AGSO

TASMANTE SWATH-MAPPING AND REFLECTION SEISMIC CRUISE OFF TASMANIA USING R.V. *L'ATALANTE*

AGSO CRUISE 125 REPORT

BY N.F. EXON, P.J. HILL, J.-Y. ROYER, D. MULLER, G. WHITMORE, D. BELTON, A. DUTKIEWICZ, C. RAMEL, N. ROLLET & A. WELLINGTON

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DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. David Beddall, MP
Secretary: Greg Taylor

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SUMMARY

AGSO Cruise 125 used the French research vessel *l'Atalante* on an exchange basis, because it has a Simrad EM12D swath-mapping system, capable of mapping the sea bed in a swathe up to 22 km wide. Final bathymetric contour maps and images of the sea floor were produced aboard ship. The *Tasmante* cruise (from Tasmania and *L'Atalante*) started in Auckland on 12 February 1994 and finished in Adelaide on 29 March (Fig. 1). 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 (Fig. 2).

The region's geological history bears on the history of the entire southern margin of Australia. This 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.

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 define bathymetry and surface texture with a degree of accuracy and rate of coverage unobtainable in any other way. This mapping helps to clarify the offshore Tasmanian 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. It also provided information on large-scale sedimentary structures and patterns 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.

Much of the continental *South Tasman Rise* is more than 200 nautical miles south of Tasmania. It 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 (Figure 3 & 4). Both fault systems are clearly related to the break-up of Australia and Antarctica, starting 130 million years ago. Swath-mapping coverage from this cruise is 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 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 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.

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, 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

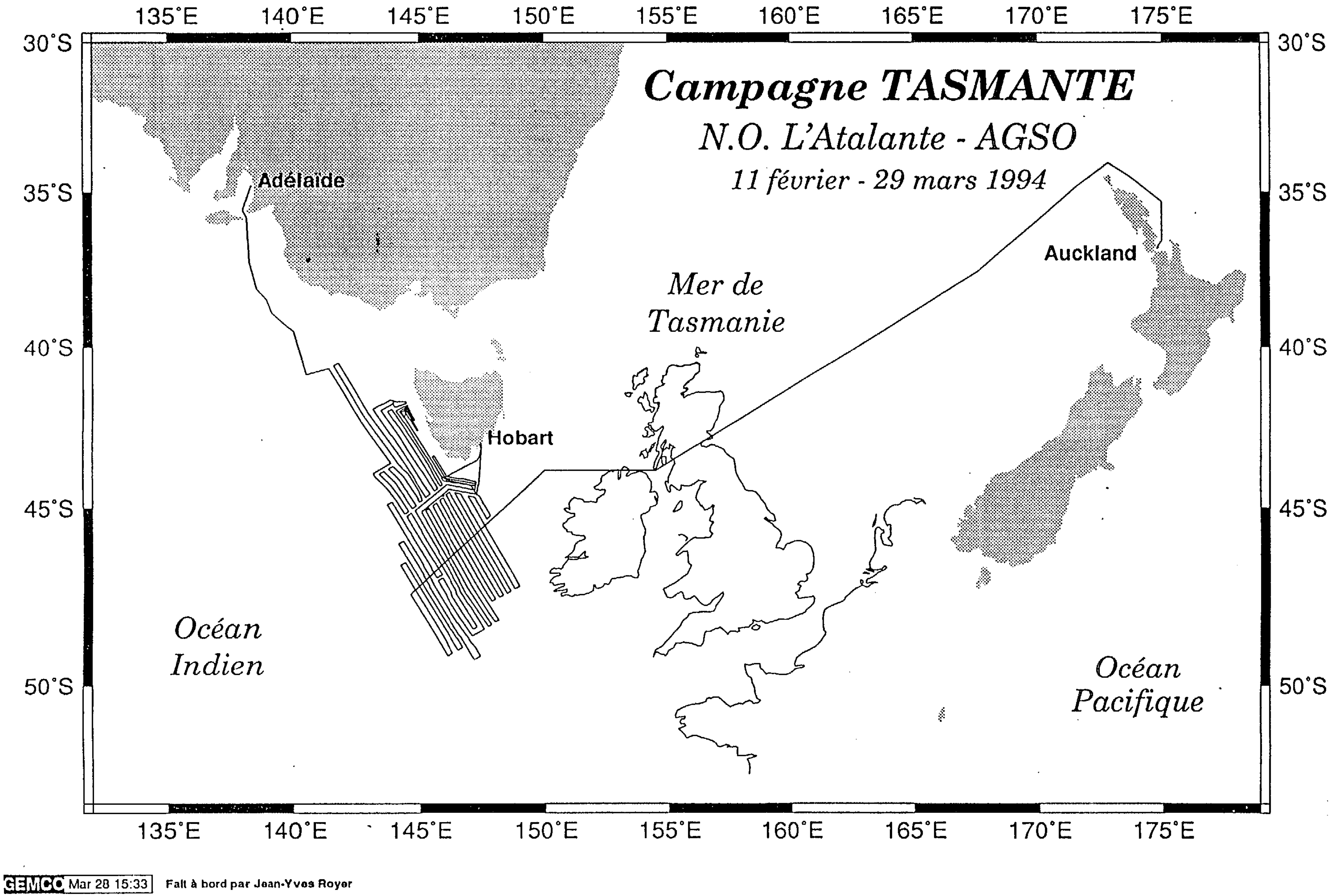


Figure 1. Track map for the entire *Tasmante* cruise from Auckland to Adelaide. Map of northwest Europe at the same scale is provided for contrast.

Figure 2. 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.

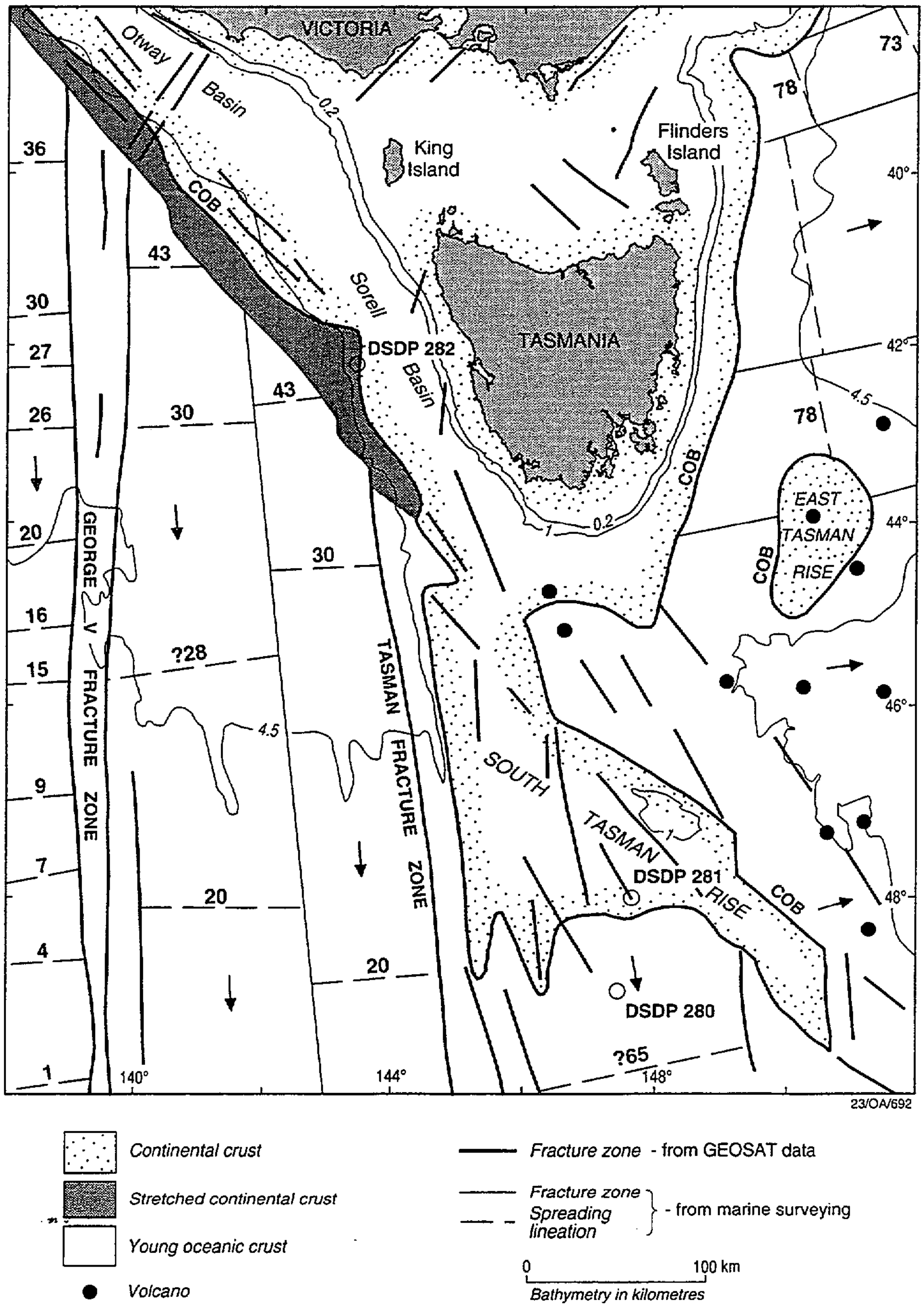


Figure 3. The tectonic elements of the offshore Tasmanian region. The position and ages (in millions of years) are taken from CCPEMR (1991). COB = edge of non-stretched continental crust.

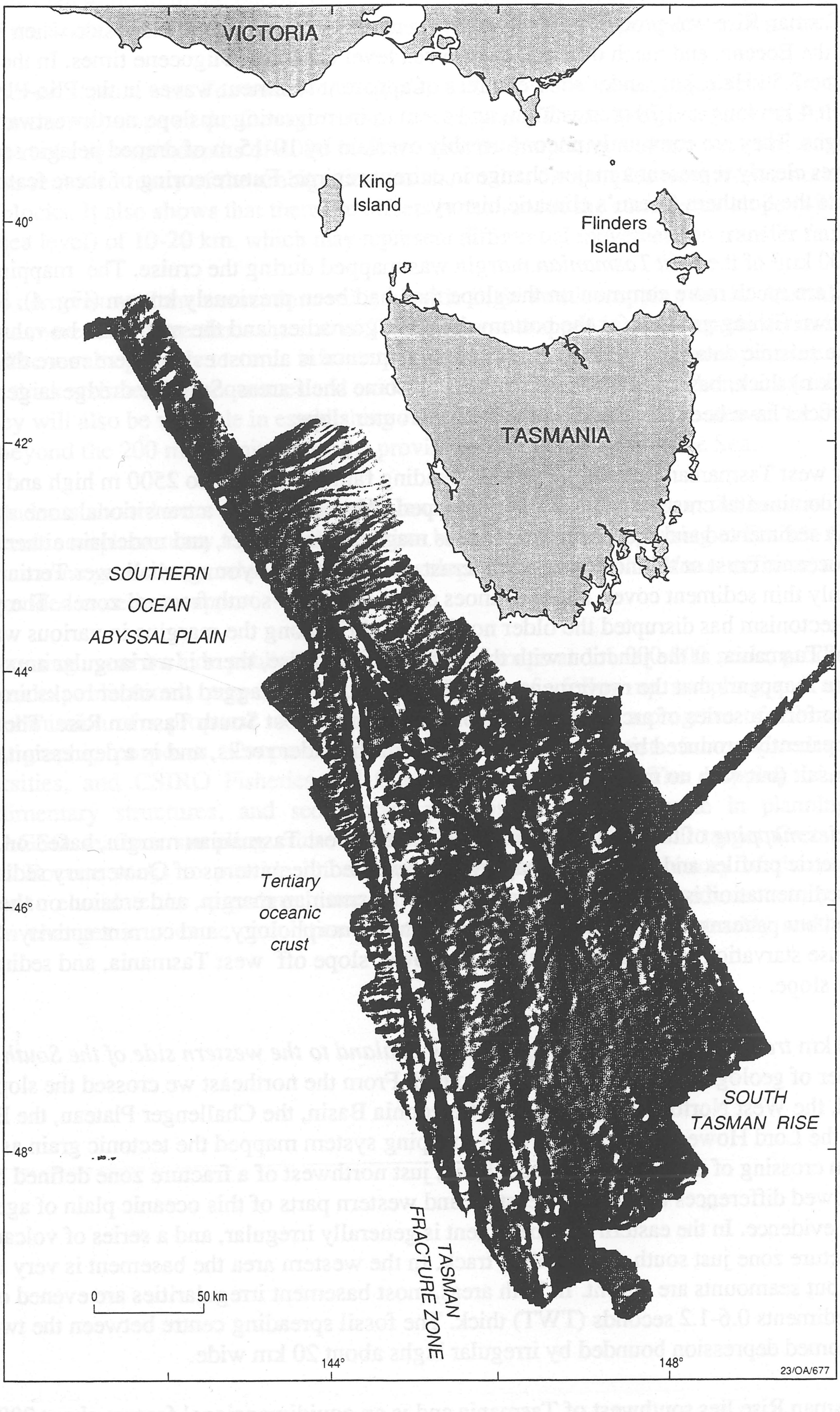


Figure 4. Relief diagram of the region surveyed off Tasmania from *Tasmante* data. Water depths are in the range 1000-4500 m. Note the older 320° and the younger 345° fault directions, the deepwater volcanic cones west of Tasmania, the canyons on the western margin of Tasmania. The sea-floor spreading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

the individual grounds are the tops of about 80 volcanoes, each about 200-400 m high. Maps of that area have been provided to the fishing industry.

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 mapped during the cruise. The mapping showed that canyons are much more common on the slope than had been previously known (Fig. 4). Several of them are known fishing grounds for the bottom-dwelling grenadier, and the maps will be valuable to the industry. 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 identified 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, have been swath mapped. 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 (but with 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 revealed the patterns of Quaternary sedimentation. 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.

On the 3200 km *transit from the North Cape of New Zealand to the western side of the South Tasman Rise* a number of geological provinces were examined. From the northeast we crossed the slope of the North Island, the West Norfolk Ridge, the New Caledonia Basin, the Challenger Plateau, the Bellona Trough and the Lord Howe Rise, and the swath-mapping system mapped the tectonic grain as we went. The 1080 km crossing of the Tasman Abyssal Plain, just northwest of a fracture zone defined by satellite imagery, showed differences between the eastern and western parts of this oceanic plain of age 82-56 Ma on magnetic evidence. In the eastern area basement is generally irregular, and a series of volcanic cones mark the fracture zone just south of the ship's track. In the western area the basement is very irregular and faulted, but seamounts are absent. In both areas, most basement irregularities are evened out by a blanket of sediments 0.6-1.2 seconds (TWT) thick. The fossil spreading centre between the two areas lies in a flat-bottomed depression bounded by irregular highs about 20 km wide.

The East Tasman Rise lies southwest of Tasmania and is an equidimensional feature about 200 km across, from which rises the Eocene volcanic cone of Soela Seamount. The 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).

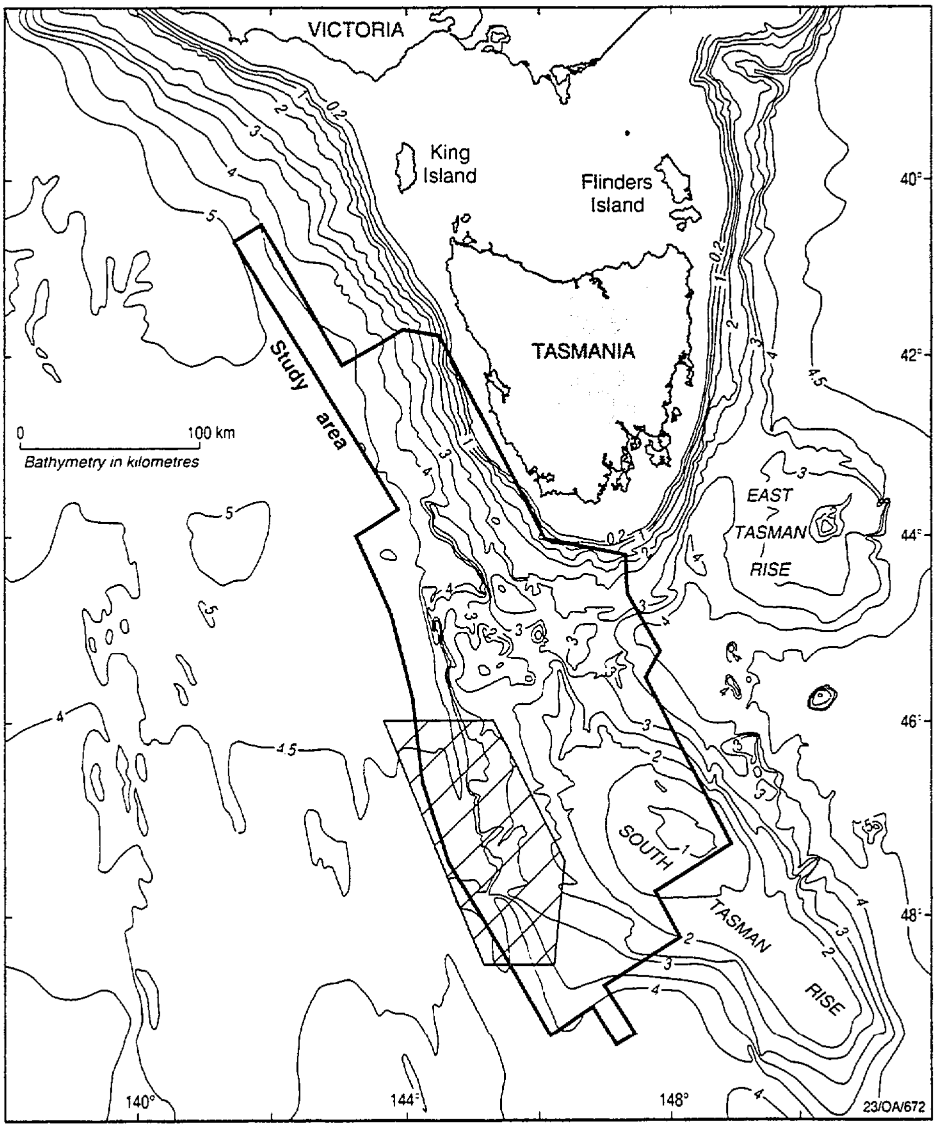
On the 500 km *transit from west Tasmania to Adelaide*, the locations of seven *Rig Seismic* dredge sites on the lower continental slope of the Otway margin were mapped. These dredges recovered Palaeozoic and Cretaceous rocks in water depths of 4000-5000 m, and the morphology of the sites was obscure. The single swath has removed many of the ambiguities and shown that the samples were from a number of NW-trending blocks. It also shows that there are offsets in the foot of the continental slope (4800-5000 metres below sea level) of 10-20 km, which may represent differential movement on transfer faults.

This cruise has demonstrated the tremendous value of wide angle swath-mapping on the Australian margin. An area more than three times the size of Tasmania was mapped in considerable detail in 42 days (Figs. 4 & 5). 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.

Three of the students aboard were to work toward Honours or Masters degrees on the basis of the data, in areas of interest complementary to AGSO's. This has been an excellent beginning to French-Australian cooperation in marine geoscience, which should be developed further. The l'*Atalante* officers, crew, and technicians provided excellent support.

Plans for the coming year include publication of an Atlas of maps at 1:1 000 000 scale, production of several outside publications, preparation and carrying out of follow-up sampling and seismic cruises, and submission of a proposal to the French scientific system for a program of submersible dives for stratigraphic purposes. Cooperation will continue with scientists from Australian and French universities, and CSIRO Fisheries and Oceanography Divisions. The mapping of rocky outcrops, sedimentary structures, and sedimentary patterns will be invaluable in planning the forthcoming AGSO seafloor sampling cruise in early 1995. This sampling will target Cretaceous, Paleocene and Eocene rocks to provide information on the pre-separation history of the margin, oceanic basalts to elucidate the spreading history, and Oligocene and younger sediments to provide information on changes in oceanic circulation and climate as Australia moved steadily north from Antarctica.

Figure 5. Bathymetric map of the Tasmania and South Tasman Rise region. From GEBCO digital file and G. Wissmann (BGR). Contours in 500 m intervals.



INTRODUCTION

The *Tasmante* cruise (AGSO Cruise 125) started in Auckland on 12 February 1994, and ended in Adelaide on 29 March 1994 (Fig. 1). The cruise used the French research vessel *l'Atalante* on an exchange basis. The French vessel was used rather than *Rig Seismic* because of the wide-angle swath-mapping capability of its SIMRAD EM12D system. Data were recorded on transits, as well as off Tasmania, our main area of interest (Figs. 1 & 2). The swath-mapping system functioned well throughout.

The maps produced are mostly at 1:250 000 scale, and cover the transit from New Zealand (T1-T7), the detailed survey off Tasmania (C1-C7), and the transit to Adelaide (T8-T9). The suite of maps generally includes 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 m contours in the west.

Regional plate tectonic setting (J-Y Royer & N. Rollet)

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 architecture of the southern continental margin of Australia is dominated by the Mesozoic 'Southern Rift System' which was associated with the fragmentation of Gondwana. This rift system extends for over 4000 km from Broken Ridge in the west to the South Tasman Rise in the southeast. In most places this system underlies the continental slope, where it has physiographic expression in such margin features as the Eyre, Ceduna and Beachport Terraces, and the South Tasman Rise. However, in some areas, most notably south of the Eyre Terrace and off the Otway and Sorell Basins of west Tasmania, it appears to give rise to an abnormally wide (*ca.* 200 km) lower continental slope/continental rise at nearly abyssal depths (4000-5000 m). The Southern Rift System developed in the latest Jurassic and earliest Cretaceous and was largely formed by strike-slip faulting oriented approximately NW-SE (Willcox & Stagg, 1990). The rift system filled with thick, non-marine Jurassic and Early Cretaceous syn-rift volcanogenic sediments.

Breakup may have propagated eastwards, possibly in discrete stages, and may not have reached the eastern part of the southern margin until the Eocene. The subsidence history tends to support this concept: for example, shallow marine to deltaic middle Eocene rocks have been cored from 3726 m off west Tasmania (Hinz et al., 1985). By the mid Oligocene, when the Australia and Antarctic Plates are believed to have totally separated from each other south of the South Tasman Rise (Willcox et al., 1989), thermal subsidence should have been well advanced. However, the slow passage of the ridge crest along the Tasmania transform margin, and the buttressing effect of the adjacent continents, appear to have further delayed subsidence. Although the prominent and widespread mid Oligocene unconformity, which was probably created by shallow wave-base erosion, is in part the product of a global sealevel fall, it is accentuated by this delayed subsidence of the margin. Accelerated thermal sag, accompanied by the onset of mainly carbonate deposition, occurred only after the mid Oligocene. If this scenario holds, then the west Tasmania basins may contain locally thick, shallow-marine Palaeogene sequences, created by wrench-related block movements.

The region of interest to us extends from 40° to 50°S and 140° to 150°E, west and south of Tasmania, from the outer edge of the continental shelf to the abyssal plain (Figs.1 & 5). The continental shelf around Tasmania is generally less than 50 km wide and is generally non-depositional at the present day (Jones & Holdgate, 1980), but some 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 3-4º. 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. 6). The Deep Sea Drilling Project showed that the rise 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 3-4°. The western slope is not great to 3000 m, but below that there is a very steep scarp trending 350° and dropping away to 4500 m. Sampling of the scarp has returned Upper Cretaceous shallow marine mudstone, siltstone and sandstone.

It has been proposed that the South Tasman Rise was attached to the Antarctic Plate during the period of slow spreading in the Late Cretaceous and Early Tertiary (starting at 96 Ma according to Cande & Mutter, 1982); or that it has moved southeastward from a position adjacent to the Otway Basin; or that it has moved southwestward from a position next to the South Tasman Rise between 118 and 96 Ma (Veevers et al., 1991); or that it has moved southward from Tasmania by Late Cretaceous and Paleocene stretching (Salge, 1989). Satellite altimetry data (GEOSAT) show it to be a complex feature cut by northwesterly and northerly trending faults.

The western scarp of the South Tasman Rise, 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.

Little has been written about the East Tasman Rise (Fig. 6), whose known character was summarised by Willcox (1982). The crest of the rise has an average depth of about 2800 m, but it is topped by a central peak, the Soela Seamount, that rises to less than 1000 m. Its eastern flank falls very steeply from 3000 m to 4000 m. Seismic coverage is poor, but basement appears to be rugged, and the overlying sediments appear to be 500-1500 m thick. The Soela Seamount has been sampled at three locations and yielded mixed rocks containing marine biogenic carbonate and volcanic debris (Quilty & Jenkins, in prep.). The biogenic carbonates include late Eocene shallow water material, deeper water Miocene material, and Quaternary deep water material. I. McDougall has dated a volcanic clast by the K/Ar technique, and it has yielded an age of 31.6 Ma (early Oligocene). The Soela

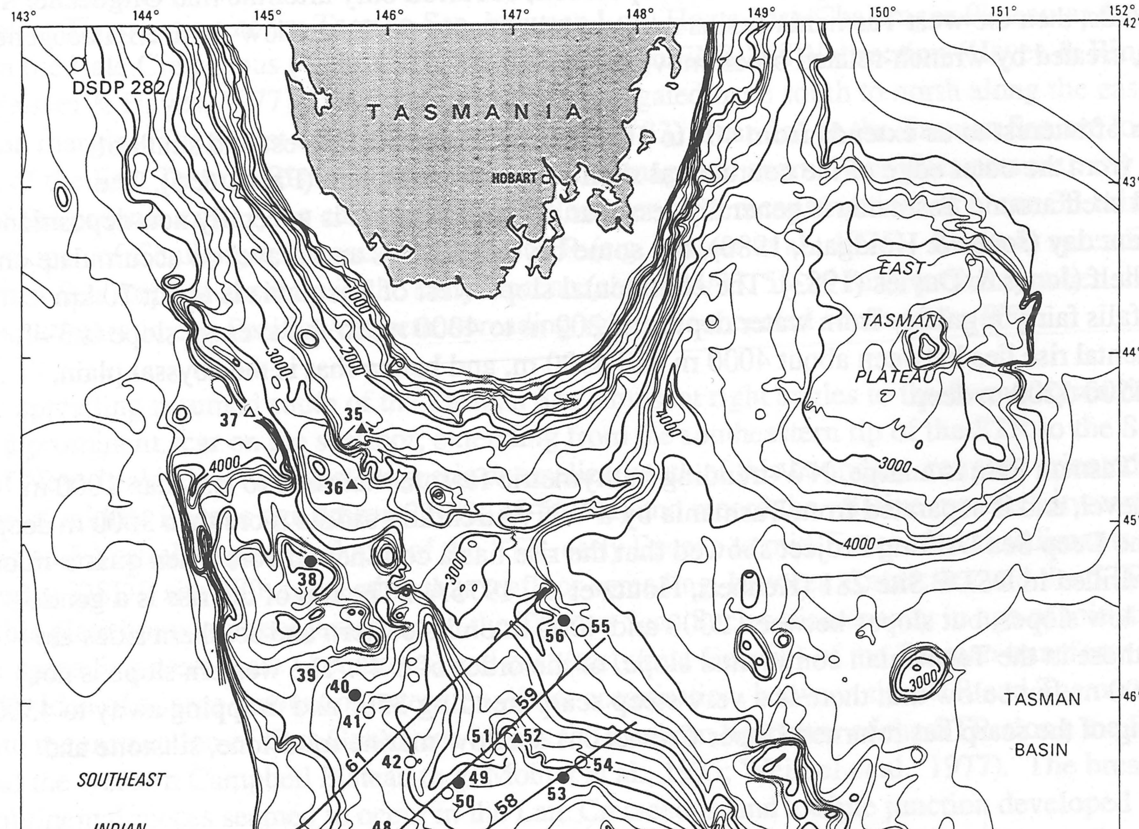


Figure 6. Bathymetric map of the South Tasman Rise. After D. Jongsma and G. Wissmann. Shows *Sonne* sampling locations, and key seismic lines illustrated in Figure 15.

Seamount is clearly a Palaeogene volcanic edifice, but whether the remainder of the rise is of continental or volcanic origin remains to be determined.

The very recent release of more detailed GEOSAT satellite altimetry data has enabled the compilation of a suite of satellite images of our study region, such as the grey tone image shown as Figure 7. These images define basement structure very well and provide excellent information on fracture zones. They confirm the 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 shown in Figure 3. The trends mentioned above are shown, as are more subtle fractures on the abyssal plain that may be related to propagating rifts and perhaps Pacific Ocean mantle pushing westward into the Indian Ocean (as postulated by Tony Crawford of the University of Tasmania, among others). This GEOSAT interpretation, in conjunction with bathymetric and other information, led us to propose that N/O *l'Atalante* be used to swath-map the area outlined in Figures 2 & 5, in order primarily to address tectonic problems.

PREVIOUS STUDIES

(N.F. Exon)

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 (1986) has suggested that breakup started 95 Ma ago.

Early cruises

The first regional seismic survey that included the Tasmanian region was the 1972 BMR Continental Margins Survey. 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 8 represent most of its profiles, and those off west Tasmania are identified in Figure 9.

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 8, and those off west Tasmania are shown in Figure 9. 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: 'The sedimentary wedge which overlies

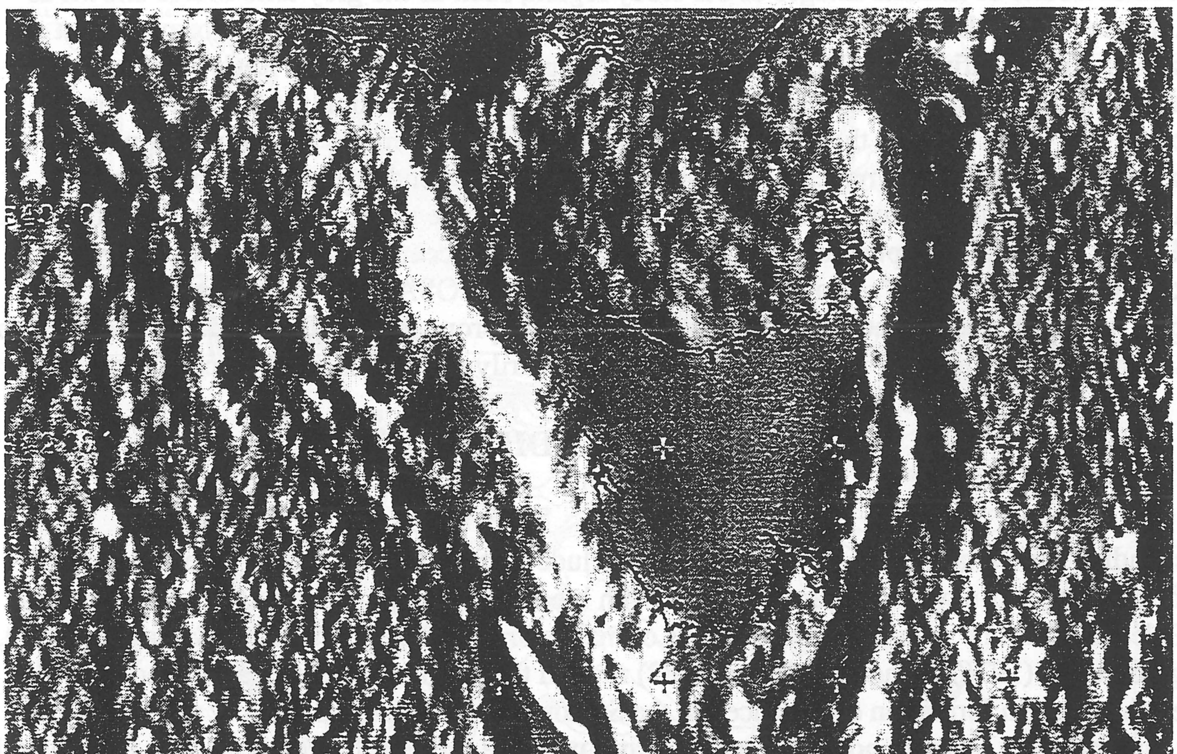


Figure 7. Map of GEOSAT satellite altimeter imagery from the Tasmania and South Tasman Rise region. Grey tone imagery prepared by J. Creasey at AGSO.

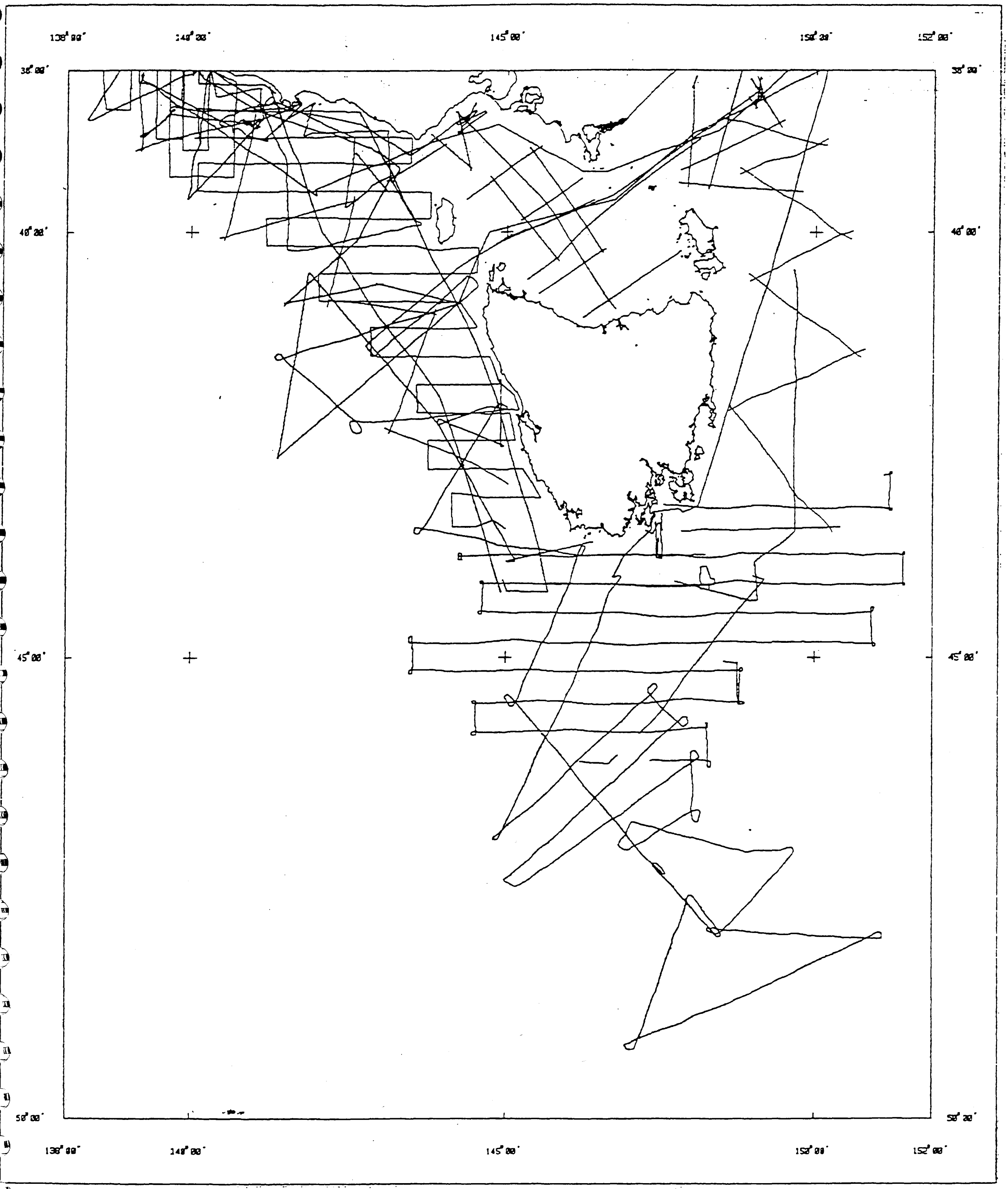
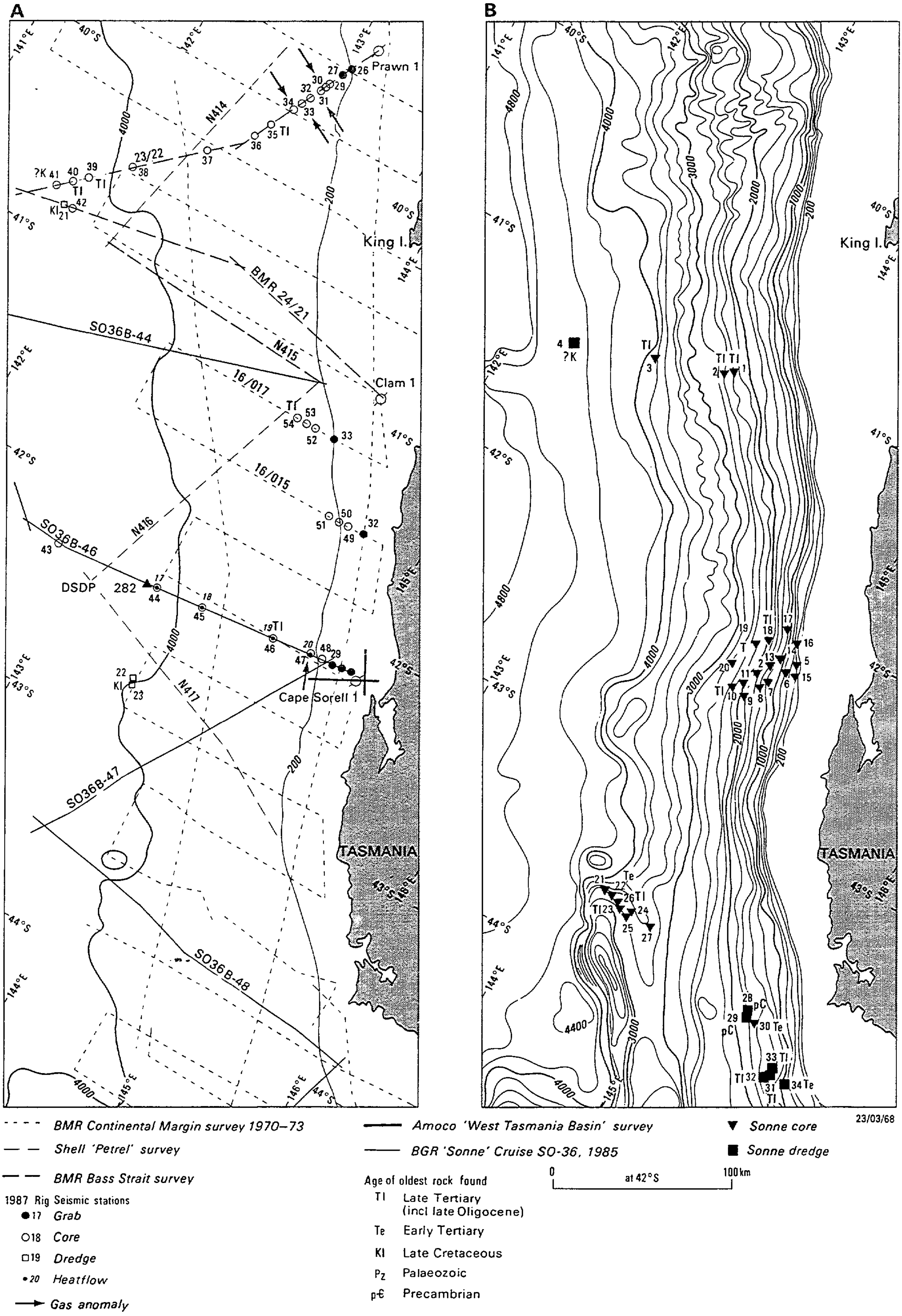


Figure 8. Map of multichannel seismic profiles in the Tasmania and South Tasman Rise region.

Figure 9. 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).



the block-faulted and collapsed continental basement is subdivided by unconformities into: (a) a continental Lower Cretaceous unit and a fluvio-deltaic unit of Upper Cretaceous-Danian age which are taken to represent rift valley stages of deposition controlled by extensional tectonics and (b) a post-breakup sequence of Tertiary units representing regional collapse and out-building of the shelf. The Upper Cretaceous sequence is missing along much of the continental edge where Tertiary sediments appear to rest directly on the Lower Cretaceous unit. Our interpretation suggests that a prolonged period of uplift took place along the axis of the rift valley prior to continental break-up. On the basis of palaeomagnetic data and biostratigraphic analysis the breakup phase started in the Upper Paleocene.'

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

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 8. Seismic profile BMR 40/22-23, from Esso Prawn No. 1 well to the base of the continental slope, is illustrated in Figure 10 and located in Figure 9.

Another relevant cruise, although northwest of our area of interest, was that of HMAS *Cook* in 1989, on the continental slope in the western Otway Basin off Robe (von der Borch & Hughes Clarke, 1993). This combined GLORIA, Seabeam and high-resolution seismic data in a study of the slope immediately seaward of the wide cool-water carbonate shelf, in an area cut by canyons. Mass-wasting proved to be very important, with widespread slump scars and obvious sediment slides. These often are sourced from just below the shelf break, and connect downslope with erosional channels. The channels have what appear to be degraded levee banks, suggesting the overflow of turbidity currents that may have been triggered by sediment slides up the slope. It is probable that a large part of the material transported downslope is bryozoan carbonate from the shelf and upper slope. The age of the sediment movements and their relationship to sea level fluctuations are uncertain. Two east-trending scarps in the mid slope may represent deep Otway Basin faults, and offset the course of one canyon.

Deep Sea Drilling Program (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*, including Site 282 on the west Tasmanian margin (Fig. 3), 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 (Fig. 11). 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

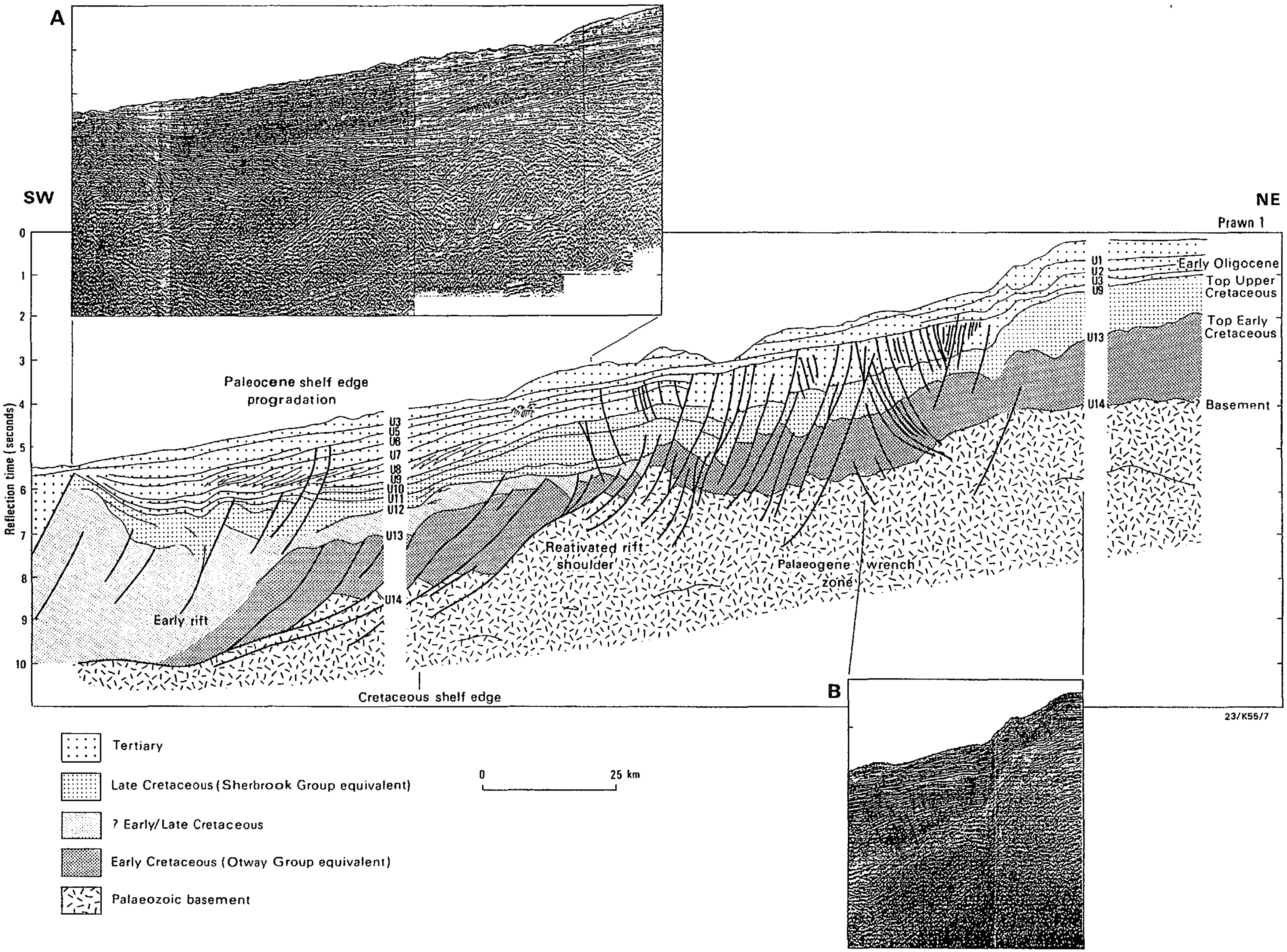


Figure 10. Line drawing of BMR seismic profile 40/22-23 from Prawn No. 1 well to southwest.
After J.B. Willcox in Hinz et al. (1986). Location in Figure 9.

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 (Fig. 3). 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 (but K/Ar age is 306 ± 10 Ma). This is overlain by a six metre thick, late Eocene, basal conglomerate consisting of angular clasts, dominantly of schist, with lesser quartz, quartzite, glauconite, glauconitic sandstone and granite. The remainder of the late Eocene sequence also consists of shallow-marine sediments: 3 m of detrital sand and nanno chalk, and about 28.5 m of grayish-olive sandy silt and silty clay. Above a major unconformity there is 3 m of shallow-water, late Oligocene, glauconite-rich detrital sand. Above another unconformity, the hole contains 79 m of Miocene foram-nanno ooze, and 36 m of Plio-Pleistocene foram-nanno ooze.

One other DSDP Site relevant to the present study is Site 283, drilled on the abyssal plain 70 km 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.

In a general synthesis of sedimentation in the Southeast Indian ocean, arising from DSDP Leg 29, Andrews et al. (1975) noted that a similar sequence of sedimentary facies marked gradual changes in the southern ocean basins newly formed by seafloor spreading, even though they were initiated at different times. At the onset, the basins were relatively small and circulation was restricted, and fine grained sediments were derived from the land, giving rise to a *terrigenous silt and clay facies*. Adundant bioturbation is apparent, showing that reducing conditions did not apply, but few organisms are preserved, probably because deposition was already below the carbonate compensation depth. Colours are dark olive grey to dark brown. Coarse detritus, primary sedimentary structures and turbidites are rare. In nearly all sites siliceous microfossils, mainly diatoms, appear in the uppermost part of the facies and there is associated silicification.

A *siliceous ooze facies* commonly overlies the terrigenous facies. At sites 280, 281 and 283 it contains abundant detrital sediment and is greenish grey to greyish olive in colour. It is a faintly mottled silty diatom ooze laid down in the open ocean and rarely stratified. Radiolaria, sponge spicules, silicoflagellates, foraminiferids and nannofossils occur in various proportions. Nearly all post-Oligocene sediments form a burrow-mottled, open ocean *calcareous facies* with nannofossil ooze predominant. There is generally an unconformity separating them from the underlying facies. At many sites the highly variable colour, the variable amounts of other constituents, and the presence of layering probably result from climatic and sea-level variations.

A palaeo-oceanographic synthesis of DSDP leg 29 results, by Kennett et al. (1975B), outlined the effects of the Antarctic glaciation in the region and the development of the Circum-Antarctic Current, for the first time. They stated "Cenozoic deep-sea sedimentation in the southwest Pacific area was controlled by large changes in the patterns of bottom-water circulation and erosion. The circulation patterns were largely controlled by the development of the Circum-Anatarctic Current south of Australia. Development of the Circum-Antarctic Current did not occur until the middle to late Oligocene [ca. 30 Ma] when final separation occurred south of the South Tasman Rise, although initial sea-floor spreading between Australia and Antarctica commenced in the late early Eocene [ca. 50 Ma]. Before the late Oligocene an erosive western boundary current flowed northwards through the Tasman and Coral Sea areas creating a regional unconformity centered near the the Eocene-Oligocene unconformity (Leg 21). When circum-Antarctic flow was established in the late Oligocene, a regional Neogene unconformity formed south of Australia and New Zealand, and sedimentation recommenced in the northern Tasman-Coral Sea area. This was due to the western boundary flow which earlier passed through the region and was largely diverted to the area east of New Zealand and into the Tonga Trench. A world-wide Oligocene unconformity was created by a major change in bottom-water circulation, in turn caused by increased bottom-water production related to the onset of substantial Antarctic glaciation near the Eocene-Oligocene boundary [ca. 35 Ma]. The separation of Australia from Antarctica led to a fundamental change in the world's oceanic circulation and its climate that marks the onset of the modern climatic regime."

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. 9). During the same cruise, nine regional seismic lines were shot on the South Tasman Rise (Fig. 8), and 19 sampling stations were occupied (Fig. 6). 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). An interpretation of the west Tasmanian seismic lines (Figs. 11 & 12), as well as that of profile BMR 40/22-23 (Fig. 10), showed that up to 5 seconds (two-way time) of section is present, and that up to 14 unconformities could be identified (Hinz et al., 1986). The core results for both west Tasmania and the South Tasman Rise are summarised in Figure 13. Sampling and well data from west Tasmania indicated (Fig. 14) that unconformity U3 represented 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.

Hinz et al. (1985, 1986) briefly described the 37 stations occupied by *Sonne* off west Tasmania (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

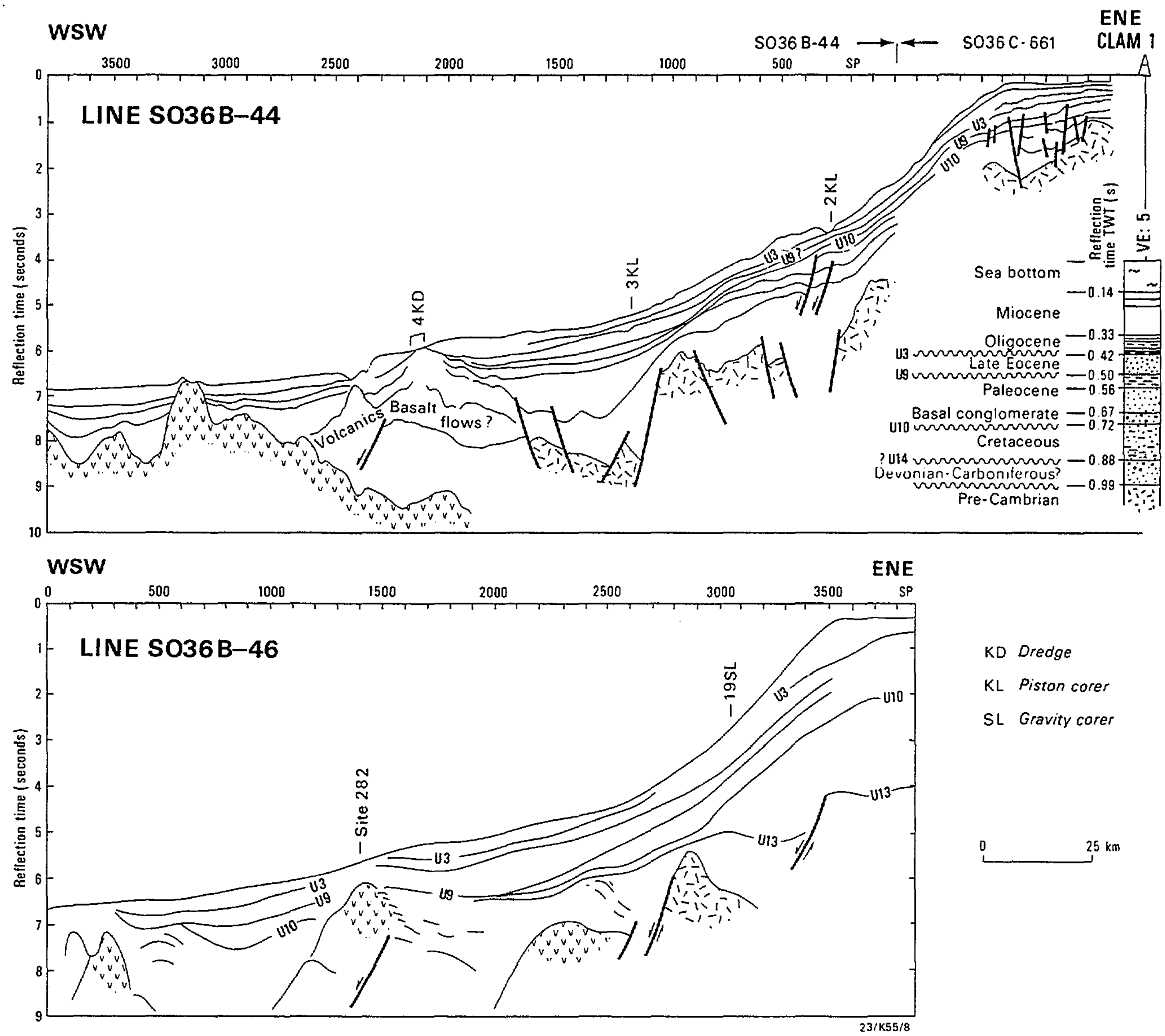


Figure 11. Line drawings of *Sonne* seismic profiles SO-36/44 & 46 from northwest Tasmanian margin. After Hinz et al. (1986). Location in Figure 9.

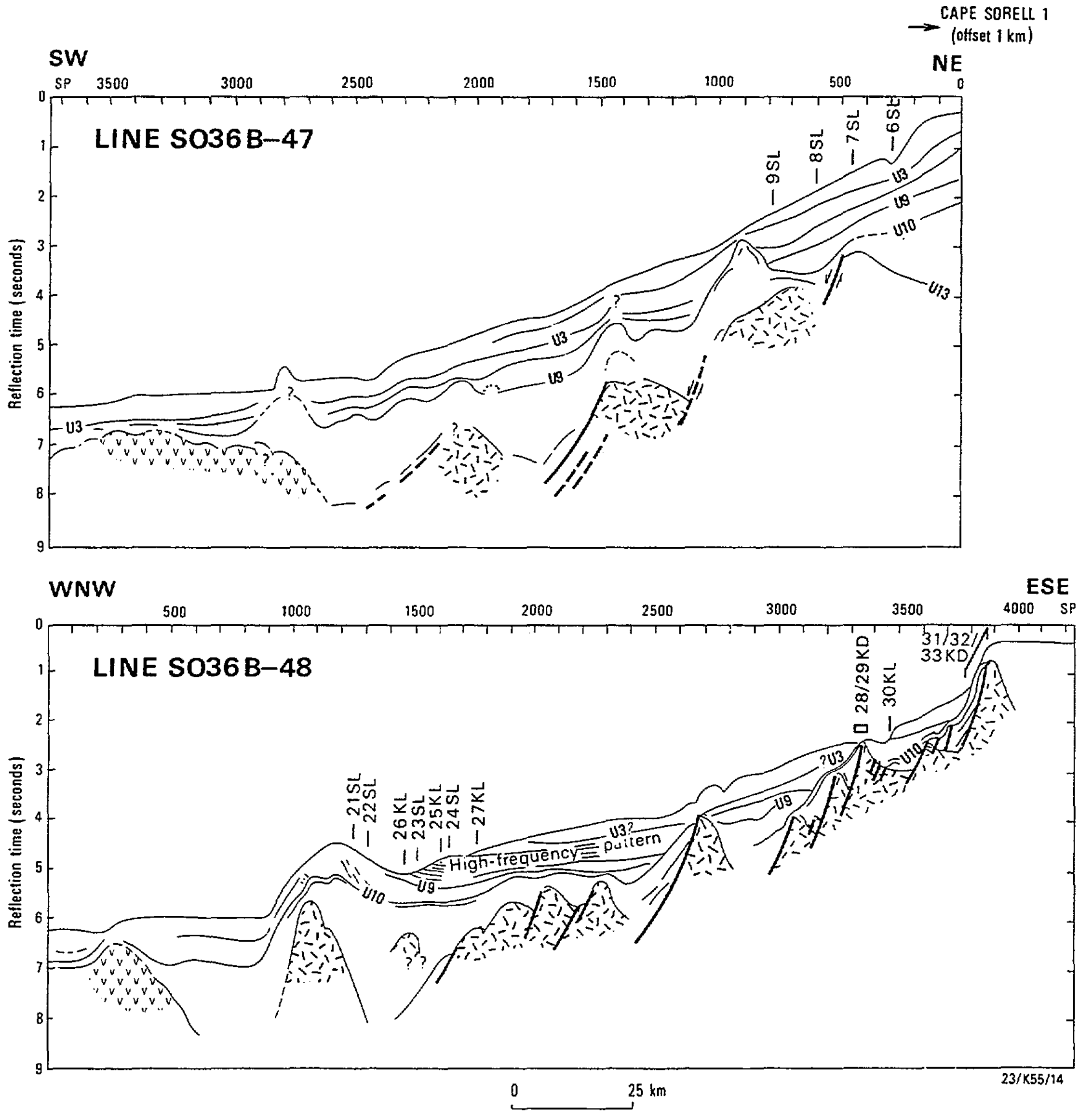


Figure 12. Line drawings of *Sonne* seismic profiles SO-36/47 & 48 from southwest Tasmanian margin. After Hinz et al. (1986). Location in Figure 9.

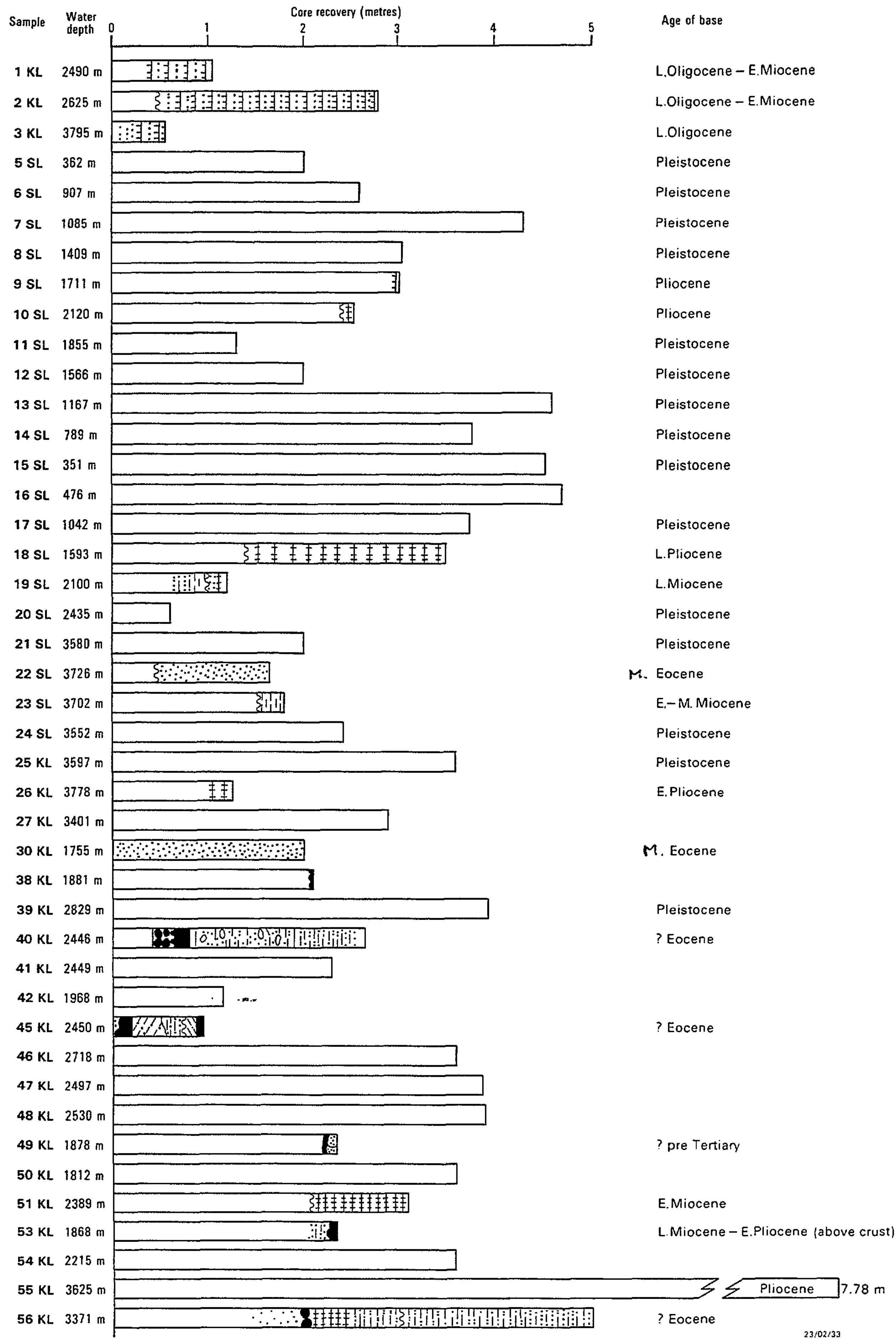


Figure 13. Simplified core logs for *Sonne* Cruise SO-36C. Modified from Hinz et al. (1985).

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		Continental–? fluvial, lacustrine	1000	Jurassic and Early Cretaceous		M Series	Casterton Beds and Otway Group Non-marine clastics and volcanogenic sediments	
	Contorted fill in first stage rift	Lower rift-fill	Alluvial fan and/or volcanics	3000 +					
U13						105			
S(12–13)	Bedded fill in first stage rift Now incorporated into tilted blocks beneath lower continental slope	Upper rift-fill, probably preceding marine transgression ? Development of shelf edge on U12	Fluvial-lacustrine possibly grading to marginal marine	0–?1000	"late" Early Cretaceous (? Albian)			Probably time equivalent to Eumeralla Formation (Otway Gp) Continental environments with volcanism	This sequence appears confined to the first stage rift
U12						95	34		
S(11–12)	Well stratified with onlap onto U12 U12/13 block-faulted beneath continental shelf	U12 (possibly U13) is main rift-onset unconformity in Otway Basin S(11–12) marine transgression	Marginal marine-marine (foram evidence from Ribis and Apthorpe, 1969)	0–?1000	Late Cretaceous (approx Cenomanian)		Slow spreading episode (Cande and Mutter, 1982)	Approximate Waarre Formation (Sherbrook Group) equivalent Shoreline facies	Wrenching and uplift of the tilted blocks beneath lower slope commenced (Willcox and Symonds, in preparation)
U11									
S(10–11)	Stratified sediment wedge with onlap onto U11 Basal channelling land ward of old shelf edge	U11 eustatic lowstand in ? Coniacian (Vail et al., 1977) S(10–11) basin transgr restricted by blocks below lower continental slope	Shallow marine (restricted basin)	0–1000 +	Late Cretaceous			Belfast Mudstone and Flaxman Formation (Sherbrook Group) Marginal marine-marine	1570 m Belfast Mudstone in Voluta 1
U10									
S(9–10)	Stratified sediment wedging out below lower slope Downlap onto U10	U9 and U10 relative falls in sea level U9-slowing or termination of movement of tilted blocks beneath lower slope	Shallow marine (regressive)	0–500 +	Late Cretaceous (approx Maastrichtian)			Curdies/Paaratte Formations (Sherbrook Group) Shoreline-continental	Slow spreading episode in southeast Indian Ocean has less influence on outer Otway Basin
U9						65	29		
S(8–9) 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

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

23/K55/15

Figure 14. 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.

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. 6). 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. 15) profiles. Three of the *Sonne* profiles over the South Tasman Rise are illustrated as line drawings in Figure 15, 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 rise consists of a triangular core of basement, flanked on all sides by sedimentary basins (Figs. 15 & 16). 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). Bolton et al. (1988) discussed manganese crusts and nodules, and their substrates. Basement rocks were recovered from dredge 44KD (locations in Figs. 6 & 15): 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 (Fig. 3). 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 et al. (op. cit.) 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 (Fig. 3) 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 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-

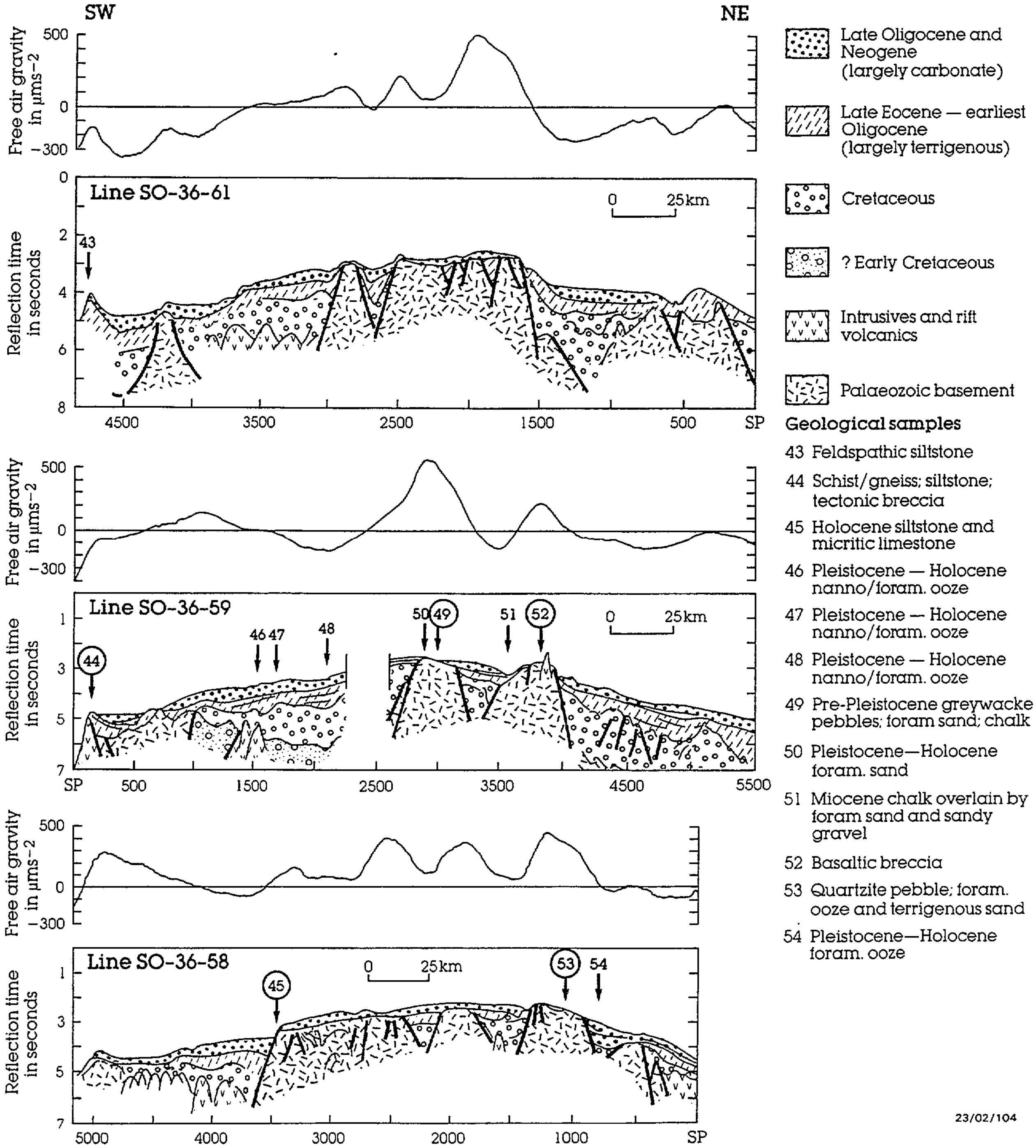


Figure 15. Line drawings of *Sonne* SO-36B seismic profiles from the South Tasman Rise, with free-air gravity anomalies and sampling sites. After Willcox et al. (1989) and Bolton et al. (1988). Locations in Figure 6.

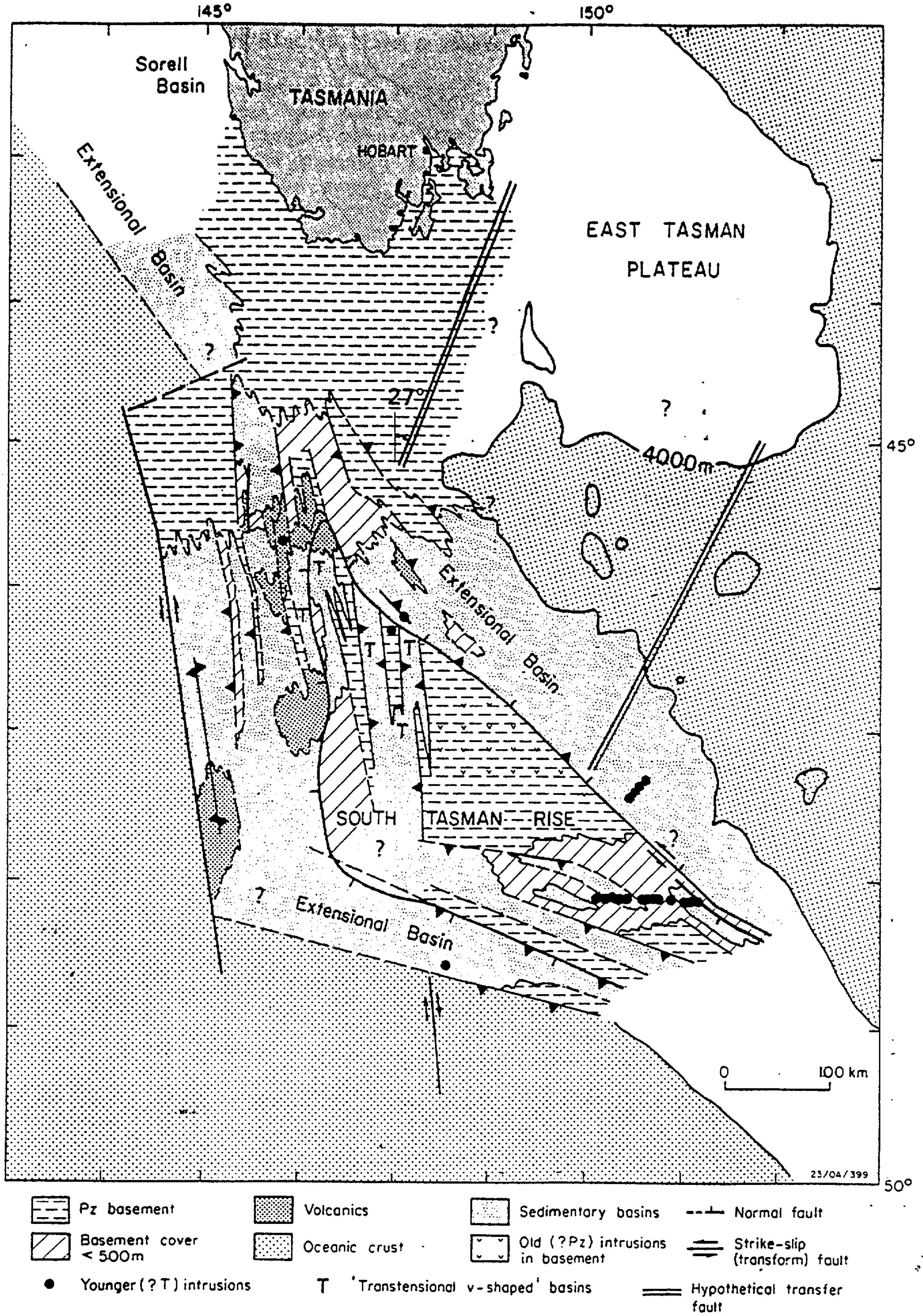


Figure 16. Preliminary structural map of the South Tasman Rise. After Willcox et al. (1989).

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-mapping of the faults bounding the plateau to the west, north and east addresses this question.

R.V. *Rig Seismic* cruises

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. 9) 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 detailed 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 decreases 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).

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.

In early 1988, R.V. *Rig Seismic* carried out BMR research cruise 78 on the Tasmanian margin (Exon, et al., 1989A). Half of this cruise was devoted to multichannel seismic profiling (Fig. 17) and the other half to geological sampling (Fig. 18). 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. 19). 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 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 mudstones. Younger sediments were cored at 37 stations and grabbed at 9 stations, 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. 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. 20).

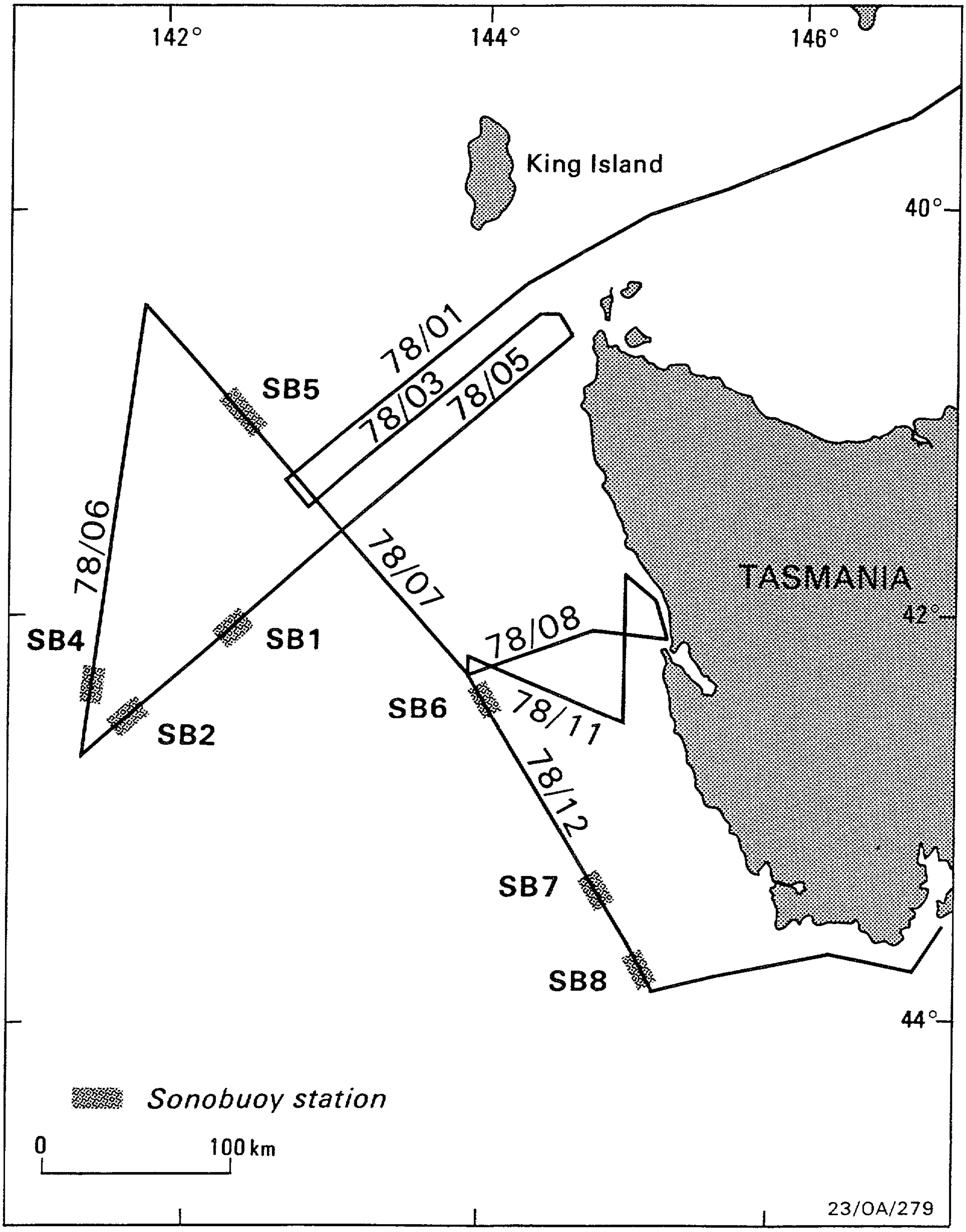


Figure 17. Map of west Tasmanian region showing 1988 BMR multichannel seismic profiles 78/1-12, and sonobuoy locations. After Exon et al. (1989).

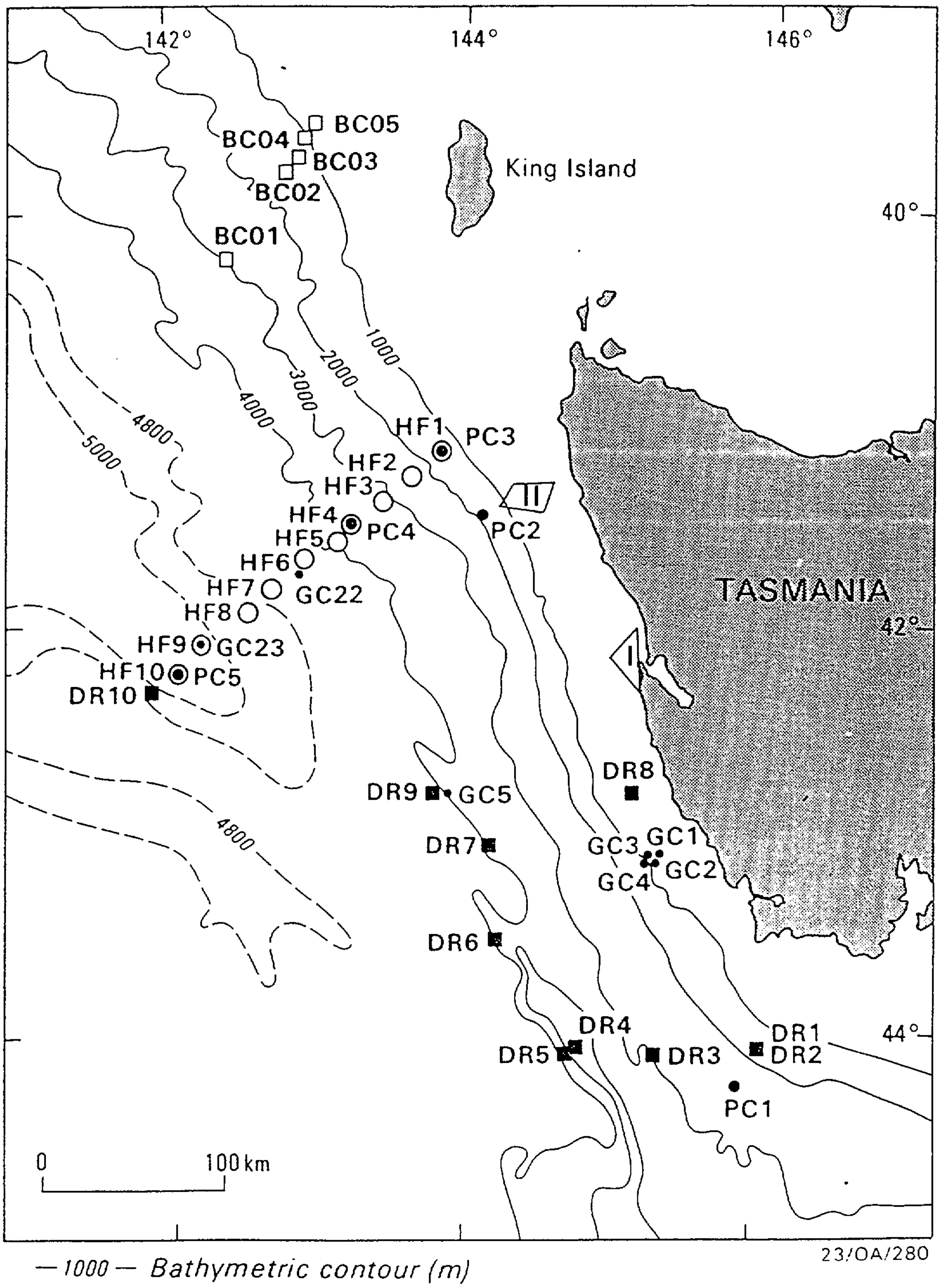


Figure 18. Map showing 1988 BMR Cruise 78 sampling and heatflow stations off west Tasmania. After Exon et al. (1989).

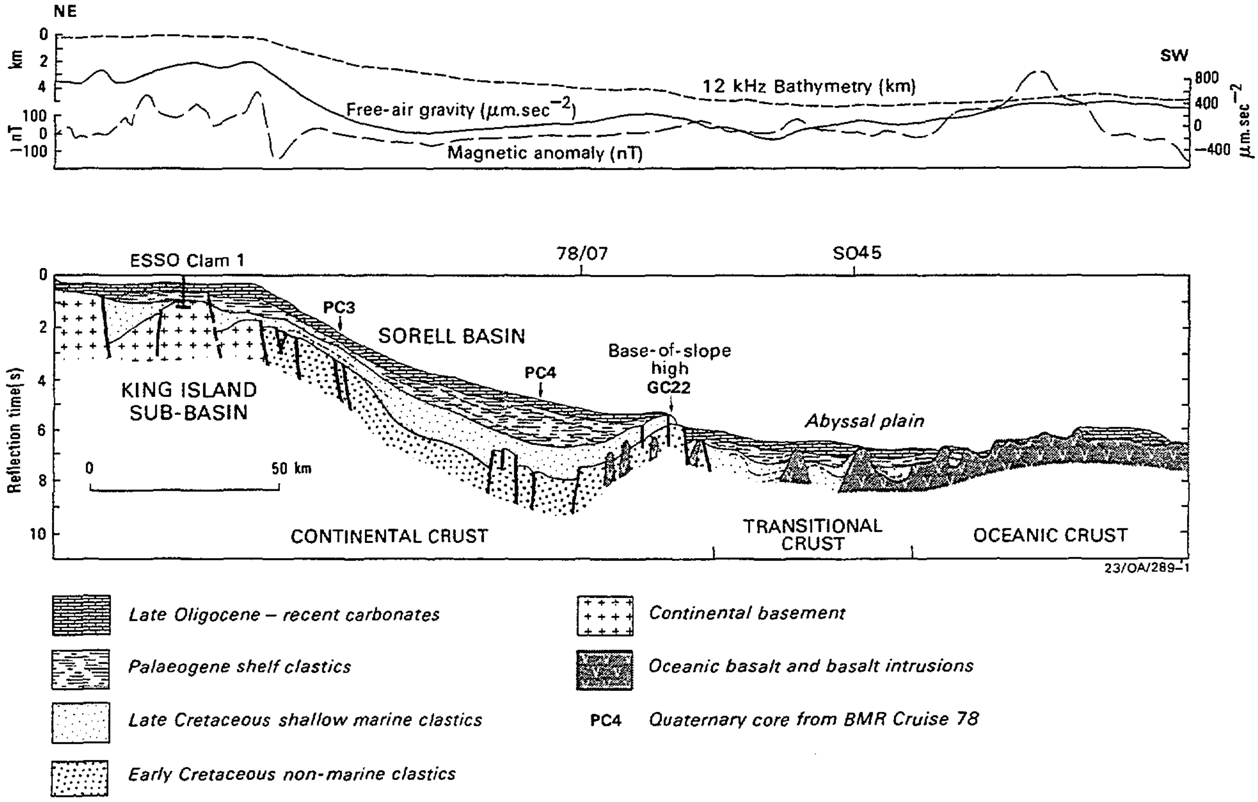


Figure 19. Line drawing of BMR seismic profile 78/05 on the west Tasmanian margin. From *BMR 1989*. Includes magnetic and gravity data southwest from Clam No. 1 well to abyssal plain. Location in Figure 20.

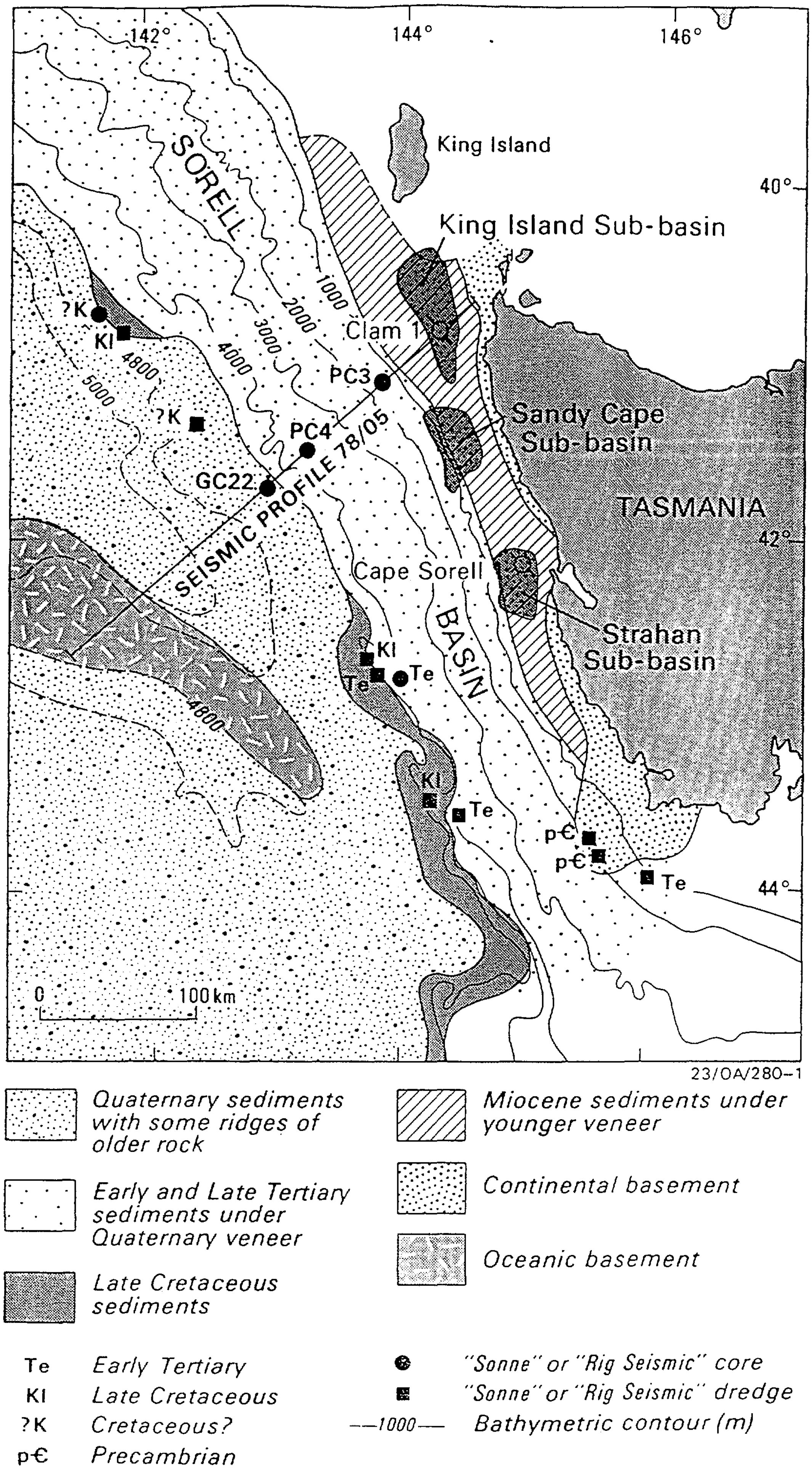


Figure 20. Map of surface sediment distribution off west Tasmania. From *BMR 1989*. Shows all dredges and cores that have recovered Lower Tertiary or older rocks, and location of BMR seismic profile 78/05 (see Fig. 19).

Petroleum exploration

Organic-rich Late Eocene silty clays at DSDP Site 282 west of Tasmania have considerable petroleum source rock potential (Hunt, 1975; 1984). In Cape Sorell No. 1 (AMOCO, 1982) extensive traces of oil were found in the latest Cretaceous/earliest Paleocene. A shipboard study of 27 *Sonne* cores (Whiticar & 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 sedimentary sequences of the southern Otway Basin and the Sorell Basin (Fig. 14). 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. 21). 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 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.

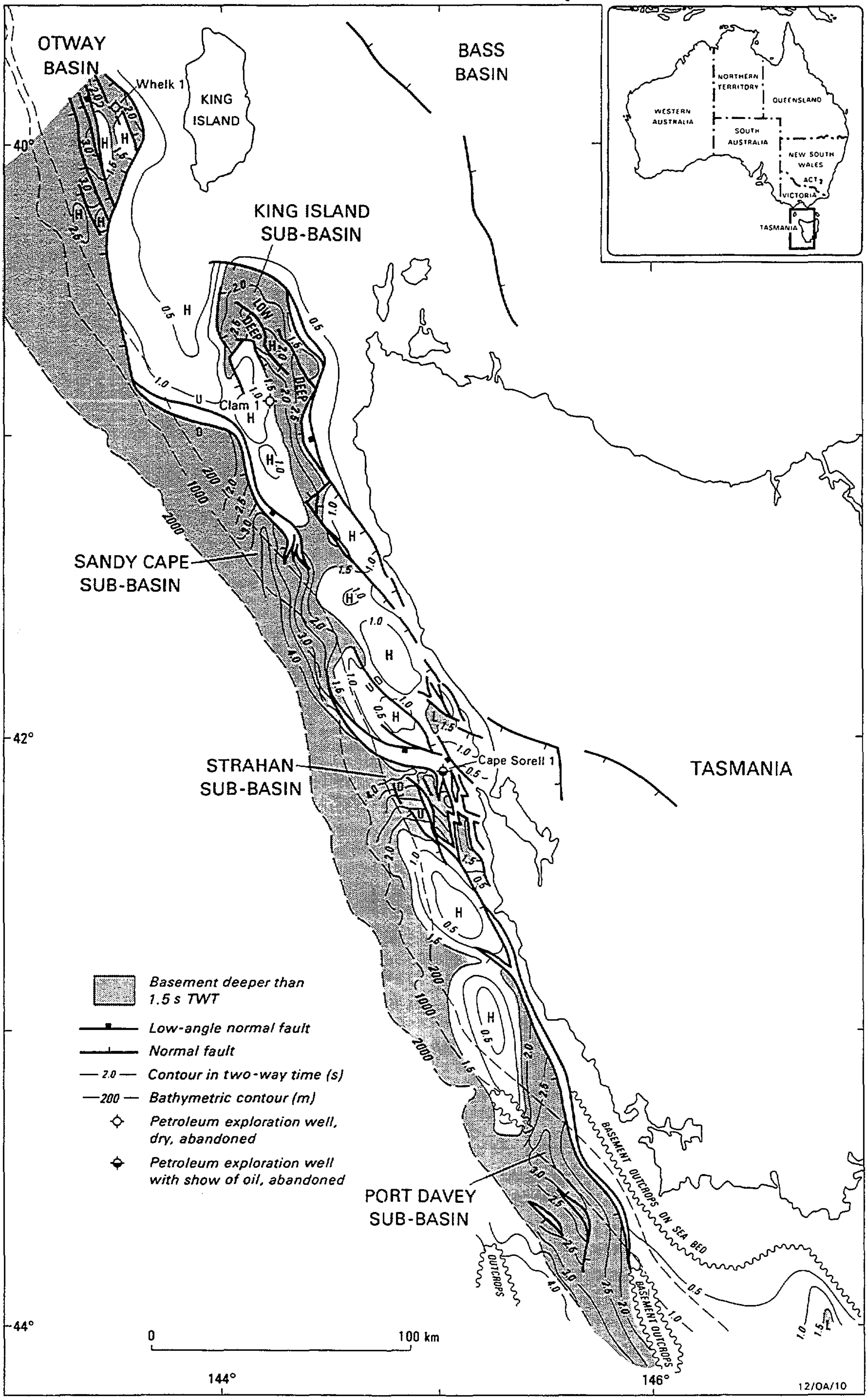


Figure 21. Map of basement structure off west Tasmania. After Moore et al. (1992). Shows basins and sub-basins in water shallower than 1000 m.

CRUISE OBJECTIVES AND PLAN

Main objectives of west Tasmania and South Tasman Rise survey

- Determine the structure of the continental slope in the west Tasmania region, particularly the geometry of the continental tilt-blocks which appear to be present out to water depths of more than 4000 metres.

- Determine in detail the azimuth and possibly the nature of deep-ocean ridges west of Tasmania, which seem to lie oblique to the trend of the coastline and shelf-edge.

- Examine the relationships between the direction of lithospheric extension, the azimuth of the seafloor spreading phases, and the formation of the transform margin along west Tasmania and the South Tasman Rise.

- Map the structure of the northern and western flanks of the South Tasman Rise, and investigate the basement blocks which lie between it and the Tasmanian slope.

- Deduce a kinematic evolution for the South Tasman Rise and account for its anomalous position in some plate reconstructions.

- 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.

- Map sedimentary structures and patterns, and work toward an understanding of Neogene sedimentary processes and their variations with time.

Plan for southern Tasman Sea and Otway Basin transits

It was planned to collect EM12D swath-mapping and other geophysical data during the transit from Auckland to the main survey area off southwest Tasmania. This work would assist future geomarine studies of the southern Tasman Basin and its margins. An almost direct route was to be followed to allow maximum time for the main survey. The plan was to start data acquisition from just north of North Cape, cross the Bellona Trough and proceed in an SW direction across the southern Tasman Basin. The transit line would tie to DSDP Site 283 (Appendix 1) and continue due west to the summit of the East Tasman Plateau.

It was also planned to collect geophysical data from the outer margin of the Otway Basin, along the final transit from northwest of Tasmania to south of Adelaide. The main aim of this work was to swath-map the foot of the continental slope and the adjacent abyssal plain for structural information. The swath was designed to include the locations of seven BMR dredge hauls on the lower slope to help put them in their geological context.

Plan for Main Survey

EM12D swath-bathymetry and acoustic imagery, 6-channel GI gun seismic, 3.5 kHz high resolution seismic, gravity and magnetic data were to be collected at a nominal ship's speed of 10 knots. Of the data-sets to be acquired, the EM12D was the most important. For this reason, the survey was designed to make the best use of this system.

Approximately 45 days of ship time were available, of which about 8 days were required for transits (Auckland-Tasmania and Tasmania-Adelaide) and a port call in Hobart. Assuming 5% of the remaining time will be taken up in transits between survey lines, the total time available for running survey lines is 35.2 days. Thus a maximum of 15 600 line-km of data could be acquired over the Tasmanian survey area at a ship's speed of 10 knots. Bad weather or equipment problems would reduce this amount.

The survey coverage is indicated in Figures 2 & 5. EM12D operations are most efficient and data quality is best when lines are run along submarine slope and parallel to seafloor structural trends (Hill, 1993). For this reason, the primary line orientation was adopted as 150° azimuth. This azimuth corresponds to the trend of the continental slope off west Tasmania, and lies between the two main deep-water structural trends seen in the existing bathymetry data and Geosat imagery, ~140° (?Jurassic/Cretaceous Australia-Antarctica spreading direction) and ~170° (latest Cretaceous-Cainozoic spreading direction). Several short lines over the far southern Tasmanian continental slope are oriented at 079° to match the local topographic trend.

The survey lines have been positioned to provide 100% EM12D data coverage over most of the survey area, with about 10% overlap of data coverage between adjacent lines. An exception is the relatively shallow (~1000 m water depth) summit area of the South Tasman Rise, where the proposed lines would provide about 70% EM12D coverage. The reduced coverage was warranted because bedrock structures in this area appear to have little or no expression in the seafloor topography due to blanketing by Late Cainozoic sediments.

The proposed survey lines had a total length of about 18 500 km, which is more than could be surveyed in the time available. The extra line-kms were planned deliberately to allow for the elimination of some lines or parts of lines after assessment of results early in the survey. There is little value in running the EM12D system in areas where rift and transform structures are not reflected in the seafloor topography. Late Cainozoic sediments may hide much of the bedrock structure, particularly in the northern part of the survey area. It was planned to run two long exploratory lines as part of the proposed grid off west Tasmania at the start of the survey, but further analysis of seismic data aboard ship provided sufficient information to consolidate the survey program.

The plan was to divide the survey area into three sectors (northern, central and southern) for acquisition purposes, and to complete the survey work in one sector before starting on the next. This would facilitate post-processing of the data onboard ship. The proposed sector boundaries were at approximately 42° 30' S and 45° 30' S. It was decided not to run a significant proportion of lines in the northern sector, due to paucity of rift/transform-related seafloor structure, so it proved advantageous to combine the northern and central sectors into one.

The survey lines would tie to, or at least closely approach, all DSDP sites in the area (280, 281 and 282 - see Appendix 1). Multichannel seismic surveys in the region, BGR SO-36B (Hinz et al., 1985) shot in 1985, and AGSO Survey 78 shot in 1988 (Exon et al., 1989A), provided cross-ties between most of the proposed *L'Atalante* lines and also ties to the DSDP holes and petroleum wells (including Cape Sorell No.1 and Clam No.1) on the shelf.

CRUISE NARRATIVE

(N.F. Exon)

This narrative summarises logistical and scientific information as it unfolded during the cruise. A detailed logistical summary was compiled on a half hourly basis, and this is available on AGSO File 94/615.

The bulk of the scientific complement arrived in Auckland on Monday February 2, for the planned departure of *L'Atalante* on February 3. After a series of delays caused by engine problems, the vessel sailed on February 12 at 0930 local time (2130 on February 11 GMT). [All times from here on in GMT; tracks are shown in Figs. 2, 22 & 23; magnetic, gravity and bathymetric profiles are shown in Figs. 24-32]. It headed for the North Cape of the North Island, and at 2300 on *February 11* it started to record multibeam data in good weather conditions on profile 0, heading northeast parallel to land in water depths of more than 300 m. On *February 12* at 1331 it started to record seismic and other geophysical data on profile 1, running northwest off Northland in water 500-1000 m deep. The multibeam data showed a deepwater terrace below which a number of canyons descended to the northeast. The seismic profile showed penetration of up to 2 seconds, with an upper well-bedded sequence underlain by a poorly bedded sequence believed to correspond to the allochthonous terrain, that was thrust over parts of Northland from the north in the Miocene; this came to the surface at 1730. The profile was completed at 1826.

On February 12, profile 2 was started at 1818, running WSW north of North Cape. Because of concern about the relatively shallow water and possible shoals, the seismic system and magnetometer were retrieved soon afterward, at 1900, and the profile continued without them. Hard, flat seabed about 100 m deep was revealed by the bathymetric systems. At 2245 the shallow platform north of North Cape was cleared, and the seismic system and magnetometer were brought back into action (2B) as we headed down slope into the Tasman Sea in relatively calm conditions. The well-bedded and allochthonous sequences were again in evidence, and faulting was apparent in the latter. The sedimentary section had thickened to 2 seconds at 0000 on *13 February*. The multibeam system showed some faults trending northwest, and also some evidence of slumping. The slope descended gently into the NNE-trending, sediment-filled Reinga Trough east of the West Norfolk Ridge, reaching its axis 2050 m deep at 0800 on February 13. A series of faulted and folded basins extended from 0750 to 1000, and the sedimentary section is up to 2.5 seconds thick. During this descent, the northern flank of the Taupo Seamount (at about 0200 an centred near 34° 49'S, 171° 36'E) was mapped by the multibeam system. It rose about 500 m above the surrounding seafloor and is an old feature onlapped by younger sediments. At 0900 the ascent up the eastern flank of the West Norfolk Ridge began and its culmination at 1650 m was reached at 1030. The eastern flank is underlain by faulted and folded sediments, but volcanic rocks lie near the surface elsewhere. The western flank gave way to the heavily sedimented New Caledonia Basin at 1330 with the older sequence being onlapped by more than 2 seconds of younger sediments. The maximum depth of the basin, 2350 m, was reached at 1530, and the flank of the Challenger Plateau was reached at 2000. The approach to the flank was signalled by a rapidly thinning sedimentary sequence. On the plateau, basement came near the surface and a young sill was apparent at 0140; some magnetic anomalies were observed. However, there is 1.5 seconds of sediment at 0300. The crest of the plateau at 830 m was passed at 0400 on *February 14*.

At 0420 on February 14 there was a course change to 237° but profile 2 continued (2C). At 0750 a basement (?volcanic) outcrop more than 100 m high was observed, with its top at 1330 m and striking SSW; on the seismic profile this was seen to be onlapped at depth. At 1030 the plateau surface was descending steadily into the Bellona Trough and the axis of the trough, 2700 m deep, with 1.6 seconds of sediment, was reached at 1230. At this point, near its northern end, the trough was about 20 km wide with steep sides trending southwest. The crossing of the southernmost Lord Howe Rise showed generally less than a second of layered sediment above acoustic basement, and the crest of the rise, with almost no sediment cover, was reached at 1800 at about 1680 m. Thereafter there was a steady but rough decline toward the Tasman basin. At 2041 the compressor failed and seismic acquisition ceased; its replacement came into action at 2118. At 2207, after about an hour of poor operation, the magnetometer was pulled in for repairs and proved to have salt water within. It was repaired and was functioning again at 0029 on *February 15*. The rise, which has about 0.5 seconds of sediment over possible basement rocks, declined steadily to 2700 m at 0500, and then

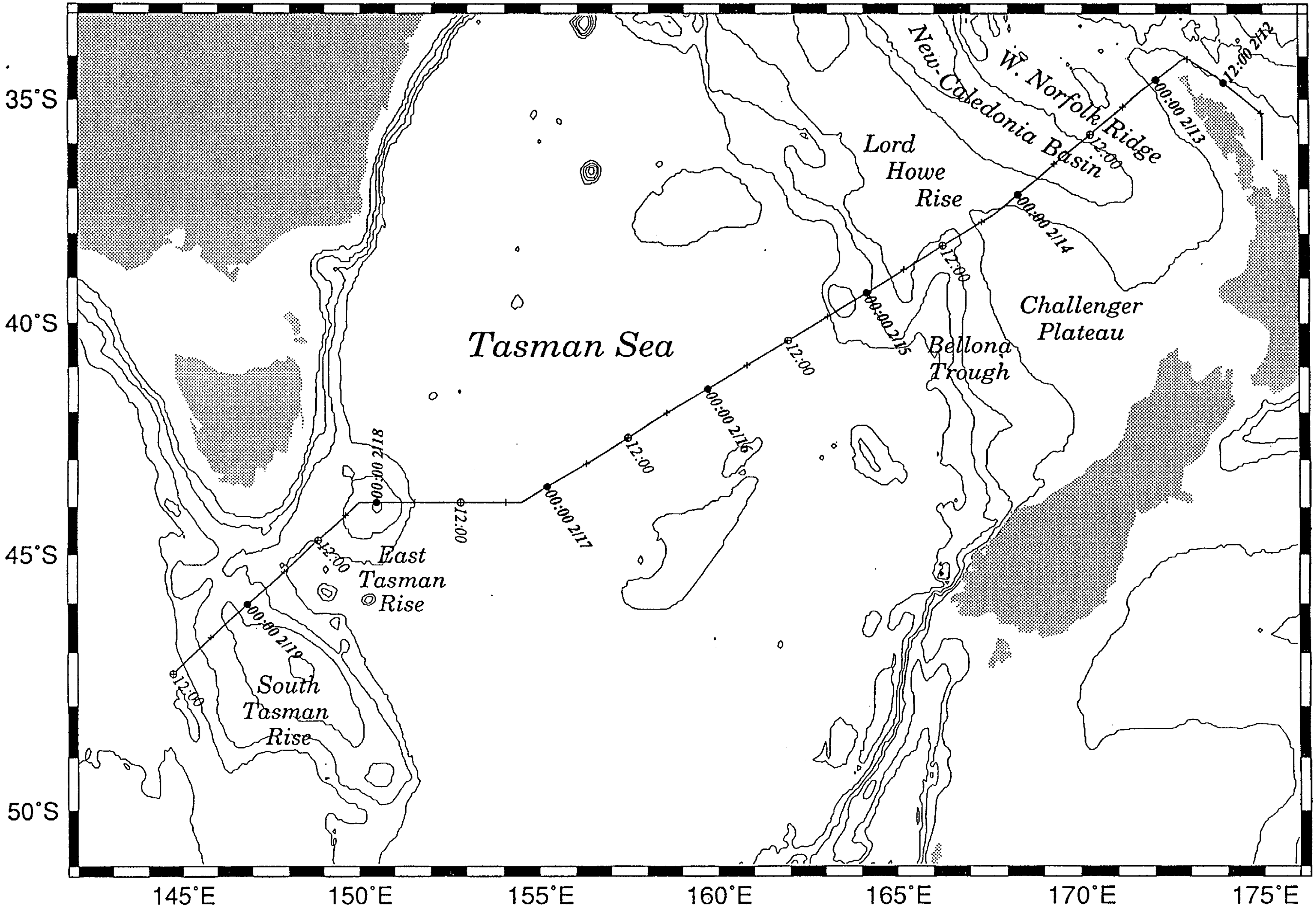


Figure 22. *Tasmante* track from northern New Zealand to western South Tasman Rise. Contours in kilometres.

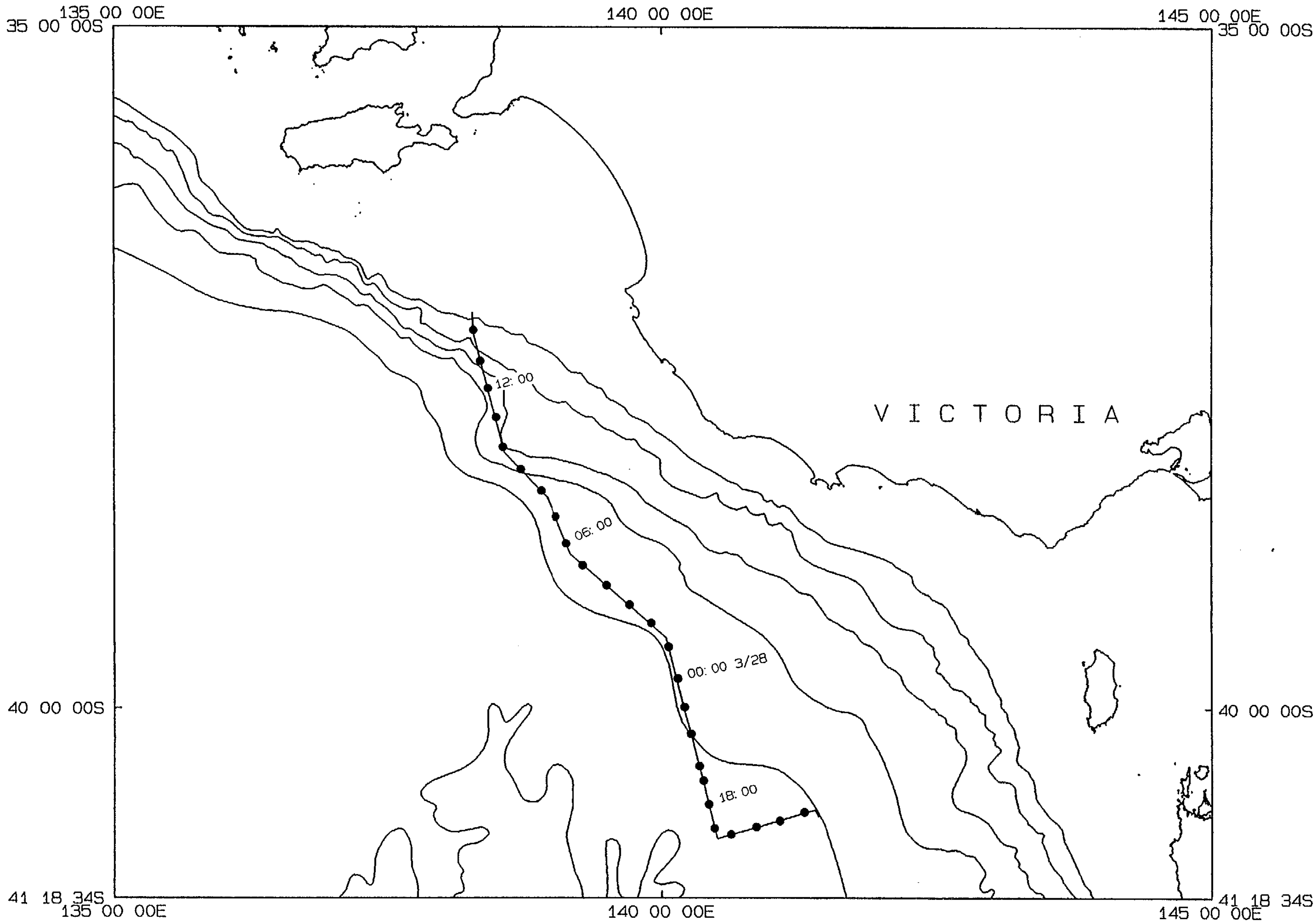


Figure 23. ***Tasmante*** **track from northwest Tasmania to Adelaide.** Bathymetry from pre-existing profile data (proved to be very inaccurate along the swath-mapped track).

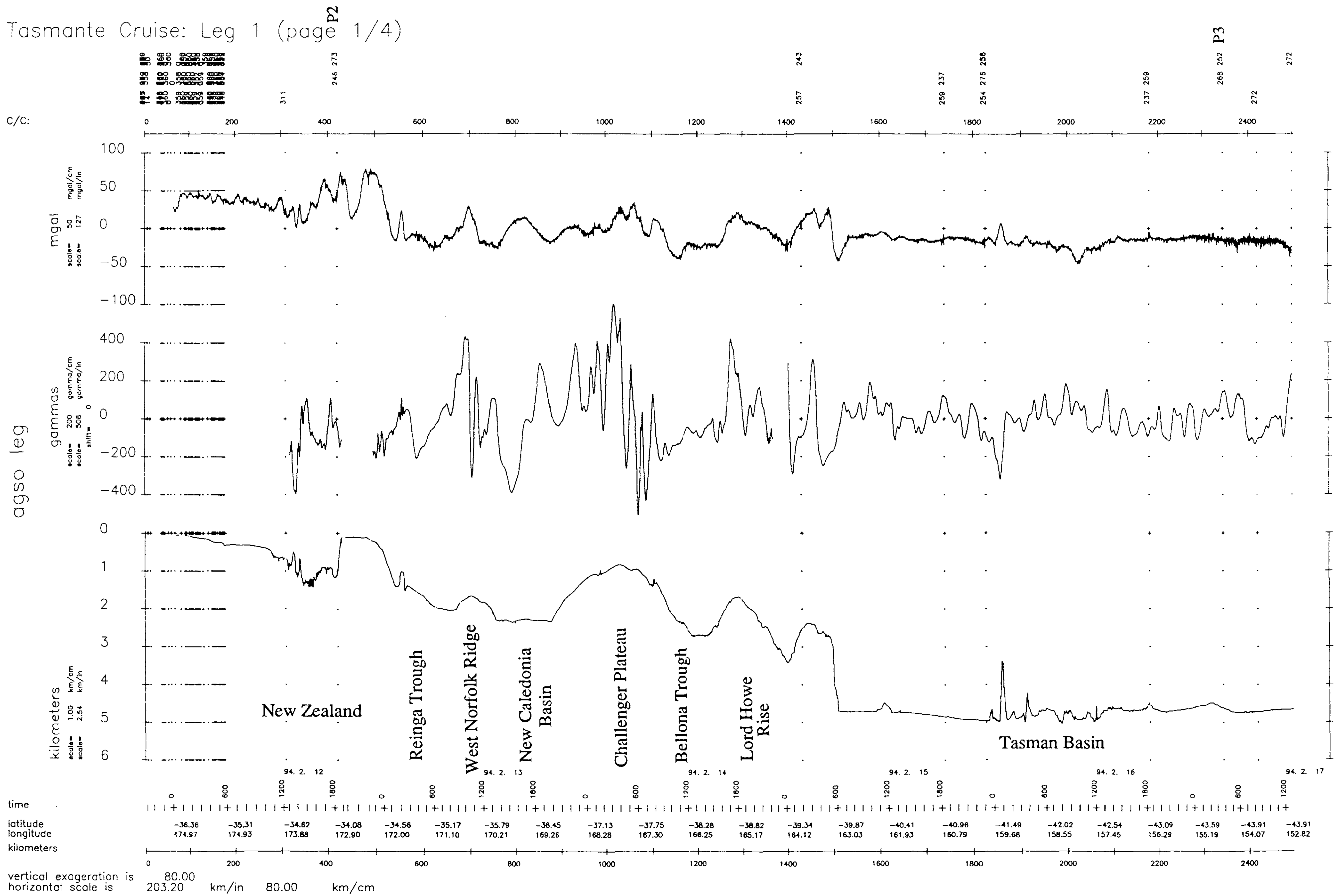


Figure 24. ***Tasmante*** **magnetic, gravity and bathymetric profiles from New Zealand to western Tasman Basin.** Location in Figure 22. 'P' at top shows beginning of each profile

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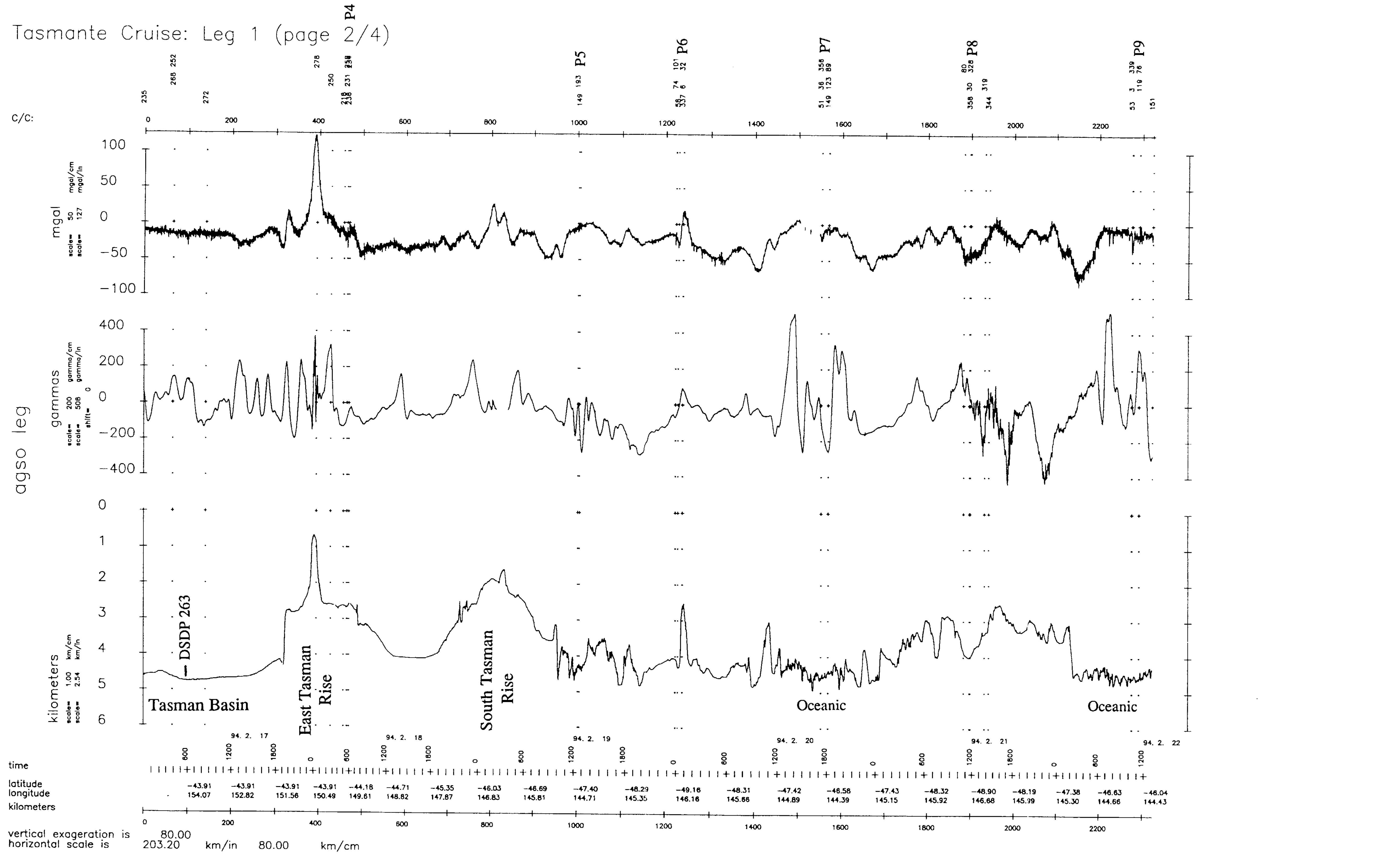


Figure 25. *Tasmante* magnetic, gravity and bathymetric profiles from western Tasman Basin to oceanic crust west of South Tasman Rise. Location in Figures 2 & 22.

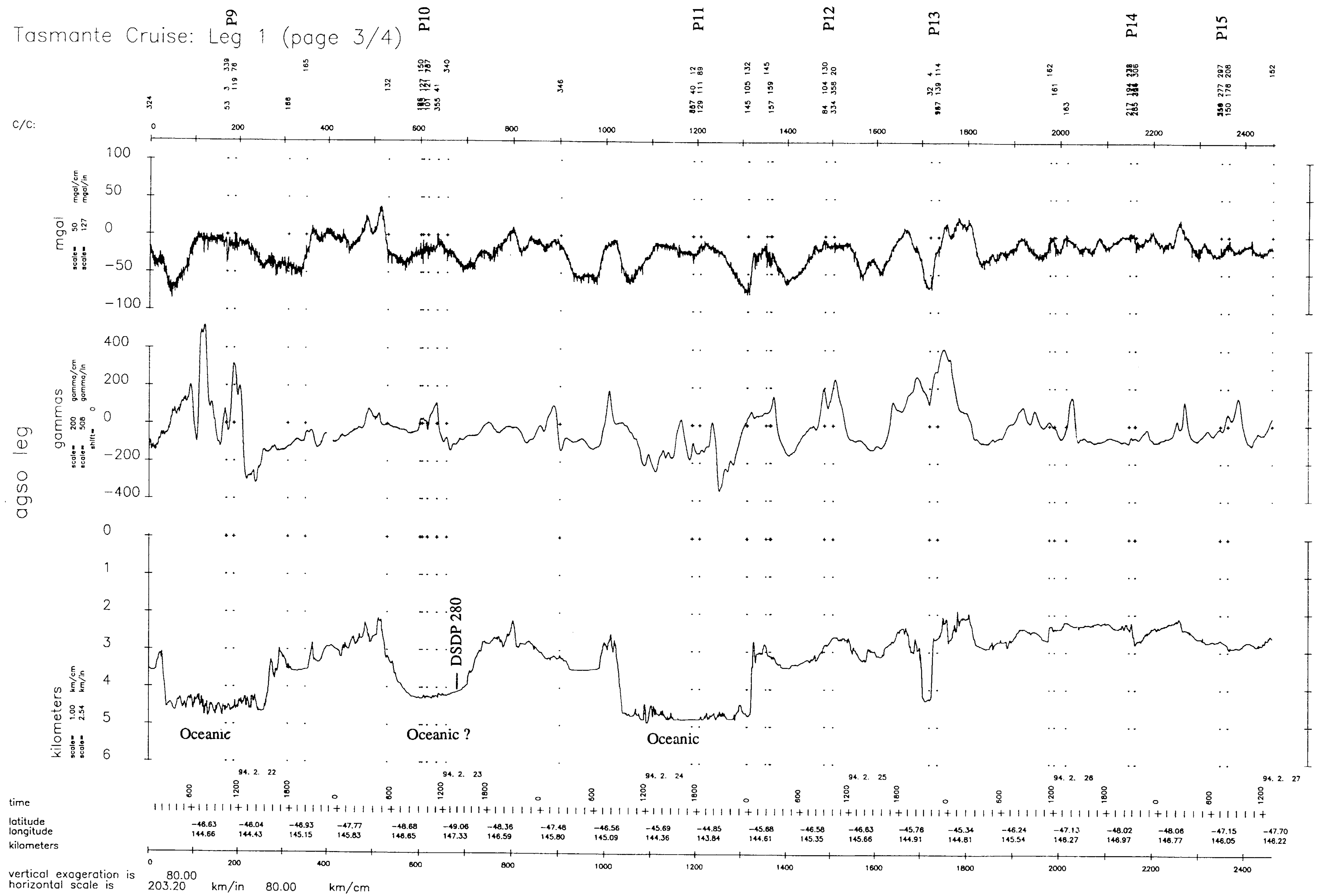


Figure 26. *Tasmante* magnetic, gravity and bathymetric profiles on South Tasman Rise and oceanic crust to the west. Location in Figure 2.

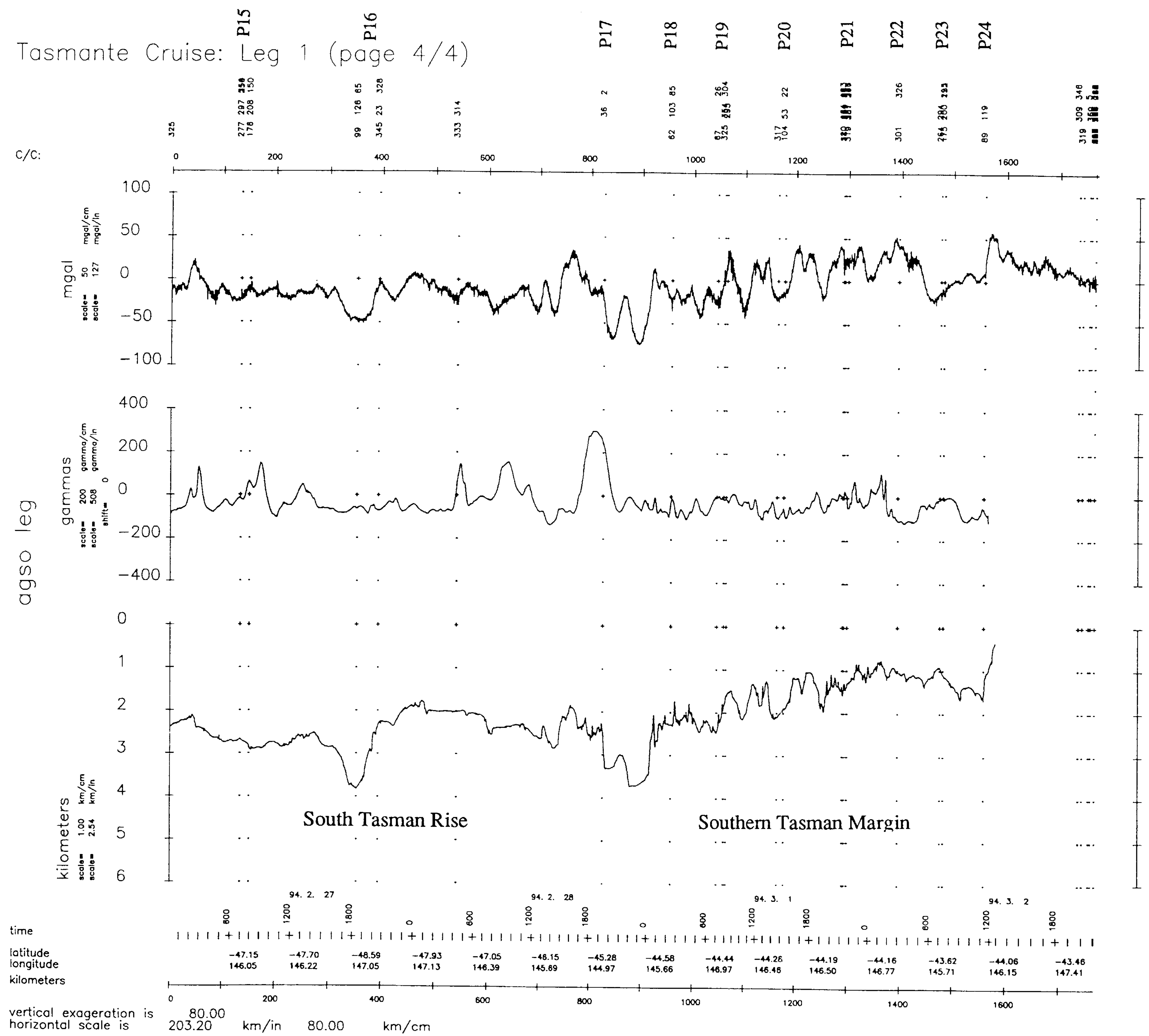


Figure 27. *Tasmante* magnetic, gravity and bathymetric profiles on South Tasman Rise and south Tasmanian margin. Location in Figure 2.

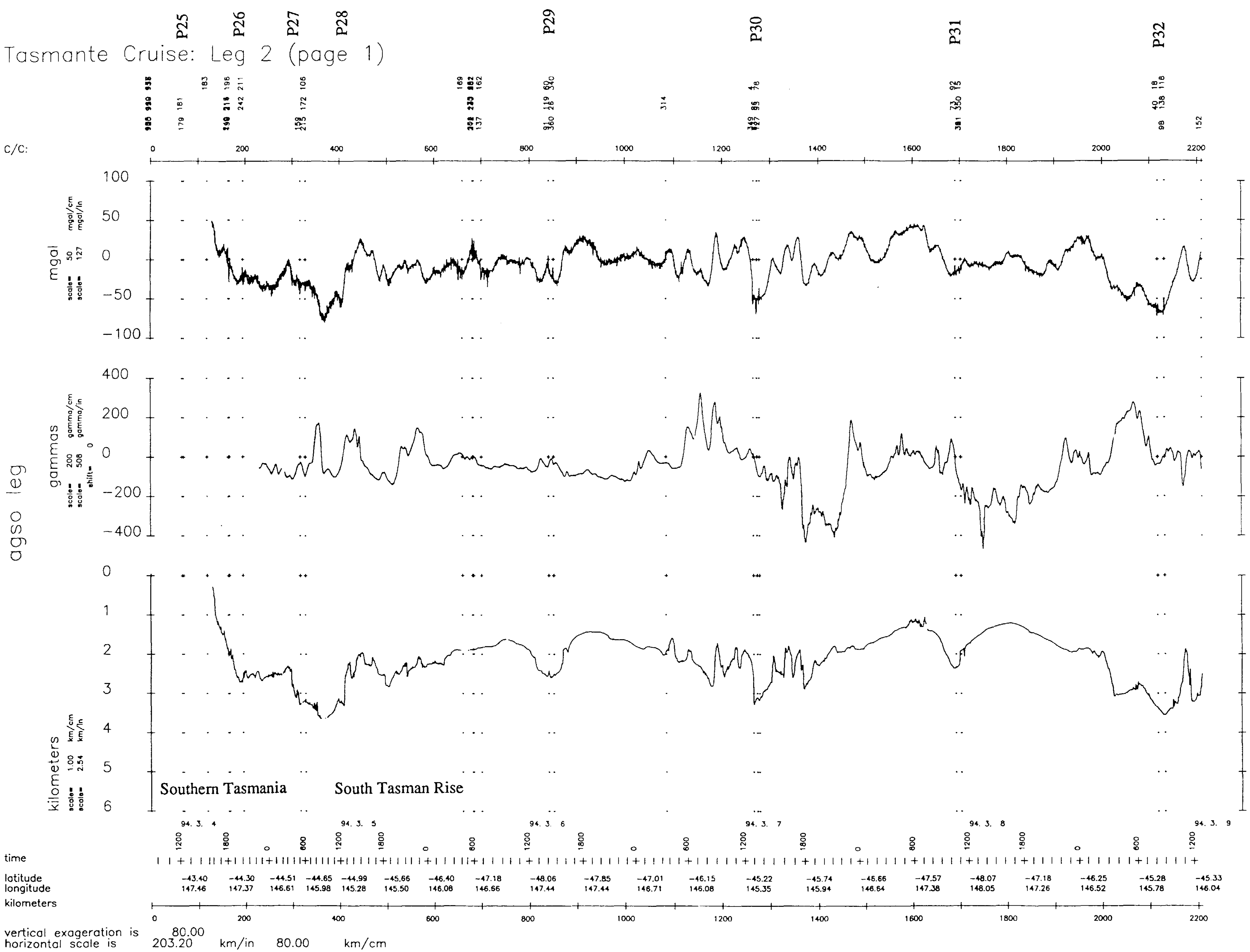


Figure 28. *Tasmante* magnetic, gravity and bathymetric profiles on South Tasman Rise and south Tasmanian margin. Location in Figure 2.

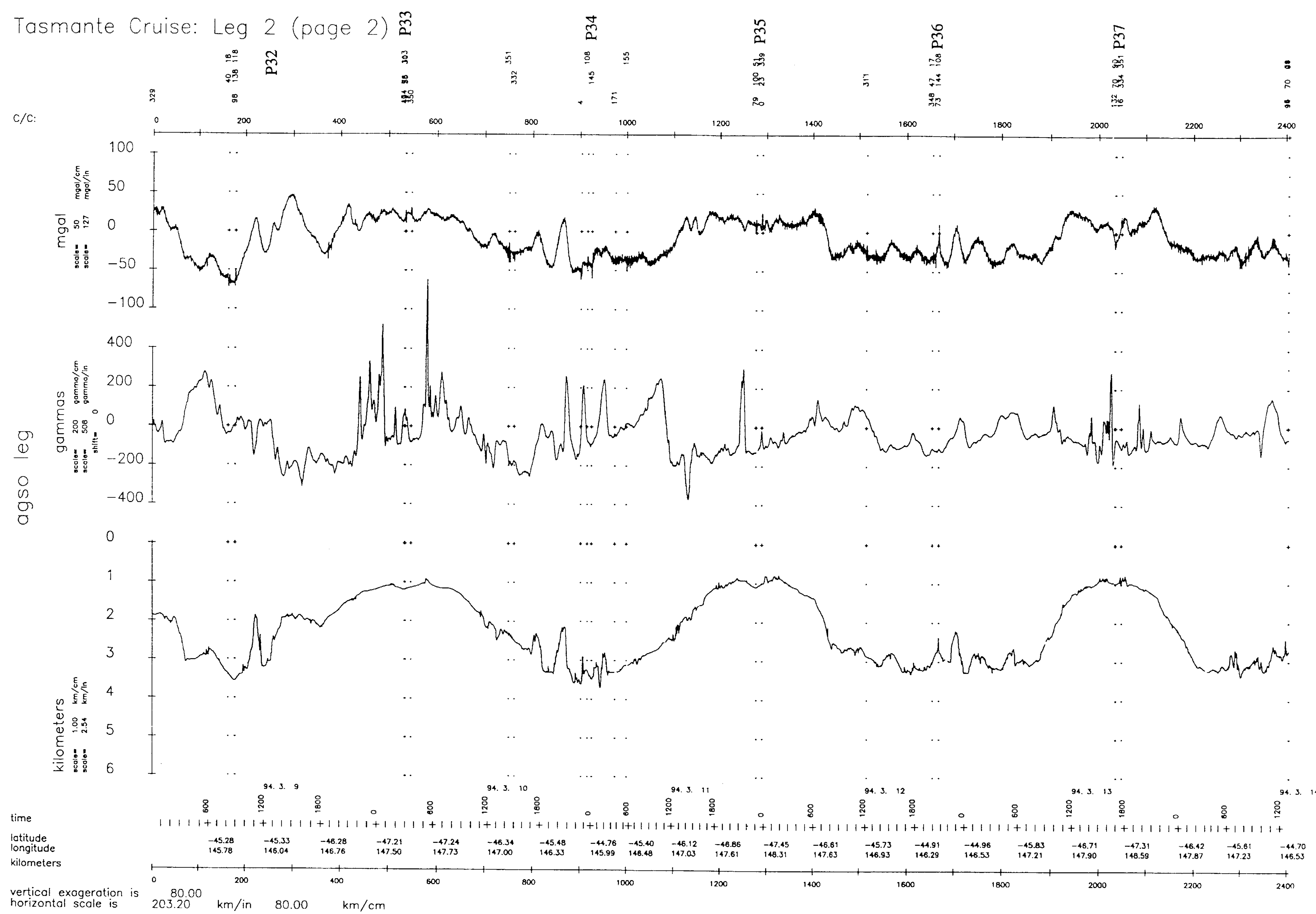


Figure 29. ***Tasmante*** **magnetic, gravity and bathymetric profiles on South Tasman Rise.**
Location in Figure 2.

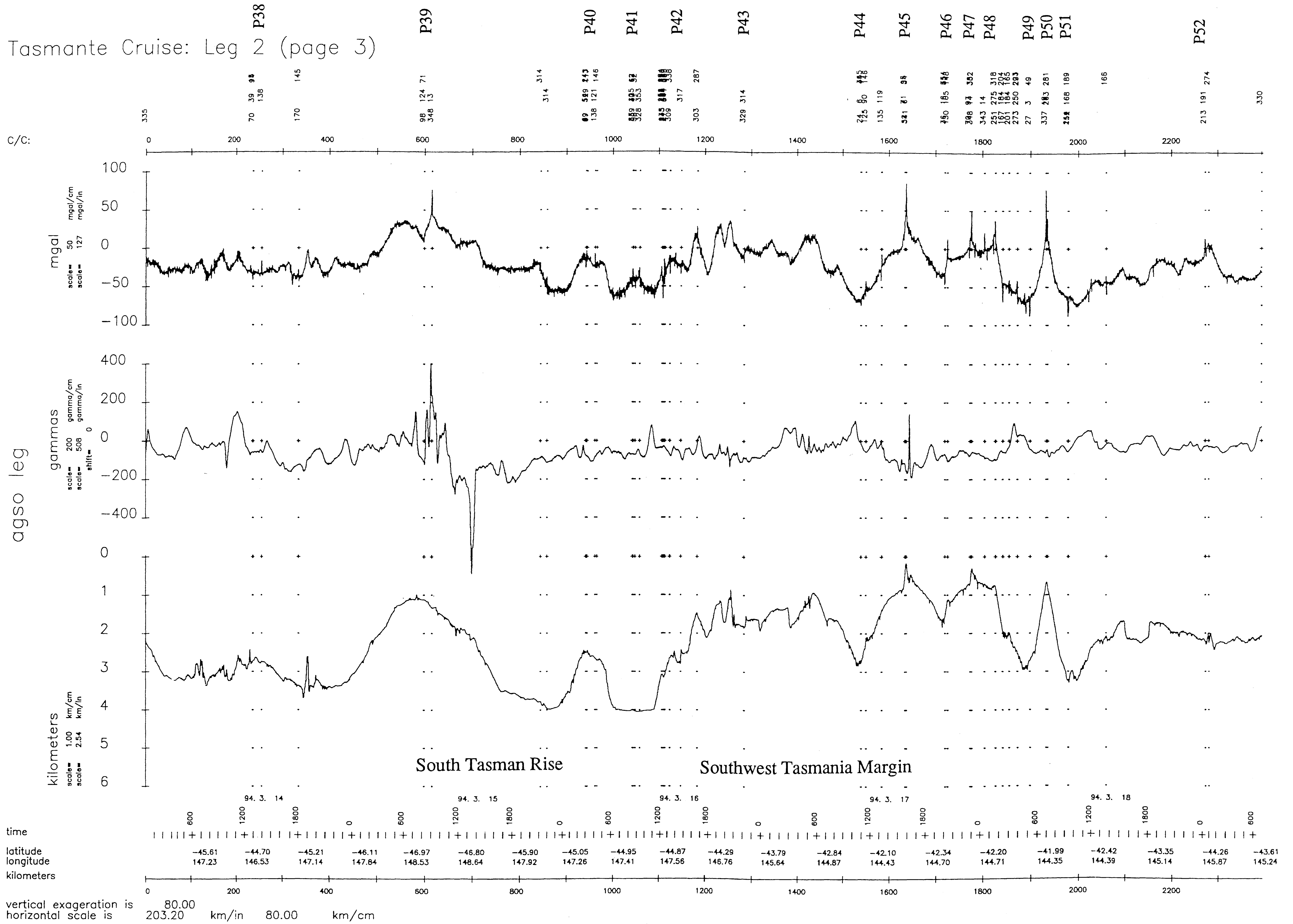


Figure 30. *Tasmante* magnetic, gravity and bathymetric profiles on South Tasman Rise and southwest Tasmanian margin. Location in Figure 2.

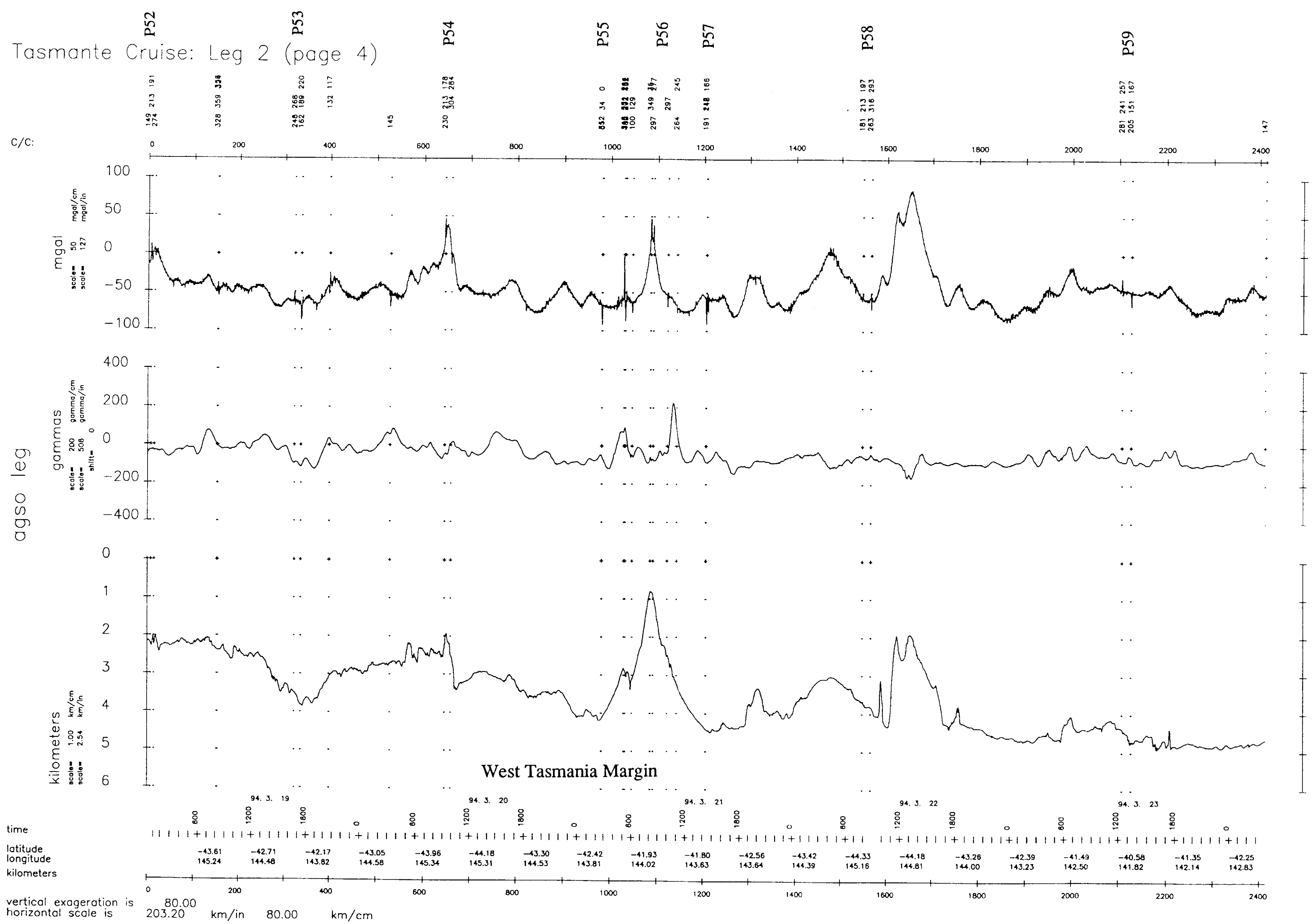


Figure 31. ***Tasmante*** **magnetic, gravity and bathymetric profiles on west Tasmanian margin.**
Location in Figure 2.

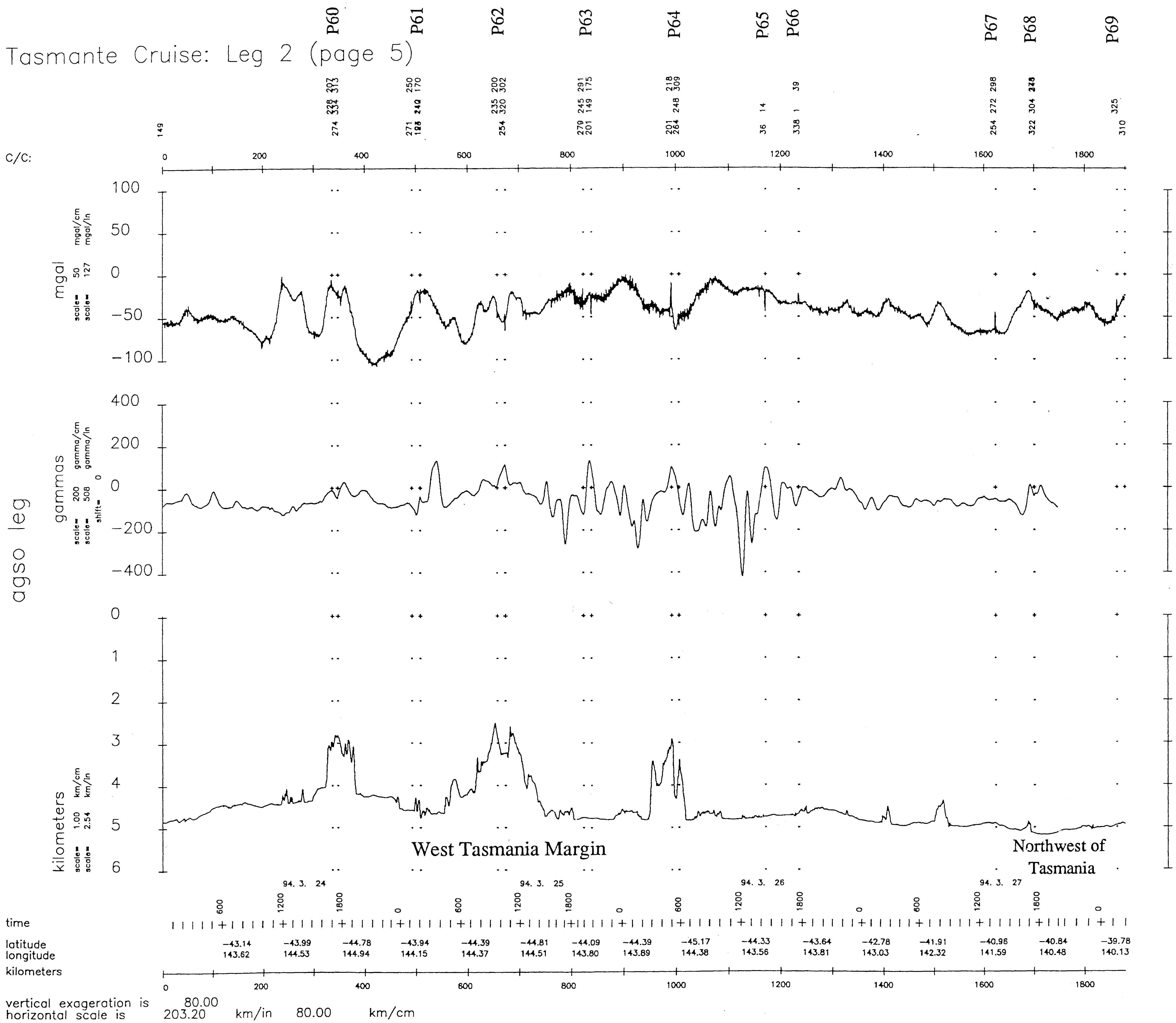


Figure 32. *Tasmante* magnetic, gravity and bathymetric profiles on west Tasmanian margin and northwest of Tasmania. Location in Figures 2 & 23.

precipitously, with complex bathymetry and some outcrops to the edge of the abyssal plain at 4700 m at 1610.

To get better seismic records a gain change was made on the flat eastern Tasman Abyssal Plain, and no data were collected from 0621 to 0626 on February 15. The seismic records show a featureless, older, fill sequence in depressions in the oceanic crust, unconformably overlain by a well-bedded sequence. The older sequence is probably Late Cretaceous and Palaeogene clays, and the younger sequence Neogene turbidites and pelagic sediments. Small canyons are apparent in the surface of the plain. The track is parallel to and immediately north of a fracture zone visible in the GEOSAT gravity data. Part 2D of the profile began at 0737, and 2E on 1044. Small seamounts related to the fracture zone are visible in the multibeam imagery, and were passed at 0850 on February 15, and 1610, 2140, 2240 and 2320. A broad rise of old sediments or volcaniclastics was crossed at 1130. After 1130, a series of large volcanic cones, up to 2000 m high, dominated the topography as far west as the spreading axis. The imagery showed that there is little young, non-reflecting sediment in the area. However, there is up to a second of poorly stratified sediment visible in the seismic records. The short spreading axis segment was reached at 0840 on *February 16*. It consists of a rise 4700 m below sea level, with a narrow axial valley 100 m deep. The troughs on either side of the axial valley are 4900-5050 m deep.

Thereafter, on the western Tasman Abyssal Plain, the sea bed was relatively flat, with no major volcanic cones, and contained an unbedded sedimentary sequence about 1 second thick, over oceanic crust showing a magnetic spreading fabric. At 1200 on we crossed a ridge aligned parallel to the spreading axis. As we headed west-southwest, in worsening weather conditions, the sedimentary sequence gradually thinned. At 2230 the profile number changed to 2F, and at 0346 on *February 17* we started profile 3 to 270°. We crossed DSDP Site 263 at 0453 and there the sedimentary sequence, about 0.65 seconds thick, consists almost entirely of Paleocene and Eocene mudstone. Bottom currents are believed to have prevented the accumulation of younger sediments, and rough sea bed is characteristic of the entire profile from the Tasman Sea spreading axis. As the East Tasman Rise was neared the sediment thickened to about 1.5 seconds, and a layered upper sequence developed (turbidites). At 0915 on *February 18* we reached the foot of the East Tasman Rise and climbed rapidly from 4250 m to 2900 m. On the slope there is no sediment cover, but a sedimentary section thickens rapidly westward away from the top of the slope to more than 1 second. It consists of a well-bedded upper part, and a structureless lower part (much like the structureless section on the abyssal plain). There was a gentle shallowing in the sea bed to the foot of the Soela Seamount at 2310. The eastern slope of the seamount rose rapidly from 2200 m to 800 m, before flattening out at 2345, and reaching a culmination of 660 m (less than the 820 m recorded on the hydrographic charts) at 0010 (43°55'S 150°29'E). At 0030 the edge of the flat surface was reached and there was a rapid fall down the western flank of the seamount from 800 m to 2500 m. There is no doubt that the seamount is a volcanic guyot, and it has small satellite cones on its slope.

At 0236 on February 18, profile 4 commenced, running to 224°. At 0639 the port compressor failed; it was replaced by the starboard compressor and seismic acquisition began again at 0659. A steep scarp dropped away to the southwest (2900-3200 m) at 0730, and the slope continued to decline away from the East Tasman Rise to 4000 m at 1300 (44°50'S 148°40'E). A relatively flat basin was present until 1900 where the slope started to climb toward the South Tasman Rise. The weather started to moderate in this period. The rise contained some scarps trending southwest from 2100 to 2300, probably associated with volcanism. The crest of the rise, about 1860 m, was reached at 0145 on *February 19*. From 0300 to 0340 (starting at 46°20'S 146°20'E) the western margin of the basement core is marked by a N-S rise of outcrop with a steep fall westward into a sedimentary basin from 1700 m to 2100 m. The profile changed to 4B at 2057. A compressor failure led to lack of seismic data from 0125 to 0147 on February 19. The basin gave way to a northerly trending basement ridge from 0300 to 0345, which rose from 2000 m to 1625 m and fell to 2075 m. There was a gentle overall fall westward to 2500 m at 0615, and a steeper fall to 3500 m at 0815, involving submarine canyons. An outer, north trending ridge, associated with a fracture zone, started at 0930 with a sharp rise from 3600 m to 3200 m, and then a very steep fall to 4600 m at 1005. More *en echelon* ridges and valleys associated with fractures continued to the end of the line at 1225.

A major survey of the South Tasman Rise started with profile 5 to 147° at 1234 on February 19. This profile down the western margin of the rise showed just how complex its structure is, with spectacular ridges and valleys controlled by two trends, one about 340°, the other about 350°, controlled by fracture zones. The main profile 5 ended just south of the rise at 2348, but continued as a transit (5B) to 60° at 2354. Profile 6 started at 0043 on *February 20*, to 330°. The gravity meter failed at 1441 and only after several tries was the gyro successfully re-started at 1712. Profile 7 started as a short transit to 60° at 1701, and the main profile 7B to 150° started at 1808. Profiles 6 and 7 both showed the complexity of the western margin of the rise, with the same two en echelon trends apparent as on profile 5; most of the section involved is probably continental crust on dredge and seismic evidence. On the abyssal plain in the northwest the spreading fabric to 75° is very apparent both in the bathymetry and in the imagery (dark and light bands are apparent). The spreading fabric disappears at a knife edge that is the Tasman Fracture Zone. At 2110 a change in recording disk led to the profile changing to 7C. The main profile ended at 1030 on *February 21*, and transit profile 7D to 60° began; this ended at 1130. Profile 8 to 330° began at 1138 as the weather began to deteriorate and the wind to swing from east to north and later to northwest. The wind speed reached 40 knots on occasions, and the average speed over the ground declined to less than 9 knots. A dramatic reduction in swath width, caused by the weather, led to our moving two miles closer to the previous profile to maintain full coverage of the sea bed (the reduction of line spacing was from 18 km to 15 km). Such deviations became common as the cruise proceeded. At 0742 on *February 22*, the automatic navigation sytem on the bridge failed because of a problem with the Doppler log, and we deviated 900 m before the problem was noticed. At 0817 we were back on course. The profile ended at 1015 well out on oceanic crust.

The transit profile 9 to 60° started at 1024 on February 22 in lessening winds from the west, and it gave way to the long profile 9B to 150° at 1121. At 2115 the seismic disk was changed, leading to the commencement of profile 9C. At 2232, because the magnetometer had been very noisy it was pulled in, and it and the cable was replaced. At 2330 the replacement was complete and the magnetometer was turned on agian. The noise continued and was thought to be related to the nearby power cable for the compressor. This was rerouted and seismic acquisition halted from 0600 to 0628 on *February 23*; thereafter the noise was diminished. The wind had increased to about 30 knots from the NW by 0630. The main profile ended well out on apparent oceanic crust with no magnetic anomalies at 0941, and the ship turned onto transit profile 9D, which ended at 1105. Profile 10 to 330° started at 1115 and the tie with DSDP Site 280 was made at 1251. The wind had fallen to a few knots by 0000 on *February 24* but then increased gradually to about 25 knots from the northwest by 1400. Profile 10 ended on the abyssal plain at 1701. The spreading fabric was less apparent than further south, perhaps because of greater sediment cover. It also appeared to trend somewhat north of west, rather than east-west.

The transit profile 11 to 60° started at 1724 on February 24 and ended at 1812. Profile 11B to 150° started at 1818. The seismic disk was changed at 2135 and profile 11C began. There was a spurious jump in the GPS location of 400 m at 2346, and another of 900 m at 0018 on *February 25*, and thereafter the GPS recorder was changed. Along this profile the wind was generally in the range 15-25 knots and from the northwest. The digital seismic recorder was stopped for checking from 0614 to 0617, and thereafter we were on profile 11D. After a gale warning was received for the southern area, the long profile 11 was terminated early, to allow us to turn northward into better working conditions. We turned at 0900 to 60° to run the short transit profile 11E. At 1002, profile 12 to 330° commenced, with the wind at 27 knots from the NW. At 2017 the port airgun was found not to be functioning and it was pulled in for repair; it was returned to the water and firing again at 2158. At 2135 profile 12 ended. At 2140 the short transit profile 13 at 50° was started; it ended at 2236. At

2242 the long profile 13B started to 150°, with the wind about 22 knots from the northwest. It ended at 2022 on *February 26*. The transit profile 14 to 230° began at 2030 and ended at 2113. This took us across to where we could run profile 14B at 2120 to 330°, to join up with the southern end of the short profile 12 in the same direction. The seismic recording disk was changed during the turn. During the profile the wind swung to the southwest, but the speed remained much the same at 20 knots. The profile 14B ended at 0653 on *February 27*, and we started the transit profile 14C to 230° at 0659 and ended it at 0753. This enabled us to start profile 15 at 0755 to 150° as a continuation of discontinued profile 11, and thus to completely fill the gap left when we turned north on February 25 to avoid a gale predicted for the south. The wind was still from the southwest along the profile at 25 knots, but caused no problems with data quality. Profile 15 ended at 1819, and we started transit profile 15B to 60° at 1824 and ended it at 2029. At 2039 we started long profile 16 to 330° and had winds from the west of 10-25 knots along the line; the profile ended at 1917 on *February 28*.

The long NNW and SSE profiles were discontinued at the end of profile 16, because it was impossible to complete one southern and one northern profile before needing to discontinue and run into Hobart for the crew change on 3 March. They will be renewed after the port call. In the meantime we decided to run the short shallow-water east-west lines planned for south of Tasmania, which would leave us not very far from Hobart. At 1926 we were on profile 17 to 51°. At 2131 the seismic disk was changed, and we continued with profile 17B which ended at 0223 on *March 1*. Profile 18 started at 0223 to 105°, about 80 km south of the southwest cape of Tasmania. By 0553 the gain on the seismic was clearly too high for the shallow, hard bottom, and the system was stopped to reset it. The profile continued as 18B from 0556. From 0700 to 0711 the seismic roll was changed and the profile number changed to 18C. The profile ended at 0745. At 0750, new profile 19 started to 280° into 30-35 knot winds and the ship's speed fell to 8-8.5 knots, and the swath width was greatly reduced by the weather in combination with the prevailing water depths of 1500-2000 m. The seismic system was stopped again from 1138 to 1139, to lower the gain further, and the profile continued as 19B. The profile changed at 1431 to 19C, heading at 327°, and ended at 1516. Profile 20 began at 1521 to 100° in 20 knot winds from the west, and ended at 2107 with a course change onto transit profile 20B to 10°. This ended at 2133, and profile 21 to 285° began with 10 knot winds from the west. This profile ended at 0255 on *March 2*, the seismic disk was changed and profile 22 to 330° began; it ended at 0702. At 0702 a brief transit profile 23 started; at 0724 there was a course change to 150° and profile 23B began. At 1107 this profile ended and profile 24 to 87° began; at 1132 it ended and at 1137 seismic recording ceased and the transit to Hobart began. Swath-mapping ended at 1252 (GMT) on March 2 and a transit to Hobart to the northeast began..

At 0800 local time on *March 3*, *L'Atalante* berthed at Hobart for a partial crew change. There was only one change to the scientific contingent, with Dietmar Müller flying home to Sydney. A Press Conference had been arranged for 1000. It was well attended, with both local TV stations represented, and about six print journalists present. Both stations played the TV interviews on the evening news, and there were also two local live radio interviews. The next day we were visited by numerous scientists and technicians from CSIRO, Geology Department of the University of Tasmania, and Antarctic Division. Some useful contacts were made with CSIRO oceanographers and fisheries scientists, and several of us visited CSIRO Fisheries Division and the *Aurora Australis*. *L'Atalante* sailed at 2000 local time on March 4 and headed south to pick up the work where it was left off.

At 1540 (GMT) on *March 4*, profile 25 began to 190° with the EM12 swath-mapping system. However, the wind was 35-40 knots from the southwest and the seismic system and magnetometer were not deployed, at the decision of the captain. The ship's speed averaged less than 9 knots on the profile, which ended at 2008. At 2016 profile 26 to 280° was started; along the profile headwinds of 30-35 knots and strong swell was encountered, reducing the speed to an average of 8 knots. The magnetometer was deployed at 2244. At 0201 on *March 5*, the magnetometer was hauled in and deployment of the seismic system started. Profile 26 ended at 0238, and profile 27 to 230° began at

0242. At 0242 the magnetometer was recording, and at 0253 seismic acquisition commenced. A gale of 35-40 knots was blowing from the west so data quality was down and the swath-width was reduced. Profile 27 ended at 0511 and the ship circled while repairs were made to the sonar Doppler system. The profile resumed as 27B at 0709 with overlap of about a kilometre allowed. The wind was about 40 knots from the west, and ship speed averaged about 7 knots along this part of the profile. At 0925 the seismic acquisition gain changed, and the profile continued as 27A! At 1200 the gain was changed again, and the profile continued as 27C at 1211. At 1332 the profile ended.

At 1348 long profile 28 began to 150° with the wind about 35° from the southwest. Changes in the delay recorded led to renaming as profile 28A at 1531, and as 28B at 1547. At 0344 on *March 6*, gun maintenance started, the two guns being overhauled one at a time, so that seismic surveying continued through this period; both guns were back in action by 0512. The magnetometer was turned off from 0512 to 0537 in order to free it from the seismic cable - across it but not wrapped around it. From 0554 to 0603 we were off course in a loop triggered by a failure in the automatic pilot system. A change in the gain of the seismic system at 0857 led to a change to profile 28C. Another change from 1001 to 1004 resulted in 28D. The long profile ended at 1403 and we turned onto the transit profile 28E to 51° at 1405. This ended at 1438.

At 1442 on March 6, we started long profile 29 to 330°. From 2108 to 2110 the seismic disk was changed and the profile changed to 29B. The weather had moderated in the last 18 hours, the wind was down to 20 knots from the west, and the swell and waves were no longer high. The long profile 29 ended at 1301 on *March 7*, when we swung onto transit profile 29C to 50°; the transit ended at 1337.

Long profile 30 to 150° was begun at 1337 on March 7, with 20 knot winds from the west. At this stage we had decided that, because of time constraints, we could not maintain full swath-mapping coverage of the crest of the South Tasman Rise, and would allow the coverage to diminish in water shallower than 2000 m. A change in the seismic acquisition gain from 2310 to 2314 led to loss of data and a new profile, 30B. The gain was again changed from 0538 to 0544 on *March 8*, and the profile changed to 30C. At 1027 there was a course change onto the short transit profile 30D to 60°, which ended at 1104.

Profile 31 to 330° started at 1104 on March 8, with a 10 knot wind from the west and calm seas. The disk was changed from 2101 to 2118, the profile continuing as 31B. The gain was changed from 0237 to 0239 on *March 9*, and the profile number changed to 31C. It was changed again at 0717-0719 and the profile changed to 31D. The profile ended at 0808. Transit profile 32 to 50° began at 0900 and ended at 1100, when long profile 32B began to 150°. The wind was 5 knots from the northeast and acquisition conditions were ideal. A change in seismic gain at 1101-1103 gave profile 32C. A change at 1158-1200 gave profile 32D. Another change at 1402-1406 gave profile 32E. Strong magnetic anomalies were noted at 2258 and 2230, and must be related to changes in continental basement. Another gain change at 0121-0123 on *March 10* gave profile 32F, which gave way to transit profile 32G to 60° at 0252; this profile ended at 0335.

Long profile 33 to 330° began at 0343 on March 10, with the wind speed 13 knots from the WNW. Seismic gain was changed at 0513-0514 and profile 33B began. Around 0520 a major magnetic high anomaly corresponds to an outcrop that could be sampled and a gentle gravity high. Between 1300 and 1330 the wind increased from 17 to 30 knots, and swung to the SSW. At 2130 both the seismic disk and the gain were changed and profile 33C began. At 2234 profile 33 ended, and at 2240 transit profile 34 to to 53° started; at 2324 it ended. At 2332 on March 10 long profile 34B to 150° began, with a 30 knot gale from the SSW. From 0334 to 0614 on *March 11* the two airguns were serviced, one at a time, while seismic profiling continued. The magnetometer was out of action from 0530 to 0550, while streaming arrangements were modified. The seismic gain was changed at 1320 and profile 34C began. At 2259 profile 34c ended and transit profile 34D to 50° commenced; it ended at 2344.

Long profile 35 to 330° began at 2349 on March 11 with 22 knot winds from the southwest. The seismic gain was changed at 0029-0030 on *March 12*, giving profile 35B. The EM12 failed from 0110 to 0112. At 0841-0844 the gain was adjusted and the profile became 35C. At 1201-1204 another gain adjustment gave profile 35D. Profile 35 ended at 1956, and there was a course change to transit profile 36 to 50° that started at 2000 and ended at 2040. Long profile 36B to 150° began at 2043 with a 14 knot wind from the south. The seismic disk and gain were changed at 2123-2127, giving profile 36C. The gain was changed again at 1103 on *March 13* and the profile changed to 36D. The long profile ended at 1650 and short transit profile 35E to 60° began; it ended at 1736.

Long profile 37 to 330° began at 1740 on March 13, with a wind of 13 knots from the SSW. A gain change at 0024-0027 on *March 14* gave profile 37B. At 0339-0453 the port airgun was overhauled. The profile ended at 1252, and the transit profile 38 to 105° was run from 1258 to 1357. Long profile 38B to 150° started at 1357 with a wind of 9 knots from the west. At 1701 there was a problem with the gravity meter. From 1748 to 1805 the paper was changed in the echosounder and no data were recorded. From 1805 to 1833 the paper was changed in the seismic plotter, but digital data continued being collected. At 2103-2109 the seismic system was stopped to change the disk, and the profile changed to 38C. The automatic wind speed recorder had failed. At 0200-0203 on *March 15* the seismic gain was changed and profile 38D commenced. At 0305 the starboard gun was found to be leaking and was pulled in for overhaul. We used one gun until it returned to action at 0523. Between 0605 and 0621 the delay between the chambers of both guns was reset to 40 ms, from lower values. At 0813 the transit line 38E to 55° was started and it ended at 0905.

Long profile 39 to 330° was begun at 0905 on March 15 with a wind of 8 knots from the WNW. It ended at 0300 on *March 16* and the transit profile 40 to 105° began at 0305. The transit profile ended at 0407 and profile 40B, a relatively short profile to 150°, began. At 0805 it gave way to transit profile 40C to 70° that ended at 0917. At 0923 profile 41 began to 330°. The wind was 20 knots from the southwest. After three XBTs failed, the ship was turned into the wind at 1210 and the next XBT was successful at 1217. We then circled anticlockwise, coming back onto course at 1242. The profile ended at 1402, and with it the methodical grid of data across the South Tasman Rise. The results overall were well up to expectations, despite some problems in linking overlapping swaths in the eastern area between 44°30' and 46°30's, because of rapid water temperature changes (10-15° C) that affected the sound velocities used. It was critically important to locate XBTs on either side of major changes. The changes were caused by the interplay of the west wind drift and eddies from the East Australian Current.

At 1402 profile 42 started with a course change to 303°, with a wind of 27 knots from the SW. This was the start of a composite profile designed to link holes left in the swath-mapping data in the fishing grounds south of Tasmania. There were a number of course changes: to 332° at 1440, 285° at 1637, and 289° at 2058. At 2115-2117 the seismic disk was changed and the profile changed to 42B to 302°. At 2207, the profile ended, and a methodical grid west of Tasmania, parallel to the coast, started with profile 43 to 328° in a wind of 23 knots from the southwest. The seismic delay was changed at 0932 on *March 17* and it is possible that there was no digital recording until 1023, when it was noticed that the digital display was not updating and the recorder was reset; the profile continued as 43B. From 0950 to 1230 the port beam of the swath-mapping system was not operational. The fault was finally found to be in the beam forming card. When this was replaced the beam operated normally. The inoperative period led to holes in the data set that had to be filled later. At 1055 profile 43 ended and transit profile 44 began to 07°. At 1128 profile 44B began to 150°, with a 10 knot wind from the west. There was a course change and change to transit profile 44C to 10° at 1542; this ended at 1553.

Profile 45 to 325° began at 1553 off Macquarie Harbour, in 228m water depth. At 2007 profile 46 began as a transit to 60°; it ended at 2025. Profile 46B to 155° began at 2028, with a 9 knot wind from the southeast. It ended at 2247 when short transit 46C was run to 48° from 2247 to 2301. Profile 47 to 330° began at 2305 and ended at 0136 on *March 18*. Profile 48 was designed to fill in spaces left by the failure of the swath-mapping system the previous day. Profile 48 to 242° was run from 0139 to 0224; profile 48B to 153° from 0228 to 0301; profile 48C to 204° from 0306 to 0356; and profile 48D to 330° from 0403 to 0513. Profile 49 to 55° started at 0516 with a wind of 11 knots from the west. It ended at 0657. Profile 50 to 246° started at 0700, changed to 50B to 238°at 0708, and ended at 0923. Long profile 51 to 148° began at 0926; at 2226-2227 the seismic disk was changed and profile 51B began. It ended at 0018 on *March 19*. Transit profile 52 to 227° began at 0030 and from 0033 to 0049 the port gun was serviced. From 0050 to 0132 the starboard gun was serviced. At 0101 the transit ended.

At 0112 on March 19, long profile 52B to 330° began, with a wind of 18 knots from the west that soon moderated to less than 10 knots. The swath-mapping system crashed between 1543 and 1548, and the profile ended at 1633. Transit profile 52B to 242°started at 1637 and ended at 1718. Long profile 53 to 150° began at 1723 and ended at 0909 on *March 20*. The transit profile 54 to 239° was run from 0912 to 0948. Long profile 54B to 328° started at 0954, with an 11 knot wind from the north. From 2118-2128 the seismic disk was changed and the profile number changed to 54C. At 0242 on *March 21* the profile ended in about 4100 m of water.

Because we had calculated that we had about 20 hours in reserve, we decided to extend the shallower-water data set west of Macquarie Harbour further to the north, and at 0246 profile 55 up the Tasmanian slope to 58° began, with a 15 knot wind from the north. At 0503 there was a course change, and the profile continued, after a butterfly turn, to 150°. At 0600-0605 there was another course change to 70°, and the line ended at 0802 in water 900 m deep. Two pods of small whales were seen from 0730 to 0800. Transit line 56 to the NNW lasted from 0807 to 0856, when profile 56B began, down the slope to 270°. The seismic gain was changed from 0856 to 0901. From 1124 to 1132 the swath-mapping system was out of action. At 1419 the profile ended.

At 1423 on March 21, long profile 57 to 150° resumed the coast-parallel data set in water 4450 m deep. The wind had fallen to an 8 knot breeze from the west. At 0357-0400 on *March 22* the seismic gain was reduced and the profile changed to 57B. At 0750 the profile ended and at 0755 transit profile 58 to 235° commenced; it ended at 0844. Long profile 58B to 328° started at 0848, with a wind of 13 knots from the SW. The swath-mapping system failed from 1220 to 1223. At 2134 the seismic disk and the gain was changed, so the profile number became 58C. From 0824 on *March 23* for some minutes the swath-mapping system failed. At 1216 the long profile ended and at 1221 the transit profile 58D to 242° began; it ended at 1315.

Long profile 59 to 150° began at 1322, with a wind of 16 knots from the NE. From 0629 to 0631 on *March 24* the seismic gain was changed, and profile 59B then began. It continued uneventfully to its end at 1704, apart from the need to deviate 3.5 miles east in the south to image the massive NNW-trending scarp southwest of Tasmania. Transit profile 60 to 230° ended at 1736, and profile 60B, one of several short lines filling the gap between the pre-Hobart and post-Hobart data, started at 1741 to 330°, with a wind of 17 knots from the NW. At 1916 the swath-mapping plotter failed and it was off, along with the digital display until 2001. At 2127 the seismic disk was changed and also the gain, so profile 60C began. At 0113 on *March 25* it ended, and transit profile 60D to 241° lasted from 0118 to 0205.

At 0209 profile 61 to 135° began in water 4620 m deep, with a wind of 19 knots from the NW. It ended at 0942. The transit profile 62 to 233° lasted from 0946 to 1031. Profile 62B to 328° began at 1035 with a 19 knot wind from the N; this increased to about 30 knots from the NNW at 1600. At 1520 there were problems with one engine, and the spare engine was switched in. The compressor stopped and there was no seismic recording from 1534 to 1600. The profile ended at 1955 and transit profile 62C to 250° lasted until 2054. At 2058 on March 25 profile 63 to 135° began. From 0343 to 0346 on *March 26* the swath-mapping system failed. At 0501 profile 63 ended and transit profile 64 to 235° began. It ended at 0549 and profile 64B to 330° began at 0555, with a wind of 29 knots from the WNW. From 0604 to 0605, and from 1015 to 1019, the swath-mapping system failed. The profile ended at 1426. The last profile in the area southwest of Tasmania was profile 65 to 58°, linking across to the last long line to the north. This started at 1431 and ended at 1739.

Long profile 66 to 327° started at 1744, with a wind of 13 knots from the NW. It joined and continued profile 60. At 2210 the seismic disk and the gain were changed, and the profile became 66B. The profile changed to 66C at 0205 on *March 27*, and ended at 1331.

Profile 67 to 252° on the transit to Adelaide, moving away from the west Tasmanian data grid across oceanic crust with the sea bed about 5000 m deep, started at 1400 and ended at 1731. A volcanic ridge up to 600 m high parallelled the northern side of the track. Profile 68 to 345° started at 1733 with a wind of 20 knots from the northeast. This mapped the en-echelon scarps trending 320° at the foot of the Otway continental slope to the east, and some isolated blocks to the west, up to 800 m high and with a similar trend. From 2000 to 2045 the vessel was slowed and the seismic streamer recovered. The recovery of the magnetometer was marred by an accident that saw its head broken off and lost. The cruise continued at 12 to 13 knots from there to Adelaide. The EM12D swath-mapping system failed from 0050 to 0053 on *March 28*, and the profile ended at 0120.

Profile 69 to 310° started at 0120, with a wind of 10 knots from the northwest, and paralleled the continental scarps at the foot of the slope. These rose more than 1000 m above the flat abyssal plain lying at 5000 m. The profile changed direction to 337° at 0533 and passed onto the abyssal plain away from continental blocks at 0645. It changed direction again at 0740 to 316° and again ran along the lower scarp extending from 3000 m to the abyssal plain at 5000 m. It changed direction to 345°at 0944 and steadily moved up the continental slope until at 1358 the water depth beneath the ship was 1000 m. Then there was a course change up-slope to 360° onto profile 70, and this ended at 1439 when all equipment was turned off in 600 m of water. The transit into Adelaide ended at 1430 (local time) on *March 29.*

A SWATH-MAPPING TRANSIT FROM NORTH CAPE, NEW ZEALAND, TO THE SOUTH TASMAN RISE

(N.F. Exon, G. Whitmore & J-Y. Royer)

The *Tasmante* transit from the North Cape of the North Island of New Zealand to the western margin of the South Tasman Rise is virtually unique in that it extends, normal to structure, 2500 km across a deep ocean basin from one major continental block to another, and that it made use of a full range of geophysical equipment including Simrad's EM12 swath-mapping system. This section of our report deals with one feature at a time, starting on the New Zealand side. It covers all the data recorded: swath bathymetry and acoustic reflectivity, 3.5 kHz profiles, reflection seismic, gravity and magnetic. Most locations referred to below can be found in Figure 22. All times refer to Greenwich Mean Time.

The *North Island* of New Zealand has an offshore extension to the west that extends southwestward steadily downward with an average gradient of 2.7° from very shallow water to 1400 metres below sea level (mbsl) (0130 on 13/2/94). On acoustic imagery the sea floor is highlighted by two bands of relatively intense reflectivity. The first band is broad, extending for 10 km across the shelf from 2120 to 2200, while the second is thin, extending 1.5 km downslope from the top of the shelf break. Acoustic facies interpreted from 3.5 kHz profiles, using a system similar to that of Damuth (1980), indicate a relatively coarse homogenous sediment (IIB, Figs. 33 & 34) corresponding to both high reflectivity bands, a thin slump or debris flow deposit (IIB^a) at the shelf break, and finally a relatively coarse sediment interspersed with rugged topography (IIB/IIIC) down slope. The seismic profile shows the poorly bedded

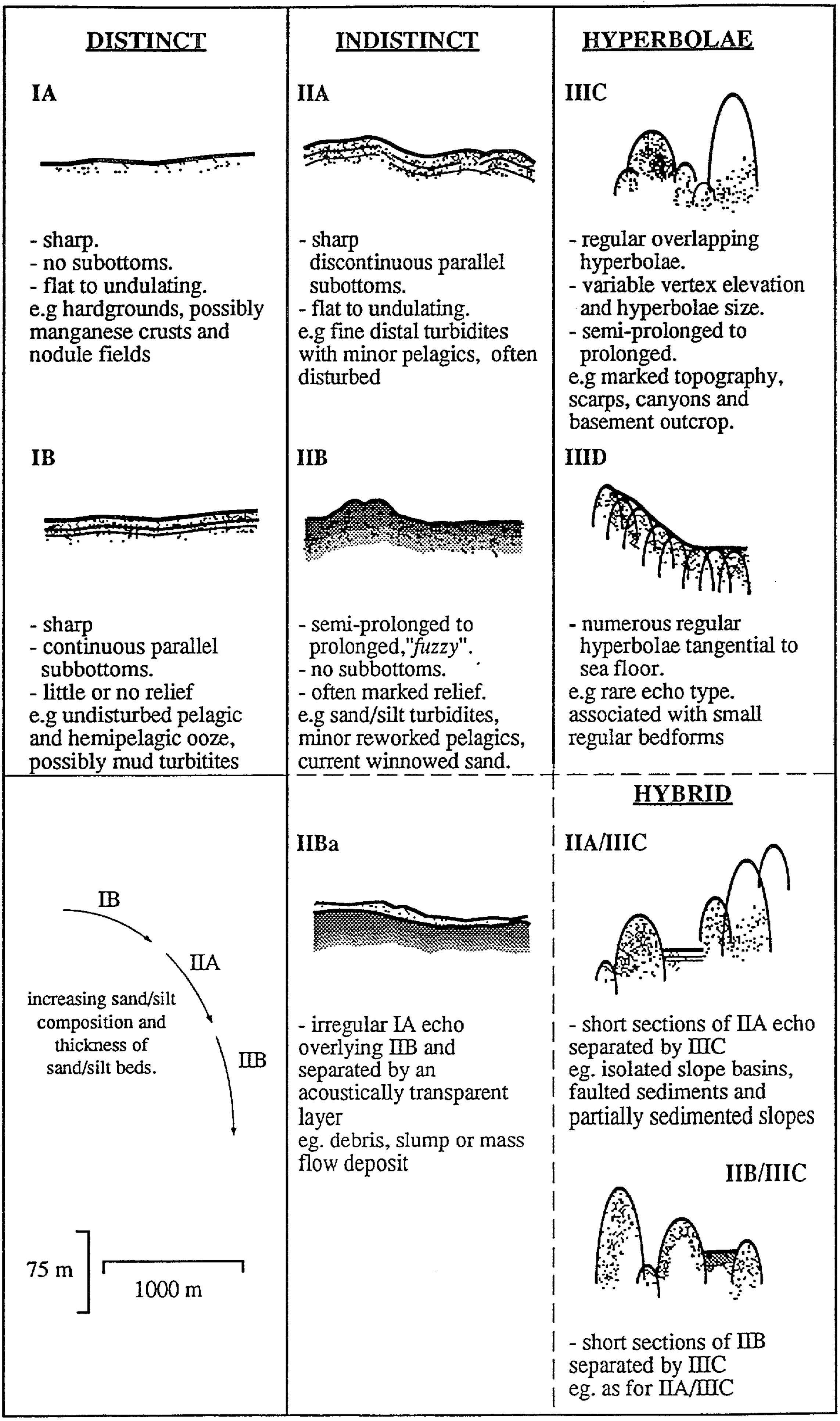


Figure 33. Acoustic facies types determined from 3.5 KHz echosounder profiles. Slightly modified from Damuth (1980).

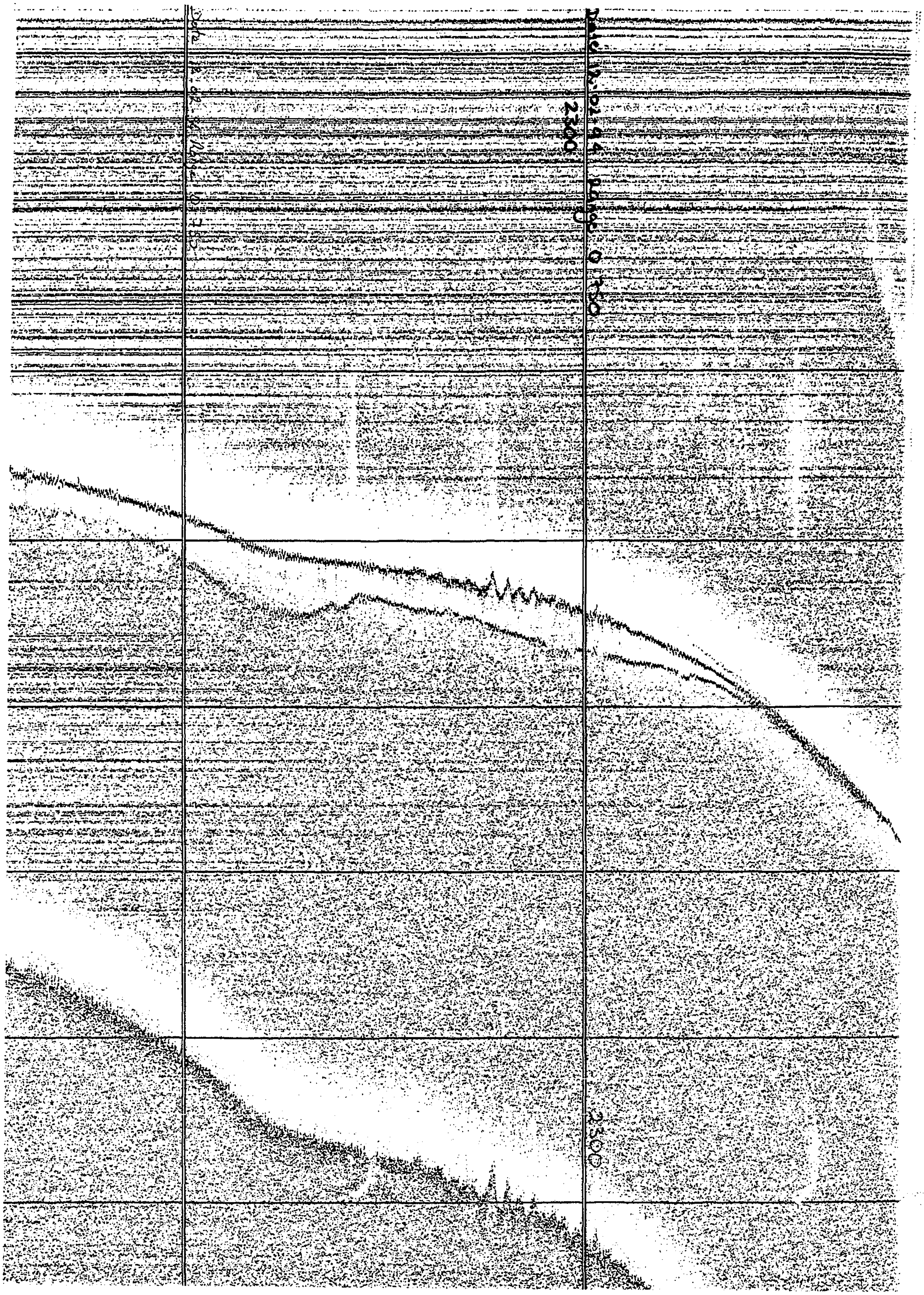


Figure 34. Echosounder profile from New Zealand slope, showing echosounder type IIB, interpreted as coarse homogeneous sediment. Horizontal timing lines in this and all other 3.5 KHz profiles are 100 milliseconds or 75 m. Vertical timing lines are 30 minutes apart.

allochthonous terrain to be overlain unconformably by up to 0.4 seconds (TWT) of well-bedded Neogene sediments containing at least one unconformity. The island corresponds to a gravity high.

New Zealand gives way down the slope to the *Reinga Basin*, which is a depression 150 km wide, bounded to the southwest by the base of the West Norfolk Ridge (0850 on 13/2/94). Along the profile the basin falls steadily from 1400 m, to 2025 m (0800) near the West Norfolk Ridge. The volcanic Taupo Seamount rises about 400 m from the western slope (centred on 0210) and is a circular, flat-topped feature about 13 km across, clearly visible from acoustic imagery. The seismic profile shows that the sediments are less than 0.4 seconds thick east of Taupo Seamount, which rises from acoustic basement and is moated on its western side. Acoustic basement can be seen about 1.4 seconds below sea floor just west of the seamount, beneath a wedge of volcanic detritus about 0.4 seconds thick. More than two seconds of sediment are visible in the axis of the basin (0715) and there are several gentle unconformities in the sequence. A transition, from irregular bedding in the lower half of the sediment section to regular continuous bedding at the top, probably represents a change from clay to turbidite deposition. This prediction is supported by 3.5 kHz profiles which reveal up to 0.1 sec of well bedded hemipelagic sediments (IB) that show evidence for minor slumping down slope and give way to more coarse homogenous sediments to the west (IIB). A basement fault block, with the fault on the west and the tilt to the east, has its highest point just 0.3 seconds beneath the sea bed (at 0740). The block is onlapped from both sides by the sedimentary sequences, indicating it is an old feature. A similar onlapped block, with its crest 0.2 seconds below the sea bed (0910), effectively marks the base of the West Norfolk Ridge and the edge of the Reinga Basin. The basin is marked by a gravity low.

Beyond the fault block at its base, the *West Norfolk Ridge* is a feature 80 km wide on its southeastern nose. It rises to 1600 m (1045) and then falls regularly in a southerly direction, to 2275 m at the edge of the New Caledonia Basin (1330). Sedimentary style within the Neogene section changes dramatically from moderately well-bedded hemipelagic sedimentation (IIA) on the eastern flank, to isolated poorly bedded slope basins (IIIC/IIB) on the more rugged western flank. West of the bounding fault block in the east is a fault-bounded transpressional basin 18 km wide, containing at least 1.6 seconds of sediments deformed by thrust faults dipping to the east, and truncated by an unconformity overlain by 0.4 seconds of well-bedded Neogene sediments. Beyond this basin, acoustic basement is initially only 0.2 seconds beneath sea bed, but it deepens steadily westward to about 0.4 seconds. Basement is cut by several east-dipping faults, that are responsible for the rugged terrain and isolated basins containing sediment wedges to the west. The overlying sequence is well-bedded. The central part of the ridge coincides with a gravity high, but the western half forms a low. The ridge forms three strong positive magnetic anomalies, suggesting that it may consist of thickened (by thrusting?) oceanic crust.

The *New Caledonia Basin* is remarkably flat across to the foot of the Challenger Plateau at approximately 2300 mbsl. The acoustic basement of the West Norfolk Ridge declines steadily westward to 1.6 seconds below sea floor at 1450, beyond which it cannot be seen. A poorly bedded sequence, whose upper surface lies 0.6 seconds beneath the sea bed of the eastern Challenger Plateau, can be traced eastward downward beneath the basin to 1.9 seconds below sea bed in its axis; its base there is below 2.6 seconds. It rises slightly before onlapping the acoustic basement traced from the West Norfolk Ridge. Rough acoustic basement, that lies 2.3 seconds beneath sea bed in the eastern Challenger Plateau, continues eastward beneath the New Caledonia Basin before dropping below the depth of resolution. The sequences above the poorly bedded sequence are virtually flat-lying, and onlap it toward the highs on either side of the basin. There is a lower structureless sequence a maximum of 0.4 second thick, a well-bedded sequence a maximum of 0.8 second thick, and an upper moderately bedded sequence a maximum of 0.6 second thick. The sedimentary sequences indicate that the basin has been a structural low for a long time during which there has been no tectonism. Despite this apparent lack of tectonism and flat topography, the basin is cut by modern submarine canyons of width less than 1 km and incised up to 70 m within the upper moderately bedded section. Two such canyons identified from the 3.5 kHz profile (Fig. 35) are bounded by well-developed levee banks of sediment alternating between well-bedded (IB, hemipelagic?) and more chaotic (IIB, turbidite ?) deposits. Away from the canyons, the surficial basin sediments have a well-

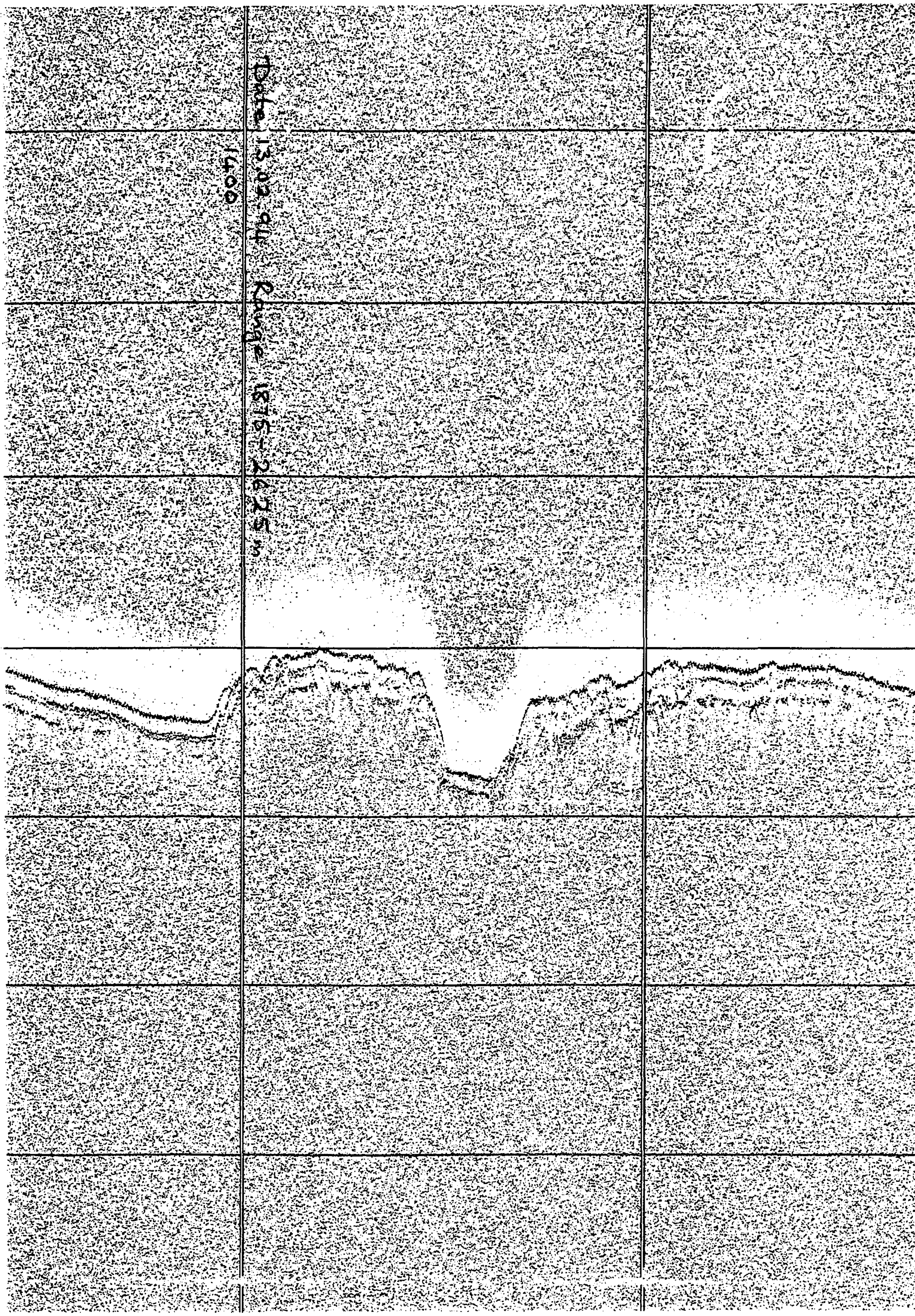


Figure 35. Echosounder profile from New Caledonia Basin, showing canyons bounded by levees. Echosounder types are IB/IIB, interpreted as mixed hemipelagic and turbidite types.

bedded acoustic facies type (IB) indicative of undisturbed hemipelagic deposition. The basin corresponds to a gravity high, suggesting that the mantle may be shallow beneath it. Its flanks are magnetic highs and its centre is a low.

The *Challenger Plateau* is 275 km across (from 1955 on 13/2/94 to 1030 on 14/2/94). According to Wood (1991), the plateau consists of thinned continental crust composed of Palaeozoic and Mesozoic granite and metasedimentary basement, that separated from Australia and Antarctica in the Late Cretaceous. Its complex origin is apparent in our seismic profile. The plateau rises from 2300 m at its eastern margin to 825 m (at 0400 on 14/2/94) and then falls to 2200 m at its western margin. Its form is broadly convex and symmetrical. However, near the top of the eastern slope is a rounded volcanic outcrop about 125 m high (0140, Fig. 36), and near the top of the western slope is a ridge 1.5 km wide and 150 m high of outcropping basement trending NNE (0745). Acoustic imagery clearly identifies both of these features and distinguishes another volcanic cone at the edge of swath (0330), possibly indicating that such features are common. On the eastern flank, deep sedimentary sequences have been extensively intruded, and plutons, sills and flows are apparent. Faulting, apparent at depth, does not greatly affect the upper half second of well-bedded sediment (IB). One vent (0140) has built up a cone of volcaniclastic sediments at depth, and a young flow rests on the present-day surface. Igneous basement comes within 0.1 sec of the surface at the crest of the plateau, and is seldom more than 0.3 seconds deep, with outcrop along a ridge at 0745. A 3.5 kHz profile (0530) shows basement 80 msec below sea floor and overlying bedding waveforms that are truncated approximately 20 mbsf (Fig. 37). A megaripple origin for this "wavey bedding" would imply considerable bottom currents, active until fairly recent times. In places, older sediments are apparent as pockets in the igneous material. The plateau forms an irregular gravity high, and corresponds with several major magnetic anomalies.

The *Bellona Trough* is a southerly-trending bathymetric depression separating the Challenger Plateau from its natural northwesterly continuation, the Lord Howe Rise. Wood (1991) notes that seismic and sampling evidence suggest that the trough may have first developed in the Cretaceous, and that it contains over 1 second of pre-Eocene sediment. Our profile cuts it near its northern limit, and here the trough is clearly a branch off the main Bellona Trough. Bathymetry along profile drops fairly steadily from 2300 m at its eastern extremity (1040 on 14/2/94) to 2700 m, and remains the same to its western margin (1420). However, the swath bathymetry shows that our profile cuts obliquely across what is a southwest-trending feature about 20 km wide, and bounded by relatively steep flanks several hundred metres in height that may be controlled by faults. The seismic profile shows that the margin with the Challenger Plateau is faulted, with igneous basement downthrown so that most of the trough contains about 1.6 seconds of sediment. Several small intrusions cut the upper sediments, comprising poorly to moderately well bedded facies (IIB/IIIC and IIA/IIIC) typical of faulted and/or slope sedimentation. About two-thirds of the way across the trough, igneous basement is upthrown to about 0.6 seconds below sea level, and then rises steadily to be virtually at outcrop at the basin margin. A lower, poorly-bedded sequence about 1 second thick, is overlain with slight unconformity by a well-bedded, flat-lying (Neogene?) sequence about 0.6 seconds thick that onlaps acoustic basement. The trough coincides with gravity and magnetic lows.

Along this profile the continental *Lord Howe Rise* consists of a broad eastern high, a low, and a narrower western high, totalling 280 km across. Several magnetic anomalies coincide with the rise. Two gravity highs and a low mimic the bathymetry which rises steadily from 2700 m (1420), to a culmination at 1700 m (1800) before falling steadily to 2400 m (2100), where there is a terrace at 2500 mbsl (2130). An irregular depression falls to the north and has its axis on the profile at 3400 m (0015 on 15/2/94). The seismic profile shows shallow complex basement on the eastern slope with less than 0.4 seconds of bedded and disturbed overlying sediment. Basement carries a thin drape of relatively coarse (winnowed?, IIB) sediment at the culmination of the Lord Howe Rise, is shallow to 1930, and then rapidly drops away westward to 1.5 seconds below the sea floor. Basement slowly rises toward the sea bed down the slope, and is less than half a second deep beneath the central depression. Indeed, the entire sedimentary section is considerably disturbed, from the lowest unbedded sequence, throughout the middle well bedded sequence and including the overlying moderately bedded sequence already mentioned.

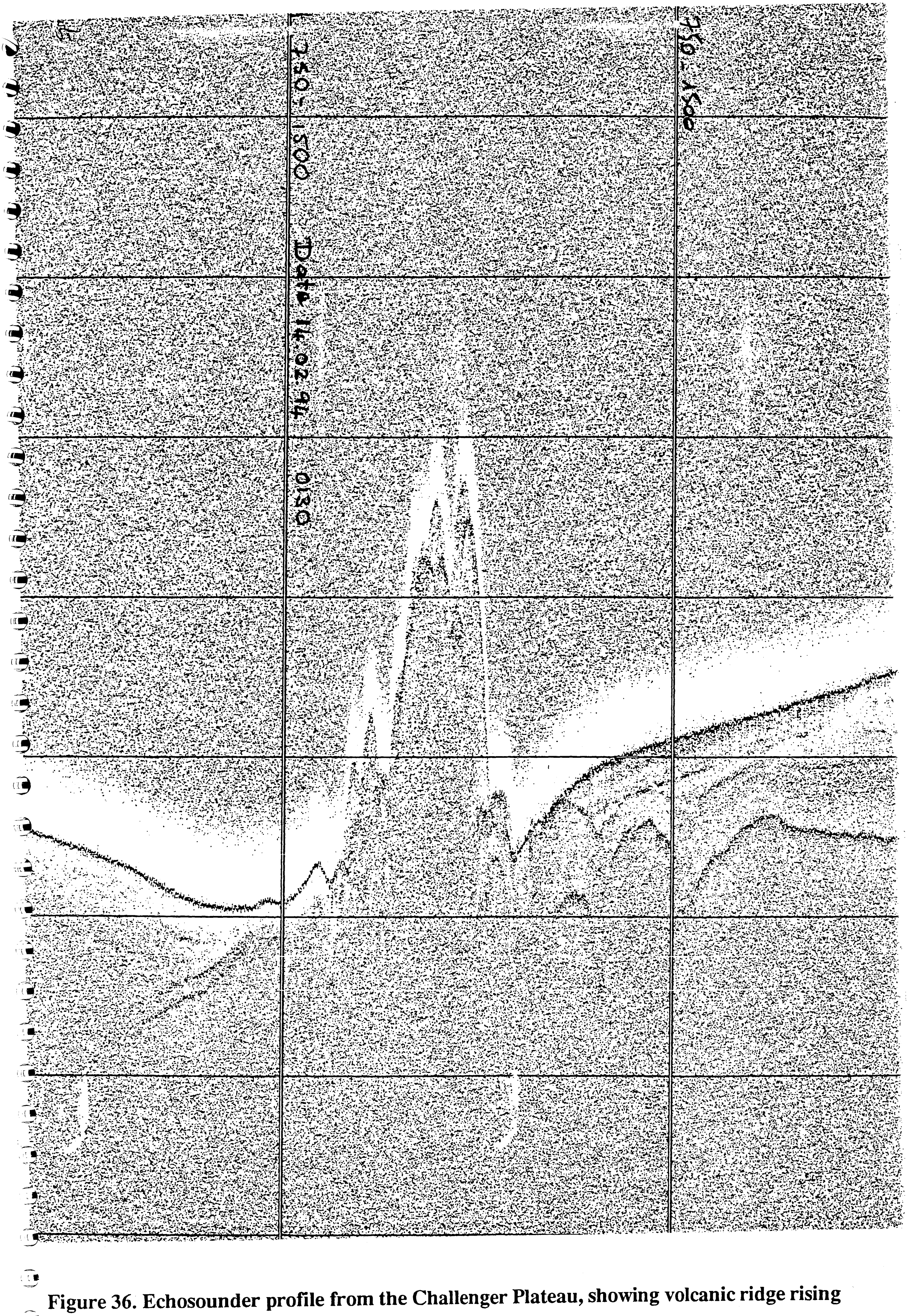


Figure 36. Echosounder profile from the Challenger Plateau, showing volcanic ridge rising above sedimented sea floor.

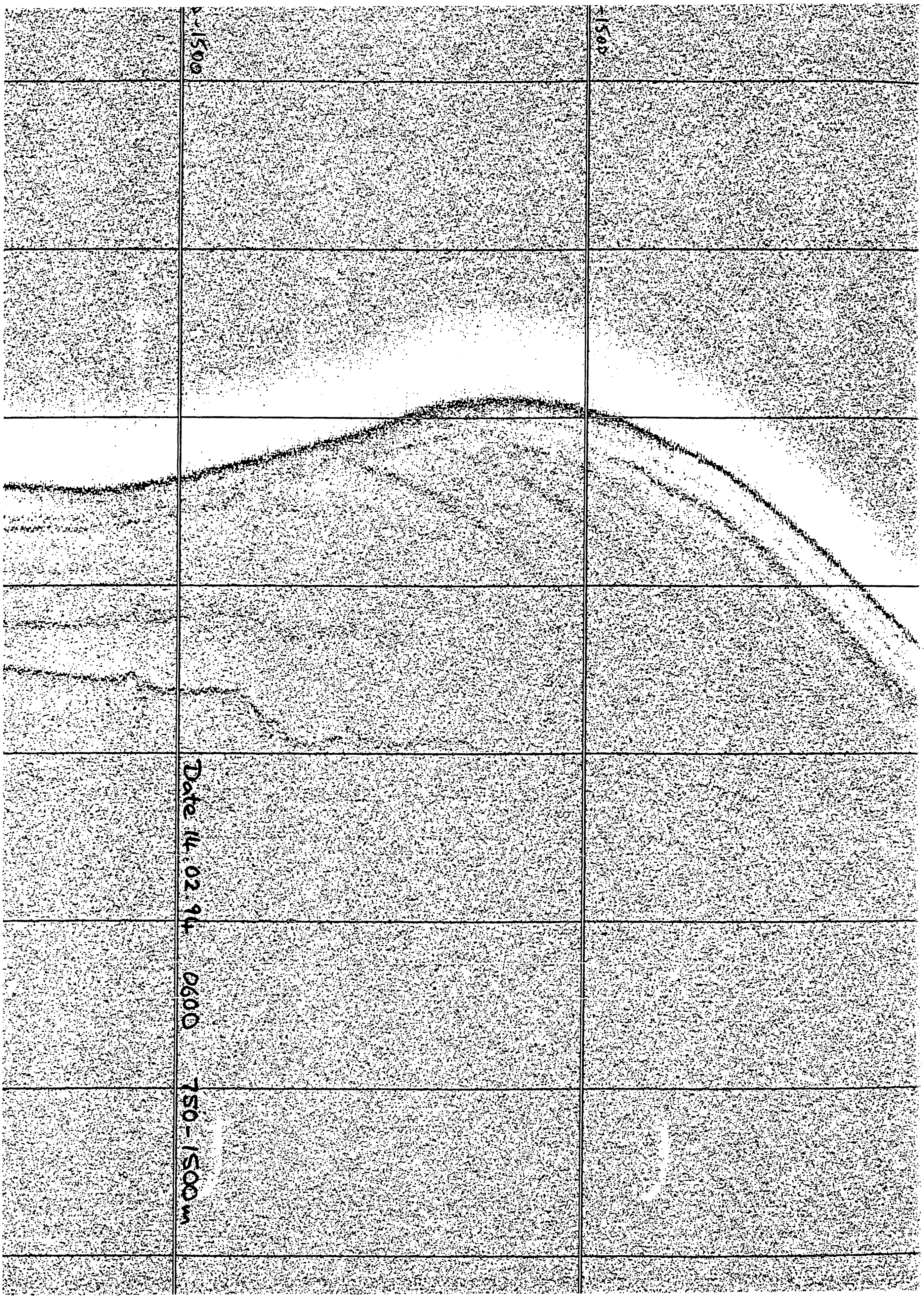


Figure 37. Echosounder profile from the Challenger Plateau, showing prograding sediments nearly 100 msec thick on igneous basement, overlain by a 20 msec blanket of draped sediment.

The *western Lord Howe Rise* bathymetry shows a high with a broad culmination at 2425 m (0300 on 15/2/94), and a rugged ridge that falls to the south and runs along the profile to 2700 m (0500). A precipitous scarp, and a slightly less steep and more complex slope beneath it, fall 1.8 km at an average of 8.5° to the Tasman Abyssal Plain (4600 mbsl, 0610). Basement is typically less than a second deep beneath the high, and there is some faulting apparent in the slope up to the culmination where basement is about half a second deep. Faulting, apparent along the western flank and within basement, suggests that this western ridge may be a faulted sliver of the Lord Howe Rise. At 0400 basement is downthrown nearly a second in a fault bounding a 10 km wide half-graben, forming a large slope basin filled with older relatively coarse sediments (IIB). Along the ridge beyond the half-graben, basement rises toward the sea bed, reaching it at the edge of the scarp, and persisting at the surface. The overlying sequence is well-bedded and thin.

The *Tasman Abyssal Plain* formed as a result of Late Cretaceous and Palaeogene seafloor spreading which moved the Lord Howe Rise away from Australia to the ENE in the south and NE in the north. According to Veevers et al. (1991), spreading started at 96 Ma (Cenomanian) and ended at 55.5 Ma (early Eocene). The way in which we oriented our profile, parallel to the fracture zones as defined by GEOSAT satellite imagery, ensured that no fractures were crossed on the transit. However, the path across the eastern half of the abyssal plain had a fracture zone immediately to the south. We assume this was a leaky transform fault that gave rise to the numerous volcanic cones visible on swath-mapping imagery. West of the old spreading axis, and distant from any possible fracture zones, there are no volcanoes. Between the foot of the Lord Howe Rise and the foot of the East Tasman Rise the Tasman Abyssal Plain is 1080 km wide. The gravity profile shows a general high over the oceanic crust, with local highs related to seamounts, and a prominent low over the extinct spreading centre. Magnetic anomalies 33 to 24/23 can be identified, suggesting that fast spreading began about 80 Ma and ended about 52-50 Ma.

The eastern part of the abyssal plain extends 520 km from the foot of the Lord Howe Rise (0610 on 15/2/94) to the old spreading axis (1000, 16/2/94). The sea floor is generally very flat (< 0.05°) for the eastern 290 km, falling from 4700m near the Lord Howe Rise to 4900 m at the western limit of the plain (2130). The seismic profile shows an irregular basement surface, generally 0.6 to 1.2 seconds below sea bed, but occasionally coming close to or to the sea bed. In some areas a two-fold split in the overlying sediments is possible: the lower third is poorly bedded (clay?), and unconformably overlain by a well-bedded and undisturbed sequence (IB, turbidites?). In these areas the ocean floor is incised by numerous canyons and channels seen from both 3.5 kHz profiles (Fig. 38) and acoustic imagery. In other places this two-fold subdivision does not apply, probably because basement is higher, the turbidite source was cut off , and so the sedimentary sequence is thinner (less than 0.6 seconds), generally consisting of a single structureless sequence (IIB). Conical buildups (IIIC) of probable volcaniclastic origin are identified, with good examples visible from swath bathymetry and acoustic imagery at 0840 and 1130. These local highs source several of the canyons disecting the abyssal plain, but the majority are believed to originate along the flanks of the Lord Howe Rise.

The remaining 230 km of the eastern Tasman Abyssal Plain is characterised by volcanic cones rising as much as 1300 m above the sea bed, most with their centres south of the profile. The cones are either round or somewhat elongated across the profile (NNW-SSE), and have a maximum diameter of 20 km. Several have small flattish tops and may be guyots. Near the spreading centre, the sea floor is cut by highs with crests at about 4600 m, and troughs with lows at about 5000 m. The seismic profiles show that the cones are frequently onlapped by younger poorly bedded sediments that are as much as 0.6-1.0 second thick. An acoustic facies interpretation for this region identifies local volcaniclastic outcrop (IIIC), enveloped by debris flow (IIIC/IIB) accumulations and faulted turbidite blocks (IIIC/IIA), with intervening areas of turbidite (IIA) accumulation. Although sediments interpreted as turbidites are present, it is suggested that they are not presently active as no submarine canyons or channels were identified from either 3.5 kHz profiles or acoustic imagery. The spreading centre itself (0840 on 16/2/94)

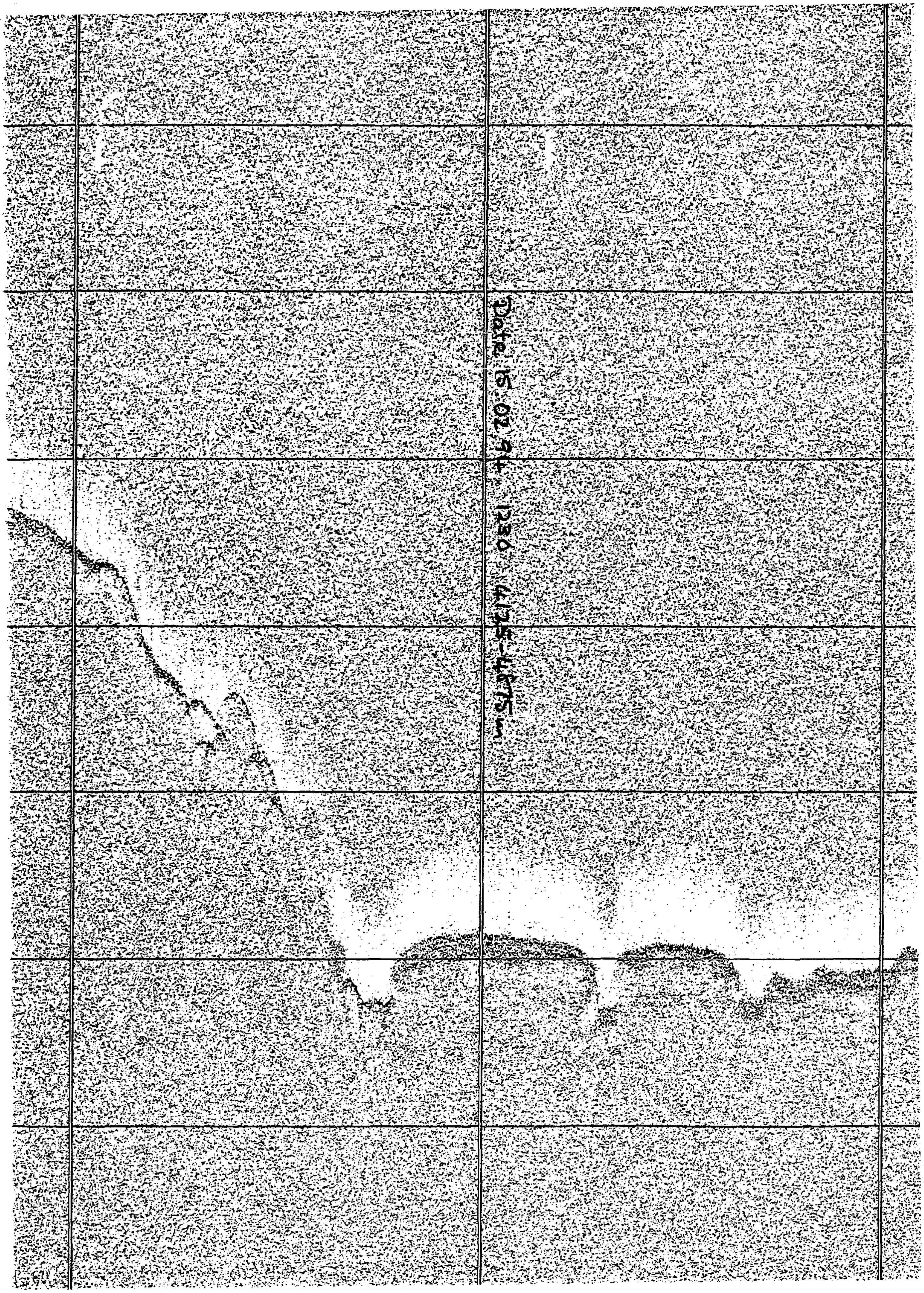


Figure 38. Echosounder profile from the eastern Tasman Basin, showing three shallow canyons flanking a volcanic ridge.

is bounded by irregular faulted highs evident at the surface (Fig. 39), is about 20 km wide, and sits in the middle of a flat-bottomed depression tilted down to the SSE, with a maximum depth of 5175 m. Basement is about 0.5 seconds beneath the bounding highs, and that basement is about 0.5 seconds above its normal level. The depressed basement beneath the spreading centre is about 8 seconds below sea level, and about 0.8 seconds below that of the flanking highs, and is overlain by 1.2 seconds of poorly bedded sediment.

The western Tasman Abyssal Plain is 570 km wide between the spreading axis and the foot of the East Tasman Rise (1910 on 17/2/94). Its average depth of 4700 mbsl is somewhat higher than that of the eastern plain and relatively few seamounts could be identified. The swath mapping shows a narrow ridge 300 m high, trending NNW across the track, 40 km west of the spreading centre. A seismic profile shows it to be oceanic basement onlapped by sediments. Basement is very irregular and faulted, but the irregularities are evened out to some extent by a blanket of poorly bedded sediments 0.6-1.0 m thick. From the basement ridge a 300 km tract of marked topographic and structural complexity (cf. surrounding oceanic crust) stretches to the west. This tract contains three elongate volcanic (?) cones rising 200 - 500 m (1245, 1345, 1500), is cut by an east-west trending ridge with 100 m relief above a basement high (1800 on 16/2/94), and ends at a broad southwest-trending sedimentary mound rising 100 m above the sea floor (0200 on 17/2/94). Between the two ridges there is an appreciable dip to the SSE and the oceanic basement is relatively smooth, although there are some faults with displacement of 0.1 second. Sediment cover is 1.0-1.1 seconds thick, and is unbedded with the exception of a thin sequence in the middle and the sediment mound to the west. Turbidite deposition is not evident from either seismic or acoustic facies interpretations, and it is suggested that the predominant, relatively coarse unbedded sediment (IIB) results from current winnowing of older sediments.

Profile 3 began at 0346 (17/2/94) with a course change to 270°. DSDP Site 283 (0453) is on a broad basement rise and the section there is 0.7 seconds thick. The sequence drilled to basement was 590 m thick, and consists almost entirely of Paleocene to Late Eocene clays, thus demonstrating that deepsea currents have kept the western Tasman Abyssal Plain clear of younger sediments (Kennett, Houtz et al., 1974). West of the site, basement drops to about 1 second below sea floor, and the sedimentary sequence gradually changes so that there is a lower, completely unbedded sequence, a middle poorly bedded sequence, and a thin upper well-bedded (Neogene?) sequence. The sea floor is generally flat at about 4600 m. At 1500 the sea floor starts to rise slowly, attaining 4200 m at the foot of the East Tasman Rise, where currents have scoured a moat nearly 200 m deep. As the sea bed rises, the basement changes to consist of large blocks, rising to 6.8 seconds below sea level and falling to 7.3 seconds. The overlying sequence is clearly differentiated into a lower structureless sequence 0.4-1.2 seconds thick that fills depressions and overtops the highs, and an upper well-bedded sequence 0.4 seconds thick. This facies change seems to represent proximity to a source of Palaeogene turbidites on the Australian landmass, rather than the incoming of Neogene sediments.

The transit profile across the Tasman Sea (Fig. 40) recorded the complete sequence of *seafloor spreading magnetic anomalies* that date the separation of the Lord Howe Rise from the East Tasman Rise from the Late Cretaceous (chron 33, 79 Ma) to the Middle Eocene (chron 24/23; 52-50 Ma). The oldest identifiable chron is 33; however its oldest extremity seems to merge with the magnetic anomaly associated with the continent-ocean boundary. The averaged (half) spreading rates are 2.0 cm/yr from chron 33 to chron 25 (young side), and 1.2 cm/yr from chron 25 to the extinction of the ridge (using Cande & Kent, 1992, magnetic reversal time scale). The symmetric synthetic model emphasizes the asymmetry of the actual seafloor spreading. The main periods of asymmetry are between chrons 33 and 32, 31 and 30, and 27 and 26; the small ridges underneath these anomalies may represent remnants of ridge jump responsible for the asymmetry. Anomaly 27 on the eastern flank is perturbed by a 1700 metres high seamount. It is difficult to date precisely the time when the ridge became extinct, as the activity of the ridge (i.e. spreading rates) probably decreased gradually from chron 25. A half rate of 1.2 cm/yr is deduced from the distance between chron 25 and 24. Extrapolation of this rate implies an extinction of the ridge at 51 Ma (middle of chron 23). A slightly younger chron, perhaps as young as

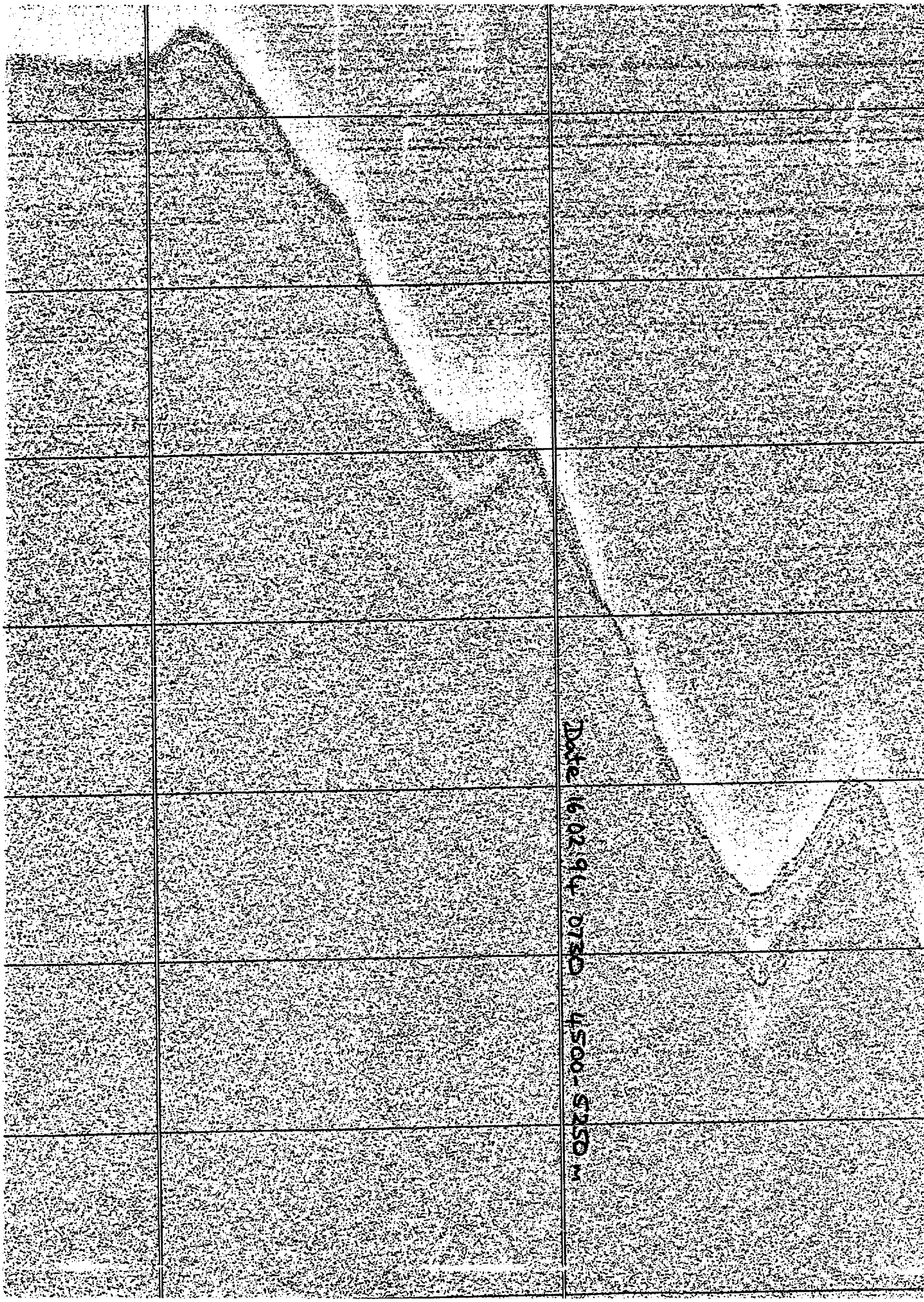
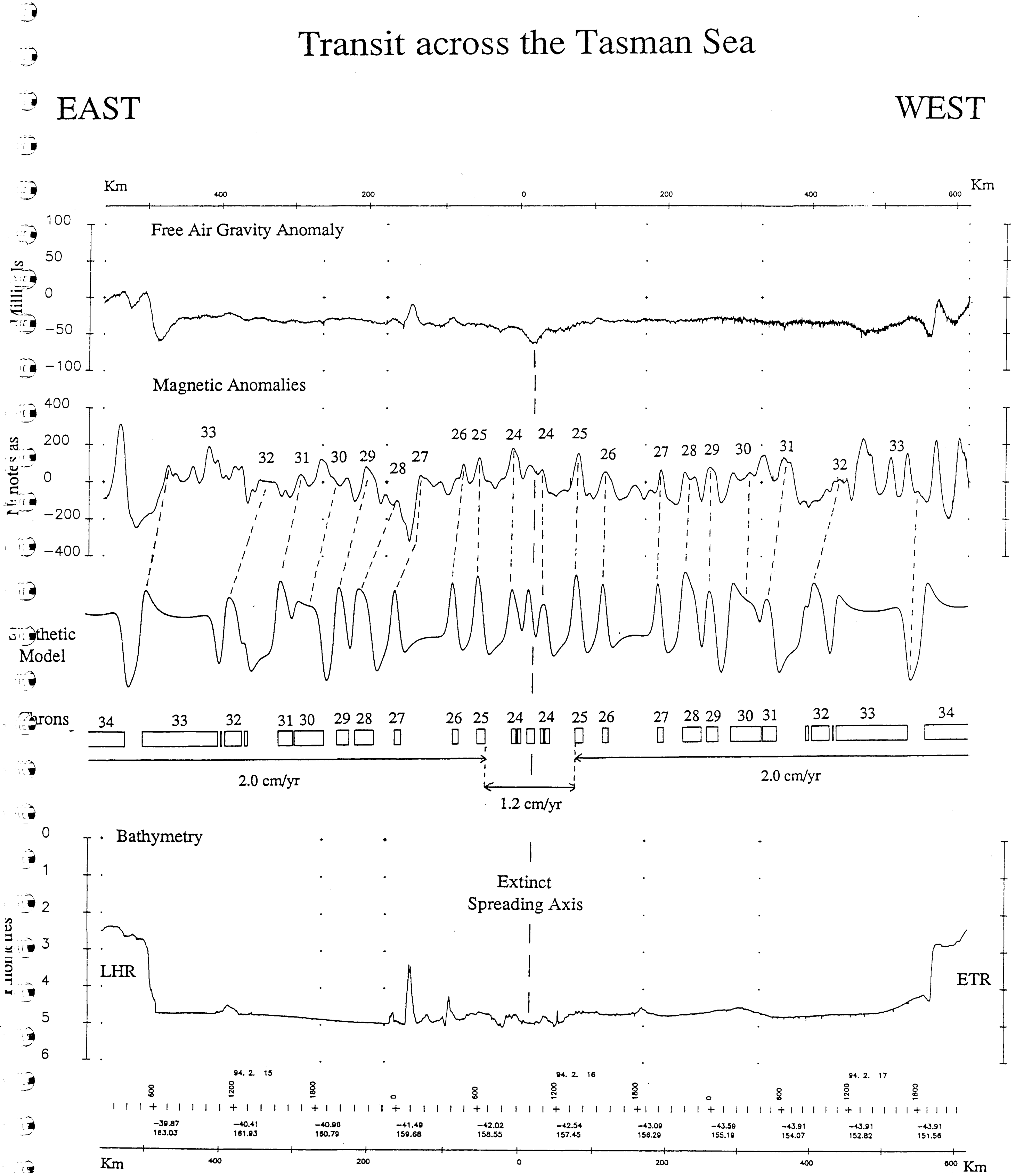


Figure 39. Echosounder profile from near the fossil spreading centre of the Tasman Basin, showing faulted and draped volcanic high.

Figure 40. Complete sequence of seafloor spreading anomalies across the Tasman Basin, related to free air gravity and bathymetric profiles. Anomalies range from chron 33 (79 Ma = Late Cretaceous) to chron 24/23 (52-50 Ma = middle Eocene). Half spreading rates were 2.0 cm/year for much of the time, but decreased to 1.2 cm/yr from chron 25. Location in Figure 21.



chron 22old (49.6 Ma), and a slower spreading rate could also account for the central magnetic anomaly corresponding to the fossil ridge axis. The extinction of the Tasman Sea spreading centres is likely to coincide with the onset of spreading between the Australian and Pacific plates; the oldest magnetic anomalies clearly identified north of the Macquarie plate boundary are chron 22, 21.

The *East Tasman Rise* is a large equidimensional feature of uncertain origin, from which the Soela Seamount rises. Our profile started to cross it westward from its eastern foot at 4300 m (1910 on 17/2/94), deviated to a southwest direction west of Soela Seamount (0236,18/2/94), and reached its southwestern foot at 3200 mbsl (0730), a length along the profile of 170 km. The gravity profile mimics the bathymetry for the most part, but points strongly to the natural limits on both sides of the plateau being those chosen above. The magnetic data also point to these limits and suggest that oceanic crust lies on both sides of the plateau. The difference in bathymetry of 900 m at the base of slope indicates that a more substantial wedge of younger sediment is sitting on oceanic crust to the southwest than to the east. The eastern flank of the East Tasman Rise forms a steep (14°) north-south scarp rising 1400 m to 2900 mbsl, and gives way to a gently rising terrace to the base of the Soela Seamount. Several small parasitic cones are evident, both on the flanks of the Soela Seamount and along the gently rising terraces to each side. The seismic profile shows sediment onlapping basement at the base of the eastern scarp, which consists of unbedded basement. Basement is downfaulted 0.5 seconds about 10 km west of the top of the scarp, and slopes down beyond that to allow accumulation of up to 1 second of fairly flat-lying younger sediments. These sediments look much like those on the abyssal plain to the east, with about 0.4 seconds of structureless material (Palaeogene?), overlain conformably by 0.2 seconds of moderately bedded sediment (also Palaeogene?), overlapped by 0.4 seconds of younger, well-bedded sediments (turbidites). Toward the foot of Soela Seamount, bedding becomes chaotic and basement rises to join this volcanic edifice, from which have been dredged Late Eocene shallow marine carbonates, and a volcanic conglomerate containing 40 Ma basalt clasts (Quilty & Jenkins, in prep.).

The steep eastern scarp of Soela Seamount rises from 2400 m to 700 m between 2335 and 2355. The top is relatively flat (a guyot) and 10 km across, culminating in less than 650 m of water south of (43°55.5'S 150°27.7'E, 0010, 18/2/94). The western scarp likewise falls steeply from 900 m to 1700 m between 0030 and 0046 (18/2/94). The complex slope further west is cut by another scarp trending 350° (a dyke?), and levels off at 2550 m (0125). The surface of the East Tasman Rise is flat until the end of profile 3, about 17 km further west. There is a maximum of 0.7 seconds of poorly bedded and disturbed sediment beneath the surface, probably derived largely as debris flows from the seamount. The sea bed continues at the same level for another 60 km (0700), and then falls sharply down a complex scarp that may contain a volcanic vent, from 2800 m to 3200 m (0735), and that delimits the rise.

The gravity and magnetic data (Fig. 25) suggest that the *depression between the East Tasman Rise and the South Tasman Rise* is oceanic. They also suggest that it extends from 0735 (18/2/94) to about 0000 (19/2/94). These positions are represented by gravity lows adjacent to the two rises, which themselves are associated with broad gravity highs. Between the marginal lows, the gravity values also are generally low. There are two major positive magnetic anomalies in the depression, one immediately adjacent to the South Tasman Rise. A small, undoubtedly volcanic cone 200 m high is at 44°22'S 149°16.5'E. Thereafter, there is an irregular gentle slope down to the edge of the flat base of the low between the East and South Tasman Rises, at 4050 m (1300). There is then a gentle rise westward to 3900 m (1900), and a more rapid one to 3250 m at 2100.

The seismic profile shows a confused jumble of faulted basement rocks with less than 0.8 seconds of sedimentary cover from 0735 to 1010 (18/2/94), from where basement drops away to up to 2 seconds below sea bed. Basement varies in depth considerably, but is not very rough on a small scale. It is overlain by a thick poorly bedded section (Palaeogene mudstone?) that is unconformably overlain by a well-bedded section up to 0.8 seconds thick, containing several unconformities (Neogene pelagic carbonates and turbidites?). A major positive magnetic anomaly is centred on 1400 above a gentle basement rise. From 1750 basement becomes more irregular and between 1900 and 1950 it forms a high less than 0.4

seconds below sea floor. The high is onlapped by the sedimentary sequences, with the poorly bedded sequence absent. A graben containing all sequences, and up to 1.8 seconds deep, lies between 1950 and 2040. Basement is shallow from 2040 to 2255, and crops out between 2130 and 2240 as a volcanic complex rises to 2500 m.

From its western foot at 2800 m (2240), the sea bed rises fairly rapidly to 2500 m at 0000 (19/2/94), the foot of a steeper slope. Another depression with up to 1 second of sediment is underlain by apparent oceanic crust to 2350, where it disappears, and at 0020 a deep reflector (probably continental basement) appears at greater depth (2 seconds below sea bed). The continent-ocean boundary (COB) may be at 2350; a large positive magnetic anomaly is centred on 2300, just east of there. The deep reflector rises steadily to be almost at the sea bed from 0140 and 0200, an area that is clearly part of the South Tasman Rise. This position (0200) marks a local high in the bathymetry of about 1900 m. The deep reflector drops down to almost 2 seconds below sea bed in a graben between 0200 and 0250. Above the deep reflector, both east and west of the high, is a complex sedimentary succession, unlike that above oceanic crust, in that the poorly bedded section is thin. There is a well-bedded section up to 1 second thick, containing complexly bedded sequences bounded by marked unconformities. Basement is at the sea bed from 0250 to 0345, where swath-mapping data show it to trend north-south, and to rise from 2000 m at 0250 to 1600 m at its culmination at 0330.

In summary, the depression is heavily but evenly sedimented. Basement is quite shallow near the two rises; if it is oceanic crust it is presumably supported by its contact with continental crust. Near the South Tasman Rise basement lies only 4 seconds (about 3000 m) below sea level. In the centre of the basin it lies 7.5 seconds (about 5600 m) below sea level. Near the East Tasman Rise it lies about 5 seconds (3750 m) below sea level. Magnetic and gravity evidence suggest that the COB could be as far east as 0735 on 18/2/94; seismic evidence shows undoubted oceanic crust extending 60 km less far to the east (1030 on 18/2/94). The evidence suggests that the COB on the western side of the depression could be as far west as 2300 on 19/2/94, the eastern edge of undoubted continental crust, or 90 km further east at the western edge of undoubted oceanic crust (1840 on 19/2/94).

A SWATH-MAPPING TRANSIT FROM WEST OF NORTHWEST TASMANIA TO SOUTH OF ADELAIDE

(N.F. Exon)

The transit (Fig. 23) from the abyssal plain northwest of Tasmania (40°42'S 141°23'E) to the upper continental slope south of Adelaide (37°09'S 138°16'E) was designed primarily to map the lowermost continental slope, including the locations of a number of earlier successful dredge hauls of Palaeozoic, Upper Cretaceous and Eocene rocks. It was planned using GEOSAT gravity imagery and the dredge locations.

Profile 67 was run to 252° away from the west Tasmanian *l'Atatalante* data grid (1400-1731 on *March 27*), and is about 60 km long. It started on the abyssal plain at 4900 m with the gentle slope of the continental rise about 15 km astern to the east. The elevation dropped slowly westward along the track to reach 5150 m (1500 to 1630), before rising to 4800 m (1700) and dropping again to 5150 m at the end of the profile (40°54'S 140°30'E; 1730). A rough ridge trending 260°, with its crest at 4400 m, parallels the track to the north from 1545 to 1730, and joins across the 4800 m saddle with two other ridges south of the track trending 280°, one of them less than 4600 m deep. Along the track the sedimentary sequence is more than 2 seconds thick to 1430, poorly layered, and little disturbed. There basement appears about 1.6s below the sea bed and is represented by a magnetic high and a gravity low. The upper part of the sequence is well-layered. Basement climbs steadily westward to reach the sea bed (1650), form a ridge 0.2 seconds high, and drop below the sea bed (1720). At the end of the track the sedimentary sequence is 0.4s thick.

Profile 68 to 345° is about 230 km long. From 2000 to 2045 the vessel slowed and the seismic streamer and magnetometer were recovered. Along the track the sediment gradually shallows from 5150 m to 5000 m, but the swath-mapping shows a ridge to the east and hills to the west. The ridge extends at least 80 km (1930-2330) at 335°, and crests at less than 4600 m; it is almost certainly a volcanic buildup on a relatively short fracture zone formed late in the Cretaceous or early in the Tertiary. The volcanic hills west of the track (2000-2230) are elongated to 310° and vary from 200 to 800 m high. They may be associated with the older Cretaceous fracture set. The sediment pile along the first 45 km of seismic profile, to its end (2000), is generally less than a second thick and highly variable because of basement highs coming to within 0.2 s of the surface (centred on 1800 and 1900). It is well-layered and contains several unconformities. There is some evidence of north-dipping layering in the basement. This profile coincides with a magnetic high.

Profile 69 to 310° started at 39°31'S 140°02'E (0120 on *March 28*). It is 230 km long and parallels the scarp at the foot of the continental slope. Along the track the sea bed is very flat and around 5000 m deep. The rather irregular slope to the northeast trends generally 310°, and the swath-mapping system mapped it up to an elevation of up to 1000 m above the abyssal plain (4000 m deep). Felsic volcanics and metamorphic rocks (Table 1) have been dredged from its southeasternmost end (BMR 67DR/9), indicating that it consists of continental rocks. The profile changed direction to 337° at 38°55'S 139°10'E (0533) and passed onto the abyssal plain, more than 5000 m deep away from the continental slope (0645-0730). Three dredges hauls (Table 1) were recovered on earlier cruises from the northwestern end of this segment of the lower slope, which totals 130 km in length. Sheared mudstone of Palaeozoic or Mesozoic age was dredged at BMR 48DR/6, black slate and mudstone from BMR 67DR/7, and early Eocene restricted marine mudstone from BMR 67DR/6.

After a gap of 20 km, where the continental slope steps back to the east, it reappears trending 310° at 38°30'S 138°56'E (0740). There the course changed to 316° and the track ran along the lower slope for 50 km, surveying the slope between the abyssal plain (5000 m) and the mid slope (3200 m). The slope is about 5°. Upper Cretaceous shallow marine mudstone and siltstone had been dredged at three locations on this part of the lower slope (Table 1), in water depths exceeding 4000 m (BMR 67DR/3, 4 & 5). The profile changed direction to 345°at 38°10'S 138°33'E (0945) and steadily moved up the continental slope until 13°17'S 138°17'E (1358), where the water depth beneath the ship was 1000 m. Along this part of the profile about 100 km long, the slope consists of several segments trending 310°, apparently cut by faults trending about 280°. A series of southwesterly trending canyons, 200-400 m deep, run down the slope between 37°45'S and 37°30'S; upper Eocene marine mudstone (Table 1), laid down on the continental slope, had earlier been dredged from one of them in about 4000 m of water (BMR 67DR/2).

There was a course change up-slope to 360° onto profile 70 (1358), and this ended at 37°09'S 138°16'E (1439 on *March 28*) when all equipment was turned off in 600 m of water. A canyon 200 m deep is apparent in the upper slope from less than 600 m to more than 2200 m; it runs initially south and then southwest, and marks a change in the strike of the slope from 315° in the southeast to 280° in the northwest.

In summary, the transit is interpreted as starting on old, heavily sedimented, highly extended continental crust northwest of Tasmania, in a belt about 25 km wide and trending 320° (Profile 67). To the west is less sedimented Early Tertiary oceanic crust, formed by spreading in the 350° direction, and including oceanic hills trending 280°. To the northwest is a ridge on oceanic crust, at least 80 km long, trending 335° and almost certainly a volcanic buildup along a fracture zone related to the younger period of spreading (Profile 68). A dozen kilometres to the west are three abyssal hills, elongated to 310° and possibly volcanic buildups related to the older period of spreading.

Most of the remainder of the transit to the NNW, nearly 350 km in total, was along the foot of the continental slope (first 210 km) or moving at an angle up the slope (Profiles 69 & 70). A segment 130 km long trends 310°, and continental rocks have been dredged from it. After a gap of 20 km, representing fault displacement, the slope reappears and the profile gradually moves up it. It generally consists of continental segments trending 310° and displaced by faults trending about 280°. A series of canyons run down the slope due west of Beachport, and another canyon marks a change westward in slope trend, to 280°. It is clear that the swath-mapping of the continental slope shows many primary structures, heavily modified in places by sedimentary processes. Offsets of 10-20 km occur in the foot of the slope and may represent transfer faults. Palaeozoic, Mesozoic and Tertiary rocks, largely sedimentary, crop out in the lower slope, and pre-existing seismic data indicate that these form stratified sequences dipping back into the slope.

Table 1: Pre-existing BMR dredge stations along *l'Atalante* traverse on Otway Basin margin

Station	Latitude (S)	Longitude (E)	Water depth(m)	Description or comments
67/DR02	37o40.3' 37o37.7'	138o16.8' 138o19.6'	4100-3800	Late Eocene & Early Oligocene grey sandy siltstone
67/DR03	38o14.6' 38o14.0'	138o36.0' 138o38.4'	4500-4000	Indurated Campanian (L. Cretaceous) marginal marine dark brown to grey siltstone in Fe oxide crust; plastic dark brown Early Eocene mud to silty claystone
67/DR04	38o26.7' 38o24.3'	138o49.6' 138o52.3'	4700-4050	Dark grey Campanian (L. Cretaceous) marginal marine laminated mudstone; mid grey siltstone in Fe oxide crust
67/DR05	38o25.4' 38o24.3'	139o54.7' 138o55.8'	3900-3850	Dark grey Late Cretaceous siltstone, shale, claystone with ammonites including *Gaudryceras* sp
67/DR06	38o45.4' 38o46.2'	139o08.9' 139o09.0'	4660-4450	Black Early Eocene restricted marine non-fissile mudstone, Mn crusts to 4 mm
67/DR07	38o47.4' 38o47.8'	139o12.4' 139o12.1'	4450-4200	Black ?Late Cretaceous slate, brown mudstone, 2 mm Mn crust
67/DR09	39o27.0' 39o26.6'	139o59.3' 139o59.9'	4800-4300	?Palaeozoic metaquartzite, metashale, quartz veined felsic volcanics, coarse felsic tuff *
48/DR06	38o49' 38o48'	139o10' 139o11'	4200-3750	?Palaeozoic sheared hard grey-green mudstone with quartz veins and ?plant remains; minor black mudstone *

* Location and depth modified to fit swath-mapping results

SWATH-MAPPING AND UNDERWAY GEOPHYSICS OF THE SOUTH TASMAN RISE AND WEST OF TASMANIA

(P. J. Hill, N.F. Exon & J.-Y. Royer)

Swath-bathymetry and acoustic backscatter

This account of the swath-mapping results over the main survey area is intended as an overview. Aspects of the morphology of the South Tasman Rise and Cape Sorell area are discussed in further detail in the following section on sedimentology.

The survey (Figs. 4 & 41) covered (i) the central, western and northern parts of the STR, and (ii) the western and southern margins of Tasmania from the upper continental slope (water depths of several hundred metres) to the western abyssal plain at 5 km depth and across to the STR in the south. The single-swath transit line from the East Tasman Rise (ETR) to the STR provided additional useful data to the southeast of Tasmania. The shipboard swath bathymetry is combined with conventional gridded 5' x 5' bathymetric data (ETOPO5) in Figure 42.

The summit area of the STR is dome-shaped and gently sloping. Down to the 1400 m isobath, it is about 150 km across. The summit is fairly flat at about 800 m depth, though several hillocks are as shallow as 725 m. The acoustic imagery suggests that the summit area is mostly covered by pelagic sediment; rocky outcrop comprises about 40%. Canyons, typically about 50 m deep, run down the northern and northeastern flanks of the Rise from about the 1500 m isobath. A number of conical hills on the northern flank are probably volcanoes. They are 200-300 m high, 3-4 km across and show high backscatter (and are therefore rocky). The northern flank is crossed by a NW-trending basement ridge and escarpment that are largely bare of sediment cover.

The deep ocean basin between the ETR and the STR has a flat, sedimented floor. The floor of the basin lies at water depths of 3950-4150 m and is about 120 km wide.

The western and northwestern STR is an region of diverse and spectacular topographic relief. The most prominent structural feature is the NNW-striking lineament of the Tasman Fracture Zone, separating the high-standing continental rocks of the STR from Paleogene oceanic crust at abyssal depths (4000-4800 m) to the west. The lineament is 600 km long and consists of a narrow (20 km wide) zone of high-relief ridges, troughs and escarpments. The scarps are 2-2.7 km high in places. Another transform escarpment, 1500 m high, is located at the extreme southwest corner of the STR. It parallels the Tasman Fracture Zone but is offset 50 km to the east. Its mapped length is 100 km. The abyssal plains (4000-4600 m depth) adjacent to the southeastern part of the STR are relatively flat-lying and appear to be mostly sediment covered, yet they produce fairly high acoustic backscatter and appear quite dark in the acoustic imagery. This suggests that either they may be covered by a pavement of manganese nodules and/or crust or that deep-sea currents have scoured the seafloor, perhaps leaving coarse lag deposits.

The swath data over the oceanic crust west of the Tasman Fracture Zone clearly display the E-W oriented spreading fabric. The acoustic imagery shows that the sediment cover is moderate to thin in the north and only a veneer or absent in the south. The repeated series of horst and grabens are produced by normal faults generally spaced 2-8 km apart. The fault scarps are typically 100-300 m high. The most pronounced spreading fabric terminates against a well-defined oceanic transform fault that lies just west of the Tasman Fracture Zone. This transform meets the Tasman Fracture Zone at a slight angle (6°).

The more elevated (3500 m depth or less) central and southern parts of the western STR are of moderate to gentle relief and mostly sedimented by pelagic cover. Some patches of bedrock outcrop are present at escarpments. A line of such outcrop trends NNE through this area. The northwestern part of the STR is a jumble of large basement blocks probably produced by wrench movements. Relief is high, often 500-1000 m, and about 40% of the seafloor appears to be exposed bedrock. A large, 1500 m high seamount at 45° 10'S 146° 00'E has little sediment cover and may be a volcano.

The continental slope immediately south of Tasmania, from ~700 m depth (upslope limit of mapping) to more than 3200 m in the saddle between Tasmania and the STR, is of rugged topography. Extensive rock exposures are present on the upper part of the slope, which is also cut by a number of jagged canyons up to several hundred metres deep. The most remarkable feature of the slope is a large field of volcanic cones in water depths of 900-2300 m. Most cones are clustered in the one field, but other more isolated cones are also present. More than 70 cones have been mapped. The cones are typically 400 m high and several km across. The larger ones are about 600 m high. Some of the cones have flat tops which could

Shipboard swath-bathymetry

Figure 41. Contour map of offshore Tasmanian region from shipboard swath bathymetry. 1' x 1' grid generated on board giving contours every 0.2 km, annotated every 1 km. Mercator projection.

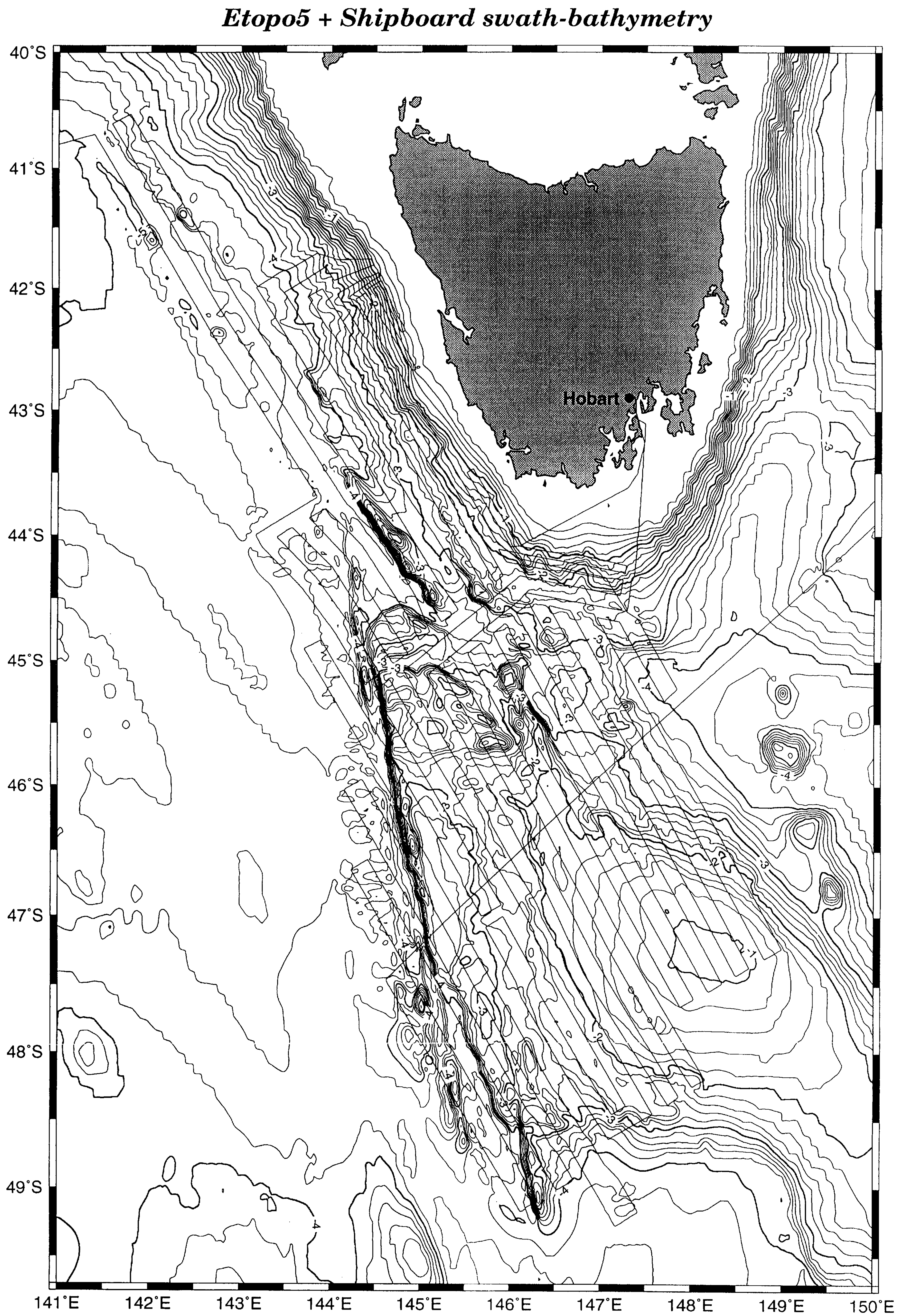


Figure 42. Contour map of offshore Tasmanian region from merged conventional bathymetric data (ETOPO 5) and swath bathymetry. 5' x 5' grid for ETOPO5 and 1' x 1' grid for swath bathymetry. Swath bathymetry has precedence. Mercator projection.

be summit craters (?now filled with pelagic sediment) or perhaps these cones were planated by subaerial erosion prior to submergence as the margin sagged.

Off western and southwestern Tasmania, the continental slope is mostly blanketed by an extensive sheet of sediment. The slope is incised by an extensive system of linear to curvilinear, 100m-deep canyons that extend 60 km or more from the shelf edge to depths of several thousand metres. A 50 km wide and 300 m deep depression on the upper slope off southwest Tasmania (centred at about 43° 10' S 145° 00' E) is probably the scar of a massive submarine landslide. Several local highs were mapped on the southwestern mid-slope. Strong acoustic backscatter from parts of these (particularly their down-slope sides), suggests exposed bedrock. A series of local highs and NW-trending ridges rise above the relatively gently inclined lower slope and flat abyssal plain in water depths of 3500-5000 m. Many of the highs are partially covered by sediment. However, most of these features are of high relief and as a result the steeper slopes have remained sediment-free. The largest of these highs is a 160 km long ridge on the lower southwest continental slope. It stands up to 2.5 km above the surrounding seafloor and the slope of its southwest side (~24°) is considerably steeper than that on the northeast (~6°).

Reflection seismic

A preliminary map of sediment time-thickness and basement structure (Fig. 43) has been produced for the entire Tasmanian/STR survey area. This map is based on the *Tasmante* monitor seismic records, but also includes data from earlier surveys. The earlier data sources include *Sonne* survey SO36B (Hinz et al., 1985; Hinz et al., 1986), AGSO *Rig Seismic* survey 78 (Exon et al., 1989A) and interpretations based on oil company surveys on the west Tasmanian continental shelf (Moore, 1991; Moore et al., 1992). Features mapped in Figure 43 have been constrained or guided by structural information from the *Tasmante* swath-bathymetry and acoustic imagery, as well as lineations seen in GEOSAT satellite gravity data. The sediment thickness shown in Figure 43 is that visible in the seismic profiles, and so represents minimum sediment thickness. Processing of the *Tasmante* data (to 6-fold stacks), which is now in progress, should improve the data quality of the profiles and could reveal greater sediment thickness over some parts of the survey area.

The structural pattern over the area is generally complex, though two main structural trends stand out. These trends are NW at about 325°, and NNW at about 350°. The 350° structures exist mainly along the western margin of the STR and are clearly related to Eocene crustal extension and Southern Ocean seafloor spreading (roughly in a N-S direction). A slightly more northerly (~356°) trend is also present in the southwest part of the survey area, where a major, relatively young transform fault within oceanic crust has this orientation. The 356° trend may represent the local Oligocene (?and younger) seafloor spreading direction. The 325° trend predominates off west and southwest Tasmania. This structural trend is less well-developed directly south of Tasmania and over the STR. Over the STR, a subsidiary and more westerly trend (~310°) is evident. It may have resulted from rotation of structures originally trending 325°.

The most sedimented part of the survey area is the continental slope off west and southwest Tasmania. The section includes both syn-rift (mainly Cretaceous) and Cainozoic post-breakup deposits. Sediment thickness from the shelf to abyssal depths (as much as 5000 m) is 1.5 s twt or more almost everywhere in this region; extensive areas have more than 2.0 s of section (Figs. 44 & 45). The adjacent continental shelf is underlain by the wrench sub-basins of the Sorell Basin (Moore et al., 1992). All of these sub-basins (King Island, Sandy Cape, Strahan and Port Davey Sub-basins) contain more than 3 km of section, but the intervening and adjoining shelfal areas have less and very variable sediment thickness. Many of the basement highs beneath the shelf have less than a few hundred metres of cover.

The area immediately south of Tasmania has several small, though fairly deep (> 1.5 s twt), fault-bounded depocentres. In general, however, this area of high relief has little sediment cover. Some of the shallow

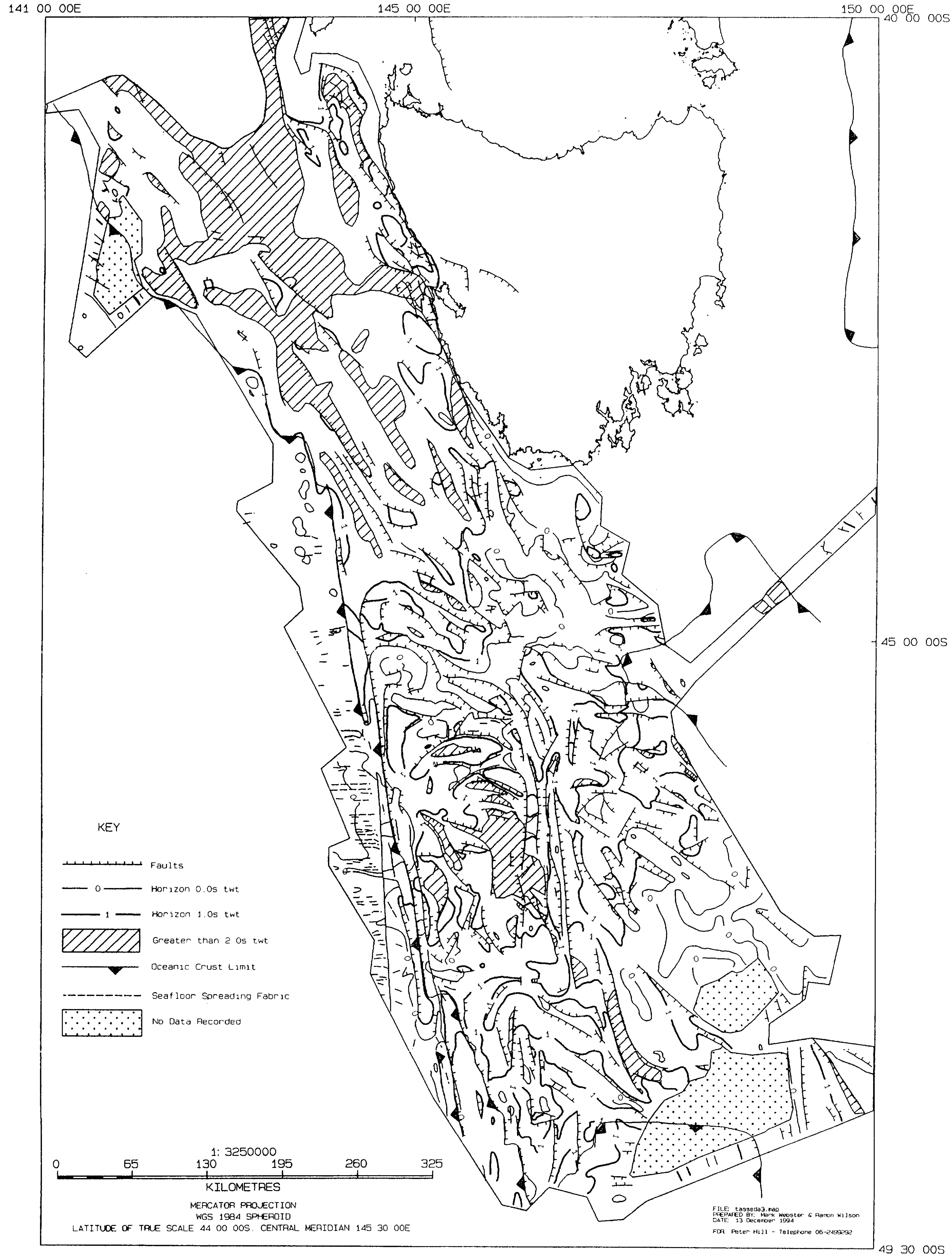


Figure 43. Structural and sediment thickness map of offshore Tasmanian region, based on interpretation of *L'Atalante* and *Sonne* reflection seismic data. Also takes account of *L'Atalante* swath maps and satellite gravity data.

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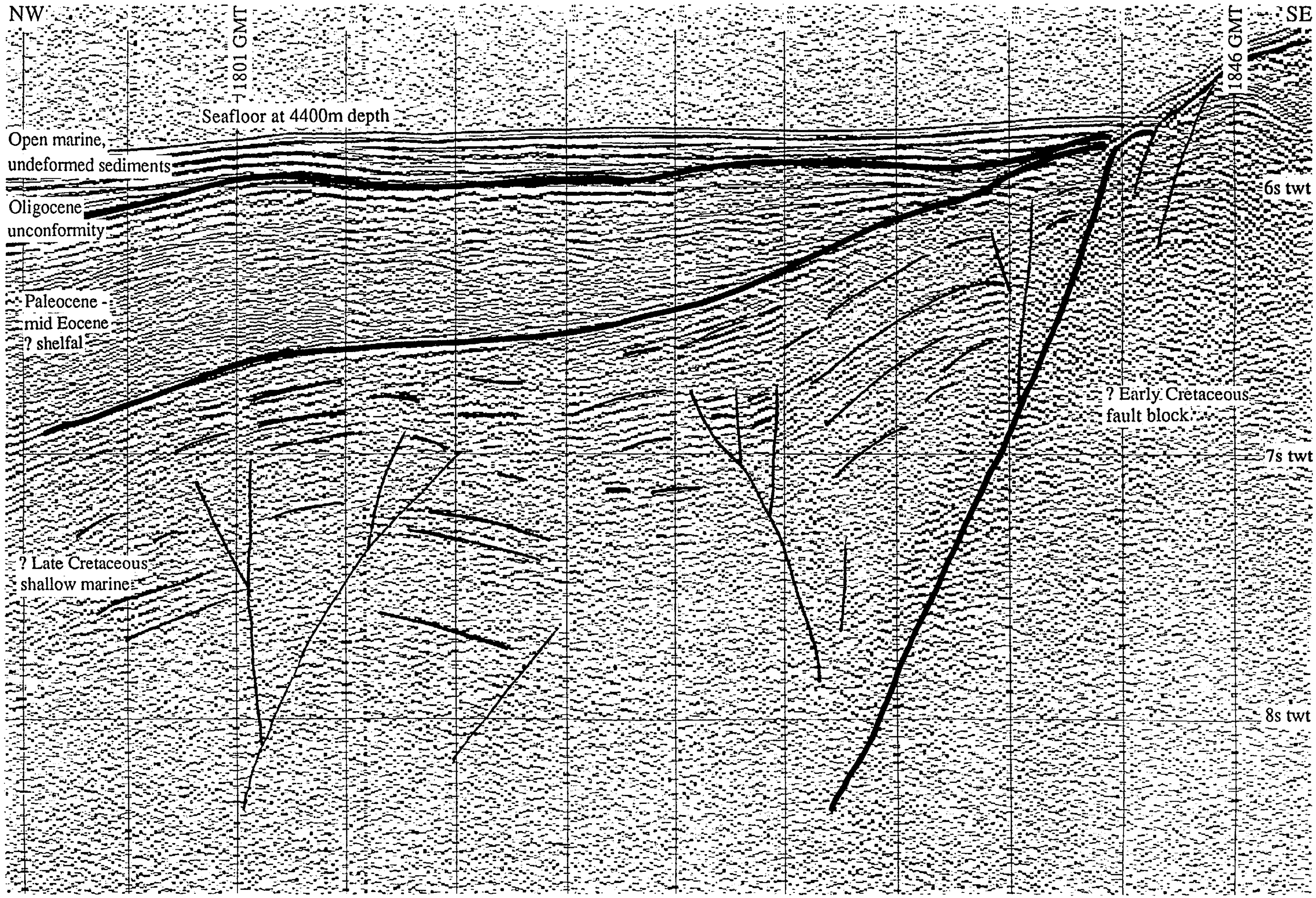

Figure 44. *Tasmante* seismic profile 55 showing thick wrenched section adjacent to continental fault block on lower west Tasmanian margin.

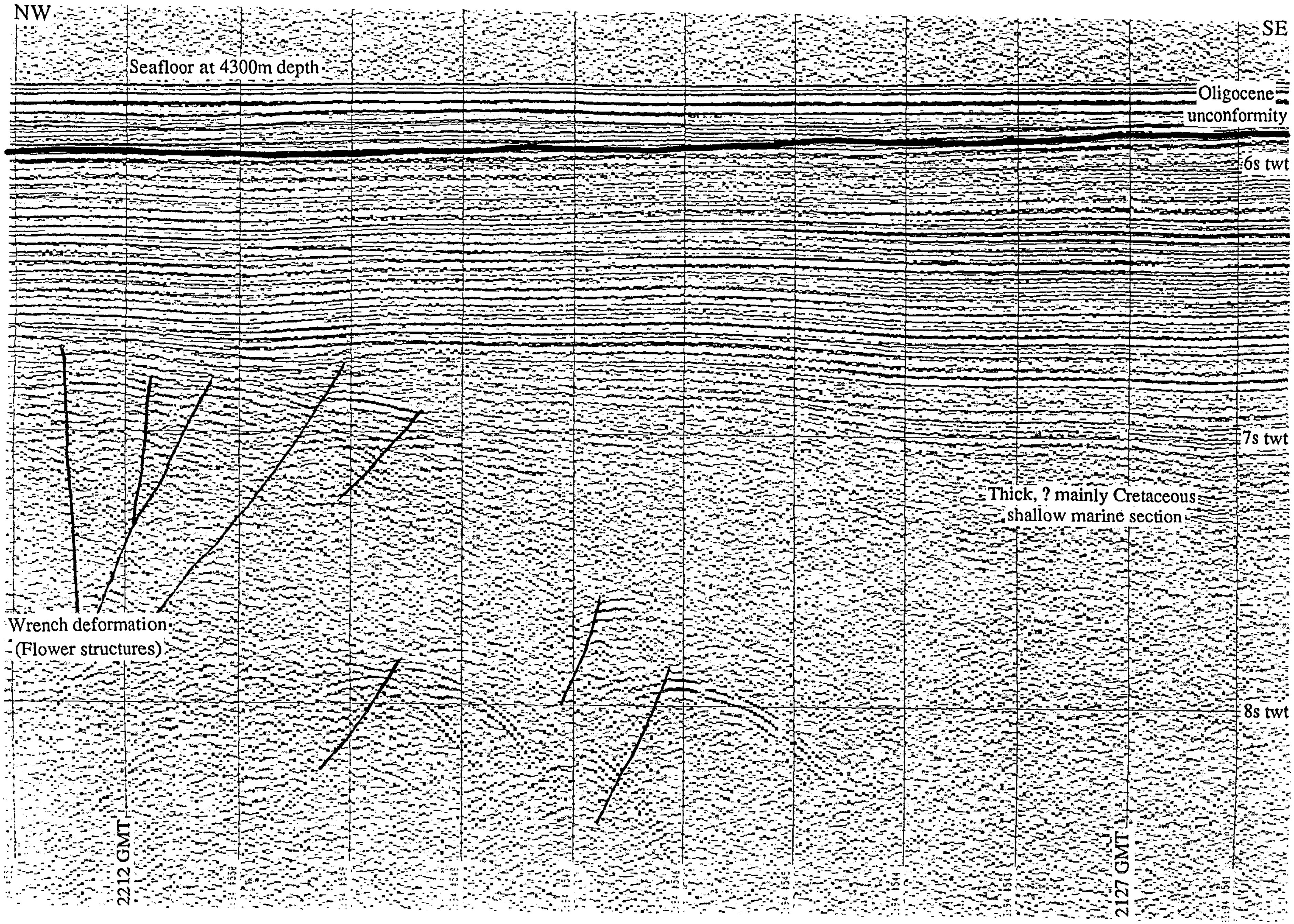

Figure 45. ***Tasmante*** **seismic profile 60 showing very thick partly deformed section southwest of Tasmania.** Lies at junction of 325° and 350° structural trends, 20 km east of the continent-ocean boundary.

basement here may be similar to the Precambrian and early Palaeozoic terrain onshore. However, it is likely that much of seismic basement may be volcanic as suggested by the presence in the swath imagery of numerous ?Tertiary volcanic cones and other edifices in this area.

The summit area of the STR, where water depths range from about 800 to 1200 m, is poorly sedimented with either basement outcrop or a cover of less than several hundred metres of late Cainozoic sediment.

The western margin of the STR is a very complex structural province. Basement faults are generally closely highly spaced and vary greatly in orientation. Much of the structure was imparted by wrench movements and crustal extension during the Late Cretaceous (?) and early Tertiary as the Australian and Antarctic plates separated. Many of the numerous transtensional rift graben in this area are relatively narrow, but often very deep, and contain sedimentary sequences commonly 2.0 s twt or more in total thickness. The largest sub-basin in this area is located on the northwest STR in water depths of ~2000-2600 m. It is about 140 km long and 70 km wide.

Pre-late Oligocene deformation of the sedimentary section is almost ubiquitous throughout the survey area. This deformation, believed to be largely wrench related, is commonly relatively mild - with small-scale faulting in flower structures and gentle local folding of the section (Figs. 44 & 45). However, along the western margin of the STR the wrench deformation is often considerably more severe. Transpressional forces acting on the narrow, once-transtensional basins have, in many places, strongly faulted and folded the basin-fill (Fig. 46). Uplift of parts of the basins has often led to subaerial/wave-base erosion and truncation of the section, particularly at the Oligocene unconformity (Fig. 47).

The continent-ocean boundary (COB), here defined as the 'landward' limit of pure oceanic crust, is indicated in Figure 43. It has been mapped mainly on the basis of seismic character and depth of basement. Evidence of stratification in fault blocks, as well as considerations such as structural fabric and magnetic expression were also taken into account in differentiating 'oceanic' from 'continental' crust.

West of Tasmania, the COB lies well out (about 200 km) from the coast and in very deep water, 4600-5000 m depths. The oldest magnetic anomaly identified with a fair degree of confidence adjacent to the COB is 19, suggesting that full-scale spreading did not start here until the mid Eocene. Though modified by ?transform offsets, the trend of the COB is approximately 325°, parallel to continental rift structures on the adjacent slope. The COB is marked by a series of 'basement' highs, some of which appear to be volcanic and others continental in origin (Fig. 48). A second ridge or series of 'basement' highs lies 30-70 km landward of the COB. This 'base-of-slope high' consists predominantly of elevated continental fault blocks. The 30-70 km wide zone is believed to be a continental/oceanic transition zone underlain by a mixture of highly thinned continental crust and oceanic/rift volcanics. The mid Eocene pillow basalt drilled at DSDP Site 282 (Kennett, Houtz et al., 1975A) located on the 'base-of-slope high' was probably extruded at the time of maximum extension of the continental crust, i.e. at the onset of seafloor spreading.

South from 43° 50' S the COB changes direction to ~350° and coincides with the Tasman Fracture Zone, a dramatic topographic lineament with over 2 km relief that separates continental rocks of the STR from Eocene-Oligocene oceanic crust. Slivers of continental crust, apparently detached during transform motion along the Tasman Fracture Zone, lie adjacent to the transform COB. The oceanic terrain west of the STR is characterised by a distinct spreading fabric comprising E-W oriented volcanic ridges and troughs with little or no sediment cover. Sediment thickness over the oceanic crust generally increases northward to the 325°-trending COB, where the thickness is mainly about 0.5-1 km. Some pockets adjacent to the COB may be up to 1.5 km thick. The thickness is greater in the north, because of a terrigenous influx from Tasmania and because the crust is older and so has accumulated more pelagic cover.

Oceanic crust immediately south of the central STR was probably emplaced at the same time that spreading occurred adjacent to the 325°-trending COB southwest of Tasmania. At DSDP Site 280, about

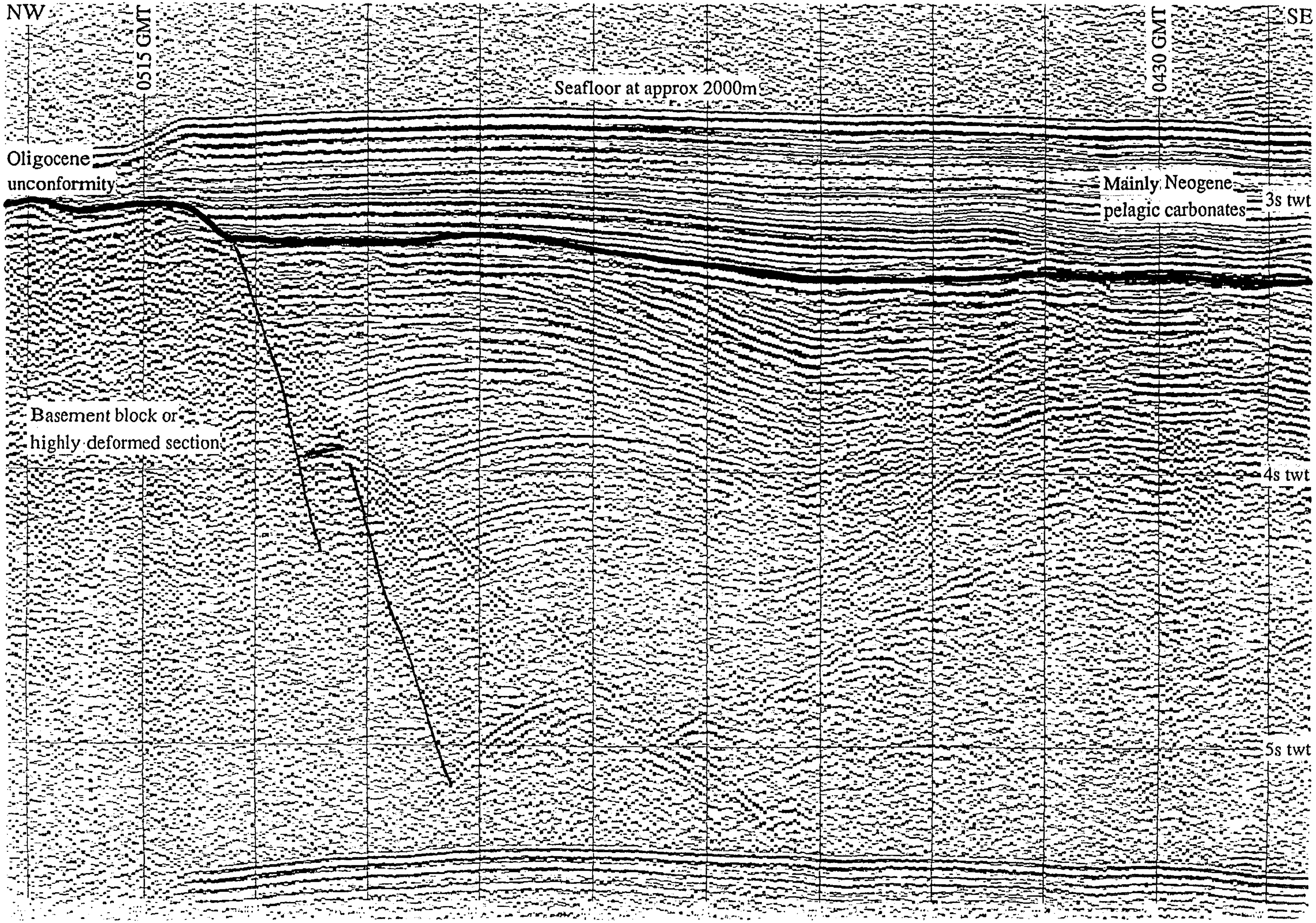

Figure 46. ***Tasmante*** **seismic profile 16 from the western South Tasman Rise.** Shows a deep Late Cretaceous to Paleogene basin folded and faulted by wrench movements, and overlain by relatively flat-lying late Oligocene and younger pelagic carbonates.

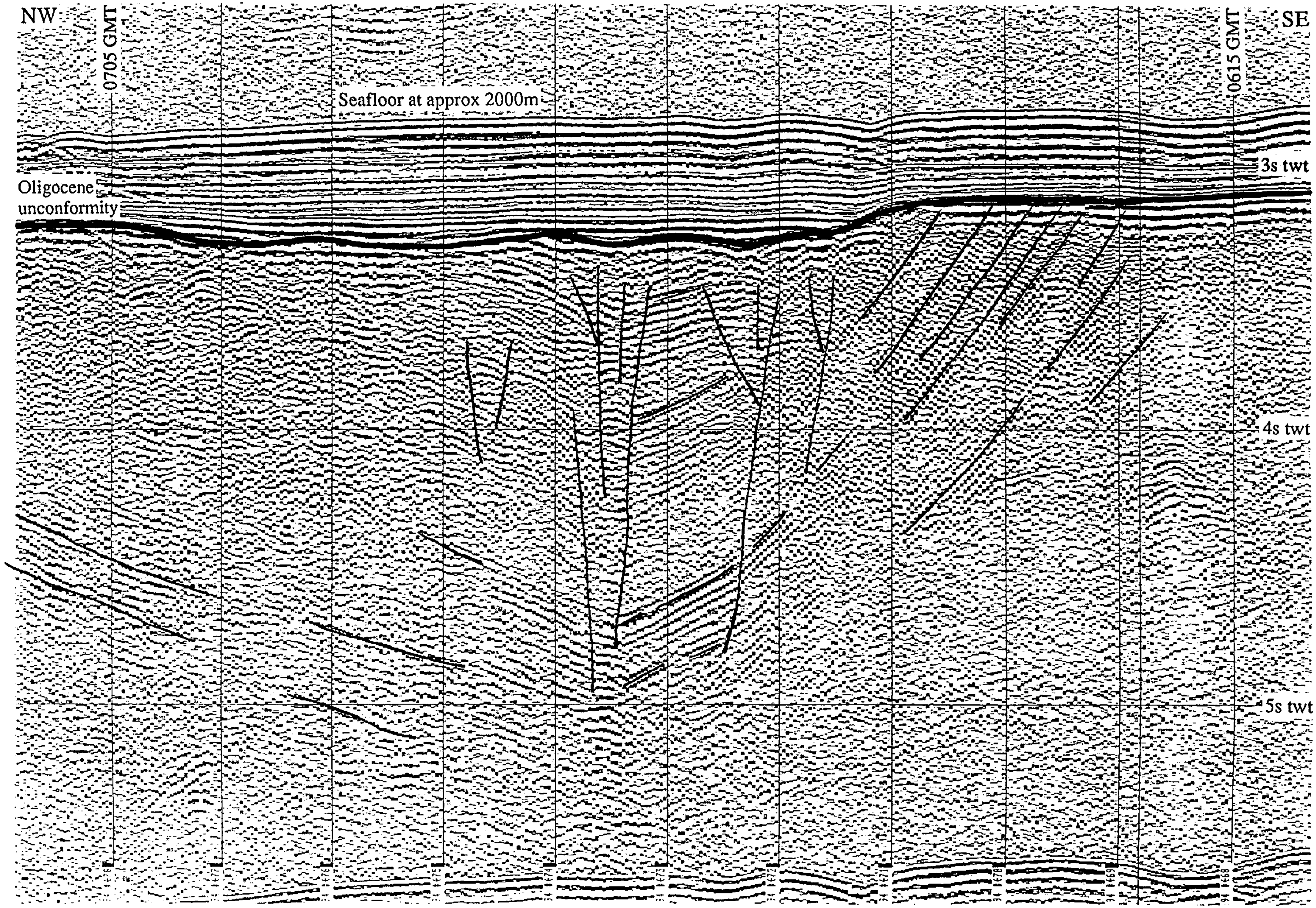

Figure 47. *Tasmante* seismic profile 16 from the western South Tasman Rise. Shows strong wrench deformation (folding and faulting)of thick sedimentary sequence beneath the Oligocene unconformity.

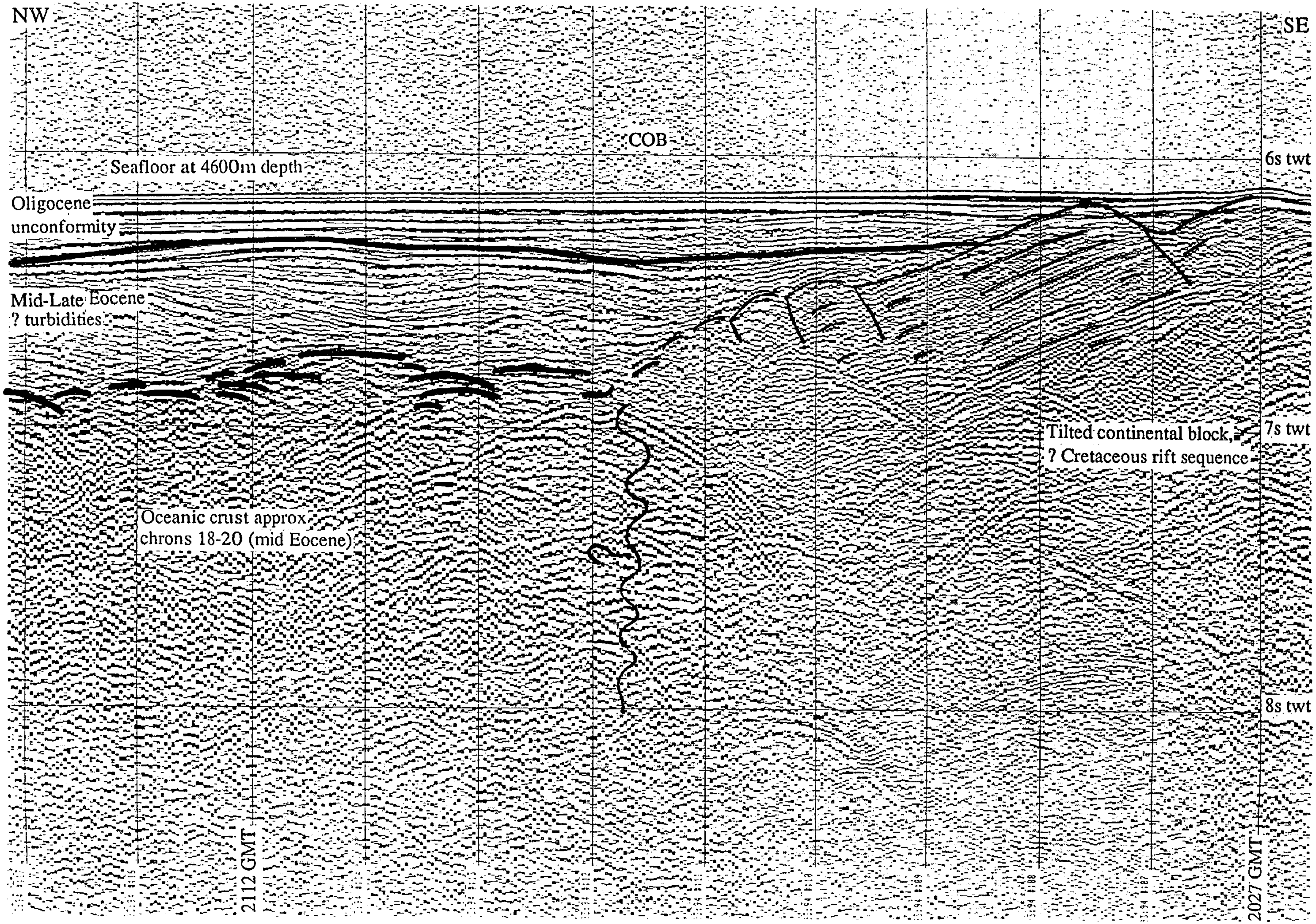

Figure 48. *Tasmante* seismic profile 66 showing continent-ocean boundary off west Tasmania.

40 km south of the mapped COB, sediment immediately above basalt basement was dated as early to mid Eocene (Kennett, Houtz et al., 1975A). Though poorly constrained by the limited available data, the spreading fabric appears to trend roughly E-W. Sediment cover over oceanic basement is much the same as at the 325°-trending COB southwest of Tasmania, and the same southward-thinning pattern is seen here. Local thick sediment accumulations (~2 s twt) at the COB may have been sourced from a then-emergent STR, and channelled south via south and southwest-trending graben.

The age of the oceanic basin southeast of Tasmania, between the East Tasman Plateau (ETP) and the STR, is uncertain. It was probably created sometime between mid Cretaceous and Eocene, in conjunction with either Southern Ocean or Tasman opening. The direction in which it opened still needs to be established. Existing data coverage is too sparse to permit mapping of magnetic lineations and their orientations. The basin is thickly sedimented (Fig. 49), with more than 2 s twt commonly adjacent to the COB. The thick section suggests that the basin is relatively old (mid/Late Cretaceous rather than Eocene). However, the substantial thickness of the sediment pile could be explained by a plentiful sediment supply originating from the elevated and adjacent ETR, STR and southeast Tasmania.

Magnetics and gravity

The total field profile data, IGRF-reduced, are shown as smoothed magnetic anomaly contours in Figure 50. No corrections for diurnal variations or magnetic storms have been made. Free-air gravity anomaly, computed from the shipboard gravity data, is presented in Figure 51 at 10 mgal contour interval. This preliminary map was generated from gravity values corrected for ties only at Noumea and Hobart.

The shipboard free-air gravity contours reflect subsurface density changes, particularly variations in seafloor topography, crustal thickness and sediment thickness. As expected, the shipboard gravity (Fig. 51) and GEOSAT gravity (Fig. 52) show strong relative correlation. The main gravity features of the region have been discussed elsewhere in this report.

Magnetic anomalies over the survey area range between about -400 and +400 nT. The Tasman Fracture Zone and adjacent area has strong associated anomalies. These anomalies, many over 100 nT in amplitude, are due to Paleogene seafloor spreading anomalies (field reversals during emplacement of oceanic crust) and magnetic contrast at the oceanic/continental crust interface. The western and northwestern flanks of the STR are characterised by a prominent set of large north to NNE-trending magnetic highs that extend right across the Rise from margin to margin. These anomalies may have been enhanced by N-S directed Paleogene wrench movements on the western part of the STR. However, it is likely that the anomalies result mainly from a much older structural grain in the underlying continental crust. The anomalies on the STR bear some resemblance to, and may even be related to, the large-scale north and NNE-trending aeromagnetic anomalies mapped over the Precambrian to early Palaeozoic terrain of onshore western and northwestern Tasmania (BMR/Tas. Dept of Mines: Tasmania, Total Magnetic Intensity Contours, 1:500,000, 1988).

The magnetic field over the summit area and northern part of the STR is disturbed and includes a number of high amplitude anomalies. Apart from the indication of a moderate NW-NNW trend, there is no distinct pattern to the anomalies.

The field over the continental slope off west Tasmania is relatively subdued. A factor contributing to this over the lower slope would be the great water depth (to ~5 km) and the thick sediment pile. The large, 160-km long, NW-trending ridge southwest of Tasmania (44.0°S, 144.7°E) is poorly expressed in the magnetic data, suggesting that it is composed of sedimentary rather than igneous rocks.

The tectonic chart (Fig. 53) shows fracture zones and lineations identified from satellite gravity data, and a new identification of magnetic anomalies by Royer and Rollet. It shows that Tasman Basin spreading started at chron 33 (79 Ma = Campanian = Late Cretaceous). It also suggests that west and south of

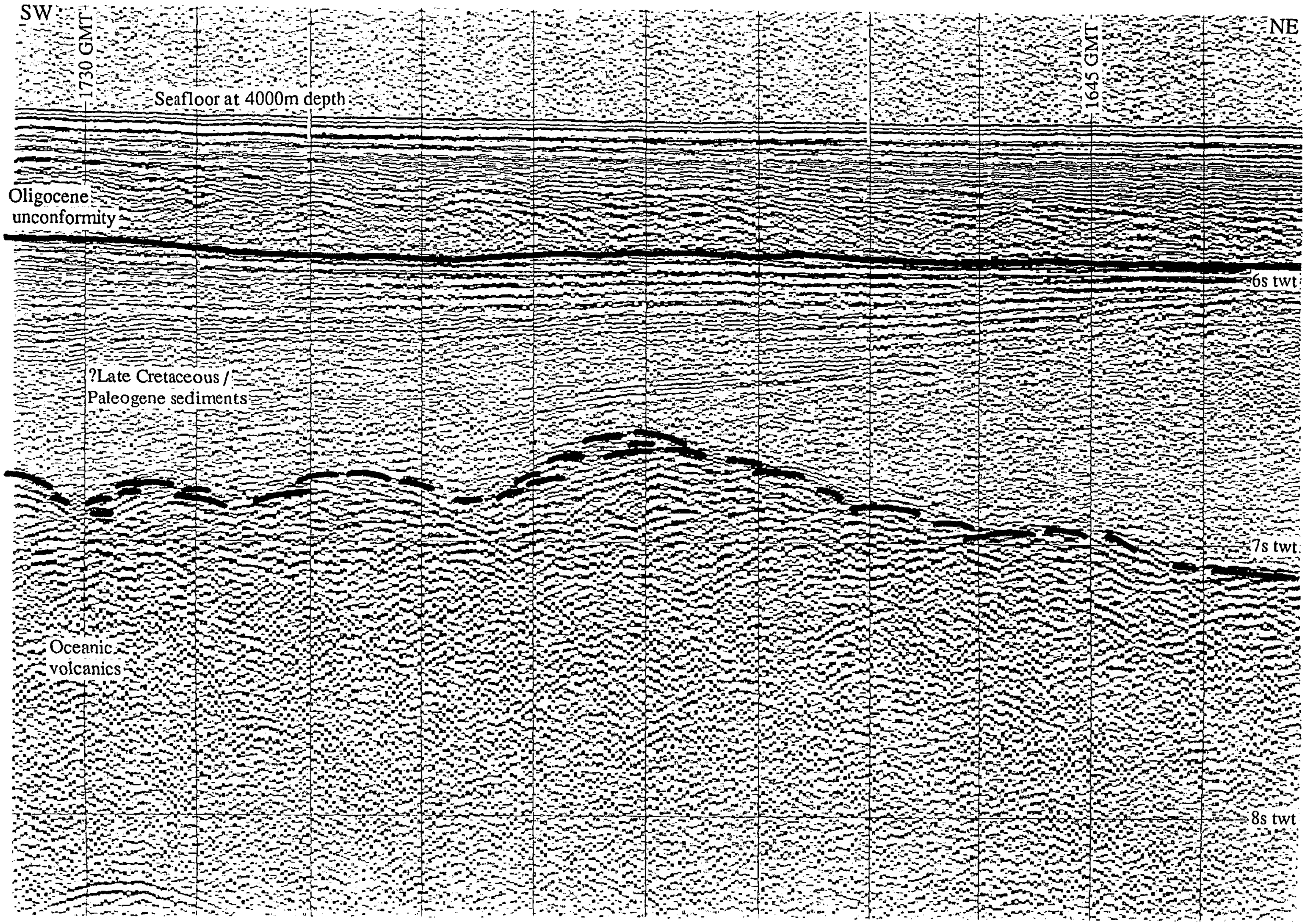

Figure 49. Tasmante seismic profile 4, showing thick sedimentary section in oceanic basin. Lies between South Tasman Rise and East Tasman Rise.

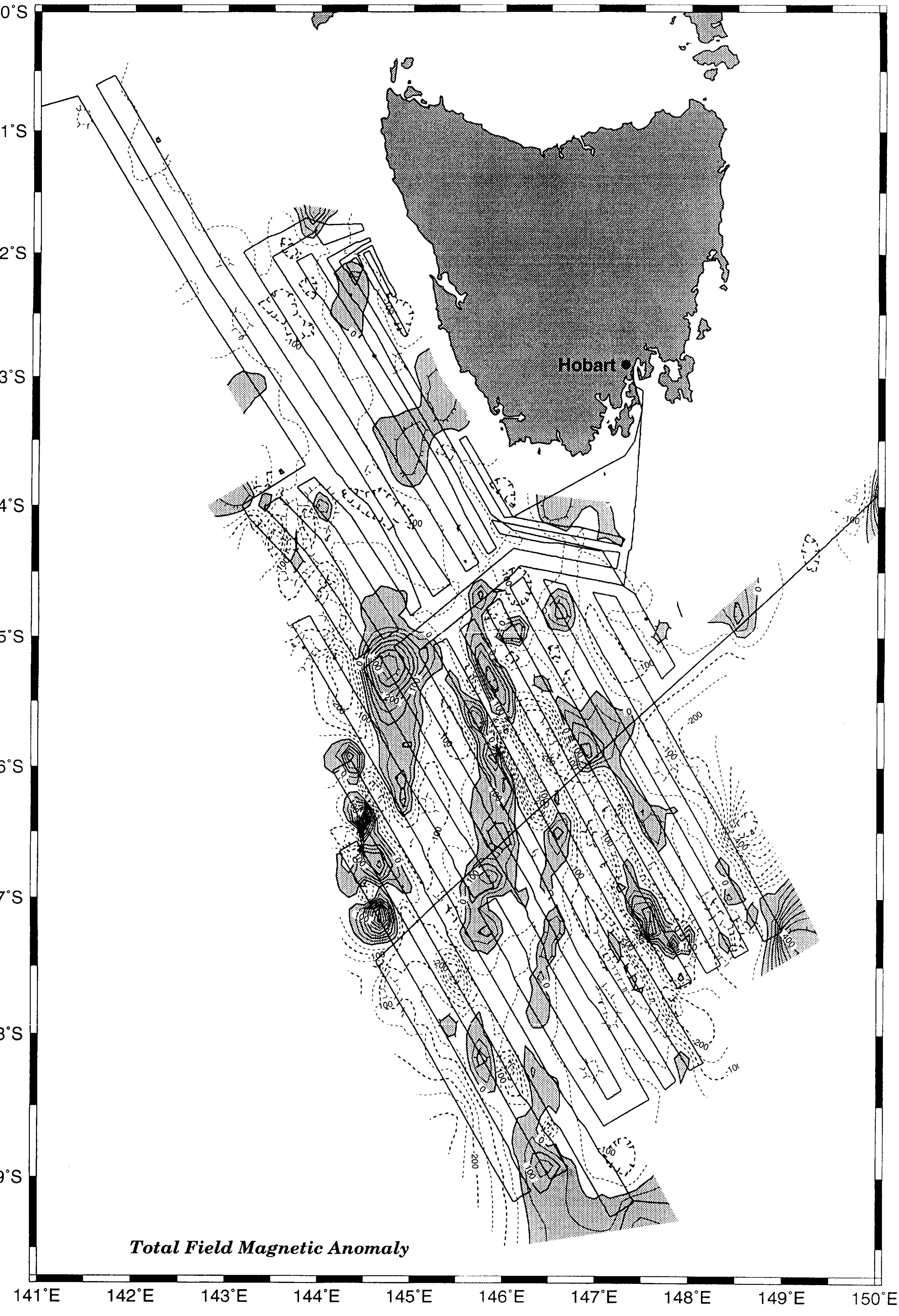

Figure 50. Shipboard magnetic anomaly contour map of offshore Tasmanian region. 5' x 5' grid based on the residual magnetic anomaly calculated. Magnetic anomaly calculated using DGRF 1945-1995. Isocontour 50 nT, annotated every 100 nT, with positive values shaded.

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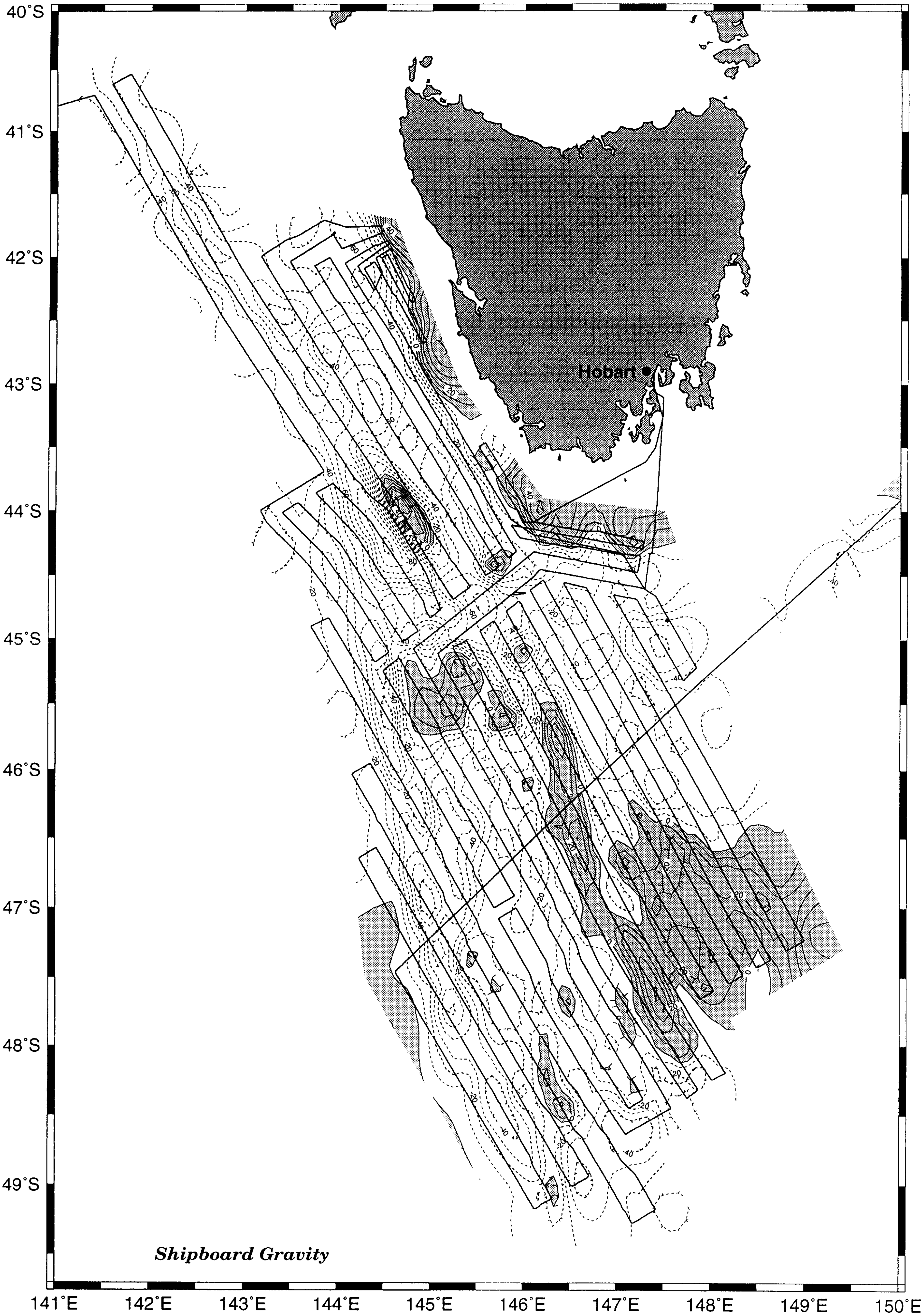

Figure 51. Shipboard free-air gravity contour map of offshore Tasmanian region. 5' x 5'grid based on the free-air anomaly calculated using IAG80 theoretical field. *The data were not corrected for the gravimeter drift between Hobart and Adelaide.* Isocontour 10 mgal, annotated every 20 mgal, with positive values shaded.

Satellite Gravity Contours

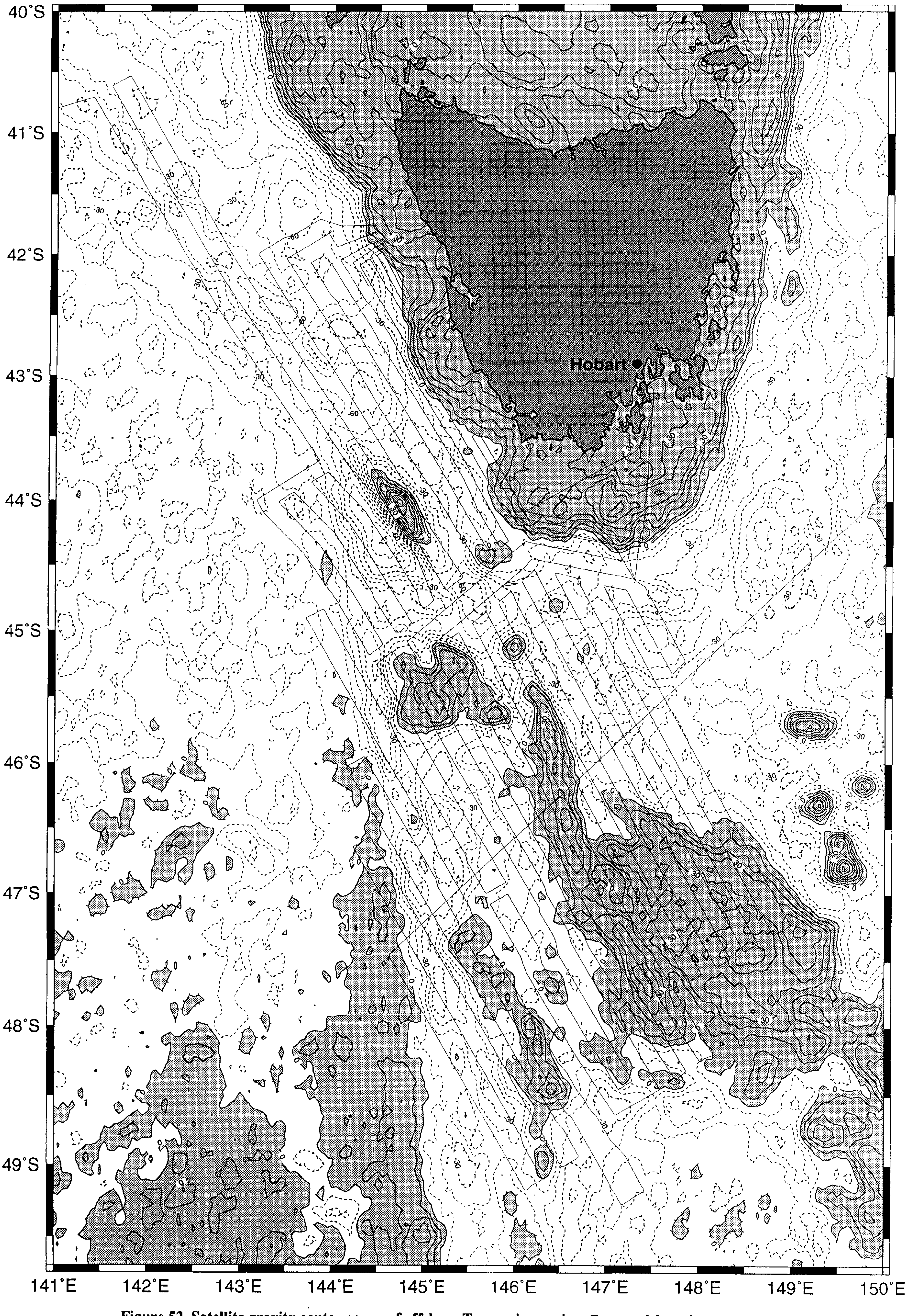

Figure 52. Satellite gravity contour map of offshore Tasmanian region. Extracted from Sandwell & Smith (1992) satellite derived gravity grid. Isocontour 10 mgal, annotated every 30 mgal, positive values shaded.

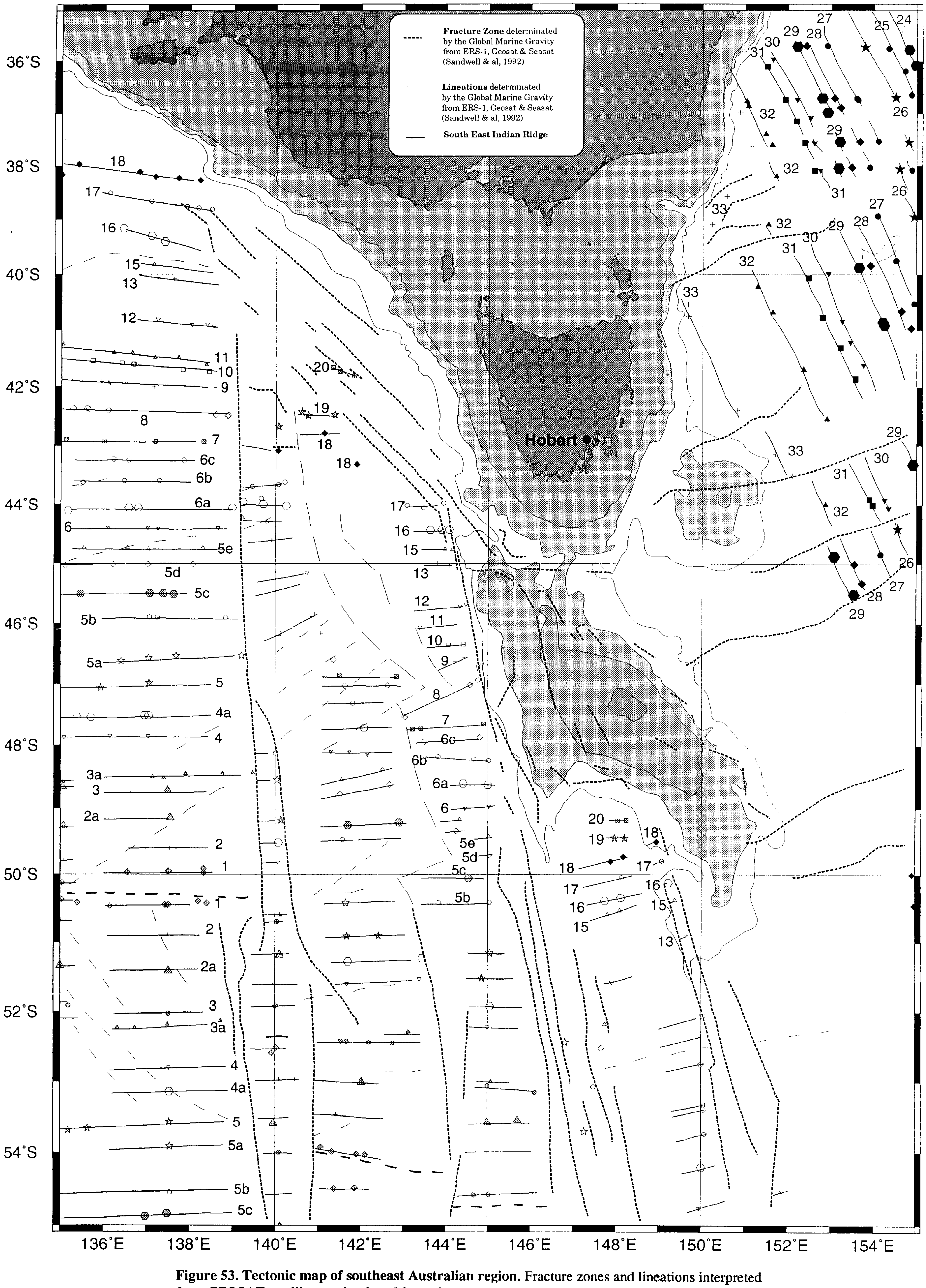

Figure 53. Tectonic map of southeast Australian region. Fracture zones and lineations interpreted from GEOSAT satellite gravity data. Magnetic anomaly pattern determined from all public data by Royer and Rollet.

Tasmania Australian-Antarctic spreading began at chron 20 (47 Ma = m. Eocene). This is 32 million years later than chron 33, which was indicated as the onset of spreading by CPCEMR (1991). Thus our interpretation has Tasman Basin spreading starting well before Australian-Antarctic spreading in this region, unlike that of CPCEMR. (Australian-Antarctic spreading still may have begun in the Cretaceous further west, and propagated eastward).

SEDIMENTOLOGY OF THE SOUTH TASMAN RISE AND WEST OF TASMANIA FROM ACOUSTIC FACIES MAPPING

(G. Whitmore, D. Belton & A. Wellington)

INTRODUCTION

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 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 (e.g. Fellows & Crook, 1993).

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.

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. 33).

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 is presented here for the first time (Fig. 54). It is accompanied by two detailed maps from the north flank of the South Tasman Rise and an area offshore of Cape Sorell (Figs. 55 & 56). The initial interpretation of 3.5 kHz echo character types was carried out aboard *L'Atalante*, while at sea. Subsequent interpretation and drafting of the South Tasman Rise and Cape Sorell areas was completed at James Cook University by D. Belton. The remaining

Figure 54. South Tasman Rise acoustic facies map prepared from *Tasmante* echosounder profiles and swath imagery by Belton, Whitmore and Wellington.

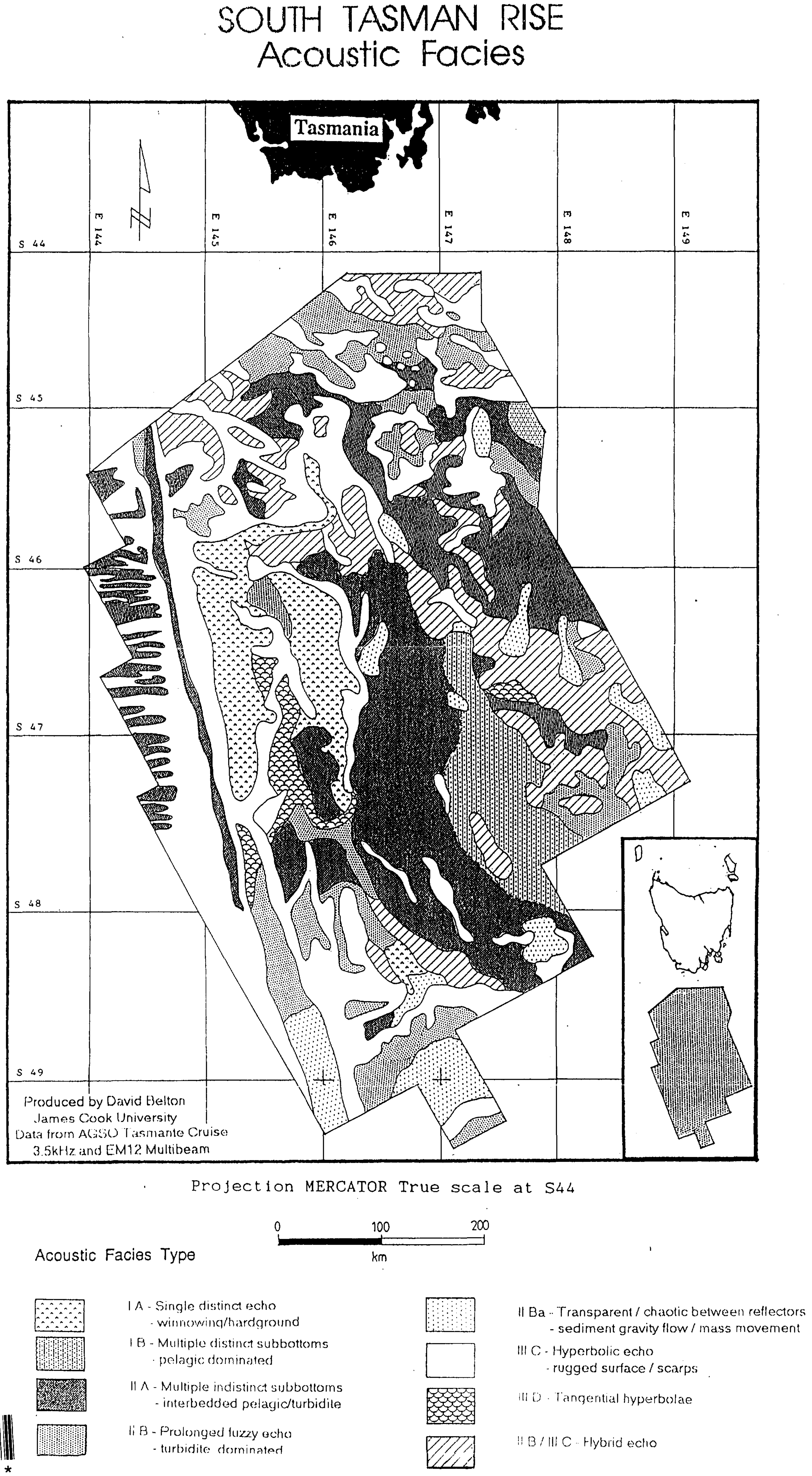

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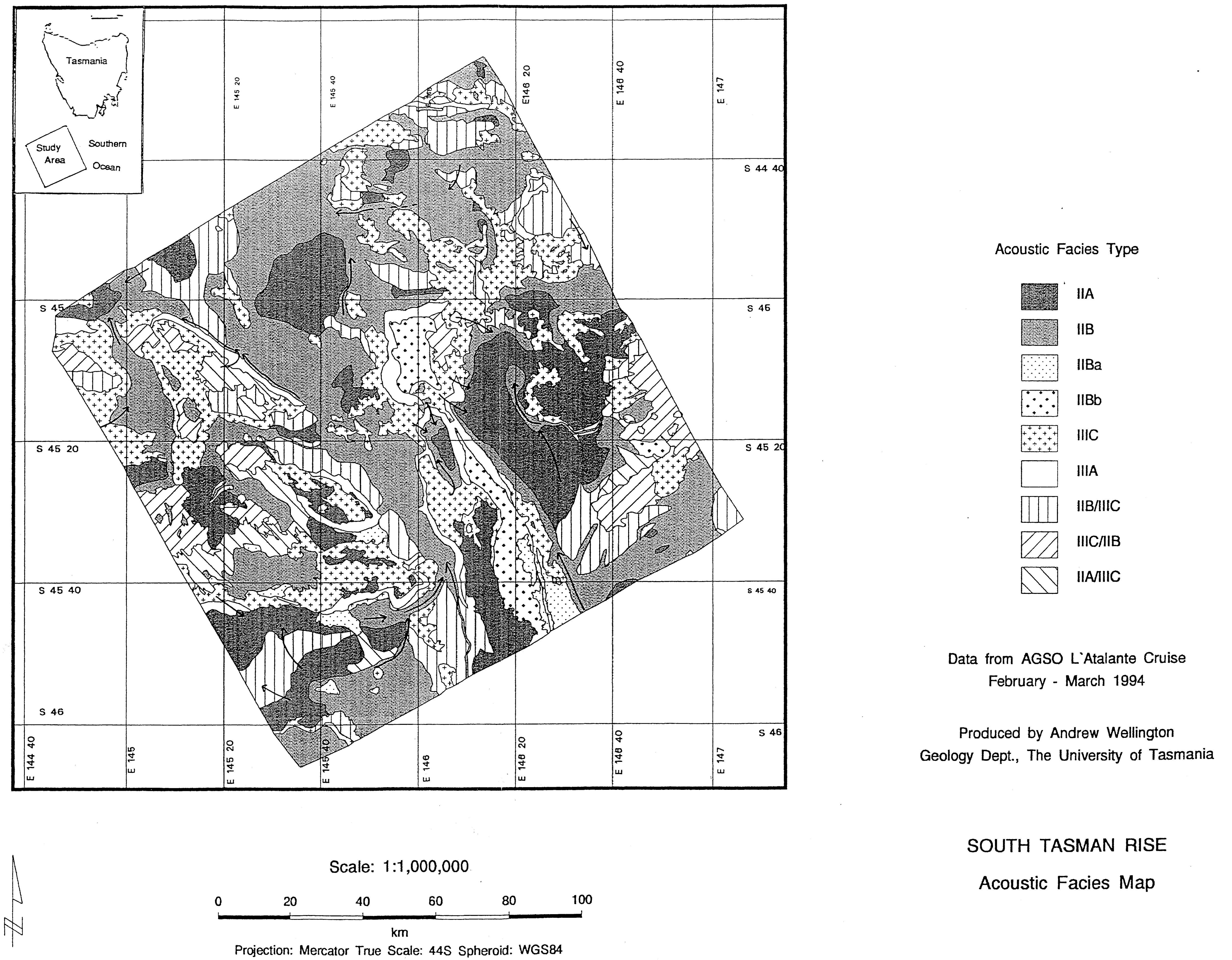
Figure 55. Northwestern South Tasman Rise acoustic facies map prepared from *Tasmante* echosounder profiles and swath imagery by A. Wellington.



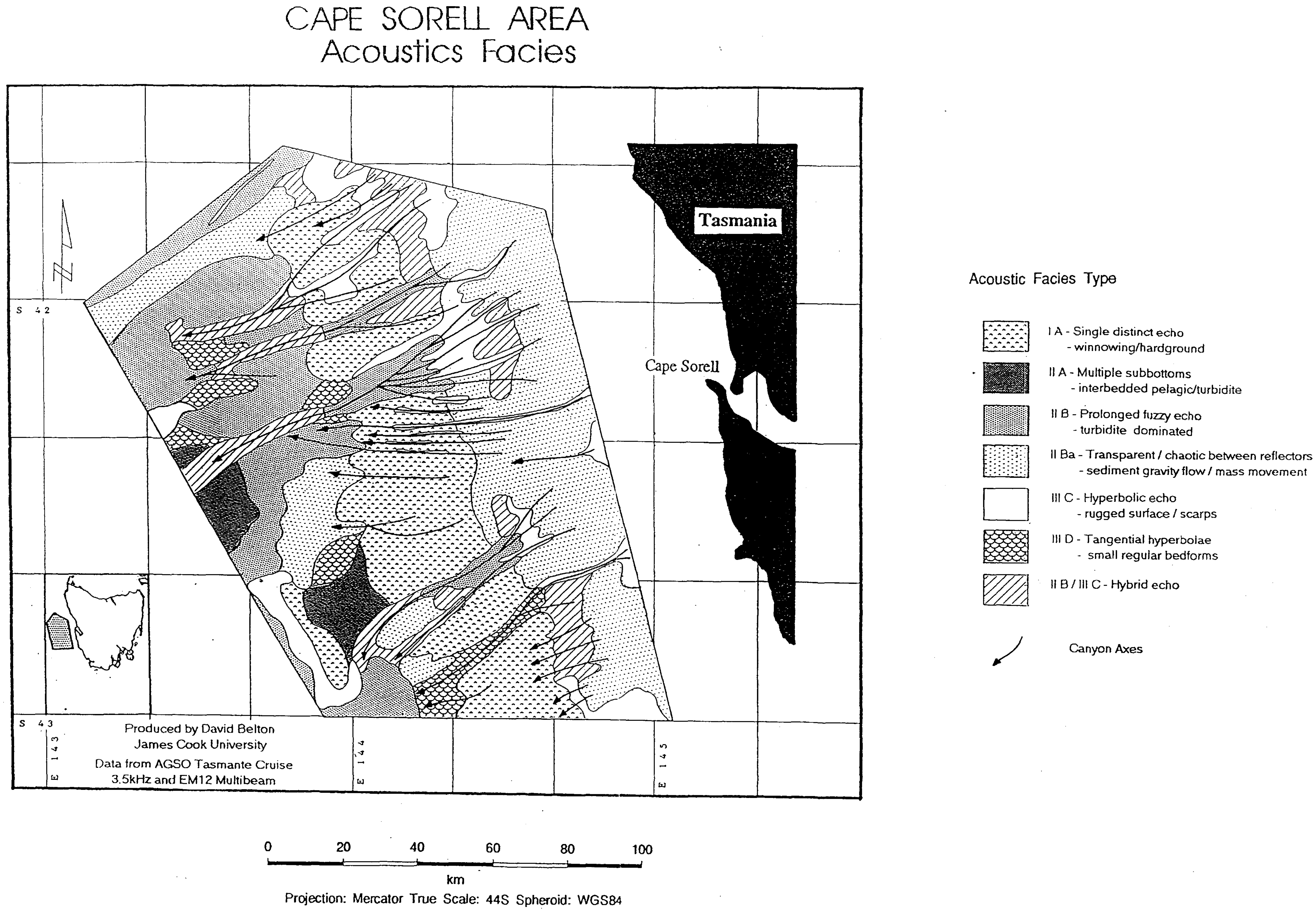


Figure 56. Cape Sorell acoustic facies map prepared from *Tasmante* echosounder profiles and swath imagery by D. Belton.

detailed map of the north flank of the South Tasman Rise was completed by A. Wellington at the University of Tasmania. Acoustic facies presented for the South Tasman Rise have been summarised from a 1:1 000 000 scale map to maintain clarity while meeting size restrictions. Publication of the complete map is expected as part of an Atlas in 1995. Discrepancies between the broad scale South Tasman Rise map and the more detailed map from its north flank are due to contrasting scales and the resultant detail each investigator was able to consider when assigning echo types.

Eight acoustic facies types (Fig. 33) 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 and line drawings produced directly from 3.5 kHz records (Figs. 57-65).

Distinct

IA (Fig. 57A) Sharp, continuous echo with no sub-bottom reflectors. Variously associated with hardgrounds and manganese nodule fields, possibly with a thin sediment cover.

IB (Fig. 57B) Sharp, continuous echo with up to 20 continuous parallel sub-bottom reflectors. Undisturbed pelagic and hemipelagic oozes. Possibly mud turbidites.

Indistinct

IIA (Fig. 58B) 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 (Fig. 61A) 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 (Fig. 60A) 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

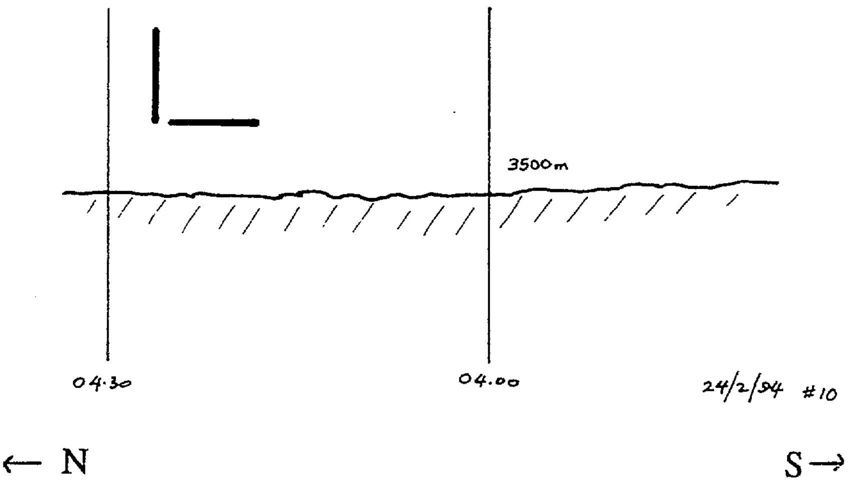
IIIC (Fig. 63A) Large, irregular, overlapping semi-prolonged to prolonged hyperbolae with varying vertex elevations. Rugged or erosional topography, canyons and scarps.

IIID (Fig. 62B) 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 (Fig. 61B) 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



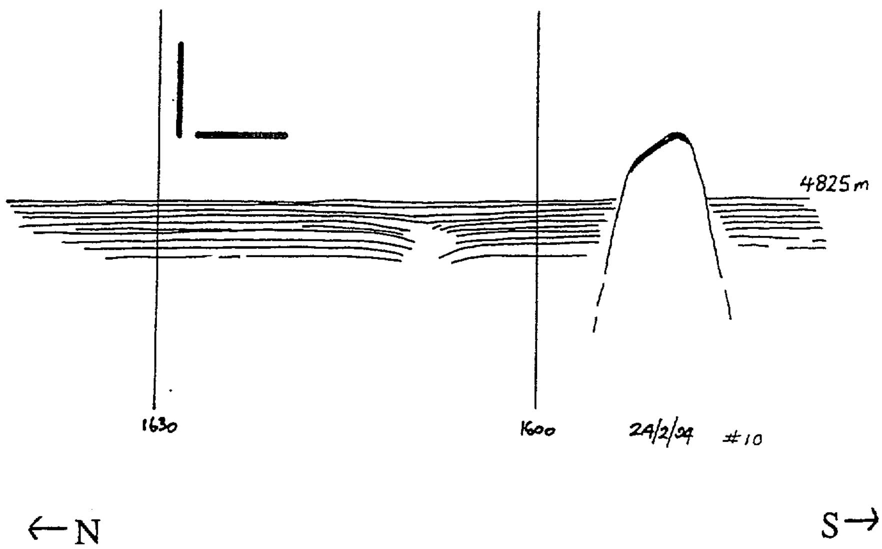
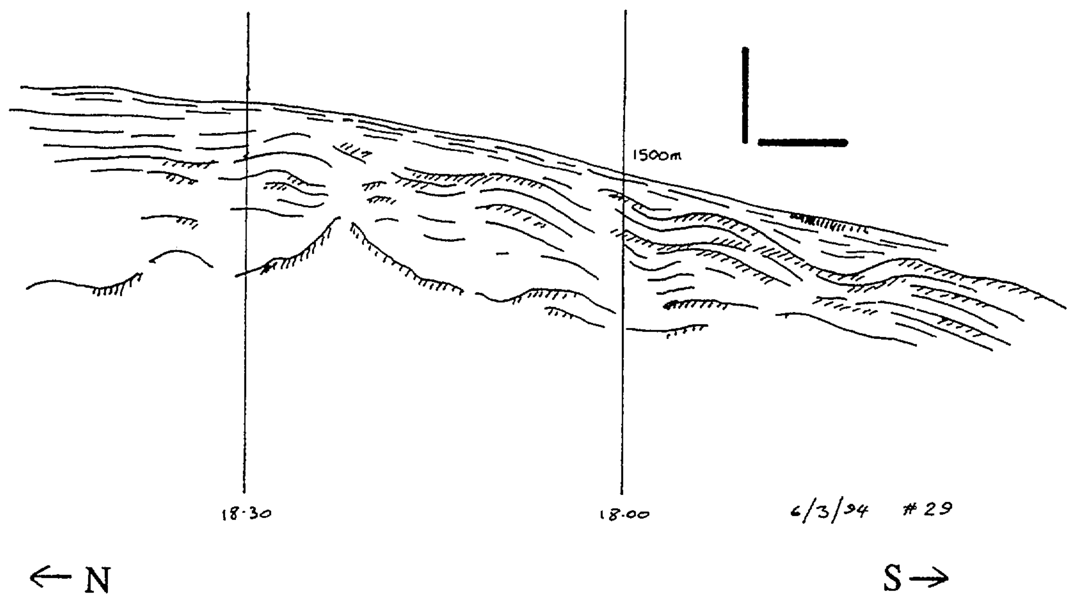


Figure 57A) Acoustic facies IA - hardground / winnowed surface. B) Facies IB - (hemi)pelagic ooze. At a ship speed of 10 knots, the horizontal scale bar represents a distance of 4 kilometres. The vertical scale is 100 m - using an estimated sound velocity (in water) of 1500 m/sec.



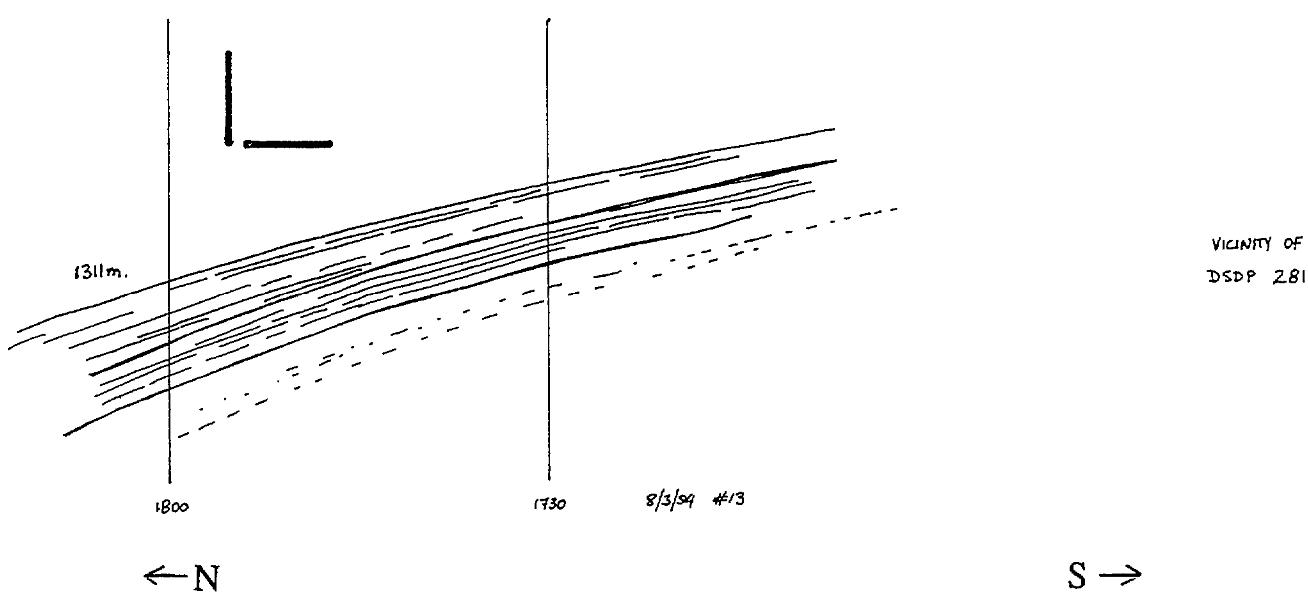
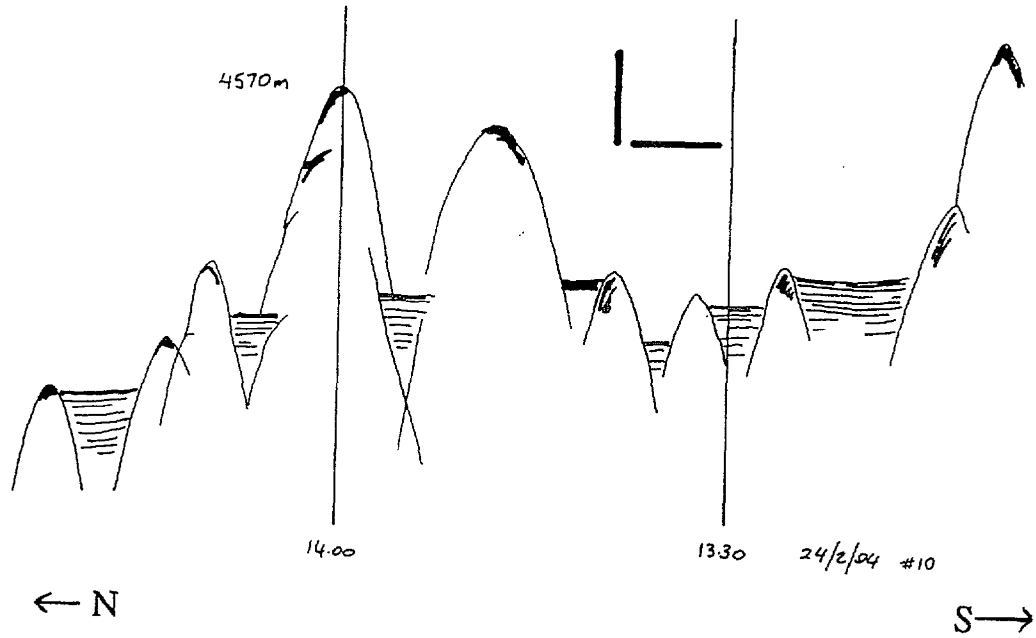


Figure 58A) Relict sediment waves with a draping of acoustic facies IIA. B) Facies IIA - reworked pelagics (in vicinity of DSDP 281). Horizontal bar 4 km, vertical bar 100 m.



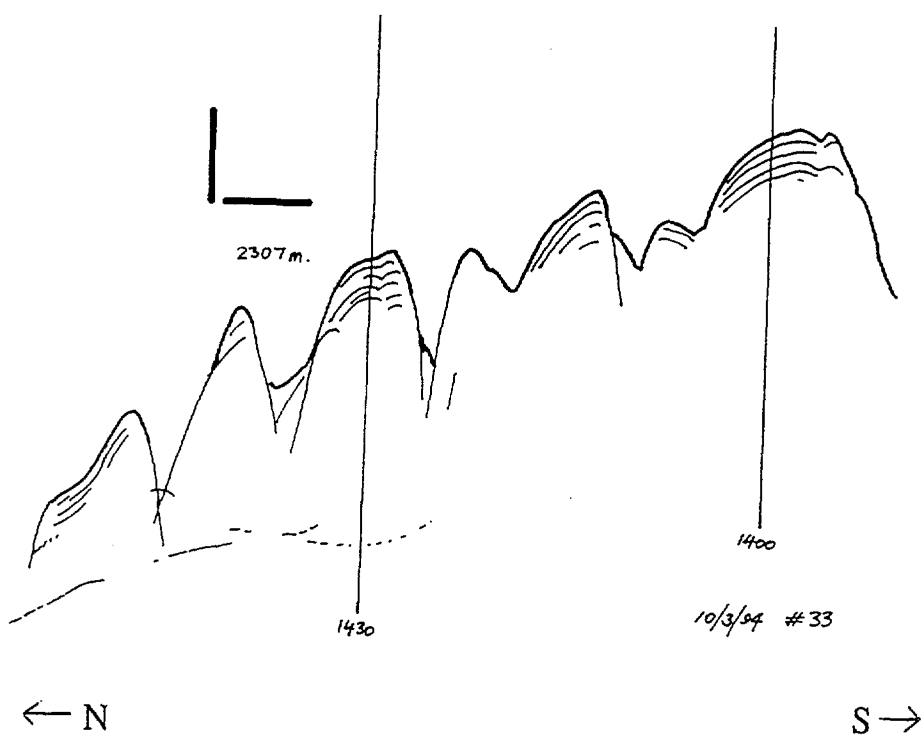
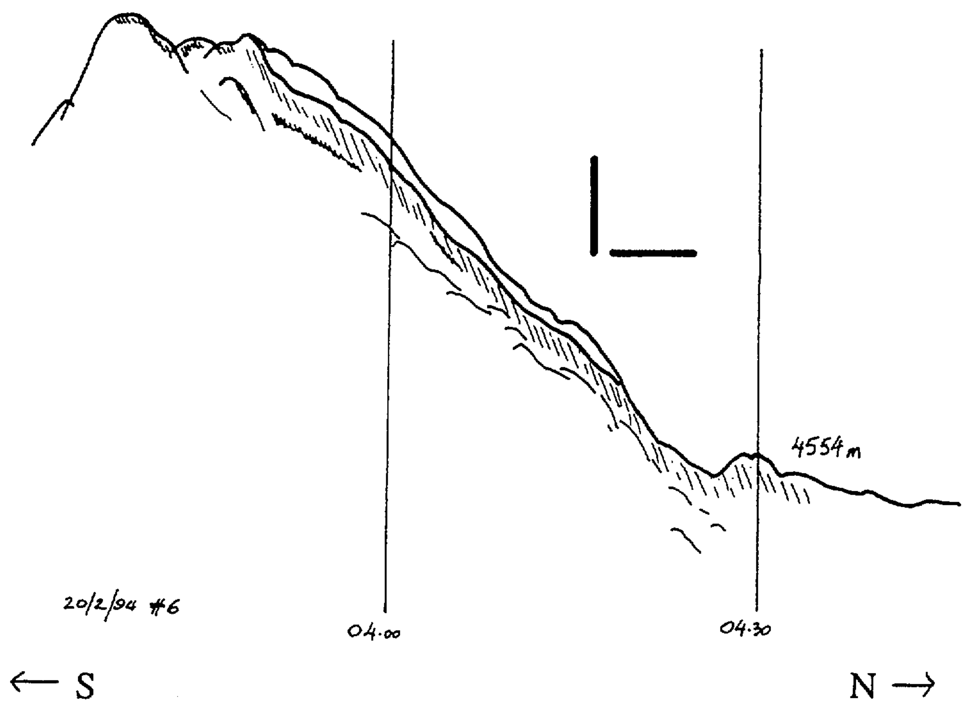


Figure 59A) Horst and graben structures on oceanic crust. B) Large faulted blocks associated with a possible slump. Horizontal bar 4 km, vertical bar 100 m.



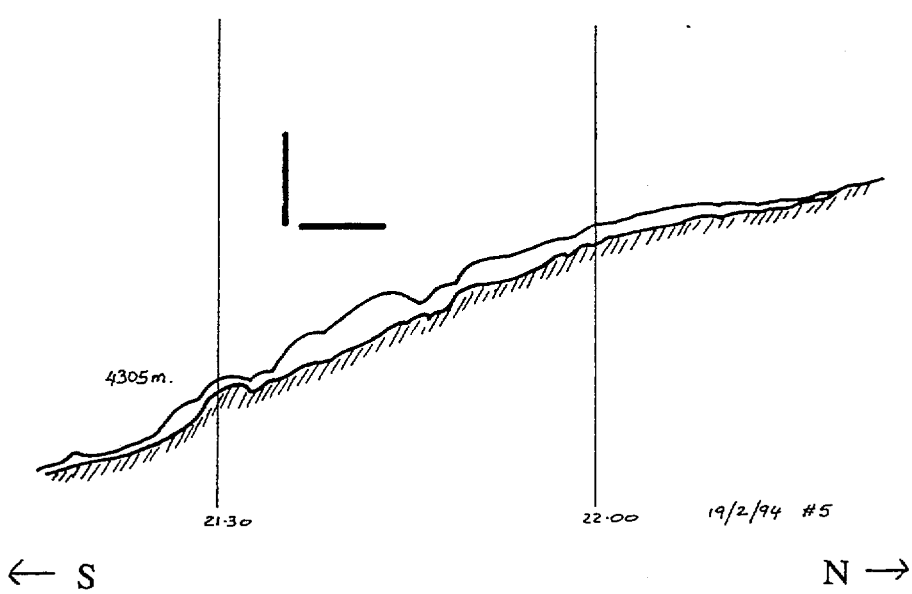
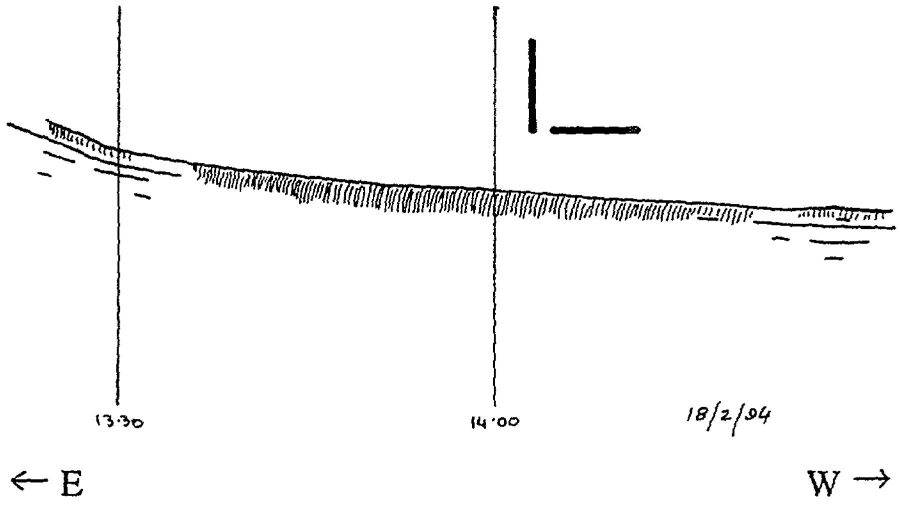


Figure 60A) Acoustic facies IIBa - chaotic reflectors with transparent zone. B) Facies IIBa - thin transparent zone between reflectors. Horizontal bar 4 km, vertical bar 100 m.



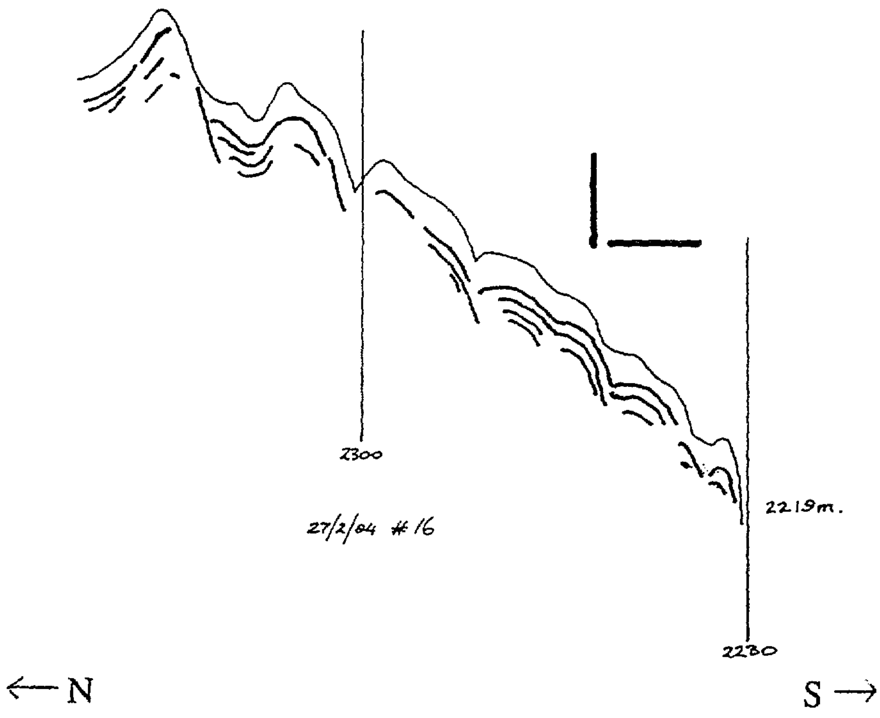


Figure 61A) Acoustic facies IIB - reworked sediments - frequently turbiditic. B) Hybrid facies - IIA/IIIC. Horizontal bar 4 km, vertical bar 100 m.

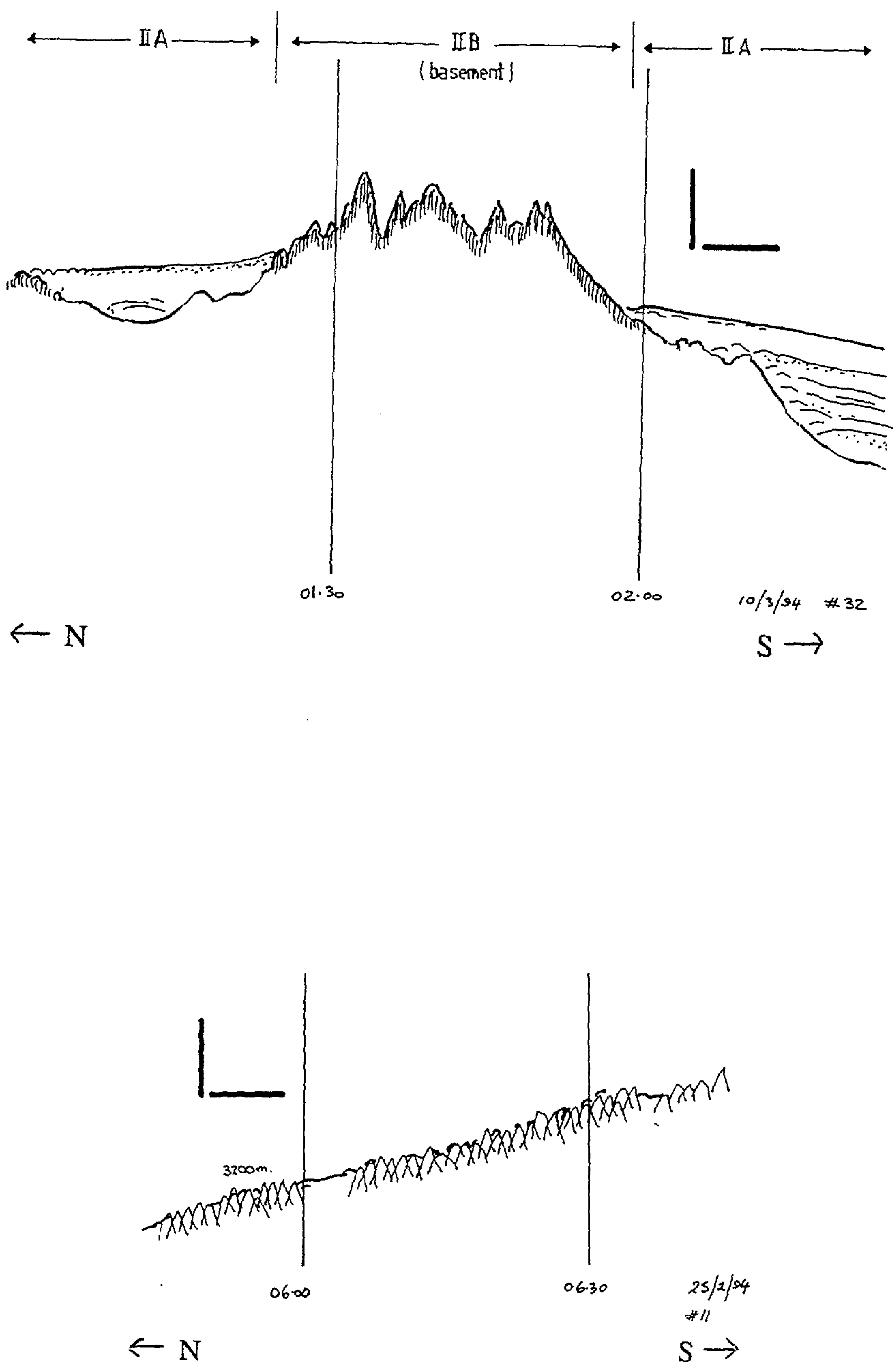
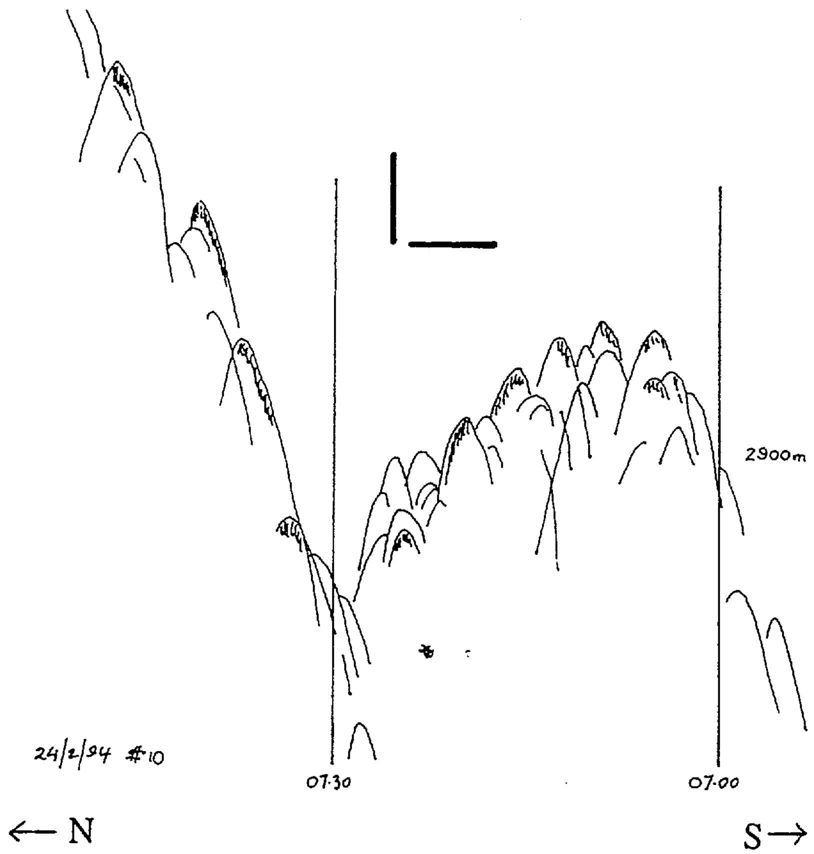


Figure 62A) Basement outcrop on South Tasman Rise. B) Acoustic facies IIID - small scale bedforms. Horizontal bar 4 km, vertical bar 100 m.



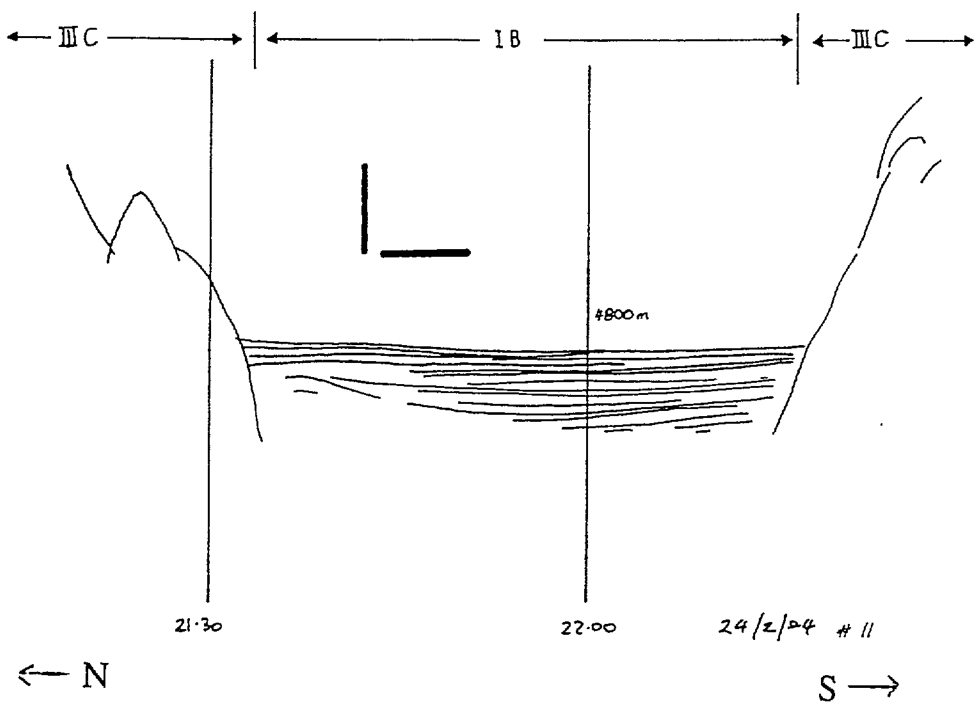
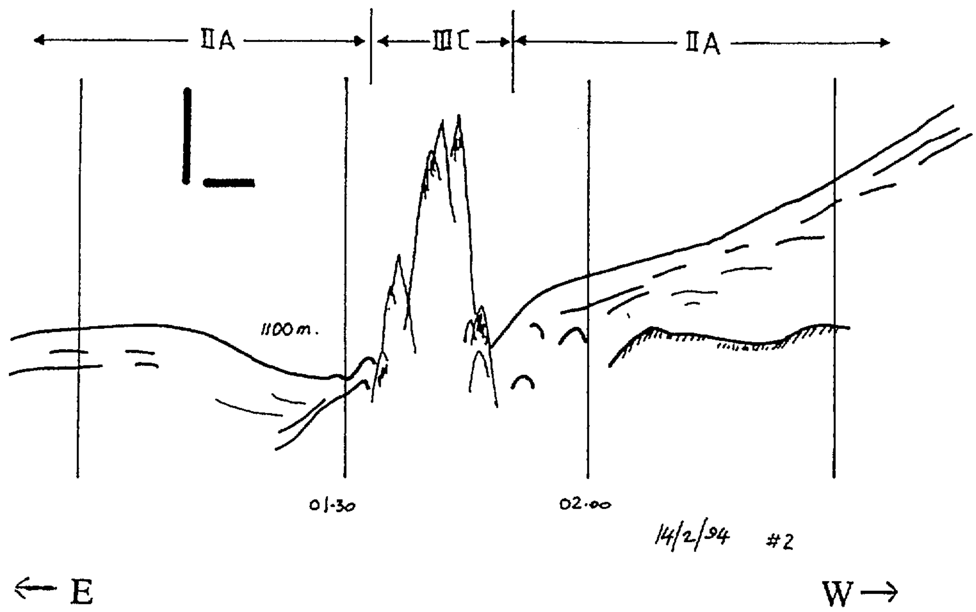


Figure 63A) Acoustic facies IIIC - rugged erosional topography. B) Facies IB - (hemi)pelagic fill in a small basin. Horizontal bar 4 km, vertical bar 100 m.



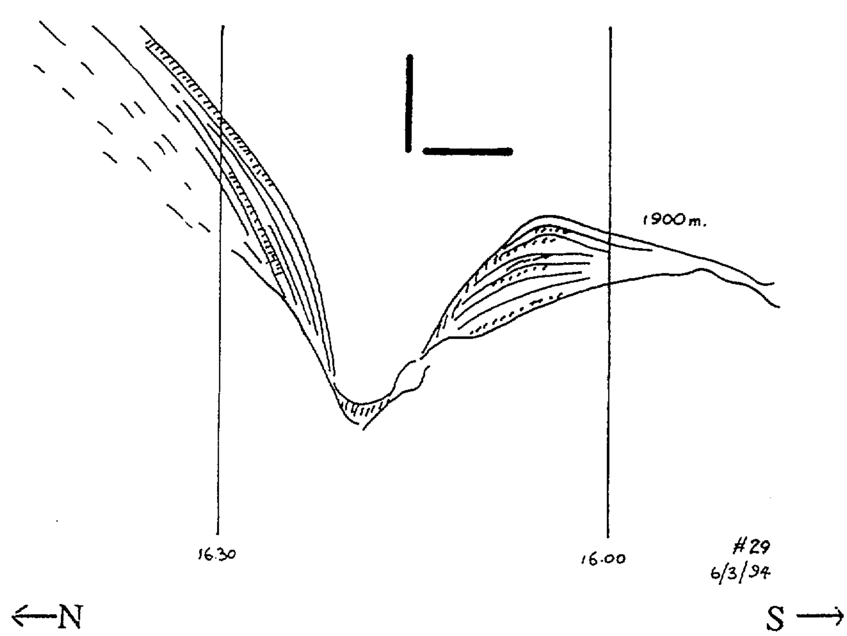


Figure 64A) Small seamount with a well developed moat - Tasman Sea. B) Submarine channel with well developed levees. Horizontal bar 4 km, vertical bar 100 m.

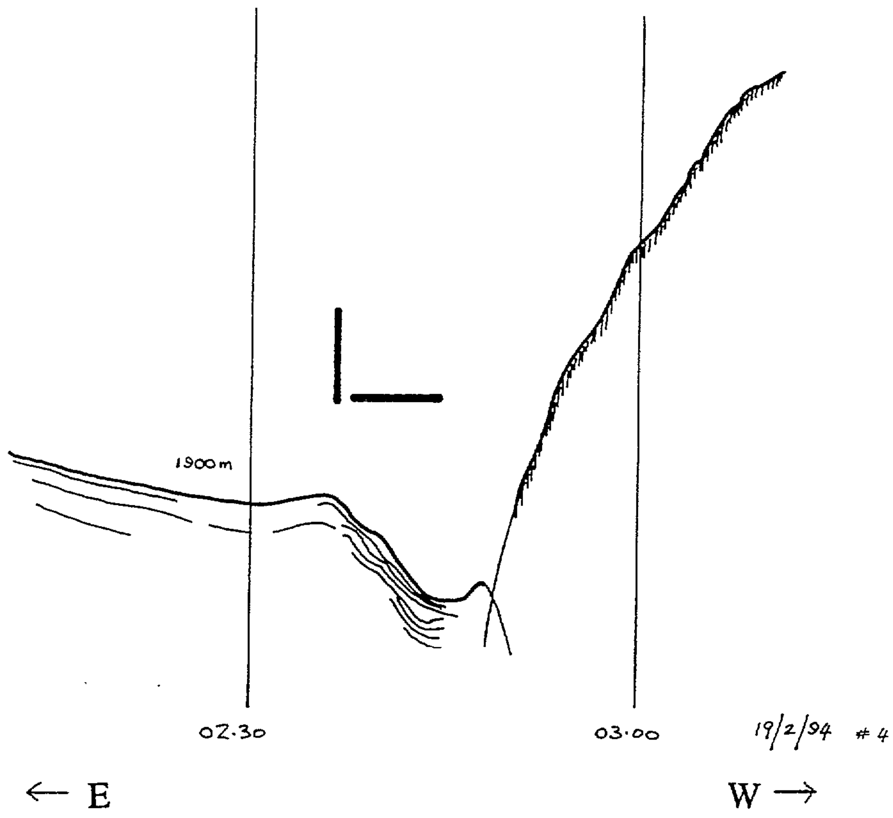


Figure 65. Moat at base of ridge/seamount. Horizontal bar 4 km, vertical bar 100 m.

SOUTH TASMAN RISE

Morphology

The morphology of the South Tasman Rise is controlled by a complex mixture of oceanic and submerged continental components, with four distinct areas (Fig. 3):
1) The Tasman Fracture Zone
2) oceanic crust to the west of the Tasman Fracture Zone
3) a northeastern portion and
4) the South Tasman Rise proper to the south east.

The Tasman Fracture Zone is an impressive scarp rising 2000 m at angles in excess of 60° and extending almost the full length of the survey area from latitude 44° S to 49° S. West of the Tasman Fracture Zone, the oceanic crust is characterised by numerous horst and graben features which run east-west, parallel to the axis of sea floor spreading. This faulted morphology becomes less distinct in older oceanic crust to the north, where a generally flat sea floor is punctuated by seamounts.

Adjacent to the Tasman Fracture Zone, between 46° and 47° S, there are two parallel, north-south trending basins which extend over 100 km and step 20 km eastwards. The most eastern of these, in 2400 m of water, is joined to a deeper western basin, in 3400 m of water, by an irregular channelled slope descending at 3° to 4°. This morphology suggests that sediment is transported first to the higher eastern basin, and then to the lower western basin via a channelled slope. However, evidence presented later refutes this interpretation and instead indicates that the channels are inactive and the basins sediment-starved.

The southernmost part of the survey area is characterised by a series of large fault-controlled scarps enclosing a deep narrow basin. One of these scarps (*ca.* 48°S 145°E) is oblique to the Tasman Fracture Zone forming a transfer fault before terminating at another large scarp 80 km to the east. There are a number of ridges and valleys associated with, and to the east of, these large scarps. At 49° S 147° E they form a semi-circular concave-south feature with a moderately steep slope to the south where relief drops rapidly to abyssal depths.

The distinction between oceanic and continental crust is less obvious to the north east, where the topography is dominated by numerous seamounts rather than elongate ridges. This area is bounded to the north by a steep slope dissected by canyons that marks the edge of the Tasmanian margin, and to the east by an essentially flat abyssal plain.

The summit of the South Tasman Rise lies in 800 m of water in the south east of the survey area. With the exception of the shallowest areas, where the topography is rough and irregular, the area is dominated by gentle slopes. On the northeastern flank, these gentle slopes give way to steeper gradients leading out onto the abyssal plain.

The northwest portion of the South Tasman Rise has ridges both parallel and oblique to the Tasman Fracture Zone. These features may be due to fold development during strike slip movement of the fracture. The area is characterised by its irregular, steep rises separated by valleys.

Acoustic Facies Interpretation

The acoustic facies comprising echo type IA (Fig. 57A) is confined to two large perched basins immediately to the east of the Tasman Fracture Zone. Despite evidence for sediment transport already mentioned, the IA echo type is thought to indicate that the seabed is floored by hardgrounds. The presence of a manganese crust could produce such an acoustic response, though ground-truthing is required.

Within the survey area the IB acoustic facies type, characterised by multiple parallel sub-bottoms, is limited to the upper part of the South Tasman Rise, in water depths down to 1500 m (Fig. 57B). Facies IB was also mapped on a transit leg over the abyssal plain to the east of the South Tasman Rise, where it is interpreted to be pelagic sediment.

Facies IIA, distinguished by multiple discontinuous sub-bottoms, is the most common acoustic facies type in the survey area. It occurs on gentle slopes surrounding the central rise where sub-bottoms define both modern and relict waveforms with wavelengths of 1-2 km and amplitudes of 10-20 m. Several profiles show larger relict sediment waves with 7-8 km wavelengths and 50-75 m amplitudes that are now draped by a gently undulating IIA facies (Fig. 58A). These slopes are interpreted as predominantly pelagic deposits that have been reworked by bottom currents, disturbing original stratification and creating discontinuous sub-bottom reflectors (Fig. 58B). DSDP site 281 is located in this facies type and shows laminated nanno-foram / foram-nanno oozes to a depth of 59m (Kennett et. al., 1975)

A more typical IIA echo type extends northwards, and is dominant in areas of little or no gradient between seamounts and ridges where it is believed to represent distal mass flow or turbidite deposits. Adjacent to the Tasman Fracture Zone, facies IIA is also found as a narrow sediment wedge marking the edge of the oceanic crust. On oceanic crust to the west of the Tasman Fracture Zone, the numerous grabens already discussed are infilled by IIA type sediments, interpreted as pelagic drape that has been tectonically disturbed to produce discontinuous sub-bottom laminations (Fig. 59A). Elsewhere, this facies is associated with broad channel and basin features and is inferred to represent distal turbidite deposition interbedded with pelagic oozes.

Acoustic facies IIB is generally restricted to areas of moderate topographic relief, especially those at the base of steep slopes and scarps and along the axis of submarine channels (Fig. 61A). This facies is interpreted as proximal mass flow or turbidite deposits. In some locations (eg. 45° 20' S 147° 40' E) a progression from proximal (IIB) to distal (IIA) is evident away from slopes and channel mouths, though this trend is difficult to discern from this large scale map.

Acoustic facies type IIBa occurs at the base of steep slopes and scarps on the south Tasman Rise. On more moderate slopes, this facies starts on the upper reaches of the slope and extends out beyond the toe of the slope onto areas of lower gradient. The acoustic character varies from large apparently faulted sediment blocks, to chaotic reflectors and hyperbolae, to relatively thin transparent zones between two non parallel reflectors (Figs. 59B, 60A & B). In some cases the echo type can be seen to progress down slope through all three variants. These are interpreted to be slumps or gravity induced massflows that occur on a range of scales throughout the South Tasman Rise.

Type IIIC acoustic facies is widespread throughout the South Tasman Rise. It highlights extreme topographic variations involving numerous scarps, ridges and seamounts as well as the widespread, moderately graded, but rough, slopes (Fig. 63A). The erosional nature of these areas is supported by a number of R.V. *Sonne* (i.e. SO-36) bottom samples which commonly recovered metamorphic rocks such as greywacke and schists (Hinz et al., 1985; Exon et al., 1992).

Hybrid acoustic facies, based on the variations of IIA/IIIC and IIB/IIIC, are similarly widespread and are closely associated with areas of IIIC facies. They are common on the tops of ridges or seamounts and on intermediate slopes between IIIC and IIA or IIB facies (Fig. 61B). They therefore represent an intermediate group interpreted as faulted or gullied sediments, which are not sufficiently eroded or steep enough to produce numerous overlapping hyperbolae. In some areas, notably the shallowest parts of the South Tasman Rise, the IIB/IIIC hybrid is interpreted as basement outcrop. This facies is mapped as IIBb on the north flank of the South Tasman Rise, where small scale mapping allows subdivisions of echo types to be made (Fig. 62A).

Acoustic facies IIID is restricted to similar geomorphological environments as IIIC. It is largely confined to a moderately steep slope dividing the two elongate basins to the east of the Tasman Fracture Zone (Fig. 62B). The numerous small hyperbolae that characterise this facies are believed to be formed by small erosional gullies (Flood, 1980) running downslope that are no longer active.

Discussion

The major sedimentary processes acting on the South Tasman Rise (Fig. 66) 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

Morphology

The continental slope adjacent to Cape Sorell is divided into three distinct parts:
1) a relatively steep upper slope (6-8°, 300 - 2200 m),
2) a moderately steep mid-slope (3-4°, 2200 - 3500 m) and
3) a gentle lower slope or rise (2°, 3500 - 4800 m)

The upper slope is incised by numerous, approximately parallel canyons, all of which are essentially straight. Most have a relief of 25-75 m and V-shaped cross-sections, with the exceptions being deeply incised channels that have a relief of 100-200 m. In the very north of the study area, a single broad, channel-like feature extends from 3000 m to beyond 4500 m at the western edge of the area. Internally, this straight channel has a rough, irregular topography indicative of mass movement.

The largest channels have flat channel floors and a stepped downslope profile. McHugh et al. (1993) attribute stepped channel axes to diagenetically generated fractures. These fractures are frequently vertical so that expansion leads to exfoliation and erosion. This stepped morphology could also be due to lithological variations or small localised faults.

With the change in gradient from upper to mid-slope, many of the smaller channels coalesce, generally forming broad, shallow channels. Two of the larger channels formed on this part of the slope remain fairly narrow and also have a stepped axial profile. On the lower slope, very wide, shallow channels predominate.

A large topographic high is found in the south west of study area, located at the foot of the continental slope. The western (seaward) side of this feature has a 1000 m scarp parallel to the continental slope. To the east, it abuts the continental slope forming a saddle with steep flanks to the north and south.

A single broad channel-like feature, in the north of the study area extends from 3000 m to beyond 4500 mbsl at the western extremity of the study area. Internally, this straight elongate feature has a rough, irregular topography, characteristic of slope failure and subsequent downslope mass movement.

Figure 66. South Tasman Rise sedimentary environments. Derived from acoustic facies map (Fig. 54) and other information.

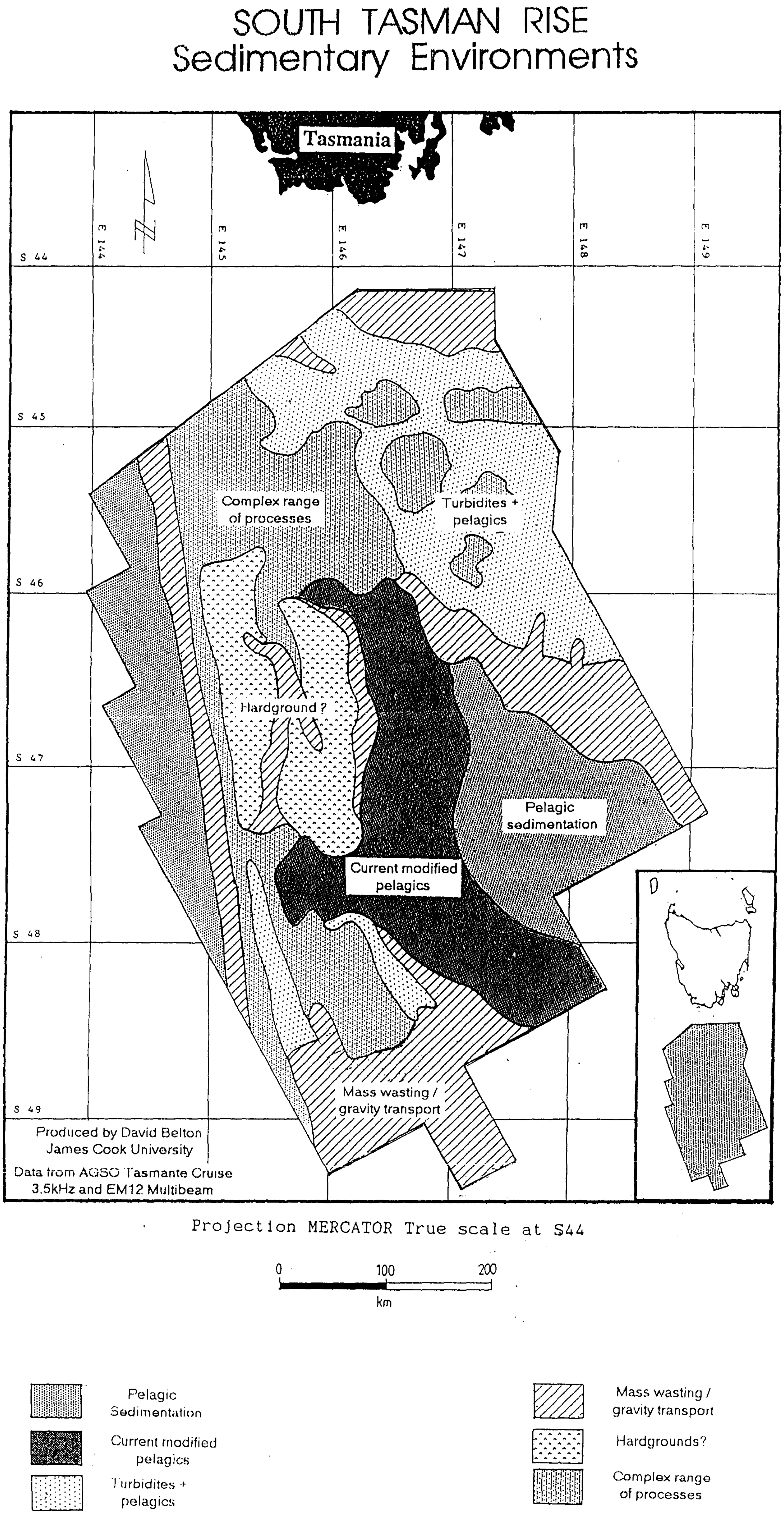


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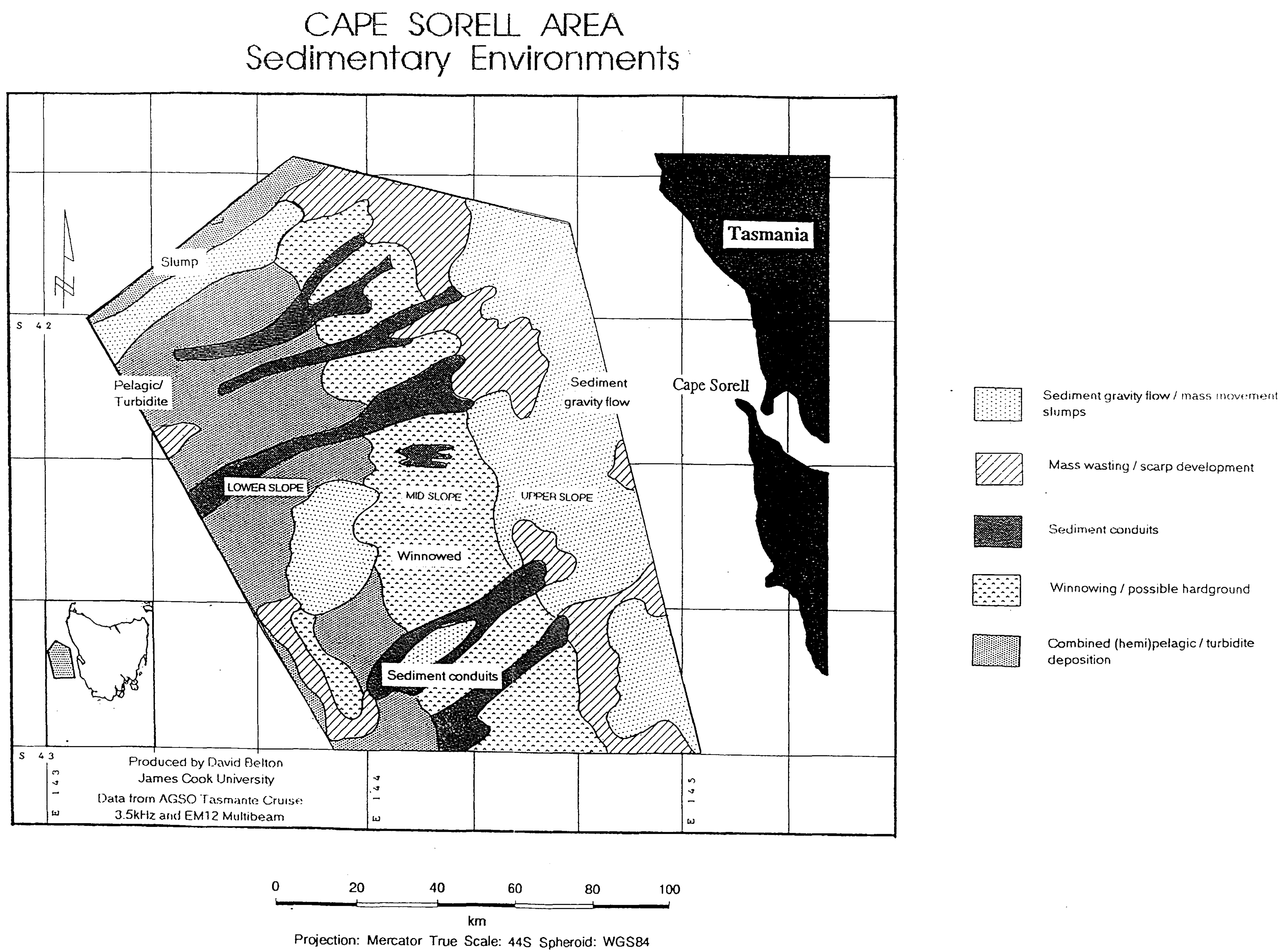
Figure 67. Cape Sorell area sedimentary environments. Derived from acoustic facies map (Fig. 56) and other information.



Acoustic Facies Interpretation

In contrast to the South Tasman Rise, the distribution of acoustic facies within the Cape Sorell study area forms a clearly organised pattern (Fig. 56). Facies along the majority of the slope are distributed parallel to each other and along slope. Those associated with canyon floors, canyon fill and levees generally run downslope.

The canyon heads and most of the channels on the steep upper slope are characterised by IIIC facies. Where the relief is less pronounced the smaller canyons and channels are defined by hybrid (IIB/IIIC) facies. Both of these facies are interpreted to be the result of erosion due to rapid sediment transport. On the mid-slope the canyons are more commonly defined by IIB facies, suggesting that coarse sediments carried by erosional currents on the upper slope are deposited in response to the reduced gradient.

On the lower slope, the myriad of canyons have coalesced into a few major canyons most of which have a IIB/IIIC facies possibly indicating minor coarse deposition. Although the gradient is reduced, the canyon floors are incised by a series of steps, possibly giving rise to the IIIC signature amongst a predominantly IIB signal.

The broad band along the upper slope is dominated by IIBa facies, suggesting that gravity driven sediment transport is widespread. The slope angle of 6-8° supports this as does evidence from R/V *Sonne* cores in the area, many of which show multiple thin turbidites commonly overlying Pliocene(?) chalk (Hinz et al., 1985). The turbidites indicate frequent downslope transport along the upper slope, while chalk horizons within 2m of the surface indicate that mass transport of overlying sediments has occurred.

The mid-slope is characterised by IA acoustic facies, previously interpreted as hardgrounds. This interpretation stands as sediments from the upper slope are predicted to be captured by canyons and bypasses the mid-slope. In addition to sediment bypassing the action of deep ocean currents, such as Antarctic Intermediate Water (Lynch-Stieglitz & Fairbanks, 1994), may sweep the slope clean of any remaining detritus, thus creating a sediment starved mid-slope or hardground.

The lower slope is dominated by IIB facies, suggesting that coarse sediments which have bypassed the mid-slope as channelised gravity flows are deposited due to waning flow. At the western extent of the Cape Sorell area, the IIB facies grades into a laminated IIA facies indicative of fine grained distal deposition.

Two other features of note are an extensive slump to the north, inferred from bathymetry and IIBa acoustic character, and zones of IIID facies adjacent to the larger central canyons. The IIID facies, characterised by numerous small hyperbolae tangential to the sea floor, are distributed as lobes on either side of the canyons. It is thought that these small tangential hyperbolae result from ripples (Flood, 1980) formed by turbidity currents.

Discussion

The continental slope adjacent to Cape Sorell is dominated by down-slope sediment transport processes initiated by gravity flows on the upper slope (Fig. 67). 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

Morphology

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

Water depths across the study area range from 1800 to 4000 m. Steep scarps (>20°) orientated approximately NW are common, reflecting major regional structural trends. These scarps bound topographic highs, interpreted as being sections of continental basement (eg. 45° 10' S, 145° 20' E) or major volcanic accumulations (eg. 45° 10' S, 146° E). Basins separating the topographic highs have shallow floors (0 to 2°) and numerous small channels define a regional drainage pattern with net northward direction.

Acoustic Facies Interpretation

Figure 55 shows the effects of three topographic highs that are interpreted as rotated blocks of continental material and are located at 45° 10' S, 145° 20' E, 45° 30' S, 145° 40' E, and 45° 40' S, 145° 50' E. These have flanks defined by IIIA facies, usually on eastern and southern margins, summits (20 to 40 km across) of IIIC facies, and small slope basins containing IIA facies. The circular feature located at 45° 10' S, 146° E is composed almost entirely of basement type reflectors with only limited development of IIIC/IIB facies and is suggested to be of volcanic origin. Depositional centres between topographic highs are defined by IIA and IIB facies.

Channels in the region are continuous over several tens of kilometres (eg channel at 45° 50' S, 146° 10' E) with channel floors defined by IIB facies interpreted as proximal turbidites, and steep slopes defined by IIIC hyperbolae (eg. 45° 15' S, 146° 35' E). As these channels approach basinal areas they widen, often developing a fan of IIA facies.

The distribution of hybrid facies is poorly defined by acoustic reflectivity images, but shows a strong correlation with seafloor slope. Those producing hybrid echo types are shallower (2 and 5°) than slopes producing IIIC or IIIA echoes (>5°), yet steeper than slopes returning typical IIA or IIB echoes (0 to 2°).

IIBa facies are found in two types of area. Deposits at the base of scarps (eg 45° 45' S, 145° 45' E), are interpreted as debris flow deposits using criteria already discussed for the South Tasman Rise. Others, (eg 45° 40'S, 146° 20'E), are found on steep slopes not associated with scarps where slumping, without full detachment, is thought to have occurred, initiating debris flows.

Sonne Sediment Samples

The German Research Vessel *Sonne* conducted sampling and seismic reflection work on the Tasmanian margin in 1985. During this sampling program, four piston cores S38, 39, 40 and 41), and a dredge (S36) were taken on the north flank of the South Tasman Rise. Their details follow:

> *Site 36.* (43° 46.32' S, 145° 37.13' E) A dredge taken within an area of IIIC facies on the northern border of the study area. Rocks recovered by the dredge included a mica schist and gneiss, manganese crusts and foraminiferal ooze.

Site 38. (43° 49.06' S 145° 56.275' E) A 2 m piston core from an area interpreted as facies IIB/IIIC. The core has traces of manganese crust, overlain by 1.7 m of foram sand containing shell fragments, and topped by 0.2 m of foraminiferal sand.
Site 39. (43° 49.05' S, 145° 56.375' E) A 2.9 m piston core from facies IIB/IIIC that recovered 2.14 m of white-pale greenish yellow foram nanno ooze overlain by 0.8 m of grey/green muddy foram nanno ooze.
Site 40. (43° 49.10' S, 145° 55.76' E) This piston core (2.3 m) in acoustic facies type IIB/IIIC recovered zeolitic mudstone, overlain by muddy sand with rock fragments, manganese crusts and at the top of the core, grey foram nanno ooze.
Site 41. (43° 49.035' S, 145° 55.87' E) Although just out of the area, This core from facies IIB consists of foram nanno ooze overlain by a thin cover of foram sand.

The siting of dredge 36 on continental basement is significant for the entire survey area, and confirms the interpretation of IIIC facies as at least partially basement. Piston cores from areas of the sea floor returning hybrid IIB and IIIC facies all recovered sections dominated by foraminiferal sand and foram nanno ooze. While this association could be expected, the proportion of ooze, at least in the top two metres, is high suggesting that the IIB facies are in some places partially pelagic in origin. The diverse stratigraphy of cores 38, 39 and 40, which varies from manganese crusts and nodules to foraminiferal sands and oozes, in believed to be indicative of sediments returning a hybrid IIB/IIIC echo type. Intermittent rather than persistent IIIC echoes within this acoustic facies are presumably created by a 'patchy' manganese crust.

Seismic Section Character

The continuity of sedimentary packages, as evidenced from seismic reflection profiles cannot be assessed because topographic highs frequently interrupt sequences. Basement can usually be clearly identified and is overlain by a series of units characterised by 1) strong, continuous reflectors, often occurring high in the section, 2) discontinuous, weak reflectors in an overall optically transparent unit and 3) closely spaced, fine reflectors.

Shown in Figure 68 are examples of these seismic types. Figure 68A shows a section of line 17 from 20:50 to 21:10. The seismic stratigraphy of the section at 21:00 shows an upper package defined by ca. 0.15 seconds of sharp, continuous reflections overlying a similar thickness of discontinuous reflectors. An unconformity below this bounds a lower package of similar characteristics above basement at 0.75 seconds.

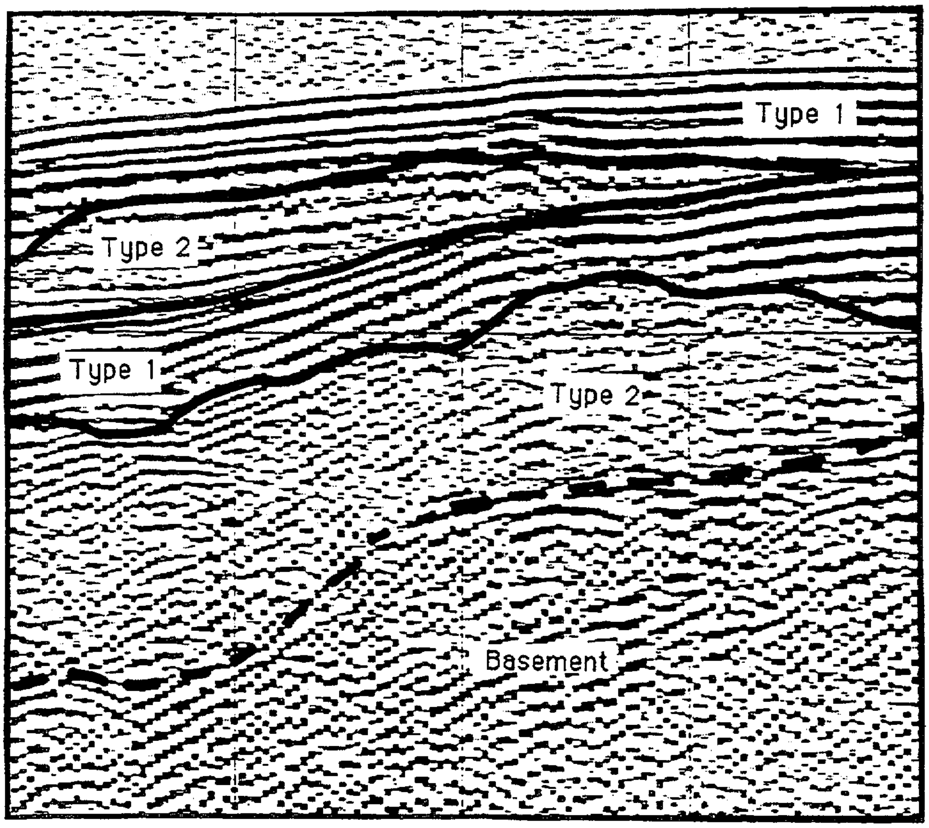
Line 36, between 22:05 and 22:25 (Fig. 68B), documents a sedimentary section defined by thin, closely spaced reflectors. The reflectors are not generally continuous, although some span the section and basement is clearly seen onlapped to the south.

Sediment Thickness

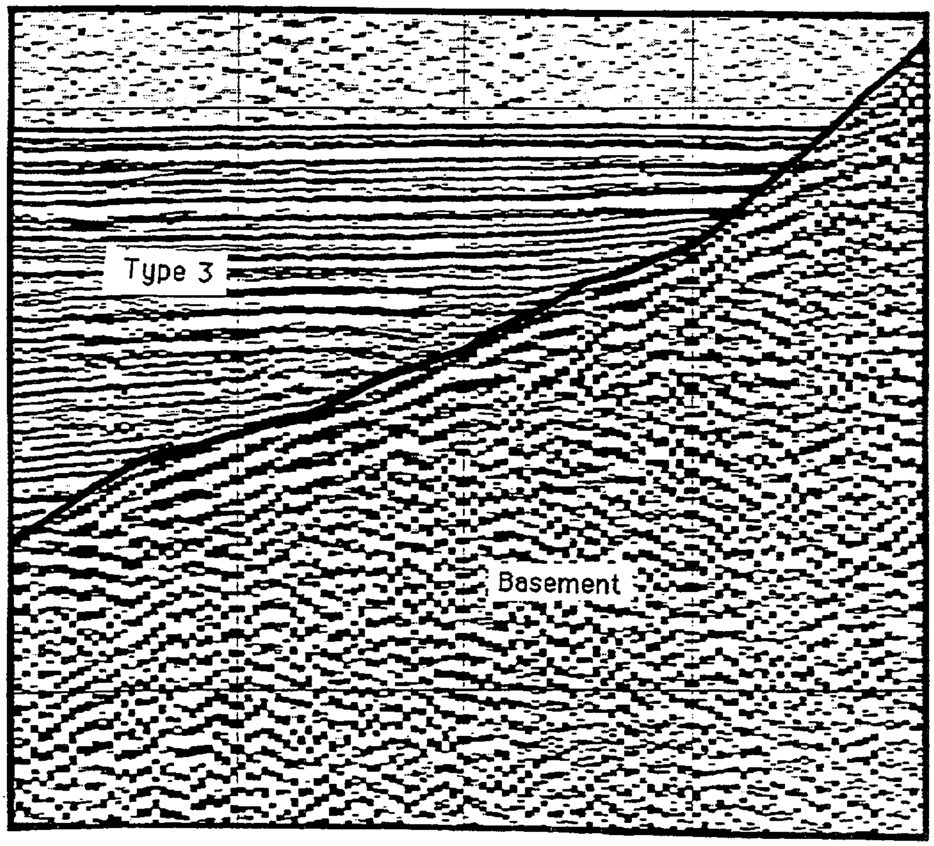
A map depicting the thickness of sediment in the study area (Fig. 69), prepared using raw single channel seismic data, shows a maximum penetration of *ca.* 3 seconds. Five thick sedimentary basins can be identified, all of which correspond to areas of widespread surficial deposition as recognised from acoustic facies types IIA, IIB and their hybrids. The largest of these basins, to the NW and E, have a maximum thickness of 1.5 to 2 and > 2 seconds respectively. They are both rimmed by IIB facies which is transitional to IIA towards their centres, and have formed behind basement highs that block drainage to the north and west. Sediment thickness within the north western basin increases dramatically from zero at its western bounding scarp to > 1.5 seconds within 3 to 4 km indicating that the scarp probably continues some distance below the seabed and formed on the edge of a graben or half graben structure.

Sediment Sources

Figure 68. ***Tasmante*** **seismic sections from northern South Tasman Rise. A** shows two character types (see text) and acoustic basement on line 17. **B** shows a third character type and basement on line 36.



Section **A**



Section **B**

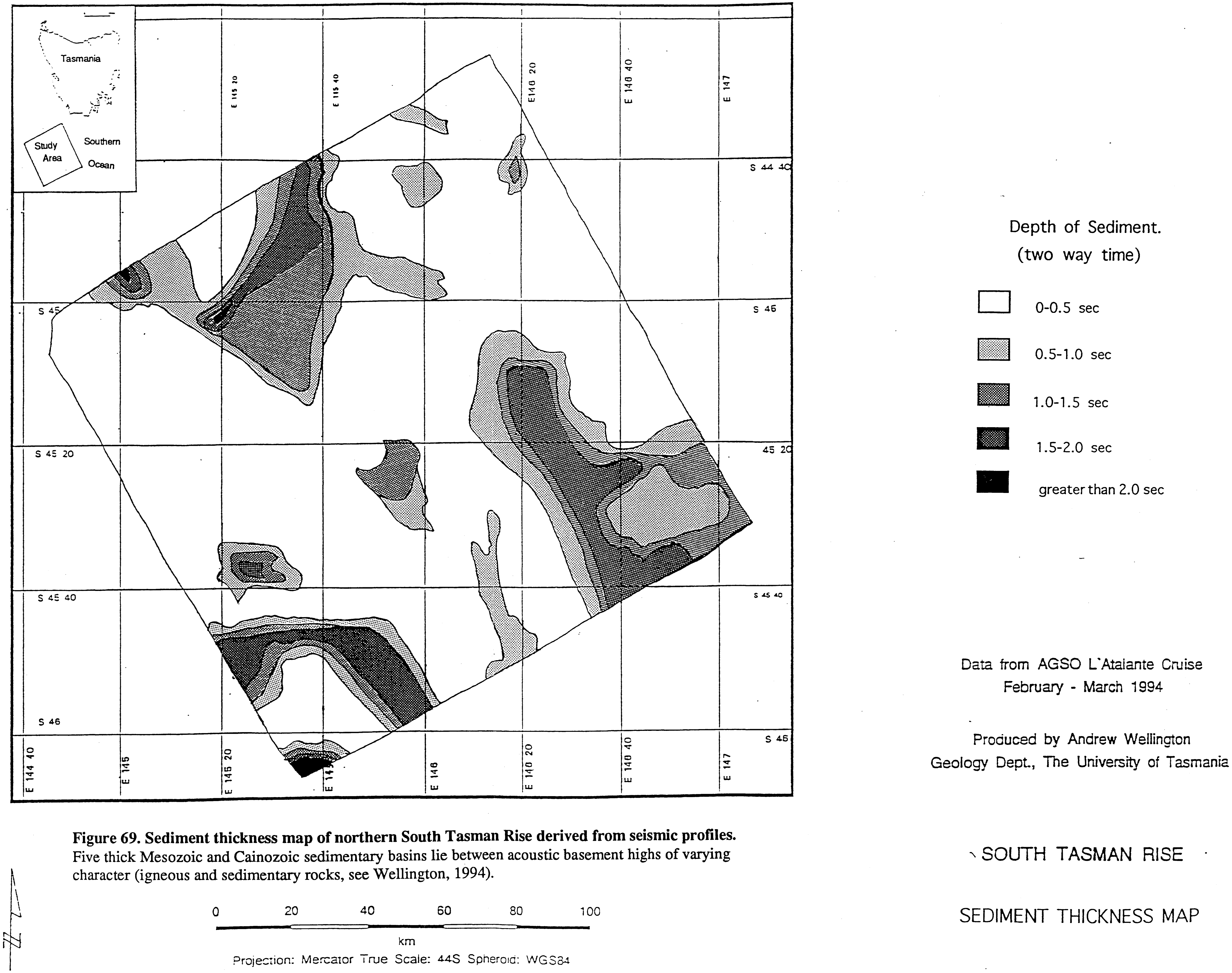


Figure 69. Sediment thickness map of northern South Tasman Rise derived from seismic profiles. Five thick Mesozoic and Cainozoic sedimentary basins lie between acoustic basement highs of varying character (igneous and sedimentary rocks, see Wellington, 1994).

Data from AGSO L'Atalante Cruise
February - March 1994

Produced by Andrew Wellington
Geology Dept., The University of Tasmania

SOUTH TASMAN RISE

SEDIMENT THICKNESS MAP

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 source of sediment deeper within the basins is less apparent. Given that the deepest sedimentary basins in the study area contain up to 5 km of sediment, and assuming a pelagic sedimentation rate of 3 cm per 1000 years, the maximum thickness of pelagic sediment accumulated after the rifting at 95 Ma (Veevers, 1986) is 2.85 km. The additional 2.15 km of sediment could then be attributed to syn-rift terrestrial and volcanogenic deposition, along with current transported sediment sourced from higher on the rise, as is the case today. Assessing the relative inputs of each, however, is beyond the present data set.

Discussion

The overall sedimentary character of the study area 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 (Figs. 54-56) 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 comprehensive ground-truthing scheduled for February 1995.

MAPPING OF FISHING GROUNDS

(N.F. Exon)

The Australian Southeast Fishery has important fishing grounds east, south and west of Tasmania, and large parts of the latter two were mapped during the *Tasmante* cruise (Fig. 70). The following discussion on the fish is drawn largely form Kailola et al. (1993), and news items in "Australian Fisheries". The fish of most interest in the fishery are orange roughy, fished south and east of Tasmania, and blue grenadier, fished west of Tasmania. Both are caught near the bottom, using demersal otter trawls. The 1994 total allowable catches (TAC) in the fishery are 8153 tonnes for orange roughy (wholesale price about $4.20/kg), and 12 376 tonnes for blue grenadier (about $2.50/kg). Orange roughy tends to live above 'hills' south of Tasmania, and blue grenadier in canyons in the west. Orange roughy is caught in winter spawning aggregations at the St Helens 'hill' off northeast Tasmania, and in summer off the southern seamounts, in water depths of 800-1200 m. Blue grenadier spawns in winter and early spring off Cape Sorell west of Tasmania, and is caught in water 300-600 m deep.

Before releasing three detailed maps of the two fisheries areas to fishermen, AGSO consulted widely with CSIRO Division of Fisheries, the Australian Fisheries Management Authority, the Australian Nature Conservation Agency, the Bureau of Resource Sciences, the Department of Environment, Science & Technology, and the Energy Programs & Fisheries Division of our own department, about conservation questions, not only concerning the fish stocks, but also the large benthic corals growing on the seamounts. A proposition was put to the Southeast Trawl Association that newly discovered deeper seamounts should be the subject of a fishing moratorium while research was carried out into their natural resources (Koslow & Exon, in press). These discussions are continuing but the maps have now been released through the AGSO Sales Centre.

The maps are at 1:100 000 scale with 20 m contours, and are a tremendous advance on the very generalised pre-existing maps of the fishing grounds. Their location is shown in Figure 70, and examples of the data are shown in Figures 71 & 72. Two maps have been produced of the southern orange roughy fishing grounds: one plain bathymetry, the other with areas of rough sea bed mapped from the acoustic imagery and also 'hill' names added. These cover water depths of 800-3000 m on a slope that generally falls southward at 3-5°, and show that the fishermens' hills are steep-side volcanoes up to 600 m high, with rocky slopes of 20-30°. About 50 known hills and 20 new ones are now very accurately located (Table 2), and mapped in the sort of detail which allows fishermen to set their nets to run just above the bottom with little danger of damage. This should considerably improve the efficiency of fishing.

The western area off Cape Sorell is a generally smooth, sedimented slope of about 5°, cut by a series of submarine canyons running downslope to the west or west-northwest (Fig. 72). Altogether there are 25 major canyons spread along 90 kilometres of sea bed. Only 15 of these canyons extend into water shallower than 1500 metres, but most of these (and some other smaller canyons) extend to the edge of the continental shelf at 170-200 m. The canyons, cut into Neogene sediments by sediment moving downslope, are steep-walled and seldom more than 100 m deep. Those in water shallower than 600 m are important to the blue grenadier fishery, and their accurate location and shape, as revealed in the bathymetric map recently released, are clearly of benefit to the fishermen.

NAMED SEA MOUNTS

NAME/NO	LATITUDE	LONGITUDE	DEPTH (M)
N.W. MATT.	-44.189039	146.155335	780
MAIN MATT.	-44.213397	146.191221	735
ON SHELF	-44.170322	146.848656	1035
GROWLER	-44.244027	146.902013	1010
SAM'S HILL	-44.312824	147.083320	1005
BANK HILL	-44.258763	147.112732	735
MAIN PEDRA	-44.259362	147.096961	720
LORNA	-44.265644	147.009040	1090
ANDY'S	-44.193189	146.981877	660
MACKA'S	-44.196282	147.041891	670
CONGER	-44.254164	147.178832	1075
THE SISTER 1	-44.276590	147.249594	930
THE SISTER 2	-44.266593	147.238534	910
PATIENCE	-44.124694	147.382864	975
DORY HILL	-44.326373	147.120178	1090
BELINDA'S DORY H.	-44.378806	147.110750	1315
4	-44.207013	146.165865	970
23/31	-44.211086	147.151883	975
26/27	-44.197788	147.210688	N/A
29	-44.212198	147.233557	975
35	-44.253779	147.285312	1240
36	-44.247043	147.372814	1350
37	-44.204323	147.394858	1235
38	-44.214879	147.355985	1195
40	-44.217759	147.299068	N/A
43	-44.186418	147.388387	1115
AA	-44.289070	147.065402	1150
NEW 3	-44.249351	146.190156	1150

UNNAMED SEA MOUNTS

NAME/NO	LATITUDE	LONGITUDE	DEPTH (M)
A	-44.157124	146.089156	1215
B	-44.219941	146.154400	955
C	-44.245963	146.163409	1195
D	-44.266843	146.188626	1335
E	-44.339478	146.198631	1735
F	-44.269915	146.234062	1200
G	-44.256932	146.278472	1345
H	-44.320483	146.342997	1790
I	-44.301454	146.383766	1570
J	-44.383468	146.549866	1755
K	-44.244604	146.639323	1470
L	-44.348733	146.860169	1755
M	-44.255058	147.004050	1055
N	-44.403553	146.992067	1530
O	-44.423960	147.037180	1885
P	POINT DELETED		--
Q	-44.398403	147.138858	1630
R	-44.411459	147.142224	1515
S	-44.281163	147.170184	1240
T	-44.300122	147.186898	1180
U	-44.324555	147.180004	1155
V	-44.394028	147.178150	1495
W	-44.434883	147.229362	1815
X	-44.390775	147.251111	1620
Y	-44.369004	147.231750	1785
Z	-44.343160	147.232679	1635
A1	-44.328356	147.273306	1335
B1	-44.308938	147.279446	1340
C1	-44.358186	147.311103	1755
D1	-44.387051	147.312657	1650
E1	-44.316517	147.328543	1770
F1	-44.356301	147.336601	1870
G1	-44.388151	147.346231	1790
H1	-44.338314	147.370676	1940
I1	-44.299609	147.344973	1675
J1	-44.256358	147.349347	1235
K1	-44.293597	147.385877	1370
L1	-44.224606	147.402366	1340

Table 2. Locations, elevations and names of seamounts in orange roughy fishing grounds south of Tasmania. Area of contour maps covering fishing grounds released by AGSO shown in Figure 70; names and numbers of seamounts are shown on one of those maps.

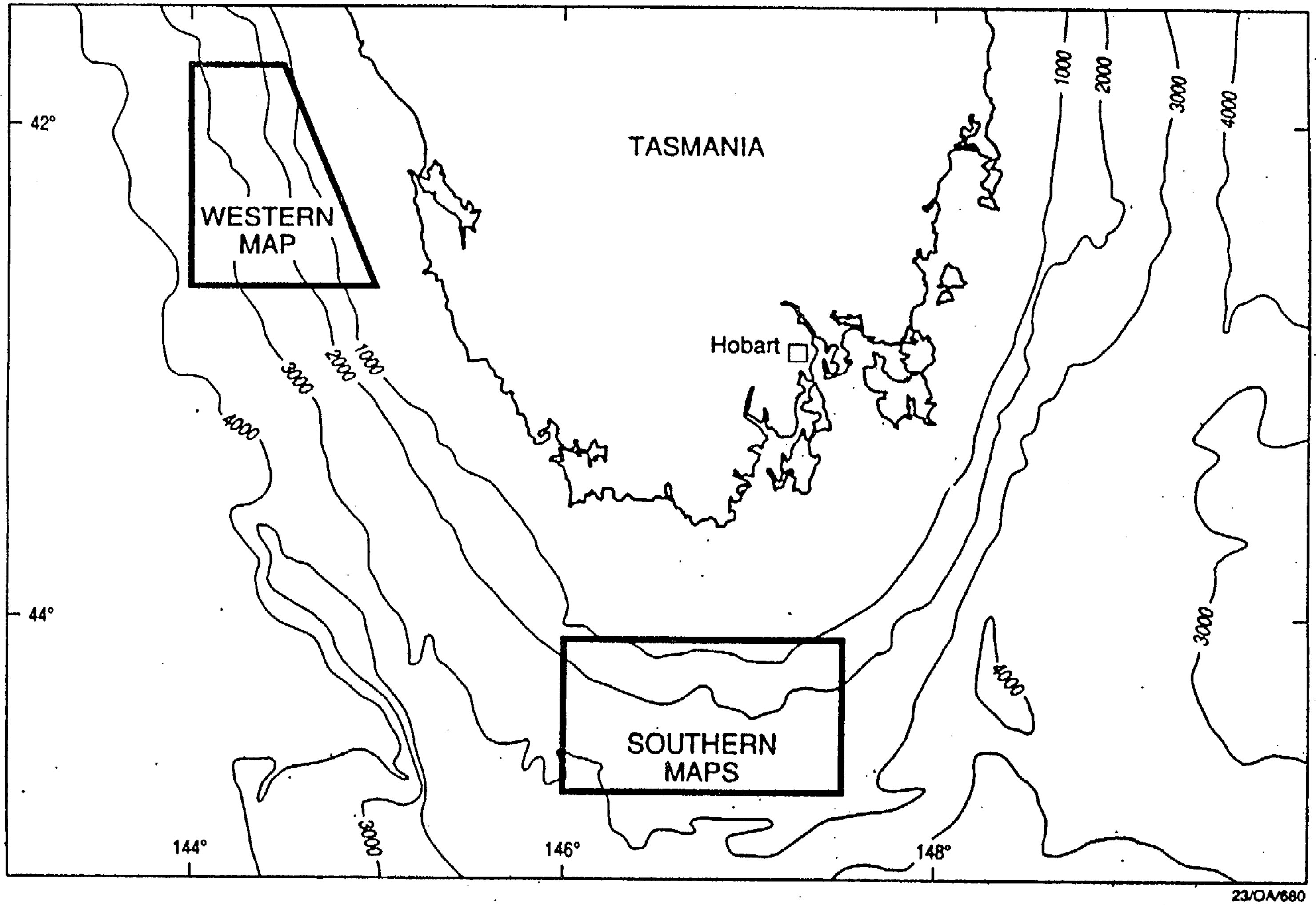


Figure 70. Map of Tasmanian offshore region showing areas covered by detailed *Tasmante* maps of swath bathymetry released to the fishing industry.

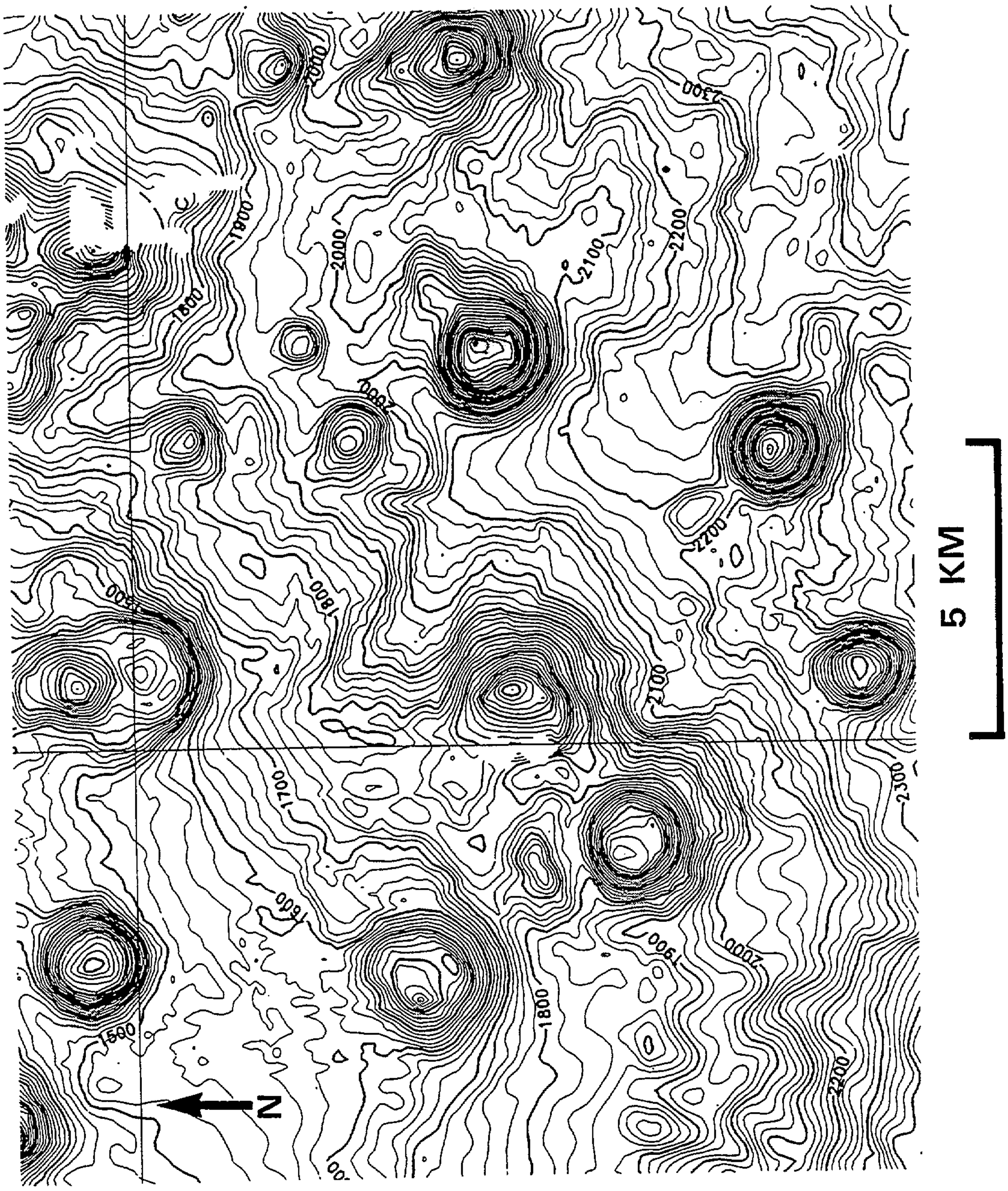


Figure 71. ***Tasmante*** **bathymetric contour map of a small part of the orange roughy fishing grounds south of Tasmania.** Contours are in metres. The seamounts are extinct volcanic cones hundreds of metres high with slopes of 20-30°, and their tops are the fishing grounds.

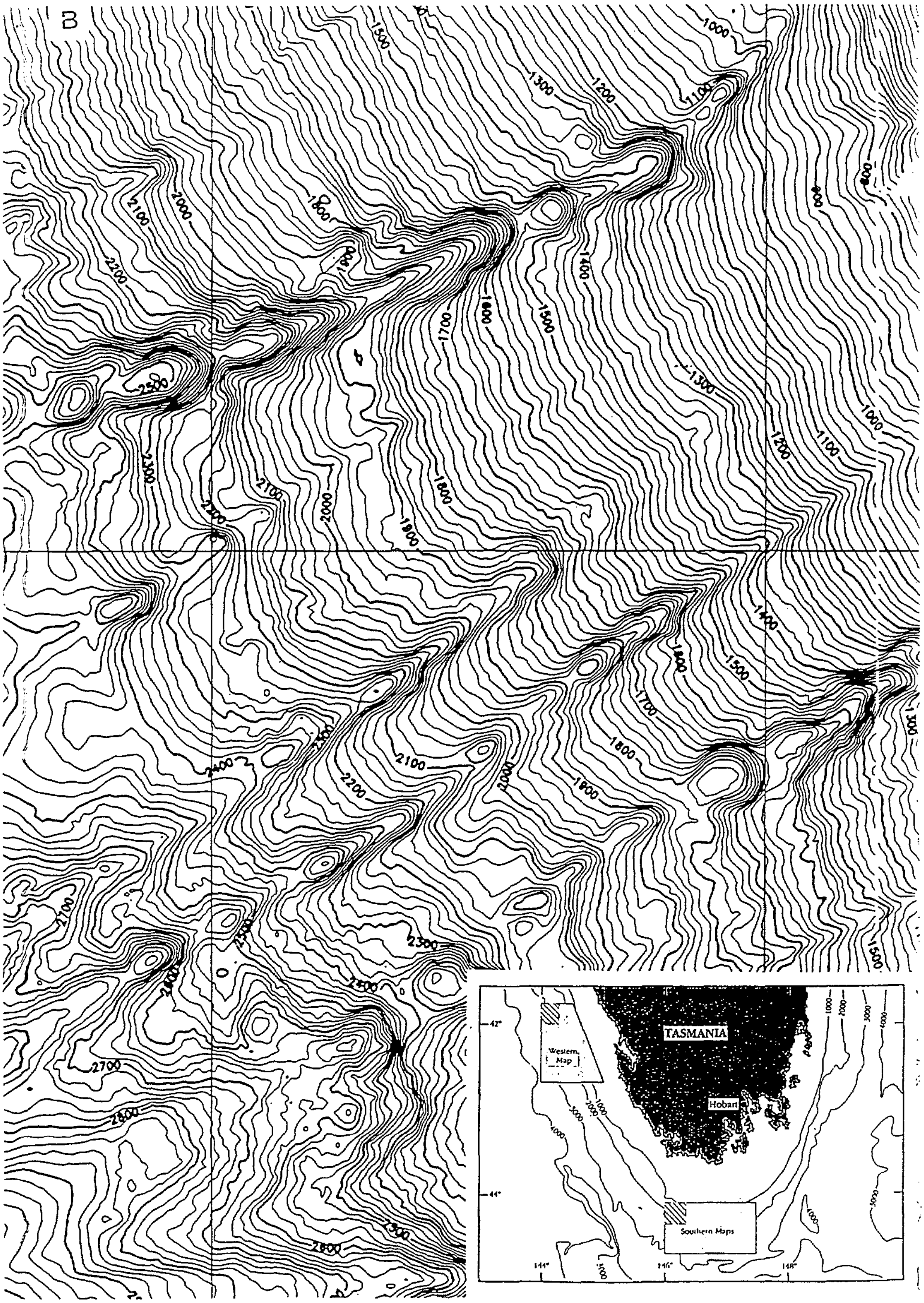


Figure 72. *Tasmante* bathymetric contour map of a small part of the blue grenadier fishing grounds west of Tasmania. Contours are in metres. Map covers hachured part of western area located in inset map. The young sediments of the continental slope are cut by canyons less than 100 m deep with which the blue grenadier is associated.

OVERVIEW OF MAJOR SCIENTIFIC RESULTS

New Zealand to South Tasman Rise

The transit (Fig. 22) from New Zealand to the South Tasman Rise was designed to map structural trends in both continental and oceanic terrains. In the Tasman Basin it was sited so as to cross no fracture zones, parallel to but just north of a fracture zone visible in the GEOSAT imagery,.

Along the transit, the *North Island* of New Zealand extends southwestward steadily downward to about 1100 m below sea level, where it gives way to the *Reinga Basin,* which is a depression 150 km wide, marked by a gravity low. Along the profile, sea bed falls steadily from 1100 m to 2000 m, before rising to 1950 m. The seismic sequence is less than 0.4 seconds thick east of the volcanic Taupo Seamount, which rises from acoustic basement on the eastern side of the basin. West of the seamount, acoustic basement is more than 2 seconds below the sea floor, and there are several gentle unconformities. The upper half of the section is much better-bedded than the lower half, probably representing a change from clay to turbidite deposition.

Where crossed on its southeastern nose, the *West Norfolk Ridge* is 80 km wide. It rises to 1650 m below sea level, and then falls regularly, to 2275 m. West of a bounding fault block is a fault-bounded transpressional basin 18 km wide, containing at least 1.6 seconds of sediments deformed by east-dipping thrust faults, and unconformably overlain by 0.4 seconds of well-bedded Neogene sediments. Beyond this basin, acoustic basement is only 0.2-0.4 seconds deep. Basement is cut by several east-dipping faults, with sediment wedges in the resulting depressions. The central part of the ridge coincides with a gravity high, but the western half forms a low. The ridge generates three strong positive magnetic anomalies, suggesting that it may consist of thickened oceanic crust.

The *New Caledonia Basin* is remarkably flat and contains very thick sediments. Rough acoustic basement is visible only on its sides. A poorly bedded sequence in the east, whose upper surface lies 0.6 seconds beneath the sea bed, onlaps basement and can be traced westward to the basin's axis, where it lies 1.9-2.6 seconds deep. The sequences above the poorly bedded sequence are virtually flat-lying, and onlap it toward either side of the basin. The sedimentary sequences indicate that the basin has been an undisturbed structural low for a long time. The basin corresponds to a gravity high, suggesting shallow mantle. Its flanks are magnetic highs and its centre is a low.

The *Challenger Plateau* is 275 km across and consists of thinned continental crust separated from Australia and Antarctica in the Late Cretaceous. It is complex, as shown in our seismic profile. The plateau rises from 2300 m at its eastern margin to 825 m, and then falls to 2200 m at its western margin. It is broadly convex and symmetrical. On the eastern flank, deep sedimentary sequences have been extensively intruded, and plutons, sills and flows are apparent. Faulting is seen at depth, but does not affect the upper half second of well-bedded sediment. Igneous basement comes near or to the surface from the crest of the plateau westward, with pockets of older sediments apparent in the igneous material. The plateau forms an irregular gravity high, and corresponds with several major magnetic anomalies.

The *Bellona Trough* is a southerly-trending feature that separates the Challenger Plateau from the Lord Howe Rise. Our profile cuts a southwest-trending branch of the main trough, 20 km wide, near its northern limit. Water depth drops along the profile from 2200 m to 2700 m. The trough is bounded by relatively steep (faulted?) flanks several hundred metres high. It generally contains about 1.6 seconds of sediment that onlaps acoustic basement. In the west, igneous basement rises toward the basin margin. A lower, poorly-bedded sequence, about 1 second thick, is overlain with slight unconformity by a well-bedded (Neogene?) sequence about 0.6 seconds thick. The trough coincides with gravity and magnetic lows.

Where crossed on the *Tasmante* transit, the continental *Lord Howe Rise* consists of a broad eastern high, a low, and a narrower western high, totalling 280 km across. There are two gravity highs and a low mimicking the bathymetry. Several magnetic anomalies coincide with the rise. The eastern base of the rise is at 2700 m, and it rises to a culmination at 1700 m before falling to a terrace at 2500 m. There is shallow and complex basement on the eastern slope. Basement virtually crops out at the culmination, and then drops away westward to 1.5 seconds below sea bed. It is less than half a second deep beneath the central depression. The overlying sequence consists of a lower unbedded sequence, a middle well-bedded sequence, and an upper moderately bedded sequence, all of them considerably disturbed. The western high has a broad culmination at 2400 m; beyond that a rugged ridge runs along the profile to 2700 m. A precipitous scarp falls from 2800 m to 4600 m on the edge of the Tasman Abyssal Plain. Basement is less than a second deep beneath the western high, but there is a half-graben about 10 km wide and filled with older sediments to the west. Along the ridge, basement rises to reach the sea bed at the edge of the scarp. The overlying sequence is well-bedded and thin.

The *Tasman Abyssal Plain* formed by Cenomanian to Eocene seafloor spreading that moved the Lord Howe Rise away from Australia. Our profile is 1080 km long and parallel to the fracture zones as defined by GEOSAT satellite imagery, so no fractures were crossed. However, the path across the eastern abyssal plain has a fracture zone immediately to the south, and this has given rise to the numerous volcanic cones. In contrast, west of the old spreading axis there are no volcanoes. The gravity profile shows a general high over the oceanic crust, with local highs related to seamounts, and a prominent low over the extinct spreading centre. Magnetic anomalies 33 to 24 can be identified, suggesting that fast spreading began about 82 Ma and ended about 56 Ma.

The eastern half of the abyssal plain is 520 km wide. An irregular basement surface is generally 0.6-1.2 seconds deep. In the east the plain is generally very flat (4700-4900 m). In some areas a two-fold division of the overlying sediments is possible: the lower third being poorly bedded (clay?), unconformably overlain by a well-bedded and undisturbed sequence (turbidites?). The remainder of the eastern plain is characterised by volcanic cones, with a maximum diameter of 20 km, rising as much as 1300 m above the sea bed. The cones are frequently onlapped by younger poorly bedded sediments, as much as 0.6-1.0 seconds thick. The spreading centre itself is bounded by irregular highs about 20 km wide, and is in a flat-bottomed depression. Basement is about 0.5 seconds beneath the bounding highs. Basement beneath the spreading centre is about 8 seconds below sea level, and about 0.8 seconds below that of the flanking highs. It is overlain by 1.2 seconds of poorly bedded sediment.

The western Tasman Abyssal Plain is 570 km wide along the profile, to the foot of the East Tasman Rise. Its average elevation is 4700 m. Overall, basement is very irregular and faulted, but the irregularities are evened out by a blanket of poorly bedded sediments 0.6-1.0 m thick. DSDP Site 283 is on a broad basement rise near the South Tasman Rise, with 0.7 seconds of section. The sequence drilled was 590 m thick, and consists almost entirely of Paleocene to Late Eocene clays. West of the site basement drops to about 1 second below sea floor, at about 4600 m. The sea floor rises slowly to 4200 m at the foot of the East Tasman Rise.

The *East Tasman Rise* is a large equidimensional and possibly continental feature, from the middle of which the Soela Seamount rises. Our 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.

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 (Fig. 25) suggest that the 250 km wide *depression between the East Tasman Rise and the South Tasman Rise* may be oceanic. There are gravity lows adjacent to the two rises, which themselves are associated with broad gravity highs. Between the marginal lows, the gravity values also are generally low. There are two major positive magnetic anomalies in the depression, one immediately adjacent to the South Tasman Rise. There is an irregular gentle slope down to the edge of the flat base of the low between the East and South Tasman Rises, at 4050 m. There is then a gentle rise westward to 3900 m, and a more rapid one to 3250 m.

The seismic profile shows basement with oceanic character up to 2 seconds below sea bed (Fig. 49). It is overlain by a thick poorly bedded section (Palaeogene mudstone?) that is unconformably overlain by a well-bedded section up to 0.8 seconds thick, containing several unconformities (Neogene pelagic carbonates and turbidites?). 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 at this stage of our studies, 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 (Fig. 43).

South Tasman Rise

The *South Tasman Rise* is a submerged continental block larger than Tasmania, that extends from 44° to 50°S, and about 150 000 km² (three-quarters) of it was mapped during the *Tasmante* cruise (Figs. 2, 3 & 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. 15 & 43), 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. 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. 10, 11, 12, 14, 19 & 21. 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. 53) 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. 53), 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. 53). 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.

Deep trawl fisheries

Areas south, east and west of Tasmania are host to major demersal fisheries for orange roughy and blue grenadier. Because the fishermen seek to run their trawls just above the sea bed, and because the existing maps were primitive, the high-quality *Tasmante* bathymetric maps of the sea bed generated a great deal of interest. Maps of two areas have been released (Fig. 70), and some 25 sets of maps were sold before the end of 1994. AGSO and CSIRO are jointly investigating ways of doing more swath-mapping of important fisheries areas, by hiring or purchasing a suitable system.

Before releasing the three detailed maps of the two fisheries areas, AGSO consulted widely with other Commonwealth agencies about conservation questions, not only concerning the fish stocks, but also the large benthic corals growing on the seamounts. A proposition was put to the Southeast Trawl Association that newly discovered deeper seamounts should be the subject of a fishing moratorium while research was carried out into their natural resources (Koslow & Exon, in press). These discussions are continuing.

Otway Basin margin

The transit (Fig. 23) from the abyssal plain northwest of Tasmania (40°42'S 141°23'E) to the upper continental slope south of Adelaide (37°09'S 138°16'E) was designed primarily to map the lowermost continental slope of the Otway Basin. It included the locations of a number of earlier successful dredge hauls of Palaeozoic, Upper Cretaceous and Eocene rocks. It was planned using GEOSAT gravity imagery and the dredge locations, and succeeded in running along the escarpment at the foot of the continental slope for much of its length.

The transit is interpreted as starting on heavily sedimented, highly stretched continental crust beneath the abyssal plain northwest of Tasmania, in a belt about 25 km wide and trending 320° (Profile 67). To the west is less sedimented Early Tertiary oceanic crust, formed by spreading in the 350° direction, and including oceanic hills trending 280°. To the northwest is a ridge on oceanic crust, at least 80 km long, trending 335°, and almost certainly a volcanic buildup along a fracture zone related to the younger period of spreading (Profile 68). A dozen kilometres to the west are three abyssal hills, elongated to 310°, and possibly volcanic buildups related to the older period of spreading.

Most of the remainder of the transit to the NNW, nearly 350 km in total, was along the foot of the continental slope of the Otway Basin (first 210 km) or moving at an angle up the slope (Profiles 69 & 70). [Seismic reflection evidence from an AGSO cruise underway in December 1994 suggests that the adjacent abyssal plain is underlain in some places by highly stretched continental crust, and in other places by oceanic crust, so the foot of the slope cannot be equated with the continent-ocean boundary]. A segment 130 km long trends 310°, and continental rocks have been dredged from it. After a gap of 20 km, representing fault displacement, the slope reappears and the profile gradually moves up it. It generally consists of continental segments trending 310° and displaced by faults trending about 280°.

A series of canyons run down the slope due west of Beachport, and another canyon marks a change westward in slope trend, to 280°. It is clear that the swath-mapping of the continental slope shows many primary structures, heavily modified in places by sedimentary processes, including transfer faults with horizontal offsets of 10-20 km at the foot of the slope. Palaeozoic, Mesozoic and Tertiary rocks, largely sedimentary, crop out in the lower slope, and pre-existing seismic data indicate that these form stratified sequences dipping back into the slope.

POST-CRUISE STUDIES

After the cruise, two of the cruise participants, Andrew Wellington and David Belton, wrote excellent BSc(Honours) theses based, in part, on the *Tasmante* data. Their results are outlined briefly below.

Wellington (1994) made a geophysical interpretation of 20 000 km^2 of the northern flank of the South Tasman Rise, using our data and data from the *Sonne*-36 cruise (Hinz et al., 1985). The area is centred on 45°20'S and 145°50'E, about 200 km south of Tasmania. The area is a complex one, with raised and sometimes rotated basement blocks bounded by fault scarps, and separated by flat sedimented areas. Water depths are generally in the range 2000-3500 m. Wellington concluded that the area consists of continental crust like that of west Tasmania, and had moved 300 km southeast along a major strike-slip fault, from west of Tasmania, in the Late Jurassic and Early Cretaceous (153-122 Ma). On geophysical character he picks pre-Cambrian siliceous and dolomitic units, granite plutons that may be Devonian in age, Permo-Triassic sedimentary sequences with dolerite intrusions, flat-lying Cretaceous and Cainozoic sedimentary fill, and a Tertiary volcano 1.6 km high. He explained the complex structures as largely being caused by the interaction of two major tectonic regimes: early strike-slip motion along a major NW-SE trending wrench system, and later oblique extension associated with the activation of N-S spreading.

Belton (1994) described the impact of climate and currents on Late Quaternary sediments on 60 000 km^2 of the west Tasmanian margin, in water depths of 500-4500 m. The study was based largely on *L'Atalante* bathymetry, imagery and 3.5 Khz echosounder records, and a very detailed sedimentological/isotope study of three cores taken by *Rig Seismic* (Exon & Lee, 1987) and one by *Sonne* (Hinz et al., 1985). The results show that in the last 120 Ka (isotope stage 5 and youger) pelagic sedimentation has predominated. The dominant sediment types are foram-nanno ooze, nanno-foram oooze and foram sand. During highstands associated with interglacials, terrigenous sediment was trapped at the coastline, and only during glacials was it transported to the edge of the shelf and down the slope by gravity transport processes. Geostrophic currents, at about 1000 m depth, have had only a limited influence by inhibiting the deposition of the finest particles. Acoustic facies mapping shows Late Quaternary sedimentation to change systematically downslope. The upper slope (300-2200 m) is dominated by gravity flow sediments of various types, the mid slope (2200-3500 m) is winnowed, and the lower slope (3500-4800 m) has a mixture of hemipelagic and turbidite sedimentation. The sediment conduits are canyons averaging less than 100 m in depth.

SCIENTIFIC EQUIPMENT AND ITS PERFORMANCE

(P.J. Hill)

L'Atalante (Appendix 2) is a modern 85-metre oceanographic research vessel specifically built for high-technology seafloor mapping. It is equipped with the advanced SIMRAD Dual EM12 multibeam echo-sounder (Appendix 3). This system maps bathymetry and acoustic reflectivity of the seafloor at a ship's speed of up to 10 knots or more. The swath width is about 7 times the water depth; the maximum effective coverage in deep water (several kilometres or more) is about 20 km.

During the *Tasmante* survey, geophysical data were acquired concurrently with the EM12D swath-mapping data acquisition. These geophysical data comprised gravity, magnetics, 3.5 kHz echo-sounder profiles and 6-channel GI gun seismic. The seismic data were digitally recorded and also displayed on a strip-chart monitor. Ancilliary oceanographic data, including SIPPICAN XBT temperature profiles (to 2000 m depth), continuously-logged surface sea-water temperature, salinity and sound velocity data, plus acoustic doppler current profiler (ADCP) data to about 600m depth, were also collected.

Survey and navigation equipment details are provided in Appendix 4. Also provided, in Appendix 5, are the geophysical acquisition parameters and a sketch of the the acquisition geometry.

The EM12D data were acquired digitally on the ARCHIV system. Bathymetry contour maps were plotted automatically (almost) in real time on a large Benson 1425 flat-bed plotter with a selection of coloured pens. The acoustic imagery was displayed as it was acquired on a Dowty Wideline 195 strip-chart recorder. As well as these hardcopy outputs, the EM12D data were also displayed in real time in various formats on large-screen, colour graphic display monitors. The numerous displays allowed very effective monitoring and quality control during acquisition, and also facilitated ongoing finetuning of survey planning. The gravity, magnetics and vertical bathymetry were displayed as profiles on a graphic display monitor. This monitor gave a continuously-updated display of the previous two hours of data.

A total of approximately 17,300 km of data (EM12D, gravity, magnetics, 3.5 kHz and airgun seismic) were collected during the cruise. Data quality was generally very good.

Navigation

Excellent non-differential GPS navigation (100% coverage) was available for the duration of the survey.

On several occasions the primary GPS navigator (GPS1) showed a sudden apparent jump in position of several hundred metres. As a result, the Auto Pilot began to take the ship off the designated course. During the few times that this happened, quick manual intervention by the officer-on-watch brought the ship back on course. The cause of the problem was not clear.

SIMRAD EM12D bathymetry / acoustic imagery

A new improved version of the EM12D acquisition software was installed at the start of the cruise. However, when tested during the sea trials off Auckland problems were encountered and the old software was re-installed. The old software contained a bug that resulted in unpredictable loss of data for short periods of time. During the *Tasmante* survey, such data loss usually took the form of a data gap of about 5 minutes duration per day.

Accurate cross-track positioning and time-to-depth conversion of the raw swath data was hampered at times, due to significant variations in sound velocity with depth, both in time and from place to place. This was particularly the case over parts of the South Tasman Rise, where abrupt changes in surface sea temperature were not uncommon. Surface temperatures were sometimes seen to change by up to 3°C over a period of less than 10 minutes (about 3 km distance). Large-scale current gyres, migrating north to south within the eastern Australian boundary current and interacting with the relatively cold circum-Antarctic polar current, were probably the cause of the temperature variations. Frequent deployment of SIPPICAN XBTs alleviated the problem, but some mismatch of bathymetric contours between adjacent swaths remained in some places. In such cases, the data across the mismatches were either smoothed out or edited out. The processing software aboard the ship did not allow the back-interpolation of velocity profile data, often resulting in minor discontinuities in the bathymetry at locations where new XBT data were entered.

Midway through Leg 2, while surveying the west Tasmanian continental slope, it was found that while in Auto mode the EM12D tended to lock into a less than optimum angular coverage sector (eg. 128°, rather than 150°). This reduced potential areal coverage (though slightly increased cross-track resolution). To achieve maximum swath-width, it was necessary from time to time to 'unlock' the EM12D by switching to Manual mode for a short period and then back to Auto.

Airgun seismic

The dual GI gun source and small-diameter, high-speed streamer were an excellent combination that provided high resolution and relatively low-noise data at ship's speed of up to 10.5 knots. In thickly sedimented areas, it was not uncommon to see structure to time-depths of 2.5 seconds (2.5-3 km) sub-bottom in the single-channel monitor records.

For Leg 1 of the survey, the generator-injector delay on the GI guns was set at 40 ms. This figure is in accordance with the manufacturer's recommendations based on the operating parameters. The setting was changed to 28 ms by the new seismic technician at the start of Leg 2. When this was discovered, tests were conducted using the two settings. The tests showed that while there was no major difference in the output gun signatures, the 40 ms setting produced a slightly better waveform. The delay was reset to 40 ms at 0620 GMT on 15 March.

The airguns required very little maintenance, on average only once per week. When maintenance was required, the usual practice was to work on only one gun at a time, leaving the other gun in the water to continue shooting. Thus, apart from having to reduce speed to 6 knots to retrieve the guns, very little time was lost due to gun maintenance.

Hamworthy compressor problems led to minor data loss, in the order of 6 hours in total. Such loss was due to a variety of problems, including faulty valves, power failures and a ruptured oil sump in one of the compressors.

The digital data for Line 54B, amounting to about 11 hours, were lost due to operator error while changing a disk in the acquisition system.

The only major loss in seismic data due to bad weather occurred soon after leaving Hobart when the ship was hit by a 50 knot gale. No seismic data were collected on Lines 25 and 26; acquisition resumed on Line 27 after the seas had abated sufficiently to allow safe deployment of the gear.

Gravity

The gravity meter appeared to perform satisfactorily throughout the cruise with almost no loss of data. Noise levels varied with sea state. Noise levels were generally 2-3 mGal under normal conditions, but up to 10 mGal peak-peak during very rough seas. Large westerly swells of 3-5 m height and about 10-15 second period were common over the South Tasman Rise and this contributed to noise levels. The raw data were smoothed by internal filter set for sea state II. This setting introduces a time shift of 120 seconds to the data, and this needs to be corrected for during post-processing.

The only significant adverse event occurred on 21 February when the meter failed and several hours of data were lost. The cause of the problem was uncertain, but may have been initiated by a power failure. There were difficulties in restarting the meter and it was suspected that the gyro had failed. As a last resort, the electrical contacts on the gyro were sprayed with cleaner. This fixed the problem and the meter operated without further incident to the end of the cruise.

A ship-shore gravity tie was made in Hobart on 3 March. This was the first check of the meter drift since the ship left in Noumea in October 1993. During the last tie in Noumea on 22 October 1993, the KSS-30 read -1741.30 mGal corresponding to a calculated gravity value of 978864.60 mGal.

The tie in Hobart was made with the assistance of Bob Richardson of Mineral Resources Tasmania using a Sodin meter. The tie was made to base station 6491.0260 on Franklin Pier. The station value is 980437.25 mGal (IGSN84). The KSS-30 read -153.10 mGal corresponding to a calculated gravity value of 980438.71 mGal. Assuming the Noumea tie was made correctly, the Noumea/Hobart drift was 14.09 mGal (3.01 mGal/month). Though this apparent drift was fairly large, it was within acceptable tolerance limits. Nevertheless, it created the first suspicion that all was not well with the meter.

Gravity ties were made in Adelaide at the conclusion of the survey. These ties were made with the help of Tony White and Desell Suanburi of Flinders University using a Scintrex Autograv (CG4-IGS2) gravity meter. Ties were made to the A/S Memorial base station (8090.0108). Ties were made while the ship was at the BP Wharf (29 March) and also while at Berth 16, Dock 2 (30 March). At the BP Wharf the KSS-30 read -901.5 mGal for a calculated gravity value of 979698.83 mGal, while at Dock 2 the meter read -900.20 mGal for a calculated value of 979699.63 mGal. The tie results suggested a Hobart-Adelaide meter drift opposite in sense to the Noumea-Hobart drift.

Observation of KSS-30 meter readings while the ship was stationary at the wharf showed an unexplained wandering drift of up to several mGal (typically over 20 minutes - 1 hour). Checking back on the performance of the meter while at the wharf in Hobart revealed a similar effect.

Apart from the wandering drift of the meter, it also appears that an incorrect meter constant may have been set in the KSS-30. The strong linear correlation between meter reading (latitudinal variation) and apparent meter correction based on all the ties since Suva indicates this. The latest post-*Tasmante* data from Davao in the Philippines (close to the equator) confirms the trend. Most of the large apparent 'long term' drift of the meter between port ties disappears if a revised meter constant is used. Thus, in the processing of the data, the best solution may be to adjust the meter readings to a new meter constant based on the tie data (eg. multiply meter readings by 0.9917), and to apply a constant meter correction (i.e. assume zero meter drift, eg. add 980591 mGal).

Magnetics

The magnetometer was operational for almost the whole period of the survey. The magnetometer data were generally of good quality with noise levels of only 1-3 nT. However, there were some periods during the survey when the data were degraded by intermittent spikes and higher noise levels. Because much of the noise consisted of spikes within otherwise good smoothly-varying data (water depths mostly being large, 1-5 km), it is anticipated that editing will effectively remove the bulk of the bad data. Most of the spikes were removed aboard ship to produce the profiles shown in Figures 24-32.

The magnetometer data first became noisy on 15 February during the Tasman Sea transit. The magnetometer sensor was retrieved and opened up. Inspection indicated that the source of the problem in this case was salt water that had leaked into the sensor. The sensor was flushed and the magnetometer worked well for some time thereafter.

Noise spikes began to appear in the data from about 20 February, while over the South Tasman Rise, and persisted with fluctuating, though generally increasing intensity, until the port call in Hobart. Because the magnetometer cable passes over and relatively close to the starboard compressor, it was thought at one stage that the problem may have been due electical interference induced by the compressor and associated electrical cabling. Experimentation to find the cause of the problem included re-routing of the magnetometer cable and the switching of the operating compressor to the port side while in Hobart. The entire magnetometer cable and sensor were also replaced with a spare set, but the problem remained. Spikes were again present in the data for a few days after leaving Hobart, and then vanished and remained absent to the end of the survey. The cause of the problem was never conclusively identified. It is quite likely that the spikes were due to an electronic problem in the M-244 instrument console. Similar and similarly elusive problems had been experienced with this equipment on a number of previous surveys.

The magnetometer sensor was lost overboard at the end of the survey on 28 March while being recovered just prior to the seismic gear being brought aboard for the last time.

3.5 kHz high resolution seismic / bathymetry

The Raytheon transducer unit and Dowty Wideline 195 strip-chart recorder functioned well during the entire cruise. The unit was operated at full power.

Sub-bottom penetration in deep-sea pelagic sediments exceeded 100 m in a number of areas. Elsewhere, penetration in young, presumably relatively unconsolidated sediment, was typically in the order of 50 m. There was good definition of internal stratification. Over the South Tasman Rise, where swell heights of up to 5 m were encountered, the 3.5 kHz traces clearly showed a regular oscillatory motion corresponding to vertical movement (heave) of the ship as it rode over the swells.

FUTURE WORK

The geophysical data gathered on the cruise are being integrated with other remote sensed data (e.g. Fig 53), to better define the history of the separation of Australia from Antarctica to the south and the Lord Howe Rise to the east. The *Tasmante* maps are proving invaluable in planning a seafloor sampling cruise of *Rig Seismic* to be carried out in February 1995. This sampling will target Cretaceous, Paleocene and Eocene rocks to provide information on the pre-separation history of the margin, and oceanic basalts to elucidate the spreading history. Cores of Oligocene and younger marine sediments will be used to study changes in oceanic circulation and climate as Australia moved steadily northward away from Antarctica.

Several reflection seismic profiles are also planned to cross the region, in conjunction with planned profiles near Tasmania, in March 1995. These should show the crustal structure to 20-30 km below the sea bed, and help reveal how this complex region formed. Our colleagues from the University of Paris in Villefranche-sur-Mer intend to apply for use of the deep-diving submersible *Nautile*, to sample the strata exposed in the cliffs flanking the abyssal plains, in order to improve our understanding of the geology of the fault-bounded continental blocks.

Plans for the coming year include publication of an Atlas of maps at 1:1 000 000 scale, and production of several outside publications. Cooperation will continue with scientists from Australian and French universities, and CSIRO Fisheries and Oceanography Divisions.

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APPENDIX 1
DSDP Sites Tied During Survey

Site	Lat. (S)	Long. (E)	Water Depth (m)	Penetra tion (m)	Max. Age of Seds	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

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

APPENDIX 2
Information on *L'Atalante*

Length overall	84.60 m
Beam overall	15.85 m
Draught (zero trim)	5.05 m
Gross tonnage	2355 tons
Net tonnage	435 tons
Cruising speed	13 knots
Maximum speed	14.5 knots
Endurance at 12 knots	60 days
Port of registry	Brest, France

Propulsion:

Diesel-electric, twin screw

- 3 diesel alternators, each 1570 kVA
- 2 main electric engines DC, each 1000 kW
- 1 directional retractable bow thruster, 370 kW DC

Deck Equipment:

22 ton rotating stern A-frame

12 ton deep-sea winch (2 x 8000 m storage capacity)

Accommodation:

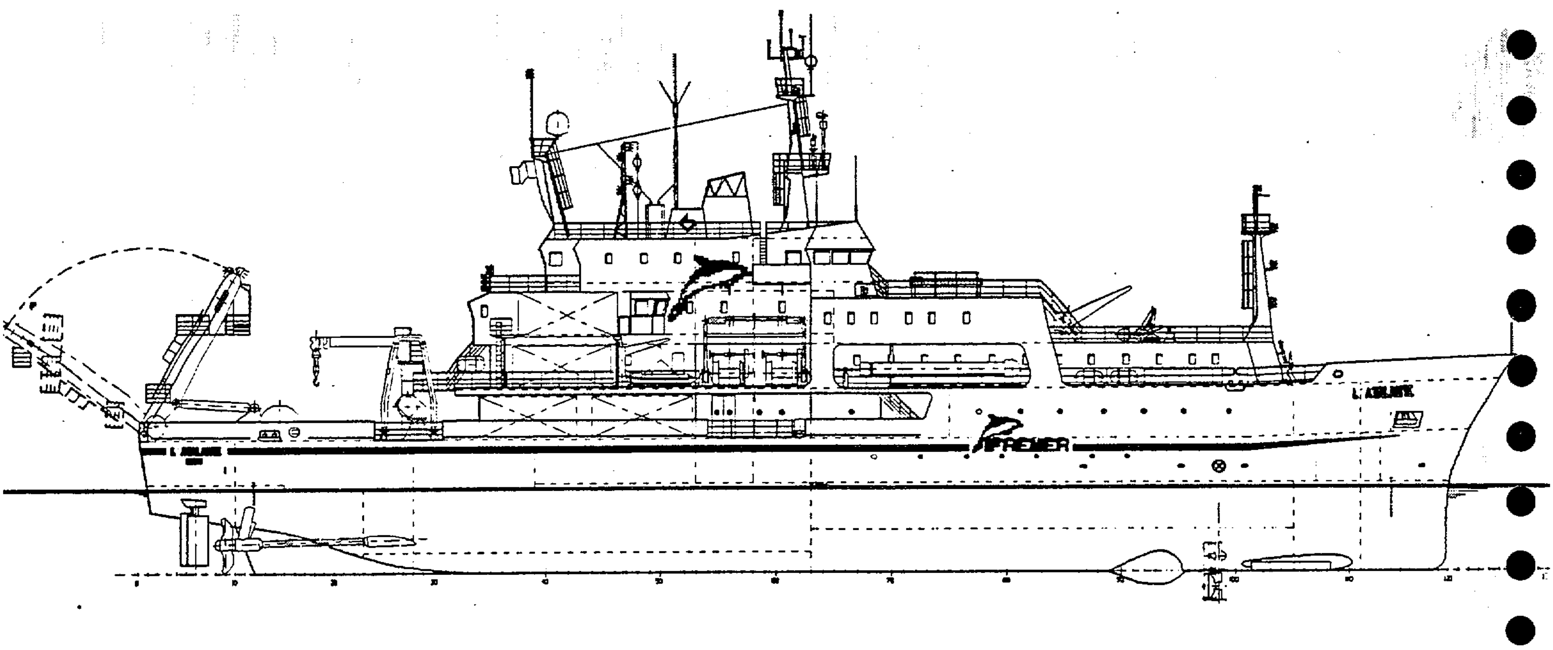
Total complement of 59 in single/double berth cabins

Officers and crew, 17-30

Scientists and technicians, 25-29

Operating company:

GENAVIR



APPENDIX 3
SIMRAD EM12D Multibeam Echo-sounder - Technical Information

The EM12D (Pohner and Hammerstad, 1991) consists of two EM12 13 kHz multibeam echo-sounders (one on each side of the ship), each generating 81 stabilized beams. The transducer arrays of each individual system are mounted in a cross-shaped configuration with one array for transmission (longitudinal relative to the ship) and one array for reception (transverse). The two sets of arrays are tilted 40° to each side from the horizontal. As presently configured, there are 3 common central beams, thus 159 points on the seafloor across-track are sampled with each ping. In the original configuration, 11 central beams were common in the two receiver arrays. This provided additional quality control.

The beam spacing of the EM12D, rather than being equiangular, is equidistant in horizontal spacing thus providing regular sampling of the seafloor. Five sector pulses are transmitted sequentially without delay. Ambiguities in reception due to sector overlap are eliminated since the sectors have different frequencies spread in a 1kHz band around 13 kHz. Unless manually overridden, the EM12D automatically selects the coverage sector according to depth, bottom conditions, and the number of beams with valid bottom detections. In deep mode, the 150° sector is usually operative in water depths to several kilometres. The swath width is 7.4 times water depth (in shallow to moderately deep water); typical cross-track coverage from about 2500 m depth to full ocean depth is about 20 km. This figure represents the effective swath-width limit in most deep ocean environments, and also represented maximum effective swath-width during our *Tasmante* survey.

The transmission sector is stabilized both for roll (±15°) and pitch (±10°). The reception beams are roll stabilized and the sampling interval in each beam is 240 cm in range (deep mode). The transmission beam-width is 1.8° and the reception beam-width is 3.5°.

A hull-mounted sound velocity sensor provides near-surface data to control beam direction. In addition, sea temperature profiles are measured up to several times per day to depths of about 2000 m using expendable probes (SIPPICAN XBTs with 0.2°C accuracy). Standard global salinity tables are used to convert the temperature data to sound velocity data.

Acoustic frequencies: 12.66/13.00/13.33 kHz
Transmission transducer dimensions: 4.8 m long, 555 mm wide, 262 mm deep
Reception transducer dimensions: 2.4 m long, 555 mm wide, 262 mm deep
Pulse length: 5 x 10ms (deep water mode)
Typical ping rate (deep water): 15 seconds
Relative precision on beams: ~0.2 %
Seabed image resolution (deep mode): ~7 m cross-track, 60-200 m in track direction

APPENDIX 4
Scientific and Navigation Equipment

Swath-mapping
SIMRAD Dual EM12 multibeam bathymetric / acoustic imagery system

Geophysical
6-channel seismic reflection system (Sismique Rapide), digital acquisition (DELPH2X system fitted in Industrial PC-610 computer with magneto optical disk drive)

DOWTY Model 3710 thermal linescan recorder (seismic monitor, channel 6)

AMG 37-43 streamer (6 active sections, each 50 m long containing 48 hydrophones and 1¾ inch in diameter)

2 GI Gun (Seismic Systems Inc.) airguns, each 2 x 75 cu. inch (i.e. total capacity 300 cu. inch)

2 Hamworthy electric-powered, water-cooled compressors (each 300 cu. m/hour air capacity, 200 bars pressure) - only one used at a time

GIRODIN electric-powered compressor (100 cu. m/hour, 250 bars) - extra spare

Raytheon 3.5 kHz echo-sounder / high resolution sediment profiler, 2 kW power
(typical penetration ~50 m)

BODENSEEWERK KSS-30 gravity meter (accuracy ~1 mGal)

BARRINGER M-244 magnetometer (~1 nT accuracy)

Navigation
SERCEL NR103 differential GPS receiver - primary navigator GPS1 (operated in non-differential mode, giving position accuracy of ~100 m)

CM015 GPS Navigator (MLR Electronique) - secondary navigator GPS2

Standby receivers: Transit MAGNAVOX MX 1107 and Loran-C MLR LRX22P

Vessel heading: 2 BROWN SGB 1000 gyrocompasses

Relative fore-and-aft & athwartship speeds: THOMPSON SINTRA Doppler log & electromagnetic ALMA log

Oceanography
RD Instruments acoustic doppler current profiler VM-ADCP, 75 kHz (nominal depth range 560 m) and 300 kHZ (nominal depth range 160 m)

SIPPICAN expendable bathythermographs (XBTs), 2000 m depth range @ 6 knots (to 700 m depth @ 10 knots)

SIS CTD+1000 thermosalinometer (fitted in tank supplied with continuous flow of seawater; can be cabled to 1000 m depth to obtain temperature/salinity profile)

APPENDIX 5
Geophysical Acquisition Parameters

The general layout of the ship's geophysical equipment is shown in Figure A. Details of the seismic and magnetics layouts are also provided below.

Seismic

Streamer length (active) 300 m [6 groups, each 50 m]
Offset, stern of ship to front of group 1 = 200 m
Depth of streamer: ~12 m
Gun depths 6 m
Gun offset from stern 7 m
Operating air pressure to guns 150 bars (2200 psi)
Shot interval 10 seconds
Record length (digital) 5 seconds; 4 seconds of data recorded on strip-chart monitor
Sampling interval 4 ms
25-125 Hz passband
Shot delay (both guns) 10 ms
Ship's speed during acquisition: 10 knots nominal
Digital data format: SEG-Y

Magnetics

Magnetometer sensor towed 270 m astern

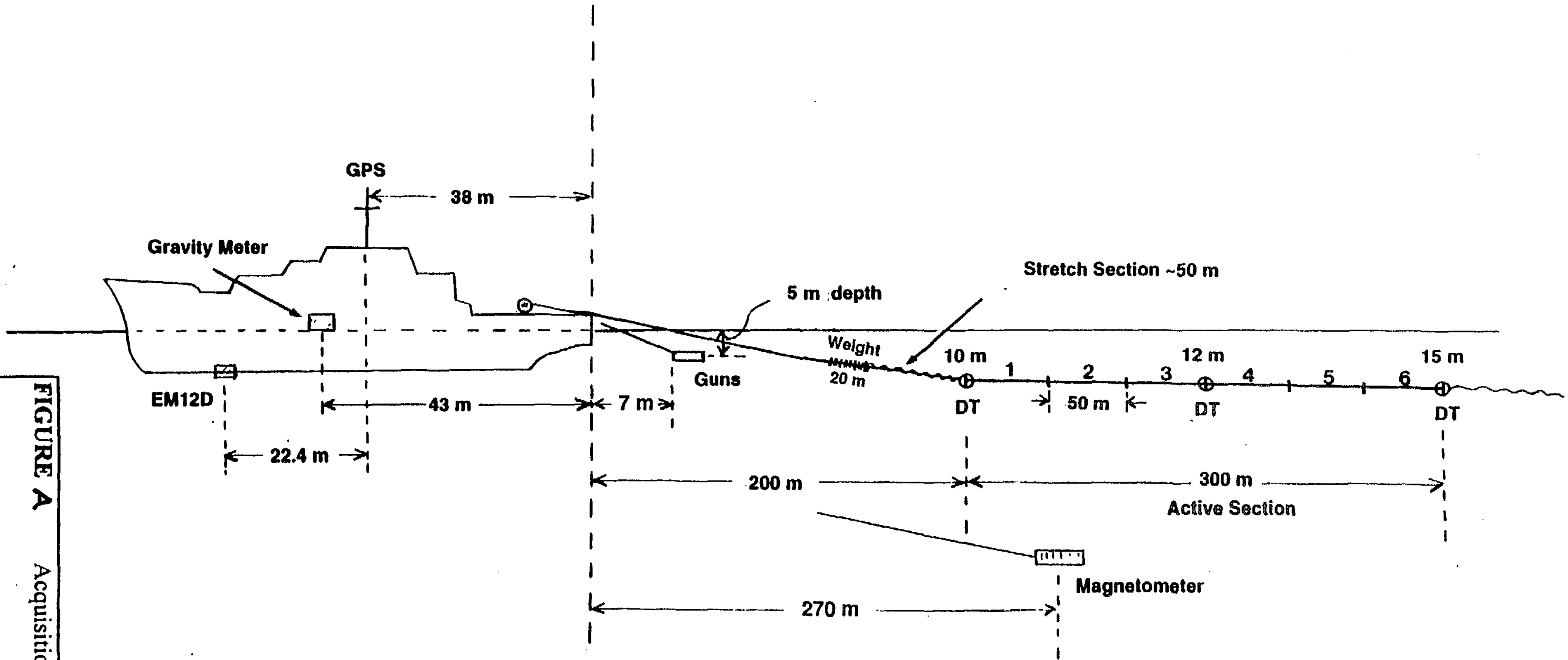


FIGURE A Acquisition geometry. L'Atalan

APPENDIX 6
Tasmante cruise participants

Scientific cruise participants

Dr Neville Exon, AGSO, Chief Scientist
Mr Peter Hill, AGSO, co-Chief Scientist
Dr Jean-Yves Royer, Observatoire Océanologique de Villefranche-sur-mer, France
Ms Nadège Rollet, Paris University, France
Ms Caroline Ramel, Observatoire Océanologique de Villefranche-sur-mer, France
Dr Dietmar Müller, Department of Geology & Geophysics, Sydney University
Mr Greg Whitmore, Department of Geology, James Cook University, Townsville
Mr David Belton, Department of Geology, James Cook University, Townsville
Ms Adriana Dutkiewicz, School of Earth Sciences, Flinders University, Adelaide
Mr Andrew Wellington, Department of Geology, University of Tasmania, Hobart

Auckland-Hobart ship's crew

Ship's crew

Jean Claude Gourmelon	Master
Gilles Tredunit	Chief mate
Philippe Moimeaux	Mate
Pascal Lazaro	Mate
Victor Talbourdet	Radio officer
Guy Courdon	Chief engineer
Remy Balcon	Second engineer
Thierry Alix	Engine officer
Gilles Ferrand	Engine officer
Guy Hall	Electronician
Philippe Le Scaon	Electronician

(plus 19 seamen, galley staff, doctor etc.)

IFREMER technicians

Bernard Guegen	Technician
Jacques Le Doare	Simrad technician
Henri Serve	Simrad technician
Yvon Queinnec	Seismic technician
Jean-Luc Le Philippe	Seismic technician

Hobart-Adelaide ship's crew

Ship's crew

Jean Claude Gourmelon	Master
Gilles Tredunit	Chief mate
Philippe Le Pape	Mate
Philippe Moimeaux	Mate
Victor Talbourdet	Radio officer
Guy Cordon	Chief engineer
Philippe Cadour	Second engineer
Thierry Alix	Engine officer
Guy Hall	Electronician
Philippe Le Scaon	Electronician

(plus 19 seamen, galley staff, doctor etc.)

IFREMER technicians

Philippe Allaire	Technician
Jacques Le Doare	Simrad technician
Joel Le Bris	Simrad technician
Claude Loussouarn	Simrad technician
Jean Charles Guedes	Seismic technician

APPENDIX 7
Weather patterns during the *Tasmante* cruise

Thoughout the cruise, the weather was monitored closely. The wind velocity and direction, and the ship's speed, were measured automatically and continuously. The wave height and swell height were estimated by the bridge officer every three hours. These data were entered and manipulated by G. Whitmore, and the results are shown in Figures A and B. The data can all be related to the Beaufort wind scale (Table A).

Table A. Simplified table of Beaufort wind scale

Beaufort number	Description	knots (kn)	metres/second (m/s)
0-6	calm and breezes	0-27	0-31
7	near gale	28-33	14-17
8-9	gale	34-47	17-24
10	storm	48-55	24-28
11	violent storm	56-63	28-33
12	hurricane	64 and over	33 and over

Figure A plots speed over the ground (SOG), wave height, swell height and wind velocity against time for the whole cruise from Auckland to Adelaide. There was a data break while *L'Atalante* was in Hobart for a crew change. The wind velocity shows a general pattern of a sudden gale or storm with winds of 30-50 knots, followed by a steady decline of winds to 10-20 knots over 4-5 days, followed by another gale or storm. This strongly affected the ship's speed, which was generally 10-10.5 knots, but reduced to about 8 knots during gales and storms (the sudden spiky reductions in speed were caused by deliberate slowing to deploy expendable bathythermographs or haul in towed equipment). Wave height averaged 1-1.5 m but increased to 2-3 m during gales or storms. Swell height averaged 3 m, and reached a maximum of 4-5 m during some storms. Other gales or storms (e.g. those of 21 and 23 February) hardly increased the swell although they did affect the waves. Large swells are built up over long fetch lengths, or even by Antarctic storms, so local winds that generate large waves may not increase the swell.

Figure B shows the relationship between wind velocity and latitude south on the one hand, and wind velocity and direction on the other, for the Tasmanian area only. Wind velocity was generally 20 knots or less, north of 44°S, but there was a marked increase south of there 44-49°S, with average and maximum speeds almost doubling. The wind rose indicates that gales and storms generally came in a segment from 190° to 340°, not surprising in the "Roaring Forties", with a few coming from 40°.

Typical weather charts are shown in Figures C and D. Figure C shows a high and good weather over the Tasmanian cruise area, with cold fronts away to the west. Figure D shows a low that has passed over the cruise area, and a cold front about to pass by; this forecast for 14/15 February coincided with two days of 30 knot winds, 2.5 m waves, and 4 m swells (Fig. A).

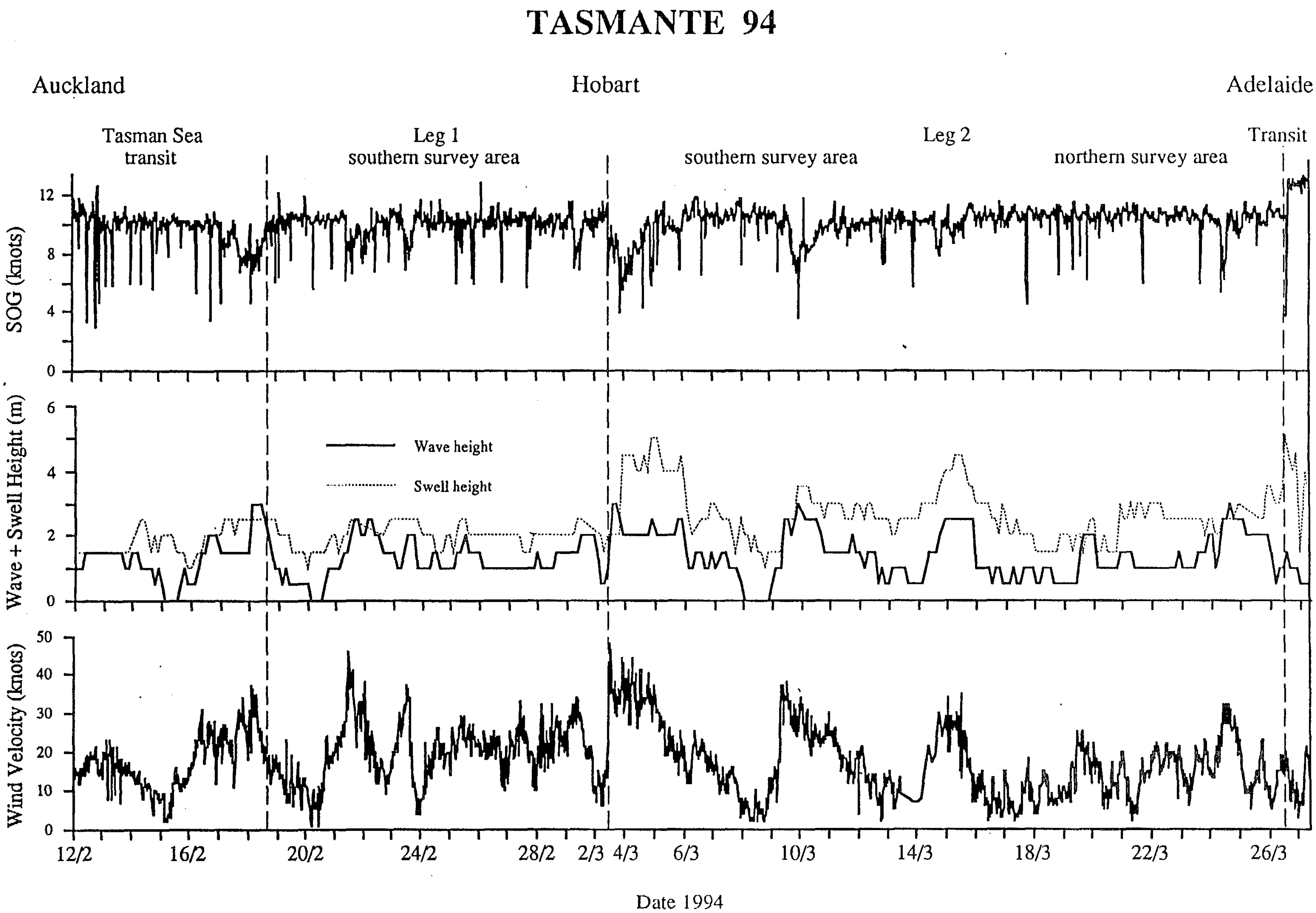
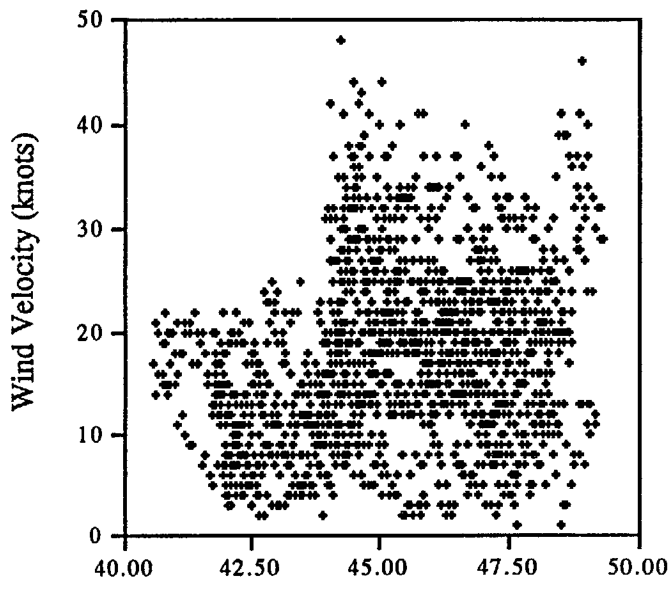


Figure A. Wind, wave, and ship's speed over the ground (SOG) from the entire *Tasmante* cruise. Ploted against days of the month.

TASMANTE 94

South and West Tasman Area Only

Wind Velocity v's Latitude South



Wind Direction v's Velocity (knots)

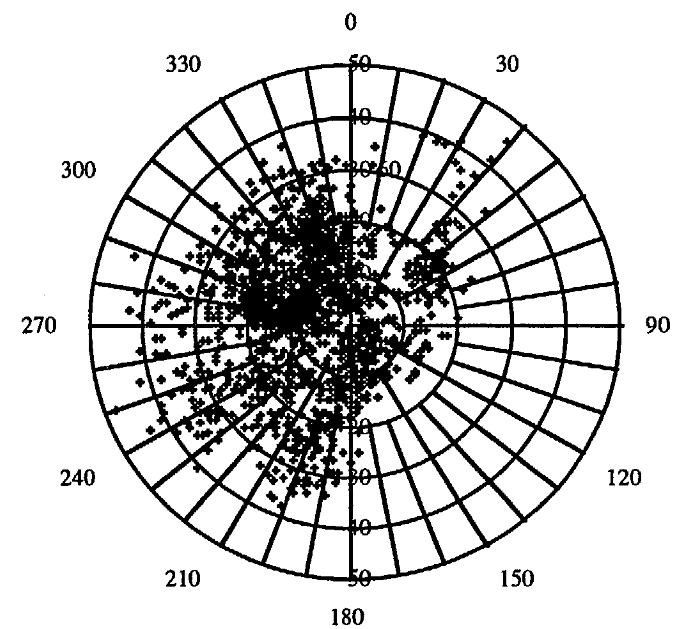


Figure B. Wind velocity plotted against direction and latitude over the South Tasman Rise and west Tasmanian margin for the *Tasmante* cruise.

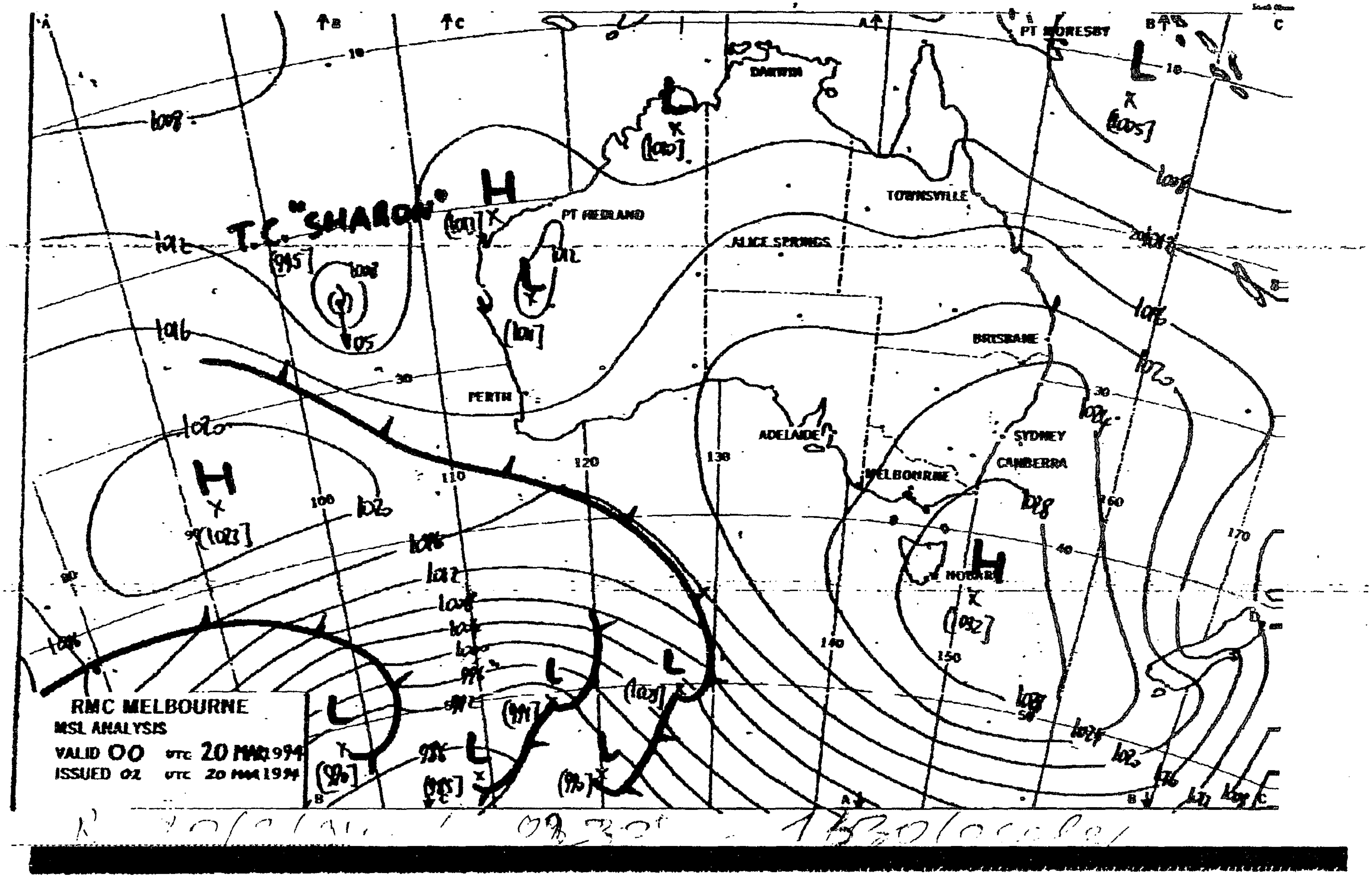
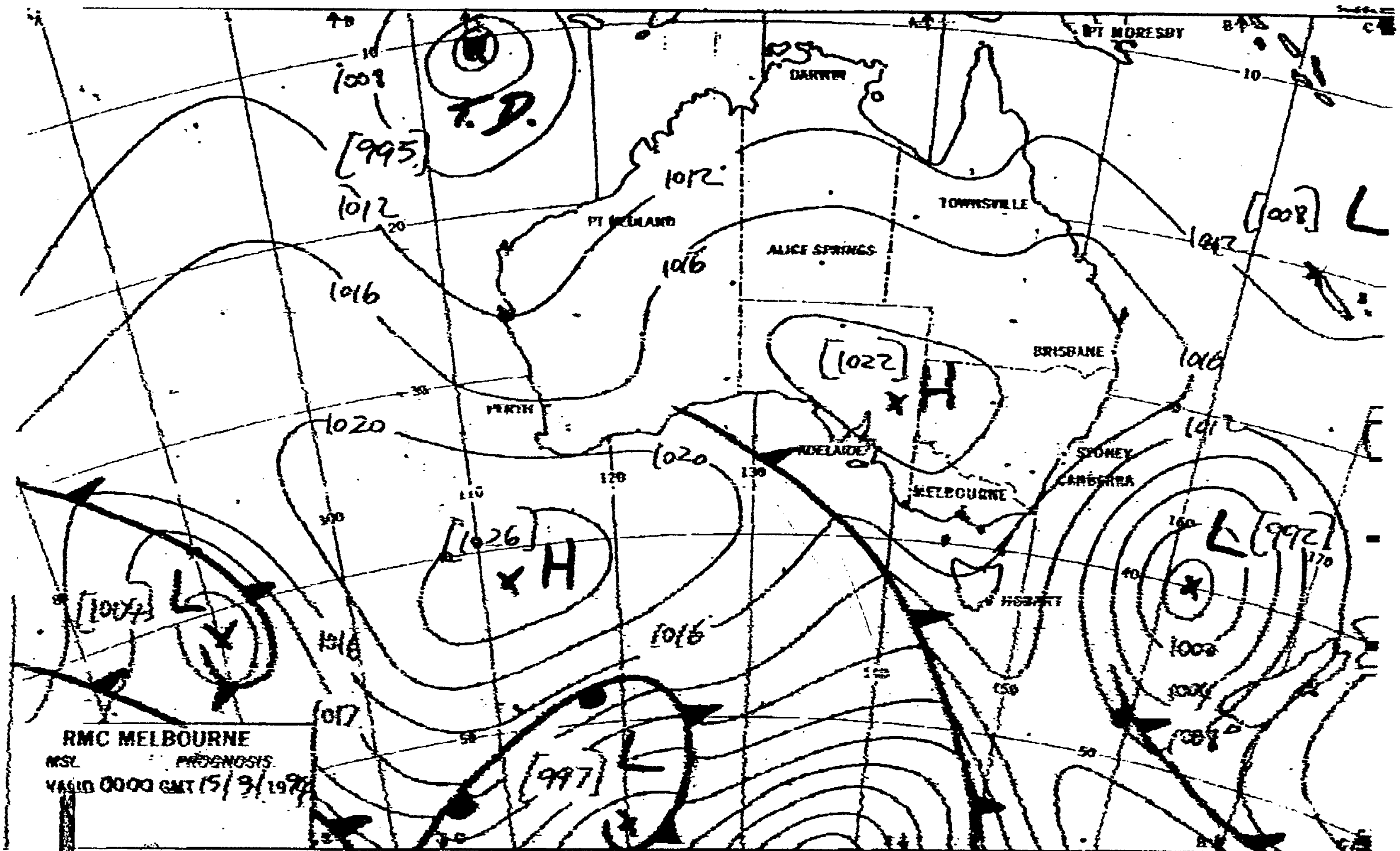
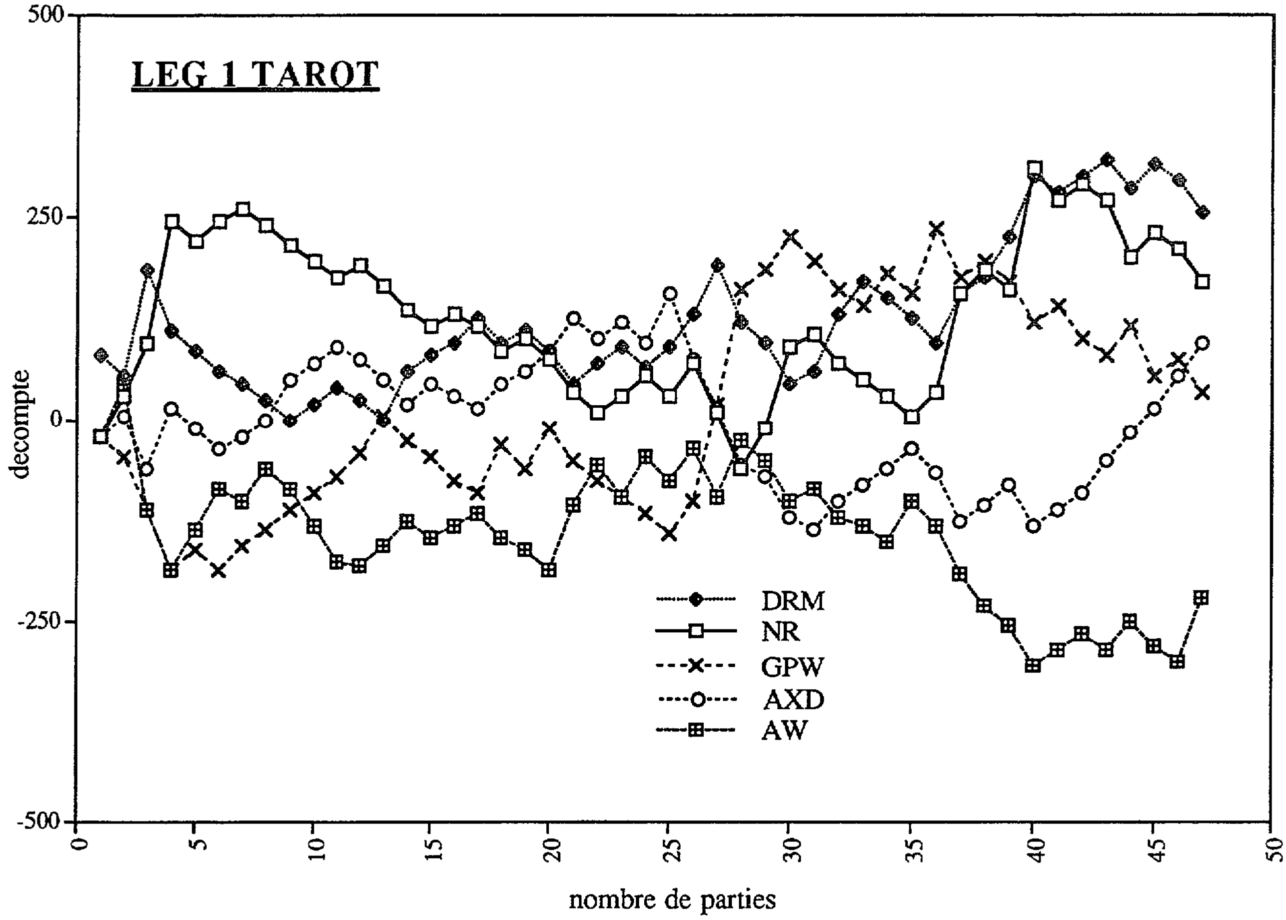


Figure C. Weather forecast for calm period in the Tasmanian region on the *Tasmante* cruise (20 March 1994).



Rec 14-3/94 - 0100 GMT = 12.00 Local

Figure D. Weather pattern during a rough period in the Tasmanian region on the *Tasmante* cruise (15 March 1994).


LEG 1 TAROT
500
250
0
-250
-500
decompte
0
5
10
15
20
25
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35
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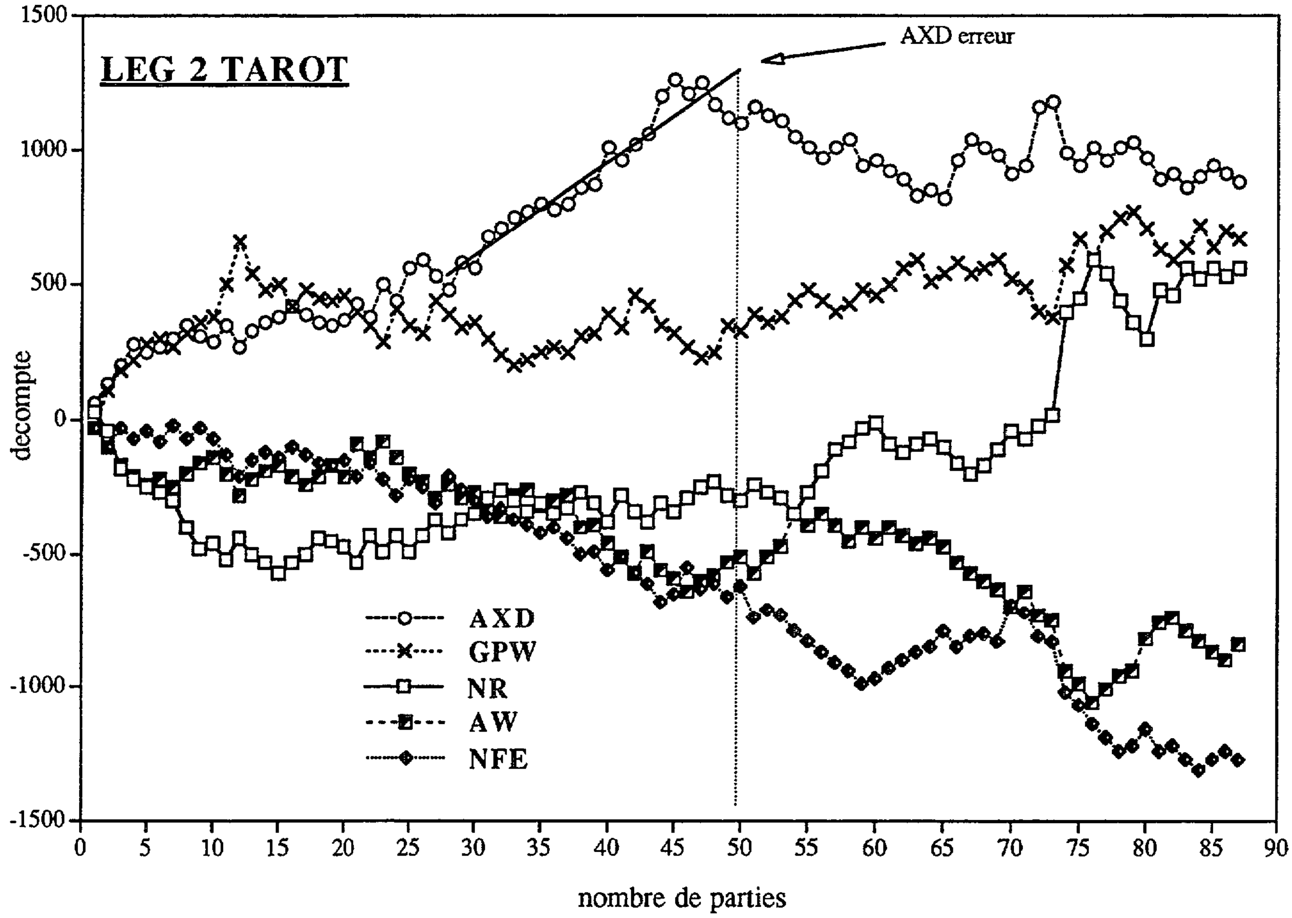
45
50
nombre de parties
DRM
NR
GPW
AXD
AW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AXD erreur
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75
80
85
90
nombre de parties
AXD
GPW
NR
AW
NFE