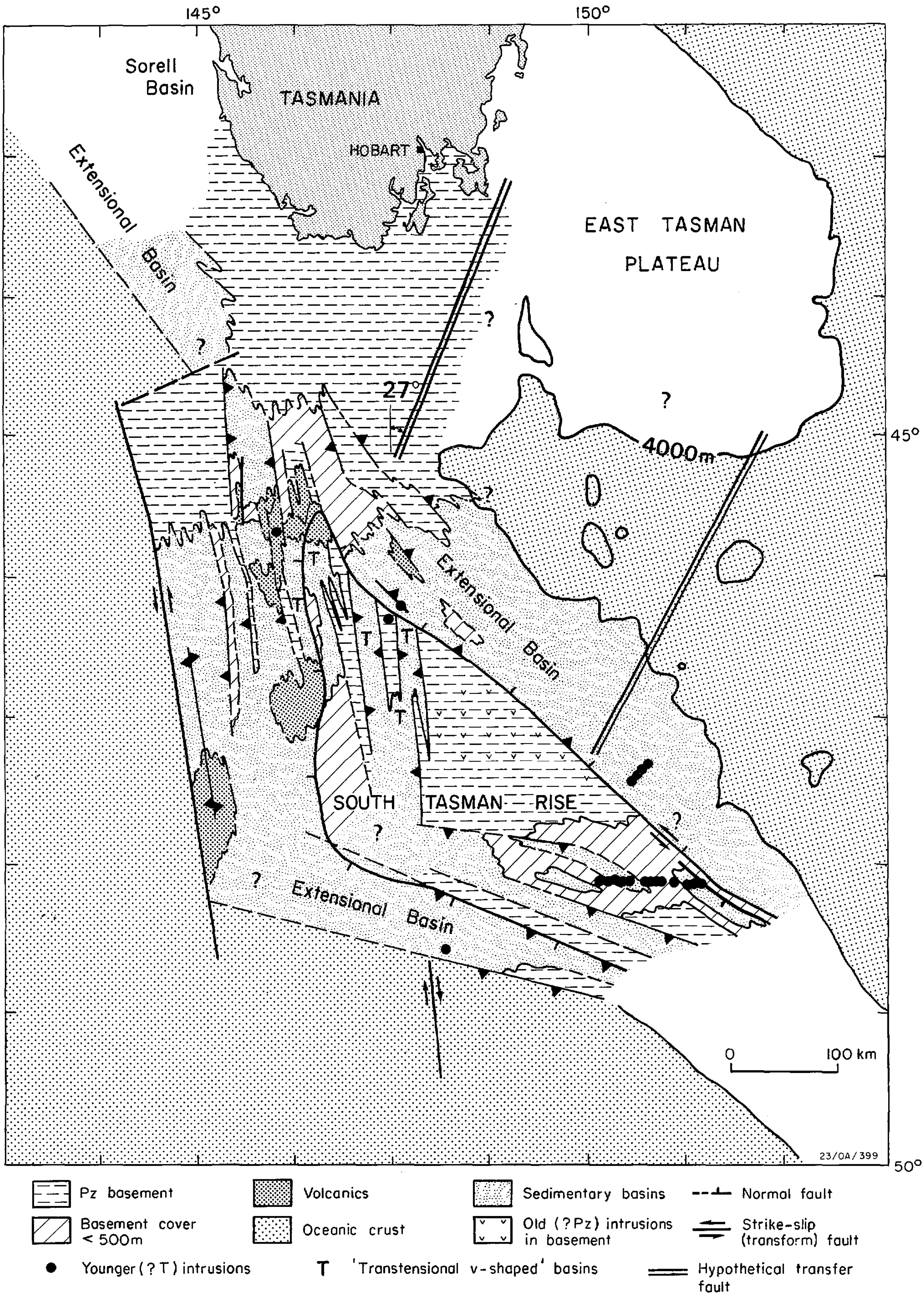


Fig. 26. Preliminary structural map of the South Tasman Rise region, from a seismic interpretation by Willcox.

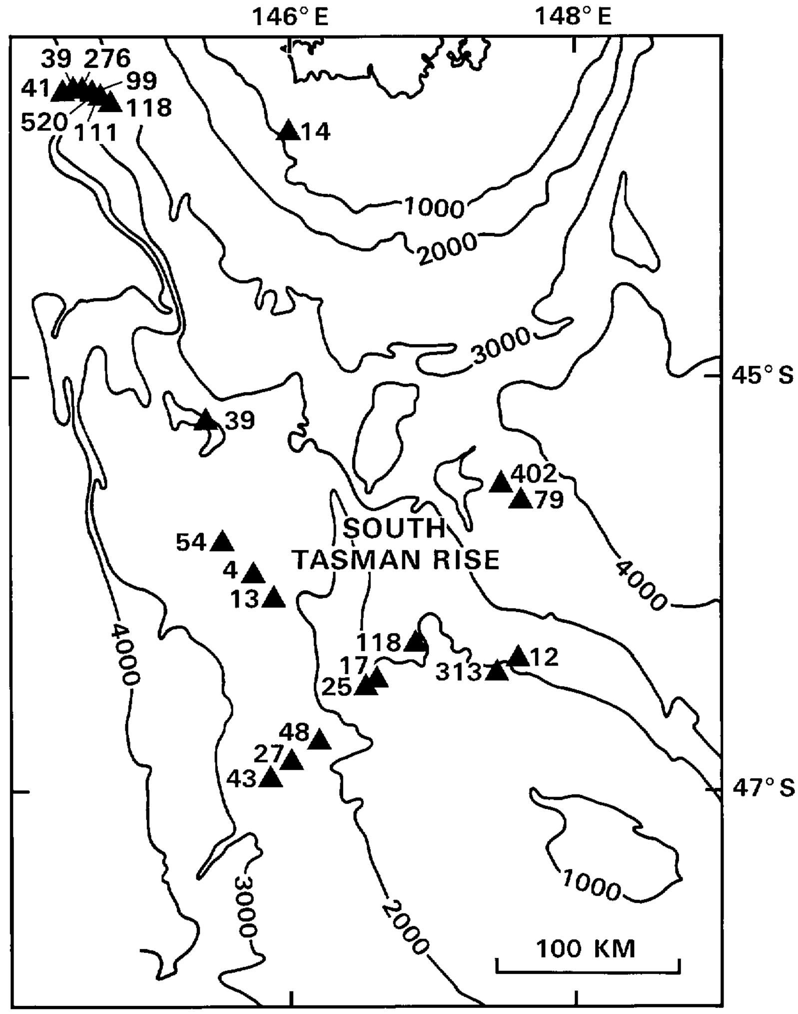


Figure 4
Total yield of thermogenically derived hydrocarbons (ppb) from surface sediments in the South Tasman Rise region (Whiticar and others, 1985)

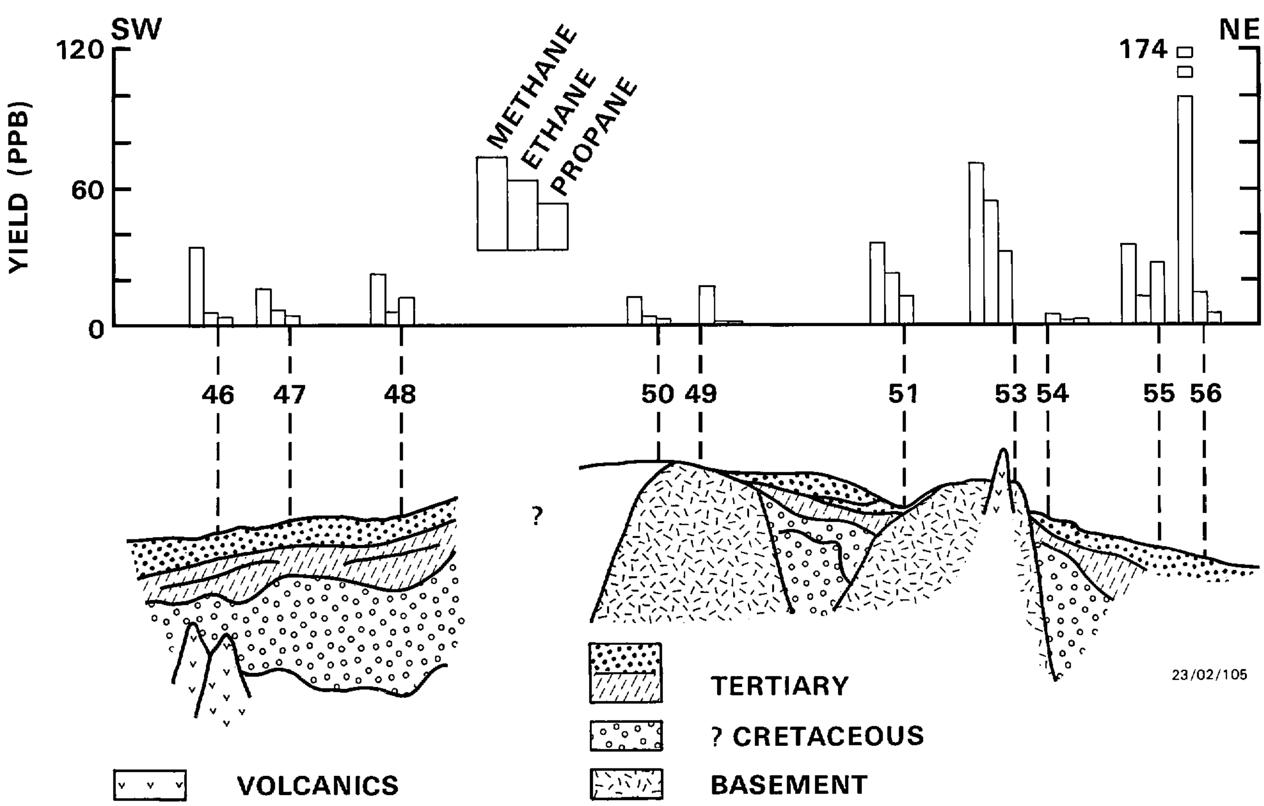


Fig. 27. Yields of thermogenically derived methane, ethane, and propane in relation to structure. After Whiticar et al. (1985).

transform fault of similar age (Figures 25 & 26). This margin is structurally similar to the western margin of Tasmania, as discussed by Hinz, Willcox & others (1986).

Thermogenic hydrocarbons in relatively substantial, but variable, concentrations have been found in surface sediment samples from the STR (Whiticar & others, 1985). The yields over the western basins and the planated areas were poor: in contrast, three stations on the eastern flank of the Rise, updip of the northeastern basin, gave relatively higher yields (Figure 27). Further examination of this area, with a view to long-term exploration for hydrocarbons, would seem to be warranted, particularly if large potential traps could be found in the shallower water (that is, less than 1000 m).

Plate tectonic reconstructions generally show the STR in its present location with respect to the Australian Plate. However, the available seismic data, and considerations of the extensional directions for the Southern Margin as a whole (Willcox & Stagg, in press), suggest that the STR may have been part of the Antarctic Plate until the Eocene, and from then on became detached along its southern and western edges. There would seem to be two possible scenarios for its movement: the first of these is that the STR moved left-laterally during the ?Late Cretaceous, from a position conjugate to the Otway Basin; and the second is that it has drifted westwards or southwestwards from a position conjugate to the East Tasman Plateau.

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