AGSO

CRUISE PROPOSAL

AGSO CRUISE 147: STRATIGRAPHY, TECTONIC HISTORY AND PALAEOCLIMATE OF THE OFFSHORE TASMANIAN REGION

BY N.F. EXON

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AGSO CRUISE 147: STRATIGRAPHY, TECTONIC HISTORY AND PALAEOCLIMATE OF THE OFFSHORE TASMANIAN REGION

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Table 2 has been omitted from the hardcopy of Record 1995/1

SUMMARY

The Tasmanian region's geological history bears on the history of the entire southern margin of Australia. The southern margin is already a major producer of petroleum from the Upper Cretaceous and Paleocene sequences in the Gippsland Basin, and has given encouraging exploration results in several other basins. The Otway Basin, in particular, is the scene of major recent offshore gas discoveries in the Cretaceous sequence. Both the west Tasmanian margin and the South Tasman Rise have petroleum potential.

The targets on the forthcoming *Rig Seismic* sampling cruise of 31 days (AGSO Cruise 147) are on the west Tasmanian margin, the South Tasman Rise, the East Tasman Rise, and the adjacent oceanic areas. The general bathymetry of the region is shown in Figure 1. The targets were defined by the early 1994 *Tasmante* cruise (Exon et al., 1994), which used the French research vessel *l'Atalante* on an exchange basis to swath-map the sea bed. About two-thirds of both the South Tasman Rise (STR) and the west Tasmanian margin were mapped, an areal coverage exceeding 200 000 km^2. The very accurate 1:250 000 scale bathymetric maps and sonar images arising from the *Tasmante* survey provide an unequalled source of structural information. A simplified bathymetric map of the region, based largely on the *Tasmante* swath-mapping, is shown in Figure 2.

The aim of the present sampling cruise is to ground truth the maps and ideas arising from the *Tasmante* cruise. It is designed to sample basement and Phanerozoic sedimentary rocks in all three continental blocks, Cainozoic volcanics in continental and oceanic terrains, and Cainozoic sediments on the continental blocks, by dredging and coring. This will help elucidate the Phanerozoic history of the area with emphasis on petroleum geology and plate tectonic hisory, and also the Cainozoic and especially Quaternary history with emphasis on plate tectonic history, and changes in climate and sedimentation patterns. Water column sampling is designed to provide more information about oceanographic controls on sedimentation. An additional aim is to sample manganese nodules in deep water to assess them as a potential resource, by the use of free-fall grabs. As a result of interest in the volcanic cones about 100 km of Hobart, mapped during the *Tasmante* cruise, which define major fishing grounds, two photographic profiles and one dredge are planned for there. The main sampling areas are discussed briefly below.

South of Tasmania

The continental South Tasman Rise is a NW-trending feature, cut by an older fault system trending NW, and a younger fault system trending almost north (Figures 1, 3 & 4). Both fault systems are clearly related to the break-up of Australia and Antarctica, starting 130 million years ago. The rise is bounded by steep scarps to the west and east, and less-marked scarps to the south. The western fault scarp above the abyssal plain, north-trending and up to 2300 m high, is part of the Tasman Fracture Zone linking Australia to Antarctica. West of the fracture zone is Tertiary oceanic crust. A number of faults splay off the scarp toward the east, and the seismic profiles suggest abundant old volcanism. The basement blocks on the central plateau are either little sedimented or unsedimented, but are separated by transpressional or transtensional basins containing several kilometres of sediment and oriented N-S to NW-SE.

The southern margin of the South Tasman Rise is delimited by south-dipping normal fault scarps beyond which is Tertiary oceanic crust. North of the margin, NW-elongated magnetic anomalies over outcropping basement apparently represent magnetic intrusions. In the east the margin is heavily sedimented, and Late Cretaceous oceanic crust has been identified beneath this sediment. In the northwest, a number of rotated fault blocks occur between major fault zones, and there are some thick

sedimentary basins. In the deep saddle between the rise and Tasmania, sediment thickness varies greatly, with areas of basement outcrop, sedimentary basins, and volcanoes up to 900 m high. Centred on a point one hundred kilometres south of Hobart, in water depths of 800-1500 m, there are about 80 volcanoes, each about 200-400 m high.

About 18 dredges will be located in this region, most on scarps to sample basement and the Phanerozoic stratigraphy, but some on Cainozoic volcanic features. In addition a number of cores will be sited to accurately sample Cainozoic sequences. Four freefall grab stations will investigate deepwater Mn nodule potential.

The South Tasman Rise was probably largely above sea level until it started to subside when Antarctica cleared it in the Eocene, and much of it stayed near sea level until late Oligocene times. Acoustic facies mapping of the South Tasman Rise, based on the 3.5 KHz bathymetric profiles and the swath imagery, has revealed varied patterns of Cainozoic and Quaternary sedimentation. In general, erosion prevails on the South Tasman Rise, but patterns change with basement outcrop, morphology, and current activity. The varied sedimentary features clearly represent major changes in current regime. Coring of the acoustic facies patterns at several stations will improve our understanding of the surface sediments. About ten gravity and box cores will be located in better sedimented areas to elucidate Late Quaternary paleoclimatic changes. In addition several gravity and vibro cores will investigate sedimentation on the shelf and slope southeast of Tasmania.

West Tasmanian region

About 50 000 km^2 of the west Tasmanian margin (Fig. 1) was mapped during the *Tasmante* cruise. The mapping showed that canyons are much more common on the slope than had been previously known (Fig. 4). These canyons presently cause starvation of much of the upper and lower slope off west Tasmania, and sedimentation on the lower slope.The seismic data show that the sedimentary sequence is almost everywhere more than 2.5 seconds (>3 km) thick, basement being visible only in some shelf areas.

On the outer west Tasmanian margin, large NW-trending fault blocks, up to 2500 m high and marking the last obvious continental crust, have been swath mapped. West of them is a transitional zone about 50 km wide, heavily sedimented and deep, underlain either by Cretaceous oceanic crust or thinned continental crust. Beyond that is young, shallower Tertiary oceanic crust with only thin sediment cover, and volcanoes along the north-south fracture zones. The younger, north-south tectonism has disrupted the older northwest fabric along the margins in various ways. Southwest of Tasmania, at the junction with the South Tasman Rise, there is a triangular area 50 km across, where it appears that the movement past of Antarctica has dragged the older rocks around and southward, to form a series of arcuate outcrops on the northernmost South Tasman Rise. The triangle itself was apparently produced by the movement south of the older rocks, and is a depression, perhaps filled with basalt.

Six dredge sites are planned to sample basement and the Phanerozoic sequence in scarps, and one freefall grab station should sample Mn nodules above a current-swept scarp.

East Tasman Rise

The *East Tasman Rise* (Fig. 1) lies southeast of Tasmania and is an equidimensional feature about 200 km across, from which rises the Eocene volcanic cone of Soela Seamount. It is probably of continental origin. A *Tasmante* profile shows the rise to be bounded by scarps and two dredge sites are aimed at

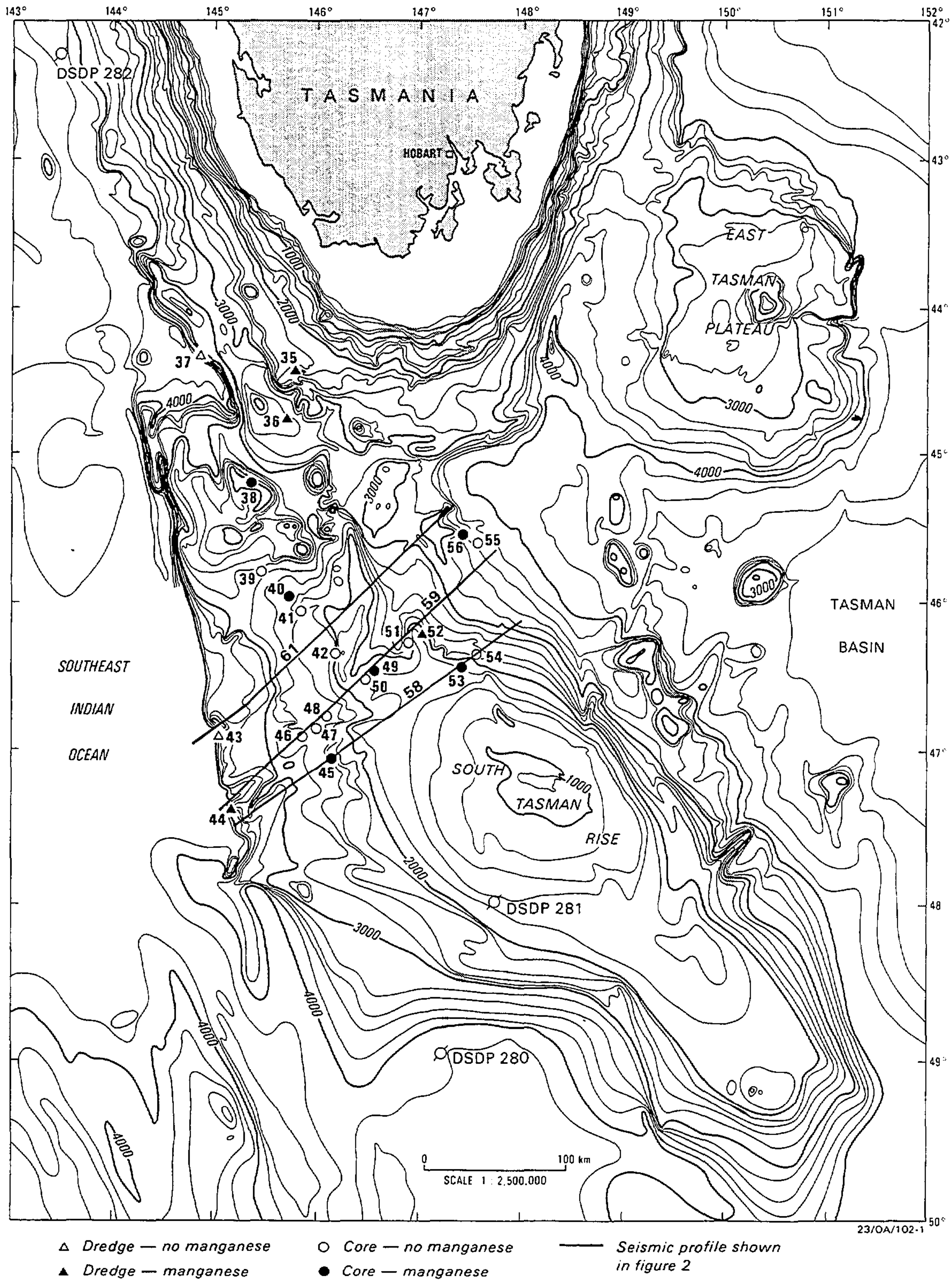


Figure 1. Bathymetric map of the study region. Shows *Sonne* South Tasman Rise sampling locations, and key seismic lines illustrated in Figure 11. After D. Jongsma and G. Wissmann (unpublished).

Etopo5 + Shipboard swath-bathymetry

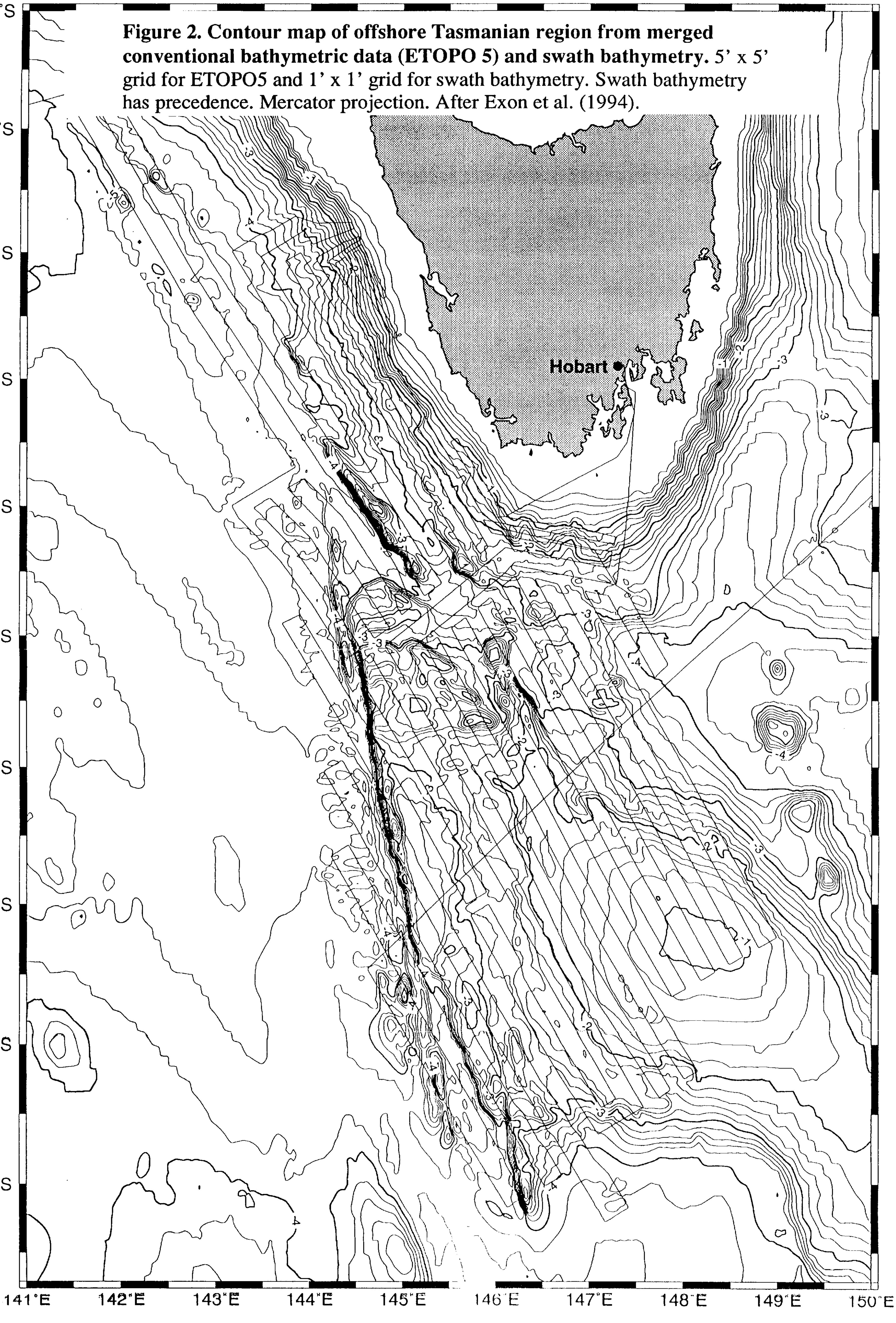


Figure 2. Contour map of offshore Tasmanian region from merged conventional bathymetric data (ETOPO 5) and swath bathymetry. 5' x 5' grid for ETOPO5 and 1' x 1' grid for swath bathymetry. Swath bathymetry has precedence. Mercator projection. After Exon et al. (1994).

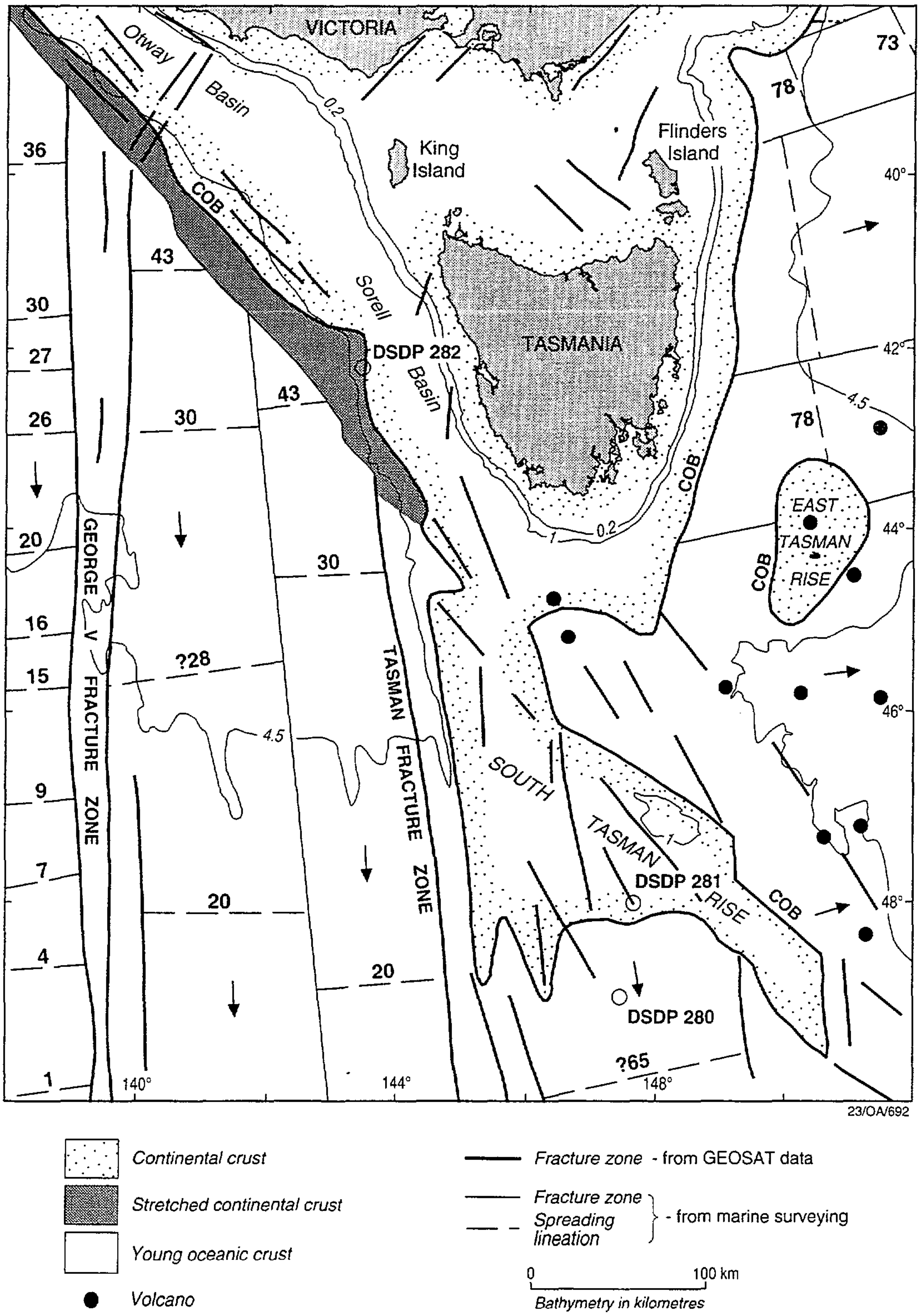
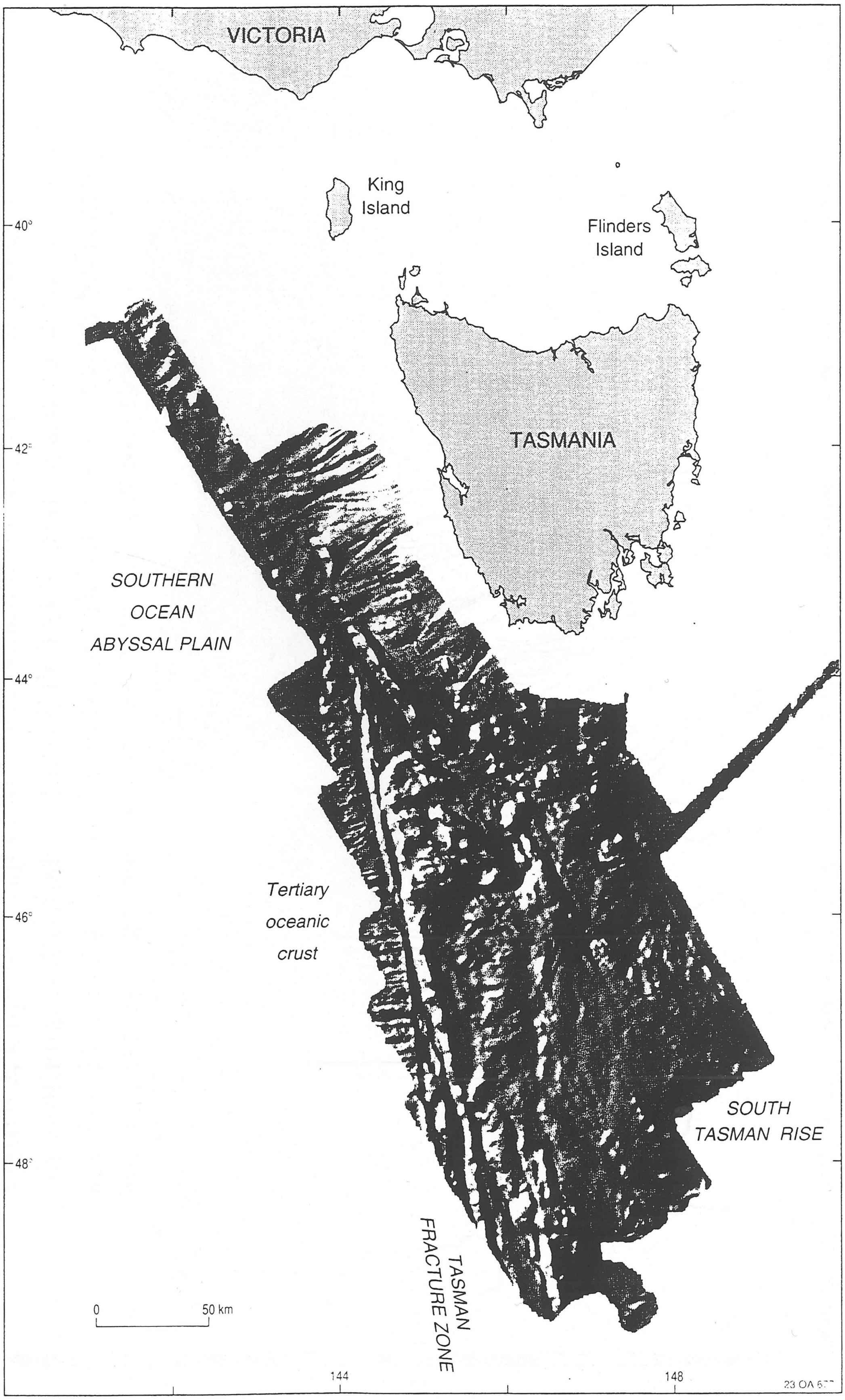


Figure 3. The tectonic elements of the offshore Tasmanian region. After Exon et al. (1994).

Figure 4. Relief diagram of the region surveyed off Tasmania from *Tasmante* data. Water depths are in the range 1000-4500 m. Note the older 320° and the younger 345° fault directions, the deepwater volcanic cones west of Tasmania, the canyons on the western margin of Tasmania. The sea-floor spreading fabric is visible at the sea bed in the west as easterly trending ridges. After Exon et al. (1994).



Etopo5 + Shipboard swath-bathymetry

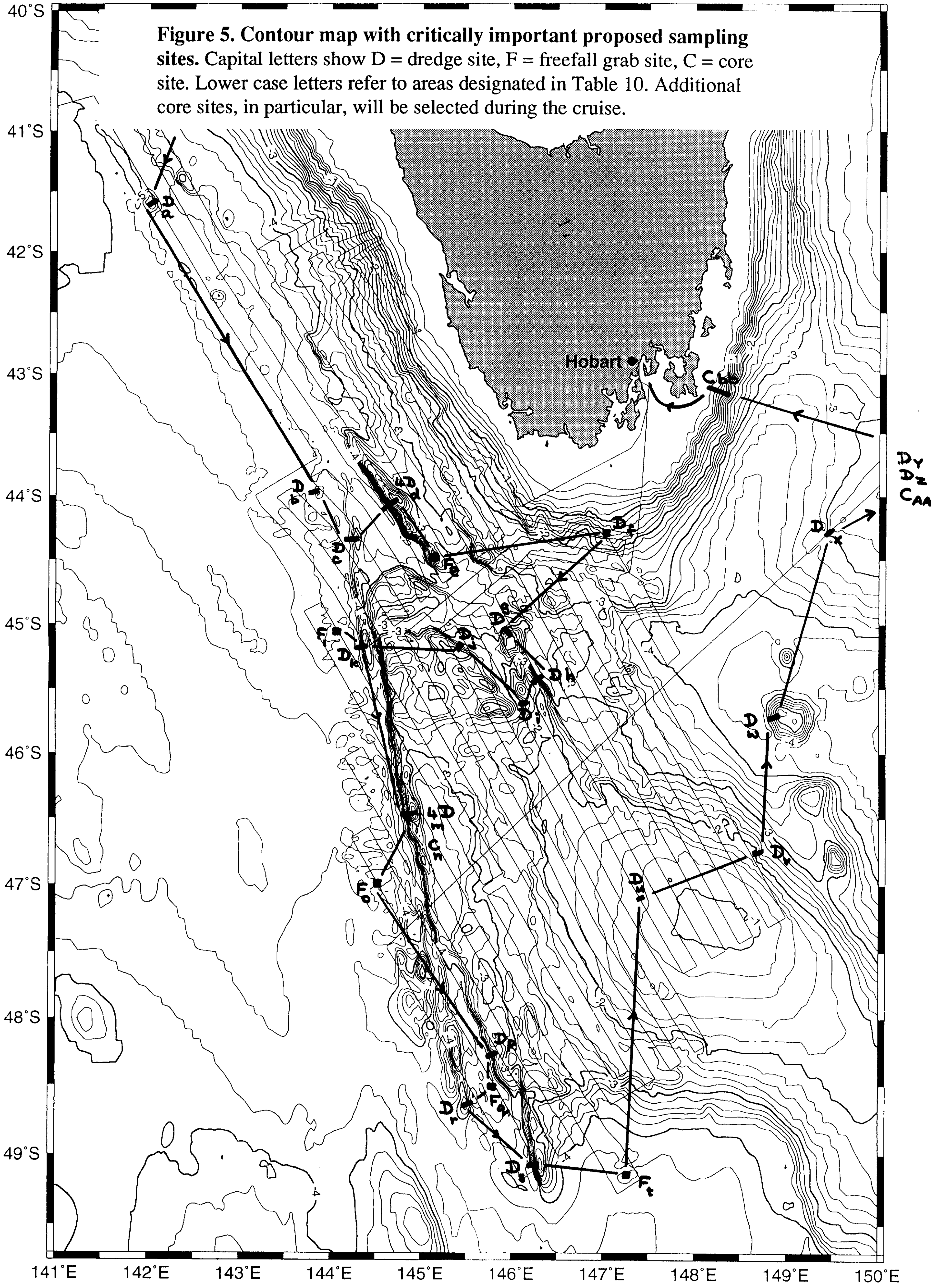


Figure 5. Contour map with critically important proposed sampling sites. Capital letters show D = dredge site, F = freefall grab site, C = core site. Lower case letters refer to areas designated in Table 10. Additional core sites, in particular, will be selected during the cruise.

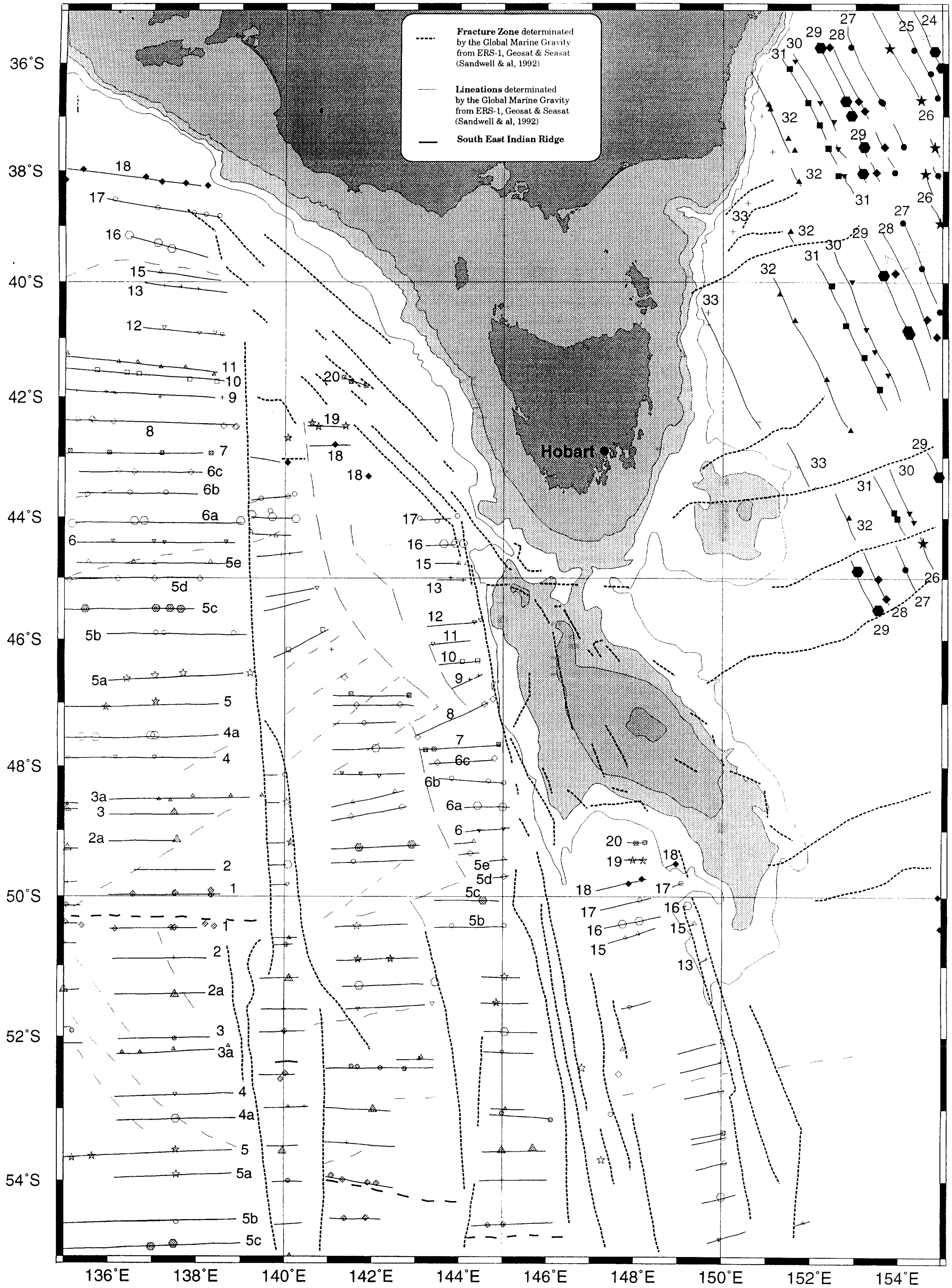


Figure 6. Tectonic map of southeast Australian region. Fracture zones and lineations interpreted from GEOSAT satellite gravity data. Magnetic anomaly pattern determined from all public data by J.-Y. Royer and N. Rollet (1994).

basement and Phanerozoic sequences there. The seamount is flat-topped, ten kilometres across and 1200 m high, and it culminates 650 m below sea level. One dredge will sample its slopes. Several cores and box cores will sample Late Quaternary sediments on the rise for palaeoceanographic purposes.

Conclusions

Figure 5 shows the proposed program in preliminary form, and the program will be modified as the cruise progresses. Altogether, we plan about 25 dredge stations, 20 gravity cores, 8 box cores, 5 vibrocores, 5 freefall grab stations (Table 10), and a number of water bottle deployments. If we have reasonable success, these samples, in conjunction with rock and sediment samples taken on earlier cruises by American institutions, R.V *Sonne* and R.V. *Rig Seismic*, will greatly improve our understanding of a large part of the Australian margin. Some of the area to be sampled lies beyond the Australian Exclusive Economic Zone but within our legal Continental Shelf.

INTRODUCTION

The west Tasmanian margin and the South Tasman Rise have been the subject of a number of BMR/AGSO cruises over the years:

- BMR Continental Margins high-energy sparker seismic survey - 1972
- BMR low-energy sparker seismic survey of continental shelf - 1973
- BMR Cruise 40 Bass Basin contract seismic survey - 1982
- *Sonne* SO-36B & C cooperative seismic and sampling surveys - 1985
- BMR Cruise 67 *Rig Seismic* sampling survey - 1987
- BMR Cruise 78 *Rig Seismic* seismic and sampling survey - 1989
- AGSO Cruise 125 *l'Atalante* swath-mapping and seismic survey - 1994

These cruises have provided a great amount of morphological and geological information about the region. When AGSO Cruise 147, the *Rig Seismic* sampling cruise planned for February 1995 and outlined in this report is complete, along with the *Rig Seismic* deep seismic cruise planned for March 1995, AGSO will be able to carry out a full review of the geological framework and offshore resource potential of this part of the Australian margin, extending well beyond the Australian Exclusive Economic Zone. Altogether, about 25 dredge stations, 20 gravity cores, 8 box cores, 5 vibrocores, 5 freefall grab stations, and a number of water bottle deployments are planned for AGSO cruise 147, to start in Melbourne on 27 January and end in Hobart on 27 February.

Regional plate tectonic setting

This section is drawn directly from Royer & Rollet (1994). Their map of the present-day tectonic elements is shown in Figure 6. The South Tasman Rise (STR) is known from deep sea drilling and dredging to be of continental origin, and as such was part of the former East Gondwana continent. Reconstructions of Gondwana show that the STR was contiguous to several continental fragments that are now thousands of kilometres apart. Going counterclockwise, the STR was bounded by Victoria Land, Antarctica, to the west, by the Ross Sea shelf to the south, by the Campbell Plateau to the southeast, by the Challenger Plateau and Lord Howe Rise to the east, and by Tasmania and Australia to the north. The STR is certainly the smallest of these Gondwana fragments, and because of its central location in the plate boundary framework that developed within East Gondwana, it underwent all the major tectonic events that led to the dispersal of the Gondwanan fragments. These tectonic events span from the Late Jurassic to the Late Oligocene, after which the STR drifted passively northward along with the Australian plate. The STR is therefore a centre piece in understanding the complex tectonic history of this region.

Early extension between Australia and Antarctica started in the Late Jurassic along a NW-SE direction (relative to a fixed Australian plate; Willcox & Stagg, 1990). Extension in the Bass Strait, between Tasmania and the mainland, is contemporaneous and, in large part, in the same direction (Willcox et al., 1992). This extension phase lasted until the Late Cretaceous when seafloor spreading started in the Great Australian Bight (Cande & Mutter, 1982). The continent-ocean boundary is dated as 95 Ma old (Cenomanian; Veevers, 1986). Subsidence studies along the southern Australian margin, as well as the conjugate pattern of seafloor magnetic anomalies off Australia and Antarctica, suggest that the break-up between Australia and Antarctica propagated from the Great Australian Bight towards Tasmania (Mutter et al., 1985). Seafloor spreading started at a very slow spreading rate (< 1 cm/yr, full rate) until the Early Eocene, increasing somewhat to a slow rate (~ 2 cm/yr) until the Middle Eocene. The western margins of Tasmania and STR paralleled the north-south seafloor spreading direction and therefore behaved as a transform margin. It is possible that north-south extension initiated at this time between Tasmania and the STR (Veevers et al., 1991), as the STR might have still been attached to Antarctica.

Seafloor spreading between Australia and Antarctica accelerated drastically (up to 4-5 cm/yr) in the Middle Eocene (~ Chron 18; 45 Ma); this event coincides with major reorganisations of the plate boundaries in the Indian Ocean. During this second stage, the STR remained attached to the Australian plate; but this does not preclude any further extension, if not early oceanisation, between the STR and Tasmania. At chron 13 (36 Ma; late Oligocene), the large transform offset of the Tasmanian and STR margins (~ 750 km long) was still preventing any deep water circulation between the Australian-Antarctic Basin and the Pacific Ocean. The Southeast Indian ridge axis remained in contact with the STR western margin until about chron 8 (30 Ma). As seafloor spreading continued, the transform margin of the STR gave birth to the large offset Tasman and Balleny oceanic fracture zones. The outstanding signatures of these fracture zones on the satellite gravity data provide major constraints to reconstruction of the relative motions of Australia and Antarctica (Royer & Sandwell, 1989).

Rifting along the eastern margin of Australia, Tasmania and the STR, probably began in the mid Cretaceous. The opening of the Tasman Sea, between Lord Howe Rise/Challenger Plateau and Australia, started in the Late Cretaceous (~ chron 33; 80 Ma), along an ENE-WSW direction (Hayes & Ringis, 1973; Weissel & Hayes, 1977). Seafloor spreading propagated from south to north along the eastern Australian margin. The oldest magnetic anomalies (chron 33) identified in the Tasman Sea are located just east of the East Tasman Rise. Further south, lack of magnetic anomaly profiles prevents any exact dating of the oceanic crust lying east of the STR. However plate reconstructions at chron 33 bring the western slopes of Challenger Plateau next to the STR (e.g. Molnar et al., 1975). Seafloor spreading in the Tasman Sea stopped abruptly in the early Eocene (chron 24/23, 55-50 Ma), probably when the Australian-Antarctic and Pacific-Antarctic spreading systems connected south of the STR.

Seafloor spreading resumed south of the Tasman Sea almost at right angles to the former spreading ridge, leaving a prominent scar on the seafloor, extending from the southeastern tip of the STR to the South Island of New Zealand. The oldest magnetic anomalies, south of this boundary, roughly oriented east-west, are of middle Eocene age (chron 21-22; 45-50 Ma) and record the relative motion between the Antarctic and Australian plates. South of the STR, early Eocene to mid-Eocene basal sediments were recovered at DSDP site 280, suggesting that seafloor spreading, between Antarctica and the STR, started during this plate boundary reorganisation in the Tasman Sea. Such a discrepancy in age of

initiation of seafloor spreading west (Late Cretaceous) and east (early/mid-Eocene) of the Tasman transform margin, favors the idea of a large amount of extension, if not oceanisation, between the STR and Tasmania.
The plate reconstruction of East Gondwana brings the southern boundary of the STR along the Ross Sea shelf and the western Campbell Plateau (e.g. Molnar et al., 1975; Weissel et al., 1977). The breakup of these continental pieces seemed to occur in the Late Cretaceous, and a triple junction developed in the vicinity of the STR. The three branches of this system being: to the north the Tasman spreading ridge between Tasmania-Australia and the Challenger Plateau-Lord Howe Rise, to the south the early Pacific-Antarctic Ridge separating the Ross Sea shelf from the Campbell Plateau, and to the east a transform boundary splitting the Challenger Plateau from the Campbell Plateau. An additional plate boundary is hypothesized between East and West Antarctica, across the Ross Sea.

The study region

The region of interest to us includes the area mapped by R.V. *L'Atalante* with the multibeam EM 12 swath-mapping system, and extends from 40° to 50°S and 140° to 152°E, west, south and east of Tasmania, from west of King Island to the crest of the South Tasman Rise, and east to the outer edge of the East Tasman Rise, and from the outer edge of the continental shelf to the abyssal plain (Fig.1). The continental shelf around Tasmania is generally less than 50 km wide and non-depositional at the present day (Jones & Holdgate, 1980), but bryozoal sands and gravel do accumulate on the outer shelf (Jones & Davies,1983). The continental slope west of Tasmania is about 70 km wide, and falls fairly regularly from water depths of 200 m to 4000 m, so the average slope is 3-4°. The continental rise lies between about 4000 m and 4500 m, and below that is the abyssal plain, generally 4500-5200 m deep.

The South Tasman Rise is a large, NW-trending bathymetric feature that rises to less than 1000 m below sea level, and is separated from Tasmania by a WNW-trending saddle more than 3000 m deep (Fig. 1). The Deep Sea Drilling Project showed that it has a continental core, when quartz-mica schist was drilled in DSDP Site 281 (Kennett, Houtz et al., 1975A). The top of the rise is a gentle dome with low slopes, but slopes between 2000 and 4000 m on its eastern and southern sides are much like those in the Tasmanian continental slope, of the order of 3-4º. The western slope is not great to 3000 m, but below that there is a very steep scarp trending 350º and dropping away to 4500 m. Sampling of the scarp has returned Upper Cretaceous shallow marine mudstone, siltstone and sandstone.

This scarp and several NNW-trending ridges, in the continental slope and on the deep ocean floor, west of Tasmania and off the Otway Basin, seem to mark tilt-blocks of continental rocks, necessarily overlying highly extended and thinned continental crust. Dredging of one such ridge on the abyssal plain off Victoria by AGSO's *Rig Seismic* has led to the recovery of Tasman Geosyncline metasediments (Exon, Williamson et al., 1987). Other ridges, off the west coast of Tasmania and oblique to the continental shelf edge, may lie on the continent-ocean boundary, or may be the trace of old transforms associated with the early stages of seafloor spreading between Australia and Antarctica.

The East Tasman Rise is a nearly circular feature, separated from southeast Tasmania by a saddle 3200 m deep (Fig. 1). The area above 4000 m depth is about 60 000 km^2 and that above 3000 m is about 20 000 km^2. Slopes are generally 3-4° but they are considerably greater on the outer flanks. Atop the plateau is the Soela Seamount, a guyot that rises to 660 m below sea level. This guyot formed as the result of Palaeogene hotspot volcanism, and has yielded early Eocene shallow-water carbonates from its flanks (Quilty & Jenkins, in prep.). It is uncertain whether the plateau itself, that has up to 1.5 seconds (TWT) of sedimentary section in places, is of continental or oceanic origin but the *Tasmante* results suggest that it is continental.

The mapping of seafloor magnetic anomalies starting with Weissel & Hayes (1972), and the interpretation of satellite altimeter data (e.g. Royer & Sandwell, 1989, repeat mission Geosat data; Veevers, 1990, Seasat data; Sandwell & Smith, 1992, 1994, Geosat and ESR-1 data) has shown that the abyssal plain west of Tasmania is characterised by fracture zones trending 350-335°, and that Late Cretaceous and Cainozoic magnetic anomalies are probably normal to the fracture zones. Tasman Sea spreading started east of Tasmania in the Late Cretaceous at about 80 Ma, and ended in the Eocene at about 55-50 Ma, according to Royer & Rollet (1994). The anomaly pattern and the GEOSAT data suggest that the associated fracture zones trend 70-80°. The most modern anomaly pattern and representation of the fracture zones is shown in Figure 6.

Satellite images of our study region define basement structure very well and provide excellent information on fracture zones. They confirm an older NW-trending fracture direction (Jurasic-Early Cretaceous) close to the continental margin, and the younger 350-355° fracture direction further out on the abyssal plain. They also indicate that the South Tasman Rise is cut by major deep faults. An interpretation of the Geosat imagery is incorporated in Figure 3.

PREVIOUS STUDIES

Tectonic studies which have touched on this region include that of Falvey (1974), who produced a model of this margin as a typical Atlantic margin, with breakup between Australia and Antarctica in the late Paleocene, in line with the interpretations of magnetic anomalies by Weissel & Hayes (1972), and Deighton et al. (1976). Cande & Mutter (1982) revised the magnetic identification and concluded that margin formation commenced in the Santonian, with a period of slow spreading from 90 to 43 Ma, followed by more normal spreading rates until the present. Falvey & Mutter (1981) and Willcox (1982) included the region in general reviews of Australia's continental margins. Veevers (1985) has suggested that breakup started 95 Ma ago.

Early cruises

A great deal of seismic and sedimentological information, arising from cruises of R. V. *Vema*, R.V. *Robert D. Conrad* and USNS *Eltanin*, for the area between Australia and Antarctica, is presented in a synthesis volume edited by Hayes (1971). The basic data for five papers discussing the sediments of the southeast Indian Ocean come from a collection of about 300 cores taken on a number of cruises carried out in a very methodical manner. Conolly (1971) has written a brief and useful overview of the results, and he outlines the physiography, the sediment thickness above basement, the distribution of surface sediment types, and the Tasman manganese pavement south and southeast of the South Tasman Rise. Conolly & Payne (1971) mapped the manganese pavement largely by bottom photography. It consists of a pavement of nodules and/or reworked or relict foram and manganese sand that overlies firm grey siliceous ooze. Its distribution follows the deep troughs associated with the Tasman Fracture Zone between Tasmania and the mid-oceanic ridge, and spreads eastward onto the floor of the Tasman Abyssal Plain. The authors suggested that it was created by bottom water movement eastward around Tasmania and the South Tasman Rise. The manganese pavement coincides with an area of 3 000 000 km^2 of non-deposition or low deposition for at least the last 3 million years, documented by palaeomagnetic and faunal studies (Watkins & Kennett, 1971).

A number of cores were taken by R.V. *Eltanin* in the region near Tasmania and the South Tasman Rise (Watkins & Kennett, 1971), and these are summarised below in Table 1. All cores taken by US institutions are listed in considerable detail in Appendix 3.

TABLE 1: CORES TAKEN BY USNS *ELTANIN* NEAR TASMANIA

Station	Latitude (S)	Longitude (E)	Water depth (m)	Length (cm)	Sediments
36-23	43°53.0'	150°02.0'	2533	542	Calc ooze
34-10	44°31.6'	149°58.4'	2853	1136	Calc ooze
34-12	45°11.6	147°11.6'	3932	2262	Calc ooze
34-11	45°12.6'	147°48.2'	3932	440	Calc ooze
34-13	45°11.5'	145°04.2	4022	dredge	Mn nods
34-9	45°20.1	146°06.2'	2743	588	Calc ooze
39-64	45°33.6'	150°21.0'	4652	453	Calc ooze
39-62	46°56.8'	149°32.6'	3219	684?	Calc ooze
39-49	47°06.0'	142°33.6'	4678	382	Calc ooze
36-22	47°32.0'	148°01.0'	1102	422	Calc ooze
39-52	47°34.8'	142°59.7'	4581	462	Calc ooze
39-53	48°48.5'	144°32.0'	3987	411	Calc ooze
36-21	49°27.0'	149°08.0'	3846	443	Calc & rad ooze
39-55	49°56.9'	145°55.8'	4810	862	Diatom ooze

Houtz & Markl (1971) summarised numerous seismic profiles from the area between Australia and Antarctica, and produced a general isopach map. They commented on a 1 second (TWT) thick sequence of predominantly transparent sediment that abuts the southern side of the South Tasman Rise and extends southward to about 56°S. They illustrate a profile south of the rise, running east-west at about 55°30'S, which shows about 0.5 second of transparent sediment east of the Tasman Fracture Zone, that is cut by the Balleny Fracture Zone but continues eastward beyond it into the Tasman Basin. The Tasman Fracture Zone on this profile is a ridge about 1000 m high that separates rough unsedimented oceanic crust to the west from the sedimented area south of the South Tasman Rise.

The 1972 BMR Continental Margins Survey was the first regional seismic survey that included the Tasmanian region. This survey used a 120 kilojoule sparker source, and extended from the shelf to the abyssal plain, with a line spacing of about 50 km, and was the basis of a report on the Australian southern margin by Willcox (1978). The east-west lines in Figure 7 represent most of its profiles, and those off west Tasmania are identified in Figure 8.

In 1973, BMR recorded about 1000 km of low-energy sparker 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 (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 the inner shelf is covered by quartz sand with some shell debris, and the outer shelf by 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 conducted a reconnaissance survey off southern Australia using the M.V. Petrel. This included nine lines zig-zagging from the shelf to the abyssal plain in the Otway Basin-West Tasmania region and included in Figure 7, and those off west Tasmania are specified in

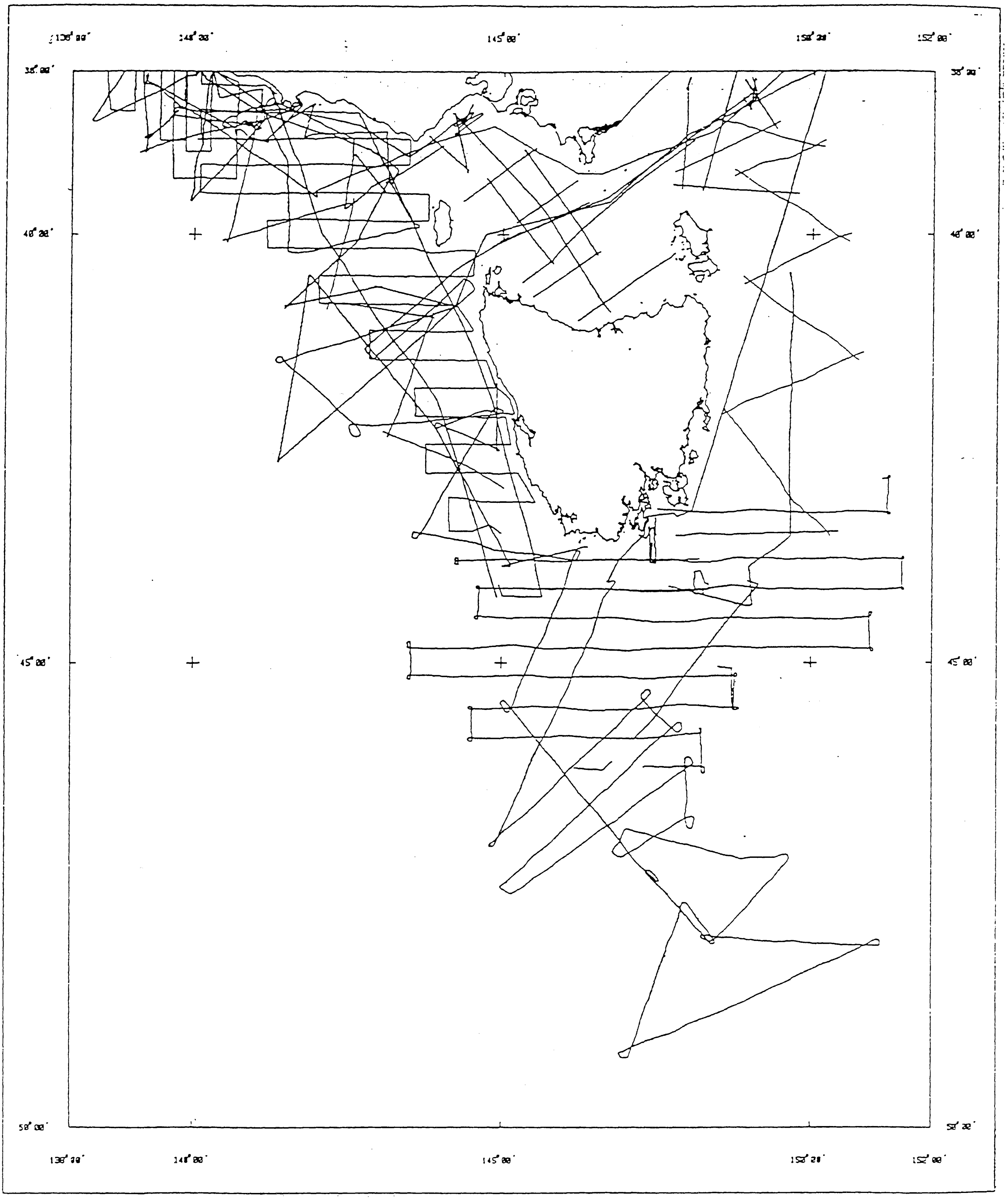


Figure 7. Map of multichannel seismic profiles in the Tasmanian and South Tasman Rise region.

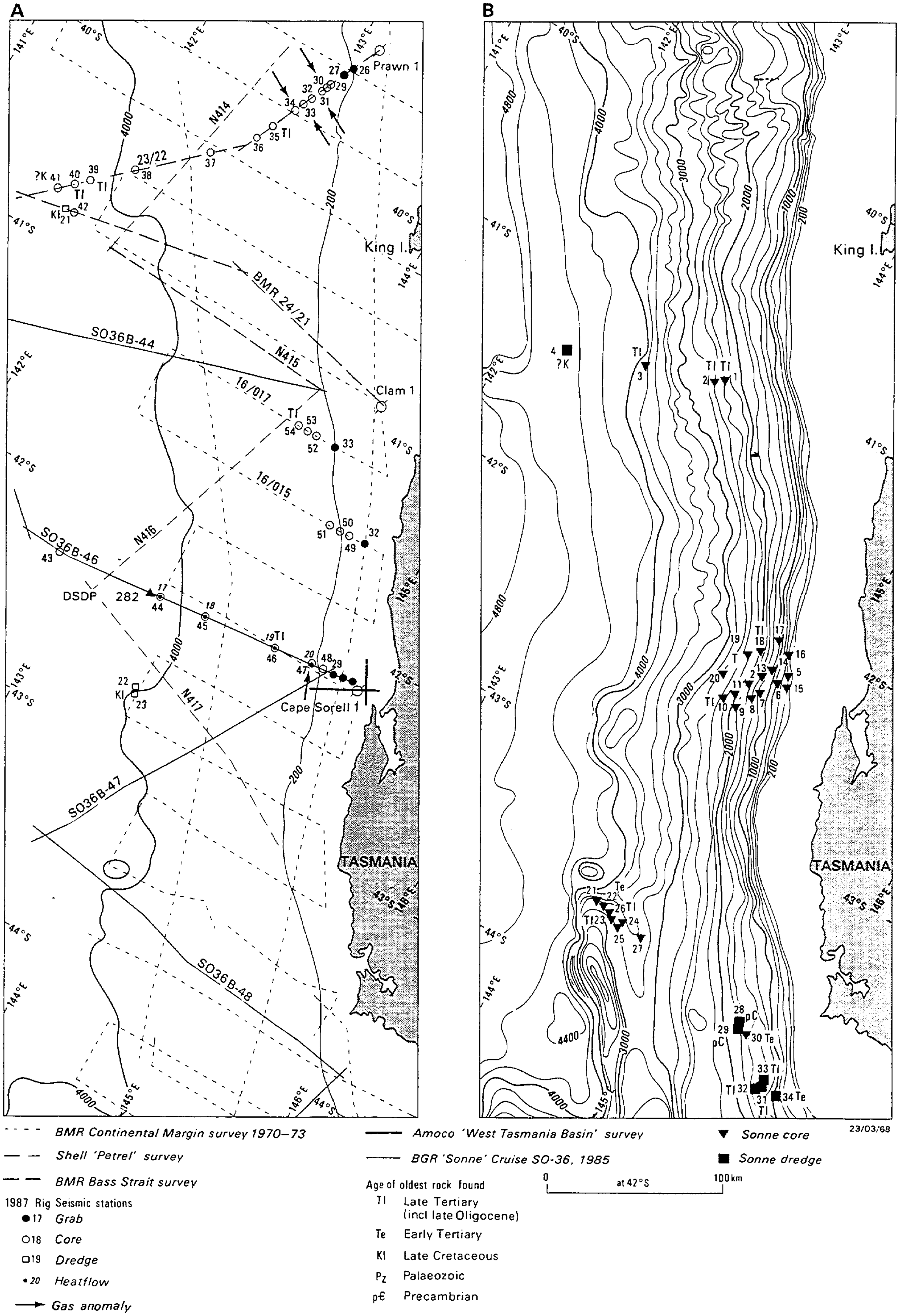


Figure 8. Map of sampling and heatflow stations for 1985 *Sonne* (SO-36C) and 1987 *Rig Seismic* (BMR 67) cruises off west Tasmania. Shows bathymetry, petroleum exploration wells, key deepwater seismic lines, and major gas anomalies in surface sediments. After Exon et al. (1992).

Figure 8. They showed 3 to 4 seconds (two-way time) of penetration. An interpretation by Bouef & Doust (1975) showed that this was a passive margin, with a thick wedge of sediments that was bounded by oceanic crust on the edge of the abyssal plain. Beneath the continental rise, block-faulted continental basement was recognised. They stated:that the sedimentary wedge which overlies faulted and collapsed continental basement is subdivided by unconformities into a continental Lower Cretaceous rift unit and a fluvio-deltaic unit of Upper Cretaceous-Danian age, and a post-breakup sequence of Tertiary units representing regional collapse and out-building of the shelf. They stated: '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.'

In 1982, BMR contracted Geophysical Services International (GSI) to carry out a multichannel seismic survey of the Bass Basin (BMR Survey 40), which also included regional seismic lines extending on either side of King Island, from the Otway and Sorell Basins out to the abyssal plain. These lines are included in Figure 7.

Deep Sea Drilling Project (DSDP)

In 1973, Leg 29 of the Deep Sea Drilling Project (DSDP) drilled four partly cored holes in the Tasmanian region using the *Glomar Challenger* (Fig. 3 & Appendix 1), including Site 282 on the west Tasmanian margin which was some 310 m deep in 4202 m of water (Kennett, Houtz et al., 1973, 1975A). Site 282 lies 160 km west of Cape Sorell on *Sonne* line 36B-46, which shows it to have been on a basement high. The sequences drilled in it include 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. The sedimentary sequence is presumed to be entirely abyssal, and includes 55 m of early Miocene to Pleistocene nannofossil ooze containing shelf-derived bryozoa and glauconite in part, 135 m of early and middle Oligocene silty clay, and 103 m of late Eocene silty clay, organic-rich and containing hydrocarbons.

DSDP Leg 29 also drilled Sites 280 and 281 on the South Tasman Rise. Site 280 was drilled to 524 metres in water 4181 m deep on the southwestern slope of the rise, and bottomed in an "intrusive basalt". It penetrated a veneer of late Miocene to late Pleistocene clay and ooze underlain, beneath a sampling gap, by 55 m of siliceous early Oligocene sandy silt, and 428 m of middle Eocene to early Oligocene sandy silt, containing chert in the upper 100 m, and glauconite and manganese micronodules below that. The lower 200 m is rich in organic carbon (0.6-2.2 %). All sediments are presumed to be abyssal types.

Site 281 was drilled to 169 metres in water 1591 m deep, southwest of the culmination of the rise, and bottomed in a quartz-mica schist of probable PreCambrian age. This is overlain by a six metre thick basement conglomerate consisting of angular clasts, dominantly of schist, with lesser quartz, quartzite, glauconite, glauconitic sandstone and granite. The hole contains 36 m of Plio-Pleistocene foram-nanno ooze, 79 m of Miocene foram-nanno ooze, and 3 m of late Oligocene glauconite-rich detrital sand.

Below a major unconformity there is about 33 m of shallow-marine late Eocene sediment: an upper 28.5 m of grayish-olive sandy silt and silty clay, a middle 3 m of detrital sand and nanno chalk, and the basal conglomerate.

One other DSDP Site relevant to the present study is Site 283, drilled on the abyssal plain east of the East Tasman Rise in 4756 m of water to a depth of 592 m. It recovered entirely abyssal sediments above 4 m of pillow basalt. The sedimentary sequence consists of about 13 m of Plio-Pleistocene zeolitic clay, 163 m of late Eocene siliceous ooze, 139 m of M Eocene silty clay, and 273 m of Paleocene silty clay with some chert.

R.V. *Sonne* cruises

In 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 also four regional multichannel seismic lines and several short tie lines (1000 km long in all) were recorded off west Tasmania, and 34 sampling stations occupied (Fig. 8 & Table 2). During the same cruise, nine regional seismic lines were shot on the South Tasman Rise, and 19 sampling stations were occupied (Fig. 1). A detailed cruise report was provided by Hinz et al. (1985), and a discussion of the west Tasmanian results was provided by Hinz et al. (1986). The core results for both west Tasmania and the South Tasman Rise are summarised in Figure 9. An interpretation of the west Tasmanian seismic lines, as well as that of profile BMR 40/22-23, showed that up to 5 seconds (two-way time) of section is present, and that up to 14 unconformities could be identified (Fig. 10). Sampling and well data from west Tasmania indicate that unconformity U3 represents the regional Oligocene unconformity, U9 the basal Tertiary unconformity, and U12 the basal Late Cretaceous unconformity. The relatively thin Tertiary sequences consist essentially of Neogene carbonates and Palaeogene terrigenous sediments. The Late Cretaceous sequence appears to subcrop along the foot of the continental slope, along with continental basement which was sampled at three stations.

West Tasmania

Hinz et al. (1985, 1986) briefly described the 37 stations occupied by *Sonne* (Fig. 9), of which sixteen recovered pre-Quaternary rocks. Foraminiferal dating aboard ship was by D. Belford (BMR), and he revised and published his results in Belford (1989). P. Cepek of BGR identified coccoliths in selected samples after the cruise. High grade metamorphic rocks were recovered from stations 28 KD, 29 KD and 32 KD, about 50 km southwest of Port Davey, and granitoids from 32 KD. Station 28 KD gave K/Ar ages of 344 and 349 Ma (Early Carboniferous) from muscovite; station 29 KD gave a K/Ar age of 355 Ma (Early Carboniferous). High grade metamorphic rocks were also recovered from 36 KD, about 100 km southwest of Tasmania and near the continent-ocean boundary, and K/Ar ages of 95 and 98 Ma (Cenomanian) were obtained from biotite. This young age may be related to re-heating just prior to Late Cretaceous breakup of the Tasman Sea.

Rocks of probable Mesozoic age were obtained at stations 4 KD (sandstone and basalt), 29 KD (pebbles of quartz, chert, ?basalt), 35 KD (quartz sandstone pebble) and 37 KD (micaceous quartz sandstone). Stations 4 KD and 37 KD lie very near the continent-ocean boundary. Middle Eocene sediments are present at four stations: moderately deep water bryozoal limestones 50 km southwest of Port Davey at stations 32 KD and 34 KD; and shallow marine to deltaic carbonaceous mudstones at stations 22 KL near the continent-ocean boundary, and 30 KL some 50 km north of 32 KD (palaeoenvironment determined by E. Truswell, AGSO, pers. comm., on basis of dinoflagellates). A major Oligocene unconformity separates the generally siliciclastic Palaeogene sediments from

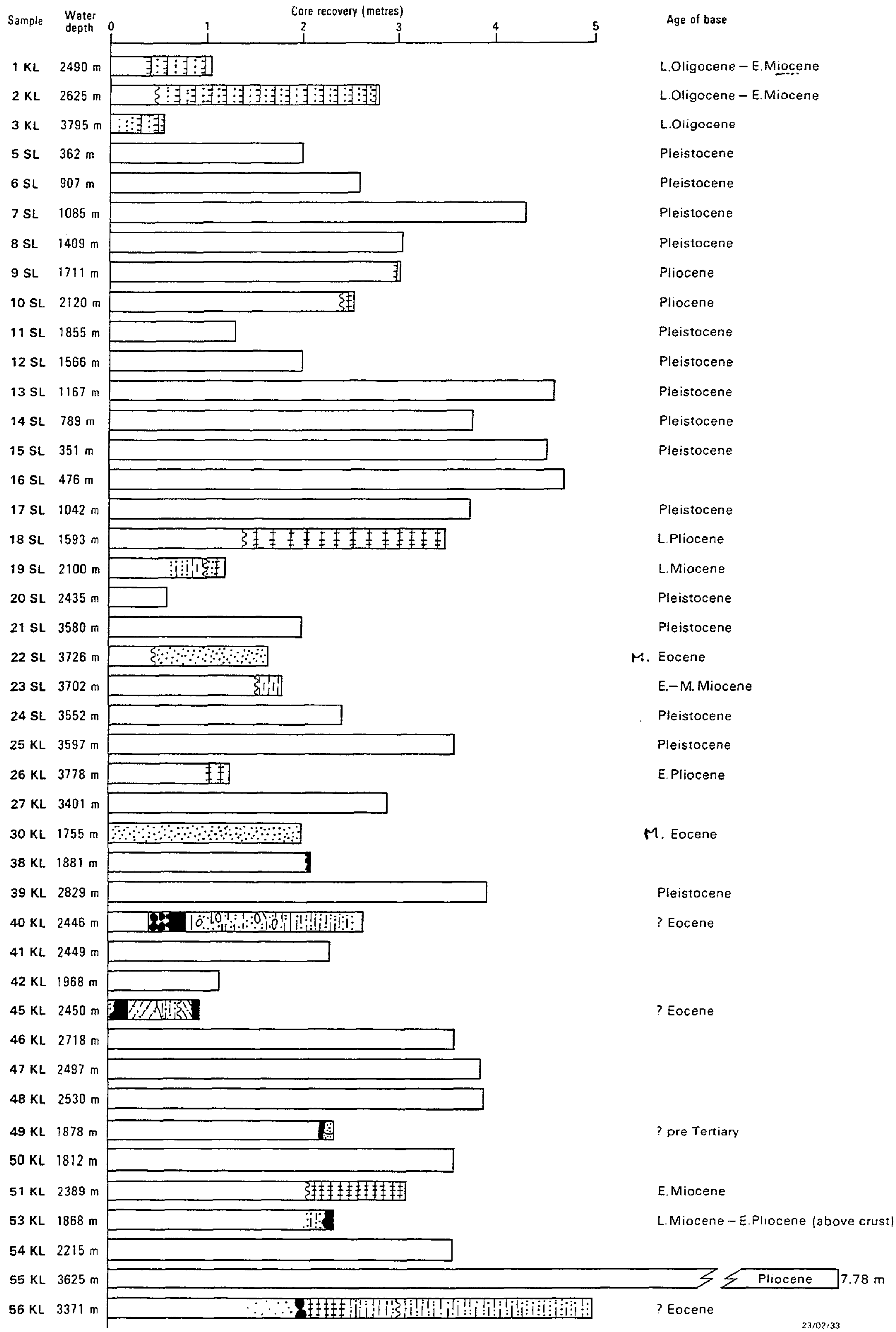


Figure 9. Simplified core logs for *Sonne* Cruise SO-36C. Modified from Hinz et al. (1985).

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 Contorted fill in first stage rift	 Lower rift-fill	Continental–? fluvial, lacustrine Alluvial fan and/or volcanics	1000 3000 +	Jurassic and Early Cretaceous		M Series	Casterton Beds and Otway Group Non-marine clastics and volcanogenic sediments	
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) 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)
Tectonic events after Willcox and Symonds (in preparation)

Figure 10. Tabular representation of seismic stratigraphic sequences, with unconformities and tectonic events, for Otway and Sorell Basins. After J.B. Willcox in Hinz et al. (1986).

calcareous Neogene sediments. Late Oligocene and early Miocene bryozoal limestones are present at stations 29 KD, 32 KD, and 33 KD, and marls at stations 1 Kl, 2 KL, 3 KL, and 31 KD. Younger chalks and oozes are widespread.

South Tasman Rise

The South Tasman Rise was discussed by Willcox et al. (1989) on the basis of the *Sonne* seismic profiles. It covers an area of 140 000 km^2 between 800 and 3000 m (Fig. 1). A continental origin is deduced from the schists drilled at ODP Site 281 and dredged by *Sonne*, from plate tectonic reconstructions, and from the relatively quiet magnetic and gravity (Fig. 11) profiles. Three of the *Sonne* profiles over the South Tasman Rise are illustrated as line drawings in Figure 11, which shows that there are basement highs separated by graben with several thousand metres of sedimentary fill, most of it believed to be Cretaceous in age. Structurally, the culmination of the rise consists of a triangular core of basement, that is flanked on all sides by sedimentary basins (Figs. 11 & 12). The basement is extensively planated and it surface is continuous with the regional Oligocene unconformity.

The *Sonne* sampling results for the South Tasman Rise were outlined by Hinz et al. (1985) and are summarised in Table 2. Bolton et al. (1988) discussed manganese crusts and nodules, and their substrates. Basement rocks were recovered from dredge 44KD (locations in Fig. 1): garnet-bearing schist and gneiss, granodiorite and pegmatite; K/Ar ages of 444, 457, 458, and 469 Ma (Late Ordovician) were obtained on micas. Dredge 52KD recovered a basaltic breccia consisting largely of palagonitic basalt fragments in a collophane-bearing fine grained matrix, and encrusted with manganese. Pre-Tertiary basement rocks were recovered in cores 49KL and 53KL - fine grained graywacke and quartzite respectively. Eocene olive or grey-green mudstones were present in dredges 43KD and 44KD, and cores 40KL, 45 KL and 56 KL, and Paleocene mudstone in core 56 KL. The mudstones contain zeolites, and are highly bioturbated with little evidence of bedding. They also contain poorly preserved radiolaria and arenaceous forams, and occasional glauconitic sands. Determinations on the basis of forams were carried out aboard ship by D. Belford, and some were published by Belford (1989). P. Cepek identified coccoliths in some samples after the cruise. Neogene sediments from above the Oligocene unconformity are nanno-foram and foram-nanno ooze and chalk.

Willcox et al. (1989) described a large extensional basin in the southwest, containing up to 6000 m of sedimentary fill, probably including syn-rift volcanics, and noted the presence of another basin in the northeast. The dominant structures were interpreted as being oriented either N-S or NW-SE, as indicated also by the GEOSAT imagery. The preliminary mapping suggested that the stratigraphy and structure of the rise was consistent with a common origin with the Otway and Sorell Basins. Willcox suggested that major dislocations in the basins may represent the locations of transfer faults. The western half of the rise is characterised by northerly-trending slivers of basement, and intervening V-shaped basins, probably created by Eocene and early Oligocene transtensional movements. Wrench faults extend up to the Oligocene unconformity. The western margin (Figs. 1 & 12) is clearly a transform fault, with movement presumably ending in the Oligocene with the separation of Australia and Antarctica.

Salge (1989) presented an alternative history of the South Tasman Rise from a major study of the *Sonne* profiles. He concluded that the rise had always been adjacent to Tasmania, rather than transported with Antarctica southward from an original position west of the Otway Basin. He suggested that rifting in the Early Cretaceous formed NW-SE trending basins in basement rocks, characterised by listric and low-angled faults. Apparently in the mid or Late Cretaceous, when slow spreading between Australia and Antarctica started, there was left-lateral movement between Australia and Antactica to the west of

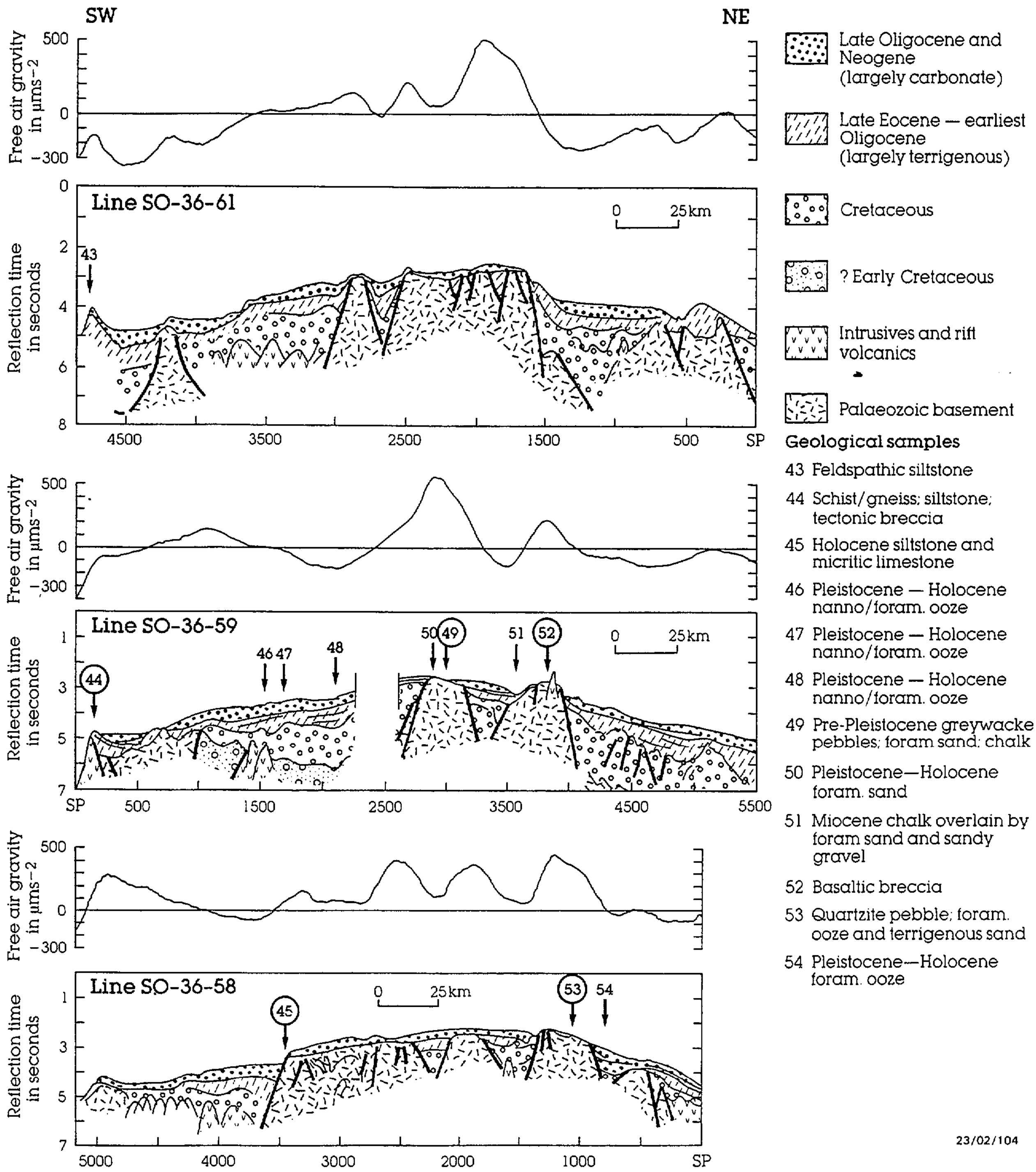


Figure 11. Line drawings of Sonne SO-36B seismic profiles from the South Tasman Rise, with free-air gravity values and the location of sampling sites. Locations in Figure 1. After Willcox et al. (1989) and Bolton et al. (1988).

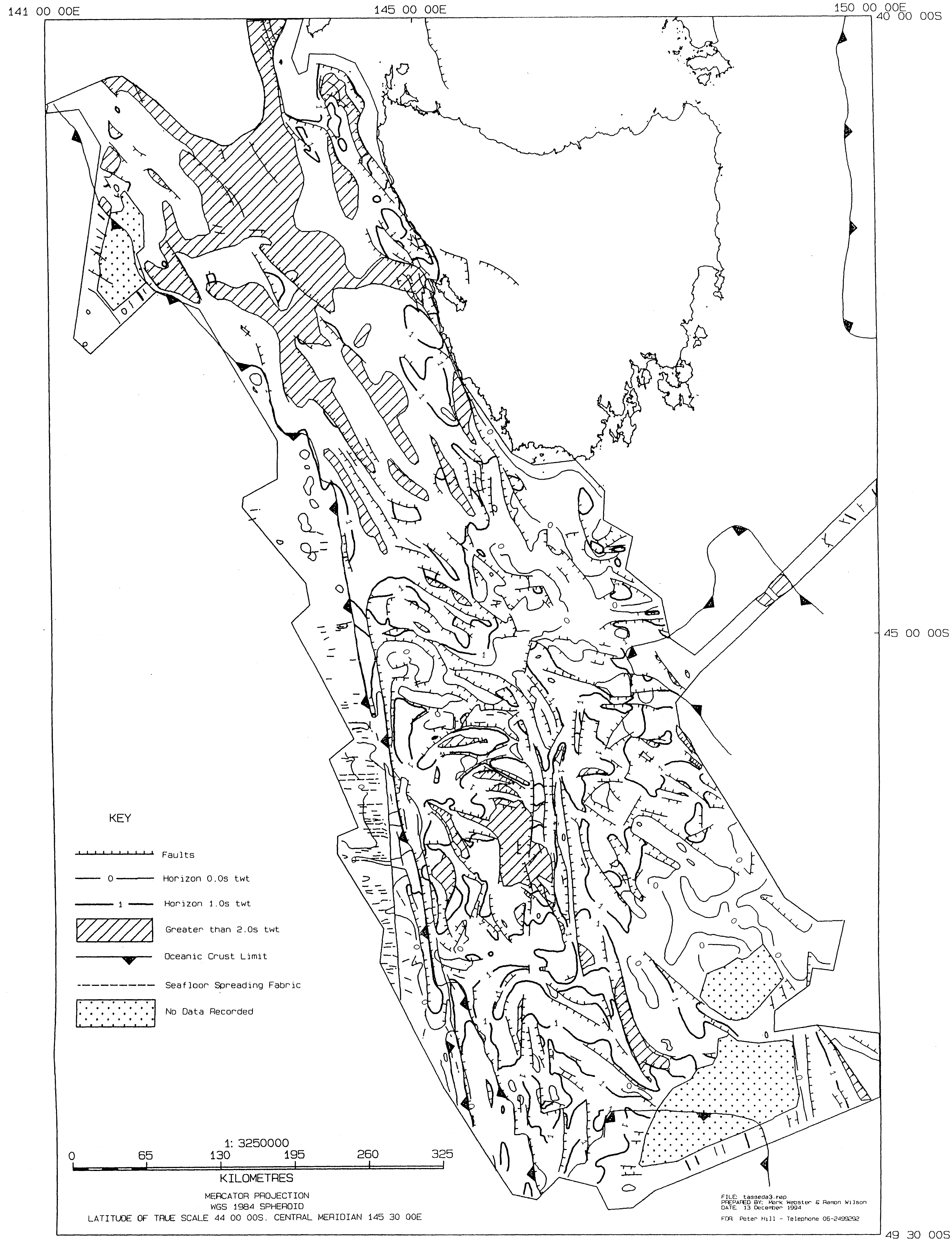


Figure 12. Structural and sediment thickness map of offshore Tasmanian region, based on interpretation of *L'Atalante* and *Sonne* reflection seismic data. Also takes account of *L'Atalante* swath maps and satellite gravity data. After Exon et al. (1994)

Tasmania and the South Tasman Rise, and this resulted in wrench faulting of the basin-fill sediments. Major transcurrent fault zones caused the formation of transpressional features in the basins. An extensional zone developed between Tasmania and the rise. With the formation of oceanic crust in the adjacent Indian Ocean in the middle Eocene, subsidence and drift sedimentation began. Marginal marine detrital sediments were derived from high areas and show progradation or onlap in places. The continuing subsidence, the development of the Circum-Antarctic current as Antarctica cleared this southern prolongation of the Australian continent in the early Oligocene, and the fall in oceanic bottom water temperature as the Antarctic ice sheet developed in the latest Eocene and Oligocene (Kennett et al., 1972), led to major erosion that formed the regional Eocene-Oligocene unconformity, and to major changes in sediment type from detrital to pelagic. There was little Neogene sedimentation in high areas, because of current erosion and slumping into deeper water.

There is a major disagreement between Salge's (1989) view that the rift basins of the South Tasman Rise formed in the Early Cretaceous and filled with Cretaceous sediments, and the earlier view of Hinz et al. (1985) and Willcox (1989) that they formed in the Late Cretaceous and most of the fill is Palaeogene in age. Which interpretation is correct remains to be proven. The other open question is whether the South Tasman Rise was originally located northwest or south of Tasmania. The *Tasmante* swath and seismic mapping of the faults bounding the plateau to the west, north and east (Fig. 12), and oceanic magnetic lineations suggest movement from the northwest.

R.V. *Rig Seismic* cruises

BMR Cruise 67

In early 1987, R.V. *Rig Seismic* carried out a research cruise (BMR Cruise 67) over the Otway Basin and the Sorell Basin of the west Tasmanian margin, to provide new geological, geochemical and heatflow data, in an area with considerable petroleum potential (Exon & Lee, 1987; Exon et al., 1992). Altogether, 130 sampling stations were occupied using dredges, corers, grabs and a heatflow probe (Fig. 8). The dredge reults are summarised in Table 3, and the core results in Table 4. Among the rocks recovered were: Palaeozoic volcanics and metasediments; Late Cretaceous sandstones, siltstones and mudstones; early Tertiary siltstones; and late Tertiary carbonates. The Cretaceous sequence was dated by palynology at five localities as Santonian to early Campanian, Campanian and Maastrichtian, and the depositional environment in all cases was marginal marine (M.K. Macphail, Appendix D *in* Exon et al., 1992). Two early Tertiary samples were identified as early Eocene and marginal marine, and two as middle Eocene and marginal to open marine. All samples were taken along seismic profiles, so that the results could be incorporated easily into the regional geological framework. In general, the further down the continental slope, the older the rocks. Palaeontological results indicate that there has been very considerable post-Eocene subsidence of the slope.

A great variety of Quaternary sediments were recovered, and these have allowed a sedimentation model to be developed. Shelf areas are characterised by relatively high-energy deposits: shelly bryozoal sands and fine sandy oozes. These sediments are dominantly calcareous, and most likely sourced by a middle to outer shelf `carbonate factory', dominated by bryozoa, pelecypods, gastropods and benthic foraminifera. There is extensive bioturbation by a relatively large infauna giving thick homogeneous units. Shelf sands periodically move downslope as turbidity currents or grain flows; their contribution to overall slope sedimentation is considerable (V. Drapala, pers. comm.). However, slope and abyssal areas appear to be dominated by pelagic and hemipelagic carbonates, typically olive-grey and greenish grey, foraminiferal and nannofossil oozes. Terrigenous clays and muds, sourced from coastal areas, are present only in small amounts. Variations in the terrigenous component appear to be cyclic, and may be climatically controlled. Bioturbation decrease downslope, and the cores are typically banded. More detailed studies on these and other cores from the Otway margin have since been made by Boreen et al. (1993) and Boreen & James (1993).

TABLE 3 : BMR CRUISE 67 DREDGE STATIONS

Station	Latitude (S)	Longitude (E)	Water depth (m)	Seismic profile	Recovery	Description or comments
DRO1	37o49'	138o06	5200	N409 67/02	None	Not on bottom
DR02	37o37.7' 37o40.3'	138o16.8' 138o19.6'	4100- 3800	N409 67/02	5 kg	L. Eocene & E. Oligocene grey sandy siltstone;grey Quaternary foram nanno ooze
DR03	38o14.6' 38o14.0	138o36.0 138o38.4'	4500- 4000	48/41 67/04	40 kg	Indurated Campanian (Late Cretaceous) marginal marine dark brown to grey siltstone in Fe oxide crust; plastic dark brown Early Eocene mud to silty claystone
DR04	38o26.7' 38o24.3'	138o49.6' 138o52.3'	4700- 4050	48/42 67/04	300 kg	Dark grey Campanian (Late Cretaceous) marginal marine laminated mudstone; mid grey siltstone in Fe oxide crust; pink Quaternary ooze
DR05	38o25.4' 38o24.3'	139o54.7' 138o55.8'	3900- 3850	48/42	200 kg	Dark grey Late Cretaceous siltstone, shale, claystone with ammonites including Gaudryceras sp.; pink Quaternary ooze
DR06	38o45.4' 38o46.2'	139o08.9' 139o09.0'	4660- 4450	N410 67/05	1 kg	Black Early Eocene restricted marine non-fissile mudstone, Mn crusts to 4 mm; grey Quaternary ooze
DR07	38o47.4' 38o47.8'	139o12.4' 139o12.1'	4450- 4200	N410 67/05	0.1 kg	Black Late Cretaceous? slate, brown mudstone, 2 mm Mn crust; light brown Quaternary ooze

DR08	39o01.2' 39o02.7'	140o03.4' 140o00.9'	4350- 4050	48/43	2 kg	Late Santonian/Early Campanian (Late Cretaceous) brown, restricted-open marine mudstone; brown Quaternary pelagic mud
DR09	39o26.9'	139o59.5'	4800	48/43	300 kg	Metaquartzite; quartz veined felsic volcanics; metashale; coarse felsic tuff; light brown Quaternary mud; rocks ?Palaeozoic or Mesozoic
DR10	38o05.2' 38o04.5'	139o45.2' 139o46.4'	1950- 1700	48/42	200 kg	Fossiliferous calcareous clay, white (L. Oligoc) and grey (M. Eocene; L. Eocene-E. Oligocene); chert concretions; E-L. Oligocene bryozoal calcarenite; limonitic concretions in quartzose host; light brown mud
DR11	37o58.6' 37o58.4'	139o49.0' 139o49.5'	1400- 1200	16/85		Olive-grey Quaternary foram nanno ooze
DR12	37o46.3' 37o46.7'	139o25.3' 139o25.6'	1350- 1150	16/45	40 kg	E. Miocene chalk, L. Oligocene soft chalk, grey E-M. Oligocene and L. Oligocene chert or porcellanite, quartz-rich sandstone and sandy mudstone, grey sticky mud; pale grey foram nanno ooze
DR13	38o30.2' 38o30.2'	140o52.0' 140o53.7'	1020- 500	16/33		Green mud, soft and firm
DR14	38o50.0' 38o49.8'	140o35.4' 140o35.0'	3050- 2450	48/54	40 kg	White E. Oligocene, L. Oligocene & E-M.Miocene brown siltstone; grey ?Palaeozoic hard tuff and volcanic sandstone; minor quartz-granule conglomerate; grey ooze; white Miocene calcareous clay
DR15	38o58.3' 38o56.8'	140o51.8' 140o50.2'	3120- 2500	48/04		Grey and brown ooze

DR16	38o53.5' 38o50.4'	141o29.2' 141o29.0'	1450- 800	16/39		Light olive grey ooze
DR17	39o09.0' 39o09.0'	141o51.1' 141o53.0'	2270- 2060	16/29		Grey clay
DR18	39o12.9' 39o11.8'	140o07.2' 142o11.5'	1950- 1650	16/029	2 kg	White M Miocene chalk; brown L. Eocene-E. Oligocene and ?Miocene siltstone; grey mud-stone; white calcareous mud; olive-grey Quaternary ooze and mud
DR19	39o29.2' 39o29.5'	142o13.4' 142o16.2'	2600- 2100	16/27	2 kg	White L. Oligocene chalk; brown mudstone; Quaternary grey ooze; and brownish grey ooze (L. Oligocene)
DR20	39o05.8'	143o19.9'	66	16/29		Chain bag dredge broke off at weak link
DR21	40o50.3' 40o49.5'	141o46.0' 141o49.0'	4580- 4155	40/24	20 kg	Yellowish brown, f-m, well-sorted quartz lithic sandstone. Some Maastrichtian restricted - marginal marine clayey sandstone containing clay clasts and lenses
DR22	42o40.4' 42o42.2'	143o43.4' 143o43.2'	4200- 3900	16/08	1 kg	Brown and grey v.f. micaceous sandstone andsiltstone; tough, dark grey Maastrichtian restricted-marginal marine mud; white and pale olive-brown foram nanno ooze
DR23	42o39.0' 42o41.6'	143o43.1'143o 42.8'	4257- 4000	16/08		Brown foram nanno ooze

TABLE 4: BMR CRUISE 67 GRAVITY CORE STATIONS

Station	Lat (S)	Long (E)	Water depth (m)	Seismic profile	Recovery (cm)	Description or comments
GC01	37o10.2'	138o35.8'	425	16/49 67/01	220	80 cm greenish grey foram nanno ooze, over greenish grey fine sandy and silty muds
GC02	37o23.9'	138o34.7'	1270	16/49	54	Greenish grey foram nanno ooze

GC03	37o33.0'	138o35.0'	1476	16/49	310	Olive-grey to greenish grey foram nanno ooze
GC04	37o35.0'	138o35.0'	1526	16/49	184	130 cm greenish grey foram nanno ooze, over bluish grey claystone; ashy horizon 144-147 cm
GC05	37o45.5'	138o34.9'	2235	16/49	80	Olive-grey foram nanno ooze, over L. Eocene semilithified mud
GC06	39o30.8'	139o57.7'	4590	48/43	263	Olive-grey foram nanno mud; minor calcareous turbidites; ashy horizon 111-112 cm
GC07	39o20.1'	139o59.2'	4120	48/43	287	Banded olive-grey foram nanno ooze and mud; ashy horizon 66-68 cm
GC08	39o02.2'	140o02.9'	3980	48/43	294	Olive-grey and greenish grey foram nanno ooze and mud; ashy horizon 34 cm
GC09A	38o57.1'	140o06.6'	3615	48/43	203	Olive-grey foram and greenish grey nanno ooze and mud; minor calcareous turbidites; ashy horizon 27 cm; Middle Eocene restricted marine firm brown mud in core catcher
GC10	38o51.7'	140o06.1'	3332	48/43	374	Light olive-grey foram nanno ooze; minor turbidite; ashy horizon 25 cm
GC11	38o45.0'	140o07.4'	3214	48/43	308	Greenish grey and grey foram nanno ooze and mud; thin calcareous turbidites; ashy horizon 30 cm
GC12	38o42.6'	140o07.1'	3150	48/43	10	Peaty, open-marine siltstone, Middle Eocene; corer tipped over, young material washed out
GC12A	38o42.6'	140o07.1'	3133	48/43	306	Olive-grey and greenish grey foram nanno ooze; ashy horizon 35 cm
GC13	38o27.9'	140o10.0'	2525	48/43	364	Olive-grey foram nanno ooze; minor calcareous turbidites
GC14	38o25.4'	140o09.0'	2250	48/43	357	Olive-grey and greenish grey foram nanno ooze; one minor calcareous turbidite
GC15	38o22.9'	140o10.6'	1964	48/43	291	Olive-grey and greenish grey foram nanno ooze; one minor calcareous turbidite
GC16	38o20.0'	140o10.9'	1650	48/43	196	Olive-grey and greenish grey foram nanno ooze
GC17	38o17.2'	140o11.1'	1490	48/43	326	Olive-grey and greenish grey foram nanno ooze; one minor calcareous turbidite

GC18	38o11.6'	140o11.5'	1035	48/43	233	Olive-grey foram nanno ooze
GC19	38o07.2'	140o13.0'	345	48/43	176	Olive-grey bryozoal sand to 28 cm; olive-grey mud below
GC20	38o05.0'	140o14.36 '	166	48/43		No recovery; ?bottom contact
GC20A	38o05.2'	140o14.4'	166	48/43		No recovery; bent pipe suggests sand
GC21	37o59.4'	140o03.6'	315	48/042	232	Olive-grey shelly muddy foram sand
GC22	38o02.3'	139o58.0'	1003	48/042	319	Olive-grey foram nanno ooze; one minor calcareous turbidite
GC23	38o03.2'	139o55.9'	1146	48/042	277	Olive-grey foram nanno ooze; minor calcareous turbidite
GC24	38o35.1'	141o09.6'	392	48/007	184	Olive-grey sandy calcareous ooze
GC25	39o36.5'	141o10.5'	450	48/007	184	Olive-grey sandy calcareous ooze
GC26	38o37.9'	141o11.1'	469	48/007	224	Olive-grey sandy calcareous ooze, thin coarse bioclastic bed 114-117 cm
GC27	38o38.9'	141o11.5'	506	48/007	225	Olive-grey foram nanno ooze, minor coarse bioclastic bed 188-192 cm
GC28	38o40.1'	141o12.5'	545	48/007	248	Olive-grey foram nanno ooze, minor coarse bioclastic bed 178-190 cm
GC29	39o34.0'	142o59.0'	240	40/022	364	71 cm olive-grey shelly carbonate ooze over olive shelly mud
GC30	39o35.0'	142o57.4'	558	40/022	145	28 cm olive-grey sandy calcareous ooze over greenish grey clay
GC31	39o36.0'	142o57.0'	829	40/22	296	Sandy olive foram nanno ooze over olive-grey calcareous ooze
GC32	39o40.1'	142o54.7'	1244	40/22	93	Olive-grey muddy foram nanno ooze
GC33	39o45.5'	142o52.0'	1433	40/22	270	Olive-grey and greenish grey foram nanno ooze
GC34	39o47.7'	142o48.8'	1630	40/22	287	Light-olive-grey and greenish grey foram nanno ooze, with two calcareous sand turbidites
GC35	39o54.8'	142o44.2'	2280	40/22	144	Light-olive-grey foram nanno ooze, containing E-M Miocene mudstone slump
GC36	40o00.9'	142o40.1'	2182	40/22	259	Grey and greenish grey foram nanno ooze; L. Pliocene at base
GC37	40o14.1'	142o25.2'	3090	40/23	275	Greenish grey foram nanno ooze, with three carbonate sand turbidites.

GC38	40o27.9'	142o04.9'	3850	40/23	194	Greenish grey foram nanno ooze, with two carbonate sand turbidites
GC39	40o37.9'	141o50.1'	4300	40/23	135	Olive-grey foram nanno ooze, with one sand turbidite, over L. Oligocene green clay
GC40	40o41.5'	141o46.4'	4370	40/23	62	Grey foram nanno ooze over E. Miocene olive-brown calcareous clay
GC41	40o43.8'	141o42.4'	4645	40/23	190	Two thick calcareous turbidite sequences, above multi-coloured pre-Quaternary clays
GC42	40o49.6'	141o48.8'	4161	40/23	84	Light grey foram nanno ooze, over yellow to reddish mottled pre-Quaternary gypsiferous clay (soil profile)
GC43B	42o17.8'	142o51.7'	4830	SO36/46	2	Light olive-grey v.c. gritty bryozoal sand
GC44	42o14.8'	142o31.6'	4103	SO36/46	146	Greenish grey foram nanno ooze, with four calcareous sand turbidites; ?ash horizon 40 cm
GC45	42o13.6'	142o52.5'	3715	SO36/46	360	Grey and greenish grey foram nanno ooze, L. Pliocene at base
GC46	42o12.1'	144o24.8'	2360	SO36/46	176	93 cm greenish grey foram nanno ooze, over 7 cmcalcareous sand turbidite, over soft light greenish grey chalk
GC47	42o10.6'	144o40.9'	765	SO36/46	134	Grey foram nanno ooze, with four carbonate sand turbidites
GC48	42o10.8'	144o44.3'	377	SO36/46	190	Olive-grey mixed c. bryozoal sand and foram nanno ooze
GC49	41o31.4'	144o20.3'	838	16/015	294	Olive-grey bryozoal sand, foram sand and foram nanno ooze
GC50A	41o30.5'	144o17.4'	1081	16/015	169	Olive-grey and greenish grey foram nanno ooze
GC51	41o31.2'	144o13.1'	1557	16/015	127	Greenish grey foram nanno ooze
GC52	41o10.9'	143o57.5'	1145	16/017	175	Olive foram nanno ooze
GC53	41o10.9'	143o55.4'	1367	16/017	166	Olive-grey foram nanno ooze
GC54	41o10.9'	143o50.2'	1634	16/017	97	Olive-grey foram nanno ooze, over L. Oligocene hard greyish olive mudstone

In the west Tasmanian region (Exon et al, 1992) there is a clear trend in Quaternary sediments from shelf to abyssal plain.

- In-situ lithology changes rapidly downslope, from outer shelf shelly sands and sandy oozes with more than 70% carbonate, to slope foram-nanno oozes with about 60-65% carbonate, and finally to rise and abyssal plain oozes with less than 50% carbonate. The sand fraction declines in parallel: about 60% in shelf sands, 10-15% in mid slope oozes, and less than 10% in rise oozes.

- Calcareous turbidites, generally absent on the shelf, are found in slope and abyssal plain cores. The coarser fraction of these turbidites contains 70-80% carbonate and is derived from the shelly shelf sands. A thin turbidite is tentatively correlated between cores along BMR profile 48/043 , and is overlain by a decreasing amount of sediment downslope, suggesting slower rates of deposition towards the abyssal plain.
- A yellow-brown surface-oxidised layer, generally absent in the outer shelf cores, increases in thickness downslope. Its presence is related to oxygen-enriched cold bottom waters.
- A thin green or brown band present in many cores is probably a volcanic ash layer.
- Cores from the shelf consist of thick bioturbated, homogeneous units. Internal banding becomes more important downslope, as bioturbation decreases. Lithological variation between bands is generally slight (except in GC4), and is recognised by the alternation of light greenish grey and darker olive-green colours.The banding is probably cyclic and may be climatically related.
- The style of bioturbation changes with water depth. Outer shelf cores are extensively bioturbated and preserve little internal structure. Below about 1000 m, bioturbation decreases and internal banding becomes increasingly preserved. Sediments are generally mottled, and contain infilled horizontal *Zoophycos* and other burrows. *Zoophycos* seems restricted to 1000-2500 m. Below about 4000 m mottling is absent, and the only evidence of bioturbation is the presence of small (1 mm diameter), sulphide-filled burrows.

Heatflow calculations from 20 stations suggest that the present zone of thermal maturation of hydrocarbons is 2-4 km deep. Headspace gas analyses of many cores indicate that thermogenic hydrocarbons are widespread, with particularly high readings in both the eastern and the western Otway Basin and on the west Tasmanian margin. Thus, mature hydrocarbon source rocks must also be widespread.

BMR Cruise 78

In early 1988, R.V. *Rig Seismic* carried out BMR research cruise 78 on the Tasmanian margin (Exon, et al., 1989). Half of this cruise was devoted to multichannel seismic profiling (Fig. 13) and the other half to geological sampling (Fig. 14). Off west Tasmania, 1750 km of seismic data were recorded with a single airgun string (1600 cubic inches) and a 1200 m seismic cable (48 channels). Off southeast Tasmania, 265 km of seismic data were recorded near Hobart with an 80 cubic inch water gun and a 600 m seismic cable (48 channels). The west Tasmanian survey better defined the King Island and Strahan sub-basins of the Sorell Basin, tested the structure from the continental shelf to undoubted oceanic crust, and provided a mid-slope tie through the thick sedimentary sequence of the Sorell Basin right along the Tasmanian margin. The survey showed that the area has tectonic complexities and that there is normally more than 3 seconds (TWT) of sedimentary section. The magnetic and gravity profiles, in conjunction with seismic reflection and sonobuoy refraction profiles, show that there is a transition zone about 50 km wide on the abyssal plain between the foot of the continental slope and undoubted oceanic crust (Fig. 15). The southeast Tasmanian survey was bedevilled by the presence of Jurassic sills, and is of little use.

During the geological work on the west Tasmanian margin, twelve dredge stations, 37 core stations, 9 grab stations, and 10 heat flow stations were occupied. The dredge stations (Table 5) were designed to sample basement and other relatively old outcropping sequences, in order to help elucidate the early history of the margin. The palynology of four samples showed that one was a Santonian-Campanian marginal marine mudstone. The other three were Paleocene to early Eocene marginal marine

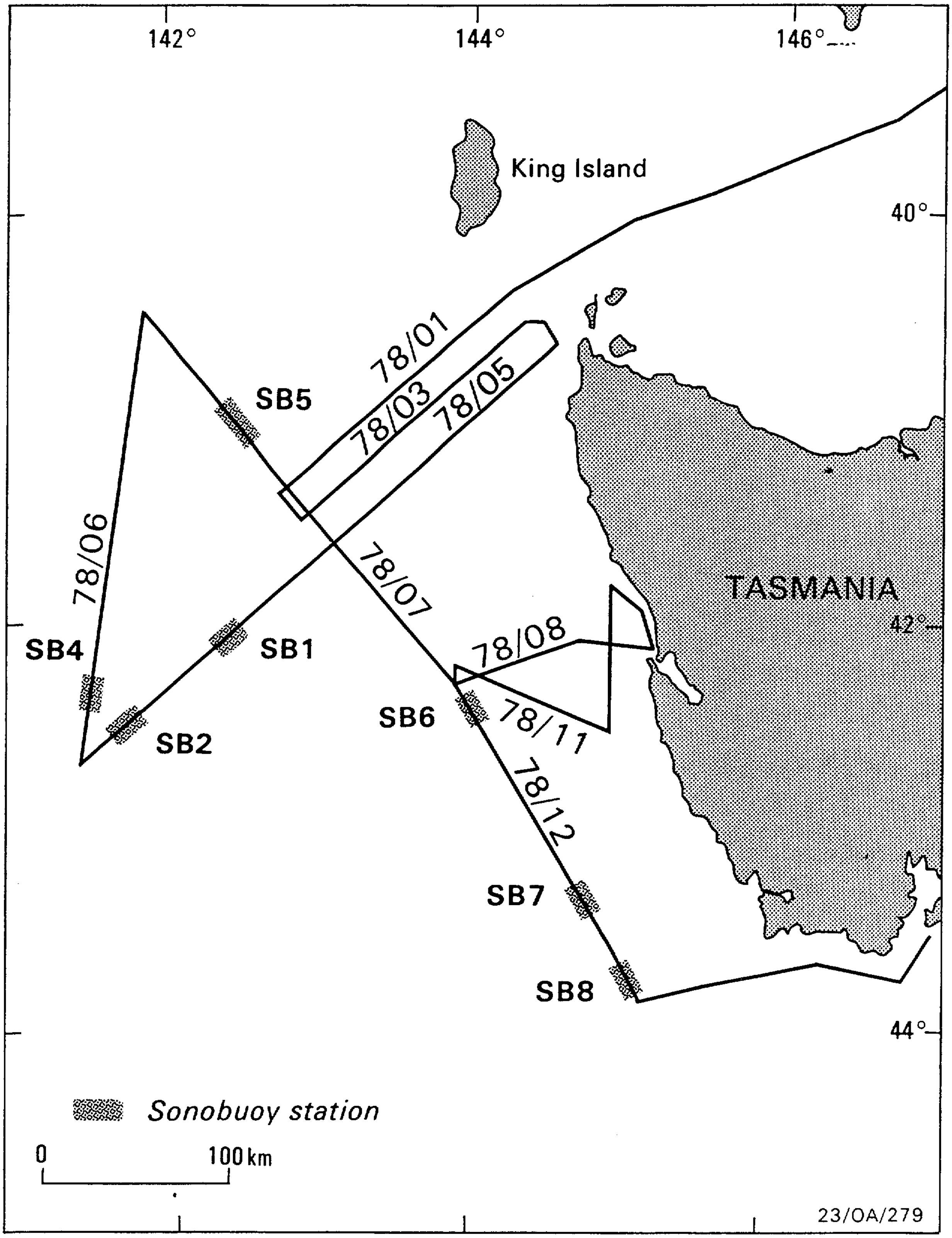


Figure 13. Map of west Tasmanian region showing 1988 BMR Cruise 78 multichannel seismic profiles 78/1-12, and sonobuoy locations. After Exon et al. (1989).

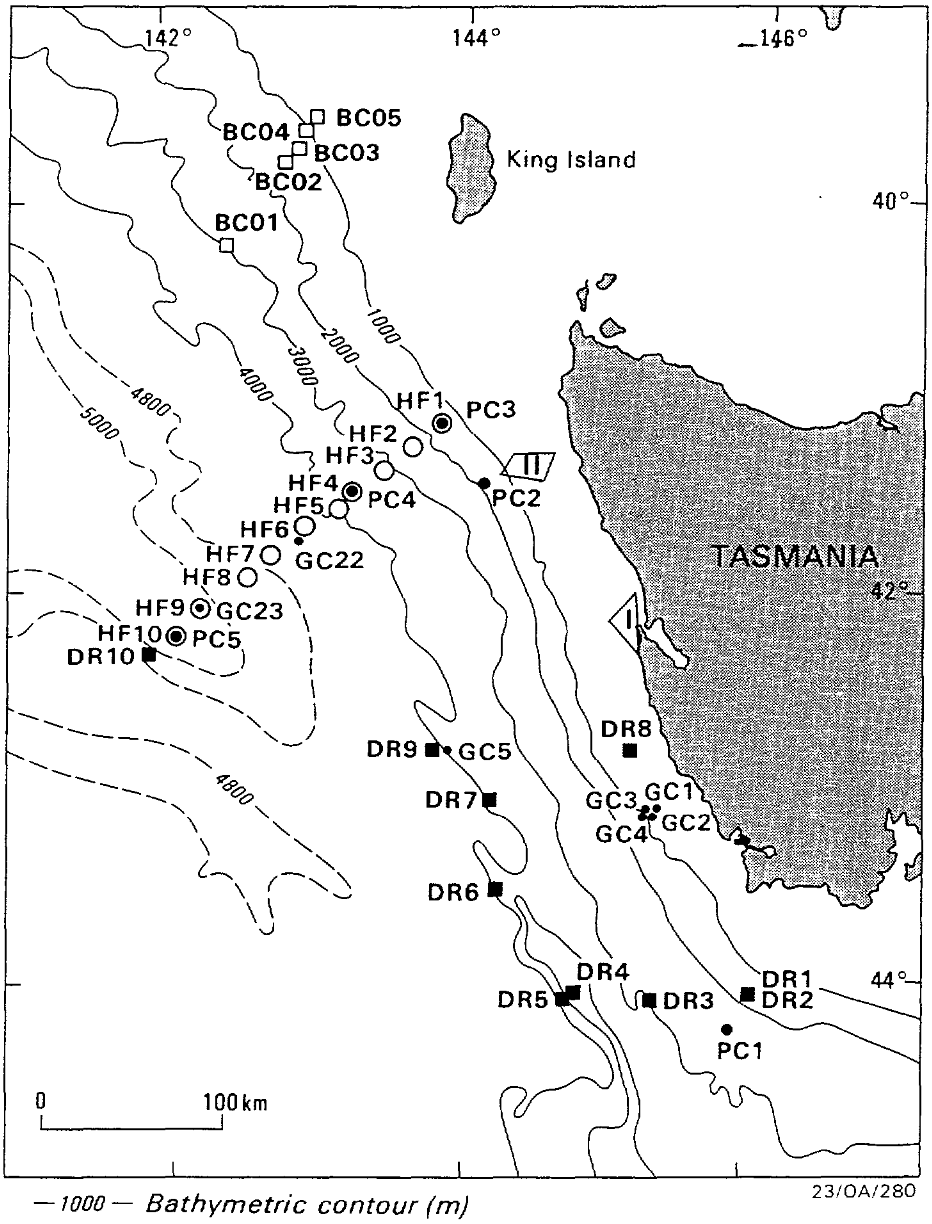


Figure 14. Map showing 1988 BMR Cruise 78 sampling and heatflow stations off west Tasmania. After Exon et al. (1989).

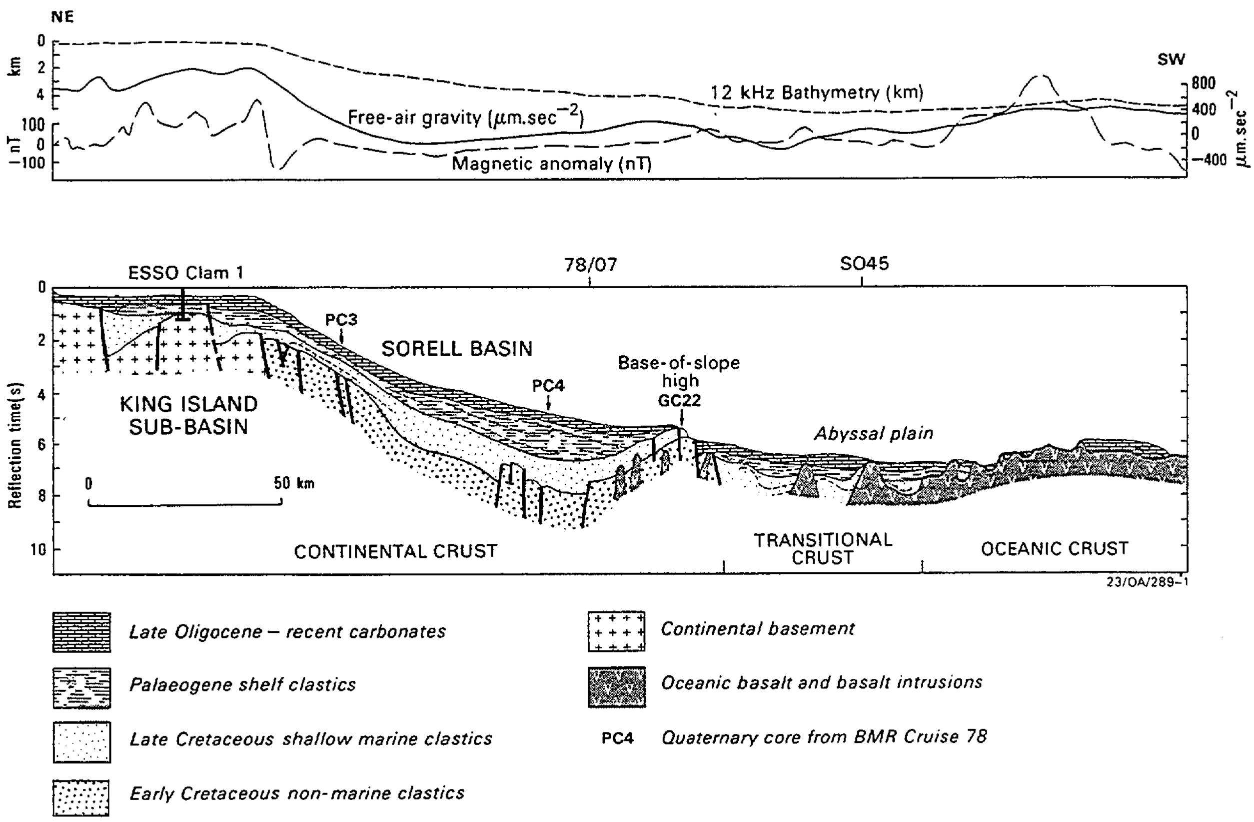


Figure 15. Line drawing of BMR seismic profile 78/05 on the west Tasmanian margin southwest from Clam No. 1 well to abyssal plain. Includes magnetic and gravity data. Location in Figure 13. After *BMR 1989*.

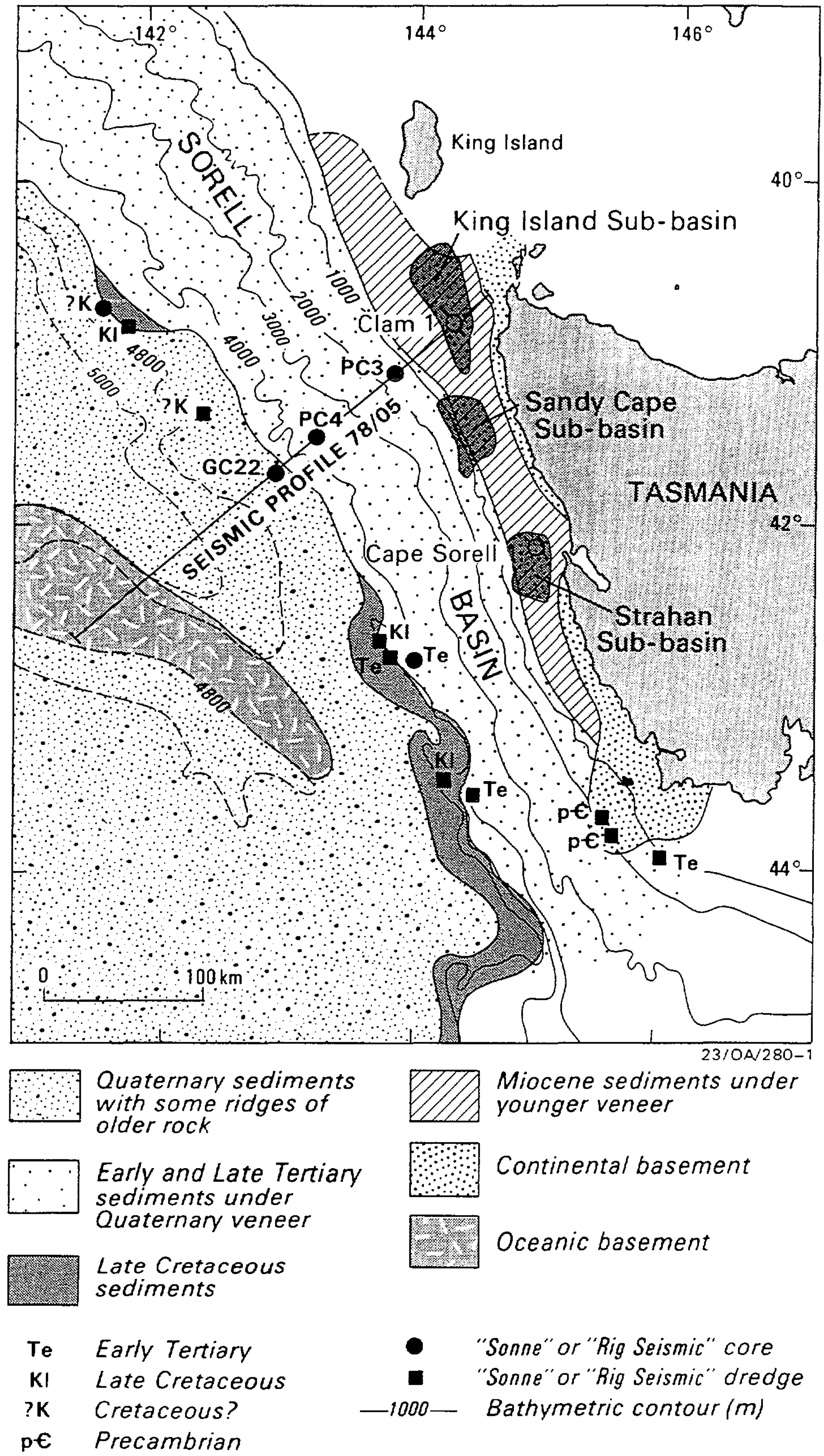


Figure 16. Map of surface sediment distribution off west Tasmania. Shows all dredges and cores that have recovered Lower Tertiary or older rocks, and location of BMR seismic profile 78/05 (see Fig. 15). After *BMR 1989.*

mudstones. Younger sediments were cored (Tables 6 & 7), and grab samples obtained, to build on our model for Cainozoic sedimentation and to provide material for analysis for thermogenic gas. Sixteen cores were sampled for gas, and provided the first evidence that thermogenic gas is being generated in the Sandy Cape sub-basin (Exon et al., 1989). Five stations gave thermal gradients which, when combined with conductivity measurements on three cores, suggest that heatflow may be lower (average 30 mW/m^2) than on the Otway Basin margin to the northwest. The sampling results from this cruise and its predecessors were combined in a map of surface sediments (Fig. 16).

TABLE 5: BMR CRUISE 78 DREDGE STATIONS

Station	Lat. (S)	Long. (E)	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 Quaternary foram ooze in pipe dredge; 1 piece (1 cm) dark greenish grey ?metasiltstone with laminae, possibly 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 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 25 cm thick.
DR05	44 10.2' 44 08.8'	144 41.7' 144 43.8'	3730-3050	11/009	1 kg	Semi-indurated medium grey siltstone/mudstone with manganese crust (1 mm 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	SO48	One pebble	Dark greenish grey Santonian indurated mudstone. Quaternary 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 broke on chain bag dredge	In pipe dredge: A. Quaternary pale olive fine to coarse 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	42 50.2'	145 07.2'	120		None	Large pipe dredge deployed; lost
DR09	42 50.0'	143 49.7'	3700-4370		None	In pipe dredge: A. Quaternary greyish orange (10YR7/4) foram ooze. B. 0.5 kg nannofossil-free, brownish grey (5YR4/1) Paleocene silty claystone. 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).

TABLE 6: BMR CRUISE 78 - SUCCESSFUL TASMANIAN REGIONAL CORES

Station	Lat (S)	Long (E)	Water depth (m)	Seismic profile	Recovery (cm)	Description or comments
GC01	43°09.9'	145°17.2'	307	16/05	282	Quaternary bryozoan shell hash; pink above 23cm, grey green below
GC02	43°10.9'	145°15.9'	478	16/05	2	Coarse shelly sand
GC03	43°08.9'	145°12.1'	643	16/05	20	Bryozoal ooze; greyish orange above 12 cm, bluish grey below. E-M Miocene at base
GC04B	43°09.8'	145°12.4'	793	16/05	383	Quaternary olive grey bioclastic sandy mud
GC05	42°50.1'	143°51.1'	3530	16/07	60	Quaternary pale orange nanno-foram ooze above E Eocene brownish black semi-plastic mud
GC22	41°45.3'	142°50.5'	3970	78/05	730	Quaternary light olive, light grey and light brown interbedded foram-nanno ooze, chalky toward base

PC01A	44°19.9'	145°53.0'	2270	SO/49	539	Quaternary interbedded light grey and greenish grey foram-nanno ooze and foram sand turbidites
PC02	41°30.0'	144°06.2'	1703	16/15	633	Not described; M-L Miocene at base
PC03	41°06.9'	143°50.0'	1265	78/05	494	Quaternary dusky yellow green foram-nanno ooze beneath 6 cm light olive grey muddy foram sand
PC04	41°30.3'	143°13.6'	3560	78/05	738	Quaternary greenish grey and light olive grey foram-nanno ooze with thin turbidite sands

TABLE 7: BMR CRUISE 78 - SUCCESSFUL CORES FROM SANDY CAPE SUBBASIN

Station	Lat (S)	Long (E)	Water depth (m)	Recovery (cm)	Description
GC06	41°30.0'	144°25.0'	325	385	30 cm brown bryozoal shell hash above yellow green foram-nanno ooze. Quaternary
GC07	41°27.5'	144°24.3'	516	373	Olive grey sandy foram-nanno ooze
GC08	41°28.0'	144°28.0'	118	40	Bryozoal shell hash on chips of brown ?M Miocene calcarenite
GC09	41°26.0'	144°26.3'	131	10	Bryozoal shell 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 hash
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; E-M 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. Quaternary
GC17	41°18.0'	144°20.0'	111	1	Bryozoal shell hash
GC18	41°23.1'	144°14.0'	814	410	15 cm yellowish grey foram-nanno ooze, above olive grey calcareous silty mud. Quaternary
GC19	41°24.8'	144°15.1'	910	394	37 cm pale yellow fine bioclastic sand, above light olive grey calcareous silty mud. Quaternary
GC20	41°24.0'	144°18.6'	641	20	Sandy bioclastic ooze. Quaternary
GC21	41°24.6'	144°21.7'	438	114	9 cm light olive grey bioclastic sand, above olive grey foram-nanno ooze. Quaternary

Tasmante (l'Atalante) **cruise**

The present offshore Tasmanian project commenced in early 1994 with AGSO Cruise 125, which used the French research vessel *l'Atalante* on an exchange basis. The following discussion is drawn from Exon et al. (1994). The French vessel was used, rather than *Rig Seismic*, because of its Simrad EM12D swath-mapping system, capable of mapping the sea bed in a swathe up to 22 km wide at 20 km/hour, and of producing final bathymetric contour maps and images of the sea floor aboard ship. The *Tasmante* cruise (from Tasmania and *L'Atalante*) started in Auckland on 12 February and finished in Adelaide on 29 March. Data were recorded on the transits, as well as near Tasmania. The swath-mapping system, high speed seismic system, echosounder, magnetometer and gravity meter were deployed successfully throughout. Underway oceanographic data were also recorded. About 3200 km of geophysical data were recorded on the transit from New Zealand, 13 600 km on the South Tasman Rise (STR) and west Tasmanian margin, and 500 km on the transit to Adelaide, a total of about 17 300 km. All data were recorded digitally with the exception of the 3.5 KHz echosounder profiles. Seismic penetration of 2 seconds below sea bed was common. Total swath-mapping coverage in Australian waters exceeds 200 000 km^2 (Figs. 2, 4 & 17). The very accurate bathymetric maps and sonar images arising from this survey provide an unequalled source of structural information for AGSO and the petroleum exploration industry.

The maps defined bathymetry and surface texture with a degree of accuracy and rate of coverage unobtainable in any other way. This mapping of an area three times that of Tasmania helped to clarify the region's structural pattern and Cretaceous-Tertiary tectonic history, the latter strongly influenced by the final separation of Australia and Antarctica about 40 million years ago. Large-scale sedimentary structures and patterns were mapped to help elucidate Tertiary sedimentary history, and morphology to help define Australia's Legal Continental Shelf under the United Nations' Law of the Sea Convention.

The continental *South Tasman Rise* had been shown by satellite gravity maps to be a NW trending feature, cut by an older fault system trending NW, and a younger fault system trending almost north (Fig. 3). Both fault systems are clearly related to the break-up of Australia and Antarctica, starting 130 million years ago. Swath-mapping coverage was 150 000 km^2, or about two-thirds of the rise. Coverage of the sea bed was virtually 100 %, except in water shallower than 2000 m on the culmination of the rise. The results emphasise that the rise is bounded by steep scarps to the west and east, and less-marked scarps to the south (Figs. 2 & 4). The western fault scarp above the abyssal plain, north-trending and 2000 m high, is part of the Tasman Fracture Zone linking Australia to Antarctica. West of the fracture zone is Tertiary oceanic crust. A number of faults splay off the scarp toward the east, and the seismic profiles suggest abundant old volcanism. The basement blocks on the central plateau are either little sedimented or unsedimented, but are separated by transpressional or transtensional basins containing several kilometres of sediment and oriented N-S to NW-SE (Fig. 12).

The southern margin of the rise was shown to be delimited by south-dipping normal fault scarps beyond which is Tertiary oceanic crust. On the rise's culmination, north of the southern margin, NW-elongated magnetic anomalies over outcropping basement apparently represent magnetic intrusions. In the east the margin is heavily sedimented, but the continent may give way to Late Cretaceous oceanic crust immediately east of a major basement high trending NNE, south of Tasmania. In the northwest, a number of rotated fault blocks occur between major fault zones, and there are some thick sedimentary basins. In the deep saddle between the rise and Tasmania, sediment thickness varies greatly, with areas of basement outcrop, sedimentary basins, and volcanoes up to 900 m high. One hundred kilometres south of Hobart, in water depths of 800-1500 m, there is a major fishing area for orange roughy and dory. The mapping shows that the individual grounds are the tops of about 80 volcanoes, most about 200-400 m high.

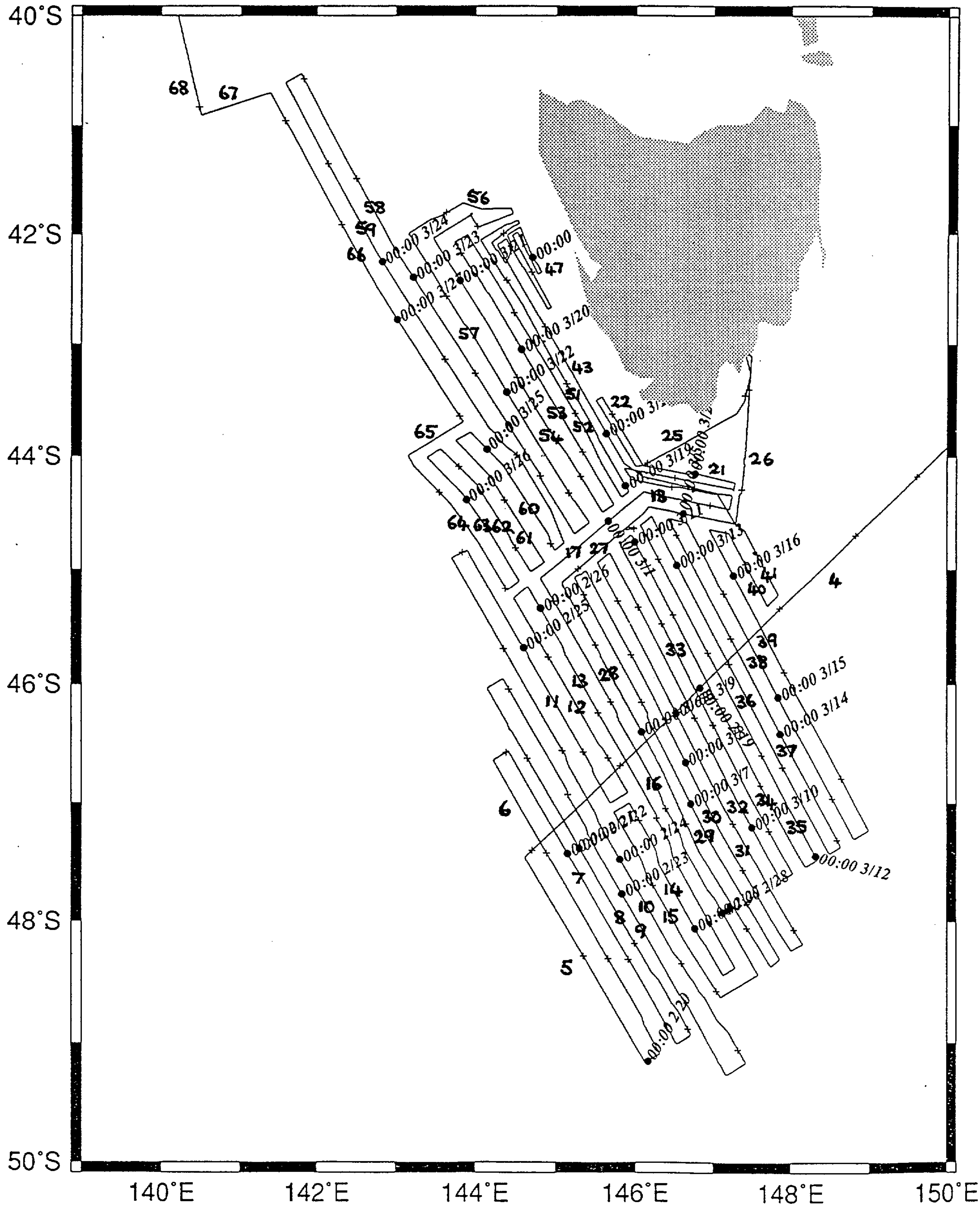


Figure 17. Track map for the detailed part of the *Tasmante* cruise off Tasmania. Position at beginning of each day shown as dot with 00:00 Month/Day. Six-hourly positions shown with cross. After Exon et al. (1994).

The South Tasman Rise was probably largely above sea level until it started to subside when Antarctica cleared it in the Eocene, and much of it stayed near sea level until late Oligocene times. In the centre of the plateau the 3.5 kHz echosounder showed areas of apparent sediment waves in the Plio-Pleistocene that are about 4 km long and 70 metres high, and seem to be migrating upslope northwestward toward basement highs. They are commonly unconformably overlain by 10-15 m of draped pelagic sediments. These features clearly represent a major change in current regime. Future coring of these features will help elucidate the Southern Ocean's climatic history.

About 50 000 km^2 of the *west Tasmanian margin* was also mapped. The mapping showed that canyons are much more common on the slope than had been known (Fig. 4). Several of them are known fishing grounds for the bottom-dwelling grenadier. The seismic data show that the sedimentary sequence is almost everywhere more than 2.5 seconds (>3 km) thick, basement being visible only in some shelf areas. Suitable dredge targets for Cretaceous rocks have been found on the mid and outer slope.

On the outer west Tasmanian margin, large NW-trending fault blocks, up to 2500 m high and marking the last obvious continental crust, were mapped at the surface (Figs. 2 & 4). West of them is a transitional zone about 50 km wide, heavily sedimented and deep, with no obvious magnetic anomalies, and underlain either by Cretaceous oceanic crust or thinned continental crust. Beyond that is young, shallower Tertiary oceanic crust with only thin sediment cover, and volcanoes along the north-south fracture zones. The younger, north-south tectonism has disrupted the older northwest fabric along the margins in various ways. Southwest of Tasmania, at the junction with the South Tasman Rise, there is a triangular area 50 km across, where it appears that the movement past of Antarctica has dragged the older rocks around and southward, to form a series of arcuate outcrops on the northernmost South Tasman Rise. The triangle itself was apparently produced by the movement south of the older rocks, and is a depression, perhaps filled with basalt (no magnetic anomalies).

Acoustic facies mapping of the South Tasman Rise and the west Tasmanian margin, based on the 3.5 KHz bathymetric profiles and the swath imagery, has allowed the patterns of Quaternary sedimentation to be mapped and interpreted. In general, sedimentation is more prevalent on the west Tasmanian margin, and erosion on the South Tasman Rise, but patterns change with basement structure, morphology, and current activity. Canyons presently cause starvation of much of the upper and lower slope off west Tasmania, and sedimentation on the lower slope.

The East Tasman Rise lies southeast of Tasmania and is an equidimensional feature about 200 km across, from which rises the Eocene volcanic cone of Soela Seamount. A single *Tasmante* profile shows the rise to be bounded by scarps and probably of continental origin. The seamount is flat-topped, ten kilometres across and 1200 m high, and it culminates 650 m below sea level. The depression between the East Tasman Rise and the South Tasman Rise is about 300 km wide, and gravity, magnetic and seismic data suggest much of it is oceanic. Basement is overlain by 1-1.5 seconds of sediment, this thickness explaining why the sea bed is not much deeper than 4000 m in the middle of a presumed oceanic basin. Our data indicate that the eastern side of the South Tasman Rise may be further west than we had expected (see Fig. 3).

The *maps* produced of all the areas are mostly at 1:250 000 scale, and for the detailed survey off Tasmania (C1-C7) include ship tracks, sonar imagery, detailed and less detailed contour maps (25 and 50 m contours), and an overlay of sonar imagery on the less detailed contours. In addition, 1:1 000 000 scale maps of the entire Tasmanian survey area were produced of bathymetry (50 m contours) and imagery. Finally, 1:100 000 scale maps were provided of two fisheries areas off Tasmania: 20 m contours and imagery in the south, and 20 contours in the west.

This cruise showed the tremendous value of wide angle swath-mapping on the Australian margin, and that Australia should move toward acquiring such a system for itself. An area of Australia more than three times the size of Tasmania was mapped in considerable detail in 42 days (Figs. 2 & 4). The results provide tectonic information in plan view on areas that have petroleum potential, with thick sedimentary sequences and evidence of thermogenic hydrocarbons in surface sediments. They will also be valuable in establishing Australia's claim for the large area of the South Tasman Rise beyond the 200 mile limit, under the provisions on the UN Law of the Sea.

Other sedimentological studies

Boreen et al. (1993) studied the sedimentology of the shelf and slope of the Otway Basin, an area sedimentologically similar to the west Tasmanian margin. He used *Rig Seismic* and R.V. *Franklin* cores: vibrocores on the shelf and gravity cores on the slope. The shelf is a high-energy, open, cool temperate environment, partitioned hydrodynamically into three: ultimate abrasion depth (70 m), swell wave base (130 m), and storm wave base (250 m). They concluded that there are five depth-related zones of carbonate production and sedimentation. The shallow shelf is characterised by production of carbonate particles like molluscs, red algae and encrusting bryozoans, and these are abraded and swept away. The middle shelf consists of sand shoals formed largely of branching bryozoans. The outer shelf accumulates burrowed and storm-bedded fine bioclastic sands. The shelf edge and upper slope is relatively nutrient rich, and bryozoans and sponges flourish. Muddy carbonate sand is deposited and moved down slope. The lower slope accumulates well-bedded pelagic carbonate, and is largely bypassed by other sediment.

Boreen and James (1993) discuss the Holocene sediment dynamics in the same area, on the basis of radiocarbon dated vibrocores and gravity cores. The Otway shelf has a patchy Holocene carbonate sand cover, less than 1.5 m thick, over Tertiary and late Pleistocene limestone. The Holocene slope deposits are bryozoan muds 0.5-3 m thick, over similar late Pleistocene deposits. The shelf edge and upper slope is a zone of carbonate production, accumulation of fines, and redeposition. The deep slope is dominated by pelagic and hemipelagic sediments, with climatically driven carbonate and terrigenous cycles. The authors develop a model that covers sedimentation in four phases: highstand and shallow flooding at 60-26 ka, lowstand at 20-18 ka, transgression at 18-6.5 ka, and highstand and deep flooding from 6.5 ka to the present. They discuss accumulation rates in detail, and conclude that differential accumulation rates, high in shallow protected waters, and low at the shelf margin, lead to the formation of a carbonate ramp. The shelf-margin bryozoan community is little affected by eustatic changes of 50-100 m, so there is continuous platform progradation.

Bolton et al. (1988) described eighteen samples of ferromanganese crusts and nodules dredged and cored by R.V. *Sonne* on the South Tasman Rise, and related them to the rocks or sediments with which they were associated. The samples came from four dredge hauls and six cores. These slowly-forming deposits formed largely on current swept outcrops. They overlie a variety of basement rocks, and also frequently occur at the major hiatus above the Eocene mudstone and siltstone. The chemical composition of all samples is broadly similar, but subsurface samples are more contaminated and hence show lower metal values. Average values of the metals of economic interest are: Mn 15%, Fe 19%, Ni 0.39%, Cu 0.16%, and Co 0.33%. These are quite unexceptional values, although one deposit had high Co values of 0.8-1.0%.

Petroleum exploration

Organic-rich Late Eocene silty clays at DSDP Site 282 west o: Tasmania have considerable petroleum source rock potential (Hunt, 1975; 1984). In Cape Sorell No.   (AMOCO, 1982) extensive traces of oil were found in the latest Cretaceous/earliest Paleocene. A shipboard study of 27 *Sonne* cores (Whiticar & others, 1985) indicated that wet gas of thermogenic origin is abundant in surface sediments on the west Tasmanian margin, indicating the presence of mature source rocks. Fourteen cores were analysed for gases on the South Tasman Rise and most were relatively poor in hydrocarbons. However, three stations in the east gave higher yields with a thermogenic signature. More than 20 exploration wells have been drilled in the offshore Otway and Sorell Basins.

The petroleum prospects of the continental margin of western Tasmania were reviewed by Moore et al. (1992) and this section is drawn from their work. The margin is underlain by the southern Otway Basin and the Sorell Basin (Fig. 10). The latter lies mainly under the continental slope, but it includes four sub-basins (the King Island, Sandy Cape, Strahan and Port Davey sub-basins) underlying the continental shelf (Fig. 18). In general, these depocentres are interpreted to have formed at the 'relieving bends' of a major left-lateral strike-slip fault system, associated with 'southern margin' extension and breakup (seafloor spreading). The sedimentary fill could have commenced in the Jurassic.

Maximum sediment thickness is about 4300 m in the southern Otway Basin, 3600 m in the King Island sub-basin, 5100 m in the Sandy Cape sub-basin, 6500 m in the Strahan sub-basin, and 3000 m in the Port Davey sub-basin. Megasequences in the shelf basins are similar to those in the Otway Basin, and are generally separated by unconformities. There are Lower Cretaceous non-marine conglomerates, sandstones and mudstones, which probably include the undated red beds recovered in two wells, and Upper Cretaceous shallow marine to non-marine conglomerates, sandstones and mudstones. The Cainozoic sequence often commences with a basal shallow marine sandstones, mudstones and marls, and grades up into Eocene shallow marine limestones, marls and sandstones, and Oligocene and younger shallow marine marls and limestones. The sequences in four unsuccessful petroleum exploration wells, west and northwest of Tasmania, are summarised in Figure 19.

The presence of active source rocks has been demonstrated by the occurrence of free oil near the base of Cape Sorell No.1 well (Strahan sub-basin), and thermogenic gas from surficial sediments recovered from the upper continental slope and the Sandy Cape sub-basin. Geohistory maturation modelling of wells and source rock 'kitchens' has shown that the best locations for liquid hydrocarbon entrapment in the southern Otway Basin are in structural positions marginward of the location of Prawn No. 1 well. In such positions, basal Lower Cretaceous source rocks could charge overlying Pretty Hill Sandstone reservoirs. In the King Island sub-basin, the sediments encountered by the Clam No. 1 well are thermally immature, though hydrocarbons generated from within mature Lower Cretaceous rocks in adjacent depocentres could charge traps, providing that suitable migration pathways are present. Whilst no wells have been drilled in the Sandy Cape sub-basin, basal Cretaceous potential source rocks are considered to have entered the oil window in the early Late Cretaceous, and are now capable of generating gas/condensate. Upper Cretaceous rocks appear to have entered the oil window in the Paleocene. In the Strahan sub-basin, mature Cretaceous sediments in the depocentres are available to traps, through considerable migration distances would be required.

Moore et al. (1992) concluded that the west Tasmania margin, which has five strike-slip related depocentres and the potential to have generated and entrapped hydrocarbons, is worthy of further consideration by the exploration industry. The more prospective areas are the southern Otway Basin, and the Sandy Cape and Strahan sub-basins of the Sorell Basin.

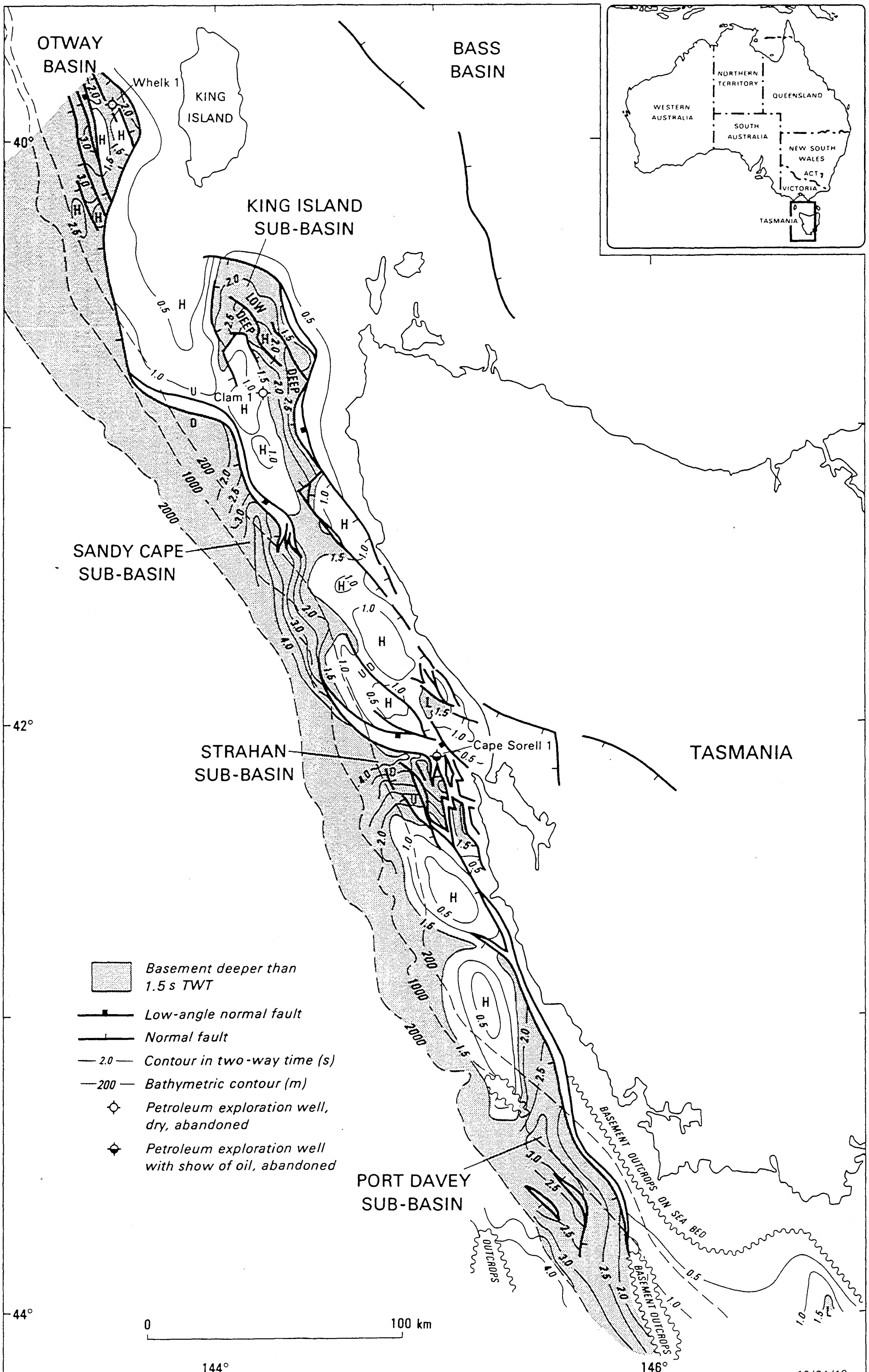


Figure 18. Map of basement structure off west Tasmania. Shows basins and sub-basins in water shallower than 1000 m. After Moore et al. (1992).

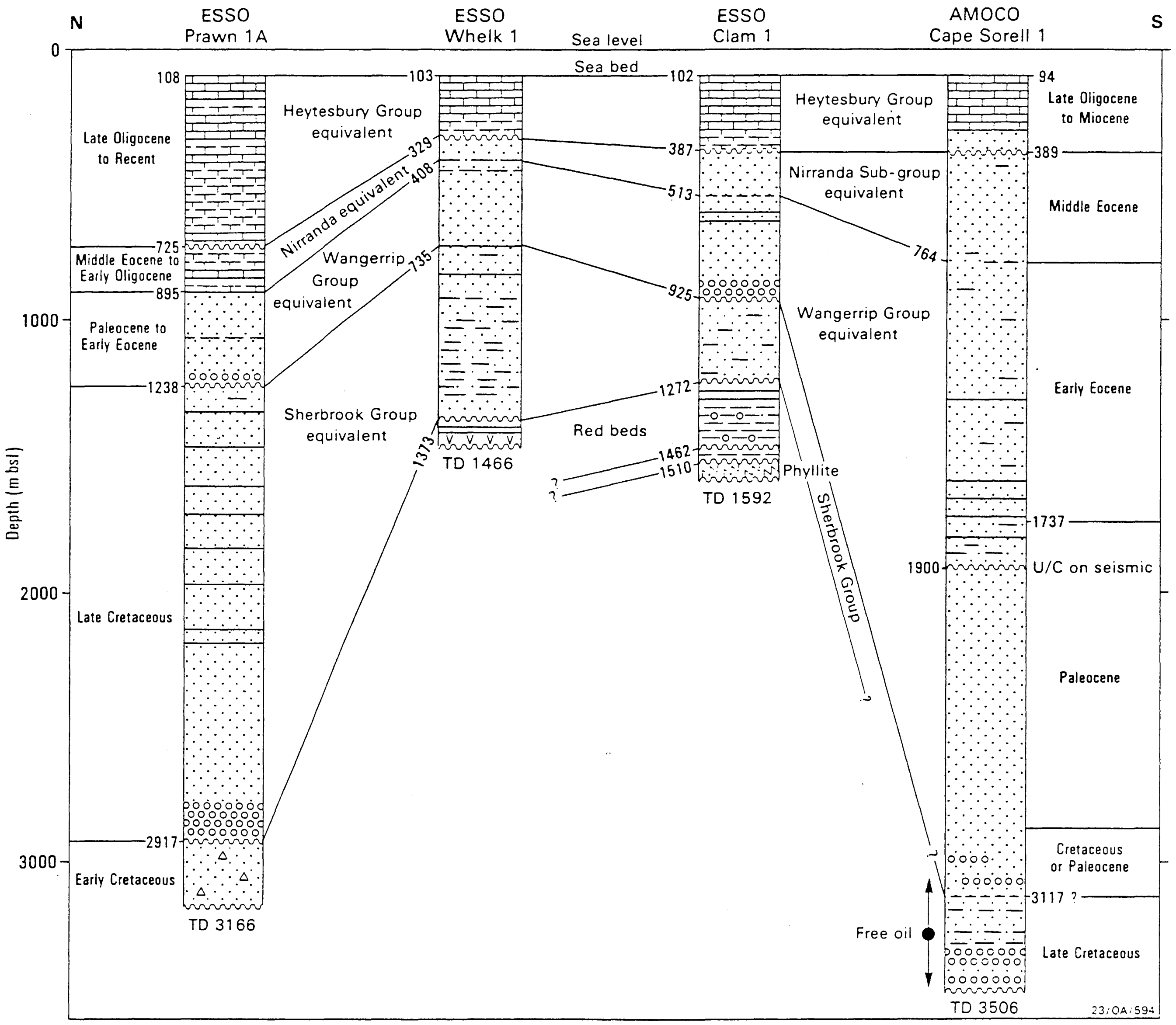


Figure 19. Well correlation diagram for four petroleum exploration wells west and northwest of Tasmania. Locations of southern three in Figure 18. Note the great thickening of the Paleogene in Cape Sorell No. 1, caused by its proximity to a fault scarp active at that time. After Moore et al. (1992).

SUMMARY OF CONVENTIONAL SEDIMENTOLOGICAL KNOWLEDGE

The situation on the west Tasmanian margin (40-45°S) is rather different from that on the South Tasman Rise (45-50°S), so this section treats the two areas separately.

West Tasmanian margin

Well stratigraphy is summarised in Figure 19. The Upper Cretaceous Sherbrook Group is thickest, 1590 m, in Prawn No. 1 well north of King Island. It consists of marginal marine to fluviatile sandstone, siltstone, mudstone and conglomerate. The Tertiary sequence is probably disconformable on the Upper Cretaceous sequence. Non-marine to shallow marine, Paleocene to lower Eocene fining upwards sequences are present in all four exploration wells, and are by far the thickest in Cape Sorell No.1, about 2250 m! The middle Eocene to lower Oligocene sequence is more calcareous, consisting of shallow marine sandstone, marl and limestone, and is thickest, 375 m, in Cape Sorell No.1. Above a major unconformity, the upper Oligocene and younger sediments are dominantly shelfal marl and limestone. They are thickest, 617 m, in Prawn No. 1.

In DSDP Site 282, located deep on the continental slope (Fig. 3), 240 m of late Eocene to middle Oligocene sediments rest on a basalt flow of presumed Tertiary age. The basal, late Eocene unit is 103 m thick. It consists of a glassy and zeolitic mudstone laid down in reducing conditions, with appreciable organic carbon, but contains shallow-water benthic forams at some levels, as well as shallow water coccoliths and sponge spicules. Thus the conclusion of Kennett, Houtz et al. (1975A), that the sequence was laid down in deep water, remains in doubt. They conformably overlying early to mid Oligocene sediments are olive grey mudstones and are 78 m thick. They contain nannofossils, sponge spicules and glauconite stringers. The next unit up is a dark olive grey, organic carbon bearing, nannofossil-rich mudstone, 9 m thick. It contains shelly fossils and a possibly shallow-water benthic foram assemblage. The uppermost middle Oligocene unit is 50 m of grey, glauconite and micronodule bearing, quartz rich mudstone, rich in nannofossils and sponge spicules, and containing a shallow-water benthic foram assemblage in one core. Above the Oligocene unconformity is 42m of early Miocene foram and glauconite bearing nannofossil marl. Late Miocene nannofossil ooze, 7 m thick, disconformably overlies the early Miocene sequence, and is overlain by a veneer of Pleistocene ooze. There is little in this well to suggest that it was in deep water until the margin started to subside in the Oligocene, and it may be that the basalt is not an oceanic basalt at all.

Grab, vibrocore, core and dredge samples from the west Tasmanian margin have provided a great deal of valuable information. They are listed in Tables 2-7 and discussed in Hinz et al. (1985, 1986), Exon, Lee & Hill (1989), and Exon et al. (1992). A general summary of the results is given in Table 8. All the Late Cretaceous, Paleocene and Eocene siliciclastic sediments are interpreted as shallow or restricted marine, and the Eocene limestones are also shallow marine. Above the Oligocene unconformity, the effect of the collapse of the margin westward is evident in the sediments, with those near Tasmania generally being shallow marine, but those further west being deposited in increasingly deep water.

TABLE 8: CHARACTER & AGE OF WEST TASMANIAN SEABED SAMPLES

Sequence	Stations
Pleistocene to Recent bryozoal shelf sands and muddy sands	67/GS 28-31; 78/GS1-9; 78/VC 1 & 2; 78/GC 8-17
Pleistocene to Recent oozes and turbidites	23 *Sonne* cores, 19 BMR Cruise 67 cores, 16 BMR Cruise 78 cores
Miocene to Early Pliocene limestone, chalk, marl, ooze and mudstone	9 *Sonne* cores, 3 BMR Cruise 67 cores, 5 BMR Cruise 78 cores
Late Oligocene shelf limestone	2 *Sonne* dredges
Late Oligocene marl and mudstone	2 BMR Cruise 67 cores
M Eocene shelf limestone	2 *Sonne* dredges
E-M Eocene nearshore marine mudstone	2 *Sonne* cores, 1 BMR Cruise 78 core
Paleocene restricted marine mudstone	1 BMR Cruise 78 dredge
Late Cretaceous shallow marine mudstone and sandstone	2 BMR Cruise 67 dredges, 1 BMR Cruise 78 dredge
Basalt	1 *Sonne* dredge, 1 BMR 78 dredge
Palaeozoic or Mesozoic sandstone, grit or metasiltstone	3 *Sonne* dredges, 1 BMR 78 dredge
Schists and related rocks	3 *Sonne* dredges, 1 BMR 78 dredge

South Tasman Rise

Two DSDP wells were drilled on or near the South Tasman Rise (Kennett, Houtz et al., 1975A). Site 281 was drilled in water 1591 m deep, southwest of the culmination of the rise (Fig. 3), and bottomed in a quartz-mica schist of probable PreCambrian age. This is unconformably overlain by a six metre thick, late Eocene, basement conglomerate consisting of angular clasts, dominantly of schist, with lesser quartz, quartzite, glauconite, glauconitic sandstone and granite. This contains a battered assemblage of benthonic forams, and was a locally derived, shallow-water, high-energy deposit, laid down during the initial transgression across the subsiding South Tasman Rise. It is overlain by 3 m of detrital sand and nanno chalk. The upper 28.5 m of late Eocene sediment consists of greyish-olive glauconitic sandy silt and silty clay, with abundant forams, radiolarians, diatoms and sponge spicules. Neritic nannofossils and benthic forams in older strata point to deposition in outer shelf or upper bathyal depths, whereas the presence of shallow-water benthic forams points to shelf deposition later. Unconformably overlying the late Eocene sequence there is 3 m of late Oligocene glauconite-rich detrital sand, unconformably overlain by 79 m of Miocene foram-nanno ooze and 36 m of Plio-Pleistocene foram-nanno ooze.

Site 280 was drilled to 524 metres in water 4181 m deep southwest of the rise (Fig. 3), and bottomed in an "intrusive basalt", almost certainly oceanic crust. It penetrated a veneer of late Miocene to late Pleistocene clay and ooze underlain, beneath a sampling gap, by 55 m of siliceous early Oligocene sandy silt, and 428 m of middle Eocene to early Oligocene sandy silt, containing chert in the upper 100 m, and glauconite and manganese micronodules below that. The lower 200 m is rich in organic carbon (0.6-2.2 %). All sediments are presumed to be abyssal types, and a brown organic stain suggests reducing conditions in parts of the late Oligocene and early Miocene.

Most of the sea bed samples from the South Tasman Rise were taken by R.V. *Sonne* in 1985, and have been described by Hinz et al. (1985) and Bolton et al. (1988). They are listed in Table 2, and have been discussed earlier in this report under "R.V. Sonne cruises". The main results are summarised in Table 9.

TABLE 9: CHARACTER AND AGE OF *SONNE* SOUTH TASMAN RISE SEABED SAMPLES

Sequence	*Sonne* Stations
Pleistocene to Recent carbonate ooze or foram sand	16 cores
Pliocene carbonate ooze	4 cores
Miocene chalk	1 core
Eocene glassy zeolitic mudstone with radiolarians	2 dredges, 3 cores
? Eocene palaeosol	1 core
Tertiary basaltic breccia	1 dredge
Palaeozoic graywacke	1 core
Schist, gneiss, pegmatite	1 dredge

The sampling results show that the early history of the two areas, west Tasmanian margin and South Tasman Rise, was probably similar. Clearly there were major differences in the Eocene, when the northern area saw the deposition of shallow marine deltaic sediments and limestones, while the southern area saw the deposition of glassy radiolarian-bearing glauconitic mudstones in a shallow sea that was restricted on occasions. As Antarctica cleared Australia there was a period of erosion in both areas, forming the Oligocene unconformity, and both areas subsided steadily. However, the southern area sank vertically as a block, whereas the west Tasmanian margin rotated downward from a hingeline near the coast, so that the further from Tasmania, the deeper the water. In the south, the circum-Antarctic current and its successors scoured most sediments away, whereas thick late Oligocene to Recent carbonate sediments are present in depocentres off west Tasmania.

ACOUSTIC FACIES MAPPING AND SEDIMENTOLOGY

Introduction

This section is drawn directly from Whitmore, Belton & Wellington (1994). Acoustic facies mapping, first used by Hollister (1967) and summarised by Damuth (1980), uses the 3.5 kHz acoustic response of surface and near-surface sediments to recognise predicted sedimentary facies (Embly, 1975; Damuth, 1975; Mullins et al., 1979; Rostek, 1991; Blum & Okamura, 1992). Complete seabed imaging is now possible using modern marine geophysical surveys carried out at constant speed, with a regular, closely spaced grid of ship tracks and 100% sea floor coverage using long range swath mapping systems. The final acoustic facies maps from the Tasmanian region incorporate information from along-track 3.5 kHz profiles with full swath bathymetry and acoustic backscatter data so that facies can be accurately mapped between shiptracks.

Many authors have investigated the relationship between sediment type and acoustic response to both low and high frequency sound. De Moustier and Matsumoto (1993) found that the character of seafloor acoustic reflections is dictated predominantly by substrate type and microtopography. Penetration of acoustic energy decreases with increasing grainsize and the presence of bedforms, due to scattering of acoustic energy (Normark, 1970; Damuth, 1975; Mullins et. al., 1979). The same studies have also demonstrated that multiple parallel sub-bottom reflections, another measure of signal character, can be produced by sand/silt layering. Despite these established relationships, it is important to note that many other subtle factors (eg. carbonate content, degree of compaction, depth and weather conditions) can also contribute to the character of signals received and without comprehensive ground-truth, an assigned acoustic facies can only be interpretive.

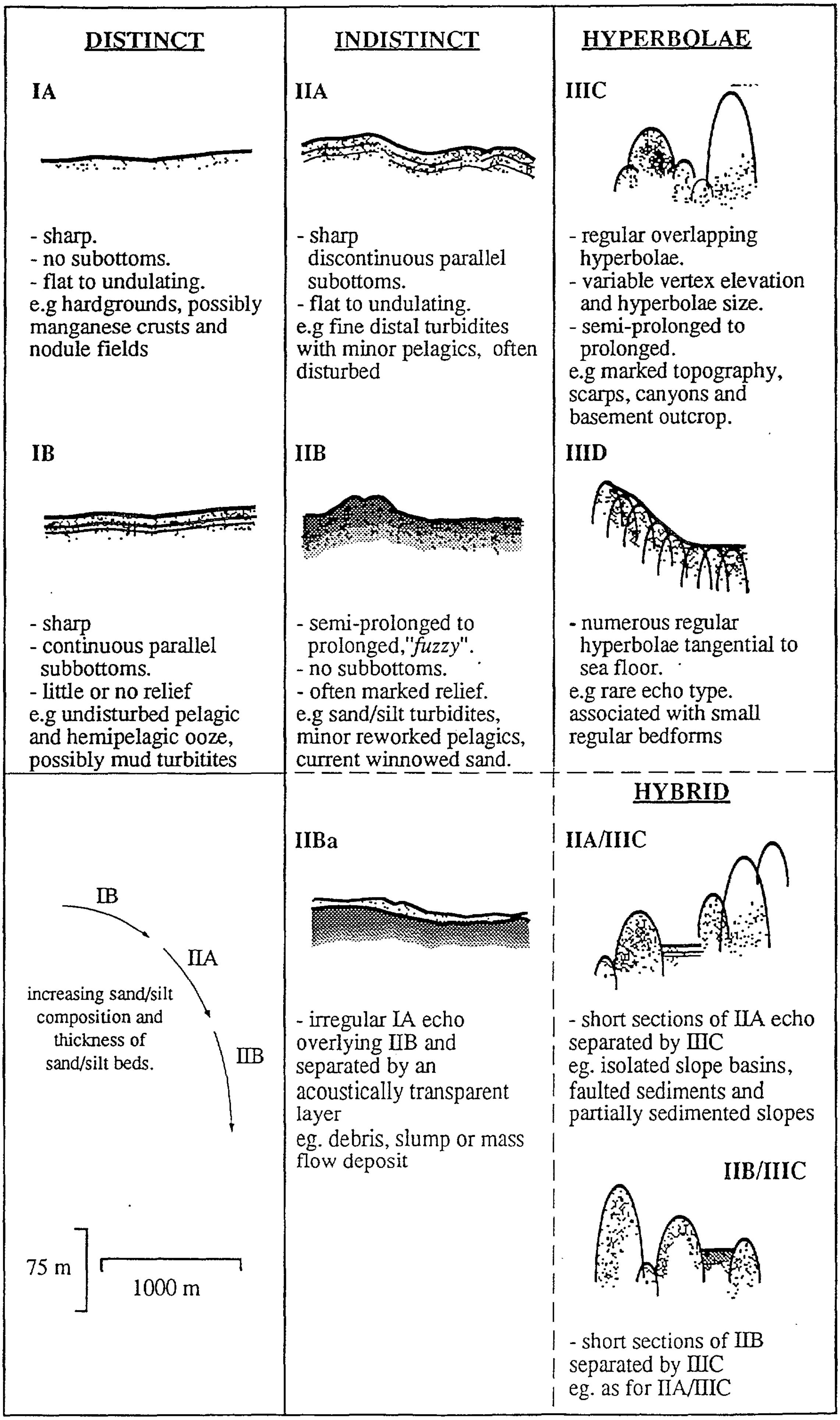


Figure 20. Acoustic facies types determined from 3.5 KHz echosounder profiles. Slightly modified from Damuth (1980). After Whitmore et al. (1994).

Discrimination of acoustic facies from 3.5 kHz profiles requires that the observer define echo character types using penetration, sub-bottom detail and the presence or absence of hyperbolae. Penetration is loosely defined as either sharp (< 1 ms), semi-prolonged or prolonged (> 3 ms), while sub-bottom detail is described according to the number and continuity of reflectors beneath the sea floor. The echo character types proposed by Damuth (1980) are generally agreed upon, though many authors, as in our case, have found it necessary to add or delete types specific to their given region (Fig. 20).

Once echo character types have been established an acoustic facies map is constructed by :

1) assigning all available 3.5 kHz records to echo character types,
2) recording the echo character picks along shiptrack and
3) mapping echo character picks between shiptracks using a combination of bathymetric and acoustic intensity information.

Acoustic Facies Maps

A generalised acoustic facies map for the South Tasman Rise and two detailed maps from the north flank of the South Tasman Rise and an area offshore of Cape Sorell were presented by Whitmore et al. (1994). Discrepancies between the broad scale South Tasman Rise map and the more detailed map from its north flank were due to contrasting scales and the resultant detail each investigator was able to consider when assigning echo types.

Eight acoustic facies types (Fig. 20) were recognised in the survey area in four broad categories 1) distinct 2) indistinct 3) hyperbolic and 4) hybrid. These are listed below together with interpreted sedimentary facies.

Distinct

IA: Sharp, continuous echo with no sub-bottom reflectors. Variously associated with hardgrounds and manganese nodule fields, possibly with a thin sediment cover.

IB: Sharp, continuous echo with up to 20 continuous parallel sub-bottom reflectors. Undisturbed pelagic and hemipelagic oozes. Possibly mud turbidites.

Indistinct

IIA: Semi-prolonged echo with discontinuous parallel sub-bottom reflectors. Turbidite deposits possibly interbedded with oozes and reworked pelagic sediments. Often interpreted as distal turbidite deposition.

IIB: Prolonged to very prolonged 'fuzzy' echoes with no sub-bottom reflectors. Sand and silt turbidite deposits, gravity flows, winnowed sands, minor reworked pelagics. Basement outcrop on the South Tasman Rise also returns a IIB-like echo. This has been mapped as IIBb for the detailed area on its northern flank, but could not be differentiated for the generalised map.

IIBa: Irregular sharp distinct echo (IA) overlying a prolonged (IIB) echo with no sub-bottom reflectors and separated by an acoustically transparent zone. Gravity flow, slump or mass movement.

Hyperbolic

IIIC: Large, irregular, overlapping semi-prolonged to prolonged hyperbolae with varying vertex elevations. Rugged or erosional topography, canyons and scarps.

IIID: Small, regular, overlapping hyperbolae, with vertices tangential to the sea floor. Associated with small regular bedforms or erosional features suggesting current activity.

Hybrid

IIA/IIIC: Short (< 1 minute or ca. 200m) flat sections of IIA echo type between larger irregularly spaced IIIC type hyperbolae. Isolated slope basins, block faulted sediments and sedimented slopes.

IIB/IIIC: As for above, though with short flat sections of IIB character. Isolated slope basins, block faulted sediments and sedimented slopes

Discussion

South Tasman Rise

The major sedimentary processes acting on the South Tasman Rise (Fig. 21) involve primary deposition of pelagic sediments and the subsequent re-working of these by both bottom current activity and gravity flow. The summit of the Rise is dominated by undisturbed pelagic deposition to the east and reworked pelagics to the west, where increased current activity governs sediment distribution. Its flanks are characterised by a range of deposits including slumps and mass flows initiated by slope failure. Similar gravity flows, constrained within submarine valleys and canyons, produce turbidites with proximal to distal sediment variations. The mobilisation of mass flow products producing slump scars and erosion by currents and turbidites serves to expose older sediments. Areas of rugged topography show a wide range of sedimentary environments encompassing elements of all processes discussed thus far. As a result of shedding from areas of higher relief, sediments are transported into depocentres on the Rise itself, as well as out onto the abyssal plain where interbedded turbidites and pelagic sediments accumulate. West of the Tasman Fracture Zone, on oceanic crust, sedimentary processes are more limited. Here primary deposition of pelagic ooze is predominant with little subsequent reworking.

Cape Sorell area

The continental slope adjacent to Cape Sorell is dominated by down-slope sediment transport processes initiated by gravity flows on the upper slope (Fig. 22). Much of the sediment activated by these flows is captured by a network of canyons, bypasses the mid-slope and is deposited due to decreasing gradients on the lower slope. The mid-slope is sediment-starved due to sediment bypassing and the action of ocean currents. The lower slope acts as a sink for coarse sediment with finer sediments being deposited on the abyssal plain.

North flank of the South Tasman Rise

The area studied, on the north flank of the South Tasman Rise, is a transitional region between the Australian continent and the semi-detached block of the South Tasman Rise. Extensional rifting

Sedimentary Environments

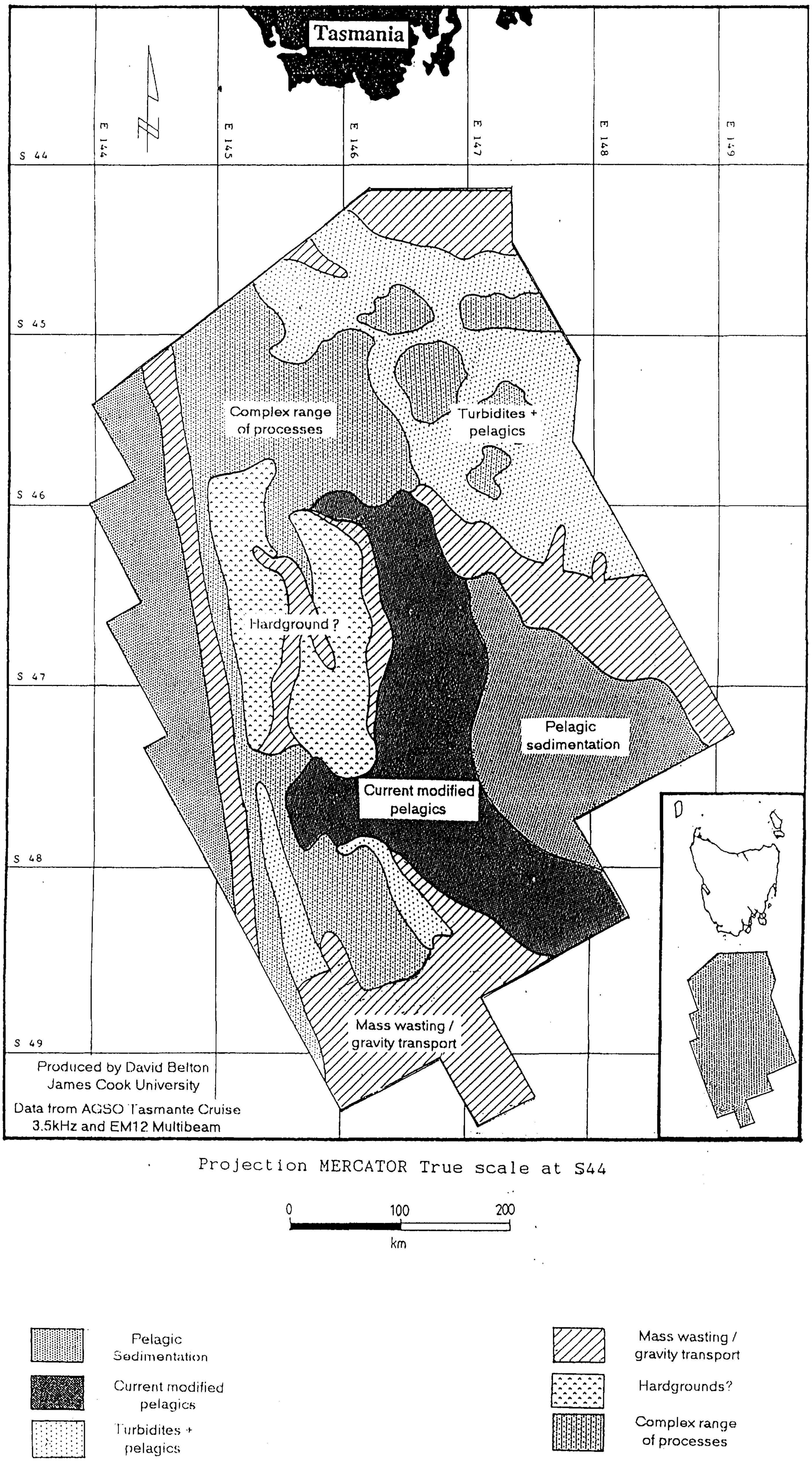
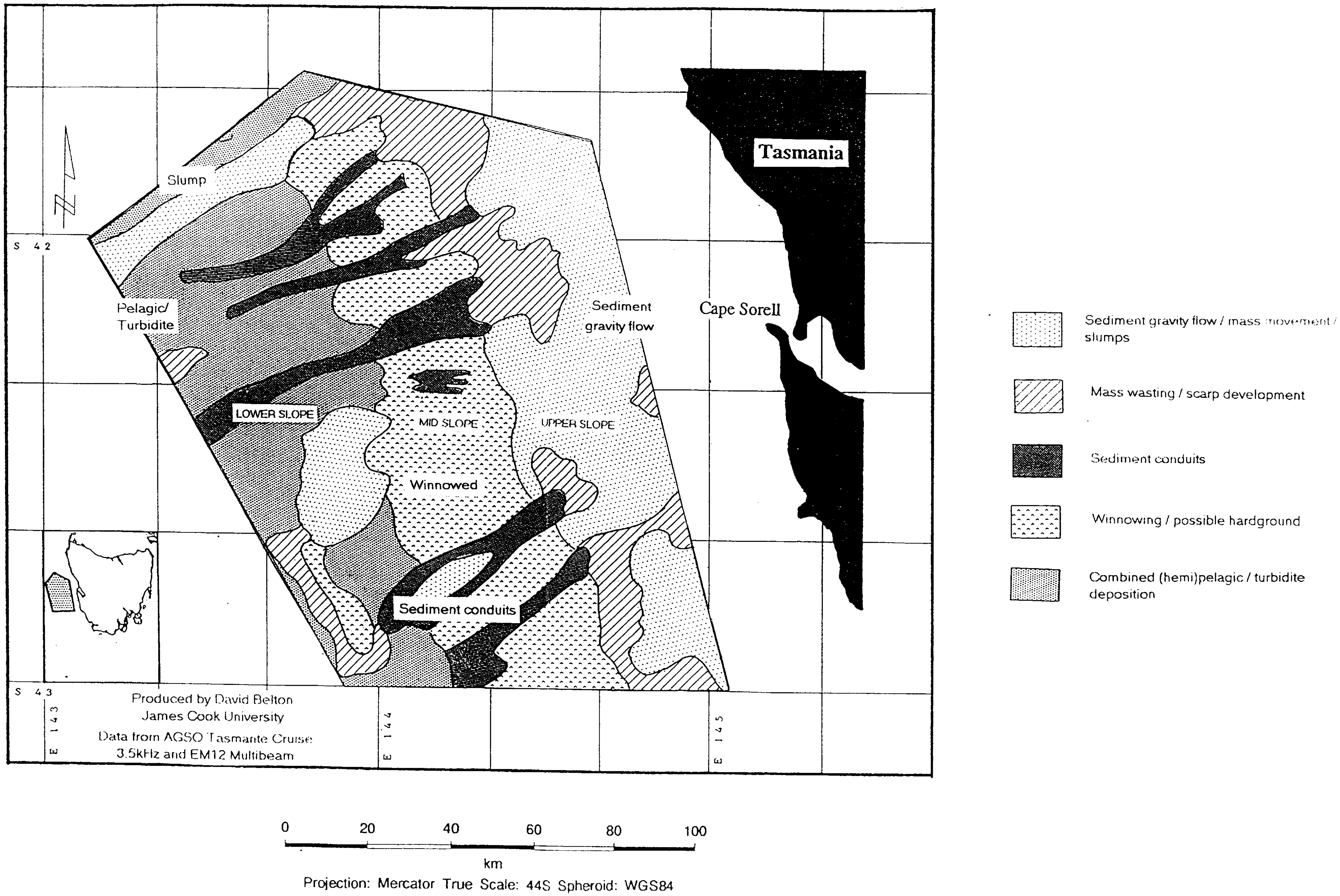
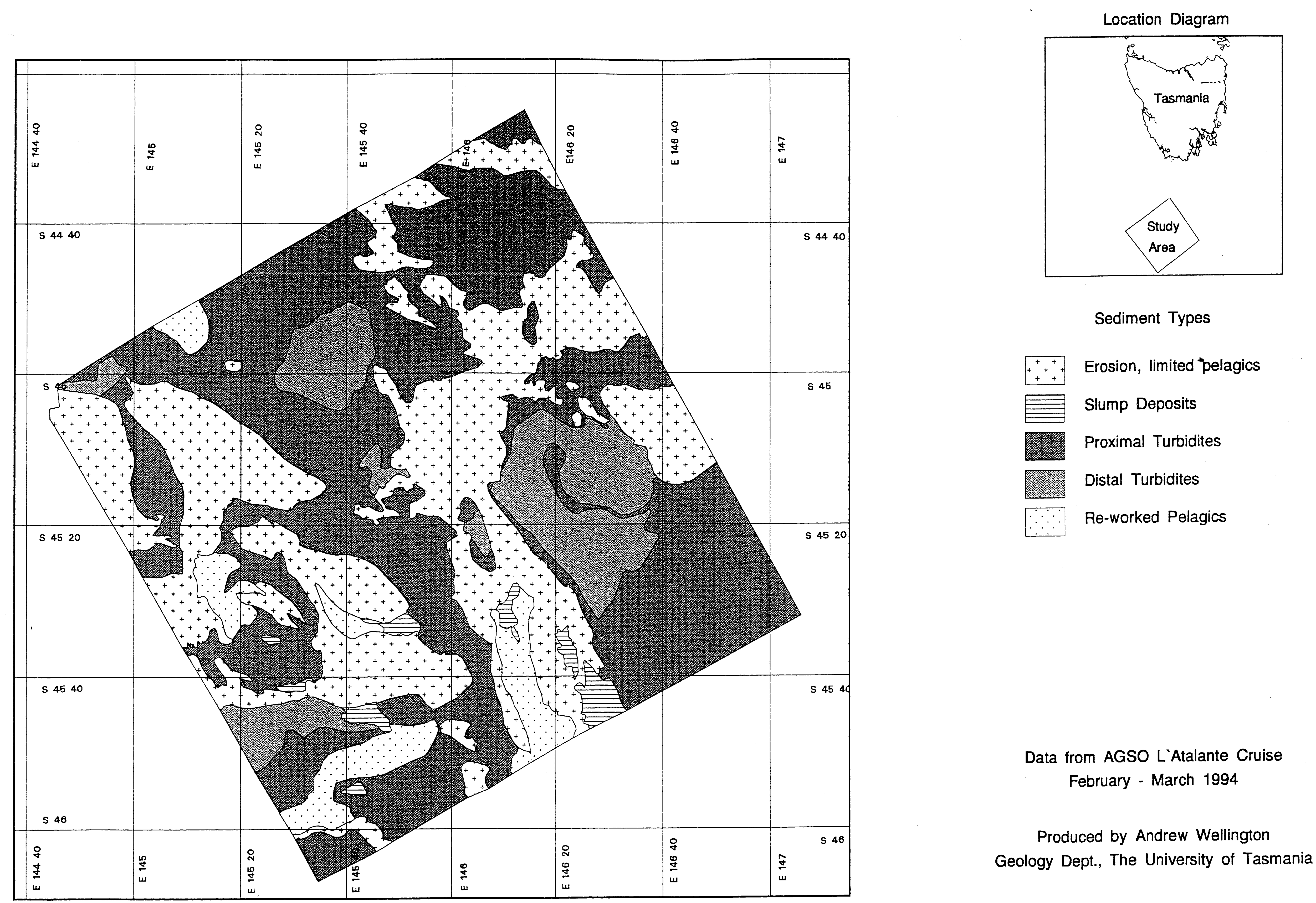


Figure 21. South Tasman Rise sedimentary environments. Derived from acoustic facies map (Fig. 54) and other information. After Whitmore et al. (1994).

Figure 22. Cape Sorell area sedimentary environments. Derived from acoustic facies map (Fig. 56) and other information. After Whitmore et al. (1994).





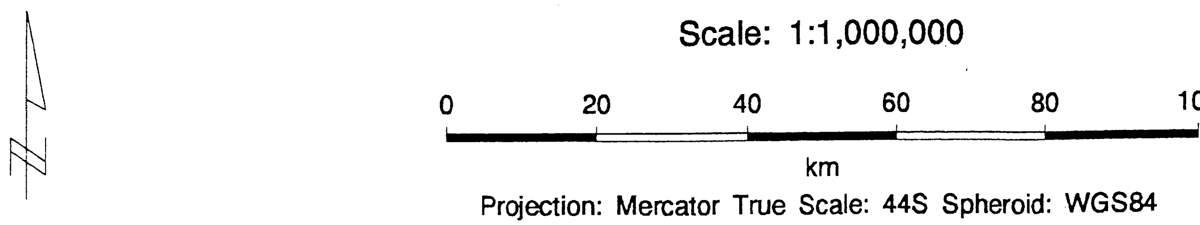


Figure 23. Northwestern South Tasman Rise surficial geology map prepared from *Tasmante* echosounder profiles and swath imagery. After Wellington (1994).

processes and transcurrent shear mechanisms have combined in this region to create complex topography.

Drainage patterns indicate that the South Tasman Rise, not the Tasmanian margin, is the main sediment source for the north flank of the rise. The dominant drainage direction throughout the area is northward, with only minimal southerly drainage from topographically high regions to the north of the area. Thus, the majority of surficial sediments present on the north flank of the South Tasman Rise are probably reworked pelagic sediments from the higher parts of the South Tasman Rise, an inference supported by R.V, *Sonne* samples from the north flank that recovered recent pelagic foraminiferal sands and oozes.

The overall sedimentary character of the study area (Fig. 23) is of deep basins isolated by topographic highs of continental basement. Sediments filling these basins may have been derived from either Tasmania or Antarctica shortly after the time of rifting. Present terrigenous deposition in the area is minimal, as evidenced by surficial pelagic sediments and the formation of manganese crusts. Submarine sediment movement does occur, as shown by the presence of the IIBa echo type indicating slump or debris flow facies.

Conclusions

Acoustic facies mapping has revealed the detailed echo-character patterns of surficial sediment in the South Tasman Rise and offshore from Cape Sorell. The combination of 3.5 kHz profiles with full swath bathymetry and acoustic intensity enables discrimination of hardgrounds, undisturbed laminated pelagic deposits, disturbed pelagic deposits with minor sandy interbeds, coarse sandy units with minor pelagic contributions, highly disturbed mass flow deposits, sedimented slopes cut by small channels or bedforms, and steep erosional slopes often characterised by basement outcrop

The major processes interpreted to operate in the survey area in the Quaternary are bottom currents, and sediment gravity flows, including turbidites and debris flows. Sediment waves with wavelengths of several hundred metres, of IIA acoustic facies, are confined to the western flank of the South Tasman Rise, indicating that strong ocean currents were once active and constrained by morphology. Modern examples are smaller than the buried sediment waves, suggesting that while deep ocean currents are still active their magnitude has abated.

Debris flows are prevalent on many intermediate and steep slopes surrounding the South Tasman Rise. They are defined by a IIBa facies rarely documented in the literature to date. Turbidity current activity is evident on the north flank of the South Tasman Rise, and also within the Cape Sorell area where the upper reaches of submarine canyons and channels produce a hybrid IIB/IIIC facies which is gradational down slope into a IIB, and finally in distal regions, into IIA facies.

A tentative identification of hardgrounds is put forward. These areas return IA echo types identified from 3.5 kHz profiles, and are morphologically isolated from sediment sources, but do not return a distinctive acoustic response. Further classification, of this and indeed all facies types, requires the comprehensive ground-truthing scheduled for the *Rig Seismic* cruise of February 1995.

PALAEOCEANOGRAPHIC STUDIES: SURFACE WATER CHANGES ACROSS THE SOUTHERN OCEAN FRONTAL ZONES AND CHANGES IN INTERMEDIATE AND DEEP WATER STRUCTURE OVER THE LAST GLACIAL CYCLE - CLUES FOR CHANGES IN ATMOSPHERIC $PC0_2$

(Elisabeth L. Sikes)

[On behalf of participating scientists: Patricia Wells (Antarctic CRC), Dan McCorckle (WHOI), Howie Spero (University of California, Davis), Prasada Rao (University of Tasmania), Clare Findlay (Antarctic CRC).]

The subtropical convergence (STC) is a major boundary between surface ocean water masses. It is the northern limit of the Southern Ocean and is marked by a strong temperature gradient of about 4°C (from 14-18°C in the summer [Tchernia, 1980]). The Polar Frontal Zone (PFZ) is also marked by a temperature gradient of about 4°C (from 2-6°C Nemoto & Terasaki, 1985; Tchernia, 1980), and it is also the site of formation of a major deep water mass, AAIW (Tchernia, 1980). The Southern Ocean is known to have a large influence on global deep ocean circulation, and is believed to have had a major influence on atmospheric pCO_2 changes that occurred during the major climatic changes (glacial to interglacial) of the late Quaternary. Consequently, understanding changes in the surface properties (such as sea surface temperature: SST) and productivity of the Southern Ocean and across its boundaries are of great interest in reconstructing the influence of the Southern Ocean on global climate change (eg. Mortlock et al., 1991; Howard & Prell, 1992).

Ice core records have revealed that the atmosphere underwent a 1/3 increase in CO_2 between glacial and Holocene climate regimes (eg. Neftel et al., 1982). What controls this natural change in atmospheric pCO_2 content is a puzzle whose answer must lie in ocean circulation because the ocean contains the world's largest exchangeable carbon reservoir (about 50 times that in the atmosphere, [Broecker et al., 1980]). The most important waters in the ocean for this exchange are the Southern Ocean and the northern North Atlantic which are the two main sites for deep water formation today. However, during the last glaciation northern source water was significantly reduced (Boyle & Keigwin, 1985, 1986) and northern source water sank only to intermediate depths (Boyle & Keigwin, 1987), greatly increasing the southern ocean influence on the deep ocean (Curry & Lohman, 1983; Oppo & Fairbanks, 1987; Dupelssy et al., 1988; Curry et al., 1988, Charles & Fairbanks, 1992). Many theories have been put forward as to how changes in the oceans composition and circulation could change the atmospheric CO_2 content by about 90 ppmV (see Broecker & Peng, 1989 for a review), but the one proposed by Boyle (1988) and modified by Broecker & Peng (1989) satisfies the geological data most closely. They proposed that shifting the nutrient sink from intermediate depth waters in the interglacial ocean (present conditions) to deep waters in the glacial ocean, changed carbonate dissolution conditions sufficiently, due to the reorganisation of nutrients, to account for the entire glacial--interglacial change in atmospheric CO_2 content. Recent work on Southern Ocean sediments by Howard & Prell (1992) on planktonic foraminiferal parameters, and Francois & Altabet (1992) on sedimentary Nitrogen 15 strongly indicate that changes in surface processes in the sub-polar waters of the Southern Ocean in the last glaciation were important in controlling atmospheric pCO_2, and thus global climate.

We wish to look at changes in Southern Ocean SST on both the East Tasman Rise and the South Tasman Rise to examine movements of the STC and the PFZ in the late Quaternary using the alkenone unsaturation ratio, $U^{k'}_{37}$, foraminiferal assemblages, stable isotopes and coccolith assemblages. These complementary measurements of SST are needed because each technique has known limitations, but each provides unique information about parameters other than SST. Using complimentary estimators is a powerful technique for understanding past SST. Where such a combined approach has been used it has offered insights into ocean processes relevant to climate change (McCaffrey et al., 1990; Sikes, 1990, Sikes & Keigwin, in press).

Drs. Sikes and Wells will be looking at foraminiferal assemblages to estimate SST. However, transfer functions may over-estimate temperature changes by reflecting large thermocline effects rather than small SST changes (Mix, 1987; Fairbanks, 1989) because individual species may modify their depth or season of growth to follow a preferred growth temperature (Fairbanks et al., 1980; Fairbanks & Weibe, 1980; Curry & Mathews, 1981; Fairbanks et al., 1982). It is well known that the $\delta^{18}O$ signal preserved in a foraminifer's test is an indicator of water temperature but also reflects ice volume and salinity.

Dr. Spero has recently concluded a study that demonstrates that the $C0_2$ content of the water can also influence their $\delta^{18}O$ [manuscript in prep.]. He will be calibrating his work, and providing absolute SST and surface water CO_2 content estimates to compare with estimates from assemblages and $U^{k'}_{37}$. Dr Sikes will analyse $U^{k'}_{37}$ which is linearly related to local water temperature (Prahi & Wakeham, 1987; Sikes & Volkman, 1993) and does not appear to be affected by the above processes because it is based on the analysis of completely different materials namely, organic compounds (long chained C_{37} alkenones). Additionally, the isotopes of the individual alkenones will be used to estimate past atmospheric CO_2 content (Jasper & Hayes, 1990), thus the foraminiferal estimates and organic estimates can be compared.

Drs. Wells and Rao will examine the effect of water conditions on the isotopic signal of present day biogenic deep water carbonate preciptation. Palaeo-deep water nutrients will be examined by Drs McCorckle, Sikes and Wells using stable isotopes (as in McCorckle, Veeh & Heggie, in press) and Dr. Wells will examine assemblages of benthic forams. Paleoproductivity will be a joint focus of these efforts. Several lines of evidence suggest that paleo-nutrient tracers in the Southern Ocean may operate differently than elsewhere in the world ocean and that paleoproductivity may play an important role in the deep as well as surface record (eg. Altenbach et al., in press).

Dr Wells and Ms Findlay will be examining modern and Holocene nannoplankton assemblages. Nannofossils are preserved in the sediments of the Southern Ocean but there has been very little published on the link between living nannoplankton and those preserved on the modern sea floor. Once such information is obtained, the trends can be applied to selected core sequences, to establish the Late Quaternary record of changes in the water column structure and ocean circulation, using these organisms. Trends in nannoplankton distribution are being studied from filtered water samples obtained from south of 48°S by the Antarctic CRC on the *R.S.V. Aurora Australis* and in cores collected by *Eltanin* and *R.V. Sonne.* To extend these studies northwards, water samples from at least 6 stations are needed. These would be collected from depths of 10, 25, 50, 100, 150 and 200 meters using Niskin bottles.

The East Tasman Rise and the South Tasman Rise are ideal locations oceanographically to investigate these interrelated topics. The STC overlies the South Tasman Rise today and the Polar Front is only a few degrees to the south. Both topographic features have bathymetric depths as shallow as 1000 m so that most of deep ocean water masses impinge on its flanks. An investigation of SST and surface water parameter changes across both the STC and the PFZ will be able to determine not only if there were changes in SST and the position of the PFZ and the STC over the last glacial cycle, but if there were significant and long term changes in upper water column properties during a major climatic change. This study will compliment work Dr Sikes has begun looking at changes in the STC on the Chatham Rise, and work that Dave Heggie and Dan McCorkle have begun on cores from the Perth Basin.

Field strategy

The location of cores relative to the present STC and PFZ is important to this study. Ideally cores should be obtained at 5-10 nautical mile intervals in a closely spaced geographic location across the fronts. Additionally, by obtaining cores from varying bathymetric depths, we can reconstruct a three dimensional section of deep water mass organisation and reorganisation of the Pacific Ocean between two different climatic regimes (see Curry & Lohman, 1985, 1990 for a detailed description of this strategy). Ideally, cores should be obtained from ~500 m depth intervals in a closely spaced geographic location. However, deep currents on the flanks of the Ridge may have caused considerable erosion and this may not be strictly possible. It is essential to obtain cores with sufficient and unbroken sedimentation for the last 100-150 ky (sedimentation rates of greater than 2 cm/ky are desirable). Additionally, benthic water samples need to be obtained from at least 1/2 (ideally, all) of the coring locations to establish the present water-foraminiferal isotope relationship, on which paleo-reconstructions can be based.

Sediment analyses

Sea surface temperatures will be determined by several methods. Organic geochemical analyses will be conducted at the same depth intervals as stable isotope analyses, foraminiferal and coccolith assemblage counts. Several supporting analyses will speed the project and improve final data interpretation. Bulk densities are important for conversion of sedimentary measurements from sedimentation rates to the more meaningful parameter of mass accumulation rates. Total organic carbon analyses will provide estimates of productivity. In order to pick likely cores from a large suite of cores it is important to do quick stratigraphy before proceeding with time consuming and costly analyses. Measuring the percent $CaCO_3$ is a rapid and simple way to determine if a core is appropriate for further analysis.

GEOLOGICAL OVERVIEW OF THE REGION

This overview is drawn from the report on the *Tasmante* swath-mapping and seismic reflection cruise of R.V. *l'Atalante* (Exon et al., 1994).

East Tasman Rise

This is a large equidimensional and possibly continental feature, from the middle of which the Soela Seamount rises (Fig. 1). A *Tasmante* profile crossed its culmination westward and deviated southwestward west of Soela Seamount, a length along the profile of 170 km. The gravity profile mimics the bathymetry for the most part. The magnetic data suggest that oceanic crust lies on both sides of the plateau. There is a very steep and straight eastern scarp, trending north-south and rising abruptly from 4200 m to 2900 m. This scarp is onlapped by the sediments on oceanic crust, and consists of unbedded basement rocks. Basement is downfaulted west of the scarp, and slopes down westward to allow accumulation of 1 second of fairly flat-lying younger sediments. Soela Seamount is an Eocene guyot about 1200 m high and 10 km across, and culminates 650 m below sea level (Fig. 24). There is a maximum of 0.7 seconds of poorly bedded and disturbed sediment beneath the surface of the western East Tasman Rise, probably derived largely as debris flows from the seamount. The southwestern scarp falls from 2800 m to 3200 m.

The gravity and magnetic data suggest that the 250 km wide depression between the East Tasman Rise and the South Tasman Rise may be oceanic. The seismic profile shows basement with oceanic character up to 2 seconds below sea bed. In the centre of the basin oceanic crust lies 7.5 seconds (about 5600 m) below sea level. How far west the oceanic crust extends is unclear from the *Tasmante* data, especially because there are younger volcanic complexes near the South Tasman Rise. On seismic evidence, undoubtedly oceanic crust is at least 120 km wide, half the width of the depression between the two rises.

South Tasman Rise

About 150 000 km² of the South Tasman Rise was mapped during the *Tasmante* cruise (Figs. 2 & 4). The rise sank completely below the ocean only in the last 20 million years, and parts of it are less than 1000 m deep. Spectacular faults and giant fault blocks occur in water depths of 2500-4500 m on its western and eastern sides (Fig. 4). The submarine cliffs dwarf anything on Australia, reaching 2300 m high, and have slopes of up to 60°. The rise consists of about 20% outcropping rock and 80% sediment cover. Ancient schist, gneiss and granite, and Palaeozoic sediments, as well as younger Mesozoic sediments and Tertiary basalts, have been dredged and cored by R.V. *Sonne* (Hinz et al., 1985). The rise is current-swept and Neogene sediment cover is thin or absent.

The geology of the South Tasman Rise surely rivals that of Tasmania in complexity. The basement rocks are separated by deep, narrow sedimentary basins (Figs. 11 & 12), filled with Cretaceous and Cainozoic sedimentary rocks, bounded by strike-slip faults trending 345° and 320°. The existence of these trans-tensional sedimentary basins, and geochemical evidence from surface samples that thermogenic hydrocarbons are being generated (Whiticar et al., 1985), suggest that it has real petroleum potential.

Sorell Basin

An area of about 50 000 km² of the Sorell Basin off west Tasmania was mapped during the *Tasmante* cruise (Figs. 2 & 4). This area is a remarkable contrast to the South Tasman Rise, being very heavily sedimented in Tertiary times, so deep structure is seldom apparent at the surface. On the continental shelf, basement blocks separate four sub-basins containing more than 3000 m of Cretaceous and Tertiary strata, much like those in the Otway Basin, and similar thicknesses are present on the continental slope (Figs. 15, 18 & 19). Some basin-forming faults were imaged on the lower slope, including a 2500 m high fault scarp trending 320°, containing Upper Cretaceous shallow marine sediments. The existence of thick sedimentary deposits, oil and gas shows (Moore et al., 1992), and some structuring, suggests that the basin has considerable petroleum potential.

Recent studies of cores from west of Tasmania, by Vicky Kosslow at the Australian National University, suggest that in the last 100 000 years the upper slope to about 2300 m has been dominated by mud flow deposition, whereas the lower slope has seen the deposition of turbidites and debris flows. This sedimentological pattern is supported by our swath-mapping data that show submarine canyons running from the upper slope to the abyssal plain. Our data suggest that the canyons are eroding the 4-5° upper slope, but allowing deposition below 2300 m, where the slope decreases appreciably.

Australia-Antarctic break-up

The oceanic basalts on the abyssal plain, 4500-5000 m deep west of Tasmania and around the South Tasman Rise, and the magnetic anomalies associated with them (Fig. 6) record much of the history of the separation of Australia and Antarctica, with Antarctica starting to move slowly past Tasmania at 130 Ma, and finally clearing it at about 40 Ma. Thereafter, what had been dry land or a shallow marine embayment west of Tasmania, subsided thousands of metres below the sea, as did the South Tasman Rise.

Early stretching between Antarctica and Australia apparently formed the major strike-slip faults trending 320°, with the movement direction changing later to produce the faults trending 345°. When the direction changed is not certain, but it may have happened as long ago as 95 Ma, perhaps along with seafloor spreading (CPCEMR, 1991), or as late as 43 Ma (Fig. 6), when all parties agree fast spreading began. These two movement directions between them formed the western margins of Tasmania and the South Tasman Rise, and the latter movement formed the southern margin of the South Tasman Rise. Their eastern margins formed differently, when the Lord Howe Rise moved away to the east-northeast from 85 to 55 Ma (Fig. 6). The southern and northern margins of the South Tasman Rise formed by stretching, with both strike-slip faults and normal faults involved. There is a resultant saddle at least 3000 m deep between Tasmania and the rise, where the crust has moved along faults trending 345°. Associated volcanoes are commonly up to 600 m high, with a field of 70 volcanic cones about 100 km south of Tasmania.

At the time of clearance (40 Ma) the easterly flowing Circum-Antarctic Current, which had flowed north of Australia, broke through in the south, leading to major oceanographic changes. East and south of the rise there is a pile of sediment more than 1000 m thick, which has probably been swept from the rise by currents. The oceanic abyssal plain west of the South Tasman Rise is very lightly sedimented, with the swath-mapping showing that the surface topography mimics that of the oceanic basement (Fig. 4), and slow-growing manganese crusts are widespread on the sediment surface.

CRUISE OBJECTIVES

We plan to use R.V. *Rig Seismic* for this major sampling cruise in order to upgrade our understanding of the evolution of the Australian southern margin and the Southern Ocean, particularly the way in which it may have affected the age and formation of petroleum source rocks and the development of migration paths, to map sedimentary structures and patterns, and to work toward an understanding of Neogene sedimentary processes and their variations with time, On the basis of all existing data including the recent swath-mapping data from R.V. *L'Atalante* (Exon et al., 1994), *Rig Seismic* will carry out targeted sampling of the area off southeastern Australia (38-50°S 138-152°E) as follows:

- ❑ Sample older sequences in the west Tasmanian continental slope for geological information, to be assessed together with seismic information, in order to help establish stratigraphy and assess petroleum potential.
- ❑ Sample older sequences on the South Tasman Rise to establish its stratigraphy and help establish its petroleum potential.
- ❑ Sample East Tasman Rise to establish whether it is all volcanic, or whether the Soela Seamount forming its crest is a volcano built on continental crust. If it is continental, to help establish its stratigraphy and petroleum potential.
- ❑ Sample tectonically controlled features (defined by swath-mapping) to provide a better tectonic history.
- ❑ Sample outer shelf and upper slope sediments off southeast Tasmania for palaeoclimatic purposes.
- ❑ Sample typical sedimentary features (defined by swath-mapping) on the continental margin to help establish its Cainozoic history.
- ❑ Take cores in undisturbed sediments, for studies of Southern Ocean palaeoclimate, on the South Tasman Rise and East Tasman Rise.

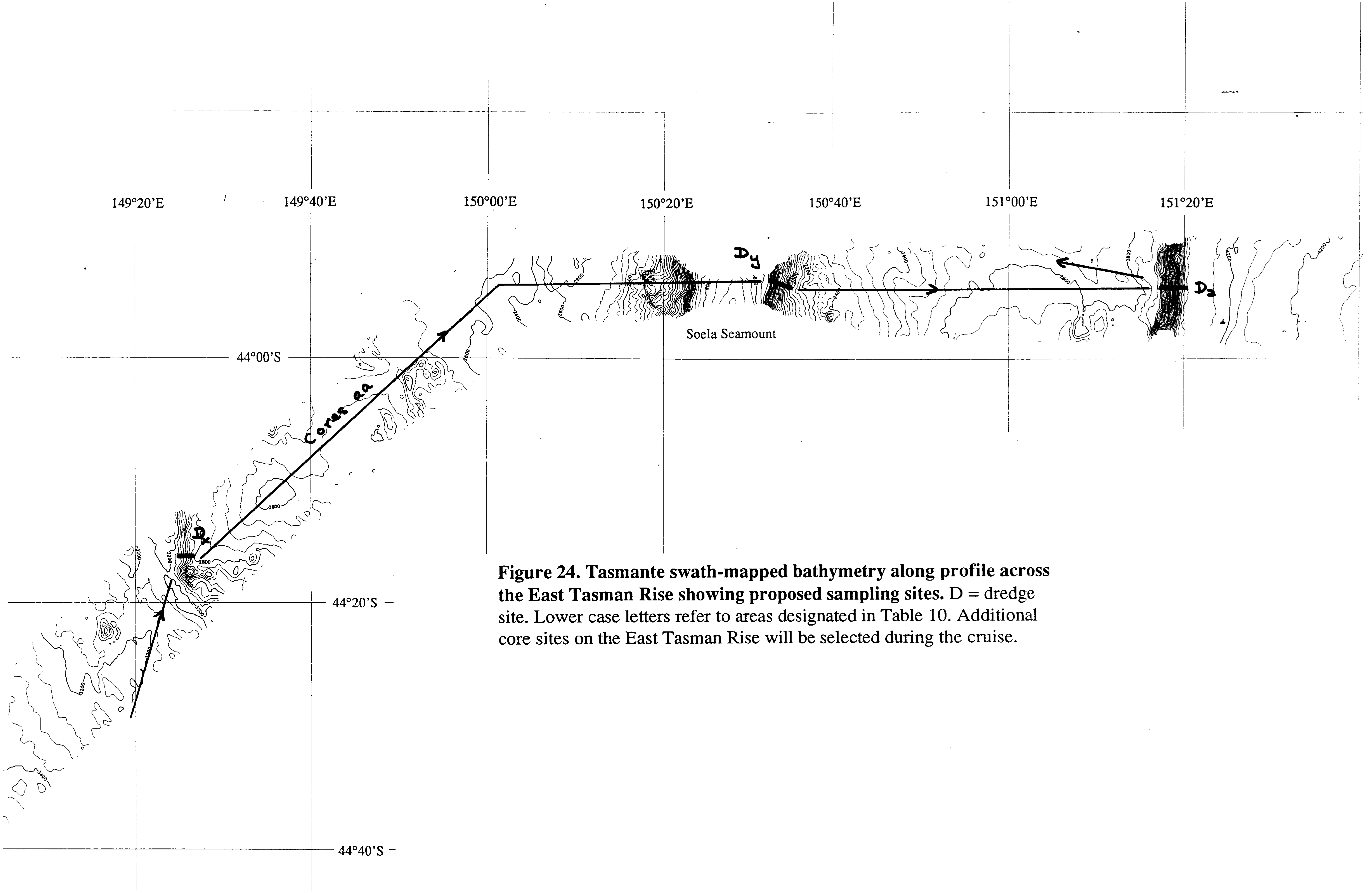


Figure 24. Tasmante swath-mapped bathymetry along profile across the East Tasman Rise showing proposed sampling sites. D = dredge site. Lower case letters refer to areas designated in Table 10. Additional core sites on the East Tasman Rise will be selected during the cruise.

- ❑ Use free-fall grabs to assess manganese resources in the known manganese nodule fields on the abyssal plains around Tasmania.
- ❑ Sample and photograph volcanic cones on slope south of Tasmania for geological and fisheries information.
- ❑ Sample surface and bottom waters for chemical analysis and plankton composition

CRUISE PLAN

The cruise is scheduled to depart from Melbourne on 27 January 1995, and berth in Hobart on 27 February, a total time at sea of 31 days. The broad plan is to sample southward down the western side of Tasmania and the South Tasman Rise, northeastward across the South Tasman Rise, cross eastward to the East Tasman Rise, and then sample south and southeast of Tasmania. The estimate for long transits, on which we will deploy echosounder, magnetometer and gravity meter (if available), is 5 days. The components to be fitted together logistically include:

1. Twenty-one stratigraphic dredges of older sequences on the plateau margins and of major scarps within the plateau (10 days).

2. Up to 5 dredges of igneous features on and near the plateaus (2-3 days).

3. Up to 10 gravity cores and 5 vibrocores for various stratigraphic and sedimentological purposes (5 days).

4. Fifteen gravity and box cores, and associated bottom water sampling, to investigate Quaternary palaeoclimatic changes (5 days).

5. Five stations of freefall grabs (three grabs at each station) to investigate Mn nodule concentrations (2 days).

6. Two camera stations on volcanic cones 100 km south of Tasmania (0.5 day).

7. Five water sample strings in top 200 m on an opportunity basis (0.5 day).

Figures 5 & 24 show preliminary locations for the bulk of the sampling. Note that the 30 core locations are not shown at this stage. Details, particularly of the coring program, will be finalised aboard ship by the interested parties, but the general areas traversed are unlikely to change very much. General information for the stations identified at this stage is set out in Table 10.

TABLE 10: INDICATIVE PLAN FOR CRITICAL SAMPLING (AGSO Cruise 147)

Area	Inferred nature	Water depth (m)	Sampling
A (WT)	isolated ?continental block	4200-5000	1 dredge
B (WT)	oceanic rise	4200-4400	1 dredge
C (WT)	Cainozoic sediment rise	3800-4600	1 dredge (?core top)
D (WT)	west-facing continental scarp	2000-4400	4 dredges
E (WT)	continental rise with Mn nodules	3000	1 FFG station
F (ST)	young volcanic cones	1500-2000	1 dredge, 2 camera runs
G (STR)	large volcano on continental crust	2000-3000	1 dredge

H (STR)	northeast-facing continental scarp	2200-3200	2 dredges
I (STR)	west-facing cuesta	2600-3000	1 dredge
J (STR)	northeast-facing scarp on rotated block	2000-2800	1 dredge
K (STR)	continental north-trending ridge	3600-4800	1 dredge
L (STR)	abyssal plain sediments with Mn nodules	4800	1 FFG station
M (STR)	west-facing continental scarp	2200-4600	4 dredges
N (STR)	sediment plain behind scarp	2600-3400	environmental cores
O (STR)	abyssal plain sediments	4500	1 FFG station
P (STR)	southwest-facing continental scarp	3200-4400	1 dredge
Q (STR)	sediment plain with Mn nodules	4500	1 FFG station
R (STR)	?oceanic ridge	3600-4200	1 dredge
S (STR)	west-facing continental scarp	2800-4000	1 dredge
T (STR)	abyssal plain with Mn nodules	4200	1 FFG station
U (STR)	magnetic volcanic ridge	1000-1200	1 dredge
V (STR)	northeast-facing continental slope	3000-3800	1 dredge
W (STR)	oceanic volcano	3000-4000	1 dredge
X (ETR)	southwest facing ?continental scarp	2800-3100	1 dredge
Y (ETR)	eastern scarp Soela Seamount	1000-2000	1 dredge, ? camera station
Z (ETR)	east facing ? continental scarp	3000-4000	1 dredge
AA (ETR)	top of ?continental rise	2300-2800	environmental cores
BB (ET)	continental shelf/slope	200-2000	environmental cores

Regions: WT = west Tasmania; STR = South Tasman Rise; ETR = East Tasman Rise; ET = east Tasmania

EQUIPMENT REQUIREMENTS

Geological equipment

Large chain bag dredges for rock dredging at 25 stations, with small pipe dredges attached
Coring equipment for 20 gravity cores of 6 m length
Box coring equipment for 8 stations
Vibrocoring equipment for 5 stations
Van Veen grab to be deployed on shelf before vibrocoring
Freefall grab equipment for 15 deployments at 5 stations
Equipment to weigh and photograph Mn nodules (shallow box 22 x 22 cm)
Camera equipment for 2-3 deployments in about 1000 m water depth
Film for deepwater and on-board photography (colour, B&W)
Water bottles for several deep deployments
Water bottles and SDL for about 6 shallow deployments
Pinger for camera and box corer deployments

Geophysical equipment

3.5 and 12 KHz echosounders (capable of synchronising to pinger)

Magnetometer for longer traverses
Gravity meter

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Appendix 1: DSDP Sites

Site	Latitude (S)	Longitude (E)	Water depth (m)	Penetration (m)	Maximum age of sediments	Basement type
280	48° 57.44'	147° 14.08'	4176	524	Early to mid Eocene	Intrusive basalt
281	47° 59.84'	147° 45.85'	1591	169	Late Eocene	Paleozoic schist
282	42° 14.76'	143° 29.18'	4202	310	Late Eocene	Pillow basalt
283	43° 54.60'	154° 16.96'	4729	592	Paleocene	Altered basalt

Reference: Kennett, J.P., Houtz, R.E. et al. (1975A)

Appendix II: Cruise participants

AGSO Representatives

Neville Exon	Client Representative & cruise leader (sedimentology)
John Marshall	Deputy cruise leader (sedimentology)
Steven Dutton	Ship Manager
George Chaproniere	Micropalaeontologist
Mark Alcock.	QC Scientist
Jon Stratton	TO Science
Peter Davis	TO Science
Greg Sparksman	TO Science
Tony Hunter	TO Science
Jim Kossatz	TO Science
Joe Mangion	TO Electronics
Mike Callaway	TO Electronics
Mark James	TO Mechanical
Brian Dickinson	TO Mechanical
Alan Radley	TO Mechanical
Ken Elphick	TO Mechanical
Stan Keyte	TO Mechanical

Visiting scientists and technicians

Dr Dan McCorkle, Woods Hole Oceanographic Institution, USA (isotopes)
Ms Nadege Rollet, Laboratoire de Géodynamique Sous-Marine, Villefranche, France (pre-Mesozoic igneous & metamorphic rocks)
Mr Greg Whitmore, Geology Department, James Cook University (Cainozoic sedimentology & acoustic facies)
Ms Michelle Elms, Geology Department, University of Tasmania (Mesozoic & Cainozoic igneous rocks)
Ms Catherine Samson, Antarctic & Southern Ocean CRC, Hobart (planktic forams)
Ms Claire Findlay, Antarctic & Southern Ocean CRC (surface water nannofossils)
Mr Bob Connell, Antarctic & Southern Ocean CRC (technician)
Ms Lisette Robinson, Antarctic & Southern Ocean CRC (technician)

AMSA crew

Mike Gusterson	Master
John Weeks	1st Mate
Danny Watson	2nd Mate
Peter Pitiglio	Chief Engineer
John Scott	1st Engineer
Ian McCulloch	Electrician
Tony Dale	Chief Integrated Rating

John Fraser	Integrated Rating
Matt Stapleton	Integrated Rating
Merv Hagner	Integrated Rating
Henk Dekker	Chief Cook
Kenny Beu	Cook
Ted Strange	Catering Attendant
Steve Stavely	Catering Attendant

Appendix 3: US Institution cores from the Tasmanian region (38-46°S 137-153°E)

(provided by the US National Geophysical Data Center)

Eltanin 27/17-PC
Florida State University piston core, diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 74 deg. 38.6 min. S Longitude: 175 deg. 21.0 min. W
Water depth: 2286 m (corrected) Date: 1966 Storage: refrigerated

0-48 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material
48-118 cm:	primary lith: (+) clay minerals
118-155 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material
	2nd sub comp.: (C) foraminifera
155-167 cm:	primary lith: (QH) undiff. terrigenous material / muddy sand
	1st sub comp.: (C) foraminifera
167-257 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
	1st sub comp.: (C) foraminifera
257-265 cm:	primary lith: (+) clay minerals
	1st sub comp.: (Q) undiff. terrigenous material
	2nd sub comp.: (C) foraminifera
265-324 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
	1st sub comp.: (C) foraminifera
324-370 cm:	primary lith: (+) clay minerals
	1st sub comp.: (C) foraminifera

Eltanin 27/19-PC
Florida State University piston core, length: 551 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 72 deg. 50.6 min. S Longitude: 179 deg. 00.7 min. E
Water depth: 1794 m (corrected) Date: 1966 Storage: refrigerated

0-10 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
	1st sub comp.: (+) clay minerals
	2nd sub comp.: (C) foraminifera
10-73 cm:	primary lith: (QI) undiff. terrigenous material / sand
	1st sub comp.: (C) foraminifera
73-197 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (+) clay minerals
197-201 cm:	primary lith: (QI) undiff. terrigenous material / sand
201-288 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (+) clay minerals
288-309 cm:	primary lith: (QI) undiff. terrigenous material / sand
	1st sub comp.: (C) foraminifera
309-319 cm:	primary lith: (QI) undiff. terrigenous material / sand
319-344 cm:	primary lith: (QI) undiff. terrigenous material / sand

	1st sub comp.: (C) foraminifera	
344-358 cm:	primary lith: (CF) foraminifera / mud or ooze	
	1st sub comp.: (+) clay minerals	
358-551 cm:	primary lith: (QI) undiff. terrigenous material / sand	
	1st sub comp.: (C) foraminifera	

Eltanin 27/29-PC
Florida State University piston core, length:405 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 47 deg. 00.0 min. S Longitude: 147 deg. 51.8 min. E
Water depth: 925 m (corrected) Date: 1966 Storage: refrigerated

0-405 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 27/30-PC
Florida State University piston core, length: 452 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 45 deg. 04.0 min. S Longitude: 147 deg. 13.7 min. E
Water depth: 3589 m (corrected) Date: 1966 Storage: refrigerated

0-67 cm:	primary lith: (+) clay minerals
	1st sub comp.: (Q) undiff. terrigenous material
67-71 cm:	primary lith: (CF) foraminifera / mud or ooze
71-163 cm:	primary lith: (+) clay minerals
	1st sub comp.: (M) undiff. biosiliceous material
163-175 cm:	primary lith: (QI) undiff. terrigenous material / sand
	1st sub comp.: (C) foraminifera
175-247 cm:	primary lith: (+) clay minerals
	1st sub comp.: (Q) undiff. terrigenous material
247-274 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material
274-417 cm:	primary lith: (+F) clay minerals / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material
417-441 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material
441-452 cm:	primary lith: (+F) clay minerals / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material

Eltanin 34/8-PC
Florida State University piston core, length: 1068 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 41 deg. 44.7 min. S Longitude: 152 deg. 15.0 min. E
Water depth: 4854 m (corrected) Date: 1968 Storage: refrigerated

0-1068 cm:	primary lith: (PF) sponge spicules / mud or ooze

Eltanin 34/9-PC
Florida State University piston core, length: 592 cm diam: 6 cm

Ship: Eltanin / Orcadas
Latitude: 45 deg. 20.2 min. S Longitude: 146 deg. 06.0 min. E
Water depth: 2760 m (corrected) Date: 1968 Storage: refrigerated

0-592 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 34 / 10-PC
Florida State University piston core, length: 1194 cm diam 6 cm
Ship: Eltanin/Orcadas
Latitude: 44 deg. 30.0 min. S Longitude: 149 deg. 57.6 min. E
Water depth: 2873 m (corrected) Date: 1968 Storage: refrigerated

0-1194 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 34 / 11-PC
Florida State University piston core, length: 1478 cm diam 6 cm
Ship: Eltanin/Orcadas
Latitude: 45 deg. 12.9 min. S Longitude: 147 deg. 47.4 min. E
Water depth: 3984 m (corrected) Date: 1968 Storage: refrigerated

0-740 cm:	primary lith: (CF) foraminifera / mud or ooze
740-1000 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (P) sponge spicules
	2nd sub comp.: (Q) undiff. terrigenous material
1000-1100 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (P) sponge spicules
1100-1280 cm:	primary lith: (CG) foraminifera / sandy mud or ooze
1280-1290 cm:	primary lith: (CF) foraminifera / mud or ooze
1290-1478 cm:	primary lith: (CG) foraminifera / sandy mud or ooze

Eltanin 34 / 12-PC
Florida State University piston core, length: 2378 cm diam: 6 cm
Ship: Eltanin/Orcadas
Latitude: 45 deg. 11.2 min. S Longitude: 147 deg. 48.1 min. E
Water depth: 3984 m (corrected) Date: 1968 Storage: refrigerated

0-988 cm:	primary lith: (CF) foraminifera / mud or ooze
988-1050 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (F) shell
1050-1115 cm:	primary lith: (CF) foraminifera / mud or ooze
1115-1730 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (F) shell
1730-2378 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (N) radiolarian

Eltanin 34 / 13-PC
Florida State University piston core
Ship: Eltanin/Orcadas
Latitude: 45 deg. 11.5 min. S Longitude: 145 deg. 04.2 min. E

Water depth: 4022 m (corrected)   Date: 1968   Storage: refrigerated

- cm: primary lith: (SN) manganese / nodules
  Bag sample

Eltanin 34 / 8-TC
Florida State University gravity core, length: 54 cm   diam: 4 cm
Ship: Eltanin/Orcadas
Latitude: 41 deg. 44.7 min. S   Longitude: 152 deg. 15.0 min. E
Water depth: 4854 m (corrected)   Date: 1968   Storage: refrigerated

0-54 cm: primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
1st sub comp.: (C) foraminifera

Eltanin 34/9-TC
Florida State University gravity core, length: 38 cm   diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 45 deg. 20.2 min. S   Longitude: 146 deg. 06.0 min. E
Water depth: 2760 m (corrected)   Date: 1968   Storage: refrigerated

0-38 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (H) calcareous spines

Eltanin 34/10-TC
Florida State University gravity core, length: 20 cm   diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 44 deg. 30.0 min. S   Longitude: 149 deg. 57.6 min. E
Water depth: 2873 m (corrected)   Date: 1968   Storage: refrigerated

0-20 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (N) radiolarian

Eltanin 34/11-TC
Florida State University gravity core, length: 57 cm   diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 45 deg. 12.9 min. S   Longitude: 147 deg. 47.4 min. E
Water depth: 3984 m (corrected)   Date: 1968   Storage: refrigerated

0-57 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (H) calcareous spines

Eltanin 34/12-TC
Florida State University gravity core, length: 55 cm   diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 45 deg. 11.2 min. S   Longitude: 147 deg. 48.1 min. E
Water depth: 3984 m (corrected)   Date: 1968   Storage: refrigerated

0-55 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 36/1-PC
Florida State University piston core, length: 1205 cm   diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 40 deg. 51.6 min. S   Longitude: 140 deg. 00.9 min. E
Water depth: 5133 m (corrected)   Date: 1968   Storage: refrigerated

0-597 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
	secondary lith: (C) foraminifera
	1st sub comp.: (F) shell
	2nd sub comp.: (H) calcareous spines
597-717 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (F) shell
	2nd sub comp.: (Q) undiff. terrigenous material
717-852 cm:	primary lith: (CF) foraminifera /mud or ooze
	1st sub comp.: (N) radiolarian
	2nd sub comp.: (F) shell
852-1205 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (F) shell
	2nd sub comp.: (P) sponge spicules

Eltanin 36/2-PC
Florida State University piston core, length: 100 cm   diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 43 deg. 32.3 min. S   Longitude: 140 deg. 05.0 min. E
Water depth: 4630 m (corrected)   Date: 1968   Storage: refrigerated

0-70 cm:	primary lith: (CF) foraminifera / mud or ooze
70-100 cm:	primary lith: (QA) undiff. terrigenous material / gravel

Eltanin 36/3-PC
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 44 deg. 59.0 min. S   Longitude: 139 deg. 51.5 min. E
Water depth: 4438 m (corrected)   Date: 1968   Storage: refrigerated

- cm:	primary lith: (CG) foraminifera / sandy mud or ooze
	1st sub comp.: (P) sponge spicules
	Bag sample

Eltanin 36/4-PC
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 48 deg. 08.8 min. S   Longitude: 140 deg. 08.0 min. E
Water depth: 4610 m (corrected)   Date: 1968   Storage: refrigerated

- cm:	primary lith: (SN) manganese / nodules
	Bag sample

Eltanin 36/20-PC
Florida State University piston core, length: 537 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 50 deg. 46.5 min. S Longitude: 150 deg. 27.3 min. E
Water depth: 3912 m (corrected) Date: 1968 Storage: refrigerated

0-12 cm:	primary lith: (QC) undiff. terrigenous material / sandy gravel
12-537 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
	1st sub comp.: (O) diatom
	2nd sub comp.: (N) radiolarian

Eltanin 36/21-PC
Florida State University piston core, length: 495 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 28.0 min. S Longitude: 149 deg. 08.6 min. E
Water depth: 3896 m (corrected) Date: 1968 Storage: refrigerated

0-66 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material
66-495 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 36/22-PC
Florida State University piston core, length: 506 cm diam: 6 cm
Ship: (1) Eltanin / Orcadas
Latitude: 47 deg. 34.0 min. S Longitude: 148 deg. 03.0 min. E
Water depth: 1099 m (corrected) Date:1968 Storage: refrigerated

0-506 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 36/23-PC
Florida State University piston core, length: 550 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 47 deg. 53.2 min. S Longitude: 150 deg. 03.2 min. E
Water depth: 2545 m (corrected) Date: 1968 Storage: refrigerated

0-550 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 36/1-TC
Florida State University gravity core, length: 29 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 40 deg. 51.6 min. S Longitude: 140 deg. 00.9 min. E
Water depth: 5133 m (corrected) Date: 1968 Storage: refrigerated

0-9 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
9-29 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 36/2-TC
Florida State University gravity core, length: 48 cm diam: 4 cm

Ship: Eltanin / Orcadas
Latitude: 43 deg. 32.3 min. S Longitude: 140 deg. 05.0 min. E
Water depth: 4630 m (corrected) Date: 1968 Storage: refrigerated

0-48 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (H) calcareous spines

Eltanin 36/21-TC
Florida State University gravity core, length: 59 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 28.0 min. S Longitude: 149 deg. 08.6 min. E
Water depth: 3896 m (corrected) Date: 1968 Storage: refrigerated

0-59 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 36/23-TC
Florida State University gravity core, length: 51 cm diam 4 cm
Ship: (1) Eltanin / Orcadas
Latitude: 43 deg. 53.2 min. S Longitude: 150 deg. 03.2 min. E
Water depth: 2545 m (corrected) Date: 1968 Storage: refrigerated

0-51 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 36/2-PH
Florida State University gravity core, length: 47 cm diam 4 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 29.1 min. S Longitude: 149 deg. 09.9 min. E
Water depth: 3907 m (corrected) Date: 1968 Storage: refrigerated

0-47 cm: primary lith: (CF) foraminifera /mud or ooze

Eltanin 38/11-PC
Florida State University piston core, length: 1187 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 47.3 min. S Longitude: 152 deg. 30.6 min. E
Water depth: 4333 m (corrected) Date: 1969 Storage: refrigerated

0-270 cm: primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
270-405 cm: primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
1st sub comp.: (N) radiolarian
2nd sub comp.: (P) sponge spicules
405-1187 cm: primary lith: (QF) undiff. terrigenous material / mud or ooze

Eltanin 38/12-PC
Florida State University piston core, length: 716 cm diam: 6 cm
Ship: (1) Eltanin / Orcadas
Latitude: 49 deg. 42.0 min. S Longitude: 152 deg. 32.5 min. E
Water depth: 4333 m (corrected) Date: 1969 Storage: refrigerated

0-420 cm: primary lith: (NG) radiolarian / sandy mud or ooze
1st sub comp.: (H) calcareous spines
2nd sub comp.: (P) sponge spicules
420-716 cm: primary lith: (QF) undiff. terrigenous material / mud or ooze

Eltanin 38/13-PC
Florida State University piston core, length: 308 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 44.3 min. S Longitude: 152 deg. 36.8 min. E
Water depth: 4333 m (corrected) Date: 1969 Storage: refrigerated

0-65 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (N) radiolarian
65-100 cm: primary lith: (QF) undiff. terrigenous material / mud or ooze
1st sub comp.: (N) radiolarian
100-308 cm: primary lith: (QF) undiff. terrigenous material / mud or ooze

Eltanin 38/14-PC
Florida State University piston core, length: 453 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 45.0 min. S Longitude: 152 deg. 36.2 min. E
Water depth: 4282 m (corrected) Date: 1969 Storage: refrigerated

0-95 cm: primary lith: (NF) radiolarian / mud or ooze
1st sub comp.: (C) foraminifera
2nd sub comp.: (O) diatom
95-285 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (N) radiolarian
2nd sub comp.: (P) sponge spicules
285-453 cm: primary lith: (NF) radiolarian / mud or ooze

Eltanin 38/15-PC
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 49 deg. 40.1 min. S Longitude: 152 deg. 34.1 min. E
Water depth: 4324 m (corrected) Date: 1969 Storage: refrigerated

- cm: primary lith: (SN) manganese / nodules
Bag sample

Eltanin 38/16-PC
Florida State University piston core, length: 557 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 43.9 min. S Longitude: 152 deg. 38.6 min. E
Water depth: 4301 m (corrected) Date: 1969 Storage: refrigerated

0-95 cm: primary lith: (NF) radiolarian / mud or ooze
secondary lith: (P) sponge spicules

	1st sub comp.: (O) diatom
95-150 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (N) radiolarian
150-557 cm:	primary lith: (NF) radiolarian / mud or ooze

Eltanin 38/17-PC
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 39 deg. 58.7 min. S Longitude: 152 deg. 01.5 min. E
Water depth: 4305 m (corrected) Date: 1969 Storage: refrigerated

- cm:	primary lith: (SN) manganese / nodules
	Bag sample

Eltanin 38/18-PC
Florida State University piston core, length: 597 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 40 deg. 03.0 min. S Longitude: 152 deg. 14.5 min. E
Water depth: 4610 m (corrected) Date:1969 Storage: refrigerated

0-59 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
59-111 cm:	primary lith: (NF) radiolarian / mud or ooze
	1st sub comp.: (C) foraminifera
111-139 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (N) radiolarian
139-188 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
	1st sub comp.: (C) foraminifera
	2nd sub comp.: (H) calcareous spines
188-255 cm:	primary lith: (NF) radiolarian / mud or ooze
	1st sub comp.: (C) foraminifera
	2nd sub comp.: (Q) undiff. terrigenous material
255-597 cm:	primary lith: (NF) radiolarian / mud or ooze
	1st sub comp.: (C) foraminifera

Eltanin 38/11-TC
Florida State University gravity core, length: 16 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 47.3 min. S Longitude: 152 deg. 30.6 min. E
Water depth: 4333 m (corrected) Date: 1969 Storage: refrigerated

0-16 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 38/12-TC
Florida State University gravity core, length: 59 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 42.0 min. S Longitude: 152 deg. 32.5 min. E
Water depth: 4333 m (corrected) Date: 1969 Storage: refrigerated

0-59 cm:	primary lith: (CF) foraminifera / mud or ooze

1st sub comp.: (H) calcareous spines

Eltanin 38/13-TC
Florida State University gravity core, length: 55 cm diam: 4 cm
Ship: (1) Eltanin / Orcadas
Latitude: 49 deg. 44.3 min. S Longitude: 152 deg. 36.8 min. E
Water depth: 4333 m (corrected) Date: 1969 Storage: refrigerated

0-55 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 38/14-TC
Florida State University gravity core, length: 58 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 45.0 min. S Longitude: 152 deg. 36.2 min. E
Water depth: 4282 m (corrected) Date: 1969 Storage: refrigerated

0-58 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 38/15-TC
Florida State University gravity core, length: 45 cm diam: 4 cm
Ship: (1) Eltanin / Orcadas
Latitude: 49 deg. 40.1 min. S Longitude: 152 deg. 34.1 min. E
Water depth: 4324 m (corrected) Date: 1969 Storage: refrigerated

0-45 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (N) radiolarian
2nd sub comp.: (H) calcareous spines

Eltanin 38/16-TC
Florida State University gravity core, length: 61 cm diam: 4 cm
Ship: (1) Eltanin / Orcadas
Latitude: 49 deg. 43.9 min. S Longitude: 152 deg. 38.6 min. E
Water depth: 4301 m (corrected) Date: 1969 Storage: refrigerated

0-16 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (N) radiolarian
2nd sub comp.: (Q) undiff. terrigenous material
16-61 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (N) radiolarian

Eltanin 38/18-TC
Florida State University gravity core, length: 52 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 40 deg. 03.0 min. S Longitude: 152 deg. 14.5 min. E
Water depth: 4610 m (corrected) Date: 1969 Storage: refrigerated

0-36 cm: primary lith: (NF) radiolarian / mud or ooze
1st sub comp.: (H) calcareous spines
2nd sub comp.: (Q) undiff. terrigenous material

36-52 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/49-PC
Florida State University piston core, length: 423 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 47 deg. 06.2 min. S Longitude: 142 deg. 36.3 min. E
Water depth: 4649 m (corrected) Date: 1969 Storage: refrigerated

0-347 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (N) radiolarian
	2nd sub comp.: (P) sponge spicules
347-423 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/52-PC
Florida State University piston core, length: 463 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 47 deg. 34.8 min. S Longitude: 142 deg. 59.7 min. E
Water depth: 4610 m (corrected) Date: 1969 Storage: refrigerated

0-414 cm:	primary lith: (CF) foraminifera / mud or ooze
414-463 cm:	primary lith: (NF) radiolarian / mud or ooze
	1st sub comp.: (P) sponge spicules
	age: (21) Pliocene

Eltanin 39/53-PC
Florida State University piston core, length: 441 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 49.0 min. S Longitude: 144 deg. 32.4 min. E
Water depth: 3965 m (corrected) Date: 1969 Storage: refrigerated

0-120 cm:	primary lith: (CF) foraminifera / mud or ooze
120-133 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (N) radiolarian
133-240 cm:	primary lith: (CF) foraminifera / mud or ooze
240-441 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (N) radiolarian

Eltanin 39/55-PC
Florida State University piston core, length: 911 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 55.9 min. S Longitude: 145 deg. 55.8 min. E
Water depth: 4782 m (corrected) Date: 1969 Storage: refrigerated

0-158 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (N) radiolarian
158-278 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (P) sponge spicules
	2nd sub comp.: (O) diatom

278-347 cm:	primary lith: (NF) radiolarian / mud or ooze 1st sub comp.: (C) foraminifera
347-576 cm:	primary lith: (NF) radiolarian / mud or ooze 1st sub comp.: (O) diatom 2nd sub comp.: (C) foraminifera
576-911 cm:	primary lith: (NF) radiolarian / mud or ooze 1st sub comp.: (Q) undiff. terrigenous material age: (21) Pliocene A=P/MIO?

Eltanin 39/57-PC
Florida State University piston core, length: 507 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 15.0 min. S Longitude: 147 deg. 37.2 min. E
Water depth: 2372 m (corrected) Date: 1969 Storage: refrigerated

0-507 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/62-PC
Florida State University piston core, length: 285 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 46 deg. 56.9 min. S Longitude: 149 deg. 32.6 min. E
Water depth: 3174 m (corrected) Date: 1969 Storage: refrigerated

0-285 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/64-PC
Florida State University piston core, length: 454 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 45 deg. 33.6 min. S Longitude: 150 deg. 21.0 min. E
Water depth: 4616 m (corrected) Date: 1969 Storage: refrigerated

0-68 cm:	primary lith: (CF) foraminifera / mud or ooze 1st sub comp.: (N) radiolarian 2nd sub comp.: (H) calcareous spines
68-150 cm:	primary lith: (CF) foraminifera / mud or ooze 1st sub comp.: (H) calcareous spines 2nd sub comp.: (F) shell
150-286 cm:	primary lith: (CF) foraminifera / mud or ooze 1st sub comp.: (N) radiolarian 2nd sub comp.: (P) sponge spicules
286-390 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze 1st sub comp.: (F) shell 2nd sub comp.: (C) foraminifera
390-428 cm:	primary lith: (CF) foraminifera / mud or ooze 1st sub comp.: (N) radiolarian 2nd sub comp.: (H) calcareous spines
428-442 cm:	primary lith: (CF) foraminifera / mud or ooze secondary lith: (F) shell 1st sub comp.: (Q) undiff. terrigenous material

442-454 cm: (continued)

2nd sub comp.: (H) calcareous spines

442-454 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (N) radiolarian
2nd sub comp.: (Q) undiff. terrigenous material

Eltanin 39/49A-TC
Florida State University gravity core, length: 67 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 47 deg. 06.2 min. S Longitude: 142 deg. 36.3 min. E
Water depth: 4649 m (corrected) Date: 1969 Storage: refrigerated

0-67 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/52A-TC
Florida State University gravity core, length: 63 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 47 deg. 34.8 min. S Longitude: 142 deg. 59.7 min. E
Water depth: 4610 m (corrected) Date: 1969 Storage: refrigerated

0-63 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/53A-TC
Florida State University gravity core, length: 66 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 49.0 min. S Longitude: 144 deg. 32.4 min. E
Water depth: 3965 m (corrected) Date: 1969 Storage: refrigerated

0-66 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/55A-TC
Florida State University gravity core, length: 58 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 56.9 min. S Longitude: 145 deg. 55.8 min. E
Water depth: 4782 m (corrected) Date: 1969 Storage: refrigerated

0-58 cm: primary lith: (NF) radiolarian / mud or ooze
1st sub comp.: (C) foraminifera

Eltanin 39/58A-TC
Florida State University gravity core, length: 13 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 15.9 min. S Longitude: 147 deg. 38.5 min. E
Water depth: 2387 m (corrected) Date: 1969 Storage: refrigerated

0-13 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/62-TC
Florida State University gravity core, length: 6 cm diam: 4 cm
Ship: Eltanin / Orcadas

Latitude: 46 deg. 56.9 min. S   Longitude: 149 deg. 32.6 min. E
Water depth: 3174 m (corrected)   Date: 1969   Storage: refrigerated

0-6 cm:	primary lith: (CF) foraminifera / mud or ooze

Eltanin 39/64A-TC
Florida State University gravity core, length: 55 cm   diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 45 deg. 33.6 min. S   Longitude: 150 deg. 21.0 min. E
Water depth: 4616 m (corrected)   Date: 1969   Storage: refrigerated

0-18 cm:	primary lith: (NF) radiolarian / mud or ooze
	1st sub comp.: (C) foraminifera
	2nd sub comp.: (O) diatom
18-55 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (H) calcareous spines
	2nd sub comp.: (N) radiolarian

Eltanin 53/9-PC
Florida State University piston core, length: 726 cm   diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 46 deg. 26.5 min. S   Longitude: 152 deg. 39.8 min. E
Water depth: 4371 m (corrected)   Date: 1972   Storage: refrigerated

0-15 cm:	primary lith: (EF) calcareous nannofossil / mud or ooze
	1st sub comp.: (C) foraminifera
	2nd sub comp.: (O) diatom
15-142 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (O) diatom
142-726 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 53/10-PC
Florida State University piston core, length: 1175 cm   diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 00.0 min. S   Longitude: 148 deg. 06.7 min. E
Water depth: 4148 m (corrected)   Date: 1972   Storage: refrigerated

0-337 cm:	primary lith: (EF) calcareous nannofossil / mud or ooze
	1st sub comp.: (C) foraminifera
337-380 cm:	primary lith: (NF) radiolarian / mud or ooze
	1st sub comp.: (O) diatom
380-1175 cm:	primary lith: (EF) calcareous nannofossil / mud or ooze
	1st sub comp.: (C) foraminifera

Eltanin 53/11-PC
Florida State University piston core, length: 15 cm   diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 51 deg. 17.9 min. S   Longitude: 148 deg. 00.3 min. E

Water depth: 4054 m (corrected) Date: 1972 Storage: refrigerated

0-15 cm: primary lith: (QF) undiff. terrigenous material / mud or ooze

Eltanin 53/12-PC
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 60 deg. 55.1 min. S Longitude: 144 deg. 44.0 min. E
Water depth: 4229 m (corrected) Date: 1972 Storage: refrigerated

- cm: primary lith: (QA) undiff. terrigenous material / gravel
Bag sample

Eltanin 53/13-PC
Florida State University piston core, length: 485 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 53 deg. 46.8 min. S Longitude: 145 deg. 28.0 min. E
Water depth: 2665 m (corrected) Date: 1972 Storage: refrigerated

0-485 cm: primary lith: (CF) foraminifera / mud or ooze
secondary lith: (O) diatom

Eltanin 53/14-PC
Florida State University piston core, length: 1423 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 54 deg. 11.2 min. S Longitude: 144 deg. 57.2 min. E
Water depth: 2750 m (corrected) Date: 1972 Storage: refrigerated

0-1423 cm: primary lith: (OF) diatom / mud or ooze

Eltanin 53/15-PC
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 51 deg. 24.6 min. S Longitude: 147 deg. 46.1 min. E
Water depth: 3990 m (corrected) Date: 1972 Storage: refrigerated

- cm: primary lith: (QA) undiff. terrigenous material / gravel
BAG SAMPLE

Eltanin 53/16-PC
Florida State University piston core, length: 412 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 53.0 min. S Longitude: 147 deg. 31.0 min. E
Water depth: 4261 m (corrected) Date: 1972 Storage: refrigerated

0-15 cm: primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
15-412 cm: primary lith: (RJ) volcanic / ash
1st sub comp.: (C) foraminifera
2nd sub comp.: (O) diatom

Eltanin 53/17-PC
Florida State University piston core, length: 1534 cm diam : 6 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 59.0 min. S Longitude: 148 deg. 11.2 min. E
Water depth: 4140 m (corrected) Date: 1972 Storage: refrigerated

0-535 cm:	primary lith: (EF) calcareous nannofossil / mud or ooze
	1st sub comp.: (C) foraminifera
	2nd sub comp.: (O) diatom
535-665 cm:	primary lith: (OF) diatom / mud or ooze
	1st sub comp.: (N) radiolarian
	2nd sub comp.: (E) calcareous nannofossil
665-1534 cm:	primary lith: (EF) calcareous nannofossil / mud or ooze
	1st sub comp.: (C) foraminifera
	2nd sub comp.: (O) diatom

Eltanin 53/18-PC
Florida State University piston core, length: 80 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 45 deg. 04.6 min. S Longitude: 144 deg. 28.3 min. E
Water depth: 3690 m (corrected) Date: 1972 Storage: refrigerated

0-80 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
	1st sub comp.: (C) foraminifera

Eltanin 53/19-PC
Florida State University piston core, length: 146 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 42 deg. 32.0 min. S Longitude: 144 deg. 37.5 min. E
Water depth: 1628 m (corrected) Date: 1972 Storage: refrigerated

0-146 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material

Eltanin 53/20-PC
Florida State University piston core, length: 1179 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 41 deg. 26.0 min. S Longitude: 144 deg. 06.1 min. E
Water depth: 1533 m (corrected) Date: 1972 Storage: refrigerated

0-1179 cm:	primary lith: (CF) foraminifera / mud or ooze
	1st sub comp.: (Q) undiff. terrigenous material

Eltanin 53/21-PC
Florida State University piston core, length: 506 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 39 deg. 36.0 min. S Longitude: 140 deg. 04.0 min. E
Water depth: 4948 m (corrected) Date: 1972 Storage: refrigerated

0-79 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
	1st sub comp.: (B) undiff. biocalcareous material
79-196 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
	1st sub comp.: (C) foraminifera
196-208 cm:	primary lith: (QI) undiff. terrigenous material / sand
208-455 cm:	primary lith: (QI) undiff. terrigenous material / sand
	1st sub comp.: (M) undiff. biosiliceous material
455-506 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze
	1st sub comp.: (B) undiff. biocalcareous material

Eltanin 53/22-PC
Florida State University piston core, length: 25 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 37 deg. 59.1 min. S Longitude: 138 deg. 30.6 min. E
Water depth: 3810 m (corrected) Date: 1972 Storage: refrigerated

0-2 cm:	primary lith: (CF) foraminifera / mud or ooze
2-25 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 53/23-PC
Florida State University piston core, length: 279 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 37 deg. 58.8 min. S Longitude: 138 deg. 32.2 min. E
Water depth: 3614 m (corrected) Date: 1972 Storage: refrigerated

0-2 cm:	primary lith: (CF) foraminifera / mud or ooze
2-279 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 53/24-PC
Florida State University piston core, length: 155 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 38 deg. 54.4 min. S Longitude: 138 deg. 31.0 min. E
Water depth: 4656 m (corrected) Date: 1972 Storage: refrigerated

0-155 cm:	primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 53/25-PC
Florida State University piston core, length: 1013 cm diam: 6 cm
Ship: Eltanin / Orcadas
Latitude: 38 deg. 11.5 min. S Longitude: 137 deg. 46.2 min. E
Water depth: 5390 m (corrected) Date: 1972 Storage: refrigerated

0-1013 cm:	primary lith: (QF) undiff. terrigenous material / mud or ooze
	1st sub comp.: (C) foraminifera
	2nd sub comp.: (E) calcareous nannofossil

Eltanin 53/9-TC
Florida State University gravity core, length: 56 cm diam: 4 cm

Ship: Eltanin / Orcadas
Latitude: 46 deg. 26.5 min. S Longitude: 152 deg. 39.8 min. E
Water depth: 4371 m (corrected) Date: 1972 Storage: refrigerated

0-56 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 53/10-TC
Florida State University gravity core, length: 57 cm diam:4 cm
Ship: Eltanin / Orcadas
Latitude: 49 deg. 00.0 min. S Longitude: 148 deg. 06.7 min. E
Water depth: 4148 m (corrected) Date: 1972 Storage: refrigerated

0-57 cm: -primary lith: (CF) foraminifera / mud or ooze

Eltanin 53/11-TC
Florida State University gravity core, length: /diam: 60 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 51 deg. 17.9 min. S Longitude: 148 deg. 00.3 min. E
Water depth: 4054 m (corrected) Date: 1972 Storage: refrigerated

0-60 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (O) diatom

Eltanin 53/13-TC
Florida State University gravity core, length: 13 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 53 deg. 46.8 min. S Longitude: 145 deg. 28.0 min. E
Water depth: 2665 m (corrected) Date: 1972 Storage: refrigerated

0-13 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (O) diatom

Eltanin 53/14-TC
Florida State University gravity core, length: 24 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 54 deg. 11.2 min. S Longitude: 144 deg. 57.2 min. E
Water depth: 2750 m (corrected) Date: 1972 Storage: refrigerated

0-24 cm: primary lith: (OF) diatom / mud or ooze
1st sub comp.: (N) radiolarian
2nd sub comp.: (C) foraminifera

Eltanin 53/16-TC
Florida State University gravity core, length: 60 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 53.0 min. S Longitude: 147 deg. 31.0 min. E
Water depth: 4261 m (corrected) Date: 1972 Storage: refrigerated

0-60 cm: primary lith: (CF) foraminifera / mud or ooze

1st sub comp.: (O) diatom

Eltanin 53/17-TC
Florida State University gravity core, length: 27 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 48 deg. 59.0 min. S Longitude: 148 deg. 11.2 min. E
Water depth: 4140 m (corrected) Date: 1972 Storage: refrigerated

0-27 cm: primary lith: (CF) foraminifera / mud or ooze
1st sub comp.: (O) diatom

Eltanin 53/18-TC
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 45 deg. 04.6 min. S Longitude: 144 deg. 28.3 min. E
Water depth: 3690 m (corrected) Date: 1972 Storage: refrigerated

- cm: primary lith: (CF) foraminifera / mud or ooze
Bag sample

Eltanin 53/19-TC
Florida State University gravity core length: 45 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 42 deg. 32.0 min. S Longitude: 144 deg. 37.5 min. E
Water depth: 1628 m (corrected) Date: 1972 Storage: refrigerated

0-45 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 53/20-TC
Florida State University gravity core, length: 54 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 41 deg. 26.0 min. S Longitude: 144 deg. 06.1 min. E
Water depth: 1533 m (corrected) Date: 1972 Storage: refrigerated

0-54 cm: primary lith: (CF) foraminifera / mud or ooze

Eltanin 53/21-TC
Florida State University gravity core, length: 12 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 39 deg. 36.0 min. S Longitude: 140 deg. 04.0 min. E
Water depth: 4948 m (corrected) Date: 1972 Storage: refrigerated

0-12 cm: primary lith: (QF) undiff. terrigenous material / mud or ooze

Eltanin 53/22-TC
Florida State University gravity core, length: 16 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 37 deg. 59.1 min. S Longitude: 138 deg. 30.6 min. E
Water depth: 3810 m (corrected) Date: 1972 Storage: refrigerated

0-16 cm: primary lith: (EF) calcareous nannofossil / mud or ooze

Eltanin 53/23-TC
Florida State University gravity core, length: 43 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 37 deg. 58.8 min. S Longitude: 138 deg. 32.2 min. E
Water depth: 3614 m (corrected) Date: 1972 Storage: refrigerated

0-39 cm: primary lith: (CF) foraminifera / mud or ooze
39-43 cm: primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 53/24-TC
Florida State University gravity core, length: 26 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 38 deg. 54.4 min. S Longitude: 138 deg. 31.0 min. E
Water depth: 4656 m (corrected) Date: 1972 Storage: refrigerated

0-26 cm: primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 53/25-TC
Florida State University gravity core, length: 24 cm diam: 4 cm
Ship: Eltanin / Orcadas
Latitude: 38 deg. 11.3 min. S Longitude: 137 deg. 46.2 min. E
Water depth: 5390 m (corrected) Date: 1972 Storage: refrigerated

0-24 cm: primary lith: (QG) undiff. terrigenous material / sandy mud or ooze

Eltanin 55/PC-1
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 39 deg. 20.4 min. S Longitude: 142 deg. 30.7 min. E
Water depth: 1702 m (corrected) Date: 19?? Storage: refrigerated

Eltanin 55/PC-2
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 39 deg. 18.6 min. S Longitude: 142 deg. 31.1 min. E
Water depth: 1336 m (corrected) Date: 19?? Storage: refrigerated

Eltanin 55/PC-3
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 38 deg. 52.5 min. S Longitude: 142 deg. 00.8 min. E
Water depth: 686 m (corrected) Date 19?? Storage: refrigerated

Eltanin 55/PC-4
Florida State University piston core

Ship: Eltanin / Orcadas
Latitude: 38 deg. 36.8 min. S   Longitude: 141 deg. 07.1 min. E
Water depth: 732 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/PC-5
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 38 deg. 40.2 min. S   Longitude: 141 deg. 07.0 min. E
Water depth: 1345 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/PC-6
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 38 deg. 51.2 min. S   Longitude: 141 deg. 03.8 min. E
Water depth: 2348 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/PC-7
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 39 deg. 40.8 min. S   Longitude: 140 deg. 59.1 min. E
Water depth: 3984 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/PC-8
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 39 deg. 49.8 min. S   Longitude: 140 deg. 40.6 min. E
Water depth: 4319 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/PC-9
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 40 deg. 03.9 min. S   Longitude: 140 deg. 23.2 min. E
Water depth: 4703 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/PC-10
Florida State University piston core
Ship: Eltanin / Orcadas
Latitude: 40 deg. 06.0 min. S   Longitude: 139 deg. 41.8 min. E
Water depth: 4996 m (corrected)   Date: 19??   Storage: (B) refrigerated

Eltanin 55/TC-1
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 39 deg. 20.4 min. S   Longitude: 142 deg. 30.7 min. E
Water depth: 1702 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-2
Florida State University gravity core
Ship: Eltanin / Orcadas

Latitude: 39 deg. 18.6 min. S   Longitude: 142 deg. 31.1 min. E
Water depth: 1336 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-3
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 38 deg. 52.5 min. S   Longitude: 142 deg. 00.8 min. E
Water depth: 686 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-4
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 38 deg. 36.8 min. S   Longitude: 141 deg. 07.1 min. E
Water depth: 732 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-5
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 38 deg. 40.2 min. S   Longitude: 141 deg. 07.0 min. E
Water depth: 1345 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-6
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 38 deg. 51.2 min. S   Longitude: 141 deg. 03.8 min. E
Water depth: 2348 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-8
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 39 deg. 49.8 min. S   Longitude: 140 deg. 40.6 min. E
Water depth: 4319 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-9
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 40 deg. 03.9 min. S   Longitude: 140 deg. 23.2 min. E
Water depth: 4703 m (corrected)   Date: 19??   Storage: refrigerated

Eltanin 55/TC-10
Florida State University gravity core
Ship: Eltanin / Orcadas
Latitude: 40 deg. 06.0 min. S   Longitude: 139 deg. 41.8 min. E
Water depth: 4996 m (corrected)   Date: 19??   Storage: refrigerated

Robert Conrad 9/132
Lamont-Doherty Geological Observatory piston core, length: 1055 cm
Ship: Robert Conrad

Latitude: 44 deg. 47. min. S Longitude: 152 deg. 48. min. E
Water depth: 4709 m (corrected) Date: 16/04/65 Storage:

0-1055 cm: age: (21) Pliocene

Robert Conrad 9/133
Lamont-Doherty Geological Observatory piston core, length: 1095 cm
Ship: Robert Conrad
Latitude: 45 deg. 45. min. S Longitude: 148 deg. 22. min. E
Water depth: 4082 m (corrected) Date: 24/04/65 Storage:

0-1095 cm: age: (12) Pleistocene

Robert Conrad 9/134
Lamont-Doherty Geological Observatory piston core, length: 828 cm
Ship: Robert Conrad
Latitude: 44 deg. 05. min. S Longitude: 143 deg. 47. min. E
Water depth: 4570 m (corrected) Date: 25/04/65 Storage:

0-828 cm: age: (22) Miocene

Robert Conrad 9/135
Lamont-Doherty Geological Observatory piston core, length: 42 cm
Ship: Robert Conrad
Latitude: 42 deg. 12. min. S Longitude: 140 deg. 46. min. E
Water depth: 5066 m (corrected) Date: 26/04/65 Storage:

0-42 cm: age: (12) Pleistocene

Vema 16/112
Lamont-Doherty Geological Observatory piston core, length: 640 cm
Ship: Vema
Latitude: 43 deg. 05. min. S Longitude: 137 deg. 10. min. E
Water depth: 4700 m (corrected) Date: 19/03/60 Storage:

0-640 cm: age: (21) Pliocene

Vema 16/113
Lamont-Doherty Geological Observatory piston core, length: 530 cm
Ship: Vema
Latitude: 48 deg. 05. min. S Longitude: 137 deg. 39. min. E
Water depth: 3599 m (corrected) Date: 21/03/60 Storage:

0-530 cm: age: (21) Pliocene

Vema 16/114
Lamont-Doherty Geological Observatory piston core, length: 1080 cm
Ship: Vema

Latitude: 49 deg. 36. min. S   Longitude: 138 deg. 13. min. E
Water depth: 3116 m (corrected)   Date: 22/03/60   Storage:

0-1080 cm: age: (21) Pliocene

Vema 18/221
Lamont-Doherty Geological Observatory piston core, length: 376 cm
Ship: Vema
Latitude: 38 deg. 09. min. S   Longitude: 137 deg. 38. min. E
Water depth: 5407 m (corrected)   Date: 22/07/62   Storage:

0-376 cm: age: (12) Pleistocene

Vema 18/222
Lamont-Doherty Geological Observatory piston core, length: 490 cm
Ship: Vema
Latitude: 38 deg. 34. min. S   Longitude: 140 deg. 37. min. E
Water depth: 1904 m (corrected)   Date: 23/07/62   Storage:

0-490 cm: age: (12) Pleistocene

Vema 18/223
Lamont-Doherty Geological Observatory piston core, length: 412 cm
Ship: Vema
Latitude: 39 deg. 47. min. S   Longitude: 141 deg. 39. min. E
Water depth: 3358 m (corrected)   Date: 23/07/62   Storage:

0-412 cm: age: (12) Pleistocene

Vema 18/224
Lamont-Doherty Geological Observatory piston core, length: 220 cm
Ship: Vema
Latitude: 39 deg. 02. min. S   Longitude: 152 deg. 07. min. E
Water depth: 4656 m (corrected)   Date: 26/07/62   Storage:

0-220 cm: age: (12) Pleistocene

Oceanographer 476/124-124
University of Washington dredge
Ship: Oceanographer
Latitude: 38 deg. 15.5 min. S   Longitude: 140 deg. 39.1 min. E
Water depth: 175 m (corrected)   Date: /09/67   Storage: refrigerated

Oceanographer 476/149-149
University of Washington grab
Ship: Oceanographer
Latitude: 43 deg. 01.2 min. S   Longitude: 145 deg. 13.2 min. E

Water depth: 76 m (corrected)   Date: /09/67   Storage: refrigerated

Oceanographer 476/179-179
University of Washington grab
Ship: Oceanographer
Latitude: 40 deg. 48.2 min. S   Longitude: 148 deg. 45.9 min. E
Water depth: 121 m (corrected)   Date: /09/67   Storage:

119 core samples, 2 grab samples, 1 dredge sample