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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AGSO Record 2000/6

Seafloor mapping of the South–east Region and adjacent waters

AUSTREA–1 cruise report: Lord Howe Island, south–east Australian margin and central Great Australian Bight

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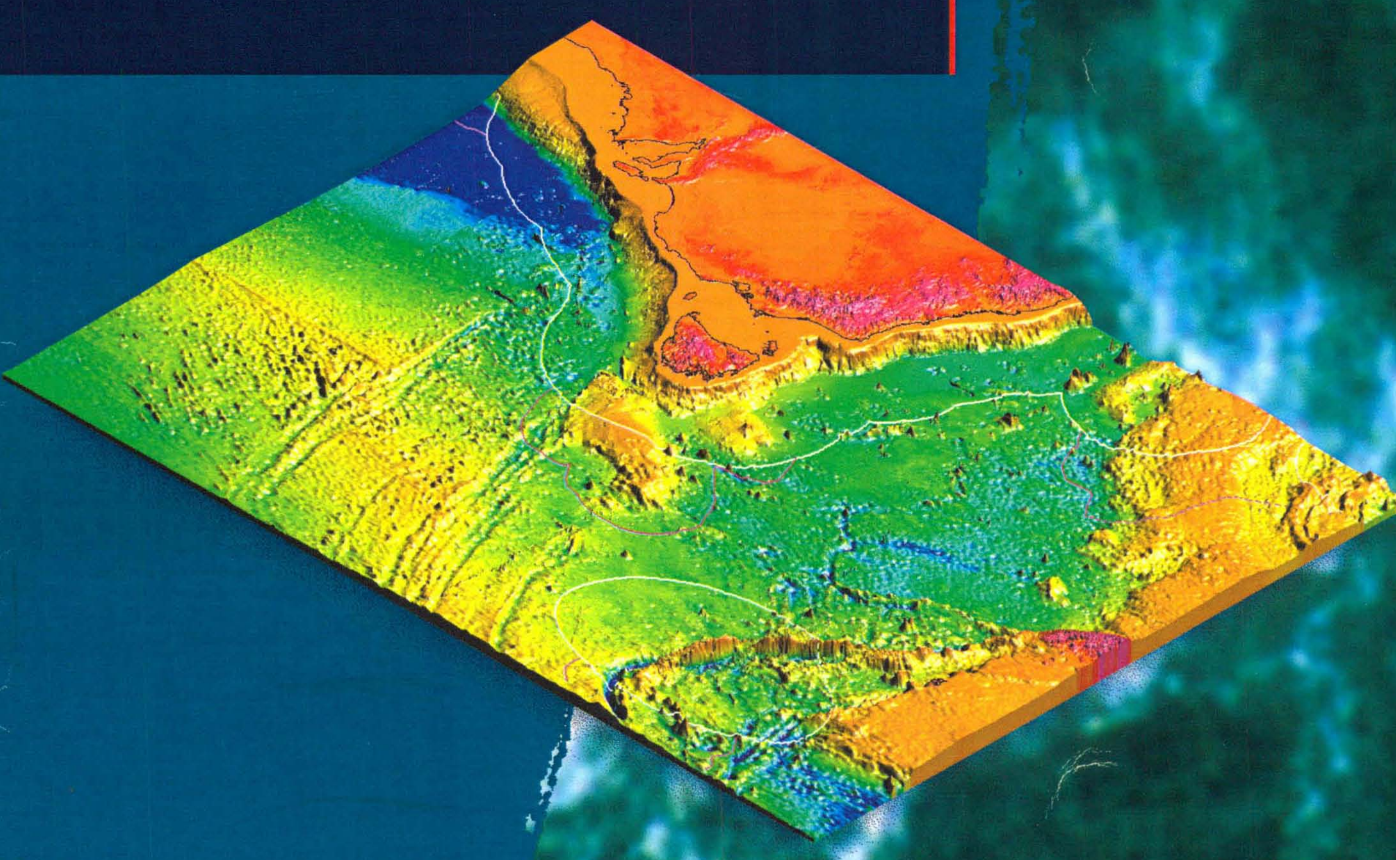

Australian Geological Survey Organisation/National Oceans Office cooperative project

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CANBERRA

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1. SUMMARY

In January 2000, the Australian Geological Survey Organisation (AGSO) completed a major, 25-day seabed swath-mapping and geophysical survey off southeast Australia for the National Oceans Office (NOO) and Environment Australia (EA). The survey, named AUSTREA-1 and designated as AGSO Cruise 222, used the 85-m French oceanographic and geoscience research vessel *L'Atalante*, departing Noumea on 18 December 1999 and ending in Hobart on 11 January 2000. The survey covered 11,000 km and mapped about 120,000 km² of seabed - an area about 1.5 times the size of Tasmania. The work was done for marine zone planning and management, for assessment of seabed living and non-living (petroleum and mineral) resources, and geological and biological research, as a major step towards implementation of *Australia's Oceans Policy* and *Australia's Marine Science and Technology Plan*, and in particular, the development of the Southeast Regional Marine Plan by the National Oceans Office.

Data collected included Simrad EM12D swath-bathymetry and backscatter imagery, 6-channel GI-gun seismic, digital 3.5 kHz sub-bottom profiles, gravity and total field magnetics. Also collected was oceanographic information - XBTs to 1800 m depth and underway ADCP (current), sea surface temperature and salinity measurements. Weather and sea conditions were generally favourable, though stormy conditions with 30-35 knot winds and associated rough seas were encountered at times. Data quality was mostly excellent.

The survey mapped the volcanic slopes of Lord Howe Island and Ball's Pyramid to the 12 nautical mile outer limits of a proposed Marine Protected Area, revealing a rugged terrain of volcanic cones, flows and canyons likely to harbour diverse benthic communities. The steep and narrow rifted continental margin off the NSW South Coast was shown to be deeply dissected by canyons and to contain gigantic continental fault blocks and ?synrift volcanic seamounts and ridges. The survey completed mapping of the huge Bass Canyon complex off southeast Victoria, revealing detailed morphology of tributary canyons up to 1000 m deep adjacent to the Gippsland oil fields. Important fishing grounds of the Southeast Trawl Fishery were mapped off Tasmania, including volcanic and carbonate pinnacle terrain off St Helens, volcanic seamounts of the Southern Hills, and the heads of canyon systems incised into the sedimented upper slope off west Tasmania. Mapping of the Tasmanian Seamounts Marine Protected Area, south of Hobart, was completed, with thirty additional volcanic seamounts found just east and north of the MPA. The seismic profiles confirmed the existence of potential frontier petroleum basins off the east, southern and west coasts of Tasmania. Parts of the deeply-canyoned upper and mid slope of the Otway Basin were mapped off northwest Tasmania, Victoria and South Australia. The Great Australian Bight Benthic Protected Area of the GAB Marine Park was fully surveyed below the 500 m isobath and was shown to be generally a uniform slope, with the gigantic Nullarbor Canyon crossing its southeastern corner, gouged into deformed Late Cretaceous sediments.

A full set of shipboard maps was provided to the National Oceans Office; copies of the digital swath-data are held for NOO at AGSO. All data from the cruise will be jointly managed by AGSO, NOO and EA.

2. INTRODUCTION, CRUISE OBJECTIVES AND PLAN

In December 1998, the Commonwealth Government launched *Australia's Oceans Policy*, aimed to develop an integrated and ecosystem-based approach to planning and management for all ocean and seabed uses. This is to be achieved through the development of Regional Marine Plans, based on large-scale marine ecosystems covering Australia's marine jurisdiction. The first Regional Marine Plan to be prepared will be for Australia's southeast Exclusive Economic Zone (EEZ), encompassing the waters off Victoria and Tasmania, including Macquarie Island, and parts of southern New South Wales and eastern South Australia.

The Regional Marine Plans need to be developed on the basis of sound knowledge of the region's physical and biological features. Accessible and accurate information on bathymetry, seabed structure and processes and high resolution maps are basic tools in a wide range of planning and management options. Using multi-beam arrays, modern acoustic survey methods allow high resolution maps and images of large areas of the seabed to be generated quickly and cost-effectively. AGSO pioneered the use of such systems in Australian waters, including parts of the Southeast Region (Exon *et al*, 1994; Hill *et al*, 1998; Figure 1). However, large areas of the offshore Southeast remained poorly mapped.

In mid-1999 an opportunity arose to charter France's premier oceanographic and geoscience research vessel, the 85-m *L'Atalante* (Appendix 1), because it was operating in the Australian region at the time. This vessel, owned by IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) is equipped with one of the best and most powerful multibeam swath-mapping systems available, the Simrad EM12D (Appendix 2). It also operates a wide range of other state-of-the-art geophysical and oceanographic systems (Appendix 3), including 6-channel GI-gun seismic, digital 3.5 kHz sub-bottom profiler, gravity meters, magnetometer, and acoustic doppler current profiler. AGSO was commissioned by Environment Australia (EA) and the newly-established National Oceans Office (NOO) to undertake a comprehensive and cooperative seabed mapping program off southeast Australia using *L'Atalante*. This survey program was named AUSTREA (AUSTRalia Environment Australia), and was completed as two cruise legs AUSTREA-1 and AUSTREA-2. AUSTREA-1 concentrated on the Australian Southeast Region (Figures 1 & 2), while AUSTREA-2 mapped an area off southeast Tasmania and completed a major survey on the Macquarie Ridge, mainly to define jurisdiction limits under UN Convention on the Law of the Sea. This Record deals with the first part of the program, AUSTREA-1.

Following discussions amongst EA/NOO, AGSO and CSIRO Marine Research, and guided by the broad objectives set out in *Australia's Oceans Policy* and the implementation strategies contained in *Australia's Marine Science and Technology Plan* (1999), an AUSTREA-1 cruise plan was prepared that involved mapping of the following offshore areas:-

- submarine slopes of Lord Howe Island (proposed marine protected area out to 12 nautical miles)
- continental slope off NSW South Coast
- offshore Gippsland Basin and Bass Canyon complex (to extend the area swath-mapped by AGSO in 1997 (Hill *et al.*, 1998, Exon *et al.*, 1999))
- deep-sea fishing grounds off east, south and west Tasmania (to extend the area swath-mapped by AGSO in 1994 (Exon *et al.*, 1994) and 1997

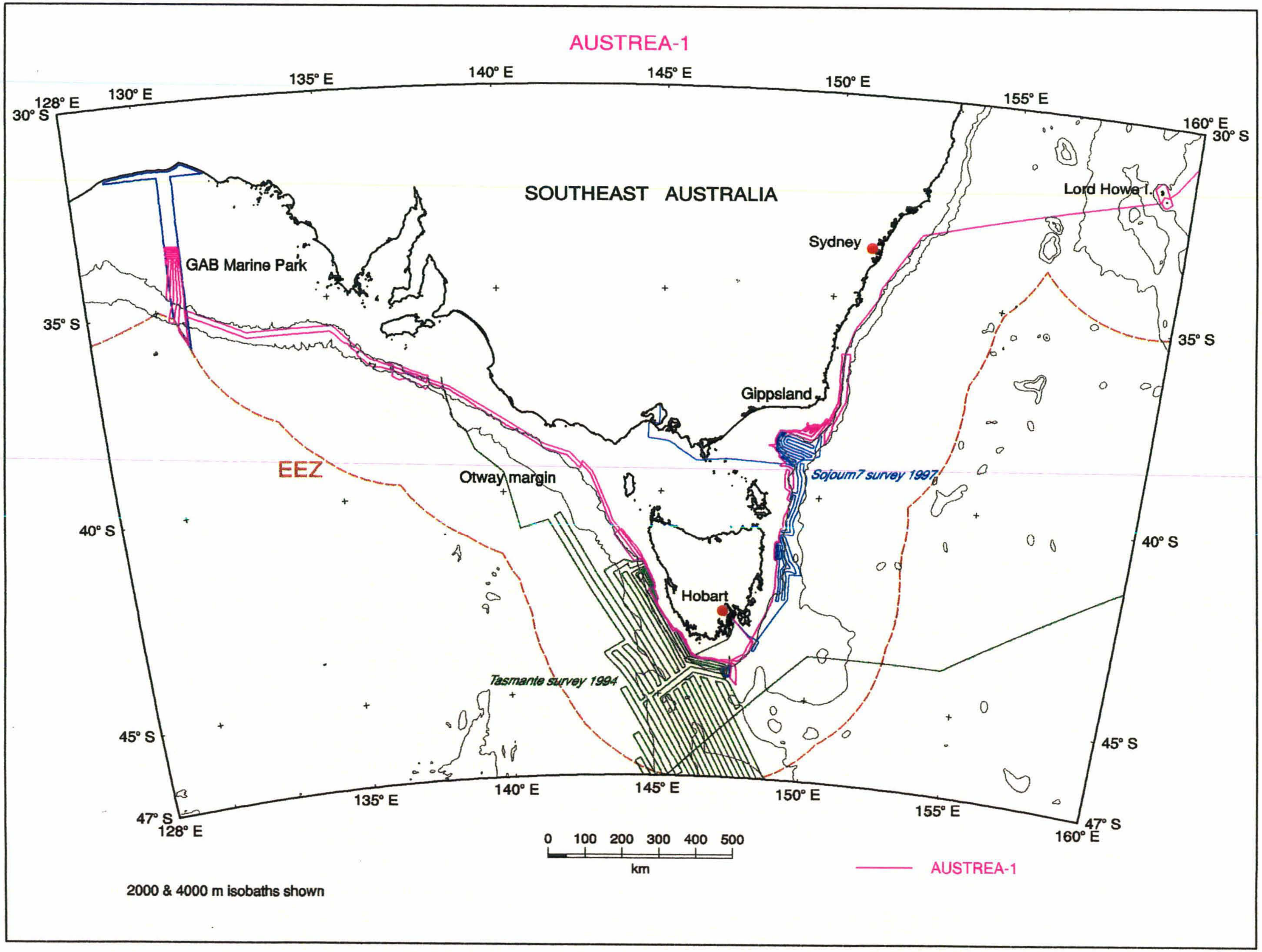


Figure 1. AUSTREA-1 location, Lord Howe Island to Great Australian Bight, and relationship to previous major swath surveys

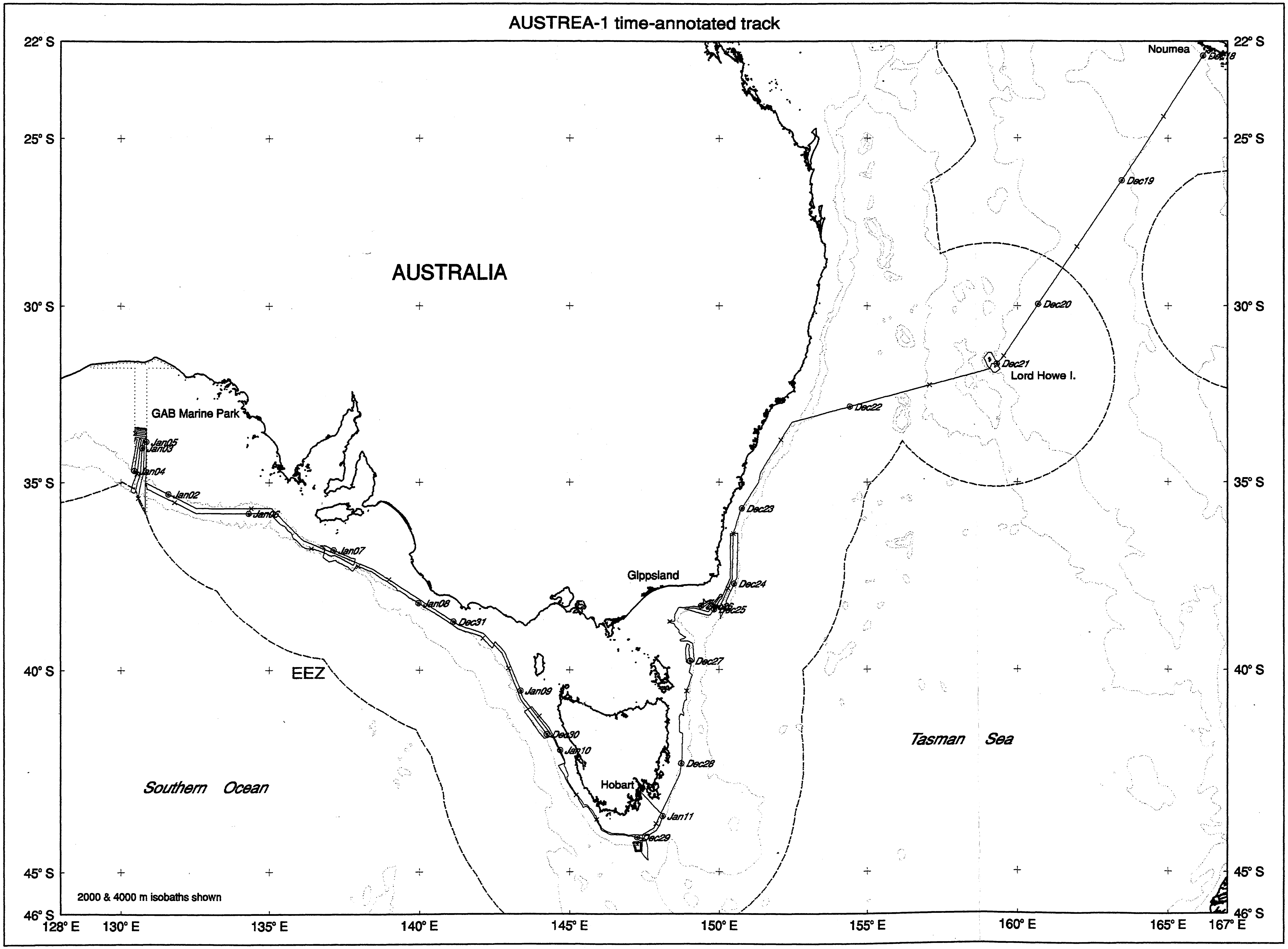


Figure 2. Ship's track (Noumea-GAB-Hobart) annotated with date and 12-hourly positions

- submarine volcanoes south of Tasmania, including the eastern part of the Tasmanian Seamounts Protected Area (Koslow & Gowlett-Holmes, 1998; MPA declared in May 1999)
- the deeply-canyoned continental slopes off northwest Tasmania, southwest Victoria and Kangaroo Island
- the Great Australian Bight Benthic Protected Area of the GAB Marine Park (Environment Australia, 1999; Slater, 1999).

AUSTREA-1 began on 18 December 1999 when *L'Atalante* left Noumea. On board were 5 Australian scientists (three from AGSO, one from Mineral Resources Tasmania and one from the University of Sydney), together with 31 French crew, engineers and technicians (Appendix 4). The chief scientist was Peter Hill. The above program was successfully completed over 25 days, and the cruise ended on schedule on 11 January 2000 in Hobart. AUSTREA-1 has been designated as AGSO Cruise 222 in the AGSO marine data base.

3. REGIONAL PLATE TECTONIC AND GEOLOGICAL SETTING

The southern and eastern margins of Australia, including the Tasmanian margins, result from the continental fragmentation, since 160 Ma, of eastern Gondwana formed by the Australian and Antarctic continents, New Zealand and the large undersea Campbell and Challenger Plateaus and the Lord Howe Rise. During the extension between Australia and Antarctica several basins developed from the Late Jurassic until the Late Cretaceous (Willcox & Stagg, 1990). Three continental extension phases are recorded. The first extension, dated from the Late Jurassic (> 160 Ma) until the Early Cretaceous, was in the Great Australian Bight (GAB) with a NW-SE trend. This led to the formation of strike-slip motion in the nascent Otway Basin and along the Tasmanian margin. The second extension, in the Early Cretaceous, produced a stretching with a NNE-SSW trend in the SE Australian basins (Otway, Bass, Gippsland) which probably produced a structural overprinting in the GAB basin. The last minor extensional phase preceded the seafloor spreading in the Late Cretaceous in the GAB (Cande & Mutter, 1982) and produced wrenching on the Tasmanian margin.

The continent-ocean boundary in the GAB is dated as 95 Ma (Cenomanian; Veevers, 1986). Recent studies based on interpretation of deep-seismic transects across the continent-ocean boundary (Sayers *et al.*, submitted), indicate that initial spreading may not have occurred until the Santonian (83 Ma). Subsidence studies along the southern Australian margin, as well as the conjugate pattern of seafloor magnetic anomalies off Australia and Antarctica show that seafloor spreading propagated eastward from the GAB towards Tasmania (Mutter *et al.*, 1985). Seafloor spreading has been hypothesised to have started in the Late Cretaceous at a very slow rate (< 1 cm/yr, full rate) until the Early Eocene, increasing somewhat to a slow rate (~2 cm/yr) until the Middle Eocene (Cande & Mutter, 1982). Spreading accelerated drastically (to 4-5 cm/yr) in the Middle Eocene (ca. chron 18, 45 Ma; Weissel & Hayes, 1972; Cande & Mutter, 1982; Veevers *et al.*, 1991); this event coincides with a major reorganisation of plate boundaries in the Indian Ocean (Royer, 1992). However, we believe that no major spreading occurred in the Otway Basin and off west Tasmania until the Middle Eocene.

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; 78.8 Ma), along an ENE-WSW direction (Hayes & Ringis, 1973; Weissel & Hayes, 1977; Shaw, 1989). 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 Plateau. 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 (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.

Because of the change in trend of the southern Australian margin, the geodynamic context changes progressively from purely extensional in the Great Australian Bight, to transtensive in the Otway Basin, and then purely strike-slip on the western Tasmanian margin (Willcox *et al.*, 1989). The abrupt termination of the major basins and the development in "en echelon" basins along the continental shelf on the western Tasmanian margin can be explained by the existence of major transform fault zones.

Great Australian Bight

The Great Australian Bight is initially associated with the fragmentation of Gondwanaland. A rift valley, which may have propagated eastwards, was considered to have stretched from the southwest of Western Australia to Tasmania in the southeast. This led to the formation of several related extensional basins from the Early Cretaceous onwards, including from west to east, the Bremer, Great Australian Bight (consisting of the Eyre, Ceduna, and Recherche Sub-basins separated by northwest striking accommodation zones), Duntroon, Otway, and Sorell Basins. The margin has long been considered a classic example of a rifted margin (e.g. Griffiths, 1971) and has been used to illustrate the concepts of detachment models for continental margin formation (Etheridge *et al.*, 1989). More recently, Whitmarsh & Sawyer (1996) consider two models to explain the observations. The first model, previously initiated by Sawyer *et al.* (1994) suggests that the ocean-continent transition is composed largely of very slow-spreading crust. The second model initially proposed by Whitmarsh & Miles (1995) invokes both tectonic and magmatic processes. Sayers *et al.* (submitted) think that a comparison with the Iberian margin can be made. The multiple shear zone model proposed by Brun & Beslier (1996) for the Iberian margin can be applied to the GAB in a less advanced stage. The lithospheric necking on a wide-scale, broadly corresponds to a pure shear process with only localised simple shear planes. So, after a first stage of rifting (Cretaceous) with faulting in the brittle upper crust, a second phase of extension occurred in the ductile lower crust before the onset of slow spreading. In this case, the upper mantle can be emplaced very high beneath the margin, and may be serpentinised in the intermediate zone at the continent-ocean boundary, by water flux along the numerous faults which affect the continental and even the oceanic crust.

The Ceduna Terrace lies at water depths of 200-2500 m on the eastern side of the GAB and is underlain by the main depocentre of the GAB Basin, the Ceduna Sub-basin (Figure 3). The Ceduna Sub-basin is a broad and thick lobe-like sedimentary basin extending out into the abyssal plain from the southern edge of the continental shelf in a southwesterly direction. While basement cannot be imaged beneath the sub-basin, interpretation of magnetic basement depths indicates that in excess of 10 km of sediments has accumulated since the Late Jurassic (dated by exploration well Potoroo-1, on the northern flank). To the north and northeast, the Ceduna Sub-basin is bounded by the shallow Precambrian basement of the Gawler Block characterised by high-angle faults in places and a dipping ramp structure in others. Jurassic to

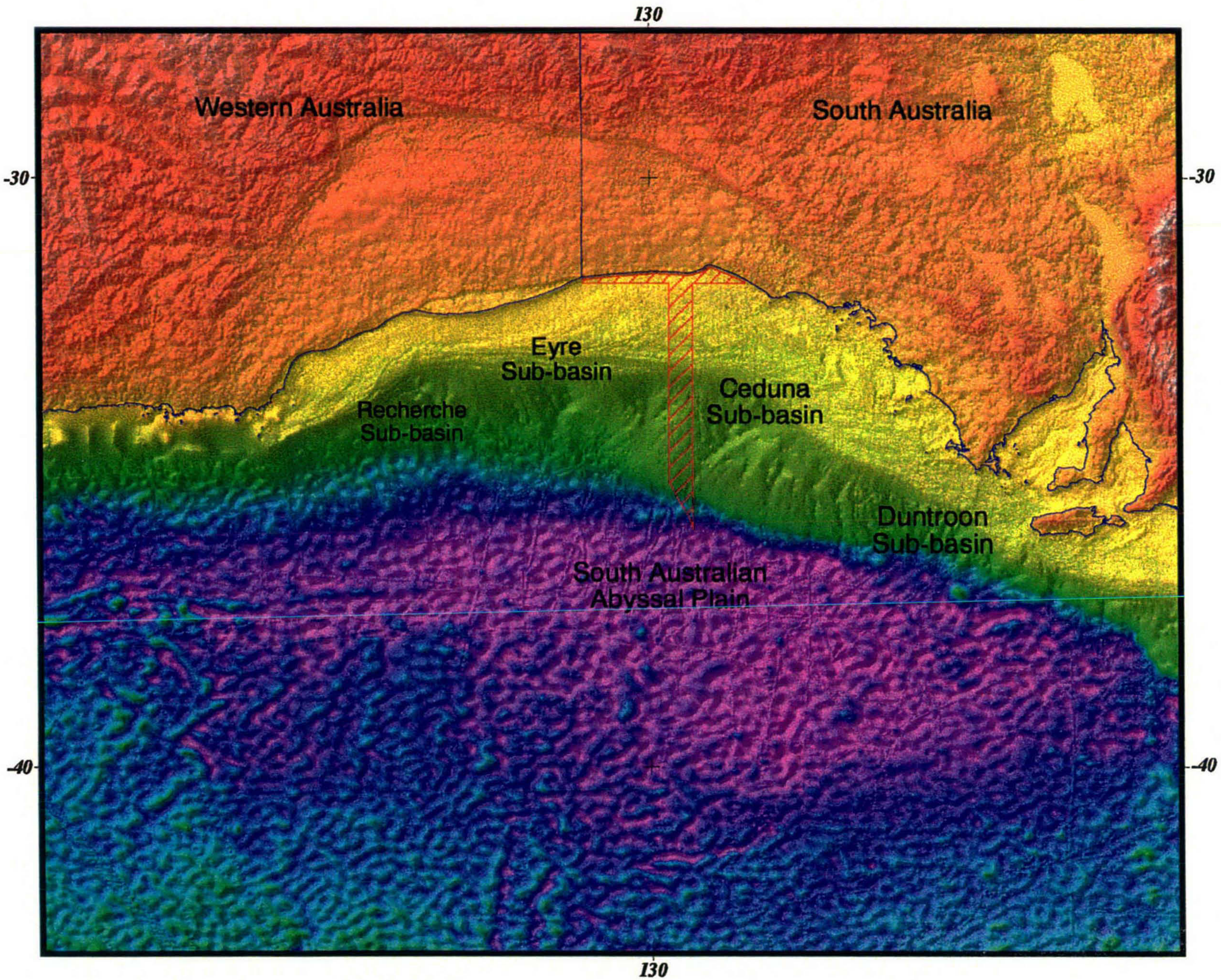


Figure 3 : Location of the different Sub-basins in the Great Australian Bight. The marine park is indicated by the striped area (bathymetry map from Petkovic et al., 1999).

Early Cretaceous basin-forming extensional fault systems and associated rift-fill are present, at least in the inboard parts of the sub-basin. These are overlain by highly structured Early to Late Cretaceous sag-phase and Tertiary passive margin deposits. The Cretaceous faults are typically southwest dipping, high angle normal faults. Low-angle growth faults and toe thrusts occur along the southwestern edge of the Ceduna Sub-basin and in the northeastern Recherche Sub-basin. They form part of an extensive Cretaceous gravity slide and gravity spreading system. After a revised interpretation of magnetic anomalies (Sayers *et al.*, submitted), no oceanic crust older than early Campanian (~chron 33; 78.8 Ma) appears to be present. Breakup occurred at the same time in the Tasman Sea but with a different spreading direction.

Two wells on this margin allowed identification of the basement and sedimentary cover of these basins. Esso Jerboa-1 well, in the Eyre sub-basin, and Shell Potoroo-1 well, on the northern margin of the GAB Basin, penetrated extensive Mesozoic-Cenozoic sections as old as Middle Jurassic (Jerboa-1) and Neocomian (Potoroo-1). Six sequences were penetrated and briefly consist of: (a) Middle to Late Jurassic sands, (b) Neocomian sand-prone lacustrine sediments, (c) Aptian non-marine claystones and shales, (d) thin Albian marine shale-prone sediments, (e) Cenomanian marine interbeded shales, claystones and sandstones, and (f) Tertiary open-marine carbonates. A sequence stratigraphic framework for the GAB region has been developed (Figure 4) based on the interpretation of exploration wells in the Bight and Duntroon Basins and a grid of new and reprocessed seismic data in the Bight Basin (Totterdell *et al.*, in press).

Extensive half graben systems were filled with fluvial and lacustrine clastic sediments (Sea Lion and Minke supersequences - stratigraphic nomenclature after Totterdell *et al.*, in press). The syn-rift successions are overlain by widespread Berriasian to Albian fluvio-lacustrine to marine sediments of the Southern Right and Bronze Whaler supersequences. The onlapping sag-fill geometry of these Early Cretaceous packages in the Eyre, Ceduna and inner Recherche Sub-basins suggests that they were deposited during a period of thermal subsidence. Accelerated subsidence commencing in the Late Albian led to the deposition of the marine shales of the Blue Whale supersequence, followed by a period of gravity-controlled faulting and deformation in the Cenomanian. The White Pointer supersequence is characterised by growth strata associated with a series of listric faults that sole out in underlying ductile overpressured shales of the Blue Whale supersequence which acted as a decollement. Open marine conditions during the Turonian-Santonian (Tiger supersequence) were followed by the development of massive shelf margin delta complexes in the Late Santonian-Maastrichtian (Hammerhead supersequence). The progradational to aggradational stratal geometries within the Hammerhead supersequence suggest initial high rates of sediment input that subsequently waned during this period. An overall transgressive phase of sedimentation in the early Tertiary (Wobbegong supersequence) was followed by the establishment of open marine carbonate shelf conditions from the early Eocene onward (Dugong supersequence).

Otway Basin

The Otway Basin comprises two rifts that overlap temporarily and spatially (Moore *et al.*, in press). The late Jurassic to mid Cretaceous rift generally trends east-west beneath onshore and nearshore areas, and formed during the early stages of extension between Australia and Antarctica. The mid Cretaceous to early Cenozoic rift trends northwest-southeast to north-south beneath the continental slope and rise, and formed during the later stages of Australia-

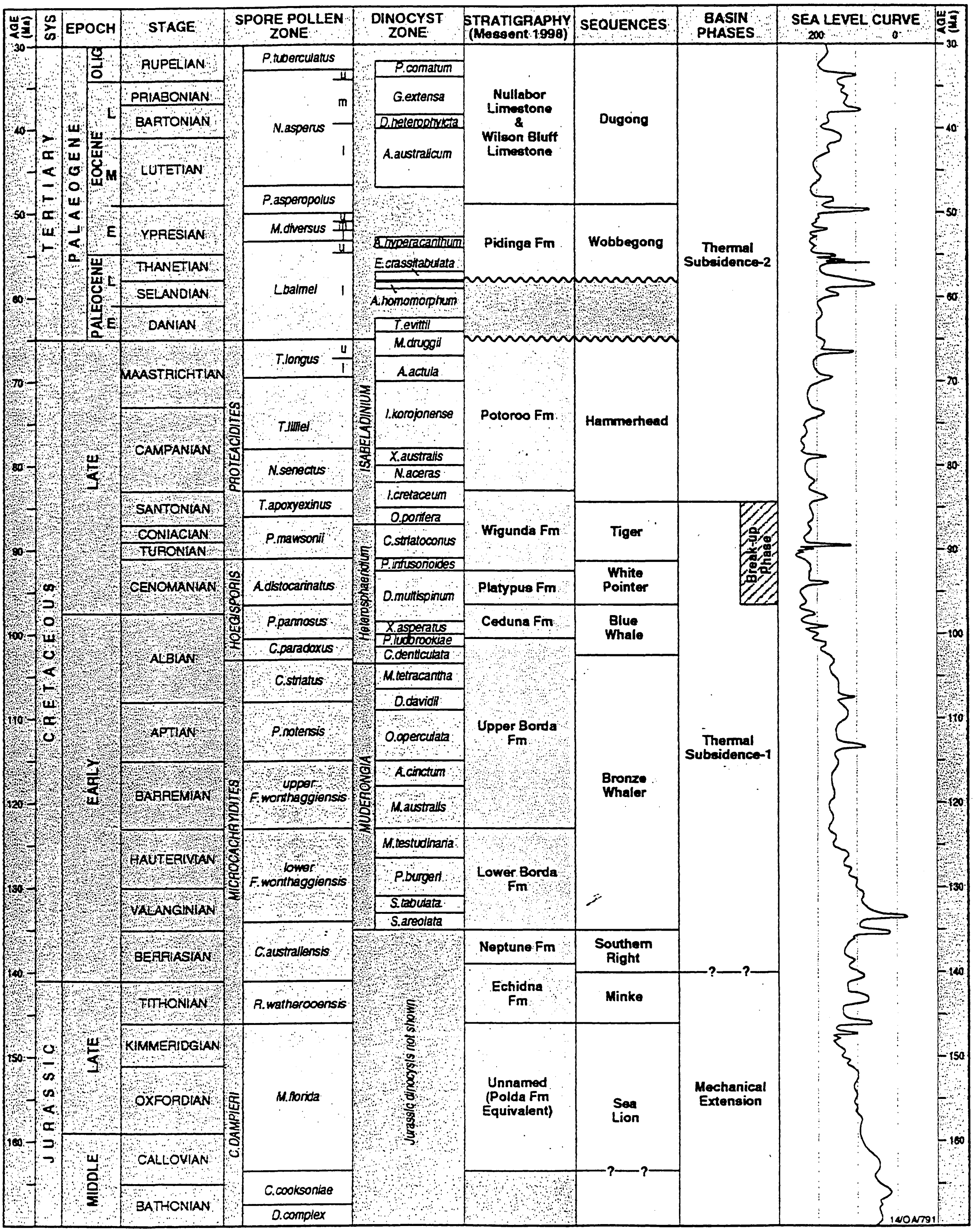


Figure 4 : Bight Basin correlation chart showing the relationship between sequence stratigraphic scheme, Duntroon Basin-Ceduna Sub-basin lithostratigraphy, basin phases and sea level (Totterdell et al., 2000).

Antarctica rifting in an overall sinistral transtensional setting. No oceanic crust older than Middle Eocene has been identified adjacent to the Otway Basin (Royer & Rollet, 1997). This situation probably applies to the whole margin from south of Kangaroo Island to south of the South Tasman Rise. This implies that the Otway Basin and west Tasmanian margin was a strike-slip or transtensional plate boundary for much of the Late Cretaceous to Early Eocene and that large-scale emplacement of oceanic crust did not commence until the onset of fast seafloor spreading. The Late Cretaceous Otway Basin would have had a conjugate margin either in Antarctica (probably George V Coast) and possibly also partly in the western sector of the South Tasman Rise (Royer & Rollet, 1997).

The continental slope sector of the Otway Basin contains the main part of the sediment volume of the basin (~8 km in thickness). This basin can be subdivided into three sub-basin elements from NW to SE, the Beachport, Morum and Nelson Sub-basins, separated by north-south trending structural highs (Moore *et al.*, in press). The structural style and relative thickness of sedimentary sequences varies widely between the basin elements, reflecting the complexities of a mixed rifted / strike-slip margin setting.

Key aspects of the stratigraphy of the Otway Basin have been described recently (e.g., Kopsen & Scholefield, 1990; Partridge, 1997). A review of the palaeontology of 36 wells in two states and the re-sampling and re-evaluation of the type sections of the early part of the Late Cretaceous in Victorian wells, resulted in significant changes in dating (Partridge, 1997). Broadly, the stratigraphy can be divided onto three phases : (1) the first rift phase Otway Supergroup (Berriasian to Albian), (2) the second rift phase Shipwreck and Sherbrook Groups (Turonian to Maastrichian), and (3) the post rift transgressive/regressive clastic cycles of the Wangerrip Group (latest Maastrichtian to early Middle Eocene), and carbonates and siliciclastics of the Eocene to Recent Nirranda and Heytesbury Groups. The southeastern end of the Otway Basin is continuous with the Sorell Basin on the western margin of Tasmania.

<u>Sorell Basin - west Tasmanian margin</u>

The continental margin off west Tasmania is about 200 km wide and covers an area of about 100,000 km^2. The continental shelf is about 30 km wide in the south and more than 55 km wide in the north. Much of the margin has a thick cover of late Mesozoic and Cainozoic sediments, forming the Sorell Basin (Willcox *et al.*, 1989; Hill *et al.*, 1997b) and the contiguous southernmost part of the Otway Basin. There are four depocentres of the Sorell Basin beneath the shelf: the King Island, Sandy Cape, Strahan and Port Davey Sub-basins (Moore *et al.*, 1992).

The margin comprises a shallow continental shelf, a continental slope with variable relief due to canyon development and uplifted fault blocks, and an abyssal plain at about 5000 m depth underlain by early Tertiary oceanic basement. Cretaceous depocentres on the shelf and upper slope are typically of half-graben or v-shaped geometry, deep and narrow, and appear to be of transtensional origin. These depocentres are located within relatively shallow Precambrian to early Palaeozoic basement and contain 2-4 s twt (two-way time)(approximately 2.0-5.5 km) of section. Sediment thickness beneath the continental slope is generally 2-5 s twt. The lower continental slope is characterised by a highly-faulted zone of uplifted basement blocks. This zone, about 60 km wide, commonly contains two main ridges 30-40 km apart. Seismic profiles across this structural high generally show a profusion of diffractions, particularly at depth, suggesting considerable igneous intrusion. A strong, angular mid-Cretaceous (?Cenomanian) unconformity in the Sorell Basin is coeval with uplift of the Otway Ranges and the eastern Otway Basin generally. The Late Cretaceous and older section has undergone significant deformation, mainly with normal faulting, ranging from near-vertical to low-angle listric and generally dipping seaward, but reverse faulting and gentle to moderate folding are also evident. Though most faults extend only to the top of the Cretaceous, minor faulting extends into the Palaeogene in some areas, particularly the nearshore part of the margin (including the Sorell Fault Zone parallel to and near the coast) and adjacent to the Tasman Fracture Zone in the south. Early Tertiary oceanic basement outboard of the high has a comparatively thin sediment cover of mainly less than 1 km, and is exposed on the seafloor in places.

Petroleum exploration in the region dates back to the 1960s, during which time a broad, sparse seismic data set was acquired. More recent exploration activity (early 1980s, Amoco; early 1990s, Maxus) has been concentrated in the Strahan Sub-basin off the central west coast of Tasmania. Only four exploration wells have been drilled on the margin, two of which (Clam-1 and Cape Sorell-1) are in the Sorell Basin. Petroleum has been generated in the Sorell Basin, at least in the Strahan and Sandy Cape Sub-basins. Indications include live oil in Sorell-1, high concentrations of thermogenic hydrocarbons recorded in geochemical surveys, and direct hydrocarbon indicators (flat-spots) in Strahan Sub-basin seismic sections.

The only known onshore part of the Sorell Basin occurs as a 500-m thick extension known as the Macquarie Harbour Graben. The sediments, which outcrop extensively on the northern shore of Macquarie Harbour, consist of early Eocene mudstones and sandstones with thin coal seams, overlain by Plio-Pleistocene gravels and sands. The Eocene beds are interpreted as having been deposited in marginal marine and sandy braidplain environments.

Geological sampling of the seafloor off west Tasmanian, mainly by dredge and corer, has provided invaluable geological information and control on seismic interpretation. Sampling cruises conducted in the area include, (i) RV *Sonne* Survey SO36C of 1985 over the west Tasmanian margin and South Tasman Rise, (ii) BMR Survey 67 of 1987 in the Otway Basin and over the far northern west Tasmanian margin, (iii) BMR Survey 78 of 1988 over the west Tasmanian margin, and (iv) AGSO Survey 147 of 1995 over the west Tasmanian margin, South Tasman Rise and East Tasman Plateau.

One of the most important results of the sampling programs has been the discovery of Late Cretaceous shallow-marine sediments exposed on fault blocks on the lower continental slope, in water depths of about 4000-4500 m. This implies substantial subsidence and crustal thinning since these sediments were deposited. In addition, the recovery of Paleocene and early-mid Eocene marginal marine sediments on the mid- and lower slope suggests that full open-marine conditions were not established until the late Eocene. These conditions resulted from post-breakup thermal subsidence of the margin about a hingeline at the present coast, combined with a reduction in the sediment supply.

In summary, the Sorell Basin developed in the latest Jurassic to earliest Cretaceous in a transtensional tectonic setting within the Southern Rift System (Willcox & Stagg, 1990), the zone of initial extension between the Australian and Antarctic cratons. Rifting was followed in the Aptian-Albian by low-energy sag-fill or late-rift deposition. Uplift and erosion in the Cenomanian coincided with the onset of Tasman Basin rifting to the east. Marine deposition first commenced in the Late Cretaceous, and occurred in elongate downwarps (such as the southeast continuation of the Eastern Voluta Trough) and in narrow, fault-controlled depocentres on the upper margin. The last major wrenching episode was in the Maastrichtian-

Paleocene, at the time of breakup (Hill *et al.*, 1997b). Thick Palaeogene prograding sequences were deposited, first in the north and then farther south, as the margin collapsed and spreading moved relatively south. Minor wrenching, mainly by reactivation of older structures, continued into the Palaeogene due to shearing as the Australian and Antarctic continental plates separated in a N-S direction. The Palaeogene wrench reactivation was confined mainly to the upper margin (including the Sorell Fault Zone) and far south of the Sorell Basin, and was associated with transform movement along the Tasman Fracture Zone and its extension to the north.

Southern Tasmanian margin and the South Tasman Rise

The South Tasman Rise (STR), located south of Tasmania, is a large submarine plateau of continental origin with its culmination at roughly 800 m. It is surrounded on three sides by Late Cretaceous and Palaeogene oceanic crust. In light of a variety of seismic data, and also satellite-derived gravity data and shipboard swath-bathymetry and magnetic data collected in 1994 during AGSO's survey aboard R/V *L'Atalante* (Exon *et al.*, 1994), west of Tasmania including the STR and the East Tasman Plateau (ETP), and dredges and cores sampled by AGSO in 1995 with the R/V *Rig Seismic* (Exon *et al.*, 1995), a tectonic review and a synthesis of the geology of the west Tasmanian margin and the two offshore plateaus have been completed.

The initial NW-SE extensional direction between Australia and Antarctica clearly implies that the STR, south of Tasmania, was not originally at its present location relative to Australia, as it would have been in the way of the Antarctic plate. Linked to Tasmania by thinned continental crust, the STR is composed of two distinct terranes (Royer & Rollet, 1997). A western domain, limited to the east by a transform margin along the Tasman Fracture Zone and to the east by a 170°-oriented boundary at 146°E, was initially attached to Antarctica. The western terrane rifted away from Antarctica in the Late Paleocene/Early Eocene and underwent severe wrench deformations as the Antarctic plate moved southward relative to the Australian plate. Shear motion continued to shape the Tasman Fracture Zone transform margin until the Early Miocene (chron 6B, 23 Ma) after which the Southeast Indian Ridge axis cleared from the western edge of the South Tasman Rise. An eastern domain limited to the east by a boundary at 146°E, rifted off from Tasmania and the East Tasman Plateau.

The STR was affected by NW-SE strike-slip motion in the Late Cretaceous, and N-S extension and strike-slip motion in the Tertiary. Basins on the STR are fault-controlled, and are believed to contain Late Cretaceous to Early Oligocene detrital non-marine and shallow-marine sedimentary rocks, and Late Oligocene and younger bathyal to pelagic chalk and ooze. The basins contain fault structures, and are prospective for petroleum in the long term, but only the central area is in water depths that are presently favourable to drilling.

Southern NSW, Gippsland and east Tasmanian margins

The Gippsland Basin developed as a transtensional rift ~140 Ma during fragmentation of the East Gondwana supercontinent (Willcox *et al.*, 1992), filling with mainly volcanogenic sediment sourced from an Early Cretaceous magmatic rift system, the Whitsunday Volcanic Province (Veevers, 2000), which lay to just to the east and extended northward. The southeast Australia region was uplifted at ~100 Ma as a prelude to continental breakup about 20 m.y. later, when the Lord Howe Rise separated from eastern Australia and Tasmania, along an ENE-WSW direction, thereby creating the Tasman Sea. Opening began adjacent to the East

Tasman Plateau at ~83 Ma and ended at 55-50 Ma (Royer and Rollet, 1997; Gaina *et al.*, 1998).

Basement onshore comprises Palaeozoic rocks of the Lachlan Foldbelt. Northeast Tasmania is underlain by quartzwacke turbidites of the Mathinna Group, which have been intruded by Devonian granites that outcrop extensively in the area. The Late Carboniferous-Triassic Tasmania Basin, up to several kilometres thick, covers much of southeast Tasmania and probably extends offshore. The basin has been heavily intruded by Jurassic dolerites. These have been exhumed by erosion and, like the granites to the north, now form extensive outcrop. Tertiary volcanics occur throughout east Tasmania. The basalts have an age range of 58-16 Ma (Sutherland, 1989). The East Tasman Plateau (ETP) is a continental block (Exon *et al.*, 1997) that subsided below sea level during margin development. Dredging has recovered metasediments and Neoproterozoic orthogneiss. The ETP generally lies at 2000-3000 m depth, but is topped by a late Eocene basaltic volcano, Cascade Seamount, that rises to 650 m below sea level and is thought to be part of the Balleny hot-spot trace (Lanyon *et al.*, 1993).

The Gippsland Basin has been Australia's major oil-producing province for 30 years. It contains up to 14 km of Late Jurassic-Cainozoic section in an ESE-trending depocentre (Willcox *et al.*, 1992; Megallaa, 1993). The sediments comprise the Late Jurassic-Early Cretaceous Strzelecki Group (non-marine, southern margin syn-rift), Late Cretaceous Golden Beach Group (non-marine, Tasman syn-rift), Late Cretaceous-Eocene Latrobe Group (mainly non-marine, sag phase, and the main petroleum producer), and the Oligocene and younger Seaspray Group (marine carbonates). Faulting and erosion have exposed much of the basin sequence in the Bass Canyon complex on the continental margin.

Good control of the seismic stratigraphy is available in the Gippsland Basin from the many wells, at least on the shelf and down to the upper Latrobe Group. Farther north, off NSW and farther south, off east Tasmania, no offshore drilling control exists on the margin. Some control on the deepwater seismic stratigraphy comes from DSDP Site 283 about 250 km east of the ETP (Kennett *et al.*, 1975). It was drilled in 4756 m of water to a depth of 592 m and bottomed in altered basalt. The sediments recovered were all abyssal clays. The section was Early Paleocene to Late Eocene, apart from the top 13 m which was Late Miocene-Pleistocene.

The continental shelf off southern NSW and east Tasmania is 20-40 km wide. It is largely non-depositional at present. Surface sediments comprise quartz sands (mainly nearshore), muddy quartzose/calcareous sediments, and bryozoan sands and gravels (Davies, 1979; Jones & Davies, 1983). Beyond the shelf edge, the continental slope falls relatively steeply to abyssal depths at 3-10°. Off southeast Tasmania, the continental slope falls to the East Tasman Saddle (between the Tasmanian mainland and the ETP), which lies at a depth of 3200 m and is located about 60 km out from the shelf edge. Off the southern NSW and northeast coasts of Tasmania, the continental slope is mainly steep and rugged and drops down to the relatively flat surface of the Tasman Sea abyssal plain at depths of ~4200-4600 m. Off Tasmania, the continental slope is about 80 km wide in the south, narrows to about 40 km in the north off southern Flinders Island, and then broadens again towards the Gippsland Basin.

The southern NSW and east Tasmanian margins formed by the stepping down seaward of large basement blocks (Colwell *et al.*, 1993; Hill *et al.*, 1998). The fault zone is 60-110 km wide, with one of the narrower sections being off northeast Tasmania. The faults appear to be largely high-angle. The continent-ocean boundary (COB) underlies the rise and generally coincides with the 4200 m isobath off Tasmania, and probably the 4600 m isobath off southern NSW. Adjacent Campanian oceanic basement lies beneath the abyssal plain at a depth of 7.5-8.0 seconds twt, and is overlain by 2.0-2.5 km of relatively flat-lying sediments that onlap the continental basement blocks to the west. In the deepwater Gippsland Basin and south to about 40° 30'S, the upper continental slope is underlain by a complex set of rift basins that are controlled by conjugate WNW faults (parallel to faults within the Gippsland Deep and also Bass Canyon) and NNE faults (margin-parallel). A narrow N-S trending rift graben, well-defined in satellite gravity images, is located beneath the upper slope off Freycinet Peninsula. Structural trends on the basement highs to the east are NW-NNW (rift direction) and NE-ENE (transfer direction). Similar narrow graben are present beneath the continental slope off southern NSW (Colwell *et al.*, 1993).

The ETP is dominated by Eocene hot-spot volcanic intrusions and constructions (Cascade Seamount and a 2200-m high seamount on its northeast margin). Volcanics occur in the post mid-Eocene basinal section, suggesting that minor further volcanism continued after the hot-spot activity. The continental basement surface beneath the ETP appears to have been planated (?sub-aerial erosion), then tilted and faulted as the margin subsided. Up to 2 km of post-rift section is present in the East Tasman Saddle. The underlying synrift section appears to contain considerable volcanics (Hill *et al.*, 1998).

The shelf and upper slope along the southern NSW and east Tasmanian margins are underlain by a wedge of Late Oligocene-Quaternary seaward-prograding carbonate sediments 500-1000 m thick (Colwell *et al.*, 1993; Hill *et al.*, 1998).

4. PREVIOUS SWATH-MAPPING STUDIES

Using the towed British ultra long-range, 6.5 kHz GLORIA sidescan system and its own 16-beam 12 kHz SeaBeam multibeam sonar, HMAS *Cook* in 1989 carried out the first wide-angle swath-mapping surveys off southeast Australia. Two relatively small areas were mapped off southeast Australia - a section of continental margin off the New South Wales south coast (Jenkins & Lawrence, 1990) and canyon systems south of the Murray River mouth (von der Borch & Hughes Clarke, 1993). The SeaBeam system (original version) gave a maximum swath-width of only 0.8 times water depth, while GLORIA could map a sidescan swath up to 35 km wide.

The survey of the NSW continental slope extended 230 km south of Sydney (Jenkins & Lawrence, 1990), and identified sediment slides, small canyons cut into the upper slope, large canyons incised into the middle and lower slope, and exposed basement ridges. The survey of the slope west of Robe in South Australia (von der Borch & Hughes Clarke, 1993) concentrated on a region cut by canyons, just beyond the carbonate shelf. Slump scars and sediment slides are very widespread, and frequently the material came from immediately below the shelf break. Two east-west scarps dominate the mid-slope, and may represent normal faults on the northwest margin of the Otway Basin.

The first major swath survey off southeast Australia was AGSO's TASMANTE survey in 1994 using the Simrad EM12D multibeam on *L'Atalante* (Figure 1; Exon *et al.*, 1994, 1996; Hill *et al.*, 1995). The main aim of the survey was to accurately map the South Tasman Rise and the west Tasmanian margin, and to use the results to establish the geological framework of the region. During this cruise an area of 200,000 km^2 was swath-mapped to the west and south of Tasmania, from the outer edge of the continental shelf to the abyssal plain (Hill *et al.*, 1997).

West of Tasmania the continental slope is about 100 km wide, and falls fairly regularly from water depths of 200 m to 4000 m, at an average slope of 3-4°. Its geology is summarised in Hill *et al.* (1997b). The TASMANTE swath imagery showed that it is mostly blanketed by sediment, and is incised by an extensive system of linear to curvilinear, 100-m deep canyons that extend 60 km or more from the shelf edge to depths of several thousand metres. Several local highs were mapped on the southwestern mid-slope, and strong acoustic backscatter suggests some exposed bedrock. A series of local highs and NW-trending ridges rise above the gently inclined lower slope and flat abyssal plain in water depths of 3500 m to 5000 m. The largest of these highs is a 160 km long ridge on the lower southwest continental slope, and sampling cruises have shown that this high is of continental origin. The continental slope immediately south of Tasmania is rugged, from 700 m depth (upslope limit of swath-mapping) to more than 3200 m in the saddle between Tasmania and the STR. Extensive rock outcrops occur on the upper part of the slope, which is also cut by a number of steep canyons up to several hundred metres deep. The most remarkable feature of the slope is a large field of more than 70 volcanic cones in water depths of 900 m to 2300 m. Most cones are clustered in the one field, but other more isolated cones were also found.

About 20,000 km^2 of sea bed, off eastern Tasmania and in the Gippsland Basin, were surveyed by AGSO in early 1997 (Figure 1; Hill *et al.*, 1998; Exon *et al.*, 1999), using the SeaBeam 2000 multibeam sonar system of the Scripps Institution of Oceanography's RV *Melville*. The mapping provided data for tectonic, basin and sedimentological studies, to aid the petroleum exploration industry, and to plan future seismic profiling and sampling. To maximise coverage, most of it was in water 2000-4200 m deep, but it extended into shallower water off St Helens and in the Gippsland Basin. The spectacular Bass Canyon complex was mapped in detail for the first time during this cruise. It comprises a large embayment, 100 km across and floored by the ESE-trending, 10-15 km wide chasm of Bass Canyon. This canyon, 60 km long and bounded by walls 1000 m high, has cut down about 2 km altogether. Two applied surveys, one of a jarosite dump site southeast of Hobart, and the other of the orange roughy fishery off St Helens, produced high quality, detailed maps of the sea bed.

5. CRUISE NARRATIVE

Saturday 18 December 1999
L'Atalante sailed from Noumea at 0900 local time (lt), as scheduled. [Note: 0000 UT = 1100 lt]. Headed for Lord Howe Island, site of the first non-transit survey. Collecting Simrad EM12D multibeam, 3.5 kHz profile, gravity and oceanographic data on the way. Seas were slight on a low swell, with weather fine but cloudy. At 1100 lt, held cruise planning meeting of the Australian team. Decided to operate 12-hour watches, 0000-1200 UT and 1200-2400 UT - starting at 1200 lt. Lifeboat and safety drill at 1615 lt. Ship's speed averaging 11.2 knots.

Weather remained good in the evening, with calm seas - so made excellent progress at ~11.5 knots.

Sunday 19 December 1999
Seas calm, low swell and less than 5 knots wind.

Meeting at 0900 lt amongst Commandant Houmard, Australian scientists and Genavir engineers/technicians to discuss survey program and operational requirements, as well as safety issues.

Crossed the French/Australian agreed maritime boundary at ~1125 lt (0025 UT), approximate location 26° 20'S 163° 24'E. Data files were split at this point. [A copy of the cruise data from the French side, on Exabyte tape, was made available in early February 2000 to France through Dr Jean-Marie Auzende of IFREMER, New Caledonia.]

At dusk, seas were slight on a moderate swell, with overcast skies. Crossed directly over a 300-m high volcanic cone on the northern Lord Howe Rise at ~1200 UT.

Monday 20 December 1999
Continued on the transit to Lord Howe Island. The weather deteriorated, with seas rising to rough on a moderate swell, and the wind increasing to 25-35 knots from the south. This forced a reduction in ship's speed to 8-10 knots.

Tuesday 21 December 1999
Approached Lord Howe Island at about midnight, and immediately began the planned survey, starting to the southeast of the island and then proceeding in an anticlockwise direction around it and Ball's Pyramid. Initially seas were rough, with 20-25 knot winds, and visibility was fair – the silhouettes of Ball's Pyramid and Lord Howe Island could be discerned on the horizon.

The loop was completed at 9-10 knots by about 1100 lt, and then a line was run through the deep-water channel between Lord Howe Island and Ball's Pyramid. Weather conditions had improved towards noon, though there were still some rain squalls, with seas moderate and wind speed down to 10-15 knots. From bearings taken on the islands and the DGPS position of the ship, it appears that Ball's Pyramid may be mislocated on existing charts such as AUS 213, and should perhaps be plotted about 400 m to the northeast of its charted position. The survey was completed at ~1300 lt, having mapped the island slopes in water depths of 300-3000 m.

Wednesday 22 December 1999
Continued on the transit across the Tasman Basin towards the Australian continental margin off Newcastle. Crossed the southern Dampier Ridge and passed over the northern flank of a large seamount (Barcoo Bank) north of Taupo Guyot, in mapped water depths ~1500-4000 m. About one hour of 3.5 kHz data were lost when the system lost bottom-track and had to be restarted. Also passed over several smaller seamounts. The 3.5 kHz showed well-stratified sediments in the cental Tasman Basin, with penetration ~70 m. Weather conditions improved, with slight seas on a moderate swell, and wind down to about 8 knots from the ESE. Getting 18 km swath-width in 4700 m water.

On reaching the mid continental slope off Newcastle, changed course to the south to follow a line along the NSW slope roughly coinciding with the 2000 m isobath.

Thursday 23 December 1999
Off Jervis Bay at 0800 lt. Heavily overcast and some showers, seas moderate with 1-1½ m swell, 10 knot wind from the northeast. Swath-width ~11.5 km, covering water depths of ~1000-3000 m.

Deployed the seismic gear (2 GI guns and streamer) plus magnetometer at ~1030 lt; all out by 1057 lt. The seismic system was operational after a short period of set-up adjustments, and was collecting good data by 0021 UT. Initially, the 3 depth transducers on the streamer were showing erroneous readings, though the streamer appeared to be running at correct depth (~ 10 m). This problem was later fixed. The magnetometer also had some initial problems, producing noisy and erratic output. After several hours work by the electronic engineers on the console and in tuning the unit, the magnetometer was brought into operation, though the output was still prone to occasional spikes (readily edited out in post-processing).

Began 3-line survey of the NSW South Coast margin. The seismic profile along the mid-slope of this margin showed a very rugged, canyoned topography, with up to 2 s twt of well-stratified sedimentary section in places.

Friday 24 December 1999
At the southern end of the NSW lines; did a loop and then surveyed the deep-water line to the north. Rough seas, moderate swell, 15-25 knot southeast wind. But getting good swath-width - up to 21 km at times. A strong southerly current (East Australian Current) of 3 knots, meant that sped over the ground was down to 7 knots on the northward run (towing speed of the seismic gear through the water is kept to a maximum of ~10 knots to avoid damage and excessive noise levels). At 2025 lt the starboard 45/45 gun was brought aboard to repair an air leak; back in the water and firing at 2226 lt.

Saturday 25 December 1999
Running the shoreward (shallow) line to the south off northern Gippsland. Overcast and raining, 10 knots speed. Strengthening easterly wind in the afternoon, 25-35 knots, with very rough seas on a 2-3 m swell. Working the northern deepwater Gippsland area, but speed reduced to 7-8 knots because of the rough seas.

Sunday 26 December 1999
Rough seas and moderate swell, wind 25-35 knots from the northeast, but generally making good progress at close to 10 knots. Surveying multiple lines in the northern Gippsland area. Some mismatch in the bathymetry contours of adjacent swaths in the real-time data - due to sound velocity profile problems, perhaps caused by warm water gyres along the coast. Running extra XBTs to reduce the problem.

Surveyed a major, 600-m deep canyon on the upper slope of the northern Gippland area - its head being known to commercial fishers as the 'Big Horseshoe'. Seas conditions became very rough, driven by 30-35 knot northeast winds, but data quality remained good.

At 1755 lt, the port 105/105 gun was stopped and brought aboard for about 20 minutes for preventive maintenance to the gun and towing cables/air lines. In the meantime, continued shooting with the small gun. By midnight, completed a short survey of the deep canyon complex (relief ~1000 m) on the upper slope at the western end of the Bass Canyon Complex.

Monday 27 December 1999
Very rough seas continued with winds consistently ~35 knots from ENE, but data quality good. Speed down to ~7 knots for much of the early hours of the morning because of the rough conditions.

Surveying off Flinders Island. Low cloud, mist and rain. The wind dropped to 10-15 knots and the seas abated in the late afternoon. Making 11 knots as the ship surveyed to the south, in the same direction as the East Australian Current. By evening, the weather had again deteriorated as the winds strengthened to 30 knots, but ship's speed was a good 10 knots as it headed south. Maintenance done on both guns, one at a time.

Tuesday 28 December 1999
Off St Helens overnight, covering areas of the upper slope adjacent to the 1997 *Melville* swath coverage, including the North Hill area and the western part of the St Helens Hill/St Patricks orange roughy fishery.

Seas were rough on a moderate swell, and the wind, at 15-20 knots, had swung to the southeast. By midday the wind had swung further, and was now from the southwest at 30-35 knots, and the ship was pounding directly into the oncoming seas.

The seismic showed at least 2 s of ?Late Cretaceous/Tertiary section in a N-S graben off Freycinet Peninsula. A large isolated magnetic anomaly was recorded at the southern end of the graben.

The ship continued southwest to the Southern Hills area.

Wednesday 29 December 1999
In the early hours of the morning, started mapping the area along and adjacent to the eastern boundary of the Tasmanian Seamounts Protected Area. Ran a N-S line, then a S-N line to the east. Weather conditions were not good, but better than forecast - wind was 20-28 knots from the south and SSW, with 2-2.5 m seas on a 3 m swell, and overcast sky.

A computer failure on the digital seismic acquisition system at ~1230 lt resulted in the loss of 4 hours digital data, though recording of the seismic data on the monitor strip-chart was unaffected.

A large volcano, 300-400 m high and flat-topped at ~450 m water depth, was crossed on the upper continental slope off southwest Tasmania, southwest of Maatsuyker Island. Continued NNW just shoreward of the 1994 TASMANTE swath coverage. Weather conditions improved, with the wind down to 20 knots and now from the southeast.

Thursday 30 December 1999
Continued the survey line to the NNW off Sandy Cape overnight, with survey conditions relatively good - wind from the south at 20-25 knots, moderate seas on a 2 m swell.

At ~0830 lt an air leak in the 105/105 gun meant it had to be brought aboard for repair, but by 1200 lt it was back in the water and firing.

The line farther to the northwest off King Island revealed numerous down-slope gullies and canyons in the sedimented upper slope. Making 10 knots in the evening in good sea conditions - wind southerly at ~25 knots.

Friday 31 December 1999
On the Otway margin, overcast with showers. 2 m seas on a 2.5 m swell, 25-30 knot wind from SSE. Making 9.5-10 knots. Numerous canyons on the sedimented upper slope, but no other major seabed structures. Some of the canyons are deeply incised, to 800 m, and v-shaped. Magnetometer noisy around 1700 lt.

Saturday 1 January 2000
Seismic acquisition was stopped at 0900 lt (2200 UT) at the request of the Commandant as a precaution against possible Y2K problems (at 0000 UT). The guns, streamer and also the magnetometer were brought aboard.

By 0955 lt ship's speed was up to 11.3 knots, in transit to the GAB survey area.

No major Y2K problems were evident in either navigation or data acquisition systems. Only one minor problem was noticed in acquisition, and that was that the year 2000 was recorded as 2028 in the digital seismic data.

Crossed very rugged and steep canyon topography off the southwest tip of Kangaroo Island, with scarps more than 1000 m high. Seas moderate on a 2 m swell, 20 knot wind from SSE.

Sunday 2 January 2000
In transit along the mid continental slope between south of Kangaroo Island and the GAB Marine Park. Sunny conditions with moderate seas and swell and 15 knot easterly wind. Doing 12.2 knots.

Reduced speed at ~1400 lt to deploy seismic gear and magnetometer at the start of the GAB survey. All systems operational by 1500 lt. Began GAB survey at 10 knots; delay in digital seismic acquisition set to 1.5 s. Exceptionally good weather conditions in the late afternoon with less than 5 knots wind and slight seas on a 1.5 m swell. In the deepwater southern part of the GAB Marine Park, the EM12D gave a 25 km swath-width (water depth ~4300 m). Here the Nullarbor Canyon crossed the southeast corner of the Park, and was seen in the multibeam data as a high relief feature (~1000 m deep) with an unusual 'pot-hole' topography, with individual depressions several kilometres across and up to 300 m deep. The acoustic imagery was strongly textured, suggesting complexly structured older sediment exposed by canyon erosion.

Monday 3 January 2000
Continued the survey of the GAB Marine Park, changing the delay on the digital seismic back to zero (from 1.5 s) as the survey entered shallower water to the north. The seafloor here was relatively flat and featureless. Two unusual mounds were mapped in the central south of the area, however. These are ~100 m high and 500-800 m across, are associated with a disturbed seismic section and appear as dark, high-backscatter points in the acoustic imagery, and are probably small volcanoes.

Skies were overcast, but sea conditions were relatively calm, with slight-moderate seas on a low swell. The wind, a 10-15 knot southerly in the morning, increased in strength by evening to 20-25 knots and came with some light showers.

There appeared to be significant changes in sea temperatures during the day, perhaps due to thermal eddies/fronts, and evidenced by changes in the shape of the EM12D cross-track bathymetry profiles from convex to concave in only a few hours. Extra XBTs were deployed to minimise the problem.

Tuesday 4 January 2000
Surveyed the central western part of GAB survey area. The imagery showed a uniform, structureless bottom. Seas were moderate on a 3-m swell; wind was from the southeast at 15-20 knots and the sky was overcast. There was a brief, unexplained failure of the EM12D, but it was restarted okay with only ~10 minutes data loss.

To speed the survey up and to save time, it was decided to stop seismic acquisition in the GAB at the end of the S-N profile AEA1027. The final lines here would be tightly spaced and seismic coverage already existed (Potoroo well being nearby). AEA1027 was ended at 1713 lt, and the seismic gear and magnetometer were aboard by 1755 lt. Speed was increased to 12 knots, and the survey continued, running E-W lines in the northern part of the survey area.

Wednesday 5 January 2000
Continued running the E-W lines in the northern, shallower part of the GAB survey area. The last, most northerly line mapped the upper slope to the 500 m isobath. Started the eastern tie line to the south at ~0845 lt. Rough seas on a 3-m swell, 20-25 knot wind from ESE; overcast with showers.

Finished the GAB Marine Park survey at 1800 lt, then turned east and began the transit line back towards the Otway margin, running this line to the south of the previous transit line. Making 10.5-11 knots into a 20-25 knot east-southeast wind.

Thursday 6 January 2000
Continued east to south of Kangaroo Island. Heading into a 20-25 knot southeast wind; rough seas on a 2.5 m swell, and overcast conditions. Making only 10.5 knots on full power (2 diesel-electrics).

Spectacular canyon development and relief on the continental slope south west of Kangaroo Island. Getting 15-16 km swath-width, with canyon floors prominent as high-reflectivity bands in the acoustic imagery. Mapped cliffs 1000 m high, and systems of converging and diverging canyon complexes.

Friday 7 January 2000
At 0603 lt, turned north, then west to run seismic along an additional line to the north of the first survey line. Started seismic on profile AEA1028 at 0734 lt. Doing 10.3 knots over the ground with following seas. Overcast and showery, moderate seas (~1 m) on a 2 m swell; wind 15-20 knots from the southeast in the morning.

Deeply-incised and complex canyon systems and cliffs were mapped on the continental slope south of Kangaroo Island. Channels in the canyon floors clearly expressed in the acoustic imagery. Experienced huge fluctuations in swath-width due to the extremely rugged topography. Finished this 4-line survey south of Kangaroo Island at ~2300 lt, then continued ESE on the southern side of the earlier survey line.

Saturday 8 January 2000
Off the Mt Gambier/Portland coast of Victoria, surveying to the southeast and still on the southern side of the earlier line. Some improvement in the weather - sunny day with 15-20 knot southeast wind, moderate-rough seas on a 2-3 m swell - doing 10.0-10.3 knots (with seismic). The 105/105 GI gun was shut down at 1548 lt and then brought aboard to fix an open circuit in the solenoid lead. It was back in the water and firing at 1727 lt.

Sunday 9 January 2000
Off northwest King Island at ~0100 lt. Turned to the north to cut across the previous track, so as to continue the survey on the shallower, northeast side of this line. Mapped a major canyon during the cross-over.

Weather was sunny, but with a strong (25 knot) wind from the northeast, and rough to very rough seas on a 2-3 m swell. Nevertheless, progress was good at 10-10.5 knots. In the afternoon, the wind increased to 25-30 knots (northeast). With both wind and seas on the port side, the ship rolled heavily. Later in the afternoon the wind dropped to just under 10 knots, giving good surveying conditions. But by evening it had picked up again to 20-25 knots northeast, but the ship was still making ~10.2 knots.

Turned shoreward at 1900 lt to run a parallel line back to the northwest but in shallower water (just seaward of the shelf edge). Crossed a number of canyon heads. The magnetometer signal became noisy, and attempts to retune and adjust the instrument were not completely successful at first, but by evening the magnetometer was again operating well.

Monday 10 January 2000
Overnight, completed the set of 4 lines off northwest Tasmania, generally coming in to the 500 m isobath and also running a deep, mid-slope line. The weather was very good in the morning, with the sun shining, a 5-10 northeast wind, and moderate seas on a low swell. The 105/105 gun was brought on deck at 0808 lt to again fix an open circuit in the solenoid lead; back in the water and operating normally by 0915 lt.

Weather conditions remained very good throughout the afternoon - slight seas and low swell, sunny day with only ~5 knots wind. Finished the line along the shelf edge off southwest Tasmania.

Tuesday 11 January 2000
Ran the final survey line along the upper slope off southeast Tasmania. About 5 more small volcanic cones (of the Southern Hills) were mapped, and the seismic showed a dipping sedimentary section at least 2 s twt thick, possibly a Cretaceous rift sequence or part of the Tasmania Basin (Permo-Triassic).

Weather was still very good, with slight seas on a one metre swell, and less than 5 knots wind in the morning.

Mapped several small (100 m high) volcanic cones off Storm Bay, just before ending the survey. Ended seismic acquisition at 1200 lt. Carried out maintenance on the seismic streamer as it was recovered (at 2-3 knots). All gear was aboard by 1310 lt, and *L'Atalante* steamed for Hobart. The ship berthed at Princes Wharf at 1805 lt.

6. DATA ACQUISITION, SCIENTIFIC EQUIPMENT AND PERFORMANCE

L'Atalante (Appendix 1) is a modern 85-metre oceanographic and geoscience research vessel specially designed and built for high-technology, deep ocean seafloor mapping, as well as other applications, such as deployment of the *Nautile* manned submersible. For seabed mapping it is equipped with the advanced and powerful Simrad Dual EM12 multibeam echo-sounder (Appendix 2). This 162-beam system maps bathymetry and acoustic backscatter of the seafloor at high resolution at ship's speed of up to 12-13 knots (typical cruising speed of *L'Atalante*). The swath width is about 7 times the water depth, with maximum effective coverage in deep water (several kilometres or more) of about 20 km.

EM12D data, gravity data and 3.5 kHz sub-bottom profiles were recorded during the entire AUSTREA-1 cruise (Figure 2), including transit legs ((i) Noumea to NSW margin, and (ii) Otway margin to GAB Marine Park). Six-channel GI gun seismic and magnetics data were collected over a total of ~17 days in the 'survey areas' off southeast Australia, along profiles 1-31 (Figures 5 & 6). With the seismic gear in the water, towing speed through the water was kept at 10 knots nominal when possible, and certainly below 10.5 knots to avoid damage to the gear, to keep the streamer and guns at the correct depth, and to minimise noise in the streamer. Otherwise, during transits, ship's speed was maintained at 11-12 knots, sea conditions permitting. It was necessary to reduce speed for short periods during XBT measurements, and deployment and recovery of the seismic streamer, airguns and magnetometer.

Survey and navigation equipment details are provided in Appendix 3. Also provided, in Appendix 6, are the geophysical acquisition parameters and a sketch of the acquisition geometry (Appendix 7).

The seismic data were recorded digitally and also displayed on a strip-chart monitor (Appendix 8). Ancillary oceanographic data, including Sippican XBT temperature profiles (to 1800 m depth - with a total of about 60 XBTs deployed during AUSTREA-1), continuously-logged surface sea-water temperature, salinity and sound velocity data, plus acoustic doppler current profiler (ADCP) data to about 600 m depth, were also collected.

The EM12D data were acquired digitally on the ARCHIV system, and displayed in real time on a colour computer screen as bathymetry contours and grey-scale acoustic imagery on a map base, using IFREMER's new multibeam processing and display software, Caraibes (v2.0). Much of the detailed on-board survey planning was done on this screen. Because pre-existing swath data could be displayed (as contours) with the new data, it was possible to precisely integrate the new and old swath coverages, to maximise survey efficiency and obtain a uniform distribution of quality data over the area surveyed. The acoustic imagery was displayed as monitor hardcopy on a Dowty Wideline 195 strip-chart recorder. The EM12D data were also displayed in real time in various formats on large-screen, colour graphic display monitors, allowing very effective monitoring and quality control during acquisition, and also facilitating ongoing finetuning of survey planning. The gravity, magnetics and vertical bathymetry outputs were displayed in real-time, both as digital values and also as profiles on a graphic display monitor, with the previous two hours of data in view.

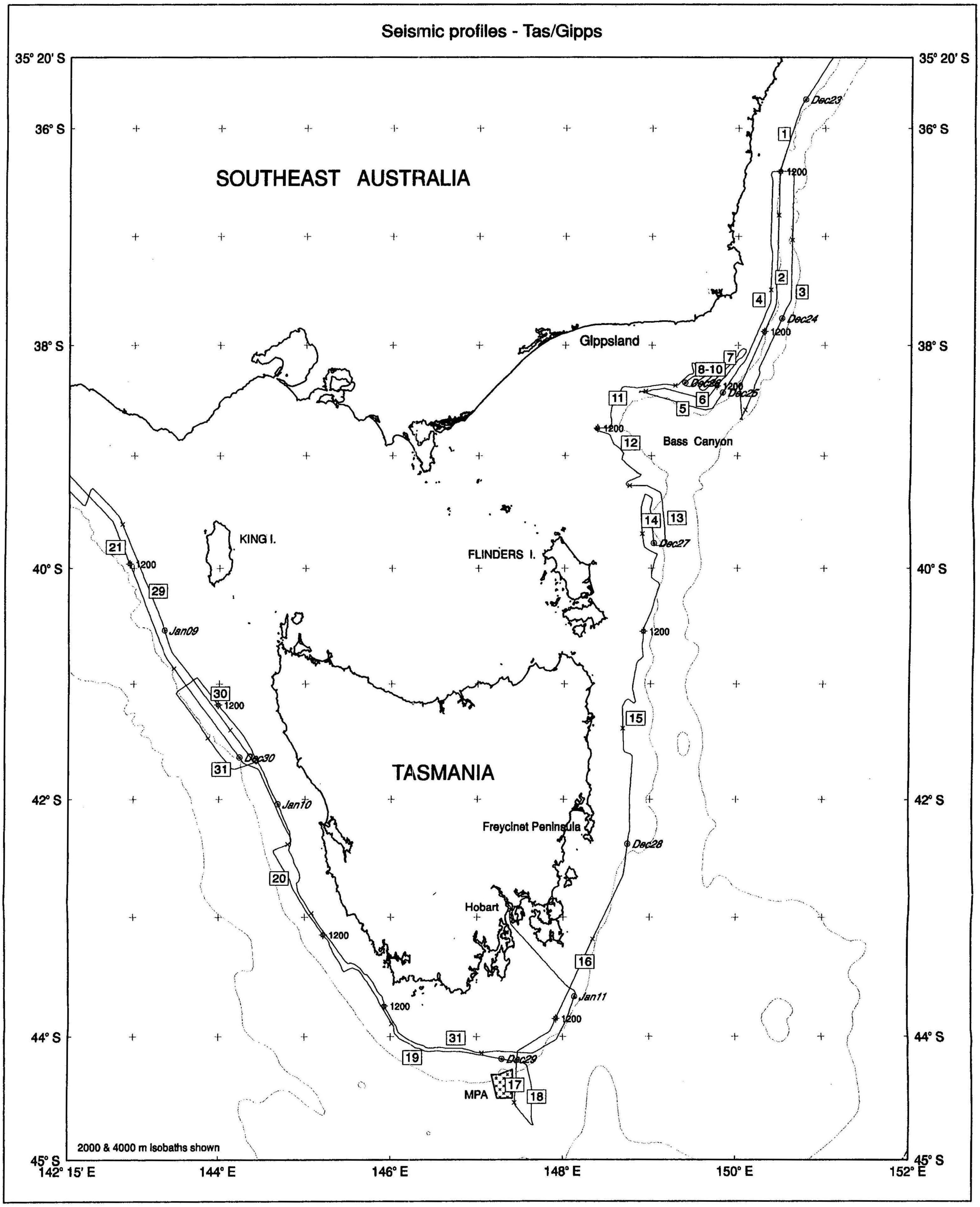


Figure 5. AUSTREA-1 seismic profile locations and 6-hourly navigation, Tasmania/Gippsland region

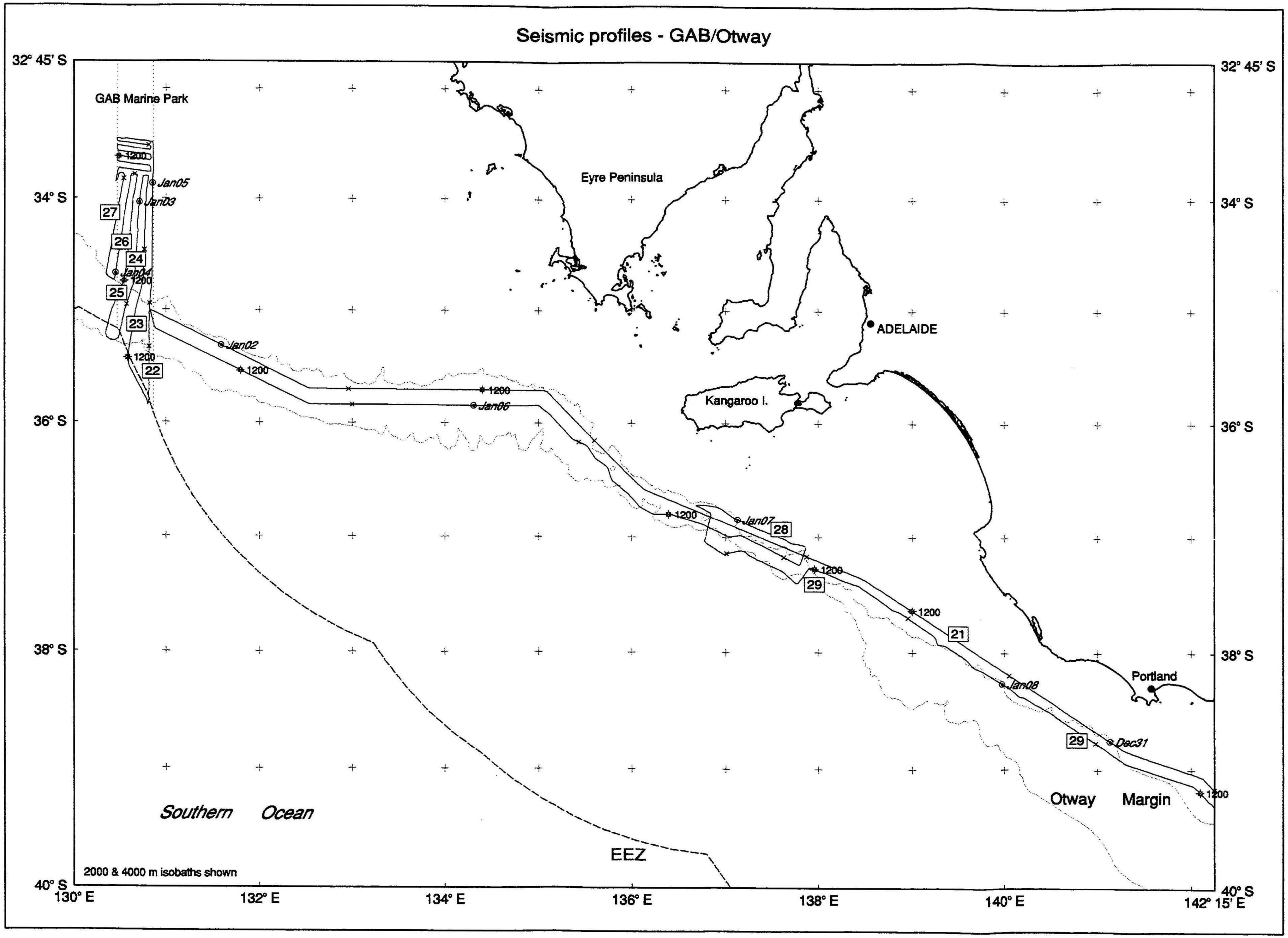


Figure 6. AUSTREA-1 seismic profile locations and 6-hourly navigation, Great Australian Bight/Otway region

No major Y2K problems were encountered as the year changed from 1999 to 2000. The only significant problems that affected this cruise were, (i) that 2000 was written as 2028 in the digital seismic records, and (ii) the Caraibes software could not handle the change in calculating IGRF magnetic anomaly values (this bug is now being fixed at IFREMER, Brest).

Weather and sea conditions can have a major impact on operations at sea. They determine, (i) whether or not deployment of gear such as seismic streamers, airguns and towed magnetometers is possible, (ii) whether ship's speed (therefore survey progress) needs to reduced to match prevailing conditions, (iii) wear and tear on deployed systems (therefore downtime for maintenance and repair), and they also have a strong influence on data quality and noise levels (particularly for multibeam, seismic and gravity data). No severe sea and wind conditions were experienced during this cruise, with winds speeds as high as 30-35 knots during only a few short periods. Rough seas at these times meant some reduction (up to a few knots) in ship's speed, but the survey program was never seriously set back, and noisy data due to the adverse sea conditions was not a serious problem. A detailed analysis of sea and weather patterns and associated survey progress is attached in Appendix 5.

Approximately 11,000 line-km of EM12D, gravity, 3.5 kHz, and oceanographic data were collected during the cruise, and about 120,000 km^2 of seabed was swath-mapped. Airgun seismic and magnetics data amounted to about 7000 line-km.

Navigation

The navigational systems on board functioned flawlessly throughout the cruise.

Normally only non-differential GPS navigation (~100 m accuracy) is provided on *L'Atalante*. However, AGSO and Environment Australia considered it important to have the cruise data as well located as possible, particularly for the important, shallower parts of the southeast Australia survey area. For this reason, differential GPS, with positional accuracy of ~1 metre, was provided on this cruise through arrangements made by Steve Dutton (AGSO). A differential GPS unit, serving as demodulator for reference data received via Inmarsat, was installed in Noumea by Fugro-contracted engineer (Colin Russell, NZ Ocean Technology Ltd) just prior to the start of the cruise. Output from this unit was linked directly into the ship's primary GPS receiver, the Sercel NR103.

Simrad EM12D bathymetry / acoustic imagery

Overall the EM12D performed very well, for both swath-bathymetry and backscatter imagery.

The system was designed for deepwater surveying, and this it does extremely well. On a few occasions it was operated for short periods on the shelf in water depths of 200 m and a little less. Here it gave poor performance, even when operated in Shallow Mode. Such areas are better and more efficiently mapped using a higher frequency multibeam system, specially designed for such shallow water depths.

Accurate sound velocity profile data enable the beams to be corrected for refraction and are vital to for precise cross-track positioning and time-to-depth conversion of the raw swath data. XBTs (expendable bathythermographs) were launched 2 or 3 times a day, sometimes more often, to provide good sound velocity information. Even then, there were times when significant mismatches between the outer beam depths of adjacent swaths were observed. Such mismatches in the raw data, in the order of 200 m, were seen in part of the northern deep-water Gippsland area, and also in the deep-water part of the GAB Marine Park. These were probably due to warm-water gyres or other water masses of different temperature moving through the survey areas. The new Caraibes (v2.0) processing software now readily allows reprocessing of data with new velocity profiles and also allows back interpolation of profile data. So by being selective in the XBT profile data used and by reprocessing, it was possible to eliminate, or at least significantly reduce, any mismatches between swaths during the on board processing of the data.

Airgun seismic

The dual GI gun source and small-diameter, high-speed streamer (Appendix 9) were an excellent combination that provided high resolution and relatively low-noise data at ship's speed of up to 10.5 knots through the water. In thickly sedimented areas, it was not uncommon to see structure to time-depths of 2.5 seconds (~3 km) sub-bottom in the single-channel monitor records.

The airguns required very little maintenance despite extended periods of rough sea conditions. Only minor repairs were needed, such as fixing worn/open-circuit wiring to solenoids. On the few occasions 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. This way, apart from having to reduce speed to 5-6 knots to retrieve the guns, very little time was lost due to gun maintenance. The streamer required no maintenance during the survey, and there was no damage due to fish bites. It was found to be in excellent condition when inspected off Hobart at the end of the cruise.

The record length for the digital acquisition was 8 seconds. Data were generally recorded from 0-8000 ms, except in areas of very deep water where a delay of 1.5 seconds was set. With a shot interval of 10.0 seconds, this was the maximum delay allowable on the system.

Information on the start and stop times and start and end shot-point for all seismic lines is given in Appendix 10.

Gravity

Two gravity meters were installed on *L'Atalante*, a Bodenseewerk KSS-30 and a Lockheed Martin BGM-5. The KSS-30 is the resident gravity meter on the ship, while the BGM-5 had been installed only recently, and was on trial. Both gravity meters functioned well throughout the cruise, and we believe that the gravity data will be of high quality after processing.

After the cruise Jean-Paul Allenou (IFREMER) was contacted for advice on a number of gravimeter-related matters. For example, it appeared from the gravity ties done in Noumea and Hobart that a meter constant (scale factor) correction was needed for the KSS-30. The following important information was provided by Allenou:

- the KSS-30 was checked and serviced in mid 1995 by Mr Kuhn of Bodenseewerk after erratic jumps of some mGals were first observed in 1994 (see discussion in Exon *et al.*, 1994) ..... the problem was thought to be due to dust particles affecting sensor movement ..... the sensor was jolted to remove such particles ..... this was successful, and the meter had been operating smoothly since June 1995 .... but the jolting may have changed the meter constant (scale factor) slightly

- no scale factor is currently applied to the shipboard KSS-30 output data (i.e. meter constant assumed to be 1.0000), because it could vary a little over time
- the specified scale factor for the KSS-30 is 8287/8336 (0.9941)
- the KSS-30 has an internal filter set for Sea-state II, requiring a 120 second delay correction to be applied in post-processing
- the BGM-5 requires no delay or scale factor corrections.

Ship-shore gravity ties were made in Noumea on 17/12/99 at the start of the cruise and in Hobart on 13/1/2000 at the end (Appendix 11). A portable Scintrex CG-3 was used for the ties. In Noumea, the reference station was 'IRD nouvelle base' with a value of 978865.33 mGal (IGSN71), while in Hobart ties were made to two stations, (i) Franklin Pier 6491.0260 with a value of 980437.25 mGal (IGSN84) and (ii) University of Tasmania, Geology Department 7499.0160 with a value of 980417.82 (IGSN84).

In Noumea the BGM-5 read 978893.54 mGal corresponding to a calculated gravity value of 978864.45 mGal, while in Hobart it read (i) 980469.31 mGal corresponding to a calculated gravity value of 980439.35 mGal (stn 6491.0260) and (ii) 980468.96 mGal corresponding to a calculated gravity value of 980439.35 mGal (stn 7499.0160) . Thus the BGM-5 meter drift was quite low, only ~0.8 mGal/month.

In Noumea the KSS-30 read -1736.7 (-1726.4 mGal assuming a scale factor of 0.9941) corresponding to a calculated gravity value of 978864.42 mGal, while in Hobart it read -153.1 (-152.2 mGal assuming a scale factor of 0.9941) corresponding to a calculated gravity value of 980439.35 mGal (for both ties). This indicates a meter drift of the KSS-30 of only -0.9 mGal/month.

Gravity tie data sheets for both meters relating to the ties made in Noumea and Hobart are attached (Appendix 11). Note that no meter constant correction has been applied on the KSS-30 sheets.

Magnetics

The magnetometer operated satisfactorily for most of the time that it was deployed, with noise levels commonly less than a few nT. However, there were some periods during the survey when the data were degraded by intermittent spikes and higher noise levels. The problem first became apparent on this cruise when the magnetometer was first deployed, off the NSW South Coast. Because much of the noise consists of spikes within otherwise good, smoothly-varying data (water depths, and so source depths, mainly greater than 500 m), it is anticipated that post-processing will effectively remove the bulk of the bad data. Most of the spikes were removed on board ship to produce the profiles shown in Appendices 12 & 13.

The problem of noisy data from the M-244 magnetometer appears to be due to an electronic fault within the console, and shows some sensitivity to ambient temperature. A very similar magnetometer problem was encountered with this unit on the 1994 TASMANTE cruise (Exon *et al.*, 1994), as well as earlier and later cruises. Since this problem has persisted for many years now, it is recommended that Genavir either thoroughly overhaul this unit or replace it.

3.5 kHz high-resolution sub-bottom profiler

The 3.5 kHz profiler comprised IFREMER's CHEOPS digital acquisition system linked to a Raytheon transducer unit. Fully annotated monitor records were provided on a Dowty Series 195 strip-chart recorder. The system functioned extremely well throughout the cruise, except for one minor incident on the transit across the Tasman Basin, when it required restarting after losing bottom-track over a seamount.

CHEOPS, linked to the EM12D and the ship's motion sensor, was a great improvement over earlier anologue systems , allowing:-

- high-resolution digital recording (SEG-Y)
- heave compensation (improving coherency and removing sinusoidal oscillation during times of heavy swell)
- recording of true depths (not slant ranges as is usually the case during ship motion with uncompensated beams).

Sub-bottom penetration was close to 100 m in areas where suitable sediments, such as the deep-sea, relatively unconsolidated pelagic sediments in the Tasman Basin, were found.

7. ON BOARD DATA PROCESSING

The raw DGPS navigational data were of very good quality, and so a final navigation file for the cruise was generated on board without problem. The EM12D data were processed on board by the Genavir technicians using 'Caraibes' software, to generate gridded data sets and a set of map products. The AGSO-specified map sheets were at 1:250,000 scale, Mercator projection with scale correct at 38°S, WGS84 datum. Two sets of data were plotted on a series of 21 map sheets (1-6T, 6Z-20; Figure 7), (a) bathymetric contours at 50 m interval, plus time-annotated ship's track (navigation), and (b) acoustic imagery (backscatter intensity) with 50 m isobaths. The plots were produced on very high quality thick white film; the 50-m contour/navigation maps were also plotted on transparent film ('mylar'). Copies of all these maps were provided to NOO immediately after the cruise. Various other colour/B&W contour and profile working maps and images were also produced by the scientists.

Seismic processing on board using the DELPH Rejeu system was limited to producing a preliminary 'stack' (sum of the 6 traces per shot), with 16-80 Hz bandpass and automatic gain control (AGC). These 'stacks' were displayed at 127 shots/inch (horizontal scale) and 700 ms/inch (vertical scale) on white film for all lines (Appendix 10).

8. UNDERWAY PROFILE DATA

Underway data were extracted from the CASINO data logger on *L'Atalante* to produce a series of daily profiles for the entire cruise, i.e. 18 December 1999 to 11 January 2000 (Appendix 12). These profiles comprise vertical water depth (bathymetry) from the central beams of the EM12D, IFREMER 'free-air gravity anomaly' from the KSS-30, total magnetic field from the M-244, and ship's speed (over the ground, i.e. based on DGPS positions). It should be noted that the free-air anomaly values were computed using the shipboard IFREMER software. At present this software makes no correction for the meter constant of the KSS-30 (pers. comm. Jean-Paul Allenou (IFREMER), February 2000). The estimated

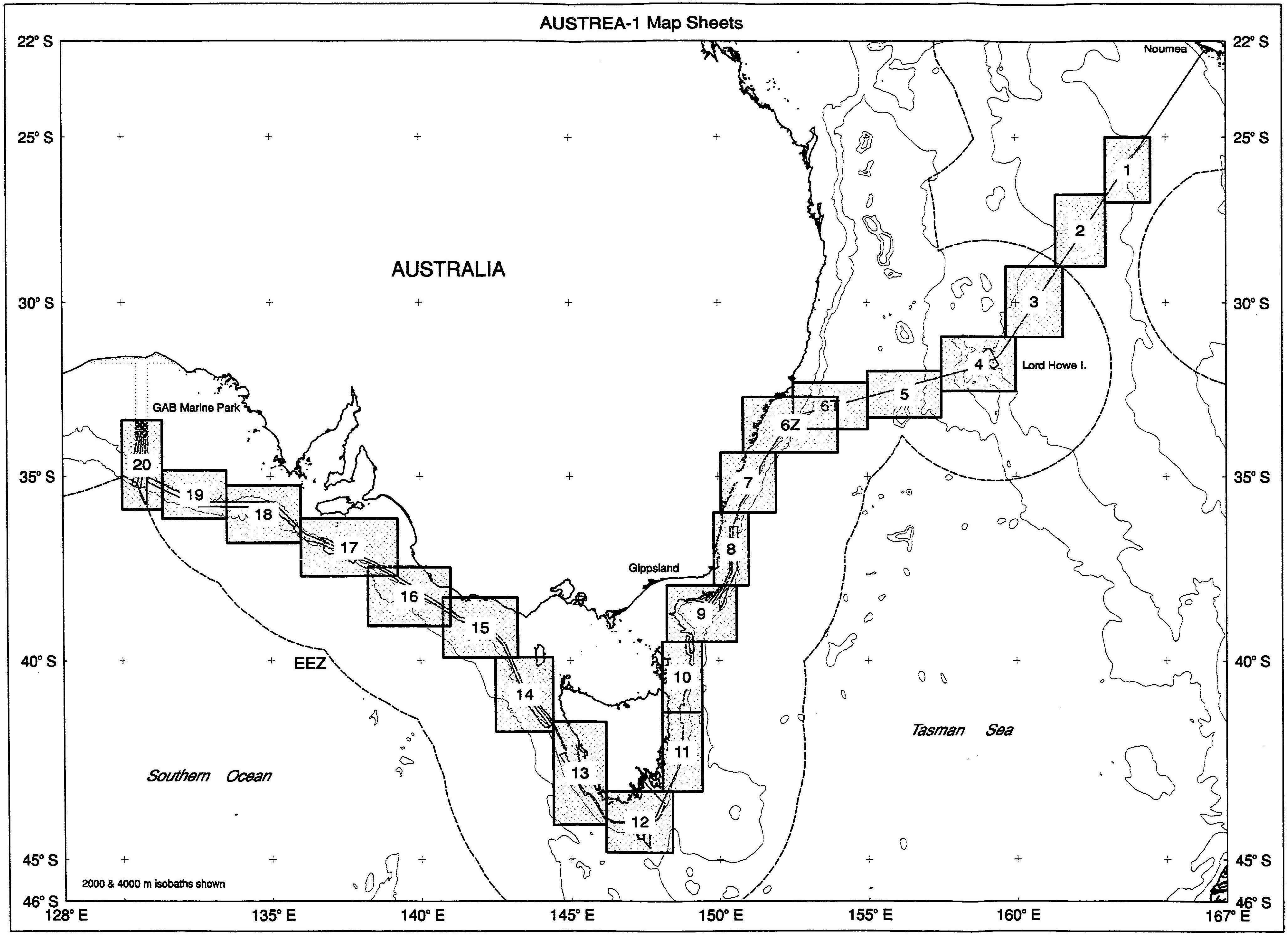


Figure 7. Index map for AUSTREA-1 1:250,000 map sheets (1-6T, 6Z-20)

meter constant (correction coefficient) is 0.9941 (see Section 6), and so the gravity profiles in the plots should be roughly correct and are useful for preliminary interpretation). The magnetic profiles shown have had some rudimentary automatic and manual editing done on them to remove noise spikes. Both the raw shipboard gravity and magnetic data will be properly post-processed at AGSO.

A compressed set of the four profile types covering the entire cruise (all days) is presented in Appendix 13. These profiles indicate that the survey ranged over water depths from a hundred metres or so (on the shelf) to ~5500 m in the Great Australian Bight, that 'free-air gravity' varied from about 130 mGal (Lord Howe Island) to about -80 mGal, that the total magnetic field was strongly latitudinally dependent (ranging from ~59000 nT in the north to ~63000 nT in the south), and that ship's speed averaged ~10 knots, with short decreases in speed corresponding to XBT launches and seismic gear/magnetometer deployments/recoveries.

9. TRANSIT FROM NOUMEA TO THE NSW SOUTH COAST, MAIN SURVEY RESULTS

From Noumea, the transit line crosses the deep (3700 m), flat-lying New Caledonia Basin. The central part of the basin is associated with a 20-30 mgal gravity high, probably an expression of thinned crust. To the west, a basement ridge with about +20 mGal gravity expression, separates this basin from the perched Fairway Basin, which lies adjacent to the northern Lord Howe Rise. The Fairway Basin is about 700 m higher than the New Caledonia Basin, and has a slightly uneven surface perhaps caused by mild bottom current erosion. The eastern flank of the continental northern Lord Howe Rise is relatively smooth and sedimented. It rises gradually, and culminates in a broad dome at 1070 m depth. On the southwest side of the highest point (on the transit), the surface of the rise is undulating with several valleys down to 1600-1700 m water depth. An isolated volcanic cone, 300 m high and 4 km across, lies right on the transit line at 28° 00.5'S 162° 09.0'E. It is surrounded by a shallow sediment moat, probably scoured by intensification of bottom currents around the edifice. A series of gravity anomalies in the order of 10-15 mGal in this general area suggest ?structural basement relief. Larger gravity anomalies (+30-40 mGal) were recorded near two local topographic culminations about 90 km northeast of Lord Howe Island, and these probably reflect significant positive basement relief.

Lord Howe Island and Ball's Pyramid, located on the western margin of the Lord Howe Rise, are the eroded, subaerial parts of volcanic edifices that were constructed by hot-spot volcanic activity about 6-7 Ma (McDougall *et al.*, 1981). The composite edifice (Figure 8) is about 90 km in a NNW-SSE direction and about 50 km WSW-ENE, and lies in water depths of 1800 m (ENE side) to ~3500 m (WSW side). Mount Gower, the highest point on Lord Howe Island, is 875 m above sea-level.. The swath data (Figure 8) show the submarine flanks of these volcanic islands to be rugged and steep, commonly 10-20°, and steeper in places. The terrain includes down-slope flow structures (probably old lava flows), canyons and numerous volcanic cones and pinnacles, many 150-300 m high. The largest flow 'chute' is 8 km wide and located on the WSW side of Ball's Pyramid. At least one cone (200 m high) occurs on the adjacent Rise. The slopes appear to be mostly rocky volcanic outcrop, with only thin patches of sediment.

The Lord Howe Basin to the west, between the Lord Howe Rise and Dampier Ridge, is 4050 m deep and generally flat-bottomed, except for a large ?volcanic seamount that rises steeply

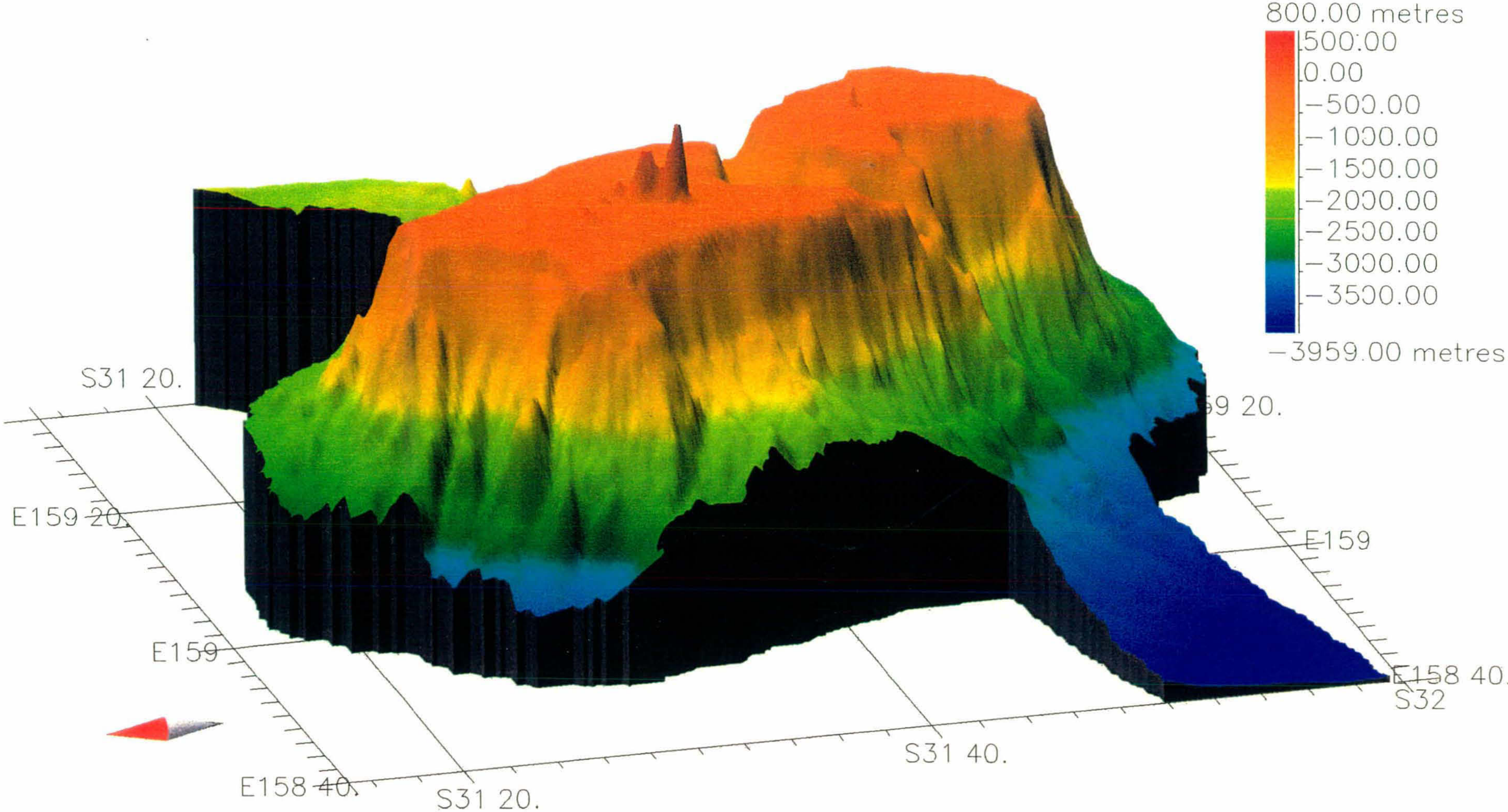


Figure 8. 3-D topographic image of the Lord Howe Island/Ball's Pyramid 'hot-spot' volcano, based on the AUSTREA-1 multibeam data below 300 m water depth

from the middle of the basin to 2800m or shallower (only the northern part of the seamount was mapped). Where crossed, the continental Dampier Ridge is 80 km wide and rises to 2000 m. The western side appears to be underlain by en echelon N-S-oriented fault blocks.

The floor of the Tasman Basin (along the transit line) is mainly flat-lying at depths of 4600-4850 m, with the deepest part adjacent to the NSW margin. Barcoo Bank, on the eastern side of the basin is a large seamount of the hot-spot Tasmantid Seamount Chain with an estimated age of 17.1 Ma (CPCEMR, 1991). It rises to less than 1400 m, and has a prominent spur radiating to the WNW. Several basement highs, located near the middle of the basin, rise to heights of up to ~500 m above the basin floor. These may be segments of the extinct (~52 Ma) spreading ridge, perhaps offset by a fracture zone.

10. SWATH MAPPING RESULTS AND UNDERWAY GEOPHYSICS OF THE SOUTHERN NSW AND GIPPSLAND MARGIN

The continental margin off southern NSW and northern Gippsland (Colwell *et al.*, 1993) is relatively narrow, only 50-70 km wide. The margin broadens out to a large embayment off Gippsland, the Bass Canyon complex (Hill *et al.*, 1998), which is about 150 km across. The continental slope generally has a slope of 4.5°-10° (between the 1000-4000 m isobaths). The adjacent Tasman Basin is 4200-4850 m deep, and flat-lying - the result of sediment infilling over the 80 m.y. since the basin opened.

The entire margin is steep, often rugged, and cut by canyons. A ?late Tertiary sediment wedge extends from the shelf to water depths of mainly 2000-3000 m. The lower continental slope is generally less sedimented and more rugged, exposing or at least reflecting, much of the margin's underlying rift structures.

Apart from the extraordinary topography associated with the Bass Canyon (Figure 9), a change from north to south in the geomorphological character of the margin is evident. In the north (from off Newcastle to just south of Montague Island (at ~36° 15'S), the upper continental slope is relatively smooth and sedimented, with a number of canyons 200-600 m deep running either downslope (incising sediment cover), or with a N-S or E-W orientation, the latter probably controlled by rift or transfer faults. Many of the canyons are 1.5-4 km wide, with some as wide as 8 km - such as the ~N-S canyon off Batemans Bay. Three 200 m local highs on the slope off Newcastle may be volcanic cones or pinnacles left by erosion.

The southern part of the margin, from near Montague Island to Gabo Island, shows a more complex geomorphology. The sediment wedge on the upper slope is highly and extensively dissected by gullies, V-shaped valleys and small canyons, typically 1-2 km wide and 50-200 m deep. Erosion may have been accentuated by the relatively steep slope at the toe of the wedge, ~17°. The seismic profiles (Figure 10) show up to 700 m of eroded Tertiary section above a strong unconformity. The lower slope (~2500-4500 m depth) also shows unusual structural complexity. The seabed is rugged, with wide canyons and scarps hundreds of metres high. It is probably largely basement outcrop, though the seismic suggests up to 1.5 s twt of rift sedimentary section in places on the lower slope. In the north, off Montague Island, large seamounts and a prominent N-S ridge (all ~600-800 m relief) were mapped on the mid-lower slope. These could be part of the igneous Mt Dromedary complex, intruded during rifting of the margin at ~100 Ma (Colwell *et al.*, 1993). In the far south (~37° 43'S), a larger, 20-km long and 800-m high ridge, also oriented N-S, was mapped on the lower slope. This

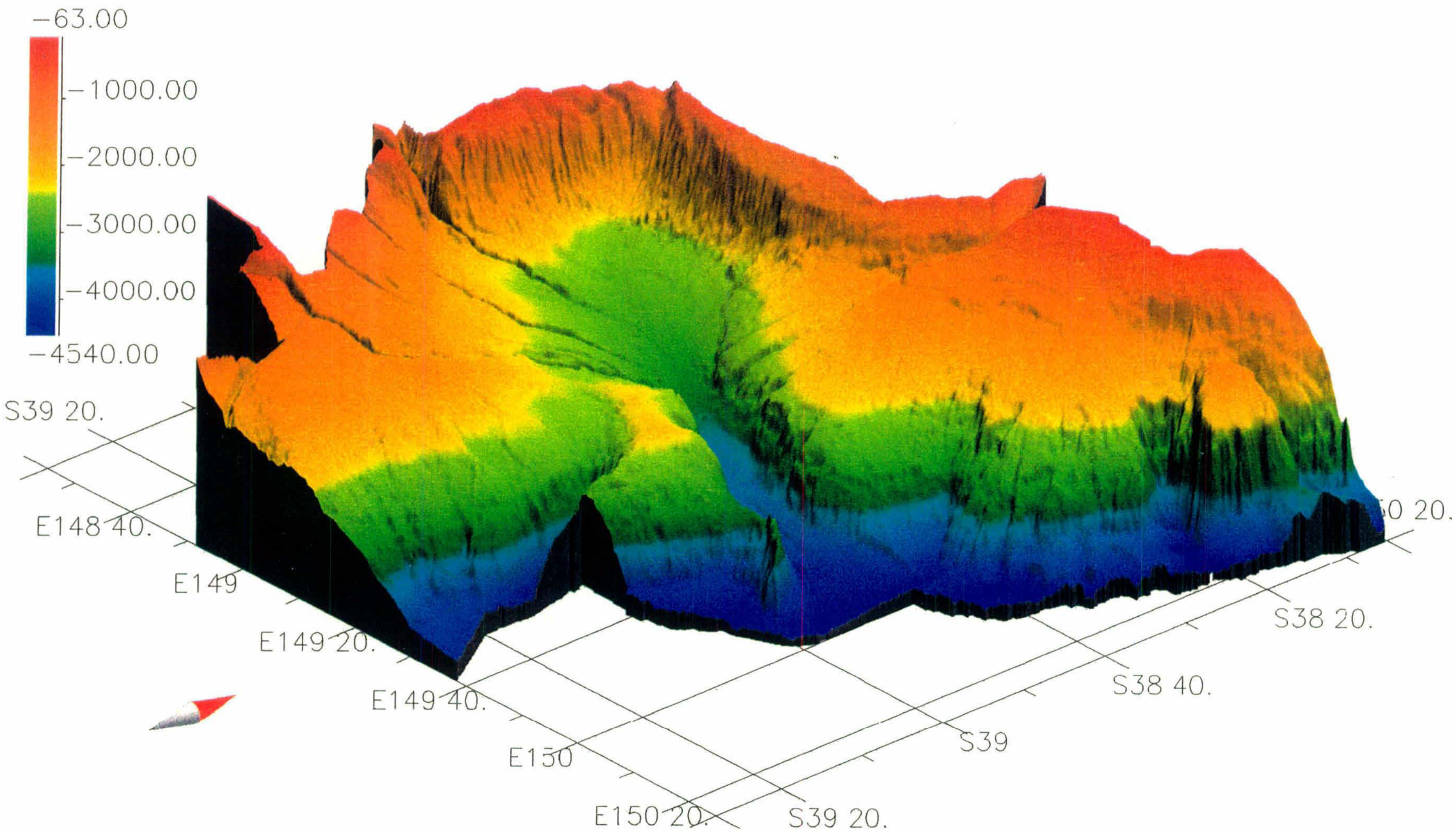


Figure 9. Spectacular seafloor topography and canyon systems of the Bass Canyon Complex off Gippsland - image produced from AUSTREA-1 swath data merged with data from AGSO's 1997 *Sojourn7* survey

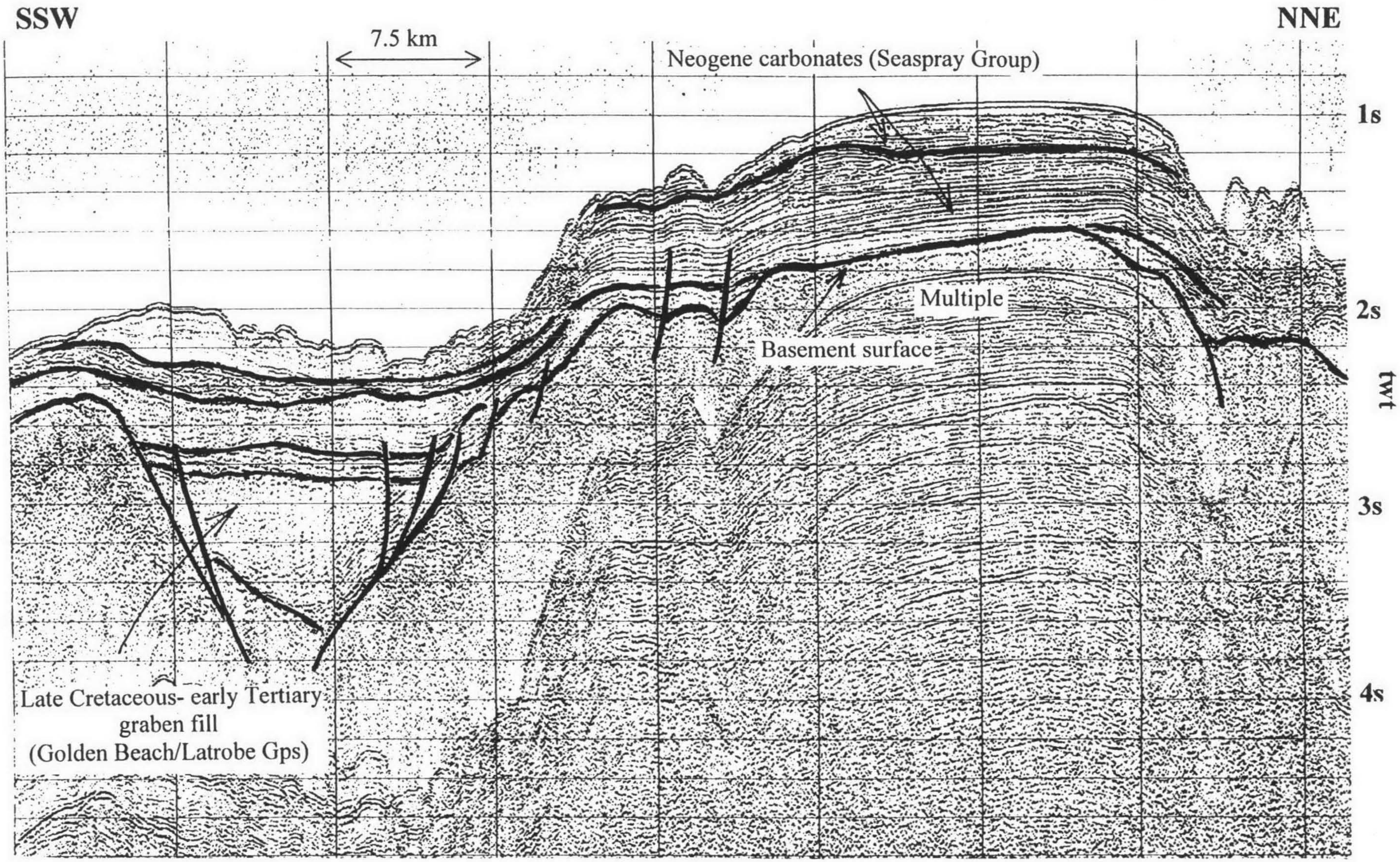


Figure 10. Seismic profile 4 on the Tasman-facing margin north of the Bass Canyon complex - showing Late Cretaceous-early Tertiary graben fill and locally-thick well-stratified Neogene carbonate cover

could also be of rift-related volcanics, but may be a more conventional rift block. Magnetic anomalies, some up to +200-300 nT, recorded along this southern section of the margin may be evidence of rift intrusions or older magnetic basement.

The mapping done in the deep-water Gippsland area is an extension of AGSO's survey by *Melville* in 1997 (Hill *et al.*, 1998; Exon *et al.*, 1999) during which the main Bass Canyon was completely mapped. AUSTREA-1 considerably extended the survey coverage to the north by multiple lines, and added a single swath to the existing coverage in the west and southwest (Figure 9).

In the north, the head of Everard Canyon (Conolly, 1968; known as the 'Big Horseshoe' in the fishing industry) and its course to the south were mapped in detail. This canyon, which runs roughly N-S, is 4 km wide and has cut a sinuous path up to 600 m deep into the Tertiary sediment wedge north of Bass Canyon. Its confluence with the Bass Canyon is farther west than mapped by Conolly (1968). Farther west, the canyon head, known as 'Little Horseshoe', is about 400 m deep. One of the deepest gorges in the Bass Canyon complex is located at the extreme western end of the complex (Figure 9), where 'West Canyon' has cut into the margin of the Tertiary wedge. The gorge here is 1000 m deep and lies at the junction of three deep canyon arms that come from the south/southwest. The outer slope of the Tertiary wedge between this area and the 'Little Horseshoe' to the north is quite steep, ~16°, and as is the case on the far southern NSW margin, the slope is strongly eroded by downslope runnels. The upper continental slope on the southwest of the Bass Canyon complex is cut by several other canyons, 100-400 m deep, including 'Southwest Canyon" and 'South Canyon'. A little farther south is Flinders Canyon (Conolly, 1968), which runs southeast. 'South Canyon' has cut a deep gorge below the shelf edge, and it appears that before this gorge was cut, the upper part of this canyon linked into Flinders Canyon, transporting sediment from the shelf to the southeast rather than to the east/northeast as in the more recent past.

The seismic profiles north of Bass Canyon (Figure 11) show up to 1.0 s twt (~1.0 km) of mainly Neogene section (carbonates of the Seaspray Group), above a further 1.2 s twt of Latrobe Group and older section in places. Total visible section is thus 2.2 s twt, about 2.5 km. The Neogene section is well-stratified but commonly erosionally truncated and cut by canyons, and marked by a strong unconformity at its base. The section shows extensive evidence of cut and fill, indicating that erosion and canyon development was a common occurrence at intervals throughout the Neogene as the carbonate wedge prograded outward. A large magnetic anomaly (~+300 nT) was recorded on the upper slope to the north of the middle of Bass Canyon. The seismic profiles here show a highly disturbed deep section, possibly intruded volcanics of Oligocene-early Miocene age. A large high-standing block, 15 km across and on the mid continental slope at 38° 15'S 150° 11'E, is composed of basement rocks. Its steep, Tasman-facing margin strikes NNE and is line with a prominent scarp farther south off the northern Gippsland margin, in about 3500 m water depth. This structure is likely to be a major normal fault created during Tasman rifting.

Northeast of Flinders Island, Flinders Canyon opens out into a broad embayment, into which a number of smaller canyons also feed. A large WNW-trending graben was mapped in this area by Hill *et al.* (1998), and the AUSTREA-1 seismic profiles confirm its presence. This structure contains at least 1.8 s twt (~2.0 km) of sediments. However, disturbed section in the middle of the graben (where crossed by the AUSTREA-1 lines) and a coincident 250 nT magnetic anomaly indicate volcanics, probably Oligocene-early Miocene, as interpreted north

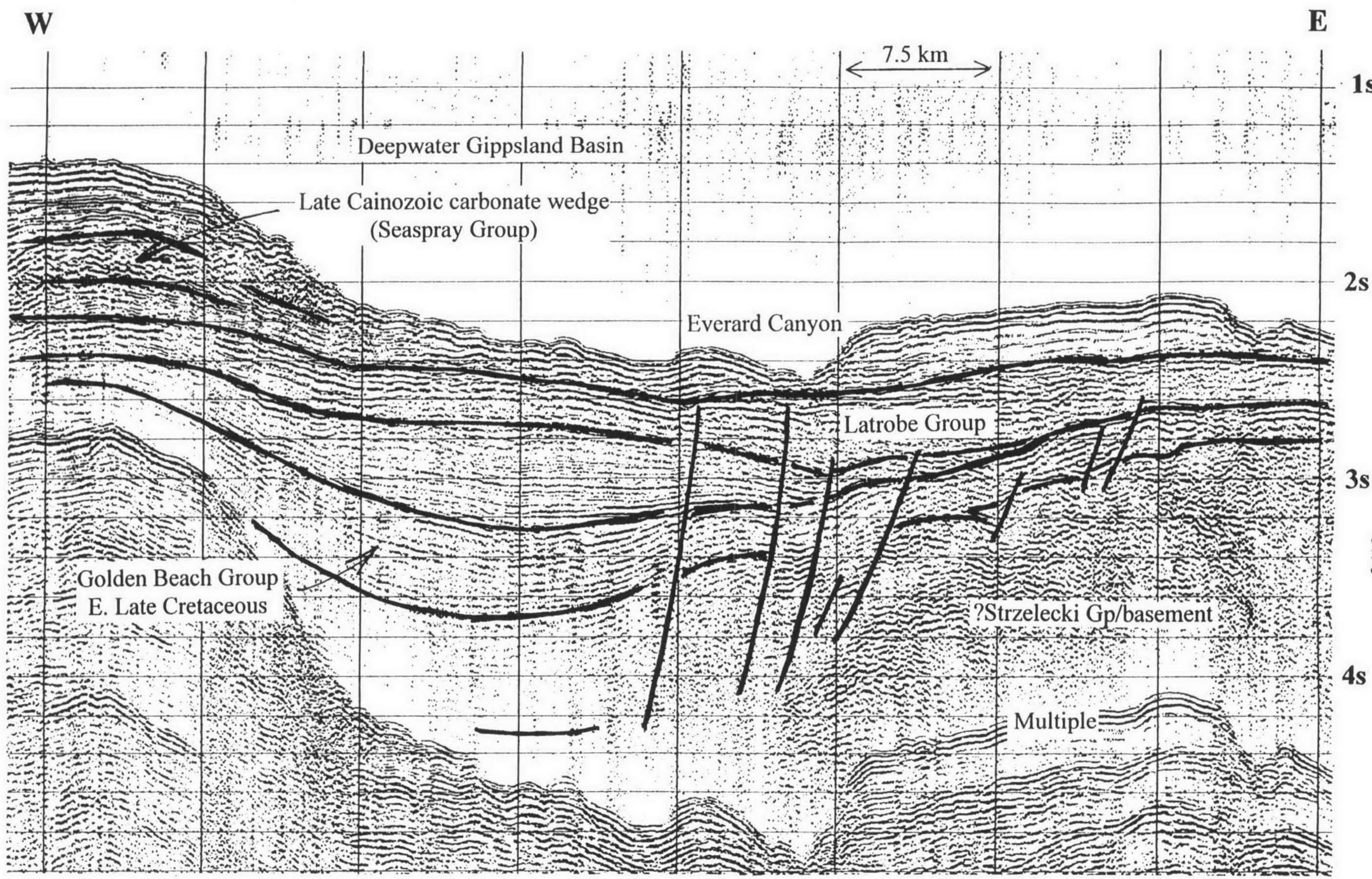


Figure 11. Seismic profile 6 in the deepwater Gippsland Basin just north of Bass Canyon - showing at least 2 s twt of sedimentary section and a late Tertiary prograding carbonate wedge incised by canyons

of Bass Canyon. Sailfish-1 well drilled on the shelf just to the west, bottomed in mid Tertiary volcanics, which may be part of the same suite.

11. SWATH MAPPING RESULTS AND UNDERWAY GEOPHYSICS OF THE NORTHEAST TASMANIAN MARGIN

The northeast Tasmanian margin (from off Flinders Island to off Freycinet Peninsula) is about 36-90 km wide from the shelf edge to the base of the continental slope, which roughly coincides with the 4000 m isobath. The narrowest section of the margin lies opposite Banks Strait, the main passage between the northeast tip of the Tasmanian mainland and Cape Barren Island. Here the mean slope (between the 1000 m and 4000 m isobaths) is 5.8°. The AUSTREA-1 transit line off northeast Tasmania was run on the upper continental slope, between water depths of 600 m to 2000 m, with the main intention of extending the swath coverage achieved during AGSO's 1997 *Melville* survey upslope.

Of special interest was the St Helens Hill and St Patricks orange roughy deepsea fishery (Kloser *et al.*, 1996), swath-mapped in 1997 and further investigated by CSIRO on *Southern Surveyor* in 1999 (Hill, 1999). AUSTREA-1 mapped North Hill, located northeast of St Helens Hill, in detail for the first time. This 300-m high volcanic cone, with its summit 900 m deep, is a significant assembly location for orange roughy aggregations, and hence an important fishing ground. Though no other large cones were mapped, the backscatter imagery suggests further scattered volcanic outcrop (flows etc) in the area of North Hill, including about 12 km to the north. A series of magnetic anomalies, to 200 nT, were recorded. There are also indications of extensive volcanic seabed terrain farther north on the steep, rugged and strongly canyoned continental slope east of Banks Strait, and this is supported by the 1997 swath data collected farther downslope. Canyon development here may have been enhanced by the strong currents that are known to flow through Banks Strait, and this passage may also be a major river drainage outlet during periods of sea-level lowstand.

The seismic profiles off northeast Tasmania show a strongly eroded and canyoned surface sequence which is up to 500 m thick, well-stratified and presumed to be Neogene carbonate progrades. A depocentre off northern Cape Barren Island (Hill *et al.*, 1998) coincides with a northwest-trending ?fault-controlled embayment and canyon 250-m deep, and contains at least 1.5 s twt of section. Off Freycinet Peninsula, where Hill *et al.* (1998) delineated a N-S-trending rift graben, the AUSTREA-1 profile, an axial strike line, indicated at least 1.8 s twt of graben fill (Figure 12). An eroded Neogene sequence 0-400 m thick unconformably overlies a thick deformed sequence that may be Late Cretaceous in age.

12. SWATH MAPPING AND UNDERWAY GEOPHYSICS OF THE SOUTHERN TASMANIAN AND SORELL BASIN MARGINS

The following is an initial interpretation of unmigrated seismic stack profiles produced on board, together with swath-mapping, gravity and magnetics data. The seismic profiles were supplemented by the single-channel monitor display which gave somewhat better resolution at shallow depths. Structure below the first seafloor multiple is obscured on both displays. Locations of noteworthy features are given as times (UT) on particular profiles.

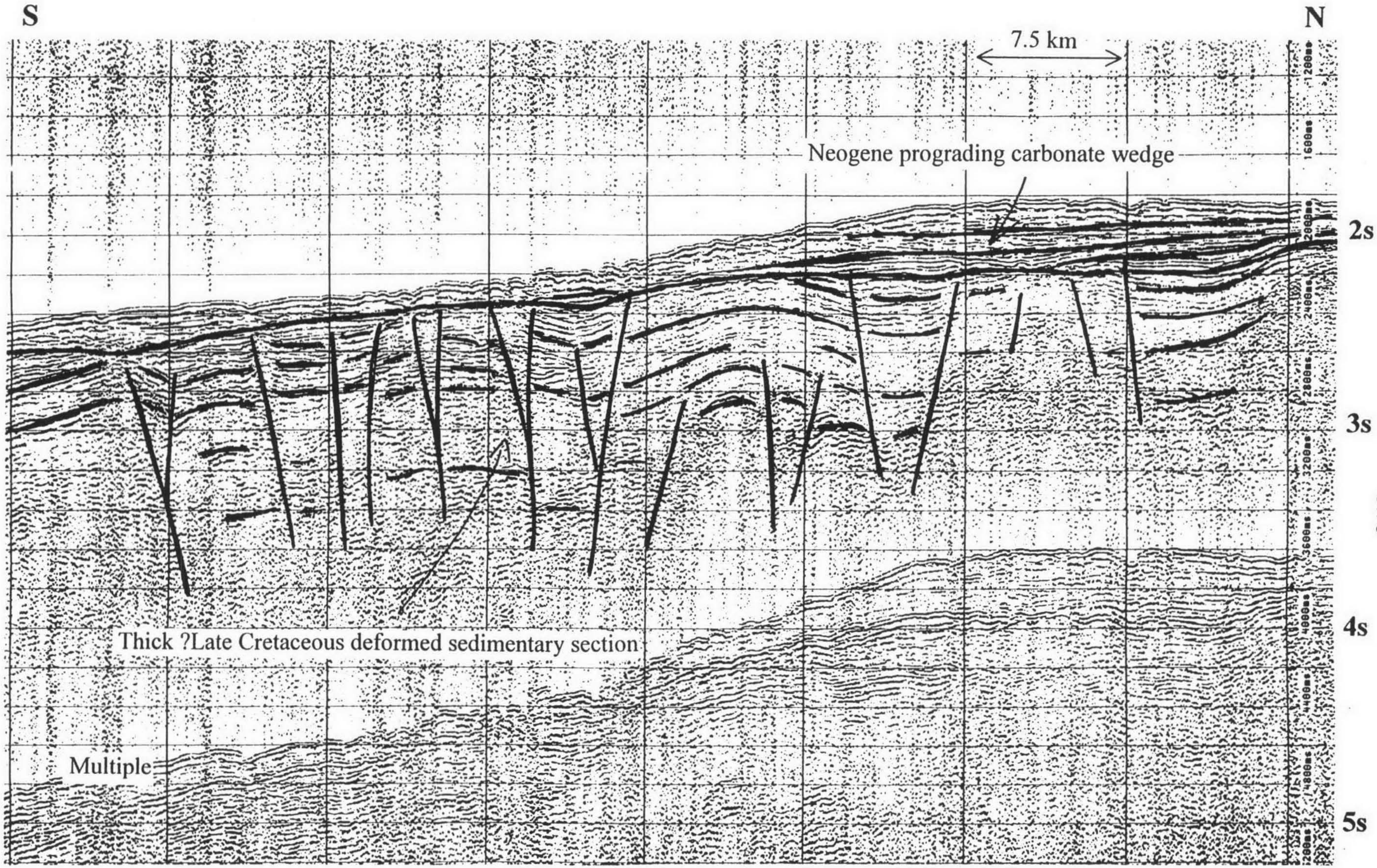


Figure 12. Seismic profile 15 along a graben off Freycinet Peninsula, east Tasmania, showing a thick, deformed ?Late Cretaceous fill with thin Neogene cover

Southeast Tasmanian margin

Along the southeast and southern margins of Tasmania, previous seismic profiling is sparse and there is no well control. This section (southern part of profile 15, profiles 16 and 16b) is characterised by the preservation of thick sedimentary successions (~2 s twt) beneath the mid-slope.The rift basin off Freycinet Peninsula/Schouten Island occupies a mid-slope terrace at 1-2.3 km depth, with a gentle east to southeast gradient. At 0045 UT, a large magnetic anomaly - 400 nT in amplitude - occurs over this basin. Width at half height is 8 km.

Further south, the seismic profile follows the mid-slope (profile 16), and the sedimentary package described above onlaps a topographic and structural high (northern part of profile 16, 0400-0500 UT) which is seismically amorphous or with sparse discontinuous reflectors - this is either basement or an older sediment package. The latter is suggested by the absence of significant positive gravity response.

Profile 16b (Figure 13) consists mainly of a folded and faulted succession, with a flat-lying veneer, 0-0.3 s twt thick, unconformably overlying it. These successions occupy a well-developed terrace at 1300-1500 m depth, with an abrupt northern and eastern edge rising 400 m above the lower slope. The folds, well displayed between 1000 and 1400 UT, are parallel in style and probably tectonic rather than compactional, and have a wavelength (apparent) of ~8 km. Dips on fold limbs are up to about 15 degrees (unmigrated, apparent). The base of this succession is not resolved, but lies at least 1.6 s twt below the sea floor. The flat-lying veneer has been eroded at the present sea floor, and has been removed completely (exposing the flat-lying unconformity surface) between 1205 and 1405 UT. Four steep ?normal faults appear to displace the veneer and its basal unconformity as well as the folded sequence between 0830-1020 UT. At 0940 UT, a 200 nT magnetic spike with a width at half height of 8 km suggests depth to magnetic basement of at least several km.

Correlation of the folded succession in profile 16b (Figure 13) is problematic. Possibilities include the Late Carboniferous to Triassic Tasmania Basin succession (Parmeener Supergroup), lower Palaeozoic Wurawina Supergroup and a Cretaceous-Palaeogene rift succession. The structural style is dissimilar to the first two alternatives, and there is no indication on the magnetic profile of the presence of thick Jurassic dolerite sills which are ubiquitous in the onshore Tasmania Basin succession. A Cretaceous-Palaeogene rift succession is therefore considered most likely.

Southern Tasmanian margin

Two south-trending dip lines of the southern slope were surveyed (profiles 17 and 18), followed by an east-trending line along the slope (profiles 19, 19b). Profiles 17 and 18 traverse a gentle southerly gradient from 1.5 to 3 km water depth, part of a broad terrace on Tasmania's southern margin. Much of seismic profile 19b was not recorded because of equipment failure, and only the single-channel monitor record is available for interpretation. Lines 17, 18 and the western part of 19 show sparse, discontinuous packages of gently dipping reflectors , presumably representing sediments of unknown age, down to at least 2.5 s twt. This is mostly unconformably overlain by a cover sequence with continuous flat-lying reflectors, 0.1-0.3 s thick. The continuity of this succession is interrupted by numerous abrupt topographic highs (volcanic cones), up to several hundred metres high and several km wide at the base. Reflections are obscured beneath the volcanoes, making it difficult to determine the

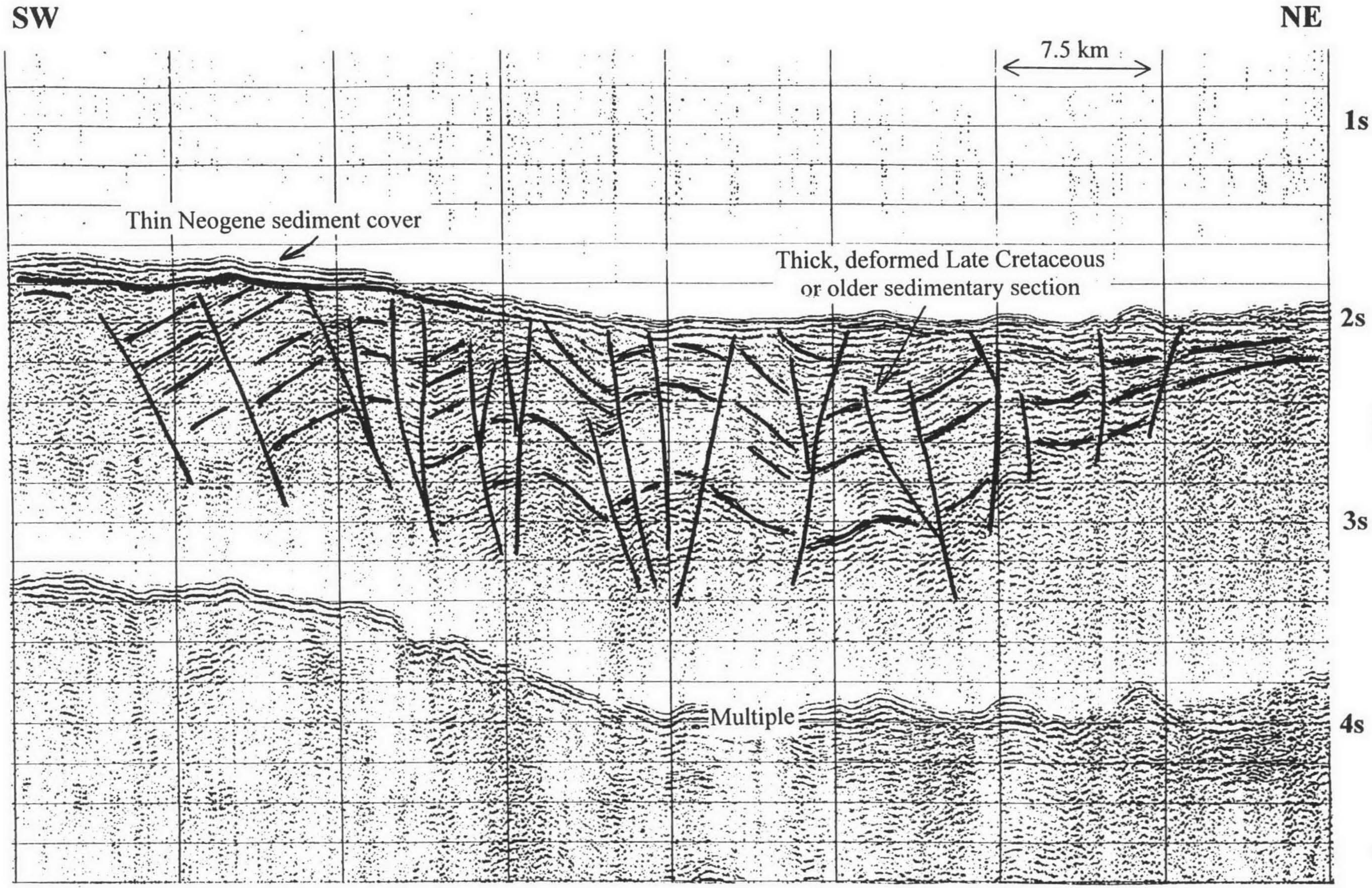


Figure 13. Seismic profile 16b on the upper continental slope south of Hobart showing a strongly faulted and folded Late Cretaceous or older sedimentary section that outcrops on the sea floor or has no more than a veneer of young cover

age relationships of the sediments and volcanics. However, sediments appear ponded on the upslope sides of the volcanoes in many places (eg. profile 17: 1510, 1540 UT; profile 18: 2120 UT; profile 19: 2350-0040 UT), suggesting the upper sediment package is at least in part younger than the volcanoes.

The western part of profile 19 and all of 19b, oriented along the slope in water depths of 500-1000 m, show a flat-lying sedimentary succession up to 0.6 s twt thick, with strong, parallel reflectors on a prominent unconformity. This sequence is eroded at the present seafloor by canyons that almost reach the unconformity in places. Below the unconformity between 0140 and 0315 UT there are less regular, sub-horizontal reflectors and this gravimetrically low and magnetically quiet interval may be a narrow basin. Its extent below 0.6 sec below the unconformity is obscured by the seafloor multiple. Elsewhere the along-slope traverse is magnetically spiky and gravimetrically high, supporting an interpretation of shallow basement. The cover sequence becomes thinner to the west, at least in part because of erosion, and underlying basement is exposed between 0340 and 0353 UT. Basement here is poorly reflective and seismically amorphous.

Only a few of the volcanoes are manifested as magnetic anomalies. The largest response is a 50 nT spike coincident with the volcano at 1523 profile 17. At 0233 seismic profile 19b shows a volcanic plug or buried volcano within the upper sequence, that almost reaches the sea floor. This coincides with a small magnetic anomaly.

West Tasmanian margin

Offshore of western Tasmania, a number of regional seismic lines have been recently interpreted by Hill *et al.* (1997b) and Moore *et al.* (1992). A close seismic grid has been shot in the Strahan Sub-basin by Maxus (1991) and Amoco. Two wells have been drilled in the Sorell Basin. Our profiles 19d, 20 and 21 (to 40°S) lie along this margin. Seismic profile 19d, at the southern end of the traverse, was not recorded due to equipment failure and so interpretation of this line relies only on the single-channel monitor printout.

The surficial sediment package has been removed by erosion at the western end of 19b, and probable basement is exposed at the southern end of profile 19d (0458-0520 UT). A guyot rises ~500 m above the basement surface, to about 450 m below sea level, at 0530 UT. This is relatively large in comparison to the other volcanic cones surveyed, but has little or no magnetic response. Its interior is seismically featureless, similar to the underlying 'basement' (which may likewise consist of volcanics). Immediately north of the guyot, the sedimentary cover reappears, 0.2 s thick, with a mostly strongly reflective basal unconformity and containing strong flat-lying parallel to wavy reflectors. Small canyons have eroded this sequence here and there. At 0640 UT, gravity begins to drop steeply and magnetics becomes quiet, and discontinuous gently north-dipping reflectors below the prominent shallow unconformity probably represent fill of the Port Davey Sub-basin. North of 0730 UT, a thicker package of more coherent reflectors in the Port Davey Sub-basin is at least 1.6 s twt thick (obscured by seafloor multiple below this depth). A shallow prominent reflector (0.3-0.4 s twt below the seafloor) can be picked, probably corresponding to the unconformity in the southern part of 19d and 19b. Where 19d crosses profile 8 of Hill *et al.* (1997b) at 43° 28'S, this surface corresponds to their Oligocene unconformity.

At the northern edge of the Port Davey Sub-basin, the sediments dip southward away from the steep flank of a structural high - possibly in part faulted - coinciding with a sharp northward rise in gravity (1100-1130 UT, profile 20). The basement high between the Port Davey and Strahan Sub-basins is marked by a broad gravity high and a number of strong magnetic anomalies, the largest 400 nT in amplitude and ~2 km wide at half height (1250 UT profile 20). The sequence with the prominent shallow unconformity in the Port Davey Sub-basin continues over this high, where it is up to 0.4 s twt thick with the basal unconformity possibly resting directly on basement. Numerous canyons erode almost to this unconformity. The Strahan Sub-basin on profile 20 is marked by a second large gravity low, quiet magnetics and at least 1.8 s twt of sediment. In the southern part of the sub-basin, traversed in relatively deep water, the shallow unconformity cannot be differentiated, but in the northern part, shot at the top of the slope, there is a strong reflector at 0.6 to 0.7 s twt which probably correlates with the interpreted Oligocene unconformity of Hill *et al.*'s (1997b) profiles 6 and 7 which cross profile 20 in this area. The reflectors within the Oligocene and younger succession are wavy and channelled-looking in this sector (1830-2230 UT). A gravity high and a 100 nT magnetic anomaly at 2100-2245 UT probably reflect a basement high separating the Strahan and Sandy Cape Sub-basins, but this is not seen on seismic because of the shallow water depth and consequent shallow seafloor multiple.

In deeper water north of 2300 UT, at least 2.6 s twt of sediment is evident in the Sandy Cape Sub-basin and contiguous Southern Otway Basin (there is no dividing basement high between these basins on profile 21). The inferred Oligocene to Recent sequence rapidly thins downslope and northward and pinches out at the seafloor at the southern end of the Sandy Cape Sub-basin on this profile (0000 UT). In the Sandy Cape Sub-basin (Figure 14), at least as far north as 40°S (1200 UT), several sequences can be distinguished, and probably correspond to the Cretaceous, Paleocene, Eocene, and largely Neogene packages of Hill *et al.* (1997b) to judge from the tie with their Profile 5. The gently folded and faulted ?Cretaceous succession is generally characterised by less continuous, weaker reflectors than the younger sediments. At 0240-0345 UT, the ?Cretaceous and ?Paleocene are gently draped over a seismically amorphous possible basement high with a strongly reflective top, 1-1.2 s twt below seafloor. Close-spaced (2 km) tensional south-dipping faulting associated with northerly dip of rotated fault blocks is seen in the ?Cretaceous in the single-channel monitor display between 0645 and 0820 UT. An angular unconformity at the base of the ?Paleocene is seen on the single channel printout at 0430 and 0920 UT. The ?Palaeogene succession is mainly 0.2-0.4 s twt thick, and characterised by strong, parallel reflectors. At 0520 UT there is a buried canyon (Figure 14), 0.5 s deep into the top of the ?Cretaceous. The upper, largely Neogene, succession, 0.2-0.4 s twt thick, has a strongly reflective basal unconformity. This succession is eroded by numerous canyons at the present sea floor. Two large canyons (crossed at 0315 and 1245 UT) are flat-floored, having eroded down to the unconformity which is presumably the upper contact of a more resistant ?Eocene unit.

13. SWATH MAPPING AND UNDERWAY GEOPHYSICS OF THE OTWAY AND GREAT AUSTRALIAN BIGHT MARGINS

This account of the swath-mapping results over the marine park located in the Great Australian Bight and also over transects across the Otway Basin is intended as an overview. The magnetic anomalies after 31/12/99 are not described in this report because of a Y2K problem with the 'Caraibes' software which does not enable us to compute magnetic anomalies at present.

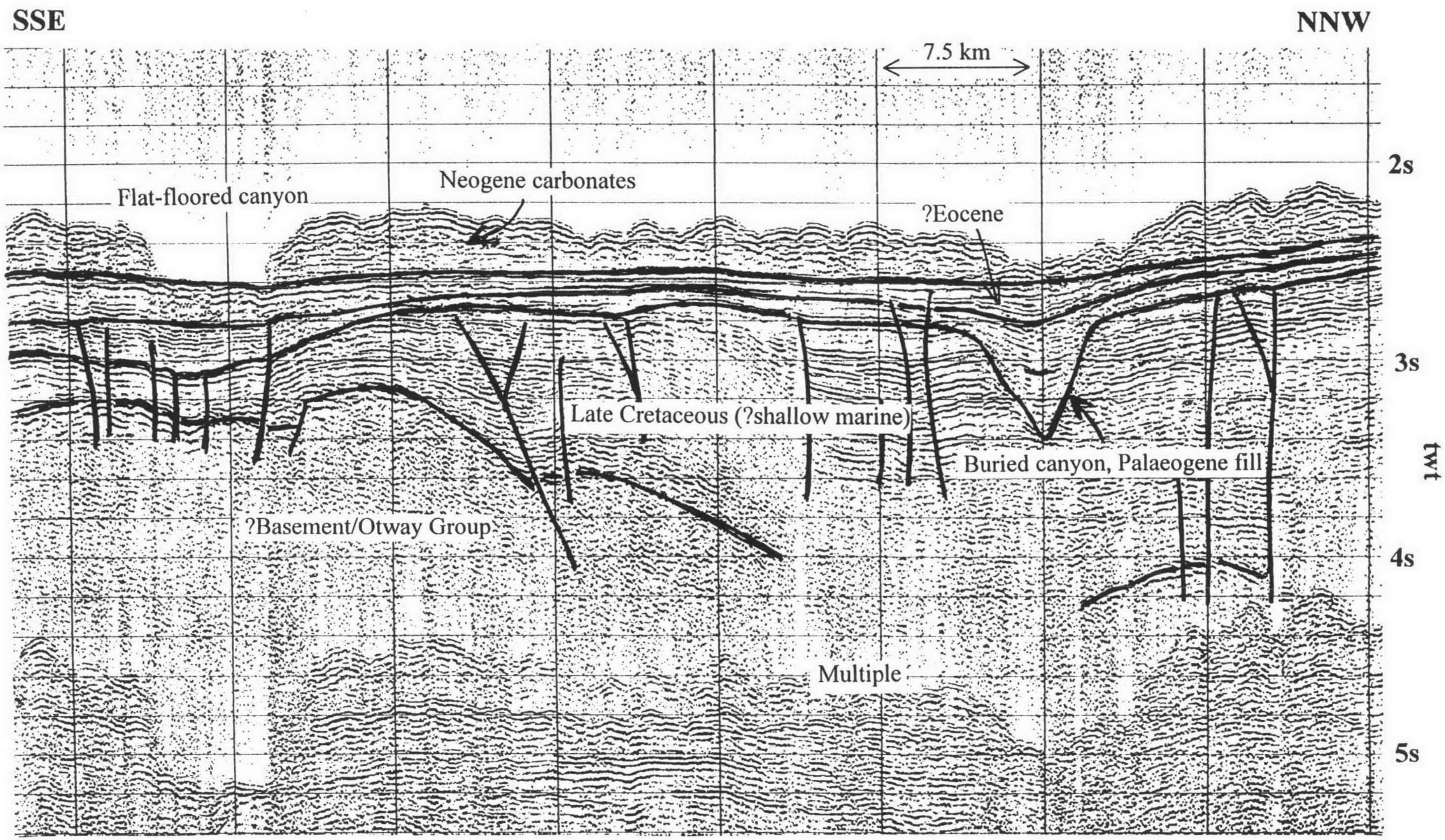


Figure 14. Seismic profile 21 over the Sandy Cape Sub-basin, off northwest Tasmania, showing a thick sedimentary section (at least 2 s twt) with a large buried canyon (Palaeogene fill), and surface canyon development

Great Australian Bight

The survey here focused on the Benthic Protection Area, located in the Bight Basin, and which has been declared part of the National Representative System of Marine Protected Areas (MPAs). The primary goal of these MPAs is to establish and manage substantial, representative examples of marine and estuarine ecosystems as protected areas to ensure their long-term ecological viability, to maintain ecological processes and systems, and to protect biological diversity at all levels. The survey (Figure 15) covered the major part of the marine park (between 130° 20'E - 131°E longitude and 33° 20'S - 36°S latitude) in the Ceduna Basin, south of the Shell Potoroo-1 well. About 16,800 km^2 of swath/geophysical data were recorded in this marine park, except seismic data on the upper margin (between 33° 30'S - 33° 50'S).

Swath-bathymetry and imagery characteristics

The depth contours are shown to trend parallel to the coastline, i.e. roughly WNW. The upper margin is gently sloping toward the ocean from 500 m depth down to the 2800 m isobath, until 390-425 km from the coast. Then the slope becomes steep, down to 4000-4500 m and continues gently down to more than 5000 m the abyssal plain. The most prominent feature on the steep slope is the Nullarbor Canyon, which is 5-6 km wide and incises the biggest slope of the Ceduna Basin from 2000 m down to more than 5000 m depth (Figure 15). The canyon trends 030°-040° down to 35° 15'S of latitude and then trends 010°-020° down to the limit of the marine park. This canyon contains big holes all along the canyon which are 300-500 m deep and 4-5 km in diameter. Such canyon geometry is not common. One of our main interests for following studies will be to better understand the formation of such holes, which are not confined purely to the canyon. A structural element to their formation is suspected, but the question arises as to why they have not been filled.

Four other canyons are present to the southeast of the Nullarbor Canyon. The nearest one, 18.5 km to the southeast, has roughly the same width (5-6 km) and is sub-parallel to the Nullarbor Canyon. The three others are narrower and incise the slope in deeper water, from 2500 m down to more than 5000 m. They have roughly the same NNE-SSW trend. This may suggest that they are tectonically controlled, but they are perpendicular to the slope as they would be if purely controlled by gravity. They are perpendicular to the normal faults observed on previous seismic lines in this region and oblique to the transform NW-SE faults which accommodated the opening between Australia and Antarctica.

A second structural trend intersects the Nullarbor Canyon in its deeper part with an E-W trend at 35°20'S of latitude and that shows progressively a fan-shaped geometry towards the south, until a 135°-145° trend at the marine park border. This second structural trend is formed by small troughs which are composed of elongated holes of 100-200 m deep. The average depth of these features is between 4000-5000m.

The acoustic imagery suggests that the upper smooth slope is mostly covered over by pelagic sediments. Only two very reflective spots are observed at about 34° 43.5'S - 130° 40.5'E and about 34° 46'S - 130° 42'E. These two local highs, which produce fairly high acoustic backscatter, suggest exposed bedrock of two small volcanoes of around 1 km in diameter and 100 m high (in 1700-1800 m of water depth). That these feature are volcanoes is reinforced

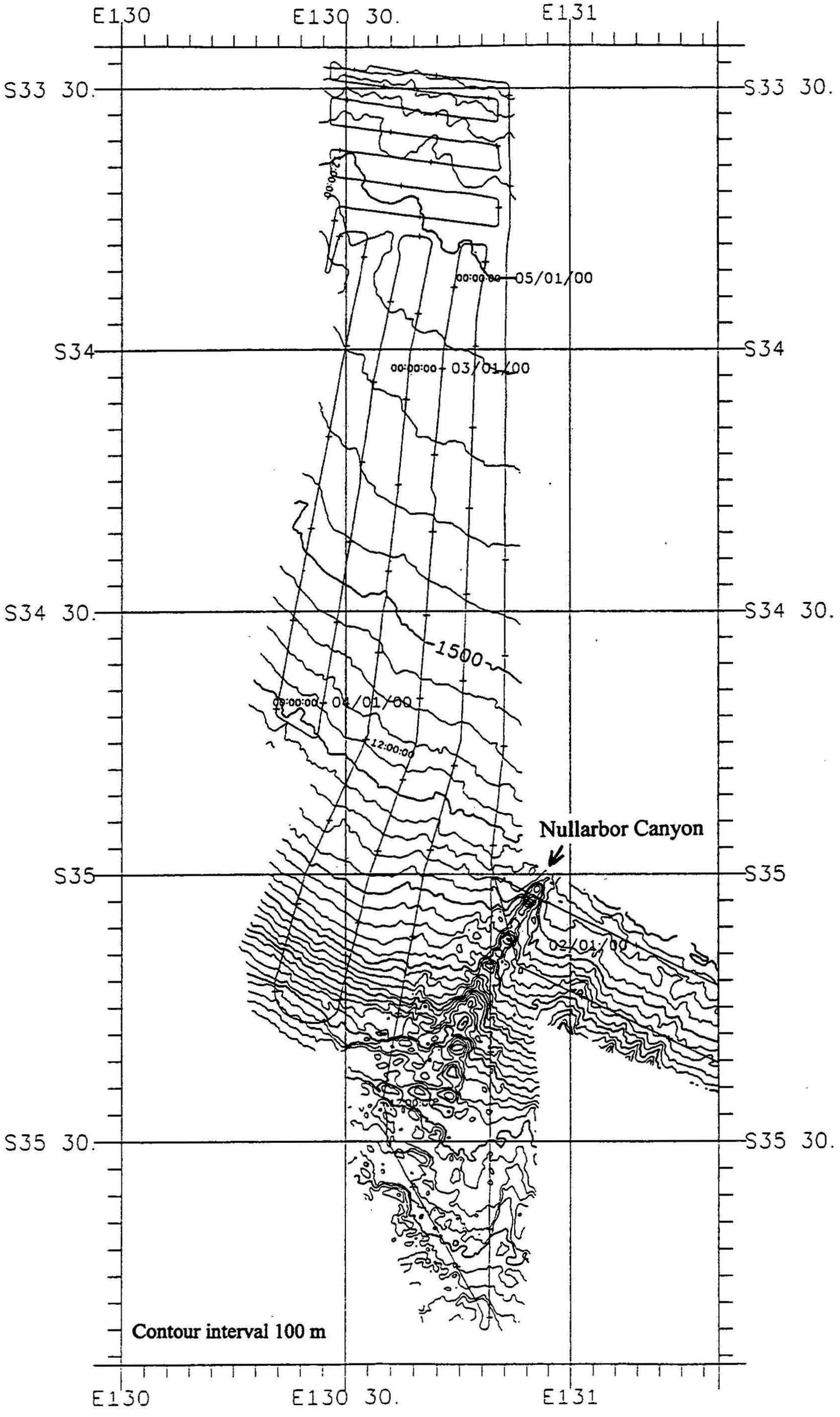


Figure 15 : AUSTREA-1 swath-bathymetry and ship's navigation in the Bight Basin.

by the fact that other volcanoes of similar size have been already observed on the Ceduna Basin in petroleum data.

The lithified sediments are restricted to the lower margin, beyond the so-called hinge line, and particularly in the Nullarbor Canyon. In fact, the strong acoustic backscatter observed in the middle of the canyon suggests that deep-sea currents have scoured the seafloor, perhaps leaving coarse lag deposits or exposed deeper and hardened sediments.

During prior cruises, few samples have been acquired in the marine park and in the Nullarbor Canyon. Two dredge hauls were made in the Nullarbor Canyon, down the slope. They were acquired during the BMR Survey 66 on the R/V *Rig Seismic* in 1986 (Davies *et al.*, 1986) and during the *Rig Seismic* cruise 102 in 1991 (Feary *et al.*, 1991). The first dredge 66DR05 did not touch the bottom and the second one 102DR03 recovered Campanian to Maastrichtian mudstone, claystone to siltstone and Quaternary nannofossil ooze in a water depth of 4180-3660 m. One core (66GC050) was recovered in the marine park area during the BMR Survey 66 on the R/V *Rig Seismic* in 1986 (Davies *et al.*, 1986). This 247cm core recovered pelagic calcareous ooze with several sandy horizons on the central part of the Ceduna Basin, in 1134 m depth (at 34° 02.305'S - 130° 41.483'E).

<u>Reflection seismic and gravity data</u>

In the GAB, particularly in the marine park area, previous seismic surveys include deep and high-resolution data sets (DWGAB 215 and HRGAB 216 surveys; Symonds *et al.*, 1998) which cover the Ceduna Sub-basin and extending into Eyre Sub-basin and Duntroon Basin. Also two deep seismic transects exist across the continental shelf (AGSO Survey 199). Six AUSTREA-1 lines have been recorded perpendicular to the Ceduna Sub-basin in the marine park zone, (AEA022, AEA023, AEA024, AEA025, AEA026, AEA027) down to the abyssal plain. Three main domains trending northwest-southeast are observed (Figure 16; line AEA1023): (1) the Ceduna Terrace on the upper margin, with a smooth slope from 1.5 s twt until 3.8-4 s twt, (2) the abrupt continental slope, from 3.8-4 s twt down to 5.5 s twt except on the line AEA1023 where the slope is steeper and deeper (to 6.5 s twt), (3) the slightly deepening continental rise, from 5.5-6.5 s twt down to 7.3 s twt.

We based our seismic interpretation on the key surfaces used to develop a recent chronostratigraphic and depositional framework in this region which has integrated the sequence stratigraphic interpretation of petroleum exploration wells (Totterdell *et al.*, 2000; Figure 4).

The Ceduna Terrace

The Ceduna Terrace is underlain by a thick sedimentary cover (much more than 2.5 s twt). The acoustic basement is not visible in our data below the strong multiple of the water-bottom reflection which masks the deeper layers. Processing of AUSTREA-1 data (3-fold stacks) which is now in progress, should improve the data quality of the profiles and could reveal structures of the basin more accurately.

Above the multiple, the sedimentary cover is composed by four main sequences. The acoustic facies of these series are as follows. The first one, 0.4 twt (s) thick on the Ceduna Terrace, has conformable bedding with the underlying series and then, down to the upper continental slope, it shows some onlaps on the basal erosional surface. This sequence can be correlated with the cool-water carbonates of the Dugong supersequence (Totterdell *et al.*, 2000), which were deposited in rapidly increasing water depth during the fast spreading episode that commenced in the Late Eocene (Cande & Mutter, 1982). The three other series are well layered and mainly in concordance. Their thickness increases to the south, up to 2 s twt just before the shelf break. It is also at this point that the three series are truncated by the overlying erosional surface and are affected by numerous normal listric faults, the strike of which averages NW-SE. Faulting within the three series increases towards the southeast (especially on profile AEA1023). In the northern parts of the Ceduna Terrace, deposition of these series appears to post-date much of the fault activity, with faulting limited to the selected reactivation of older faults.

Three periods of faulting can be observed in the seismic lines (Figure 16). The first period affected only the deeper layer with numerous small-displacement normal faults trending NW-SE. Then a second stage of faulting, with a strong NW-SE component, divided the basal series into two major blocks tilted toward the continent on the upper continental slope. This event was contemporaneous with the deposition of the overlying series which shows a fan-shaped sedimentary fill geometry between the two major tilted blocks. The third event, with faults trending roughly parallel to the slope, affected the third series and also the uppermost series in local parts of the Ceduna Terrace, between 25 km to 30-35 km from the first tilted block to the north. These fault directions are apparent trends observed in AUSTREA-1 data and need to be cross-correlated with earlier data from this area.

The lowermost series (up to 1 s twt thick) has a strongly progradational seismic character with onlaps observed on the underlying surface, around 4.8 s twt, just to the north of the two major tilted blocks (profile AEA1023 (Figure 16), between 1545-1600 UT, 2/01/00). The top of this series shows a chaotic acoustic facies, particularly in the middle of the Ceduna Terrace. This seismic character can be correlated with the base of another sequence boundary which is very thin (less than 0.2 s twt) in the middle of the Ceduna Terrace and becomes thicker to the south, up to 0.5 s twt. The boundary between the second and third unit is characterised by an angular unconformity. The third series lies on the underlying series with onlaps in the middle of the Ceduna Terrace and with downlaps just north of the first tilted block. This third series seems to have a constant thickness of 0.4-0.6 s twt from north to south in the Ceduna Terrace and then gets thinner at the top of the second tilted block to the south where the series tapers away to zero thickness.

These three last series can be correlated with the three third-order sequence boundaries identified in the Hammerhead supersequence. In Potoroo 1, the supersequence consists almost entirely of a succession of blocky sandstone units. The lowermost series can be correlated with the first third-order of Hammerhead supersequence which marks the influx of deltaic sediments into the basin. The base of the second series can be associated with the second sequence of the Hammerhead supersequence which records a drop in relative sea level below the previous shelf edge (defined by the edge of the downlaps observed at the base of the first third-order Hammerhead sequence). The third series can be correlated with the third sequence of Hammerhead supersequence which shows aggradational to progradational succession, in places like the Duntroon Basin (Totterdell *et al.*, 2000).

On the profile AEA1024 (Figure 17), between 0420-0430 UT (3/01/00), we observe a chaotic acoustic facies which cross-cuts these three series over a distance of 2.5 km. This particular acoustic facies is located just on the Ceduna Terrace, on the west side of one of the dark little circles (interpreted as volcanoes) observed on the imagery. We interpret this kind of acoustic

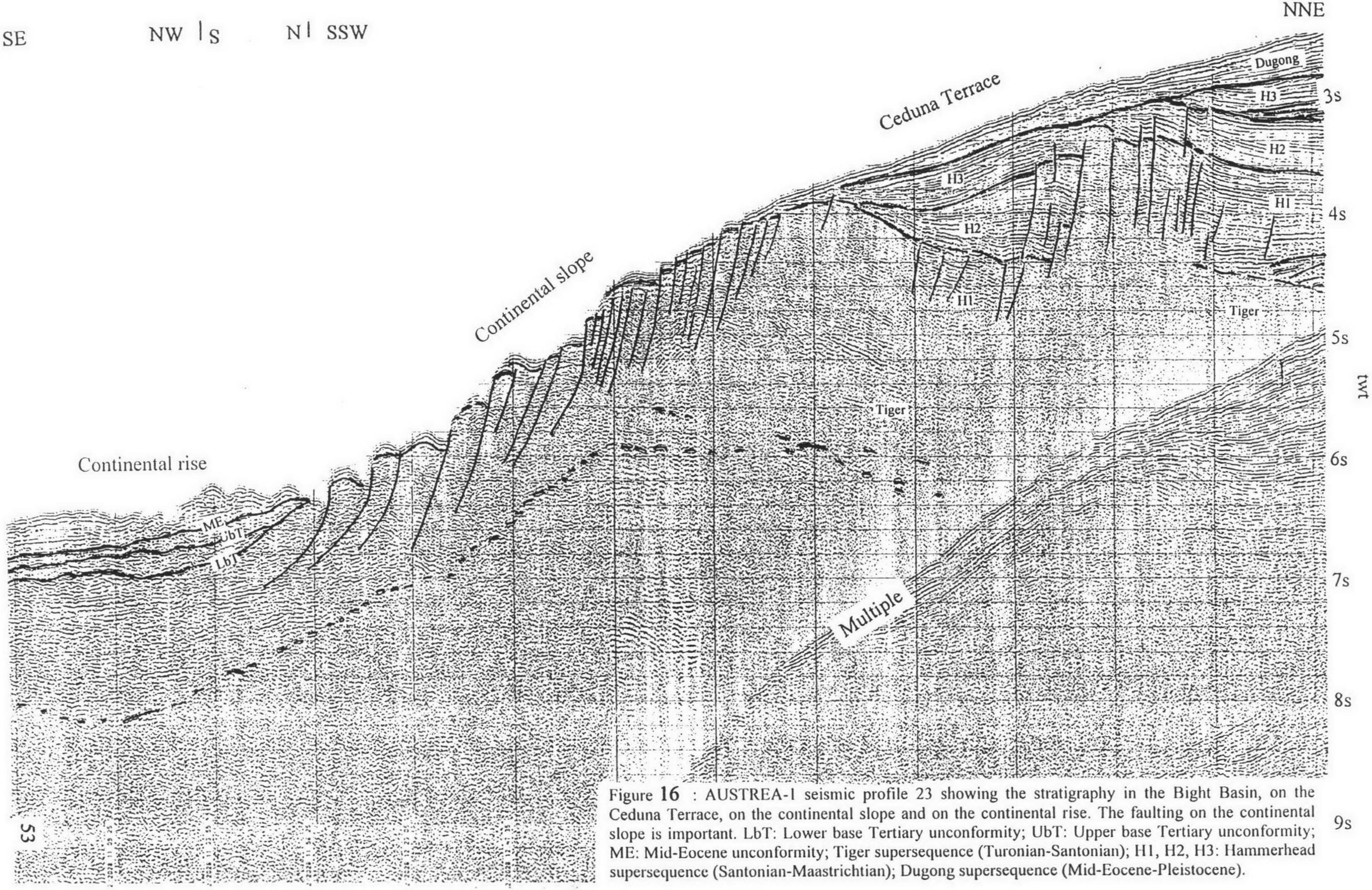


Figure 16 : AUSTREA-1 seismic profile 23 showing the stratigraphy in the Bight Basin, on the Ceduna Terrace, on the continental slope and on the continental rise. The faulting on the continental slope is important. LbT: Lower base Tertiary unconformity; UbT: Upper base Tertiary unconformity; ME: Mid-Eocene unconformity; Tiger supersequence (Turonian-Santonian); H1, H2, H3: Hammerhead supersequence (Santonian-Maastrichtian); Dugong supersequence (Mid-Eocene-Pleistocene).

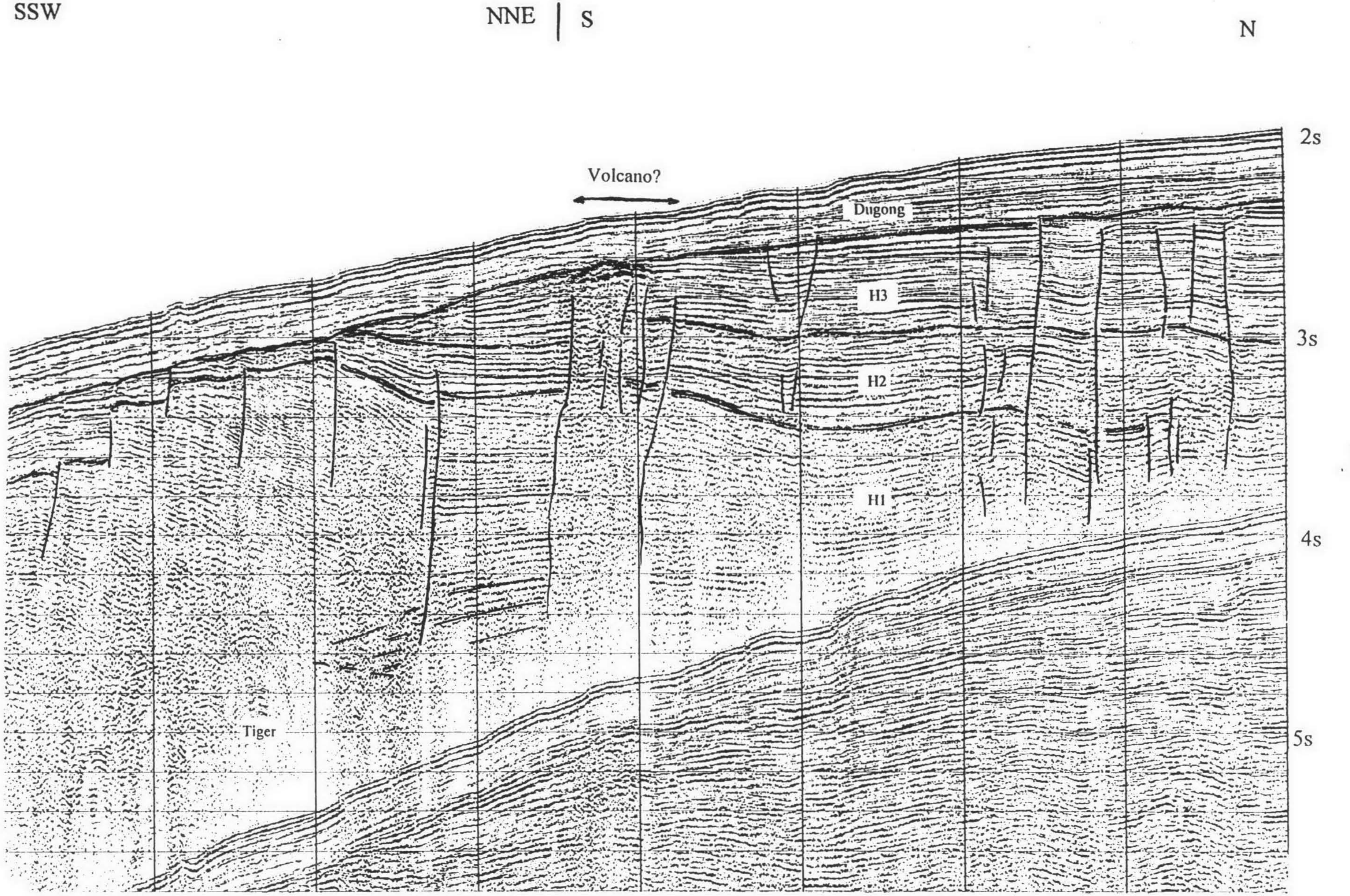


Figure 17 : AUSTREA-1 seismic profile 24 showing the particular seismic facies interpreted as volcanism associated with faulting. The top of this volcanic facies corresponds to the Cretaceous-Tertiary unconformity.

facies as igneous sills or dykes, as has been interpreted on other seismic lines in the Ceduna Basin (Totterdell *et al.*, 2000). This volcanism does not go through the uppermost series interpreted as the Dugong supersequence (Mid-Eocene to Pleistocene). This observation is consistent with the hypothesis of Totterdell *et al.* (2000) which suggests that this volcanism has developed on the Cretaceous-Tertiary unconformity.

The Ceduna Terrace corresponds to a broad -40 mGal gravity anomaly over a distance of around 70 km. The gradient of the sea bed is low in this area so the negative gravity anomaly reflects the major depocentre of the basin.

The continental slope

The continental slope is WNW-ESE trending and dips around 4° over a distance between 20-30 km. The faulting increases towards the south-east, and is particularly important on the line AEA1023 (Figure 16) where the fault throws are between 0.1-0.2 s twt, cutting the slope into little steps. It is difficult to correlate faults from one profile to another.

The slope is covered by a veneer of less than 0.1 s twt of the uppermost series observed in the Ceduna Terrace and attributed to the Dugong supersequence (Mid-Eocene to Pleistocene). In some places this veneer seems not to exist. It may not have been deposited, or may have been eroded, particularly on profile AEA1022 where the slope is steeper (around 16°). The underlying sequence is strongly tilted towards the continent by numerous normal faults. It is hard to distinguish other series at depth because of the strong tectonic movements. This underlying sequence is not correlated with the two last third-order sequences of the Hammerhead supersequence. It can be attributed either to the lower third-order sequence of the Hammerhead or to the Tiger supersequence (Turonian-Santonian).

The foot of the continental slope corresponds to a broad -75/-80 mGal gravity anomaly over a distance of 22 km. The water depth varies abruptly at the foot of the continental slope so the gravity low can be correlated locally with the water depth.

The continental rise

The continental rise is observed only on profiles AEA1022 and AEA1023 because the other lines are limited to the upper slope and to the Ceduna Terrace.

On the continental rise, down to 9 s twt, we observe four different sedimentary series which are from bottom to the top (Figure 16): (1) a layered and folded series of 1-1.5 s (twt) thick which is truncated at the top by an erosional surface, (2) a thin layer (less than 0.2 s twt) with a chaotic facies, (3) a layered series (0.2-0.3 s twt thick) dipping towards the ocean and (4) a last layered series at the top of around 0.3 s twt dipping towards the ocean and eroded at the surface and maybe affected by little normal faults.

The lowermost series is difficult to correlate with the sequences observed on the Ceduna Terrace because of the numerous faults which affect the continental slope. The second chaotic layer appears to be lenticular at the foot of the continental slope, and has a pillow shape on profile AEA1023. The basal sequence boundary is an erosional surface and forms an angular unconformity with the underlying sequence. This unconformity can be interpreted as the Cretaceous-Tertiary unconformity. The overlying chaotic facies can be attributed to the base of Tertiary. Above, the third layer comes up to the surface, at the foot of the continental slope, before to be covered by later sediments on the continental rise. This third layer crops out over a particularly long distance (around 17 km) on line AEA1022 (or may have been overlain by a veneer, less than 0.05 s twt, of recent sediments). This third layer can be interpreted as the base of the Eocene. The uppermost series can be of mid-Eocene-Oligocene age, showing the prolongation of the Dugong supersequence down to the continental rise from the Ceduna Terrace.

Transit between the GAB and the Otway Basin

During the transit between the marine park in the GAB and the Otway Basin, no seismic data were recorded. The swath-bathymetry mapped a band 30-31 km wide on the continental slope parallel to the margin, between 2000 m and 3500 m deep.

The main features observed all along the continental slope are numerous submarine canyons, commonly 500 m deep. Some of these canyons were described by Sprigg (1947), von der Borch (1968) and von der Borch *et al.* (1970) and some have been named. The AUSTREA-1 data provide more detail of the canyon features and particularly from longitude 135° E to 138° E on the 'Murray Group' canyons. In fact, the canyons east of the marine park in the GAB become more numerous and deeper (down to 1000-1500 m deep) with a NE-SW trend in the Duntroon Basin and then in the west part of the Otway Basin, in the Beachport Sub-basin. They frequently join in deep water around 2500-3000 m depth.

The boundary between the Ceduna Basin and the Duntroon Basin is emphasized by a narrow (2.5 km large) N-S canyon which incises the slope from 2500 m down to the abyssal plain forming holes 300 m deep. These features are comparable to those observed in the Nullarbor Canyon and may be controlled be the tectonic inheritance. To the southeast of the Duntroon Basin, south of Kangaroo Island and offshore from the mouth of the Murray River, several canyons incise the slope and particularly the Murray Canyon which shows a steep cliff at the foot of the continental shelf.

Otway Basin

In the Otway Basin, seismic data were recorded from 136° 50'E, along the entire length of the basin to the northwest Tasmanian margin, on both survey lines to and from the GAB. Swath-bathymetry and backscatter data, gravity and magnetics profiles were recorded at the same time along a band about 20 km wide on the continental slope and also on a larger area (about 40 km wide) over the 'Murray Group' canyons, between 136°E and 138°E.

Swath-bathymetry and imagery characteristics

The northwestern boundary of the Otway Basin is a steep continental slope. This slope is dissected by a series of submarine canyons (von der Borch, 1968; von der Borch *et al.*, 1970). Du Coédic, Murray and Sprigg Canyons are particularly large features, each with relief in excess of 1500 m. The general trend is NE-SW, but each canyon shows particular features.

The Du Coédic Canyon (between 136°E-136° 30'E) has a main axis trending 070°-080°. It is bounded to the southeast by an escarpment 3000-4700 m deep, parallel to the main axis. The northern border is formed by a steep slope from 2000 m down to 4500 m which is incised by numerous NE-SW trending narrow canyons, each about 1 km wide. They are all connected to the main large (7.5 km wide) 070°-080° canyon. To the east, before the Murray Canyon, a small canyon exists with a general NE-SW trend. It is 8 km large and incises the slope, from 2500 m down to 4000 m water depth.

The Murray Canyon (between 136° 50'E-137° 10'E) is composed by two main tributaries generally trending NE-SW with a prominent N-S trend on the lower slope, around 37°S of latitude. The two tributaries are 8-10 km wide and incise the slope from 2500 down to 4800 m deep. The Murray Canyon is bounded to the west by the Beachport Sub-basin with a N-S trend. This sub-basin forms a plateau between 500-1500 m deep. It is bounded to the south by a NW-SE escarpment from 1500 m down to 2500 m deep. To the eastern border of the plateau is bounded by the Sprigg Canyon. The Sprigg Canyon (between 137°40'E-137°50'E) is mainly N-S trending and exhibits a distinct 90° bend in its upper reaches. This canyon is 5 km wide and incises the slope from 2500 m down to 4500 m deep. It limits the western border of the Morum Sub-basin. AUSTREA-1 data confirm Seabeam imaging data already acquired in the Sprigg canyon (Von der Borch *et al.*, 1993) and show that this canyon is floored by relatively reflective material indicating a degree of surface roughness of the canyon-floor units. This observation suggests that the back-scattering material represent canyon-floor sediments. It is uncertain whether or not these three main canyons are currently active sediment conduits. Two trends are particularly present in these three main canyons, 070°-080° and N-S, suggesting some form of tectonic control. These features seem to have recorded, respectively, the first stage of spreading between Australia and Antarctica and the accommodation movement during this event. The fact that latter features have not been obliterated by pelagic sedimentation suggests either that faulting may still be active along the complex northwestern margin of the Otway Basin or that sedimentation rates in the region are abnormally low.

To the east, AUSTREA-1 data recorded swath-bathymetry between 1000 m down to 2000 m deep, crossing three sub-basins from west to east. These sub-basins have been described recently by Moore *et al.* (2000): the Morum Sub-basin (between 137° 50'E and 140° 30'E), then the Discovery Bay High (between 140° 30'E and 141° 20'E), and the Nelson Sub-basin (between 141° 20'E and around 144°E). Five canyons occur on the Morum Sub-basin and trend roughly NE-SW. They are between 3 km and 13 km wide and between 300-900 m deep. The third canyon to the east (between 139° 10'E and 139° 25'E) is located on the prolongation of the George V Fracture Zone. This fracture zone has been identified more to the south and is commonly interpreted as a main transform fault in the Antarctic-Australian Basin. The Discovery Bay High is characterised by six narrow (5 km wide) canyons close together, generally N-S trending and around 1000 m deep. Then the canyons on the Nelson Sub-basin located at wide intervals, 300 m deep on average, progressively change trends from 020° to 060°-070°.

Reflection seismic, magnetics and gravity data

In the Otway Basin hydrocarbon exploration has historically been concentrated onshore and in the nearshore parts of the basin. The main depocentre lies beneath the continental slope. All exploration wells are located onshore or on the continental shelf, and deep-water sampling is limited to a number of dredges and seabed cores recovered from outcrops on the continental slope and rise (Exon, Williamson *et al.*, 1987; Exon *et al.*, 1992; Heggie *et al.*, 1988). In 1994-95, AGSO acquired a deep-seismic data set in the basin (Survey 137; Blevin *et al.*, 1995), from the continental shelf out to oceanic crust, in waters from offshore South Australia to offshore Tasmania. These data provide the first complete transects of the offshore Otway

Basin and image the structure down to sub-Moho depths beneath the continental slope (Moore *et al.*, 2000).

The AUSTREA-1 profiles AEA1021, AEA1028 and AEA1029 cross the basin parallel to the margin and image consecutively the four major domains of the basin, which are from west to east, the Beachport Sub-basin, the Morum Sub-basin, the Discovery Bay High and the Nelson Sub-basin.

The Beachport Sub-basin, between the Murray and the Sprigg Canyons, has an acoustic facies composed of small discontinuous reflectors without any dominant orientation, covered by a veneer (not more than 0.2 s twt) of layered sub-horizontal series (Figure 18). The deepest facies shows a strong contrast, with the western facies, composed of a thick (more than 1 s twt) layered series localised in the Murray Canyon. On the basis of seismic character correlations with the Otway Basin, it is likely that the section largely comprises Otway and Shipwreck/Sherbrook Group equivalents, while the overlying veneer consists of Cainozoic sediments.

This Beachport Sub-basin is correlated with a positive magnetic anomaly of 200 nT and a positive gravity anomaly of 90 mGal. These anomalies suggest either volcanic intrusion along the fault planes or a deep magnetic source emplaced during the first stage of spreading. In the second hypothesis, the nature of the magnetic source could be either magmatism or serpentinite, as has been suggested recently in the GAB, at the continental-ocean boundary (Sayers *et al.*, in prep.).

The first canyon east of the Sprigg Canyon seems to be the location of a tectonic deformation ((Figure 19); lines AEA1021 around 1620 UT and AEA1029 around 1345 UT). In fact, the acoustic facies on both side of the canyon are different and they are separated by an angular unconformity dipping slightly to the SE (apparent dip of 5° using an acoustic velocity of 2.3 km/s for the Tertiary series (Finlayson *et al.*, 1997)). On the west side, we observe a layered series strongly deformed by numerous faults which is overlain by a thin series (no more than 0.3 s twt) deposited on an erosional surface. In contrast, on the east flank of the canyon, the sedimentary series is layered, folded sub-horizontally and is deposited on an erosional surface. The deeper series is strongly deformed by faulting. To the east, this underlying series becomes progressively tilted to the NW, parallel to the margin. In different wells, drilled on the northern flank of the Morum Sub-basin, this deep series has been identified as Cretaceous Shipwreck and Sherbrook Group sediments. The Cretaceous section has been strongly eroded beneath the continental slope in the latest Cretaceous, and overlying Cainozoic sediments comprise a veneer no more than 2 s twt above the Eocene unconformity.

The eastern side of the canyon is the site of a broad 15 mGal gravity low which is well correlated with a thick Tertiary sedimentary deposit, up to 1.4 s twt, which seems to have accommodated a normal faulting dipping to the SE, at the base of the Tertiary. On line AEA1021 (between 1245 UT and 1440 UT, 31/12/99) a broad 60 nT magnetics high is correlated with a particular less reflective seismic facies through the deeper series (Late Cretaceous) and stops at the erosional surface (Eocene unconformity). It is likely that these low reflectors beneath a strong and chaotic reflector at the top are due to volcanic intrusion along the fault planes.

It is possible that the faults may have been reactivated recently as is suggested by five recent faults observed around the prolongation of the George V Fracture Zone. They are affecting all

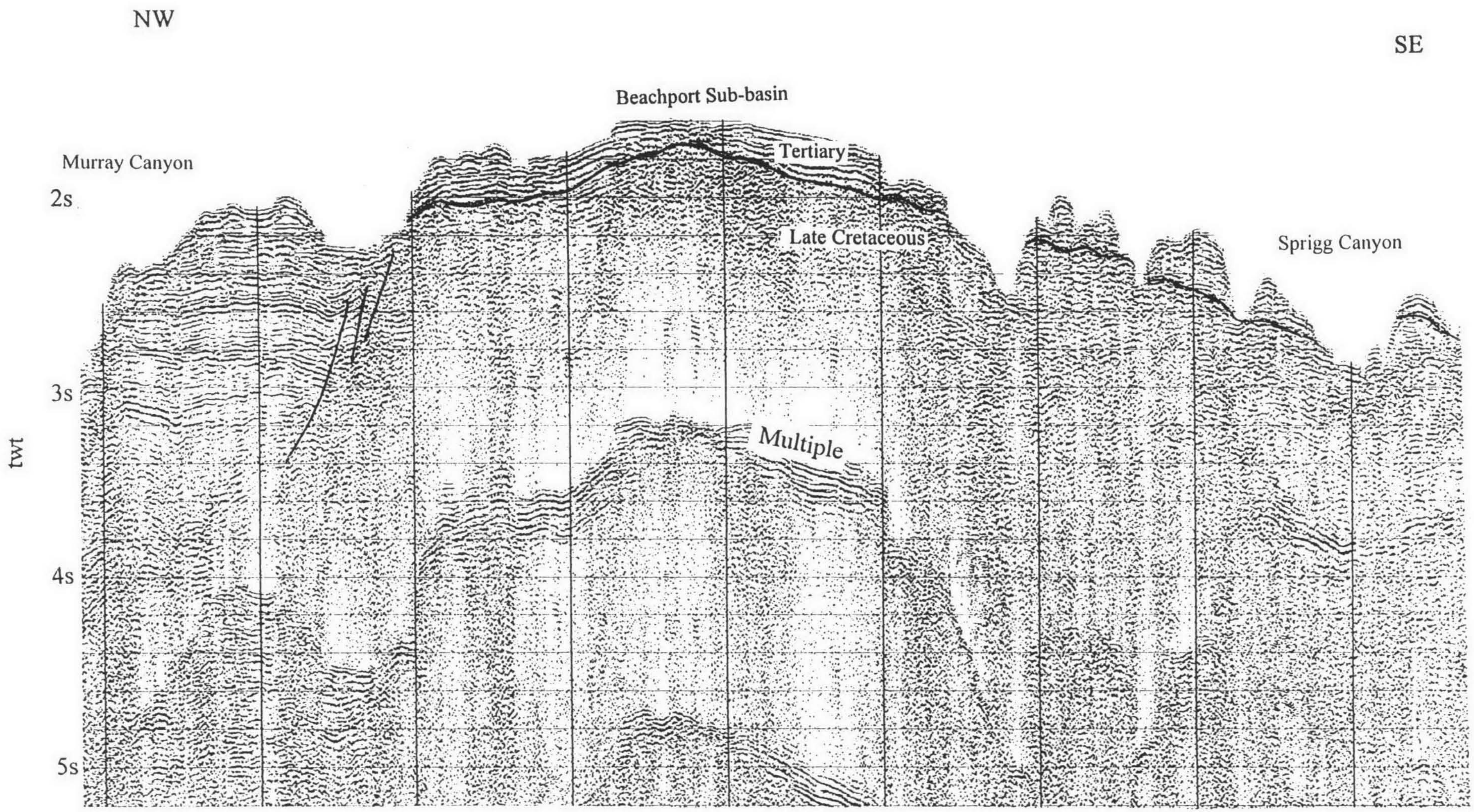


Figure 18 : AUSTREA -1 seismic profile 21 showing the acoustic facies of the Beachport Sub-basin bounded to the NW by the Murray Canyon and to the SE by the Sprigg Canyon. We observe a strong reflector below the Sprigg Canyon down to 3.8 s (twt).

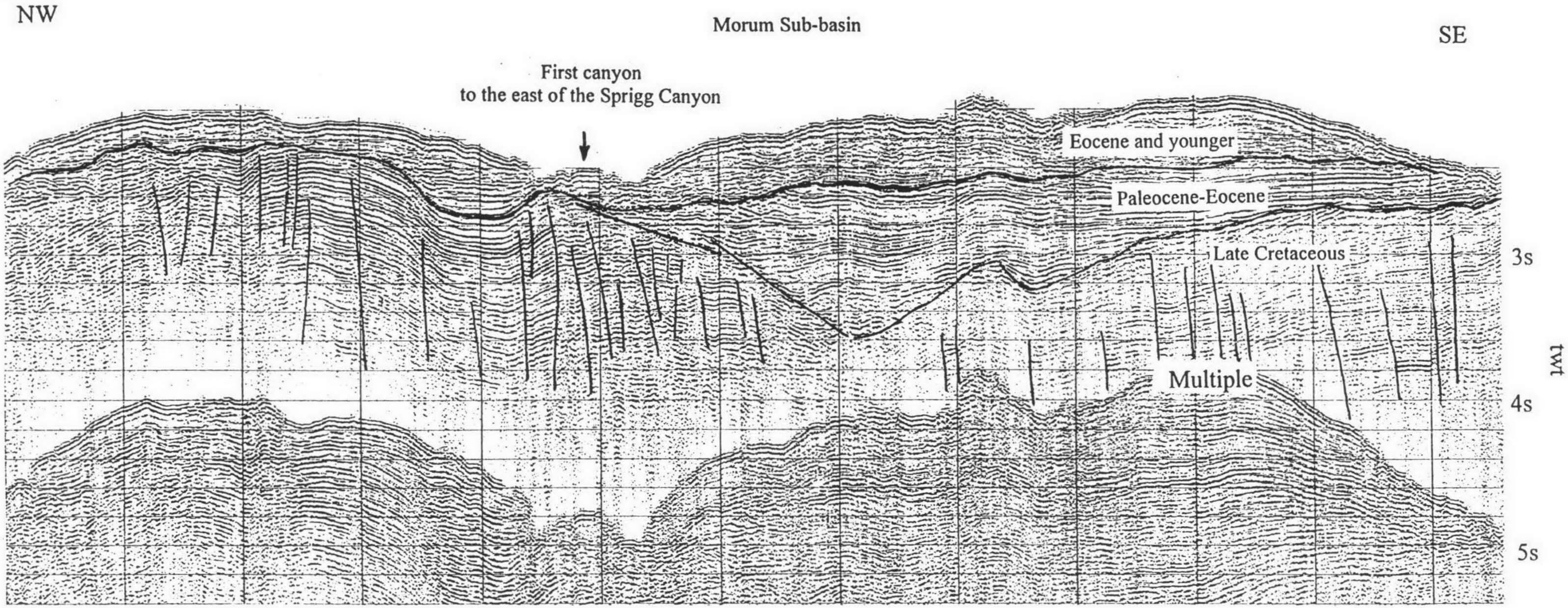


Figure 19 : AUSTREA -1 seismic profile 29 showing the first canyon east of the Sprigg Canyon which is the location of a strong tectonic deformation.

the series from the surface, through the Tertiary and down to the upper Cretaceous. Their fault throws increase towards the south (on the line AEA1029 (Figure 20), more than 100 ms twt or around 100 m in depth, taking 2.1 km/s for the acoustic velocity of the upper Tertiary). The latest stage of faulting has been described also in the Sorell Basin (Hill *et al.*, 1997b) and in the South Tasman Rise (Exon *et al.*, 1997). This suggests that the faulting in the south may have lasted into the early Tertiary. Steep-sided canyons that deeply incise the Cretaceous section show that the slope is undergoing active erosion.

Continuing to the east, the Morum and Nelson Sub-basins are separated by the Discovery Bay High. The seismic data suggest that the deeper series which can be correlated with the Shipwreck/Sherbrook Group sections is relatively uniform in thickness (more than 2 s twt) folded sub-horizontally and less intensely faulted than to the northwest and southeast. The Tertiary sediments are thin (less than 0.2 s twt) to absent. The eastern flank of the high is intensively affected by canyon incisions, down to 1-1.2 s twt deep. The canyons are guided by faulting with small fault throws, perpendicular to the margin.

The Nelson Sub-basin does not have a structural boundary between the major depocentre of the southeastern Otway Basin and the Sorell Basin to the south. Above the multiple the Nelson Sub-basin is composed of two distinct sedimentary facies. The upper series is formed by layered and strong reflectors and is not more than 0.8 s twt thick. It is deposited on an erosional surface affected by deep valley incisions down to 0.4 s twt deep. The underlying series is less reflective and is highly folded over a thickness of more than 2 s twt. The upper series can be interpreted as Tertiary sediments, while the underlying series can be interpreted as Late Cretaceous section. The structural style and the acoustic character of sedimentary fill are different to that of the Morum Sub-basin to the northwest. The deepest series starts to be strongly deformed in horst and graben from 142° 30'E to the western Tasmanian margin, with a trend sub-perpendicular to the margin.

Along the ship's track, the continental slope of the Otway Basin is marked by quiet magnetics (except in the Beachport and a part of the Morum Sub-basins) and gravity anomalies which mimic the topography of the sea bottom (except in the Beachport and a part of the Morum Sub-basins). The free air gravity anomalies show mainly the influence of the topography and not so much the effect of deeper crustal layers.

14. SEAFLOOR CHARACTER FROM 3.5 KHZ PROFILES AND ACOUSTIC IMAGERY

The following is a summary of seafloor character determined using 3.5 kHz profiles and swath acoustic imagery. The data were split into a number of regions to simplify the data interpretation. The regions discussed are: (i) Noumea to Sydney, (ii) southern coast of NSW, (iii) Gippsland Basin and the eastern coast of Tasmania, (iv) southern and western Tasmania, (v) Great Australian Bight. A log of 3.5 kHz facies and correlating imagery for these regions can be found in Appendix 14.

Most of the information regarding the sea floor character was determined by interpreting the various echo types from the 3.5 kHz profiles. To do this, a modified system originally developed by Damuth (1980) was used. This can be seen in Figure 21. This system was employed by Whitmore & Belton (1997), for the interpretation of 3.5 kHz profiles acquired during the TASMANTE cruise in 1994.

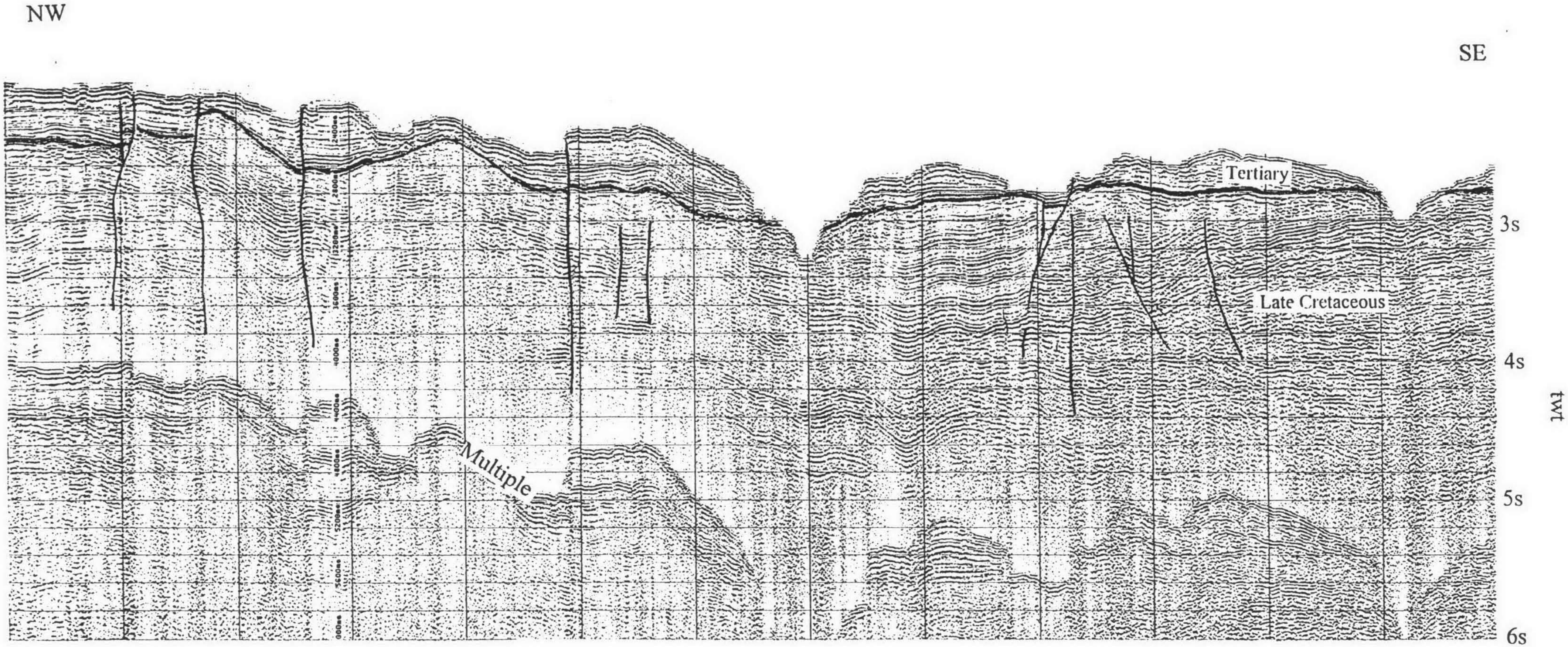


Figure 20 : AUSTREA -1 seismic profile 29 showing the recent faults observed on the prolongation of the George V Fracture Zone.

DISTINCT

IA

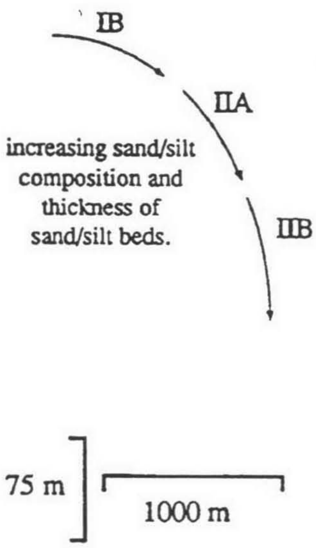
- Sharp.
- No sub-bottoms.
- Flat to undulating.

e.g hardgrounds, possibly manganese crusts and nodule fields

IB

- Sharp.
- Continuous parallel sub-bottoms.
- Little or no relief

e.g undisturbed pelagic and hemipelagic ooze, possibly mud turbidites.



INDISTINCT

IIA

- Sharp discontinuous parallel sub-bottoms.
- Flat to undulating

e.g fine distal turbidites with minor pelagics, often disturbed.

IIB

- Semi-prolonged to prolonged, "fuzzy".
- No sub-bottoms.
- Often marked relief.

e.g sand/silt turbidites, minor reworked pelagics, current winnowed sand.

IIBa

- Irregular IA echo overlying IIB and separated by an acoustically transparent layer.

e.g debris, slump or mass flow deposit.

HYPERBOLAE

IIIA

- Irregular overlapping hyperbolae. Varying vertex elevations. Larger than IIIC.

e.g Extreme topography, scarps and seamounts.

IIIC

- Regular overlapping hyperbolae. Variable vertex elevation and hyperbolae size.
- Semi-prolonged to prolonged

e.g marked topography, scarps, canyons and basement outcrop.

IIID

- Numerous regular hyperbolae tangential to sea-floor.

e.g rare. Small regular bedforms.

HYBRID

IIA/IIIC

- Short sections of IIA echo separated by IIIC

e.g isolated slope basins, faulted sediments and partially sedimented slopes.

IIB/IIIC

- Short sections of IIB separated by IIIC. e.g. as for IIA/IIIC

Figure 21 Acoustic facies types determined from 3.5 kHz echosounder profiles. Slightly modified from Damuth (1980) and Whitmore & Belton (1997).

Noumea to Sydney

The transit from Noumea to the coast of central NSW revealed a relatively undisturbed sea floor, punctuated by more rugged sections such as the shelf off Noumea, the region around Lord Howe Island and Ball's Pyramid and the shelf off eastern Australia. Upon leaving Noumea, the seafloor character appeared in the acoustic imagery as highly reflective, corresponding to a relatively coarse homogenous sediment (IIB). There was a gradual change in character as the sediment became finer down slope towards the abyssal plain, characterised by an interesting echo type seen in Figure 22. This shows a thick section of undisturbed pelagic sediment (IB) overlying an acoustically transparent zone. This zone overlies another flat to undulating section of well-bedded pelagic sediment. Approaching Lord Howe Island there is a distinct increase in seafloor disruption. This begins with a section of disturbed pelagic sediment (IIA) and reworked pelagics (IIB). These disruptions become larger with the introduction of structures protruding the sediment cover, probably of volcanic/volcaniclastic origin. The largest of these intrusions is shown in Figure 23, (centred at 1230 UT, 19/12/99). This seamount rises about 300m above the sea floor and spans 4.5 km at its base. This structure can be clearly seen in the acoustic imagery as a circular outcrop pattern and is marked by a rapid decrease in swath width. The sea floor around Lord Howe Island and Ball's Pyramid consists of extreme topography and basement outcrop (IIIA). The shallow channel between Lord Howe Island and Ball's Pyramid shows some very coarse sediments (IIB). To the west of Lord Howe Island, depth increases rapidly and thick pelagic sediment (IB) blankets the basin floor, with penetration to at least 50 m by the 3.5 kHz echosounder. Again volcanics commonly emerge through the sediment cover and appear as discrete areas of intense reflectivity in the imagery. On approaching the continental shelf off eastern NSW, the topography becomes increasingly rugged (IIIC & IIIA).

NSW South Coast

The ship's track along the South Coast of NSW follows the mid continental slope and the seafloor character is represented by rugged to extreme topography. This zone is a physically active environment and small slumps and mass flow deposits (IIBa) can be seen along the slope. The slope can be divided into two distinctly different zones depending on the level of relief. The upper slope, closer to the coast, is represented by scarps and canyons (IIIA), whereas the lower sections present less extreme topography, such as smaller canyons and basement outcrop (IIIC). Much of this facies appears in the imagery to have a moderate reflectivity suggesting the slopes have a veneer of pelagic ooze or clay. The IIIA facies is easily distinguishable from this, as it appears in the imagery as highly reflective. Occasionally interspersed with this rugged topography are short, coarsely sedimented sections (IIB/IIIC). IIB sedimentation is again seen higher up on the continental slope, but as longer sections up to 22 km across.

Gippsland

The region discussed here covers the rim of the Bass Canyon complex. The main features in the area include the steep slope on the northern edge of the canyon, the plateau further north and small canyon offshoots of the Bass Canyon. The northern rim of the Bass Canyon is rugged (IIIC) but does not appear to be highly reflective in the imagery and therefore is thought to have a veneer of pelagic ooze or clay. Just north of this section the seafloor

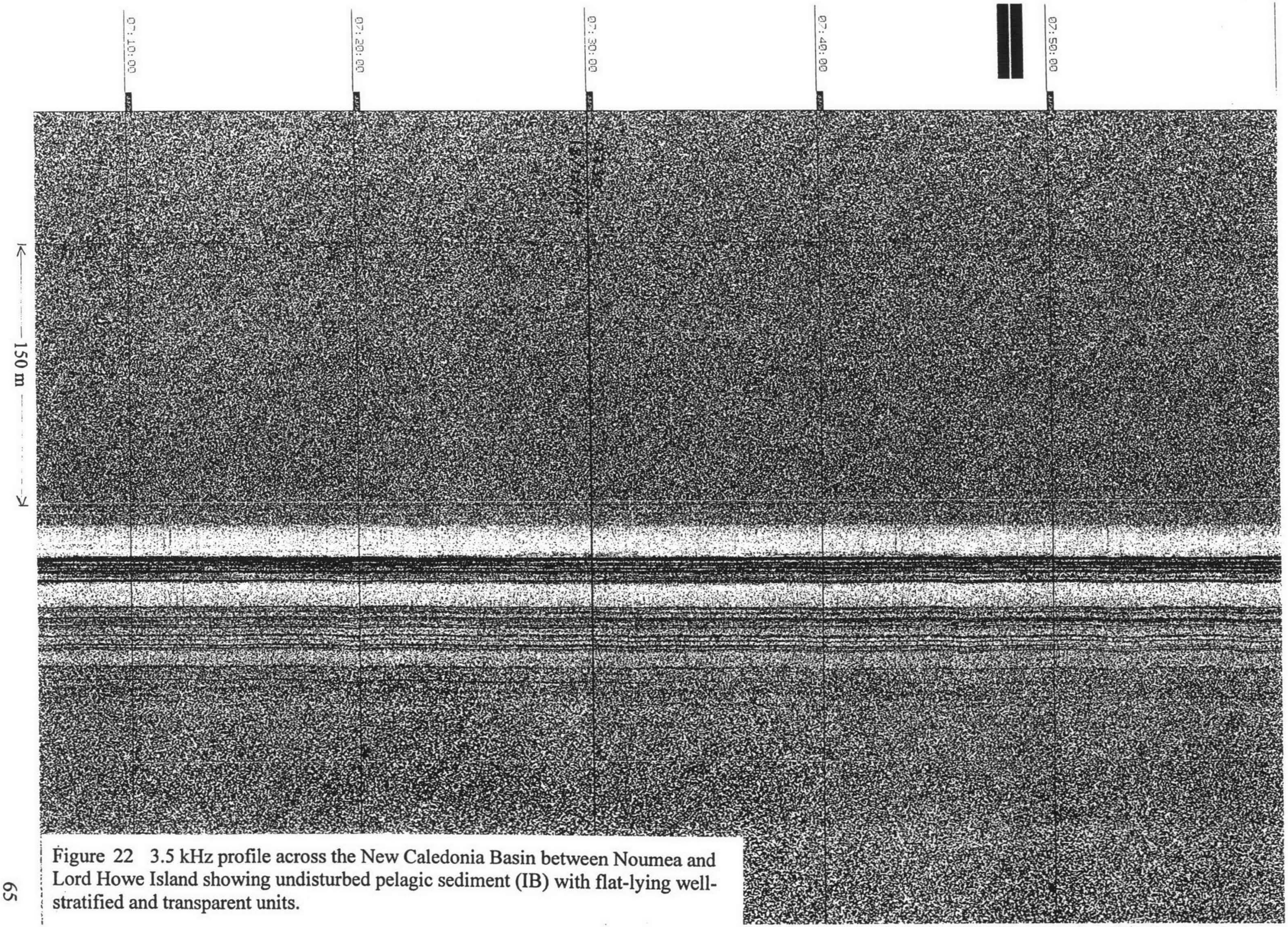


Figure 22 3.5 kHz profile across the New Caledonia Basin between Noumea and Lord Howe Island showing undisturbed pelagic sediment (IB) with flat-lying well-stratified and transparent units.

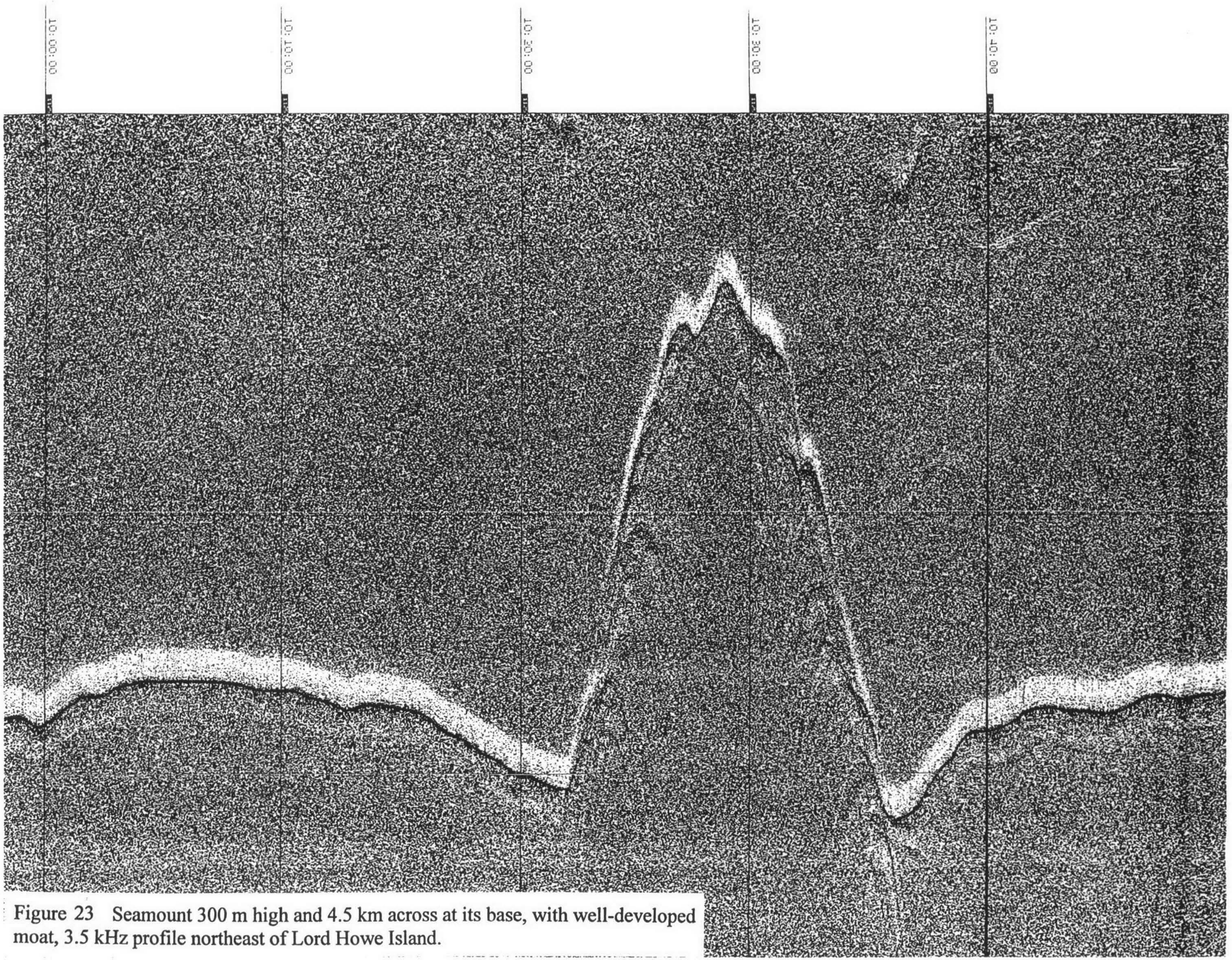


Figure 23 Seamount 300 m high and 4.5 km across at its base, with well-developed moat, 3.5 kHz profile northeast of Lord Howe Island.

gradient decreases greatly, almost forming a plateau, and here there is significantly greater young sediment cover. Sediments on the 'plateau' change character gradually from north to south. In the north, a large area of coarse sediment cover (IIB) grades to a fine grained distal deposit (IIA) in the south. A large canyon that runs into Bass Canyon from the north is of rugged relief (IIIC) and the imagery shows high reflectivity indicating there is not much, if any, soft sediment cover. In the northwest the 3.5 kHz shows structures that appear to be faulted basement blocks covered with a sediment drape (Figure 24). Figure 25 is a map summarising 3.5 kHz acoustic facies of the area north of Bass Canyon.

The western edge of the Bass Canyon complex was surveyed in relatively shallow water depths (at times only a few hundred metres deep), and the seafloor character in this shallow area was similar to that observed on the 'plateau' sediments. The coarse sediment cover is frequently interrupted by narrow canyons which appear as highly reflective bands across the swath.

Tasmanian and Otway Margin

The sea floor off the east coast of Tasmania consists of alternating sections of rugged topography (IIIC) and long sections of low reflectivity in the acoustic imagery suggesting fine to moderate sediment (IIB). The alternating sections are easily distinguishable in the imagery due to the increased level of intensity in the more rugged (IIIC) section indicating a lack of sedimentation and the occurrence of basement outcrop. The IIB section, which covers the majority of the east coast of Tasmania, is characterised by very low intensity imagery, which not only suggests a good sediment cover but also that the grain size is relatively fine.

The data collected along the southern coast of Tasmania adjoins the data collected on the TASMANTE survey. The two data sets appear to correlate well. The volcanic cones and other volcanic terrain on the continental slope south of Tasmania show a rugged sea floor character (IIIC). However interspersed with this volcanic outcrop is a section of disrupted sediment (IIA). This character correlates with the TASMANTE data where it was interpreted to be an inactive turbidite accumulation.

The slope off the west coast of Tasmania drops steeply just beyond the shelf edge at depths of ~500 m and then becomes less steep at greater depths. The AUSTREA-1 survey covered both sides of this steep zone, allowing the region to be split into two zones of differing seafloor characteristics. The upper slope is characterised by the rugged topography of the shelf break (IIIC). This is an erosional zone containing structures such as small canyons that do not always progress very far down slope. This zone also contains erosional channels, which are not as rugged as the larger canyons, and which are floored by coarse sediment (IIB/IIIC and IIA/IIIC). Much of the slope farther down is characterised by debris and gravity driven mass flow deposits (IIBa). This is a result of slope failure due to the steep gradient of the upper slope. To the north, significant sections of sediment cover varying in grain size from fine (IIA) to coarse (IIB) as a result of the low gradient of the slope.

The Otway Basin lies to the north of the Cape Sorell area and is dominated by a series of large canyons (IIIC), separated by sections of coarse sediment (IIB). Occasionally larger canyons (IIIA) cut through these sections of coarse sediment. These canyons are easily distinguishable from smaller (IIIC) canyons in imagery because they appear as highly reflective, broad, bands that extend across the entire swath. The smaller (IIIC) canyons extend across the swath as patches of intense reflectivity due to some sediment cover. Again the

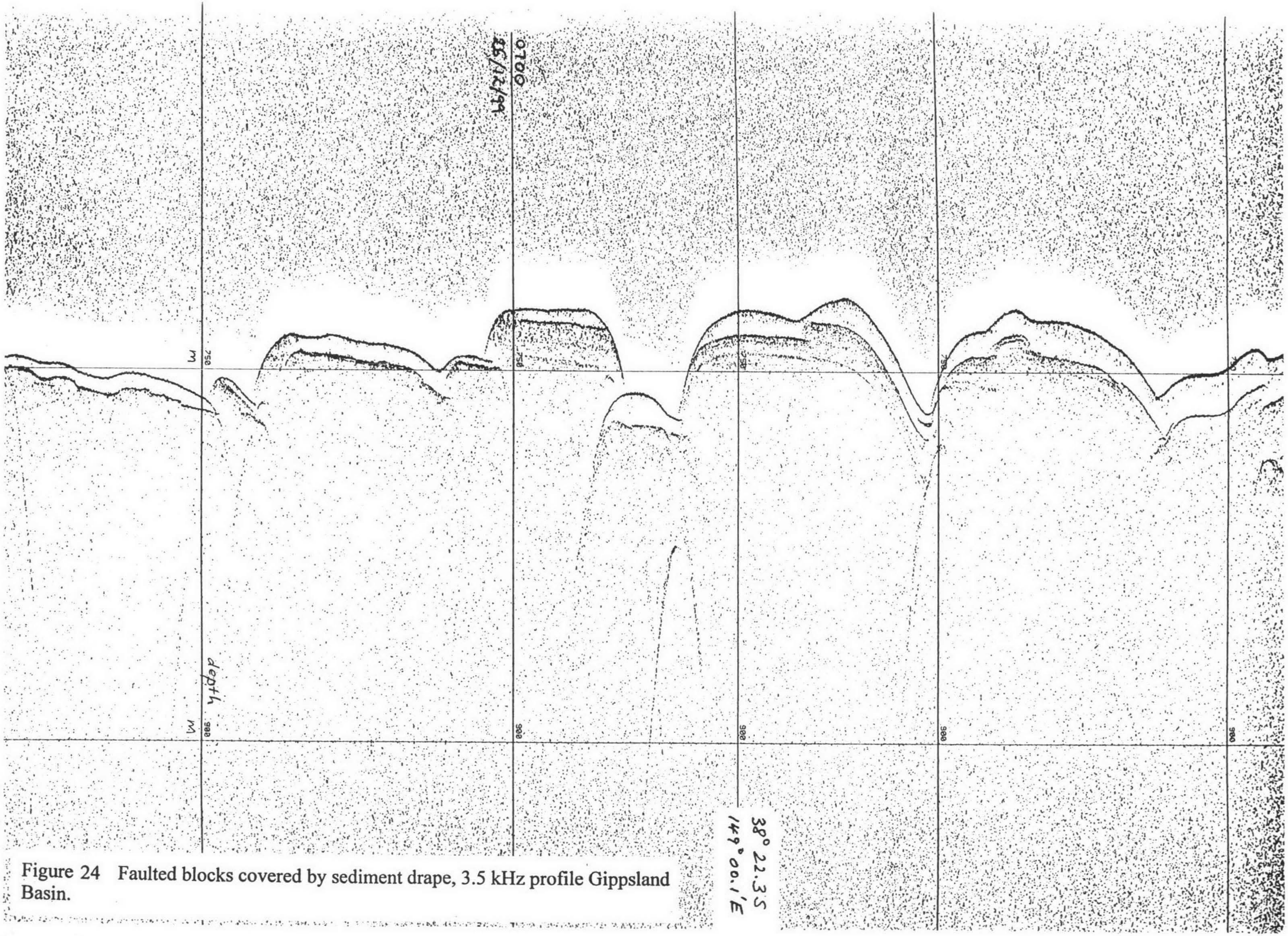


Figure 24 Faulted blocks covered by sediment drape, 3.5 kHz profile Gippsland Basin.

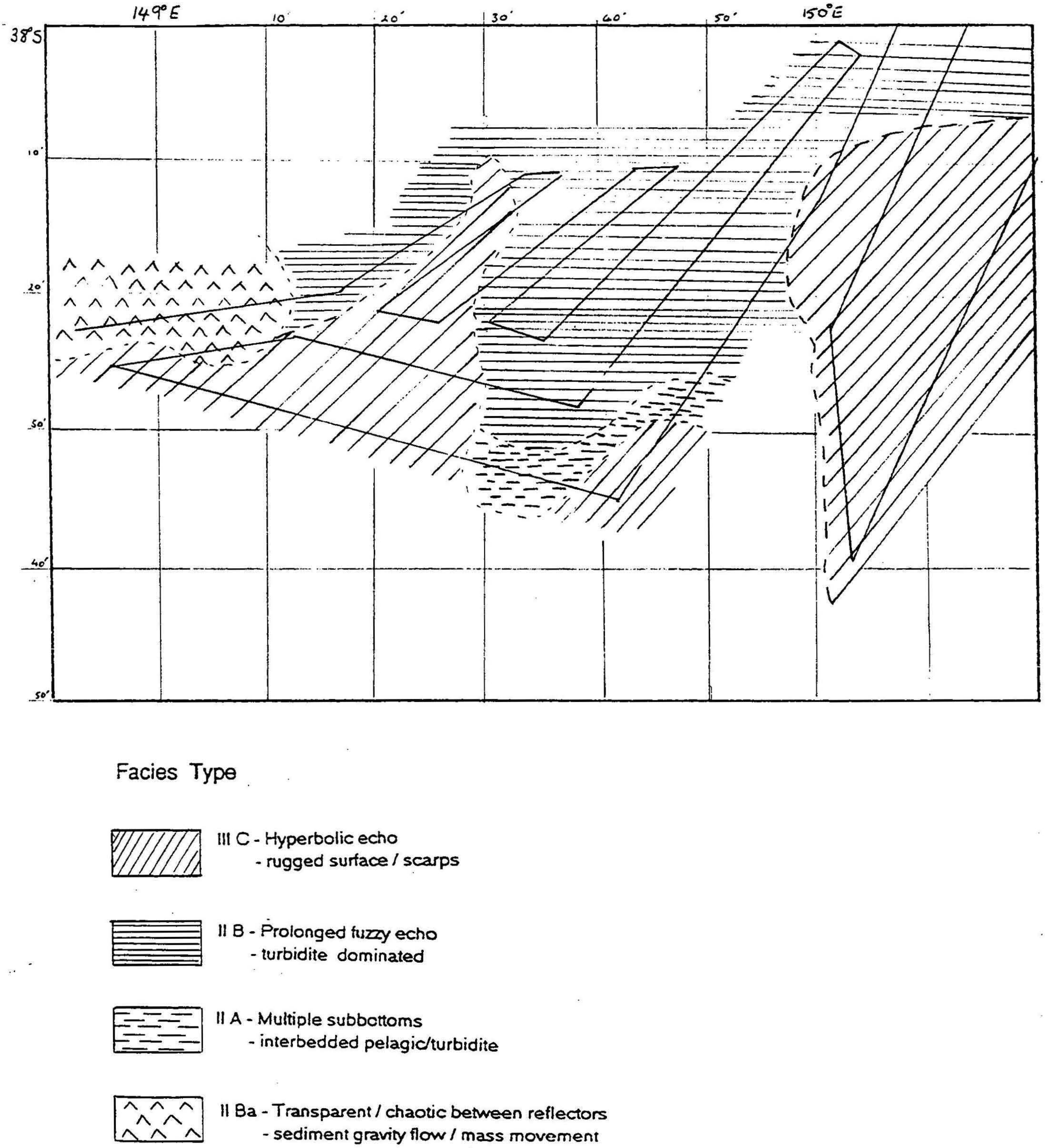


Figure 25 Map of 3.5 kHz acoustic facies for the area north of Bass Canyon, deepwater Gippsland Basin.

smaller canyons and channels are characterised by hybrid echoes such as IIB/IIIC and even IIA/IIIC. This pattern of occasional large (IIIA) canyons, frequent smaller (IIIC) canyons and frequent hybrid echoes changes towards the west. The hybrid echoes cease to occur, and the smaller (IIIC) canyons are replaced by a series of extremely large (IIIA) canyons. Throughout this region the acoustic imagery shows areas of intense reflectivity, expected from such extreme topography.

Great Australian Bight

This area (Figure 15) includes a short transit section east of the marine park. The transit zone is generally of lower topographic relief compared to the west Otway margin. There is a change from large (IIIA) canyons to smaller (IIIC) canyons, which are also gradually replaced by hybrid (IIB/IIIC) echoes marking the beginning some coarse sedimentation (IIB). This trend in topographic relief is expressed in the acoustic imagery as well as the 3.5 kHz echo character. The intense reflectivity of the extreme topography gradually decreases as the relief becomes less rugged and sedimentation becomes more dominant. The imagery shows this sedimentation as a consistent, low reflectivity zone.

The deepwater GAB marine park can be separated into two distinct regions on the basis of seafloor character. South of 35°S the sea floor is extremely rugged with little sedimentation. North of this latitude, the sediment cover grades from disturbed coarse deposits to fine undisturbed sediment. The large Nullarbor Canyon that extends to the southwest dominates the southern section (Figure 15). It becomes much wider downslope in deep water and is marked along its length by circular erosional features which can occasionally be seen in the acoustic imagery as highly reflective circles. These circular features appear to be more rugged (IIIA) than the adjacent canyon floor (IIIC), which appears to have a veneer of pelagic ooze or clay. Immediately west of this canyon the sea floor is still fairly rugged due to the high gradient of the slope. It is characterised by bedrock outcrop (IIIC) and very coarse sediments (IIB). To the north of latitude 35°S the gradient of the slope is much less, and this is reflected in the sedimentation of the sea floor. The sediment deposits include coarse reworked pelagics (IIB), disturbed pelagics (IIA), and even undisturbed pelagic and hemipelagic ooze (IB). These facies are difficult to distinguish in the acoustic imagery. The coarse sediment appears to be slightly more reflective. An interesting but rare feature in this area is a band of small regular bedforms (IIID) that cuts across two tracks of the survey. This feature is not evident in the acoustic imagery.

15. OVERVIEW OF MAJOR SCIENTIFIC RESULTS AND FUTURE PLANS

- AUSTREA-1 mapped the volcanic slopes of Lord Howe Island and Ball's Pyramid to the 12 nautical mile outer limits of a proposed Marine Protected Area, revealing a rugged terrain of volcanic cones, flows and canyons likely to harbour diverse benthic communities.
- The steep and narrow rifted continental margin off the NSW South Coast was shown to be deeply dissected by canyons and to contain gigantic continental fault blocks and ?synrift volcanic seamounts and ridges.
- The survey completed mapping of the huge Bass Canyon complex off southeast Victoria, revealing detailed morphology of tributary canyons up to 1000 m deep adjacent to the Gippsland oil fields.

- Important fishing grounds of the Southeast Trawl Fishery were mapped off Tasmania, including volcanic and carbonate pinnacle terrain off St Helens, volcanic seamounts of the Southern Hills, and the heads of canyon systems incised into the sedimented upper slope off west Tasmania.
- Mapping of the Tasmanian Seamounts Marine Protected Area, south of Hobart, was completed, with thirty additional volcanic seamounts found just east and north of the MPA.
- The seismic profiles confirmed the existence of potential frontier petroleum basins off the east, southern and west coasts of Tasmania.
- Parts of the deeply-canyoned upper and mid slope of the Otway Basin were mapped off northwest Tasmania, Victoria and South Australia.
- The Great Australian Bight Benthic Protected Area of the GAB Marine Park was fully surveyed below the 500 m isobath and was shown to be generally of uniform slope, with the gigantic Nullarbor Canyon crossing its southeastern corner, gouged into deformed Late Cretaceous sediments.

The new data and images collected on AUSTREA-1 will be used for:-

- development of the Southeast Regional Marine Plan and management of this offshore area, to balance commercial and conservation needs
- research into seabed character, geological processes operating (past and present), and the ecology and biology of our offshore regions
- assessment of offshore petroleum and mineral resources
- fisheries research and development of the industry
- hydrographic charts.

The vast amount of new information gathered on this survey, plus data from earlier geoscience cruises, will form the basis for further collaborative studies between the National Oceans Office (NOO), AGSO, CSIRO Marine Research and other Australian marine research agencies, to enable us to better understand and manage our marine environment, and to develop the Regional Marine Plans. Copies of the standard contour and reflectivity (backscatter) maps have been provided to NOO. Copies of the digital swath data are held for NOO at AGSO. All data will be jointly managed by AGSO, NOO and EA.

A series of linked research cruises involving Environment Australia/NOO, AGSO and CSIRO is planned that will build on the AUSTREA cruises. The first of these will use CSIRO's *Southern Surveyor* on a 3-leg program off southeast Australia and in the GAB, starting in March 2000. This program, led by CSIRO Marine Research, will be over and adjacent to areas surveyed by AUSTREA-1 and will involve follow-up biological/sedimentological sampling and acoustic surveys using vertical-beam systems and a shallow-water swath-mapper to obtain further information on biodiversity, habitats and seabed character.

16. ACKNOWLEDGMENTS

This was a fine example of cooperation between AGSO, EA/NOO and IFREMER, giving exceptional results of great value to Australia's Ocean Policy and the Marine Science and Technology Plan.

The Australian team would particularly like to acknowledge the considerable help and cooperation provided by the master of *L'Atalante* Commandant Michel Houmard, the ship's crew, and the Genavir engineers and technicians led by Philippe Le Scaon. Their friendship, outstanding professional skills and hard work all contributed to making AUSTREA-1 a memorable and highly successful scientific cruise. At an earlier stage, the strong support of the IFREMER scientist in charge in Noumea, Jean-Marie Auzende, and of the IFREMER Director, Pierre David, was of critical importance.

Valuable input and feedback at the planning stage was provided by our colleagues at CSIRO Marine Research - Keith Sainsbury, Alan Butler and Rudy Kloser. Gordon Anderson, of Environment Australia and now of the National Oceans Office (Hobart), coordinated the project and provided thought-provoking input. EA/NOO provided all the contract funds for *L'Atalante*, thus making this study possible.

Neville Exon (AGSO) negotiated use of *L'Atalante* with IFREMER for AUSTREA, and provided high-level guidance throughout the project. We thank him for reviewing a draft of this Record.

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APPENDIX 1
Information on *L'Atalante*

Length overall	84.60 m
Beam overall	15.85 m
Draught (zero trim)	5.05 m
Gross tonnage	2355 tons (3559 UMS)
Net tonnage	435 tons (1067 UMS)
Cruising speed	13 knots
Maximum speed	14.5 knots
Endurance at 12 knots	60 days
Call sign	FNCM
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, 19 mm wire)

Accommodation:

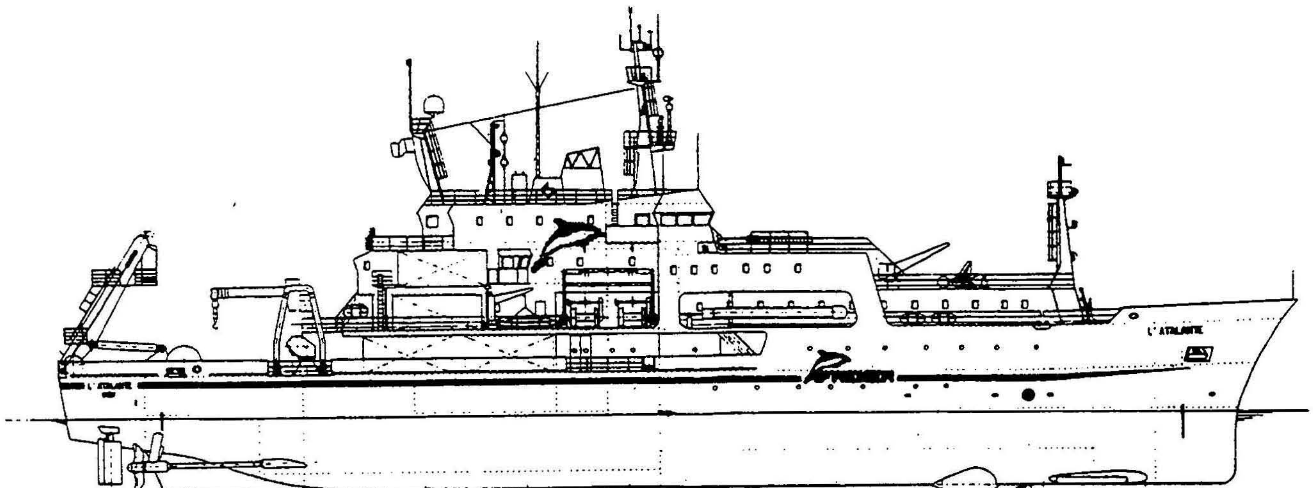
Total complement of 59 in single/double berth cabins

Officers and crew, 17-30

Scientists and technicians, 25-29

Operating company:

GENAVIR



APPENDIX 2
SIMRAD EM12D Multibeam Echo-sounder - Technical Information

The EM12D (Pohner & Hammerstad, 1991) consists of two EM12 13 kHz multibeam echo-sounders (one on each side of the ship), each generating 81 stabilised 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.

The cross-track beam spacing of the EM12D was set in EDBS mode on this cruise, so that rather than being equiangular, the beams were 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 1 kHz 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.

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 1800 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): 10-15 seconds
Relative precision on beams: ~0.2 %
Seabed image resolution (deep mode): ~7 m cross-track, 50-150 m in track direction

APPENDIX 3
Scientific and Navigation Equipment

Swath-mapping

SIMRAD Dual EM12 multibeam bathymetric / acoustic imagery system

Geophysical

6-channel seismic reflection system (Sismique Rapide), digital acquisition (DELPHWIN V1.36 software on PC-BUS Industrial IPC-600/12 computer with magneto optical disk drive RICOH (594 Mb disks)). Data recorded in ELICS format then converted on board to SEG-Y.

DOWTY Model 3710 thermal linescan recorder: seismic monitor, recording channel 2 from start of survey, then channel 3 from 0649 UT 24/12/99 on Profile AEA1003 - 31.5 cm wide film record

Krohn-Hite model 3100 filter for monitor records (bandpass setting 25-80 Hz)

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

2 GI Gun (SODERA/Seismic Systems Inc.) airguns, starboard 45/45 cu. inch chambers, port 105/105 cu. inch chambers (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

Seismic replay/processing system (DELPH Rejeu) using DELPHWIN V1.36 software installed on HP Vectra VL PC, connected to OYO Geospace GS-612 thermal plotter.

High-resolution sediment profiler, 3.5 kHz - CHEOPS digital acquisition system connected to Raytheon echo-sounder (2 kW power) - typical penetration ~50 m. Chirp 2.5/4.5 kHz, pulse length 20 ms, 24 kHz sampling, 1.5-5.5 kHz bandpass, 1000 ms record length, SEG-Y recording.

DOWTY Series 195 strip chart recorders (2) for EM12D acoustic imagery and 3.5 kHz CHEOPS monitor records (50 cm wide film or paper)

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

LOCKHEED MARTIN BGM-5 gravity meter (newly installed and on trial)

Scintrex CG-3 Autograv portable gravity meter (for station ties)

BARRINGER M-244 magnetometer (~1 nT accuracy)

Navigation

SERCEL NR103 differential GPS receiver - primary navigator GPS1 - with demodulator input from Fugro SeaSTAR DGPS via Inmarsat to give positional accuracy of ~1 m

SERCEL NR203 integrated multi differential GPS receiver - secondary navigator GPS2

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), 1800 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)

TQP sea temperature sensor

SIPPICAN MK 12 XBT launcher

APPENDIX 4
AUSTREA-1 Cruise Participants

Scientific cruise participants

Peter Hill, AGSO, chief scientist
Nadège Rollet, marine geologist, AGSO & Observatoire Océanologique de Villefranche-sur-mer, France
David Rowland, data base manager, AGSO
Clive Calver, geologist, Mineral Resources Tasmania, Hobart
Jonathan Bathgate, Honours student, School of Geosciences, University of Sydney

Ship's crew and technical staff (Genavir)

Michel (Bruno) Houmard	Master
Serge Marcade	Chief mate
Paul Henry Vimbert	Mate
Elodie Scholla	Mate
Thierry Alix	Chief engineer
Jean Luc Jaouen	Second engineer
Olivier Bass	Engineer
Philippe Le Scaon	Senior electronician
Dominique Morazzani	Electronician
Stéphane Coquet	Multibeam mapping specialist
Michel Boutbien	Seismic technical specialist
Claude Loussouarn	Simrad multibeam specialist
Joël Le Bris	Simrad multibeam specialist
Philippe Bride	Seismic technician
Frédéric Jourdain	Cadet officer,engine
Guy Milliner	Bosun
Berard Tamboueon	Leading seaman
Visesio Tagatamanogi	Seaman
Gilles Le Bris	Seaman
Kelekolio Tuataane	Seaman
Yann Floch	Seaman
Marcel Roger	Engine mechanic
Philippe Plouhinec	Electrician
Philippe Schneider	Maintenance mechanic
Ronni Mati	Able seaman
Patrick Youinou	Chief cook
Jean Paul Riou	Cook
Jean Jacques Seite	Chief steward
Philippe De Beauvais	Senior steward
José Rebelo	Steward
Frédéric Marteel	Steward

APPENDIX 5

Weather patterns during the AUSTREA-1 Cruise (Rowland)

The AUSTREA-1 Cruise was conducted between latitudes 22°S and 44°S and between longitudes 129°E and 166°E. Weather regimes ranged from tropical to cool temperate.

For the purposes of weather analysis, the survey may be subdivided into six legs. The legs, weather conditions encountered and the influence of the weather on the survey are summarised below. Figures A1 to A6 graphically show ship and wind speed from data recorded automatically at the bridge at 30 minute intervals. Sharp drops in ship speed for short durations are generally due to either, slowing to record water temperature profile data for calibration of the EM12D, or deployment/retrieval of seismic gear (air guns/streamer) and/or magnetometer sensor.

Leg 1 – Noumea to NSW South Coast (18/12/99 0000 UT – 23/12/99 0000 UT)

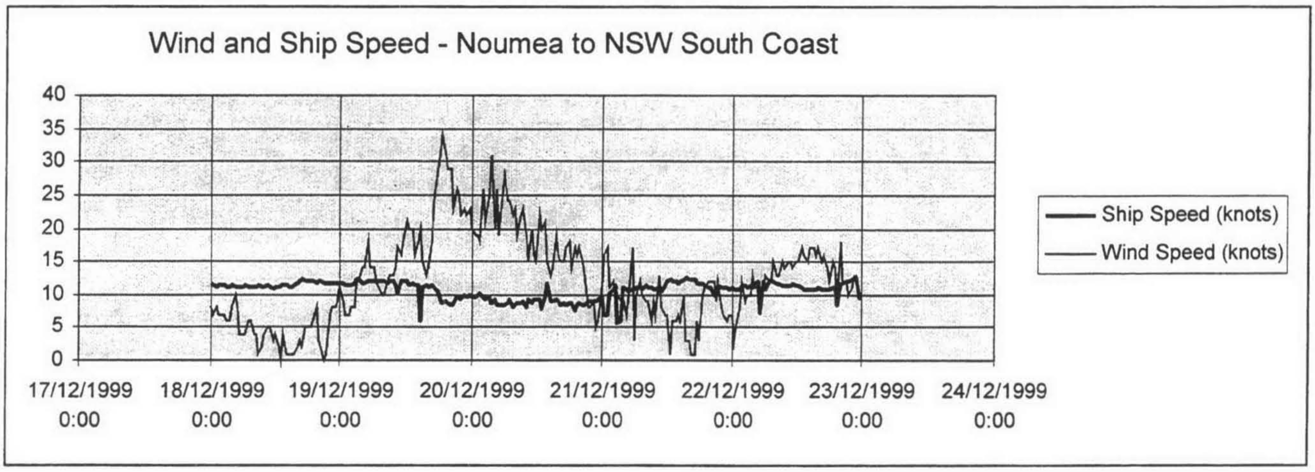


Figure A1

L'Atalante departed Noumea in a high pressure system with light winds and slight seas. The ships best cruising speed (without seismic gear/magnetometer sensor) of 12 knots was maintained until 1400 19/12/99. At this point the ship was influenced by a low pressure trough with fresh to strong head winds, rough sea and moderate to heavy swell. Ship speed was reduced to between 7 and 10 knots until 0000 21/12/99. Light to moderate winds and seas prevailed for the remainder of the leg and ship speed of around 12 knots was maintained.

Leg 2 – NSW South Coast/Gippsland Survey (23/12/99 0000 UT – 26/12/99 1200 UT)

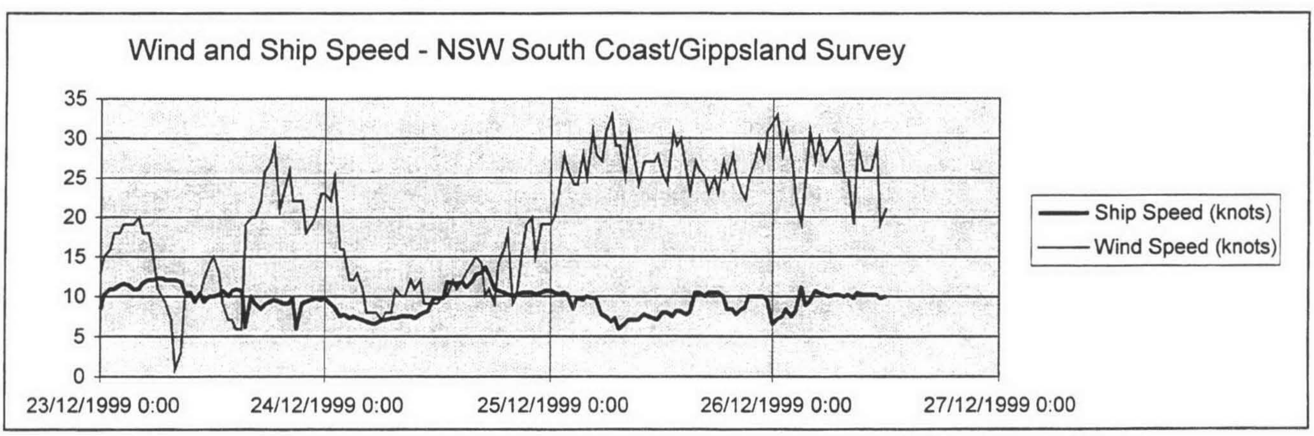


Figure A2

Seismic gear and magnetometer sensor were deployed at the start of leg 2, reducing cruising speed to around 10 knots maximum. Following a brief southerly change, a deepening low pressure trough over Victoria directed strong northeast winds through the survey area. Rough seas and/or a one to three knot north-south current frequently resulted in ship speed being below 10 knots. Figure A7 shows the synoptic chart and position of *L'Atalante* at 1200 25/12/99.

Leg 3 – Gippsland – Southern Tasmania (26/12/99 1200 UT – 28/12/99 1900 UT)

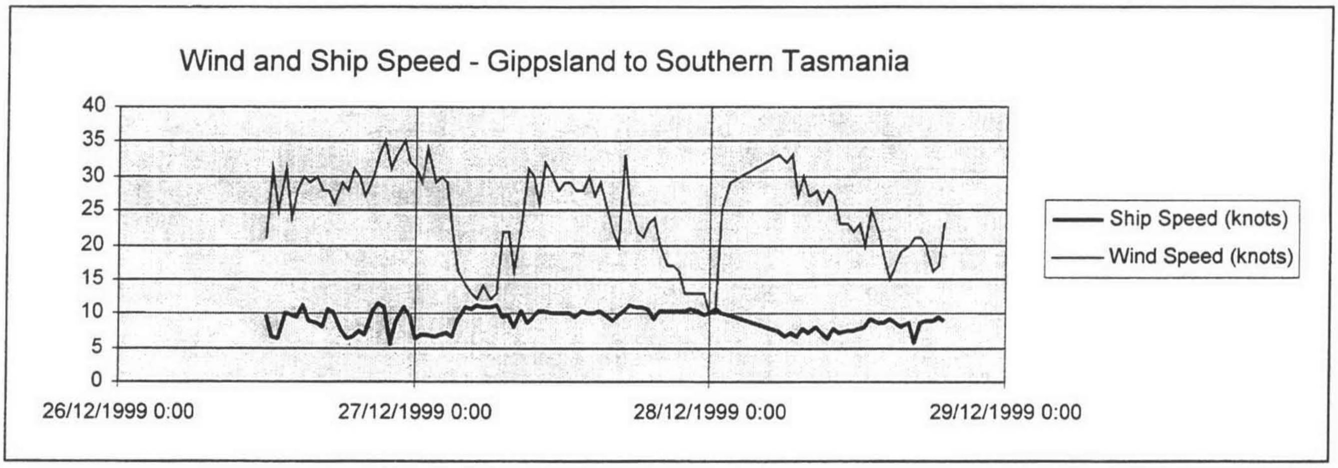


Figure A3

The strong northeasterly winds turned strong to gale force southeasterly headwinds as a low developed off northeastern Tasmania and a cold front passed through from the southwest. Rough to very rough sea and moderate to heavy swell reduced ship speed to below 10 knots for parts of this leg. Figure A8 shows the synoptic chart and position of *L'Atalante* at 1200 28/12/99.

Leg 4 –Southern Tasmania – Great Australian Bight (28/12/99 1900 – 02/01/00 0230 UT)

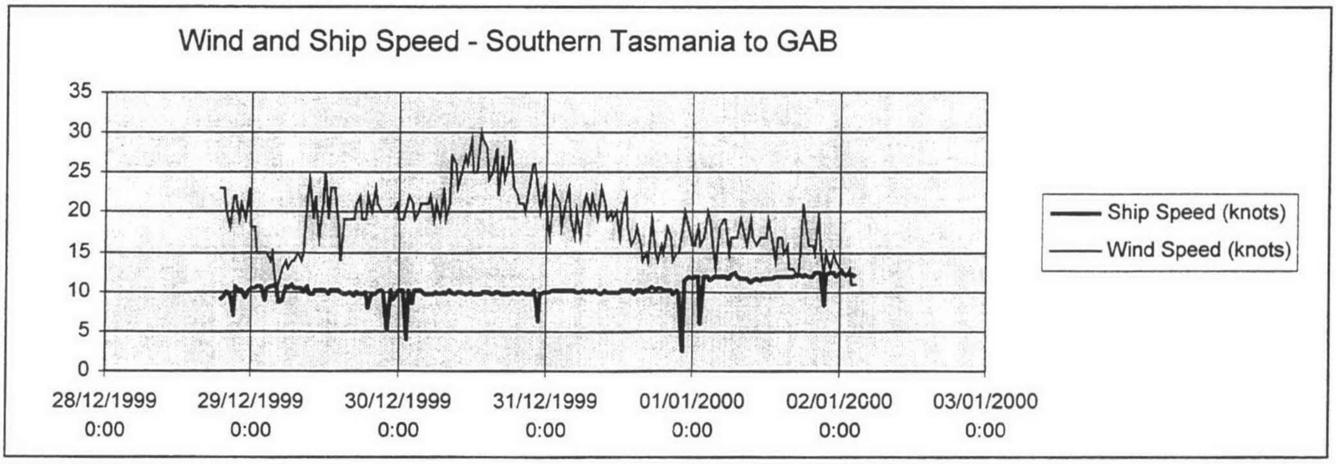


Figure A4

A high pressure system south of the Bight and a low in the Tasman sea produced good survey conditions for this leg. Moderate to fresh southeasterly tailwinds with low to moderate sea and swell. Ship speed of 10 knots was maintained until 0000 01/01/00 at which point the seismic gear and magnetometer sensor were retrieved. Ship speed of 12 knots was maintained for the remainder of the leg. Figure A9 shows the synoptic chart and position of *L'Atalante* at 1200 01/01/00.

Leg 5 – GAB Survey (02/01/00 0230 - 05/01/00 0600)

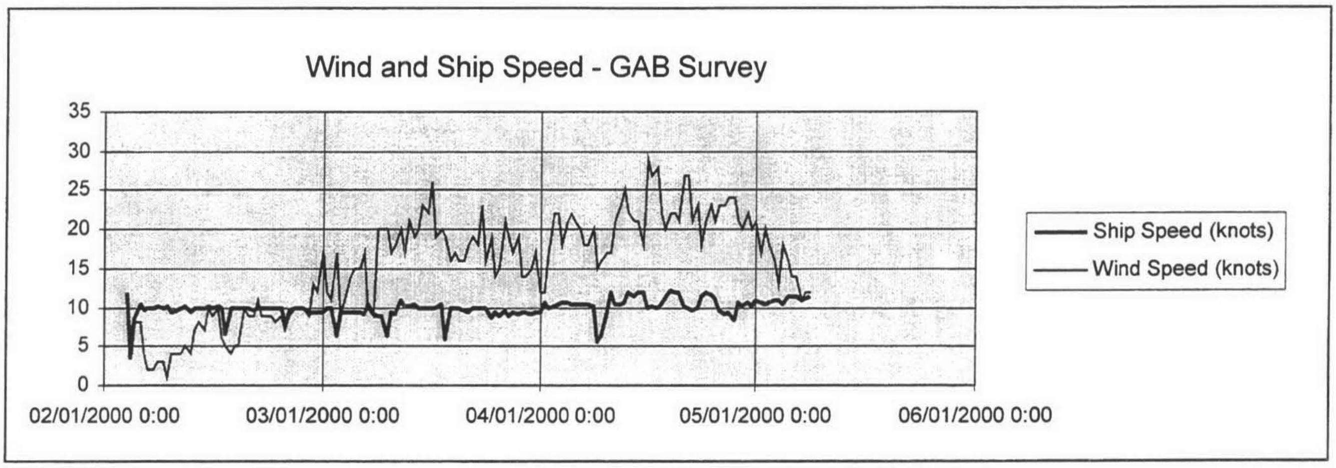


Figure A5

Seismic gear and magnetometer sensor were deployed at 0230 02/01/00 and were retrieved at 0630 04/01/00. A high pressure system centred south of the bight maintained a moderate to fresh southeasterly airstream over the survey area. Ship speed of around 10 knots was generally maintained. A weak cold front did not impact significantly on ship speed. Sea and swell were moderate. Figure A10 shows the synoptic chart and position of *L'Atalante* at 1200 03/01/00.

Leg 6 – GAB to Hobart (05/01/00 0600 – 0600 11/01/00)

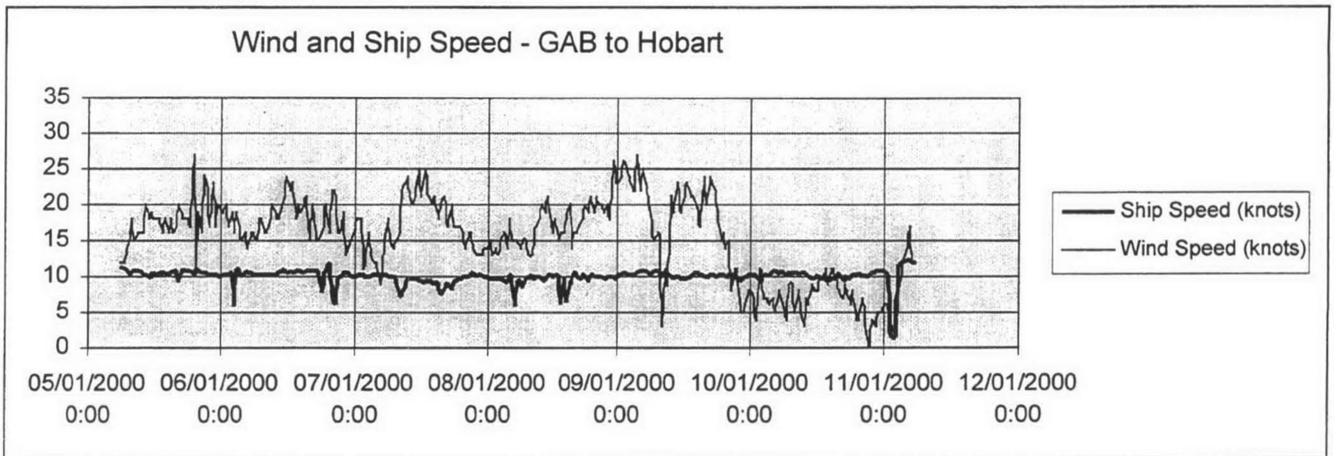


Figure A6

Seismic gear and magnetometer sensor were deployed at 2100 06/01/00 and were retrieved at 0030 11/01/00. A deepening low over Victoria directed fresh to strong north easterly winds through Bass Strait. Sea was rough on a moderate swell. Once across Bass Strait a high pressure system over Tasmania produced fine conditions with light winds, slight sea and low swell. Ship speed of around 10 knots was generally maintained throughout the leg. Figure A11 shows the synoptic chart and position of *L'Atalante* at 1200 09/01/00.

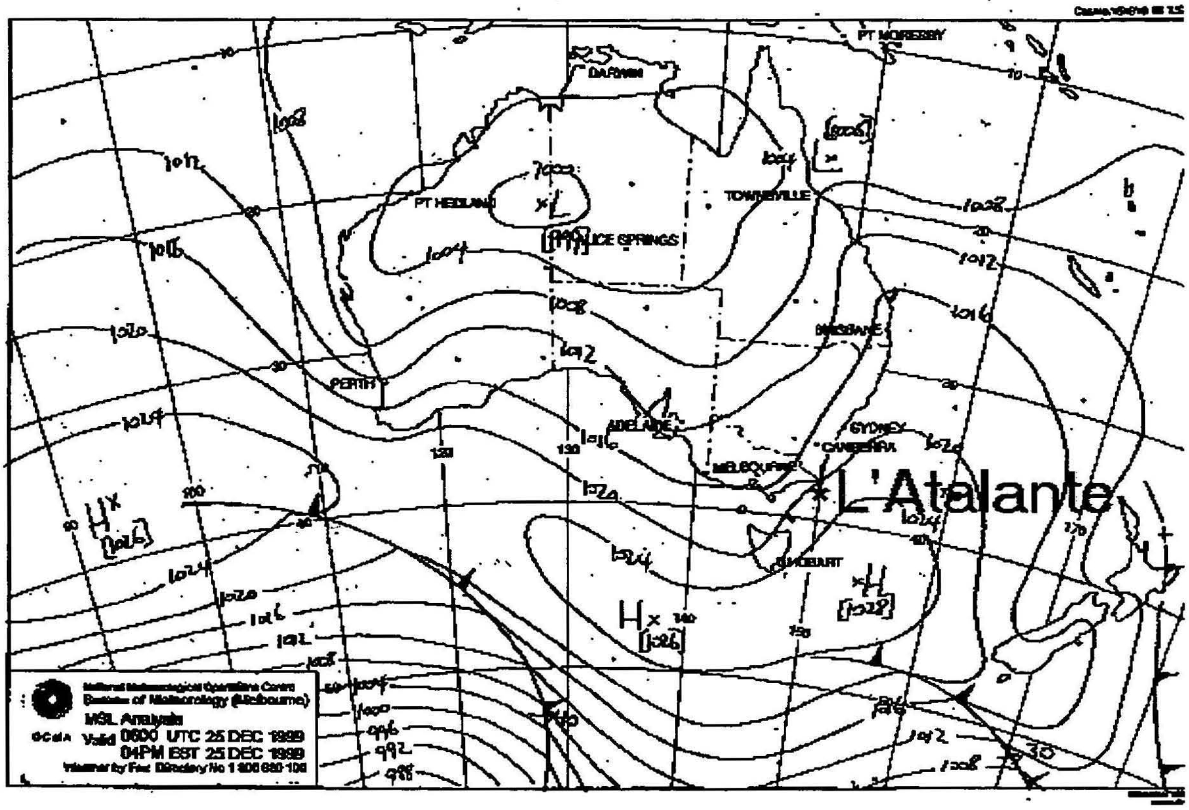


Figure A7 – Synoptic chart and approximate position of *L'Atalante* at 1200 25/12/99.

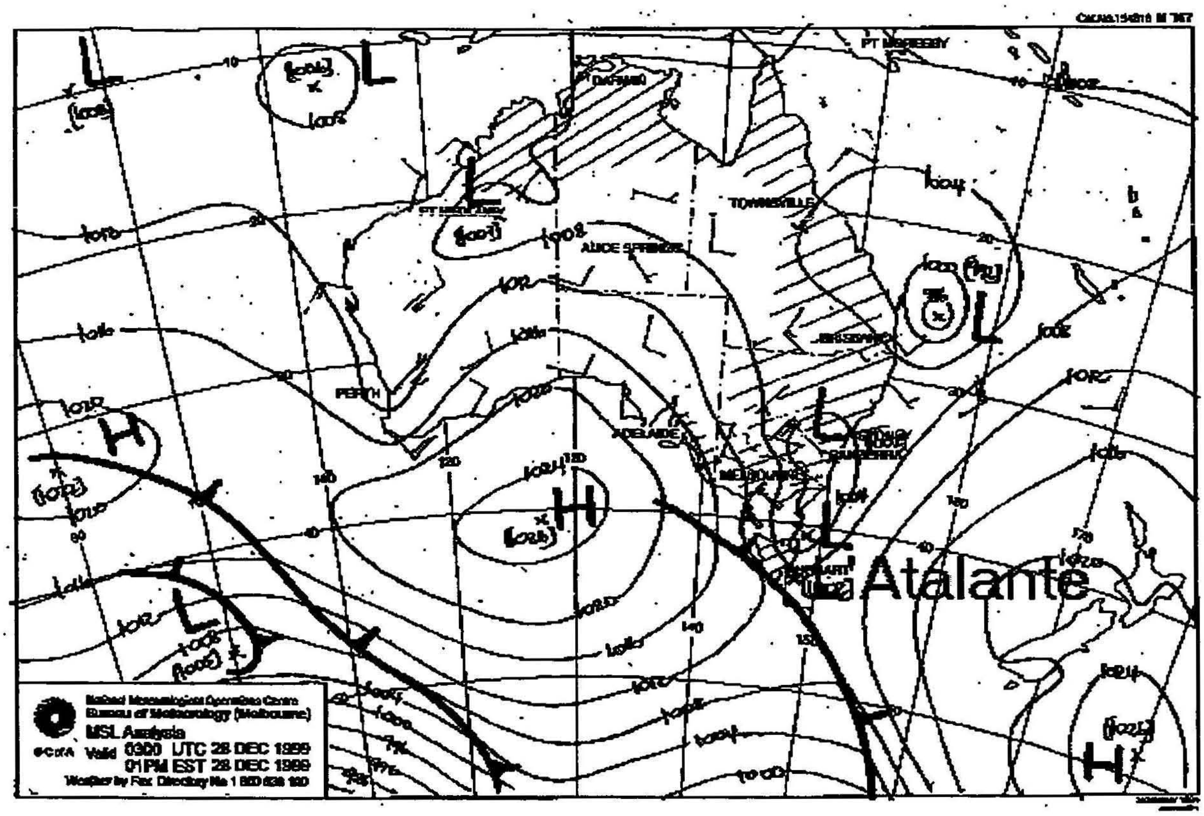


Figure A8 – Synoptic chart and approximate position of *L'Atalante* at 1200 28/12/99

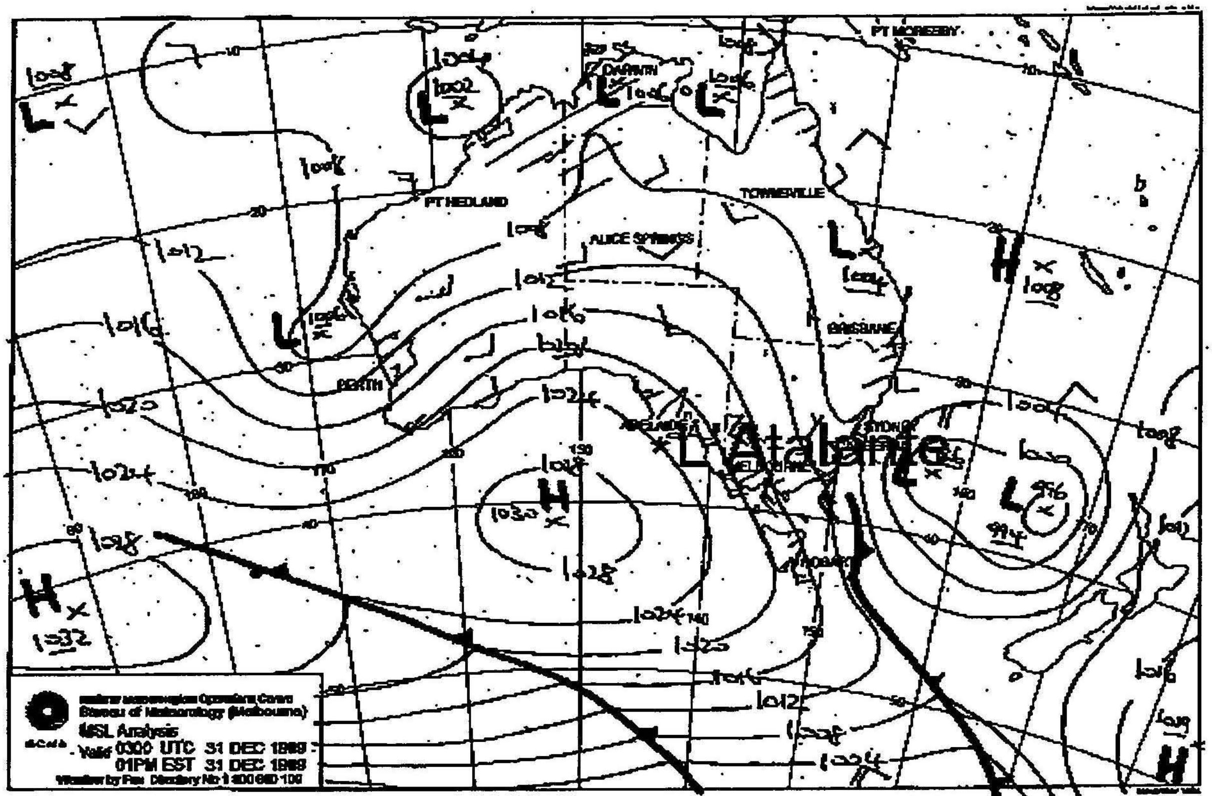


Figure A9 – Synoptic chart and approximate position of *L'Atalante* at 1200 31/12/99

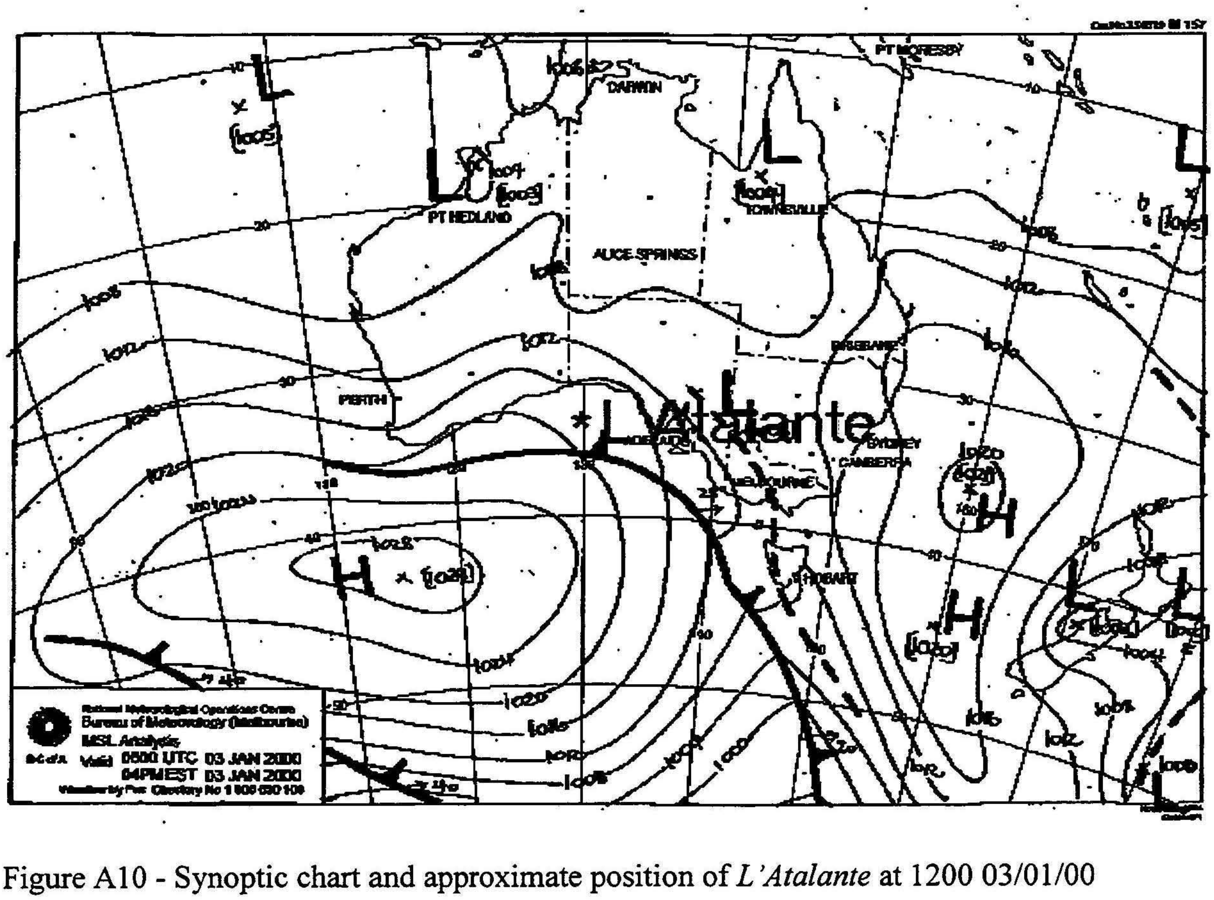


Figure A10 - Synoptic chart and approximate position of *L'Atalante* at 1200 03/01/00

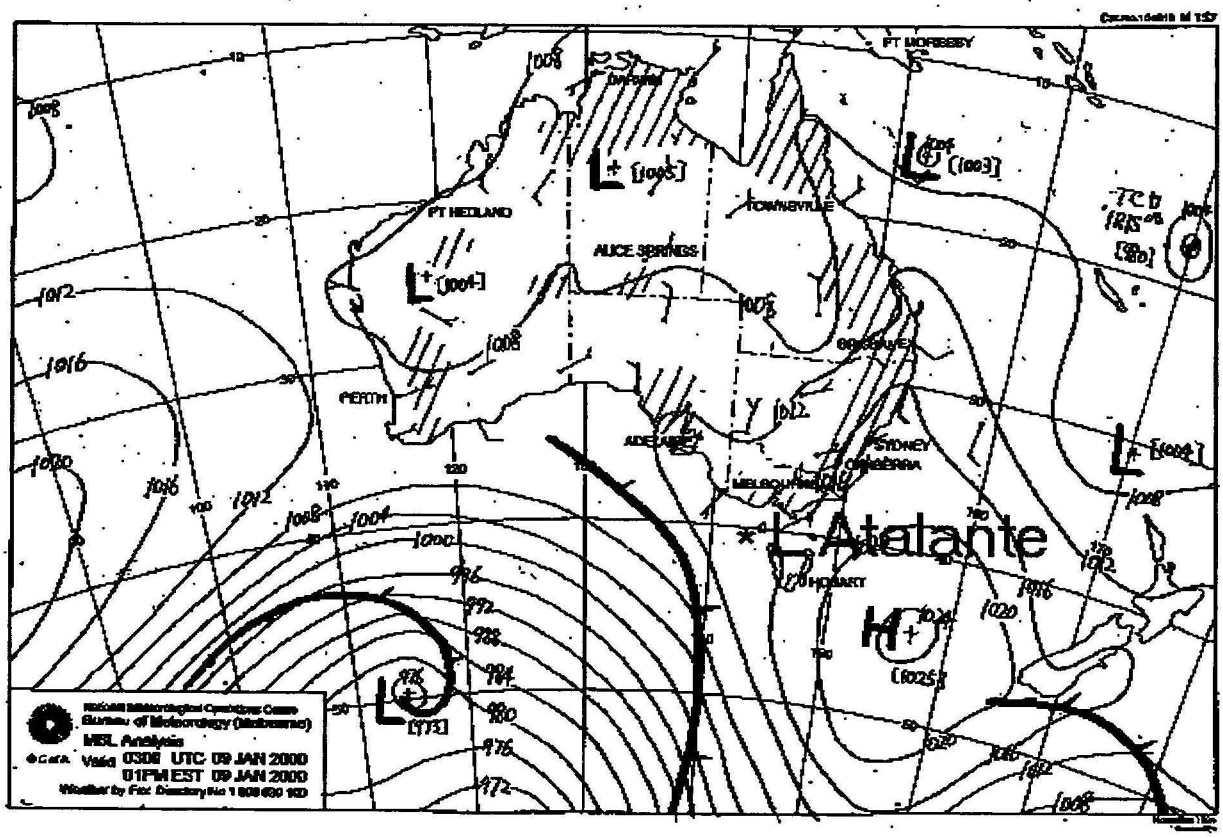


Figure A11 - Synoptic chart and approximate position of *L'Atalante* at 1200 09/01/00

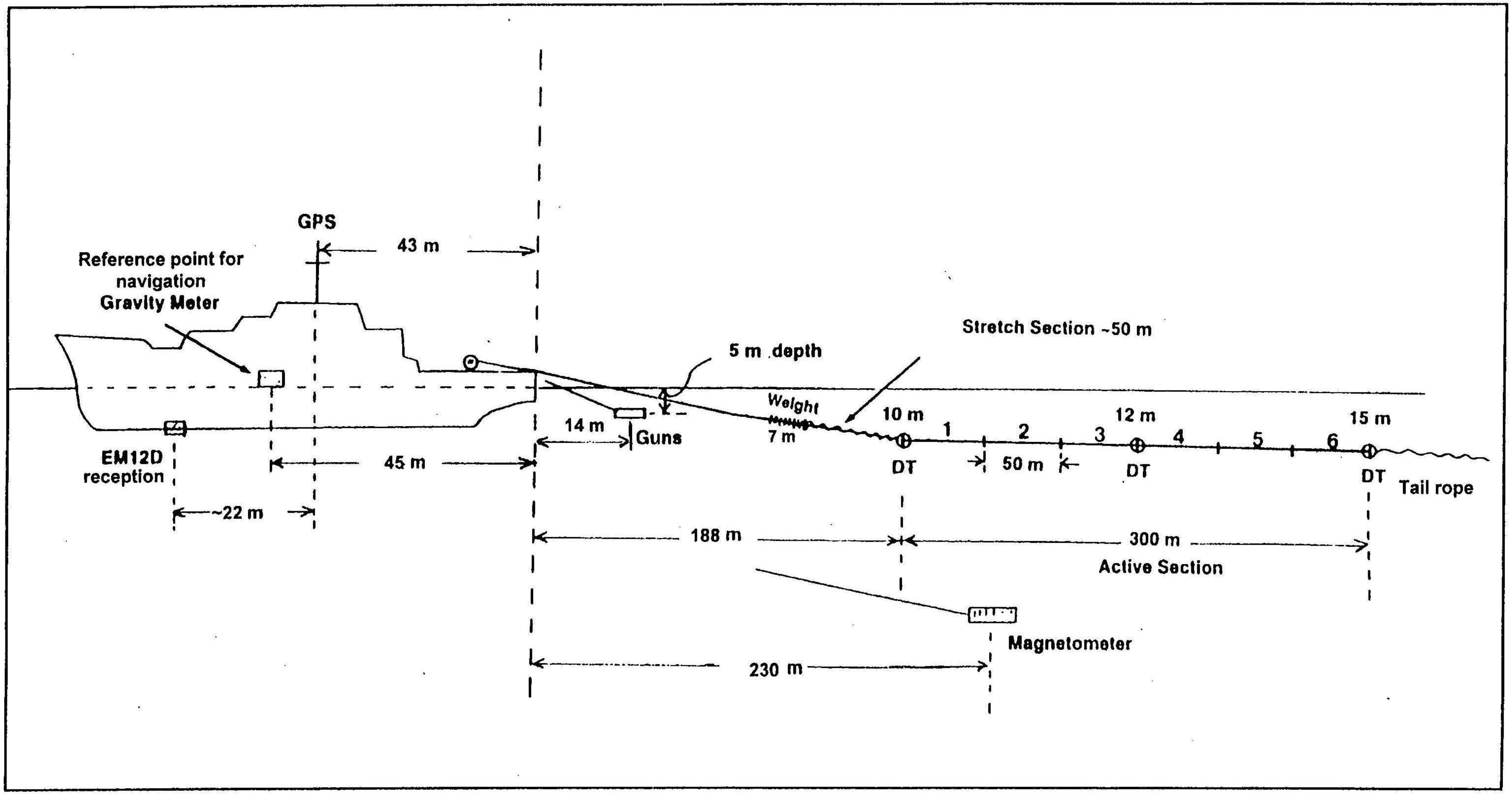
APPENDIX 6
Geophysical Acquisition Parameters

Seismic

Streamer length (active) 300 m [6 groups, each 50 m]
Offset, navigational reference to guns = 59 m
Offset, guns to centre of group (channel) 1 = 199 m
Depth of streamer: ~12 m
Gun depths 5 m
Gun offset from stern ~14 m
Operating air pressure to guns 140 bars (2000 psi)
Shot interval 10.0 seconds
Record length (digital) 8 seconds; 4 seconds of data recorded on strip-chart monitor
Sampling interval 4 ms
15-130 Hz passband for digital acquisition, 25-80 Hz for monitor records
Shot delays: Port 105/105 G 10 ms, I 52 ms; Starboard 45/45 G 10 ms, I 47 ms
Ship's speed during acquisition: 10 knots nominal
Digital data format: SEG-Y

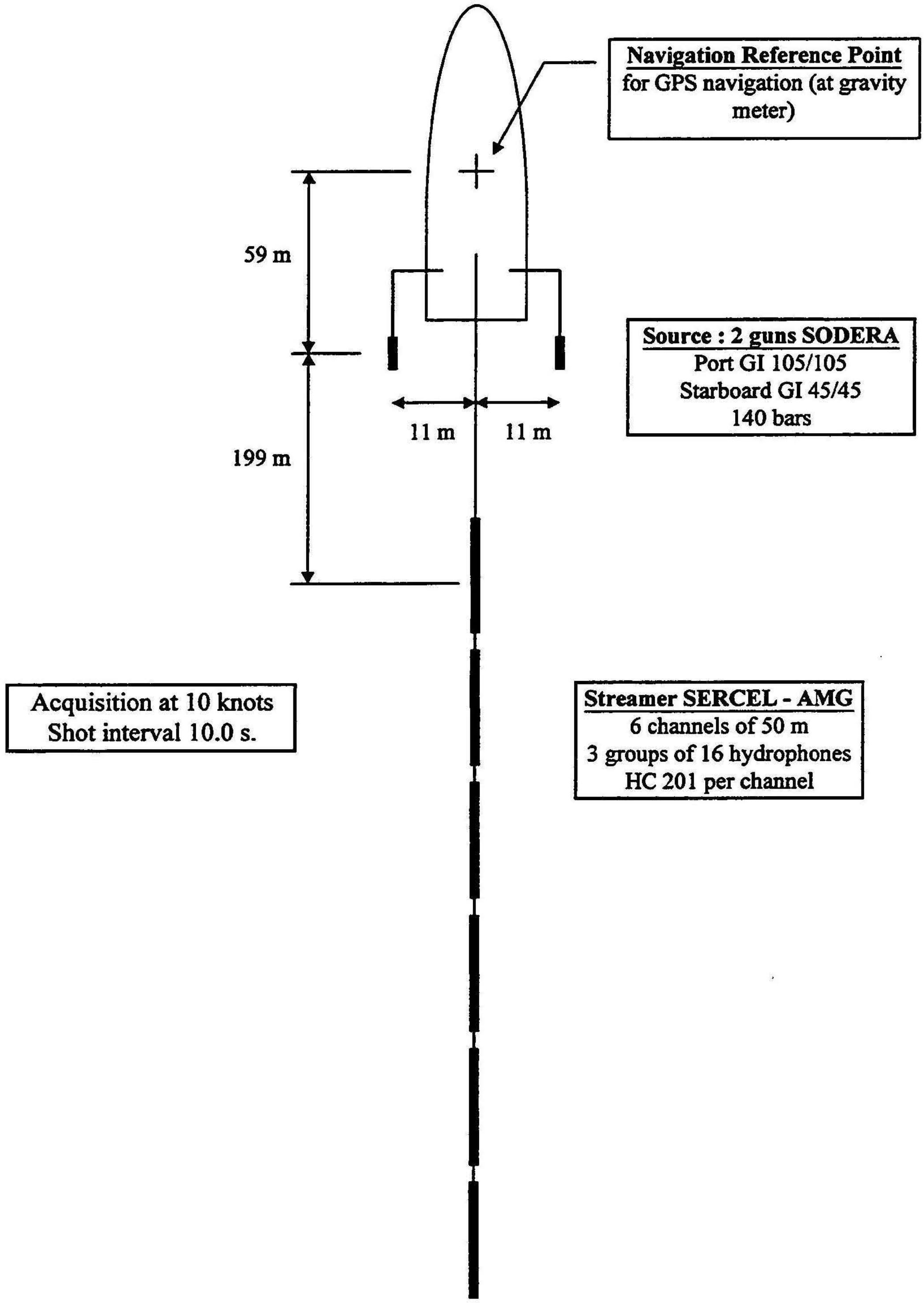
Magnetics

Magnetometer sensor towed 230 m astern

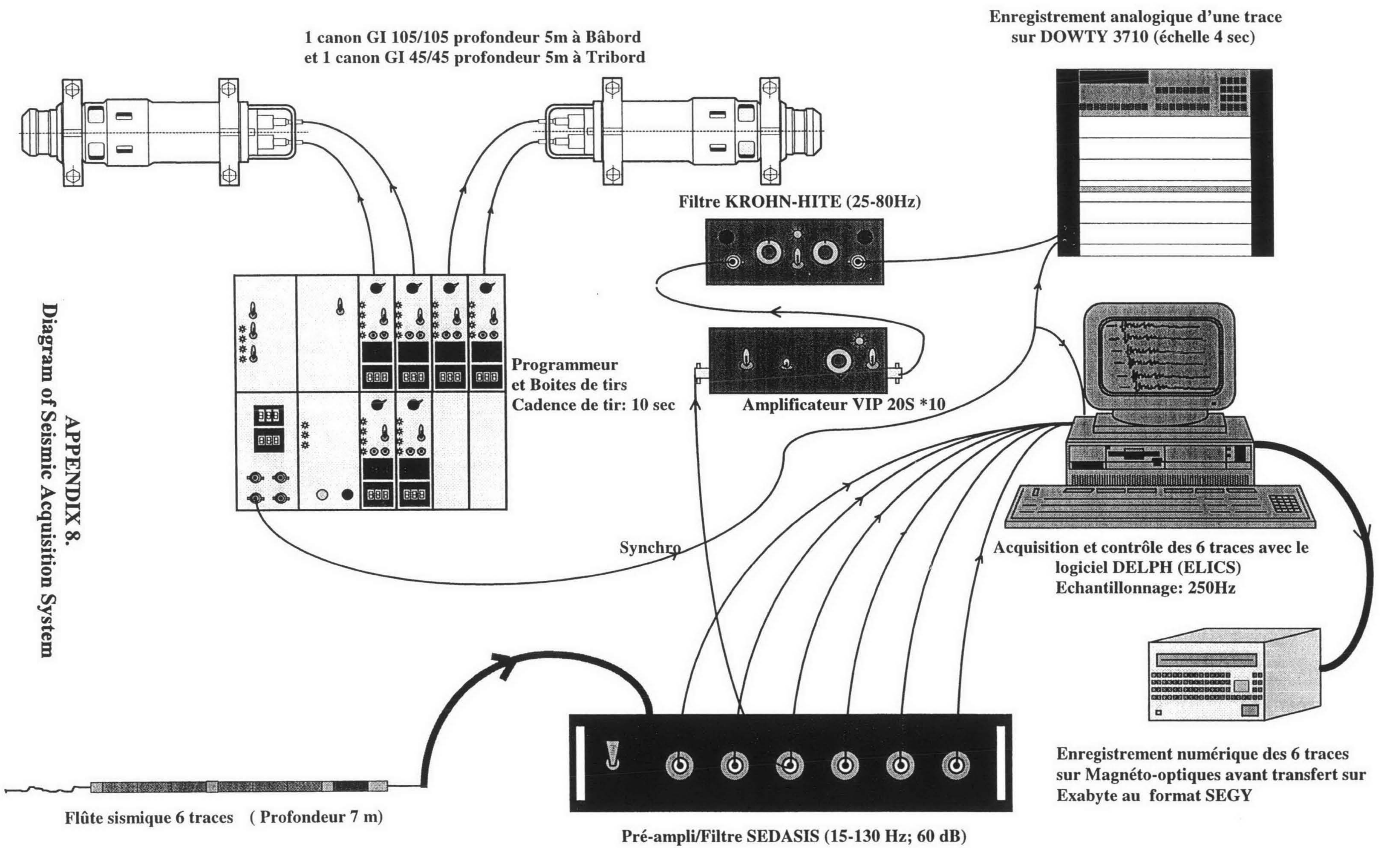


APPENDIX 7.
Geophysical Acquisition Geometry

GENAVIR - HIGH SPEED SEISMIC (SISMIQUE RAPIDE) - CONFIGURATION ON N/O L'ATALANTE



APPENDIX 8.
Diagram of Seismic Acquisition System



GENAVIR

APPENDIX 9.
Seismic Streamer Configuration

MISSION = AUSTREA1

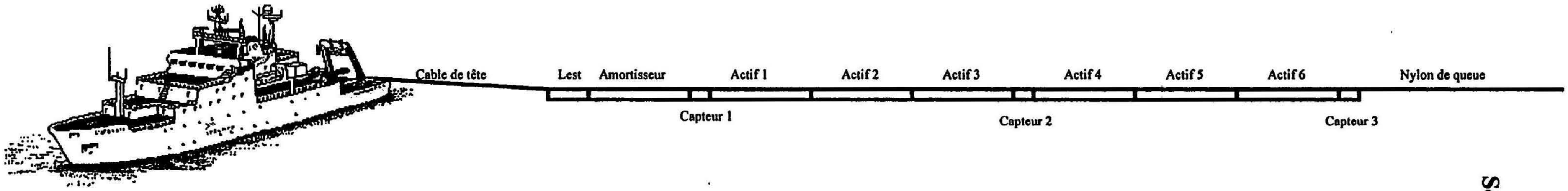
From 18 / 12 /1999 To 11 / 01 / 2000

NAVIRE = N/O ATALANTE

SISMIQUE RAPIDE (High speed seismic)

VITESSE 10 NOEUDS (speed 10 kts)

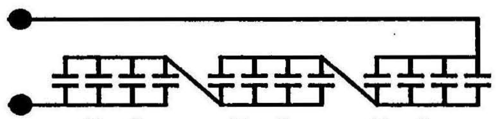
COMPOSITION DE LA FLUTE AMG (streamer configuration)



CABLE DE TETE (header cable, from stern)	**=**	**130 Mètres**
LEST (weigted section)	**=**	**7 Mètres**
AMORTISSEUR (stretch section)	**=**	**50 Mètres**
6 ACTIFS DE 50 M. (6 active sections, each 50 m)	**=**	**300 Mètres**
3 CAPTEURS DE 1 M.(DTs, 1m)	**=**	**3 Mètres**
NYLON DE QUEUE (tail rope)	**=**	**100 Mètres**
LONGUEUR TOTALE (total length)	**=**	**590 Mètres**

1 ACTIVE = 3x16 Hydrophones HC 201 in SERIES //

SCHEMATIC =



APPENDIX 10.
Seismic Profile and Shot Information

SEISMIC PROFILES

PROFILE NAME	BEGIN SHOT	TIME/DATE Begin		End		END SHOT
AEA 1001	1	22-Dec-99	23:32	22-Dec-99	3:58	1386
AEA 1002	1	23-Dec-99	4:00	23-Dec-99	17:03	4794
AEA 1003	1	23-Dec-99	17:07	23-Dec-99	11:10	6539
AEA 1004	1	24-Dec-99	11:12	25-Dec-99	1:15	5160
AEA 1005	1	25-Dec-99	1:16	25-Dec-99	5:03	1390
AEA 1006	1	25-Dec-99	5:21	25-Dec-99	15:14	3636
AEA 1007	1	25-Dec-99	15:15	25-Dec-99	18:53	1332
AEA 1008	1	25-Dec-99	18:53	25-Dec-99	21:10	837
AEA 1009	1	25-Dec-99	21:11	25-Dec-99	23:48	965
AEA 1010	1	25-Dec-99	23:49	26-Dec-99	2:31	996
AEA 1011	1	26-Dec-99	2:33	26-Dec-99	12:09	3532
AEA 1012	1	26-Dec-99	12:13	26-Dec-99	17:47	2042
AEA 1013	1	26-Dec-99	17:47	26-Dec-99	22:39	1786
AEA 10013b	1	26-Dec-99	22:46	26-Dec-99	23:11	153
AEA 1014	1	26-Dec-99	23:12	27-Dec-99	3:58	1750
AEA 1015	1	27-Dec-99	3:59	28-Dec-99	1:34	7932
AEA 1016	1	28-Dec-98	1:35	28-Dec-99	6:32	1818
AEA 1016b	1	28-Dec-99	7:08	28-Dec-99	14:58	2881
AEA 1017	1	28-Dec-99	14:59	28-Dec-99	19:30	1659
AEA 1018	1	28-Dec-99	19:30	28-Dec-99	22:42	1176
AEA 1019	1	28-Dec-99	22:43	29-Dec-98	1:19	959
AEA 1019b	1	29-Dec-99	1:40	29-Dec-98	1:48	50
AEA 1019c	1	29-Dec-99	4:56	29-Dec-99	4:49	1795
AEA 1020	1	29-Dec-99	9:50	29-Dec-99	22:47	4758
AEA 1021	1	29-Dec-99	22:48	31-Dec-99	21:58	17330
AEA 1022	1	02-Jan-00	3:30	02-Jan-00	9:06	2060
AEA 1023	1	02-Jan-00	9:07	02-Jan-00	16:13	2607
AEA 1023a	1	02-Jan-00	16:15	02-Jan-00	22:11	2186
AEA 1024	1	02-Jan-00	22:12	03-Jan-00	8:30	3787
AEA 1025	1	03-Jan-00	8:31	03-Jan-00	18:07	3628
AEA 1026	1	03-Jan-00	18:08	03-Jan-00	22:32	1620
AEA 1026a	1	03-Jan-00	22:33	04-Jan-00	0:25	683
AEA 1027	1	04-Jan-00	0:25	04-Jan-00	6:15	2141
AEA 1028	1	06-Jan-00	20:35	07-Jan-00	2:19	2103
AEA 1029	1	07-Jan-00	2:20	09-Jan-00	8:09	19769
AEA 1030	1	09-Jan-00	8:09	09-Jan-00	15:07	2555
AEA 1031	1	09-Jan-00	15:07	11-Jan-00	1:00	12442

Number of shots: 132237

19 days of seismic

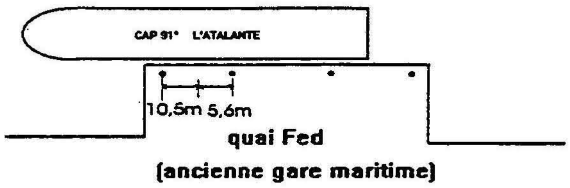
APPENDIX 11.
Gravity Tie Data Sheets for KSS-30 and BGM-5 Meters

Genavir *N/O L'Atalante*

Rattachement du Gravimètre Bodenseeverk KSS30
avec un gravimètre de rattachement Scintrex

Feuille N° **kss 201**

date	17-déc-99	*Lat.*	S 22 16	*escale*	NOUMEA
mission	AUSTREA-1	*Long.*	E 166 26	*observateurs*	SC,CL,JLB
				appareil de mesure	Scintrex CG-3 S/N 9704387



station de référence:

nom	IRD nouvelle base	
N°		
syst. réf.	IGSN 71	
Gref =	978865,33	*mGal*
H. eau : H =	1,47	*m*

quai: ☑ Creux ☐ Plein
(coeff C: creux=0.27; plein 019)

observations

Station	Grav.	SD.	Tilt x	Tilt y	Temp.	E.T.C.	Dur	# Rej	Time
1,	3280,38	0,058	3	-2	-0,17	-0,034	60	0	01:55:36
1,	3280,375	0,05	3	-3	-0,15	-0,035	60	0	01:57:13
1,	3280,375	0,049	3	-4	-0,13	-0,036	60	0	01:59:01
1,	3280,375	0,051	3	-4	-0,12	-0,037	60	0	02:00:54
1,	3280,375	0,042	2	-5	-0,1	-0,039	60	0	02:04:33
4,	3281,655	0,044	3	2	-0,13	-0,059	60	0	03:10:11
4,	3281,655	0,065	3	2	-0,13	-0,059	60	0	03:11:45
4,	3281,66	0,048	3	2	-0,13	-0,059	60	0	03:13:16
4,	3281,655	0,064	3	1	-0,12	-0,06	60	0	03:14:50
4,	3281,655	0,048	3	1	-0,11	-0,06	60	0	03:16:21
5,	3280,305	0,046	-1	-2	-0,11	-0,057	60	0	04:30:58
5,	3280,305	0,035	-1	-2	-0,1	-0,056	60	0	04:32:36
5,	3280,305	0,045	-1	-2	-0,11	-0,056	60	0	04:34:22
5,	3280,31	0,048	-1	-2	-0,11	-0,056	60	0	04:36:03
5,	3280,305	0,047	-2	-2	-0,11	-0,055	60	0	04:37:35

heures moyennes
(quai 1) t1 = **01:59**
(réf.) t0 = **03:13**
(quai 2) t2 = **04:34**

Grav. moyennes
G1 = **3280,376** *mGal (quai 1)*
G0 = **3281,656** *mGal (référence)*
G2 = **3280,306** *mGal (quai 2)*

dérive du Scintrex: (G2-G1)/(t2-t1)
DW = **-0,027** *mGal/h*
différence quai 1 - référence & quai 2 - référence
(G1-G0-DWx(t0-t1) *Δ1 =* **-1,280** *mGal*
(G2-G0-DWx(t2-t0) *Δ2 =* **-1,350** *mGal*

G abs. au quai [Gref+G2-G0-DWx(t2-t0)]: *Gquai =* **978864,026** *mGal*
correction de hauteur [CQxH]: *CH =* **0,397** *mGal*
G abs. rapporté au navire [Gquai + CH]: *Gnav =* **978864,423** *mGal*
GV relative lue sur le KSS30: *GV =* -1736,7 *mGal*

Rattachement précedent

date	13-oct-99	
escale	Nouméa	
GV0	-1738,1	*mGal*
Gnav0	978864,5	*mGal*

Correction de coefficient:
Ck = (GV-GV0).(Kreél/Kinst-1)
Ck = **-0,008** *mGal*
(Kréel = 8291; Kinst = 8336)

Dérive [(Gnav-(GV+Ck))-(Gnav0-GV0)]:
D = **-1,4596** *mGal*
Dm = **-0,6849** *mGal/mois*
Dj = **-0,0225** *mGal/jour*

Rattachement actuel
date *17-déc-99*
escale NOUMEA
GV ***-1736,7*** *mGal* *(valeurs entrées*
Gnav ***978864,4*** *mGal* *dans le gravi)*

Ball calibration [GV'-GV-CHx(t'-t)]:

	heure	haut. eau	GV
t			
t'			

Dg = ***0,0*** *mGal*
Valeur usine = *945,87* *mGal*

Genavir — *N/O L'Atalante*

Rattachement du Gravimètre
Lockheed Martin BGM-5
avec un gravimètre de rattachement Scintrex

Feuille N° **bgm 201**

17-déc-99	S 22 16
AUSTREA-1	E 166 26

escale NOUMEA
observateurs CL,SC,JLB
appareil de mesure Scintrex CG-3 S/N 9704387

station de référence:
nom IRD nouvelle base
N°
syst. réf. IGSN 71
Gref = 978865,33

H. eau à t2: H = 1,47 m

quai: ☑ Creux ☐ Plein
(coeff C: creux = 0.27; plein = 0.

observations

Station	Grav.	SD.	Tilt x	Tilt y	Temp.	E.T.C.	Dur	# Rej	Time
1,	3280,380	0,058	3	-2	-0,17	-0,034	60	0	01:55:36
1,	3280,375	0,050	3	-3	-0,15	-0,035	60	0	01:57:13
1,	3280,375	0,049	3	-4	-0,13	-0,036	60	0	01:59:01
1,	3280,375	0,051	3	-4	-0,12	-0,037	60	0	02:00:54
1,	3280,375	0,042	2	-5	-0,10	-0,039	60	0	02:04:33
4,	3281,655	0,044	3	2	-0,13	-0,059	60	0	03:10:11
4,	3281,655	0,065	3	2	-0,13	-0,059	60	0	03:11:45
4,	3281,660	0,048	3	2	-0,13	-0,059	60	0	03:13:16
4,	3281,655	0,064	3	1	-0,12	-0,06	60	0	03:14:50
4,	3281,655	0,048	3	1	-0,11	-0,06	60	0	03:16:21
5,	3280,305	0,046	-1	-2	-0,11	-0,057	60	0	04:30:58
5,	3280,305	0,035	-1	-2	-0,10	-0,056	60	0	04:32:36
5,	3280,305	0,045	-1	-2	-0,11	-0,056	60	0	04:34:22
5,	3280,310	0,048	-1	-2	-0,11	-0,056	60	0	04:36:03
5,	3280,305	0,047	-2	-2	-0,11	-0,055	60	0	04:37:35

heures moyennes
(quai 1) t1 = **01:59**
(réf.) t0 = **03:13**
(quai 2) t2 = **04:34**

Grav. moyennes
G1 = **3280,376** *mGal (quai 1)*
G0 = **3281,656** *mGal (référence)*
G2 = **3280,306** *mGal (quai 2)*

dérive du Scintrex: (G2-G1)/(t2-t1)
DW = **-0,027** *mGal/h*

différence quai 1 - référence & quai 2 - référence
(G1-G0-DWx(t0-t1) *Δ1 =* **-1,280** *mGal*
(G2-G0-DWx(t2-t0) *Δ2 =* **-1,350** *mGal*

G abs. au quai [Gref+G2-G0-DWx(t2-t0)]: *Gquai =* ***978864,050*** *mGal*
correction de hauteur [CQxH]: *CH =* ***0,397*** *mGal*
G abs. rapporté au navire [Gquai + CH]: *Gnav =* ***978864,447*** *mGal*
GV relative lue sur le BGM-5 (Filtered Gravity): *GV =* 978893,536 *mGal*

Rattachement précedent
date 13-oct-99
escale Noumea
GV0 978889,317
Gnav0 978864,539

Dérive BGM-5 [(GV-GV0)-(Gnav-Gnav0)]:
D = ***4,3111*** *mGal*
Dm = ***2,0229*** *mGal/mois*
Dj = ***0,0663*** *mGal/jour*

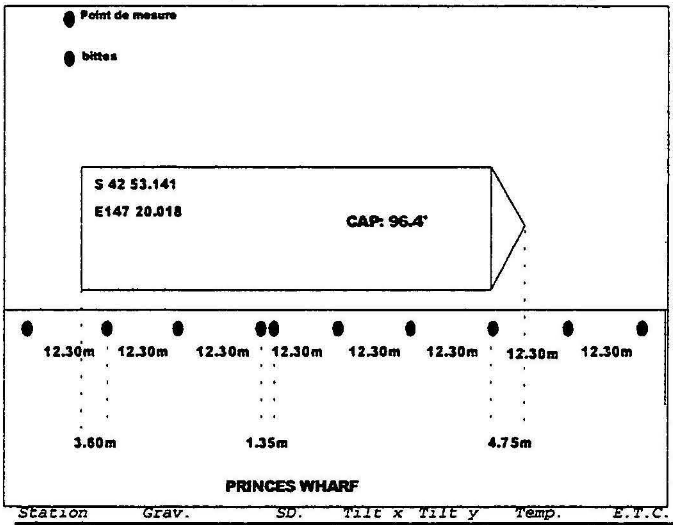
Genavir *N/O L'Atalante*

Rattachement du Gravimètre
Bodenseeverk KSS30
avec un gravimètre de rattachement Scintrex

Feuille N° **kss-202b**

date	13-jan-00	*lat.*	S 42 53,141
mission	Austrea-1	*long.*	E 147 20,018

escale	Hobart
observateurs	DV,HS,JLD
appareil de mesure	Scintrex CG-3 S/N 9704387



station de référence:

nom	Hobart Pier
N°	6 ~~4~~491,026
syst. réf.	IGSN84
Gref =	980437,25

H. eau à t2: H = 3,20 *m*

quai: ☒ Creux ☐ Plein
(coeff C: creux=0.27; plein 019)

observations

Station	Grav.	SD.	Tilt x	Tilt y	Temp.	E.T.C.	Dur	# Rej	Time
1	4567,710	0,053	5	4	-0,14	0,015	60	0	07:49:21
1	4567,710	0,055	5	6	-0,14	0,014	60	0	07:50:54
1	4567,715	0,057	5	5	-0,13	0,013	60	0	07:52:26
1	4567,710	0,063	5	1	-0,12	0,013	60	0	07:54:21
1	4567,710	0,063	5	1	-0,12	0,013	60	0	07:56:21
2	4566,470	0,052	0	-6	-0,12	0,006	60	0	08:15:25
2	4566,475	0,067	1	-7	-0,13	0,006	60	0	08:17:08
2	4566,475	0,054	1	-8	-0,12	0,005	60	0	08:18:44
2	4566,480	0,108	4	-1	-0,12	0,005	60	0	08:21:13
2	4566,475	0,059	4	-2	-0,11	0,004	60	0	08:22:46
3	4567,735	0,065	1	6	-0,19	0	60	0	08:35:41
3	4567,735	0,057	0	3	-0,15	-0,003	60	0	08:42:53
3	4567,730	0,054	0	3	-0,15	-0,004	60	0	08:44:38
3	4567,730	0,060	0	3	-0,15	-0,004	60	0	08:46:17
3	4567,730	0,050	1	3	-0,16	-0,005	60	0	08:47:57

heures moyennes
(quai 1) t1 = **07:52**
(réf.) t0 = **08:19**
(quai 2) t2 = **08:43**

Grav. moyennes

G1 = **4567,711** *mGal (quai 1)*
G0 = **4566,475** *mGal (référence)*
G2 = **4567,732** *mGal (quai 2)*

dérive du Scintrex: (G2-G1)/(t2-t1)
DW = ***0,025*** *mGal/h*

différence quai 1 - référence & quai 2 - référence
(G1-G0-DWx(t0-t1) *Δ1 =* ***1,236*** *mGal*
(G2-G0-DWx(t2-t0) *Δ2 =* ***1,257*** *mGal*

G abs. au quai [Gref+G2-G0-DWx(t2-t0)]: *Gquai =* ***980438,486*** *mGal*
correction de hauteur [CQxH]: *CH =* ***0,864*** *mGal*
G abs. rapporté au navire [Gquai + CH]: *Gnav =* ***980439,350*** *mGal*
GV relative lue sur le KSS30: *GV =* -153,1 *mGal*

Rattachement précedent

date	17-déc-99	
escale	Noumea	
GV0	-1736,7	*mGal*
Gnav0	978864,4	*mGal*

Dérive KSS30 [(Gnav-GV)-(Gnav0-GV0)]:
D = ***-8,6800*** *mGal*
Dm = ***-9,8052*** *mGal/mois*
Dj = ***-0,3215*** *mGal/jour*

Rattachement actuel
date *13-jan-00*
escale *Hobart*
GV ***-153,1*** *mGal* *(valeurs entrées*
Gnav ***980439,4*** *mGal* *dans le gravi)*

Ball calibration [GV'-GV-CHx(t'-t)]:

	heure	*haut. eau*	*GV*
t			
t'			

Dg = ***0,0*** *mGal*
Valeur usine = *945,87* *mGal*

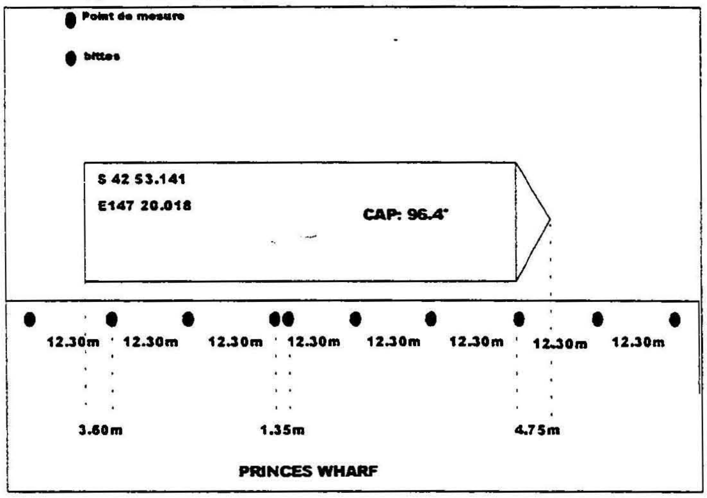
Genavir   *N/O L'Atalante*

Rattachement du Gravimètre
Lockheed Martin BGM-5
avec un gravimètre de rattachement Scintrex

Feuille N° **bgm-202b**

date 13-jan-00   *lat.* S 42 53,141
mission Austrea-1   *long.* E 147 20,018

escale Hobart
observateurs DV,HS,JLD
appareil de mesure Scintrex CG-3 S/N 9704387



station de référence:
nom Hobart Pier
N° 6X491,026
syst. réf. IGSN84
Gref = 980437,25

H. eau à t2: H = 3,20 *m*

quai: ☒ **Creux** ☐ **Plein**
(coeff C: creux = 0.27; plein = 0.

observations

Station	*Grav.*	*SD.*	*Tilt x*	*Tilt y*	*Temp.*	*E.T.C.*	*Dur*	*# Rej*	*Time*
1	4567,710	0,053	5	4	-0,14	0,015	60	0	07:49:21
1	4567,710	0,055	5	6	-0,14	0,014	60	0	07:50:54
1	4567,715	0,057	5	5	-0,13	0,013	60	0	07:52:26
1	4567,710	0,063	5	1	-0,12	0,013	60	0	07:54:21
1	4567,710	0,063	5	1	-0,12	0,013	60	0	07:56:21
2	4566,470	0,052	0	-6	-0,12	0,006	60	0	08:15:25
2	4566,475	0,067	1	-7	-0,13	0,006	60	0	08:17:08
2	4566,475	0,054	1	-8	-0,12	0,005	60	0	08:18:44
2	4566,480	0,108	4	-1	-0,12	0,005	60	0	08:21:13
2	4566,475	0,059	4	-2	-0,11	0,004	60	0	08:22:46
3	4567,735	0,060	1	4	-0,15	-0,002	60	0	08:41:11
3	4567,735	0,057	0	3	-0,15	-0,003	60	0	08:42:53
3	4567,730	0,054	0	3	-0,15	-0,004	60	0	08:44:38
3	4567,730	0,060	0	3	-0,15	-0,004	60	0	08:46:17
3	4567,730	0,050	1	3	-0,16	-0,005	60	0	08:47:57

heures moyennes
(quai 1) t1 = **07:52**
(réf.) t0 = **08:19**
(quai 2) t2 = **08:44**

Grav. moyennes
G1 = **4567,711** *mGal (quai 1)*
G0 = **4566,475** *mGal (référence)*
G2 = **4567,732** *mGal (quai 2)*

dérive du Scintrex: (G2-G1)/(t2-t1)
DW = **0,024** *mGal/h*
différence quai 1 - référence & quai 2 - référence
(G1-G0-DWx(t0-t1) *Δ1 =* **1,236** *mGal*
(G2-G0-DWx(t2-t0) *Δ2 =* **1,257** *mGal*

G abs. au quai [Gref+G2-G0-DWx(t2-t0)]: *Gquai =* ***980438,486*** *mGal*
correction de hauteur [CQxH]: *CH =* ***0,864*** *mGal*
G abs. rapporté au navire [Gquai + CH]: *Gnav =* ***980439,350*** *mGal*
GV relative lue sur le BGM-5 (Filtered Gravity): *GV =* 980469,314 *mGal*

Rattachement précedent
date 17-déc-99
escale NOUMEA
GV0 978893,536
Gnav0 978864,447

Dérive BGM-5 [(GV-GV0)-(Gnav-Gnav0)]:
D = ***0,8750*** *mGal*
Dm = ***0,9884*** *mGal/mois*
Dj = ***0,0324*** *mGal/jour*

Genavir **N/O L'Atalante**

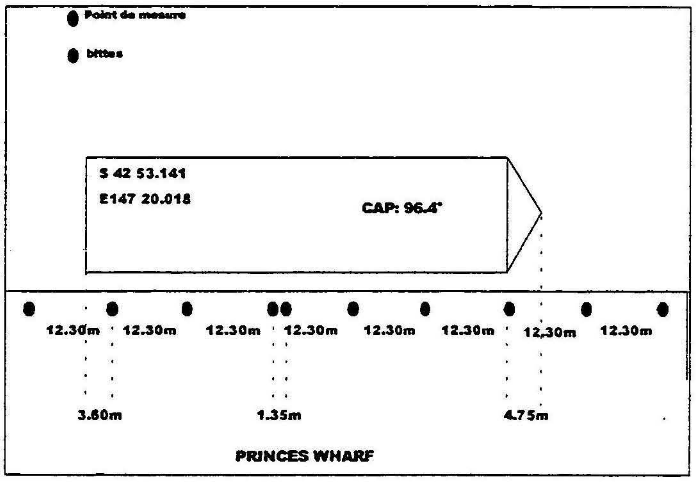
Rattachement du Gravimètre Bodenseeverk KSS30

avec un gravimètre de rattachement Scintrex

Feuille N° **kss-202**

date	13-jan-00	lat.	S 42 53,141
mission	Austrea-1	long.	E 147 20,018

escale	Hobart
observateurs	DV,HS,JLD
appareil de mesure	Scintrex CG-3 S/N 9704387



station de référence:

nom	Utas Geology
N°	7499,016
syst. réf.	IGSN84
Gref =	980417,823

H. eau à t2: H = 3,20 m

quai: ☒ Creux ☐ Plein
(coeff C: creux=0.27; plein 019)

observations

Station	Grav.	SD.	Tilt x	Tilt y	Temp.	E.T.C.	Dur	# Rej	Time
1	4567,790	0,080	2	-1	-0,26	-0,081	60	0	22:22:53
1	4567,785	0,092	1	-1	-0,26	-0,081	60	0	22:24:37
1	4567,795	0,079	1	0	-0,24	-0,081	60	0	22:26:12
1	4567,785	0,066	1	1	-0,23	-0,081	60	0	22:27:45
1	4567,790	0,064	1	2	-0,23	-0,081	60	0	22:29:34
2	4547,120	0,089	0	-1	-0,18	-0,068	60	0	23:53:44
2	4547,125	0,097	-1	-1	-0,18	-0,067	60	0	23:55:12
2	4547,120	0,079	-1	-1	-0,18	-0,067	60	0	23:56:43
2	4547,120	0,077	-1	-1	-0,18	-0,066	60	0	23:58:10
2	4547,125	0,095	-1	-1	-0,18	-0,066	60	0	23:59:37
3	4567,805	0,073	0	-5	-0,16	-0,05	60	0	00:47:12
3	4567,805	0,103	0	-4	-0,16	-0,05	60	0	00:48:45
3	4567,810	0,120	0	-4	-0,15	-0,049	60	0	00:50:15
3	4567,805	0,094	0	-5	-0,16	-0,049	60	0	00:51:58
3	4567,805	0,078	-1	-5	-0,16	-0,047	60	0	00:54:56

heures moyennes

(quai 1)	t1 =	**22:26**
(réf.)	t0 =	**23:56**
(quai 2)	t2 =	**00:50**

Grav. moyennes

G1 =	**4567,789**	mGal	(quai 1)
G0 =	**4547,122**	mGal	(référence)
G2 =	**4567,806**	mGal	(quai 2)

dérive du Scintrex: (G2-G1)/(t2-t1)

DW = **-0,001** mGal/h

différence quai 1 - référence & quai 2 - référence

(G1-G0-DWx(t0-t1) Δ1 = **20,667** mGal

(G2-G0-DWx(t2-t0) Δ2 = **20,684** mGal

G abs. au quai [Gref+G2-G0-DWx(t2-t0)]:	Gquai =	**980438,490**	mGal
correction de hauteur [CQxH]:	CH =	**0,864**	mGal
G abs. rapporté au navire [Gquai + CH]:	Gnav =	**980439,354**	mGal
GV relative lue sur le KSS30:	GV =	-153,1	mGal

Rattachement précedent

date	17-déc-99	
escale	Noumea	
GV0	-1736,7	mGal
Gnav0	978864,4	mGal

Dérive KSS30 [(Gnav-GV)-(Gnav0-GV0)]:

D =	**-8,6760**	mGal
Dm =	**-9,8007**	mGal/mois
Dj =	**-0,3213**	mGal/jour

Rattachement actuel

date	13-jan-00	
escale	Hobart	
GV	**-153,1** mGal	(valeurs entrées
Gnav	**980439,4** mGal	dans le gravi)

Ball calibration [GV'-GV-CHx(t'-t)]:

	heure	haut. eau	GV
t	03:15	2,70	-152,8
t'	04h38	2,70	792,1

Dg = **944,9** mGal

Valeur usine = 945,87 mGal

Genavir *N/O L'Atalante*

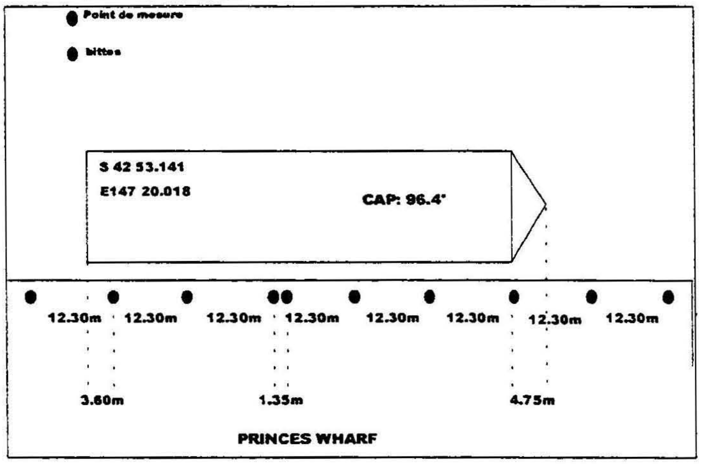
Rattachement du Gravimètre Lockheed Martin BGM-5

avec un gravimètre de rattachement Scintrex

Feuille N° **bgm-202**

date	13-jan-00	*lat.*	S 42 53,141
mission	Austrea-1	*long.*	E 147 20,018

escale	Hobart
observateurs	DV,HS,JLD
appareil de mesure	Scintrex CG-3 S/N 9704387



station de référence:

nom	Utas Geology
N°	7499,016
syst. réf.	IGSN84
Gref =	980417,823

H. eau à t2: H = 3,20 *m*

quai: ☒ **Creux** ☐ **Plein**

(coeff C: creux = 0.27; plein = 0.

observations

Station	Grav.	SD.	Tilt x	Tilt y	Temp.	E.T.C.	Dur	# Rej	Time
1	4567,790	0,080	2	-1	-0,26	-0,081	60	0	22:22:53
1	4567,785	0,092	1	-1	-0,26	-0,081	60	0	22:24:37
1	4567,795	0,079	1	0	-0,24	-0,081	60	0	22:26:12
1	4567,785	0,066	1	1	-0,23	-0,081	60	0	22:27:45
1	4567,790	0,064	1	2	-0,23	-0,081	60	0	22:29:34
2	4547,120	0,089	0	-1	-0,18	-0,068	60	0	23:53:44
2	4547,125	0,097	-1	-1	-0,18	-0,067	60	0	23:55:12
2	4547,120	0,079	-1	-1	-0,18	-0,067	60	0	23:56:43
2	4547,120	0,077	-1	-1	-0,18	-0,066	60	0	23:58:10
2	4547,125	0,095	-1	-1	-0,18	-0,066	60	0	23:59:37
3	4567,805	0,073	0	-5	-0,16	-0,05	60	0	00:47:12
3	4567,805	0,103	0	-4	-0,16	-0,05	60	0	00:48:45
3	4567,810	0,120	0	-4	-0,15	-0,049	60	0	00:50:15
3	4567,805	0,094	0	-5	-0,16	-0,049	60	0	00:51:58
3	4567,805	0,078	-1	-5	-0,16	-0,047	60	0	00:54:56

heures moyennes

(quai 1) t1 = **22:26**
(réf.) t0 = **23:56**
(quai 2) t2 = **00:50**

Grav. moyennes

G1 = **4567,789** *mGal (quai 1)*
G0 = **4547,122** *mGal (référence)*
G2 = **4567,806** *mGal (quai 2)*

dérive du Scintrex: (G2-G1)/(t2-t1)

DW = **-0,001** *mGal/h*

différence quai 1 - référence & quai 2 - référence

(G1-G0-DWx(t0-t1) *Δ1 =* **20,667** *mGal*
(G2-G0-DWx(t2-t0) *Δ2 =* **20,684** *mGal*

G abs. au quai [Gref+G2-G0-DWx(t2-t0)]: *Gquai =* **980438,490** *mGal*
correction de hauteur [CQxH]: *CH =* **0,864** *mGal*
G abs. rapporté au navire [Gquai + CH]: *Gnav =* **980439,354** *mGal*
GV relative lue sur le BGM-5 (Filtered Gravity): *GV =* 980468,956 *mGal*

Rattachement précedent

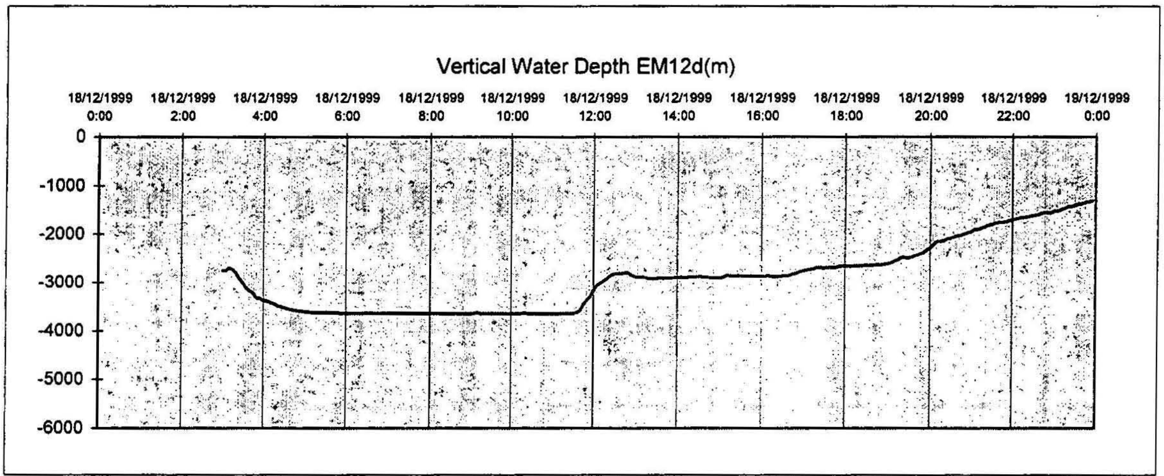
date	17-déc-99
escale	NOUMEA
GV0	978893,536
Gnav0	978864,447

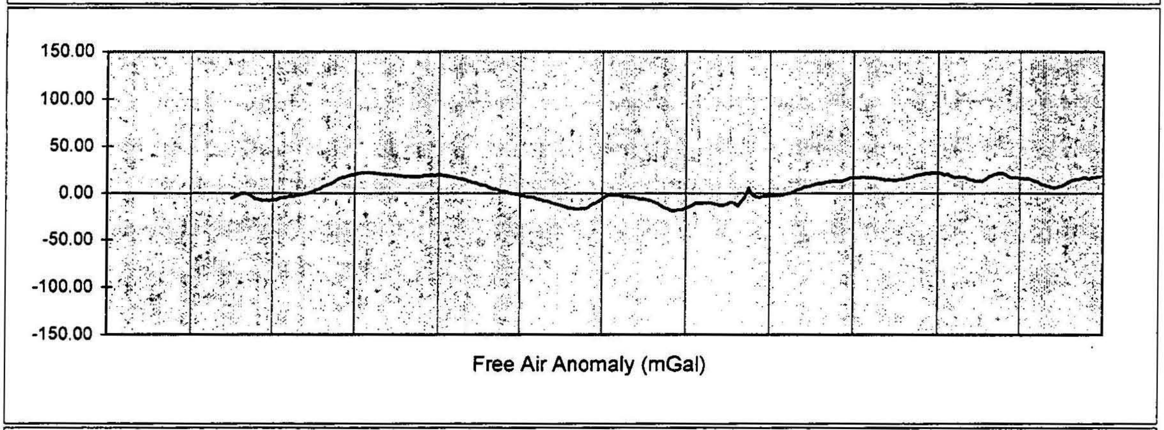
Dérive BGM-5 [(GV-GV0)-(Gnav-Gnav0)]:

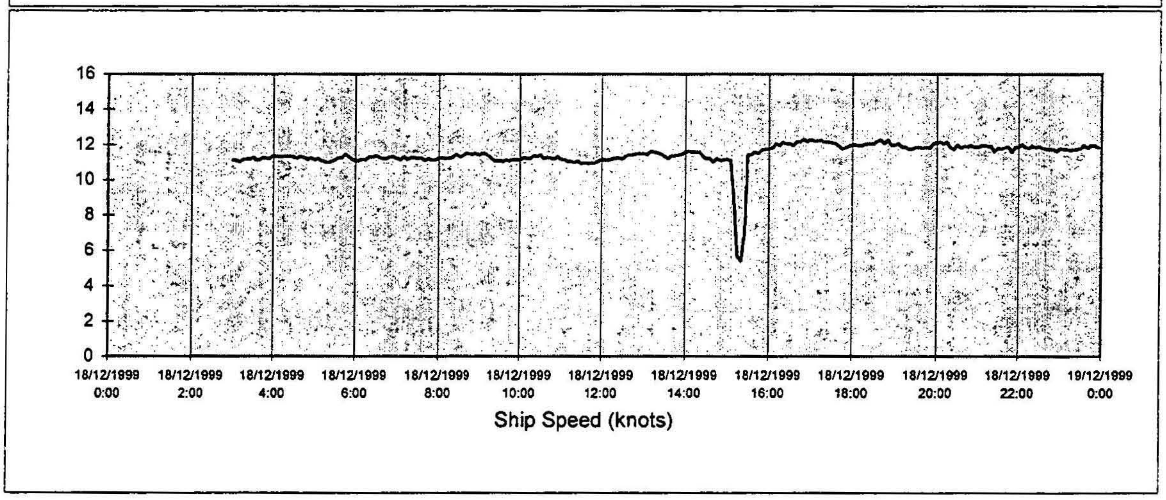
D = **0,5130** *mGal*
Dm = **0,5795** *mGal/mois*
Dj = **0,0190** *mGal/jour*

APPENDIX 12.
Daily Profiles of Vertical Depth, 'Free-air Gravity Anomaly', Total Magnetic Field and Ship's Speed

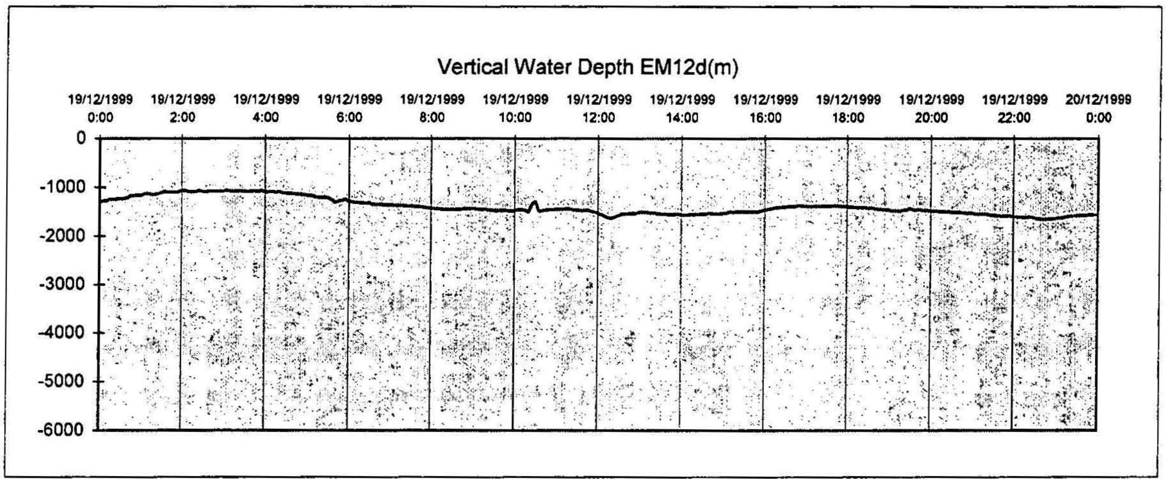
AUSTREA-1 Survey Charts
18/12/1999

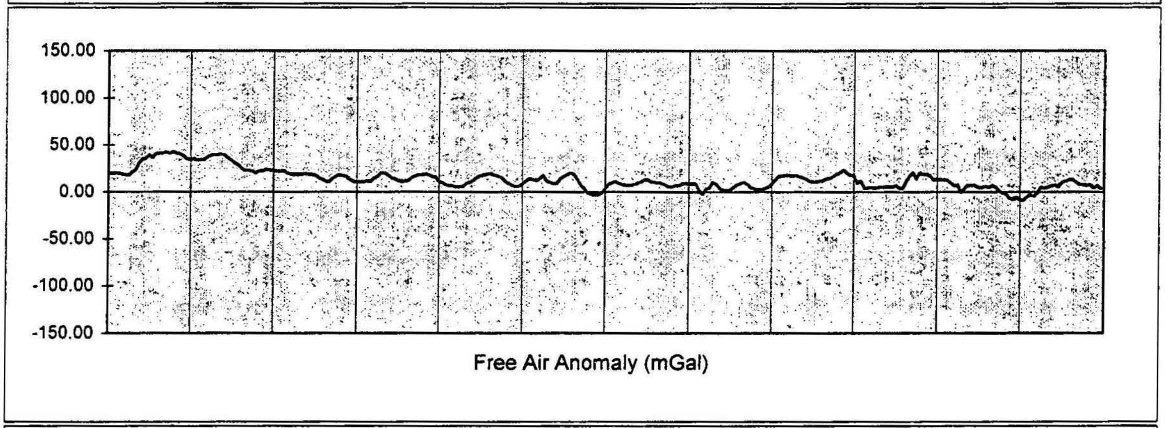


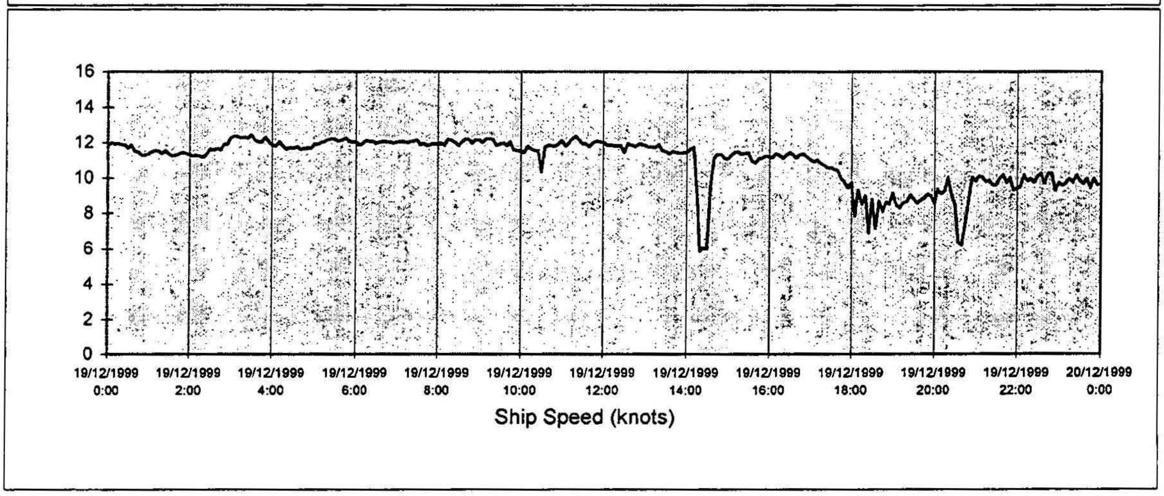




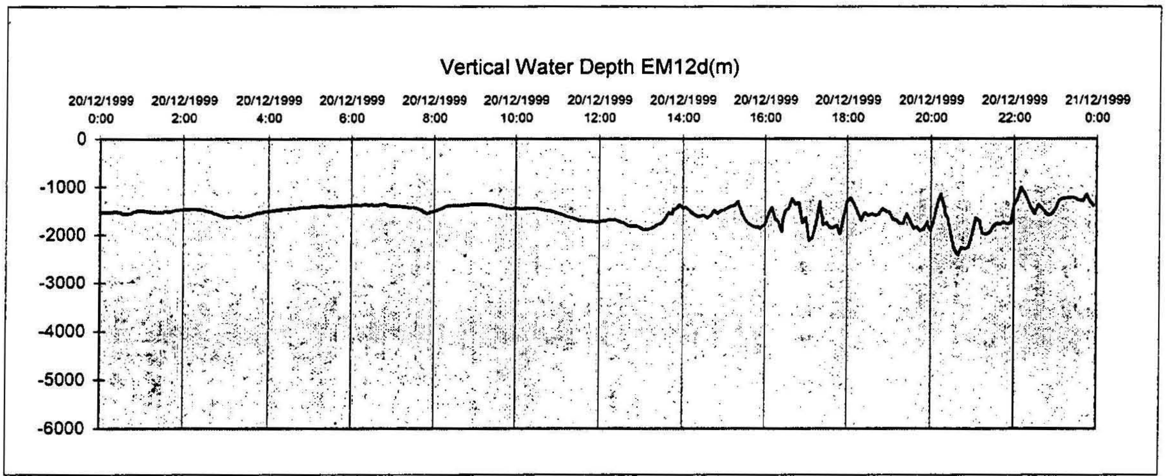
AUSTREA-1 Survey Charts
19/12/1999

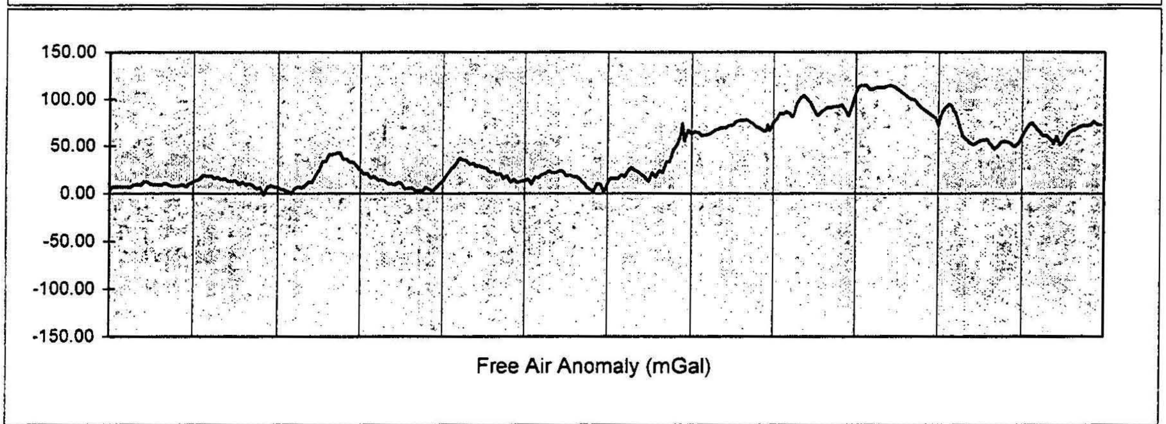


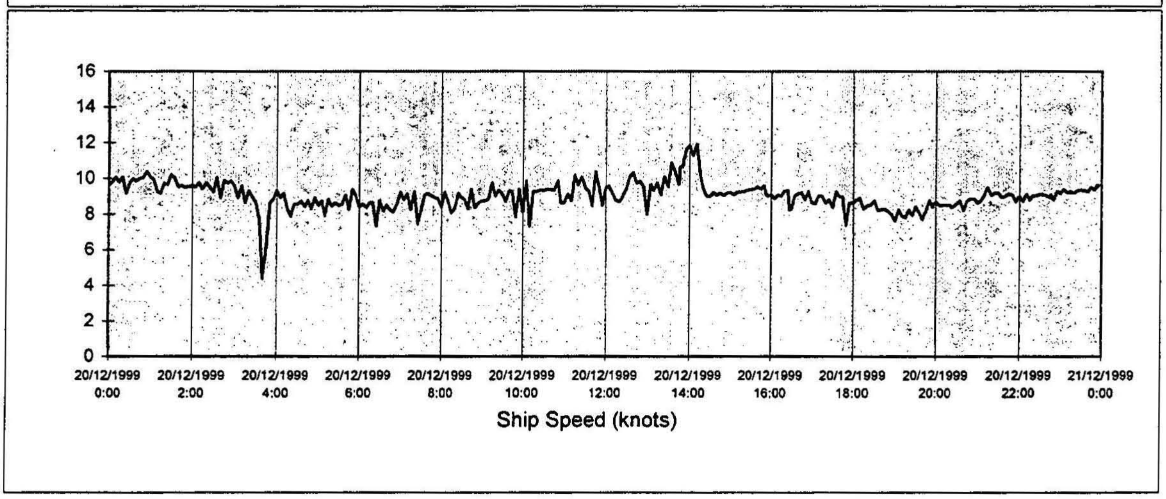




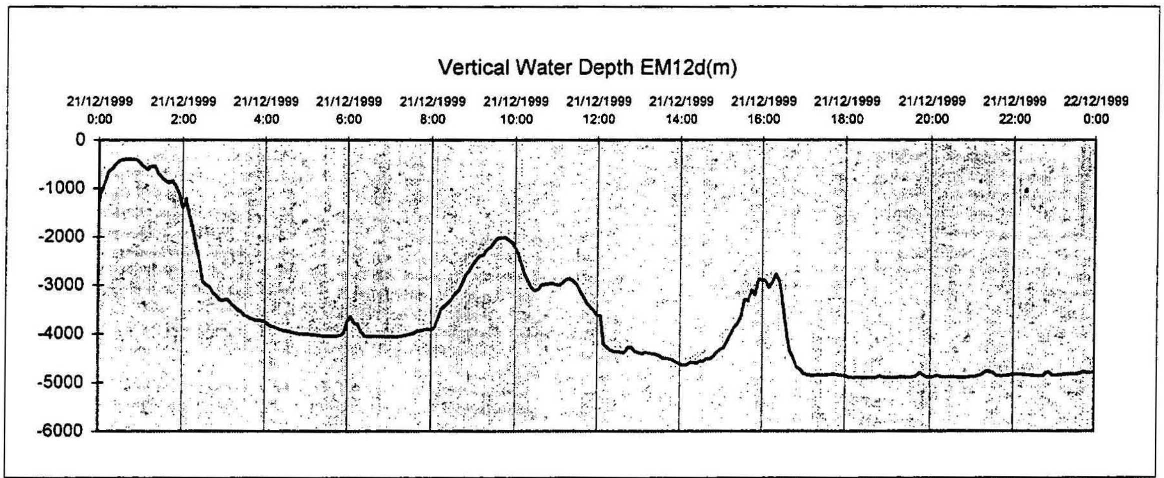
AUSTREA-1 Survey Charts
20/12/1999

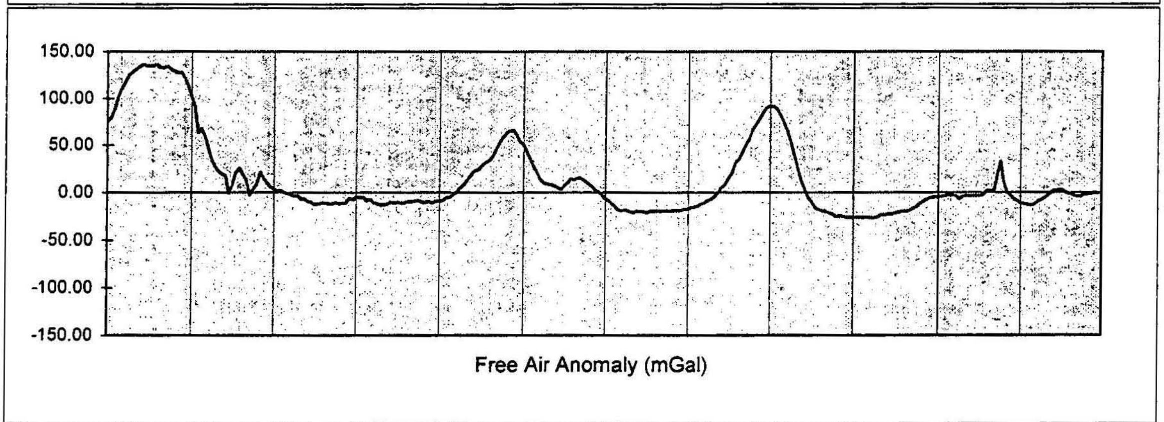


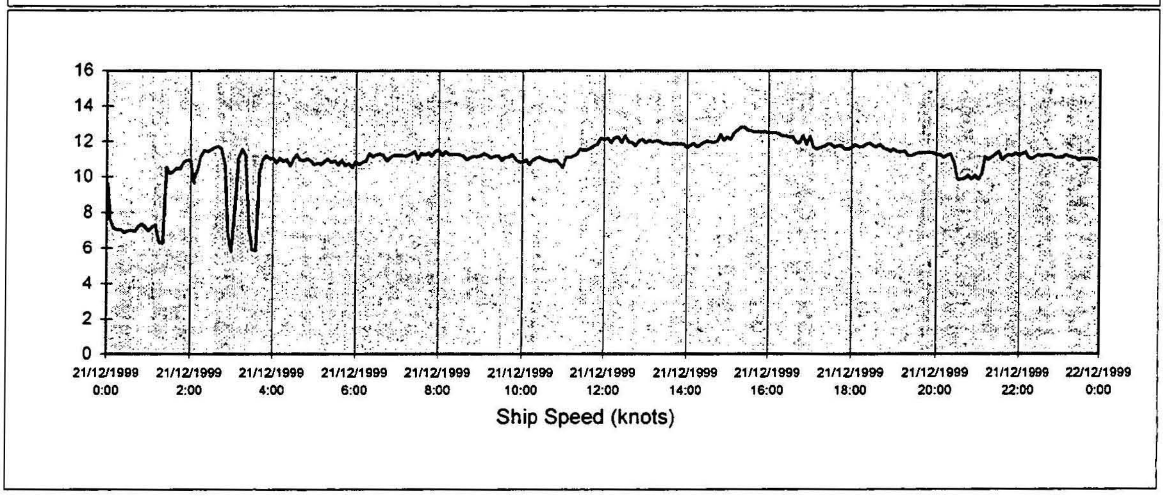




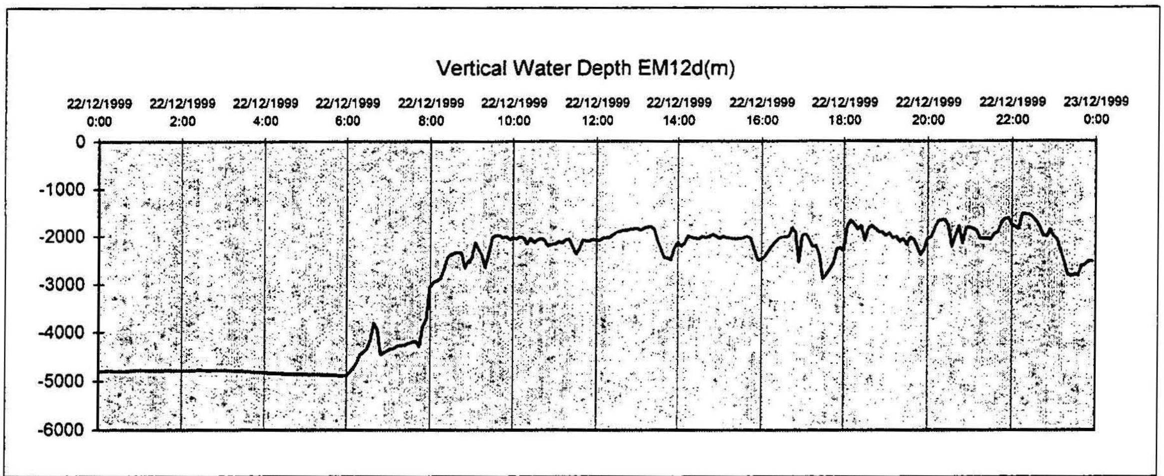
AUSTREA-1 Survey Charts
21/12/1999

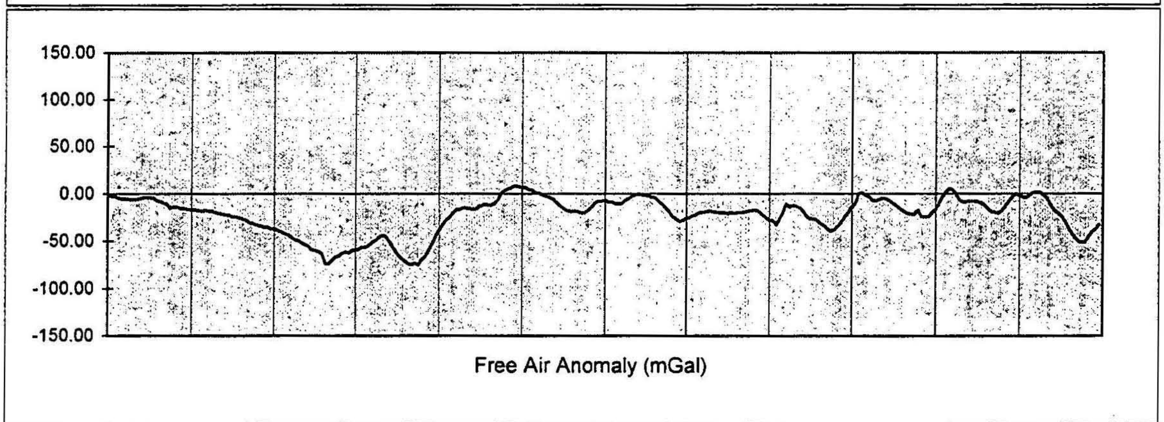


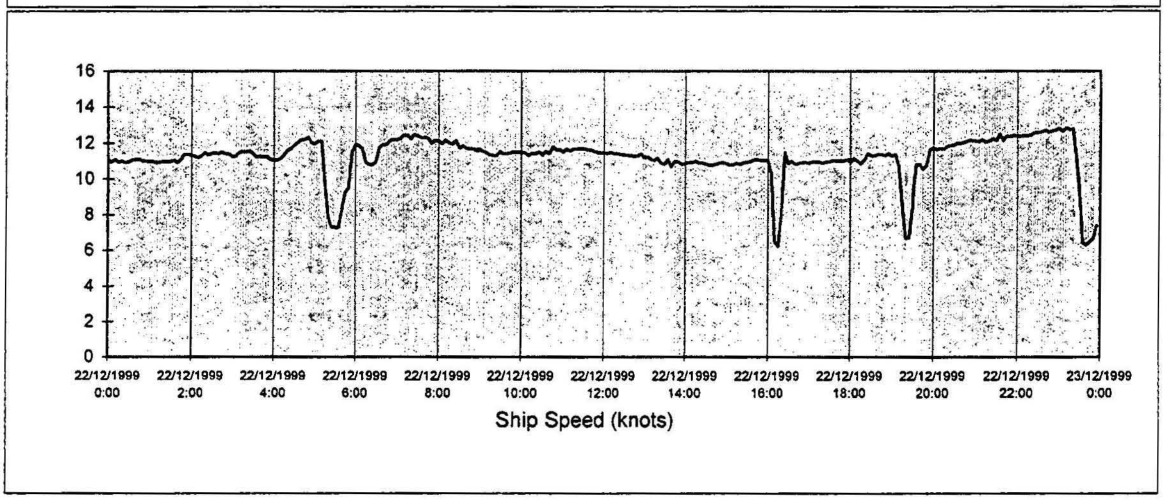


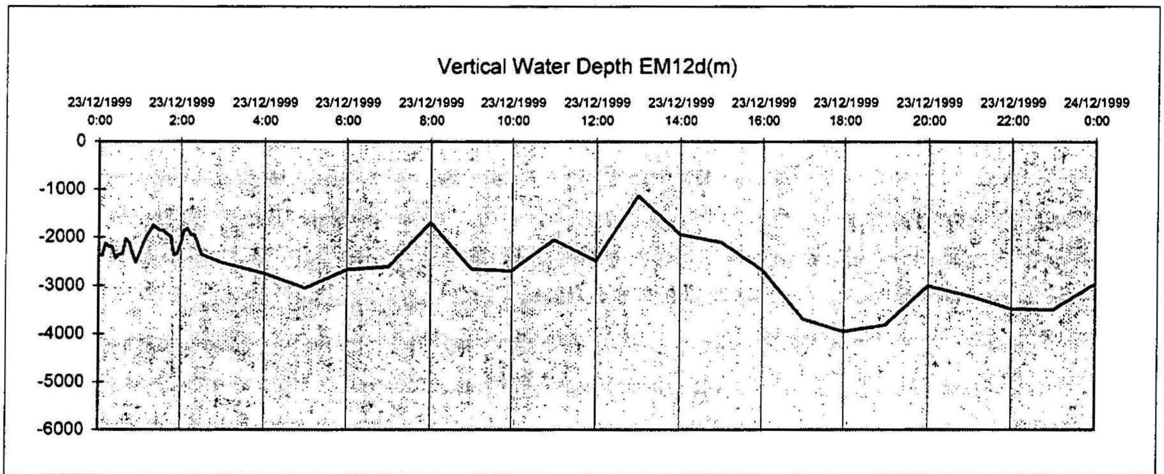


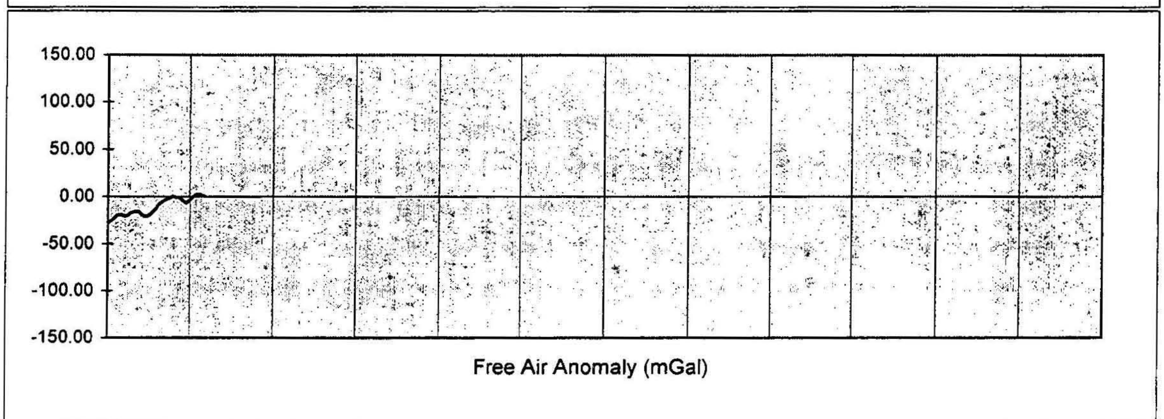
AUSTREA-1 Survey Charts
22/12/1999

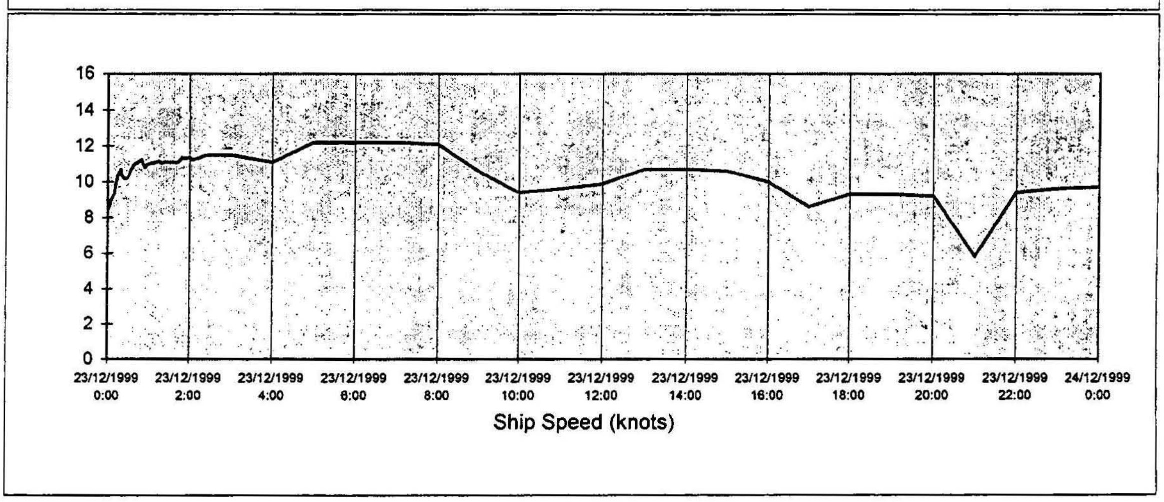







Vertical Water Depth EM12d(m)
23/12/1999 0:00
23/12/1999 2:00
23/12/1999 4:00
23/12/1999 6:00
23/12/1999 8:00
23/12/1999 10:00
23/12/1999 12:00
23/12/1999 14:00
23/12/1999 16:00
23/12/1999 18:00
23/12/1999 20:00
23/12/1999 22:00
24/12/1999 0:00
0
-1000
-2000
-3000
-4000
-5000
-6000


150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
Free Air Anomaly (mGal)


16
14
12
10
8
6
4
2
0
23/12/1999 0:00
23/12/1999 2:00
23/12/1999 4:00
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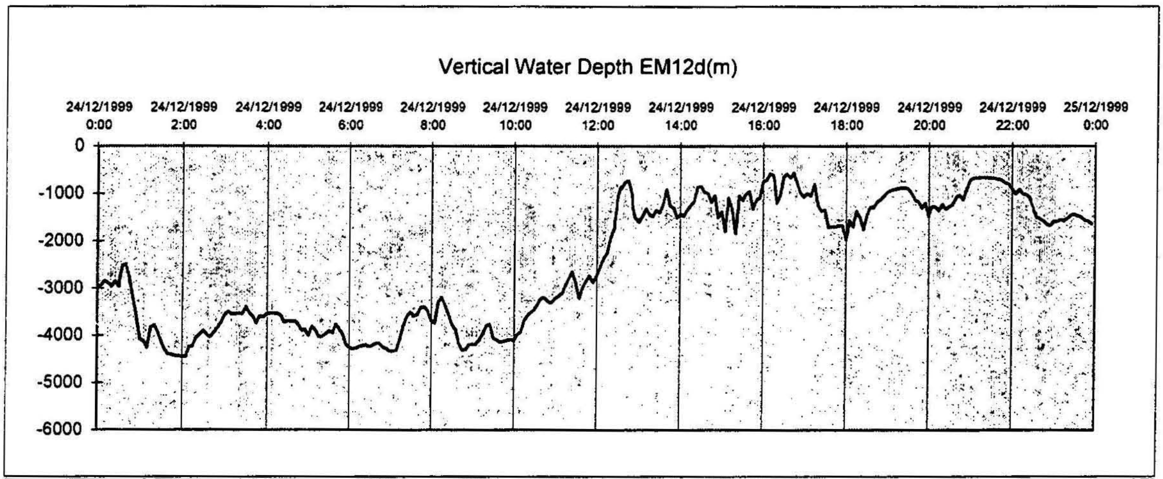
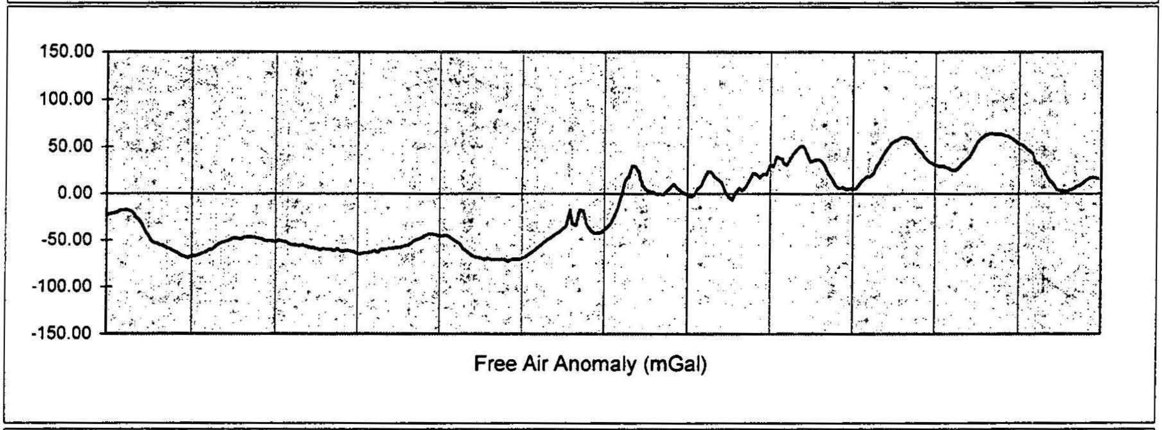
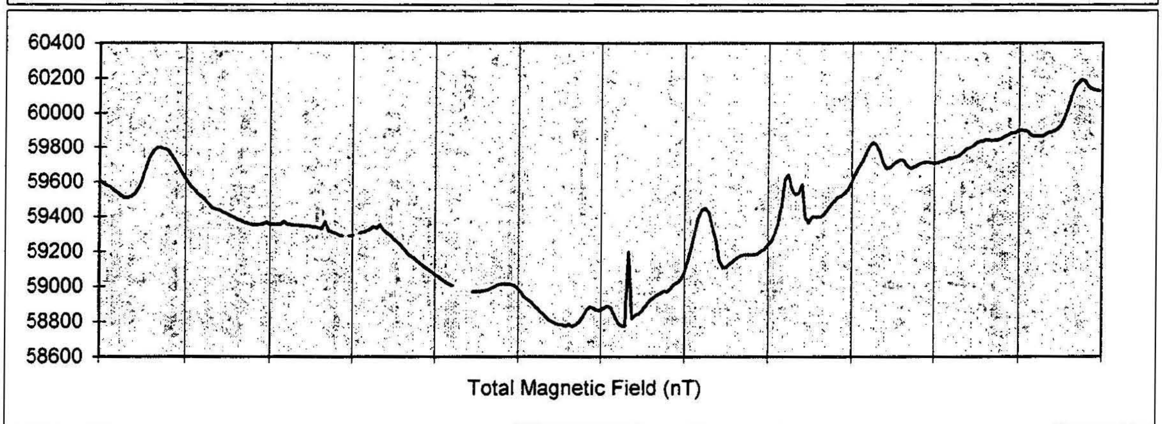
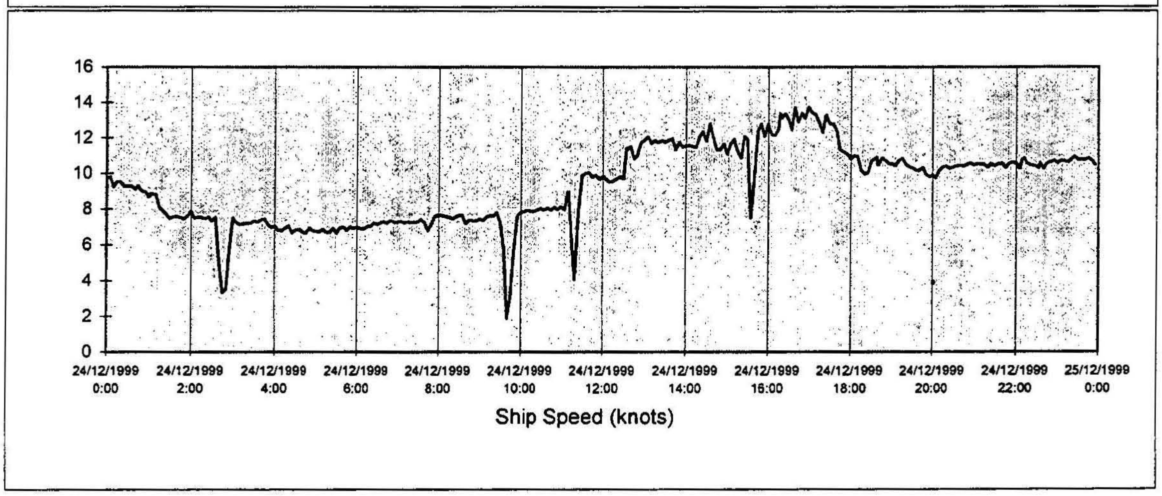
23/12/1999 8:00
23/12/1999 10:00
23/12/1999 12:00
23/12/1999 14:00
23/12/1999 16:00
23/12/1999 18:00
23/12/1999 20:00
23/12/1999 22:00
24/12/1999 0:00
Ship Speed (knots)

AUSTREA-1 Survey Charts
24/12/1999

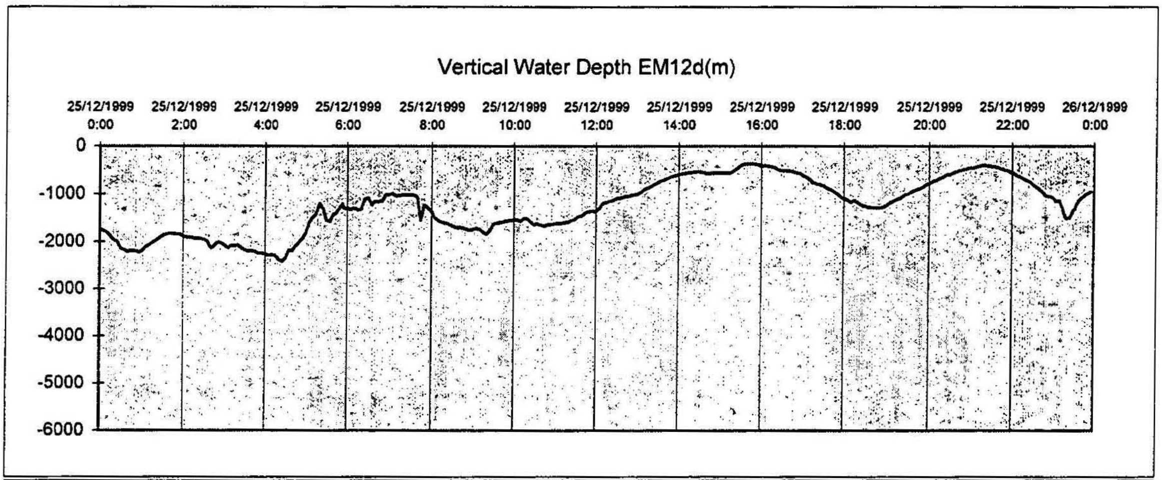


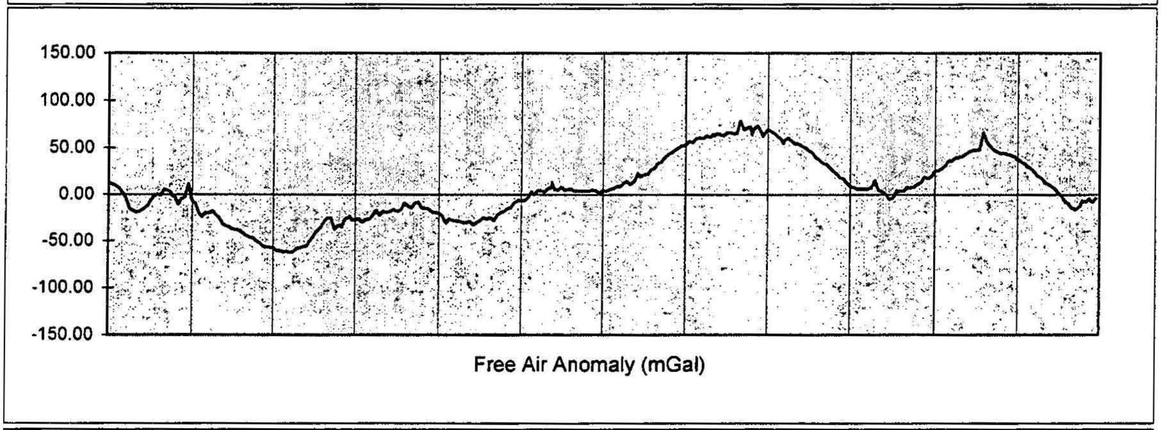


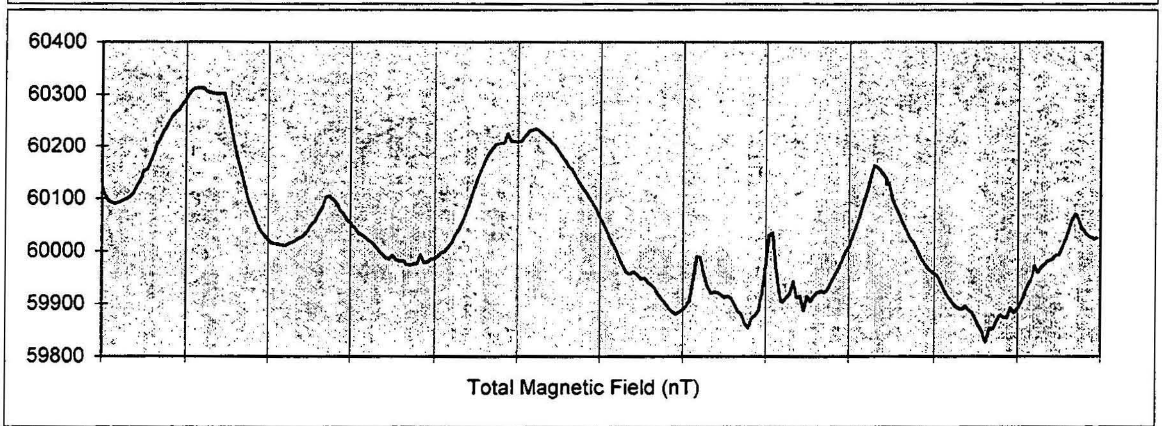


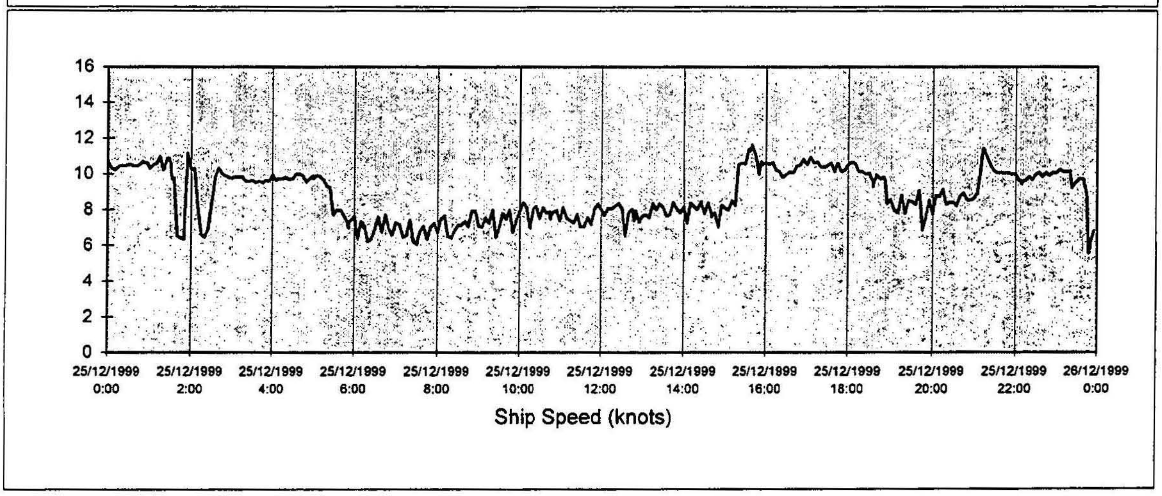


AUSTREA-1 Survey Charts
25/12/1999

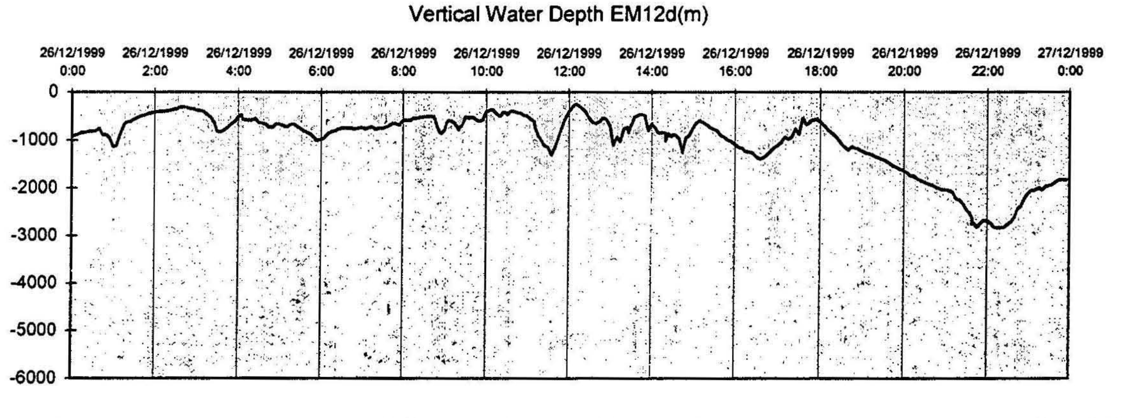


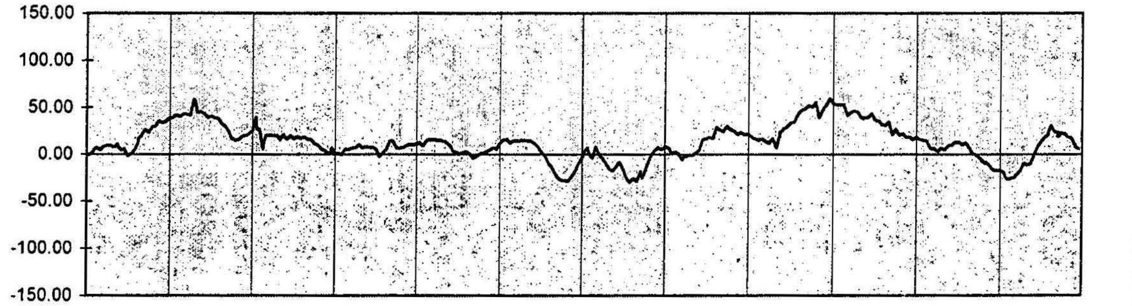




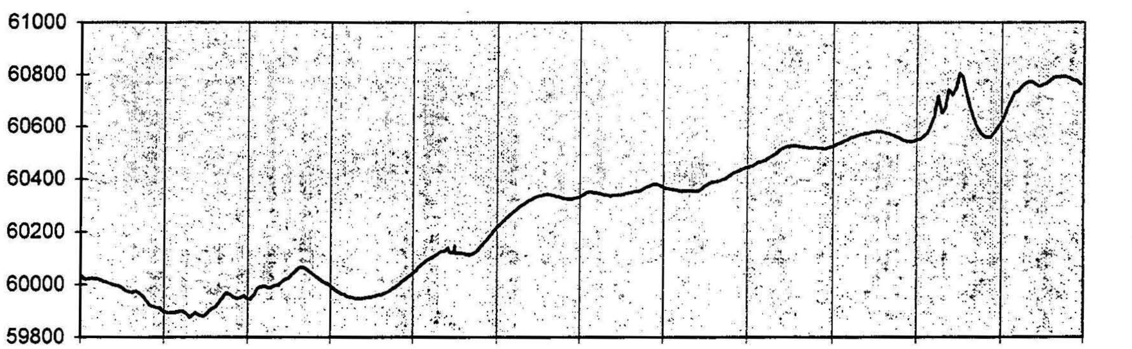


AUSTREA-1 Survey Charts
26/12/1999

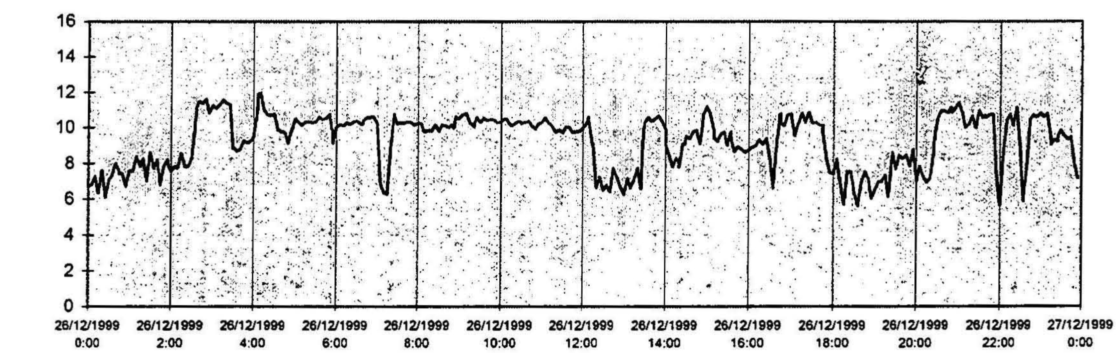




Free Air Anomaly (mGal)

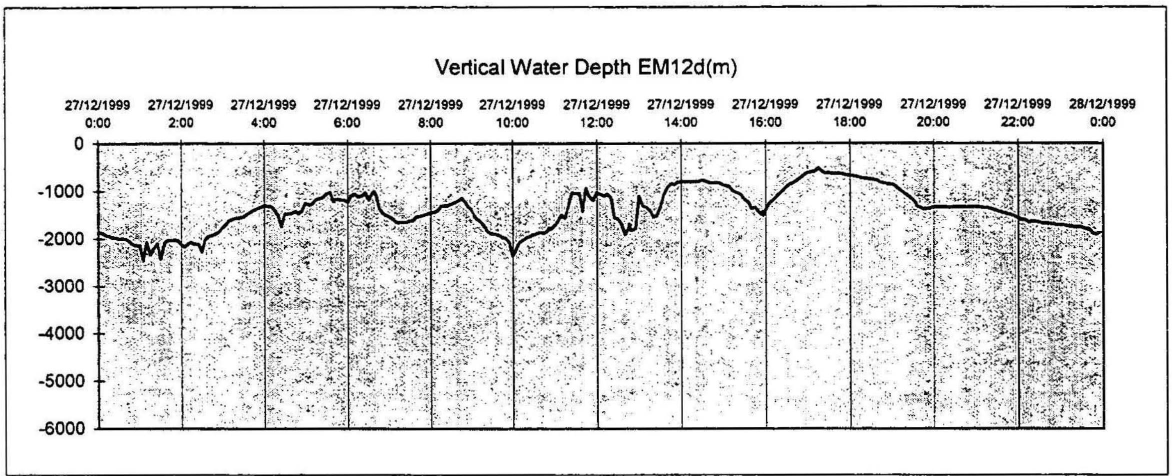


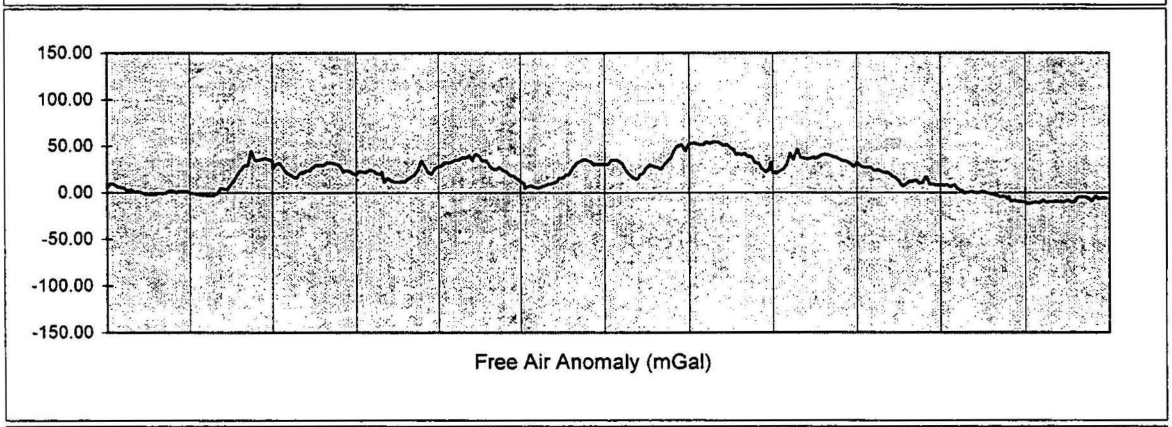
Total Magnetic Field (nT)

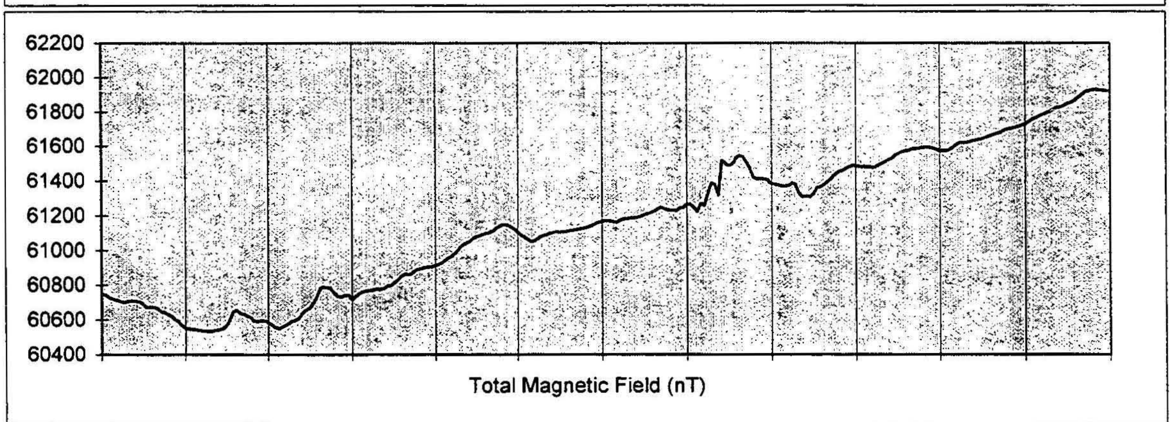


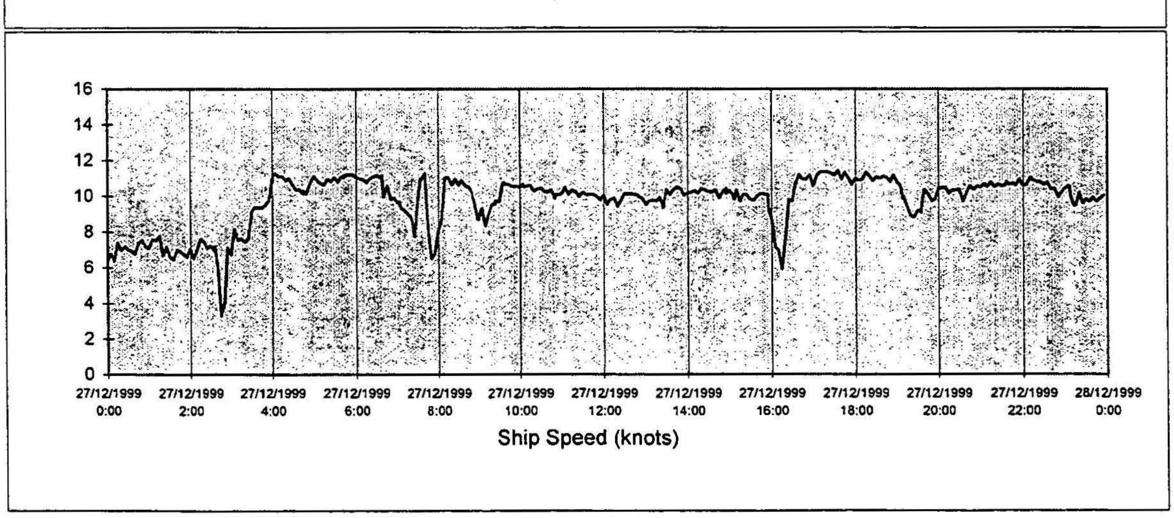
Ship Speed (knots)

AUSTREA-1 Survey Charts
27/12/1999

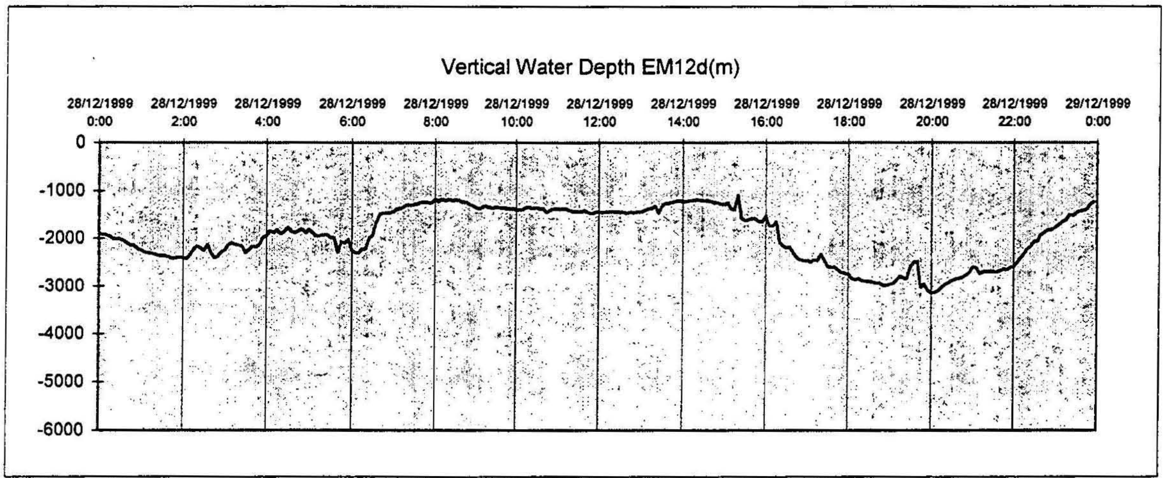


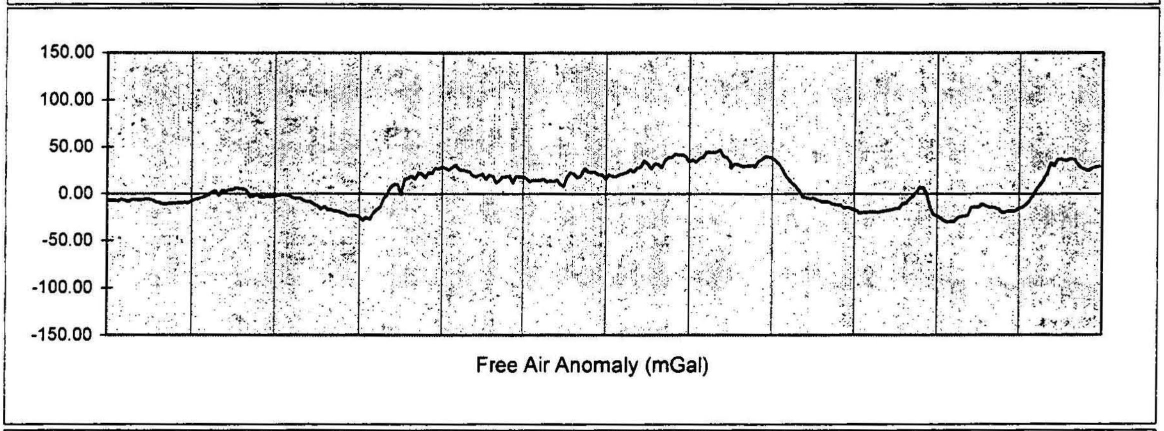


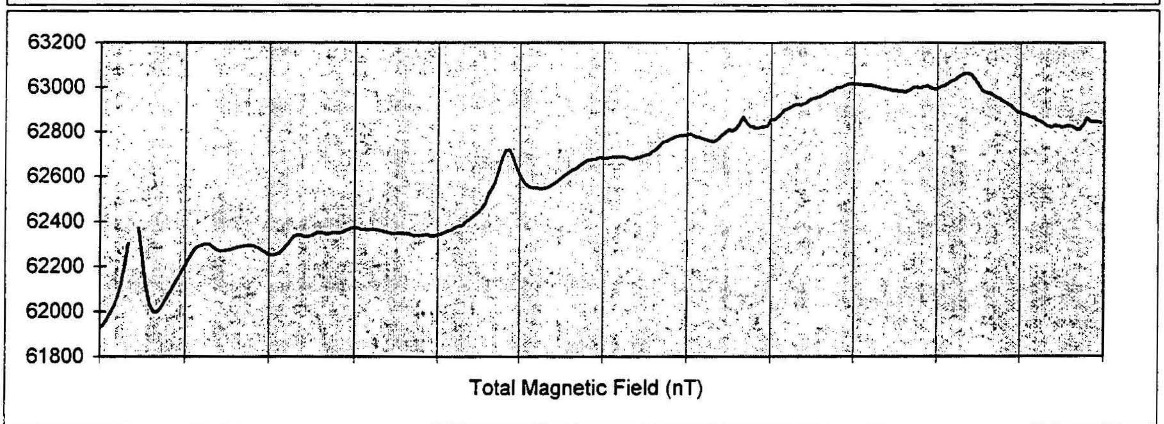


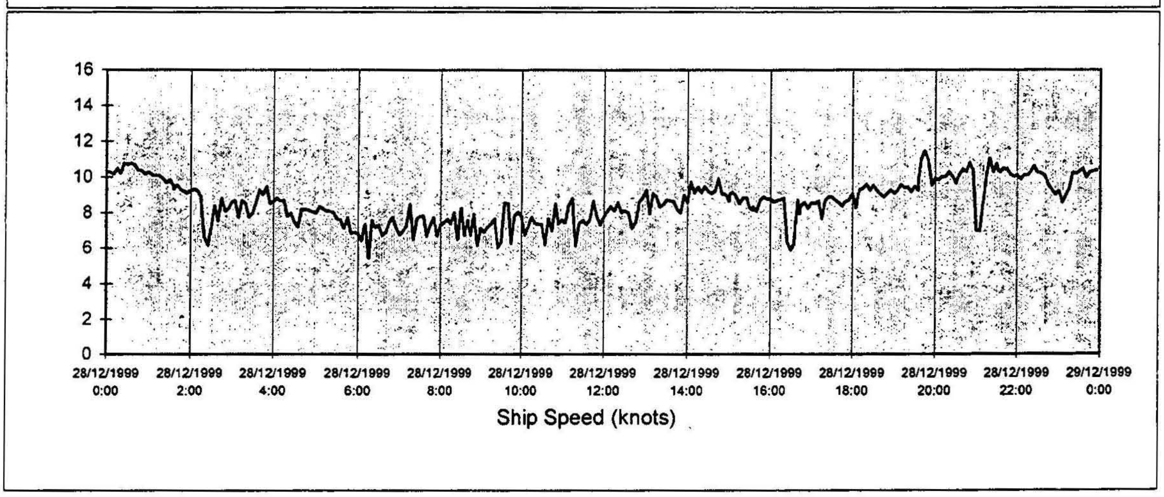


AUSTREA-1 Survey Charts
28/12/1999



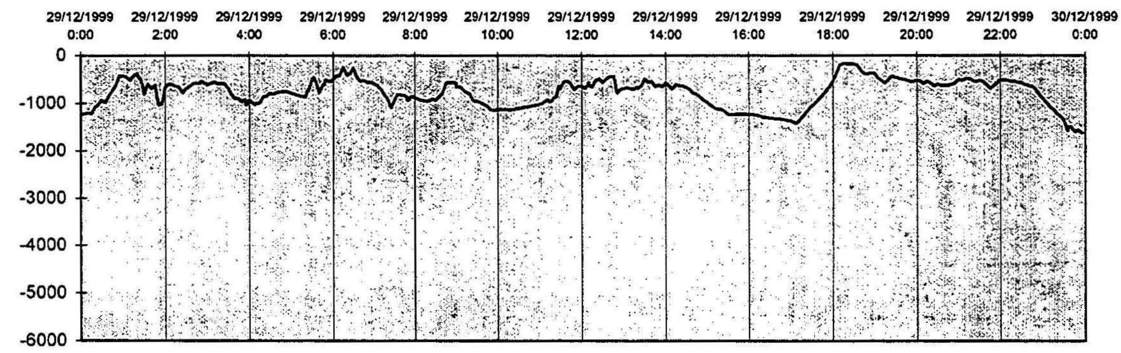


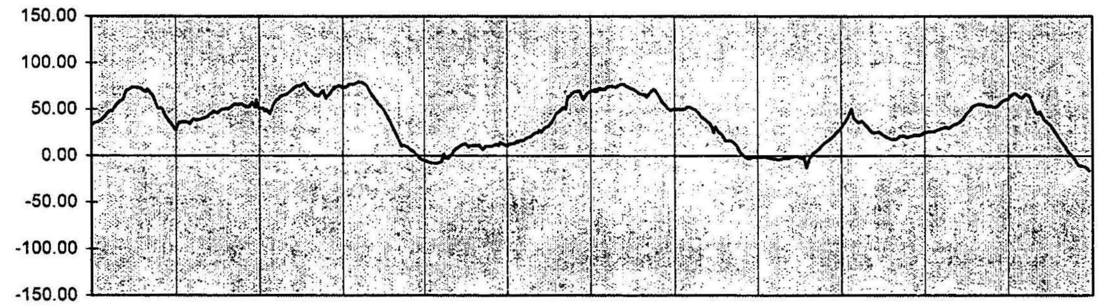




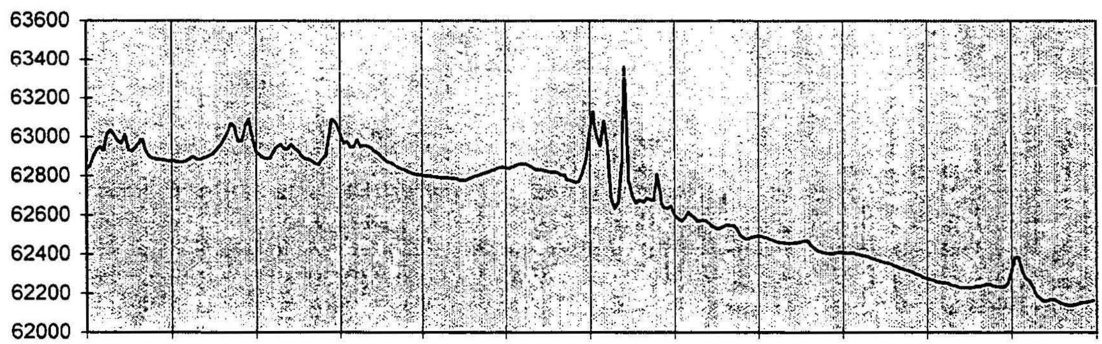
AUSTREA-1 Survey Charts
29/12/1999

Vertical Water Depth EM12d(m)

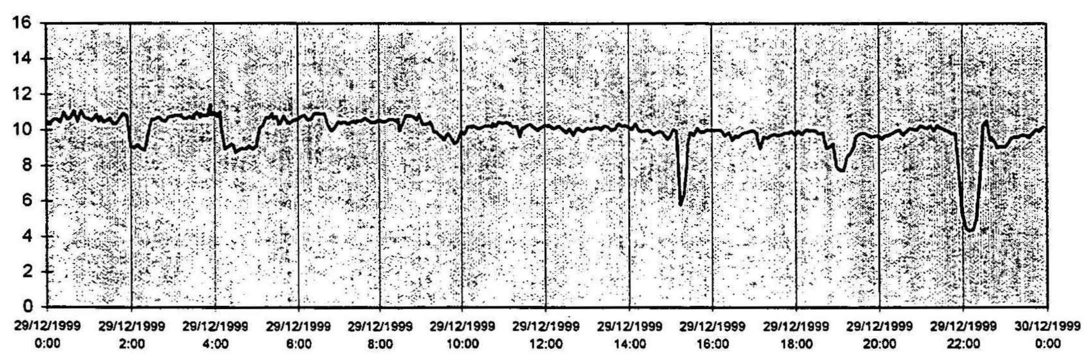




Free Air Anomaly (mGal)

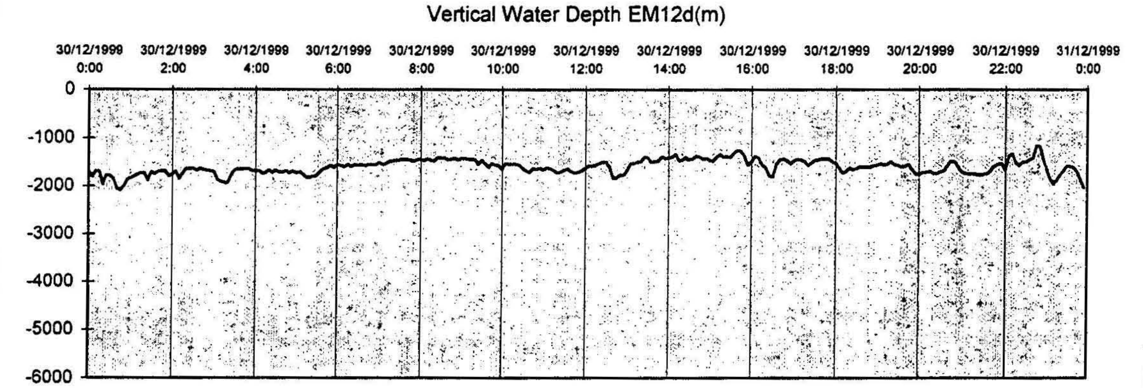


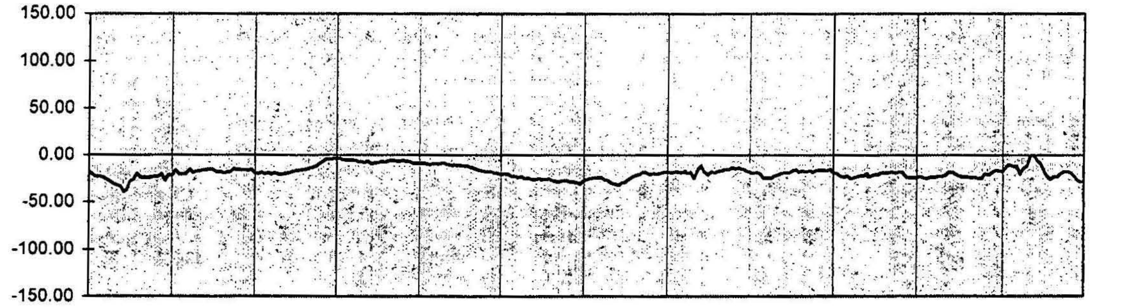
Total Magnetic Field (nT)



Ship Speed (knots)

AUSTREA-1 Survey Charts
30/12/1999





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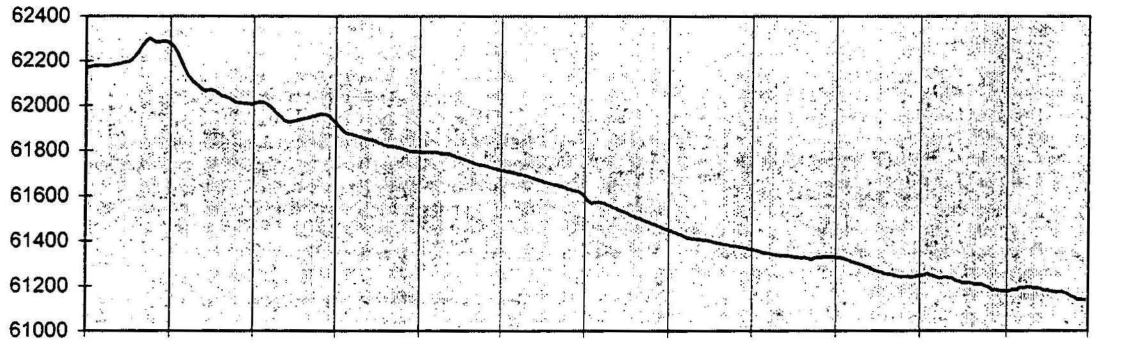
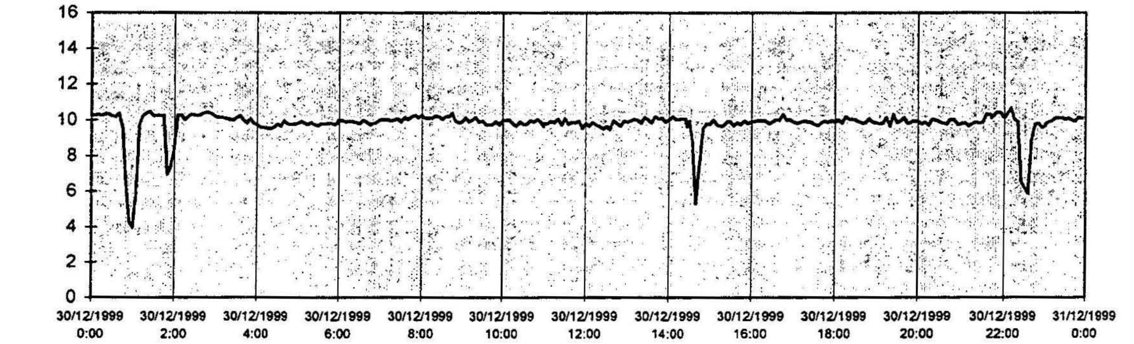
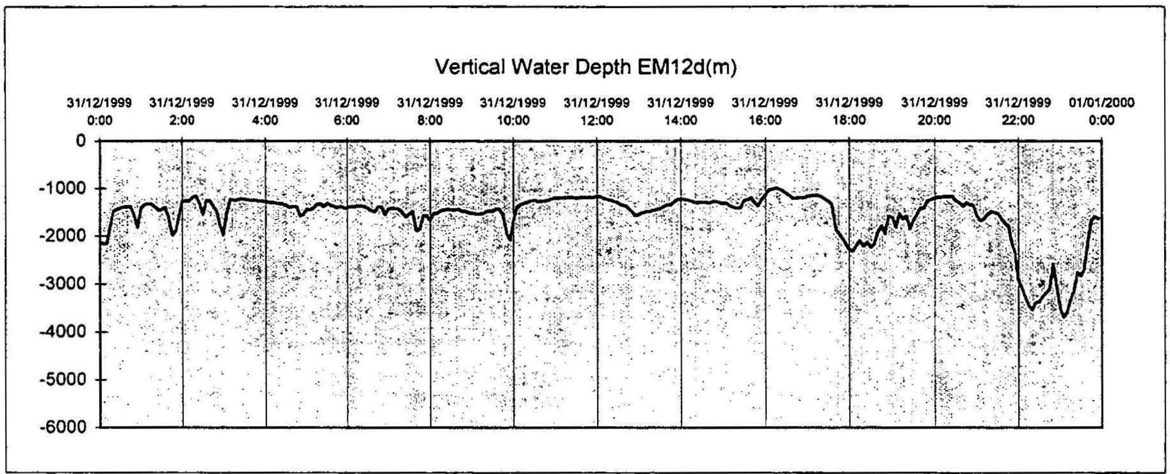


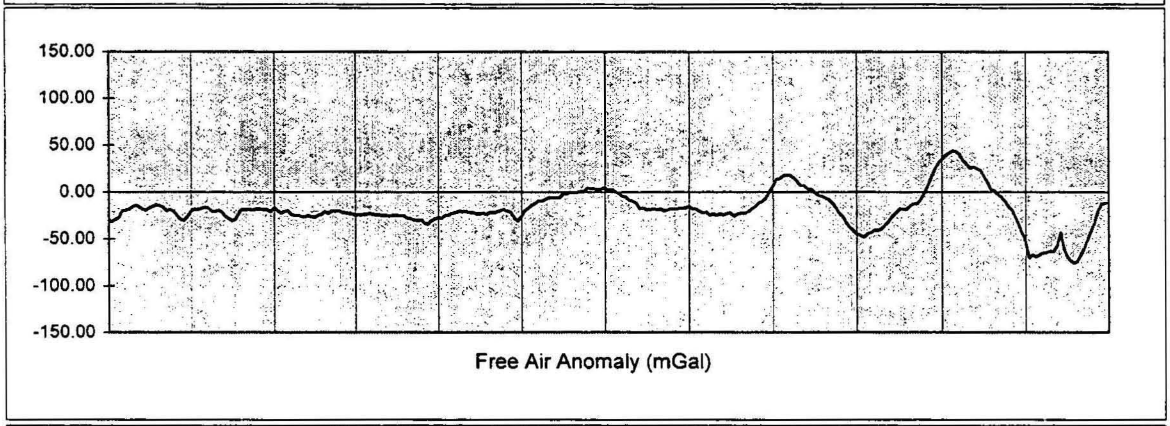
Total Magnetic Field (nT)

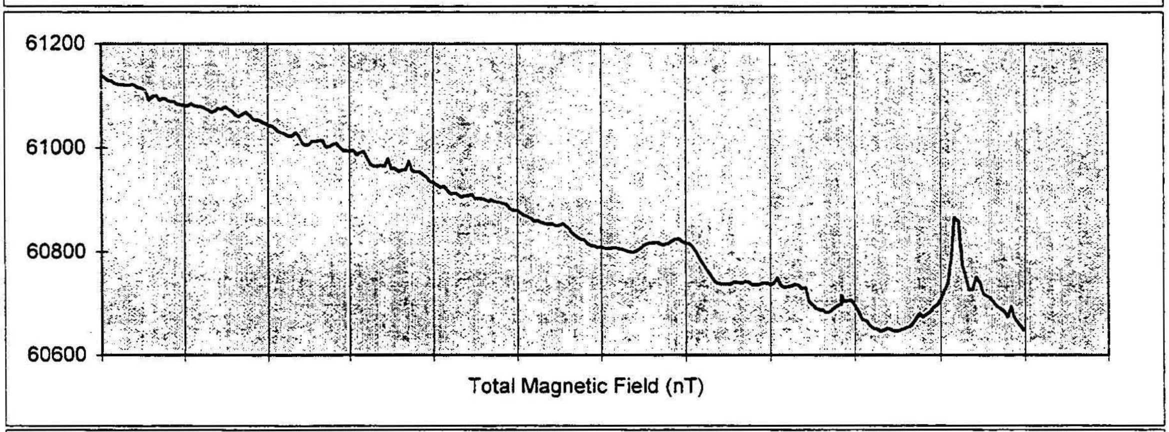


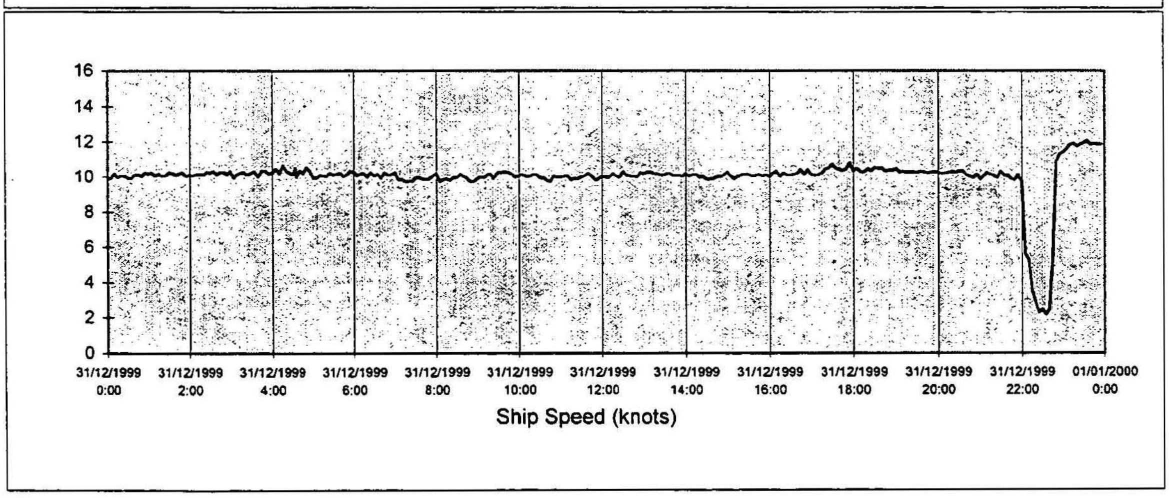
Ship Speed (knots)

AUSTREA-1 Survey Charts
31/12/1999

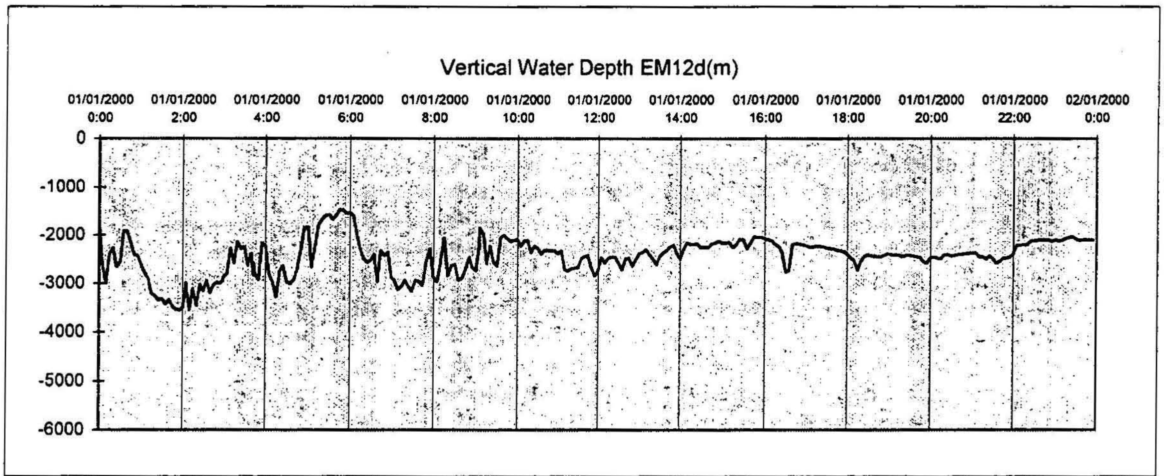


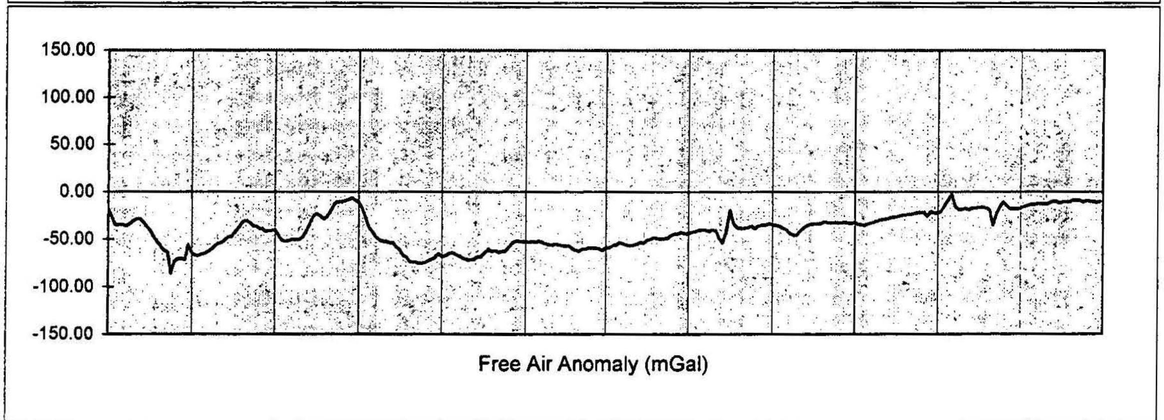


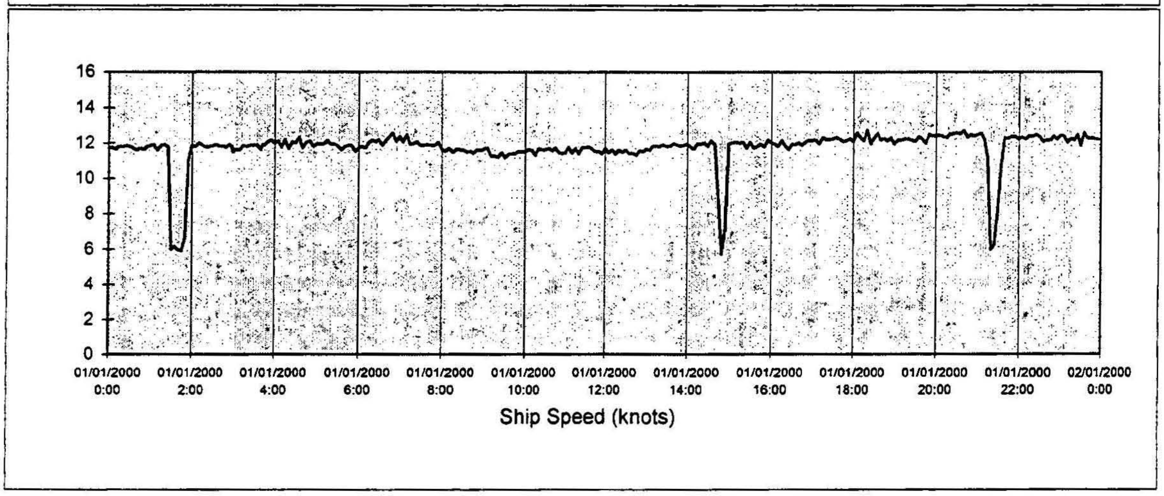




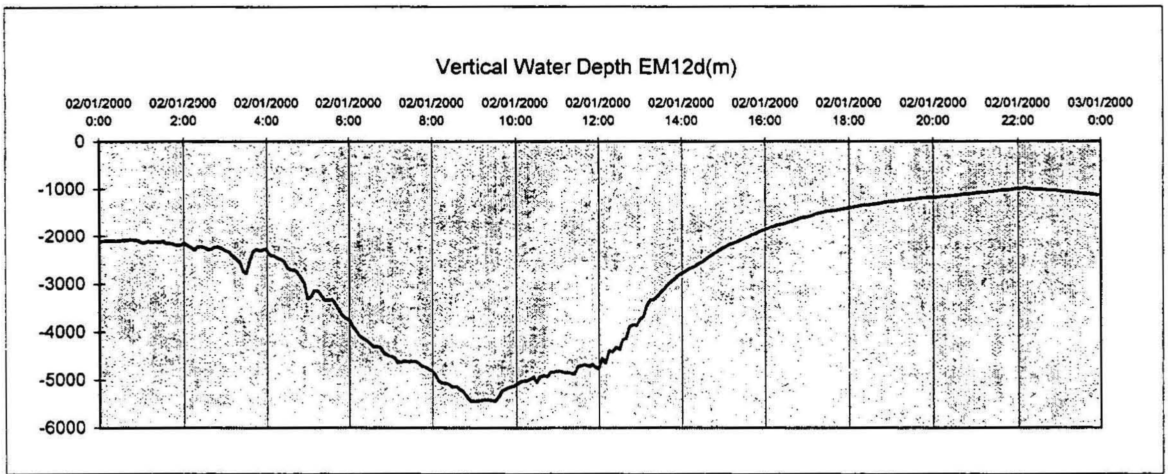
AUSTREA-1 Survey Charts
01/01/2000

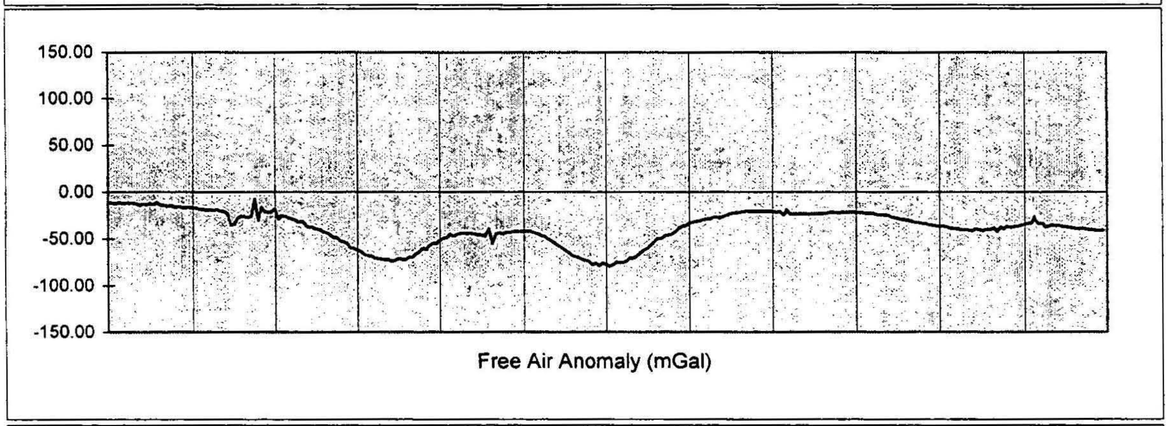


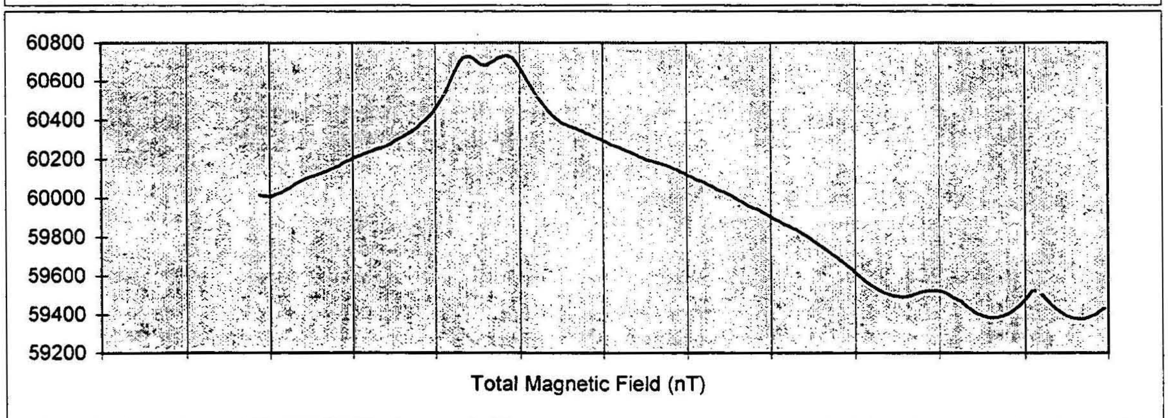


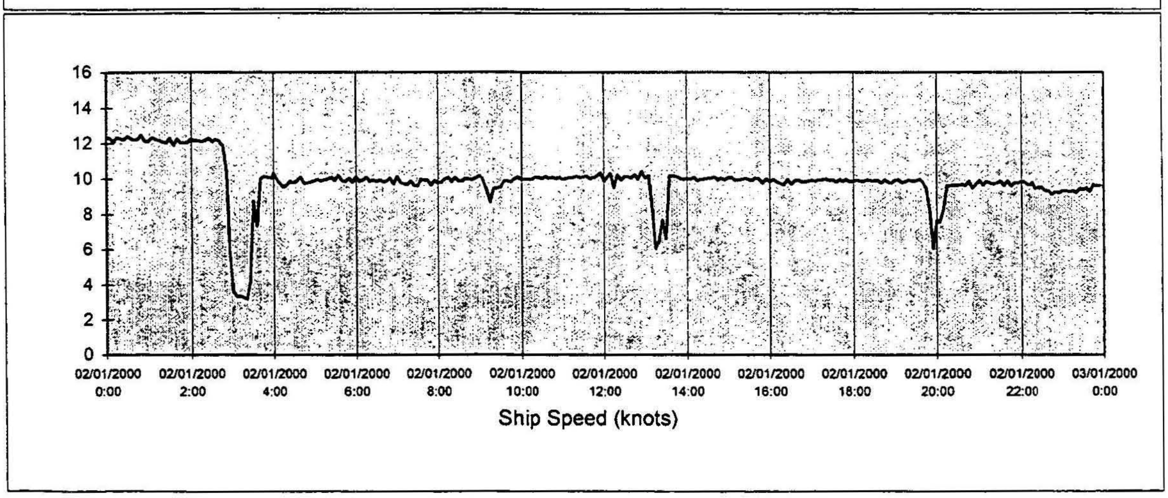


AUSTREA-1 Survey Charts
02/01/2000

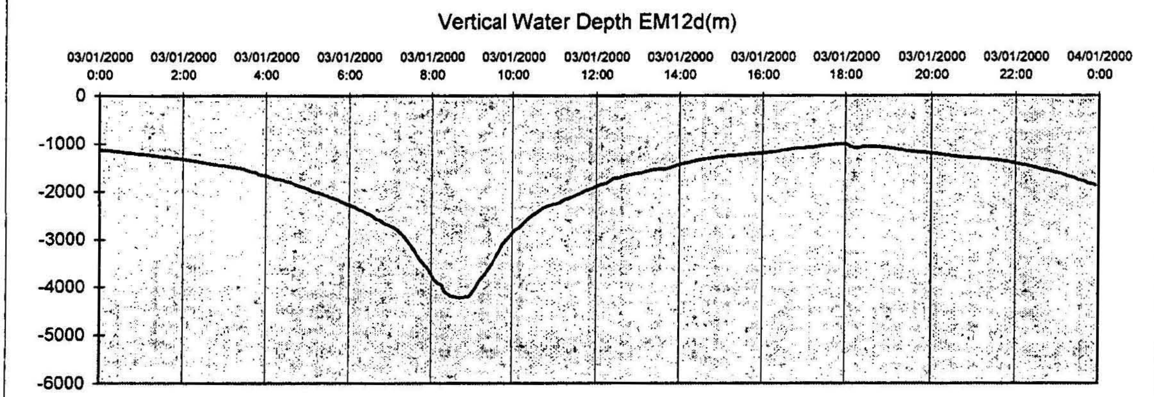


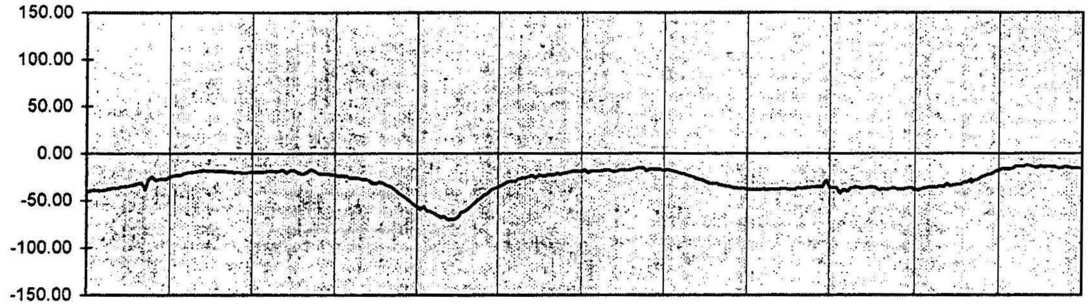




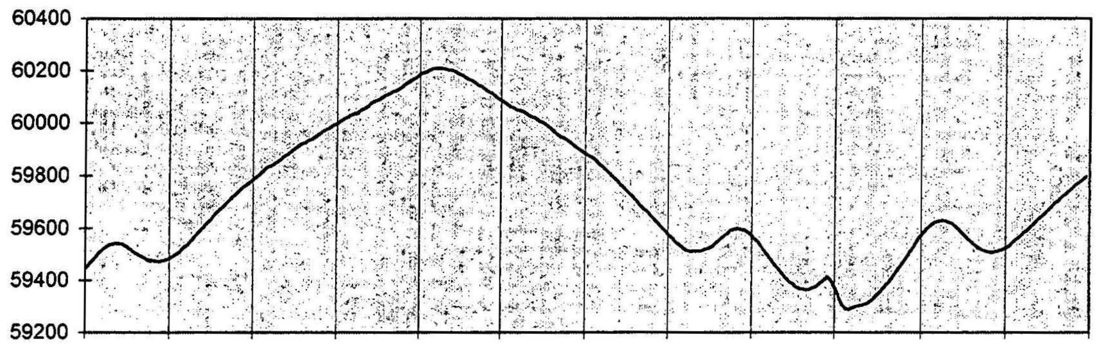


AUSTREA-1 Survey Charts
03/01/2000

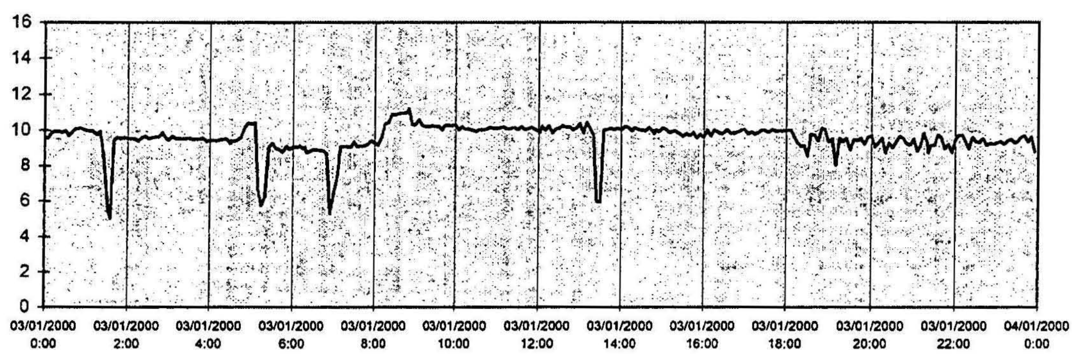




Free Air Anomaly (mGal)

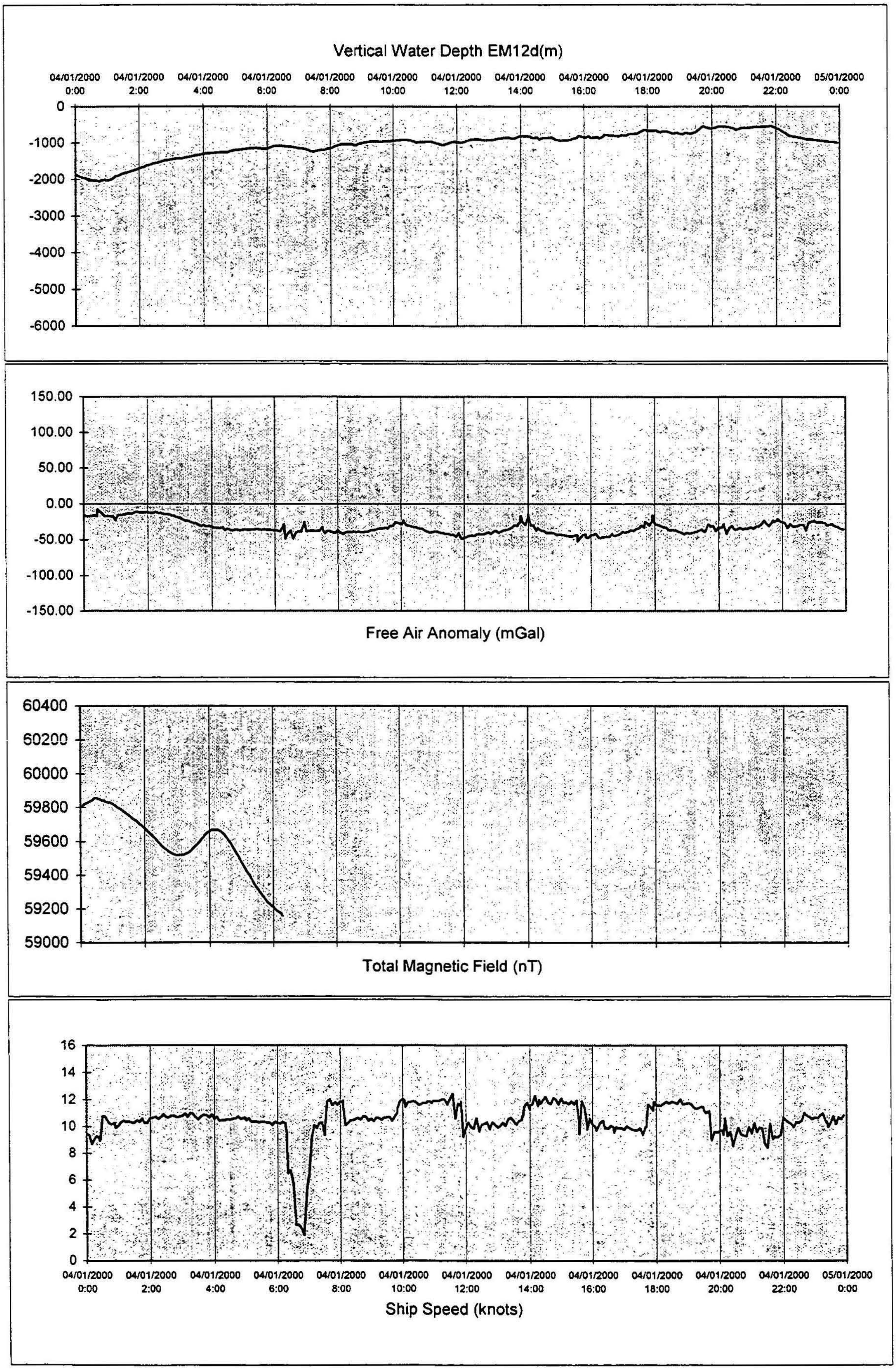


Total Magnetic Field (nT)



Ship Speed (knots)

AUSTREA-1 Survey Charts
04/01/2000



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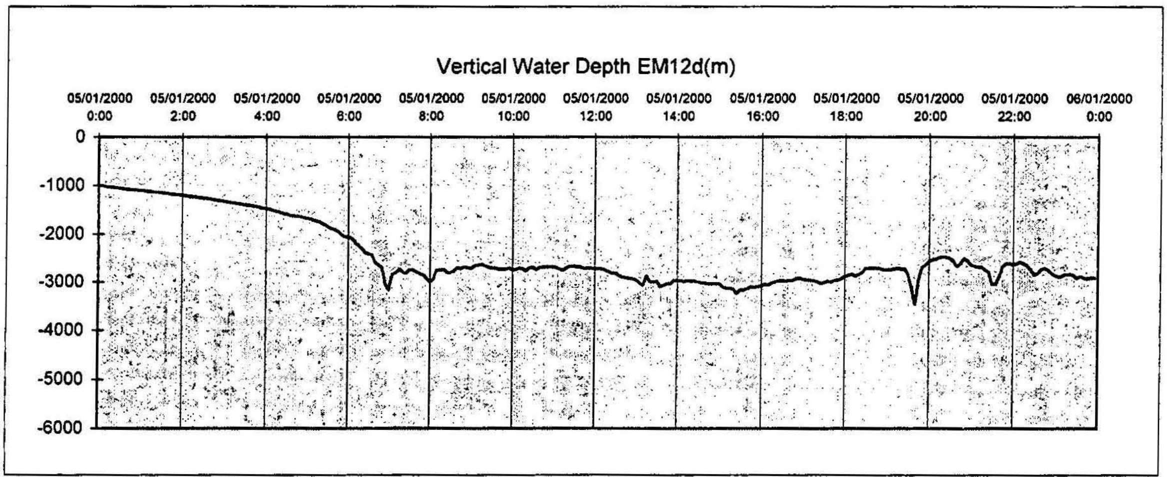
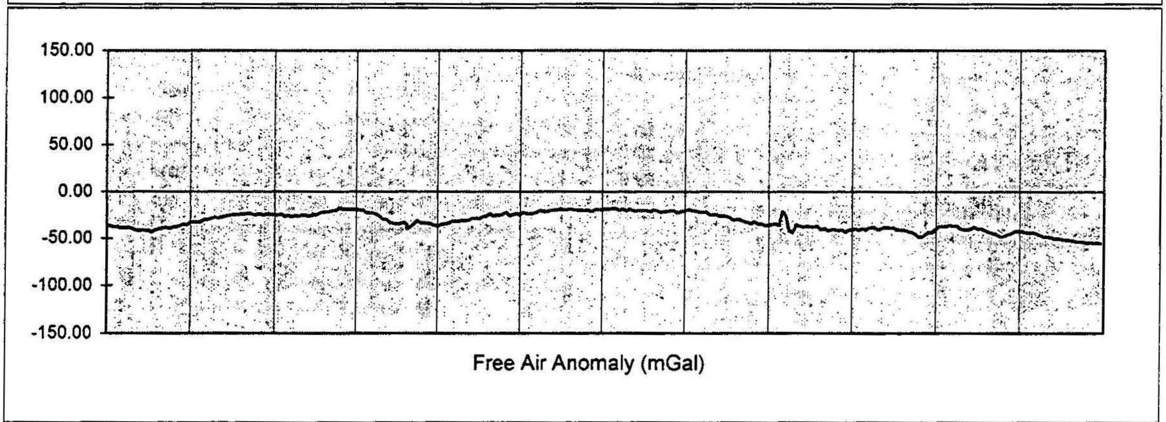
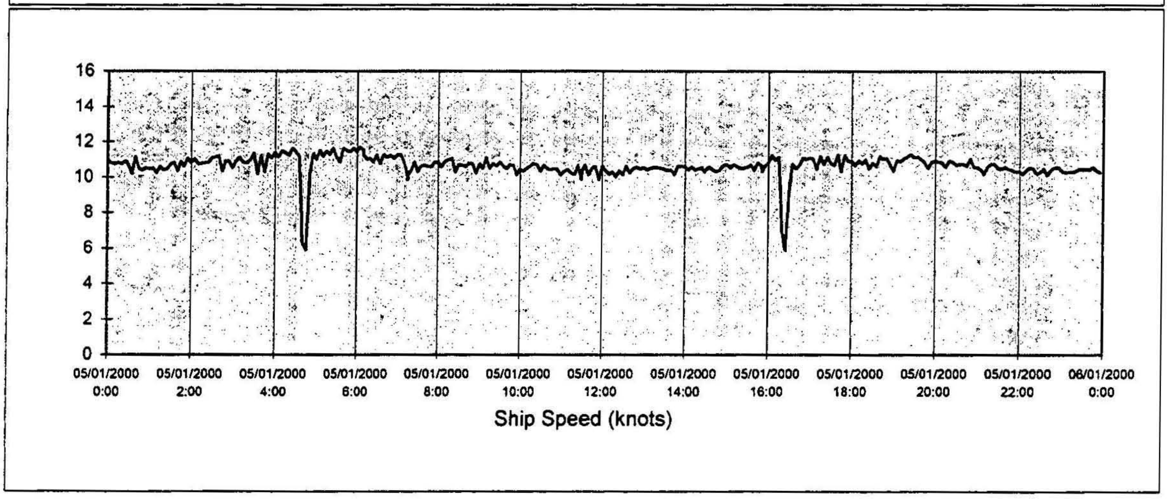
05/01/2000







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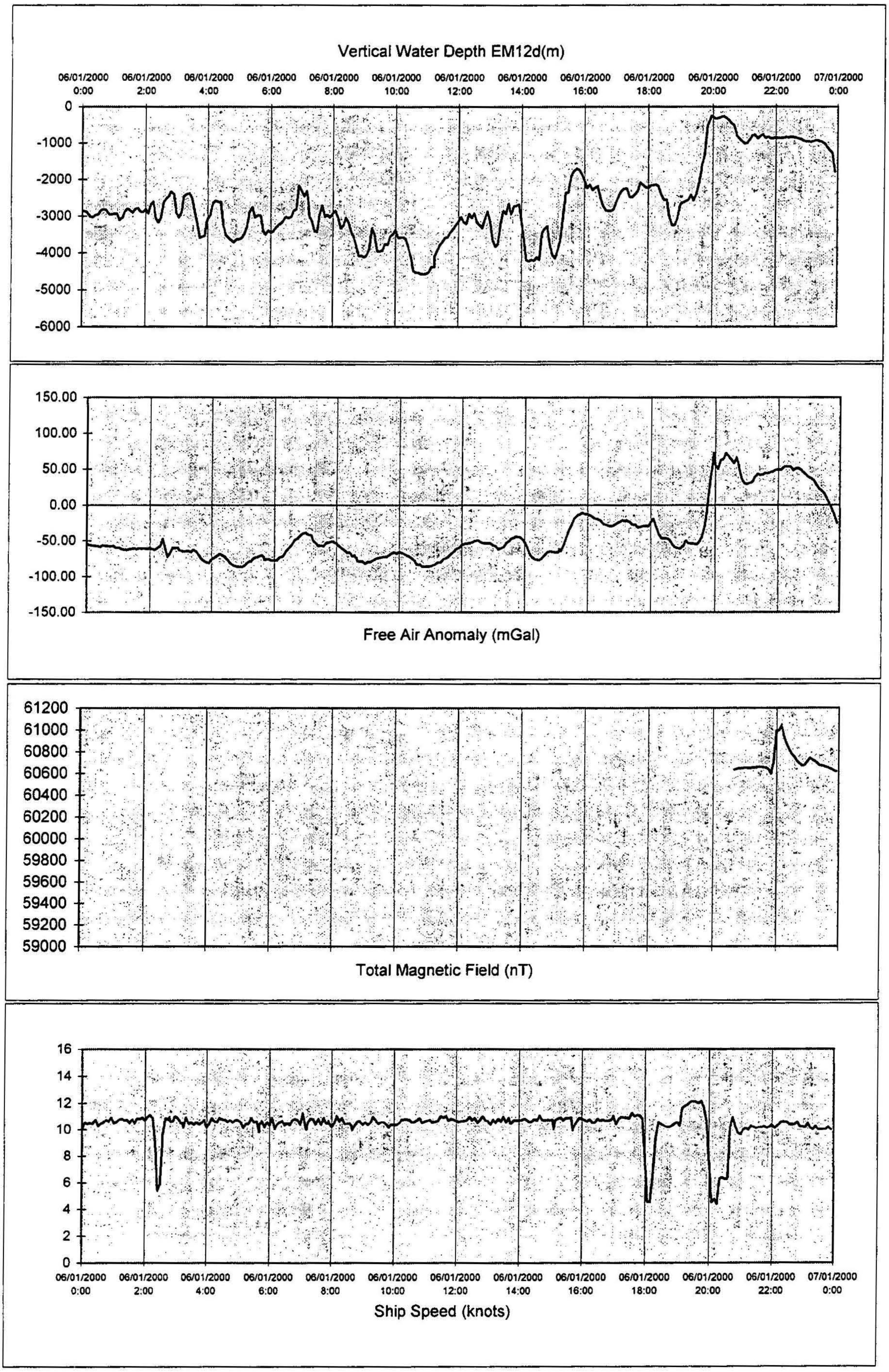
06/01/2000



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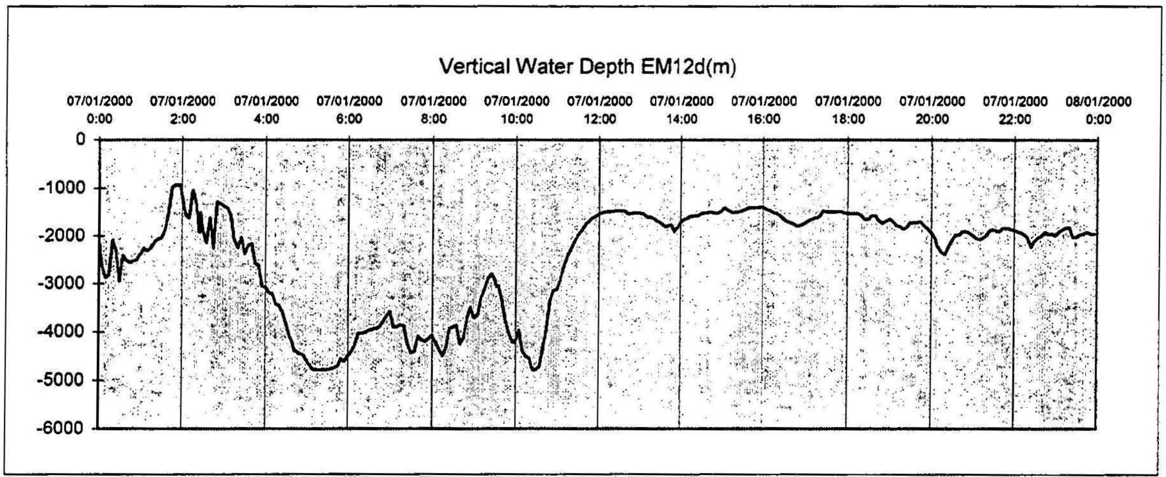
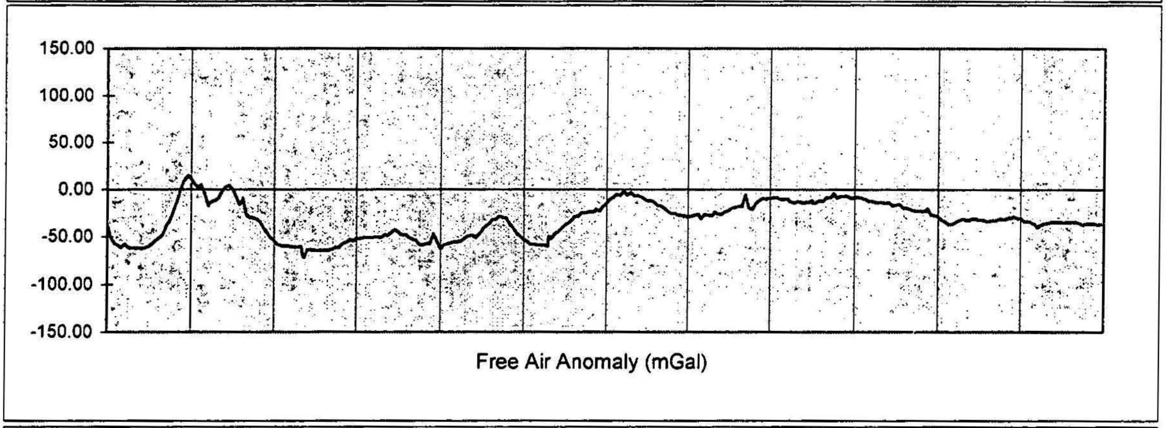
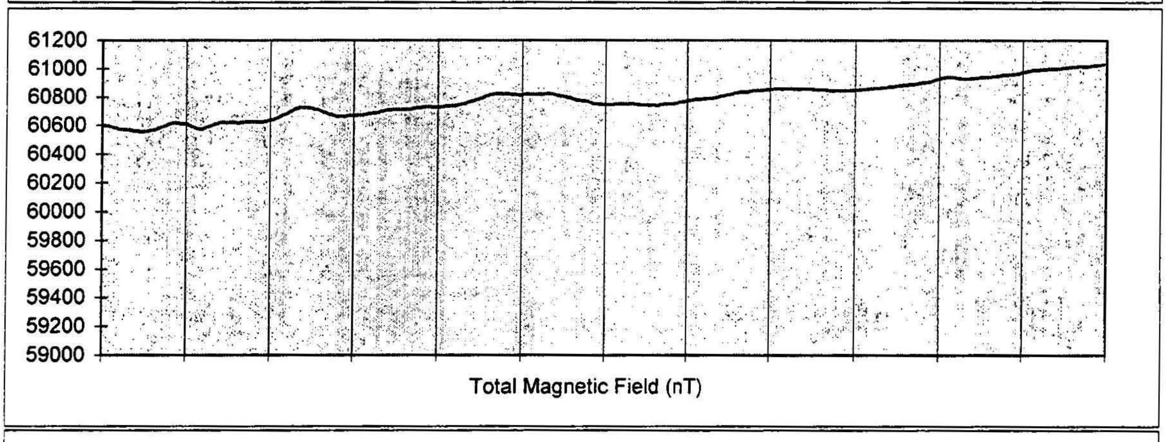
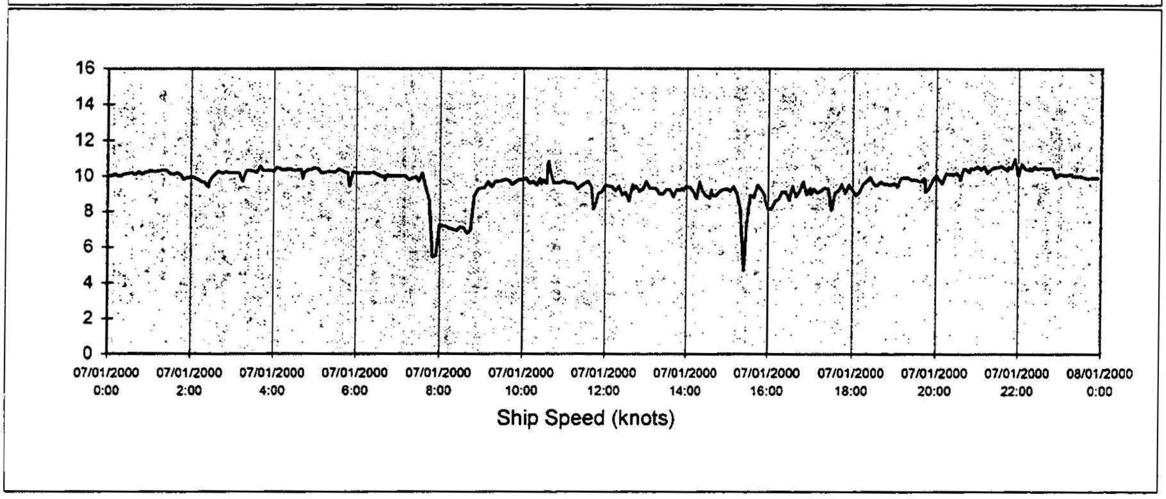
07/01/2000

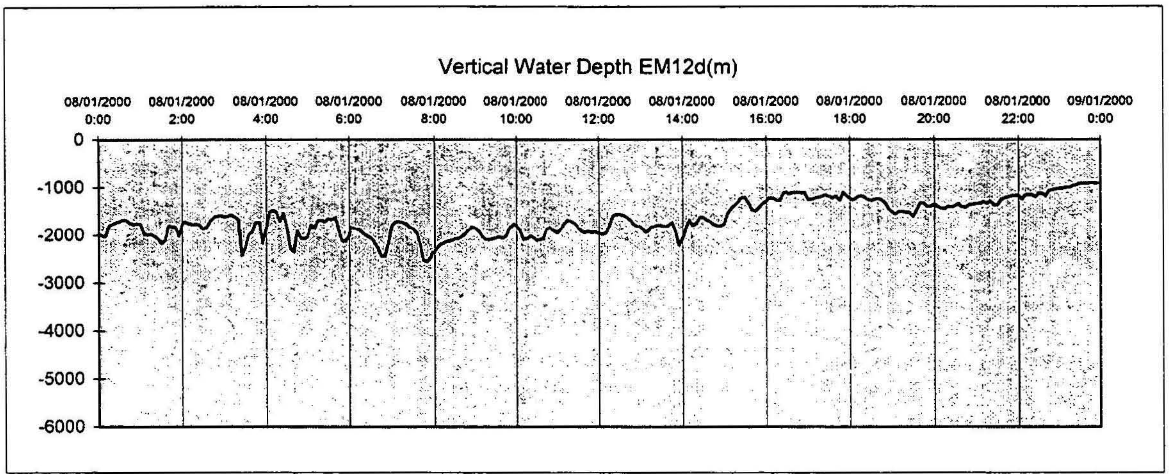


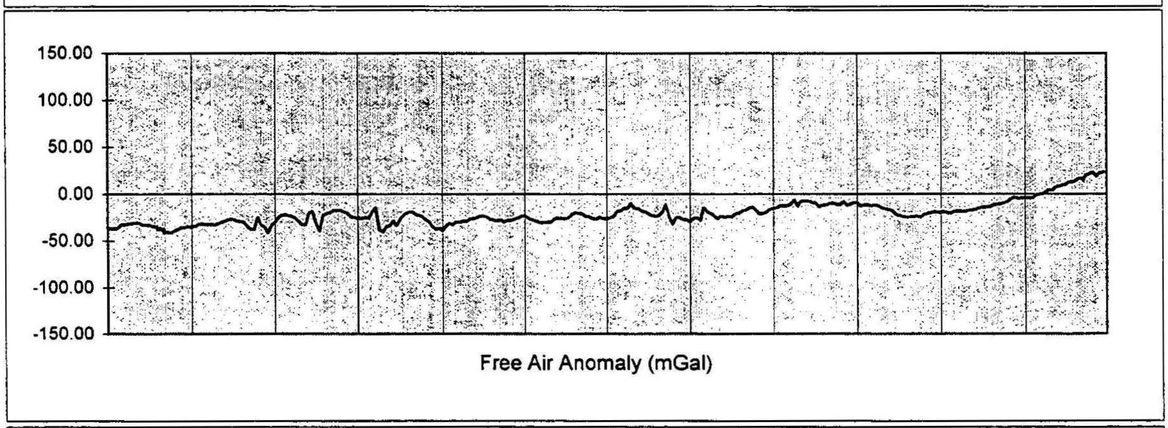


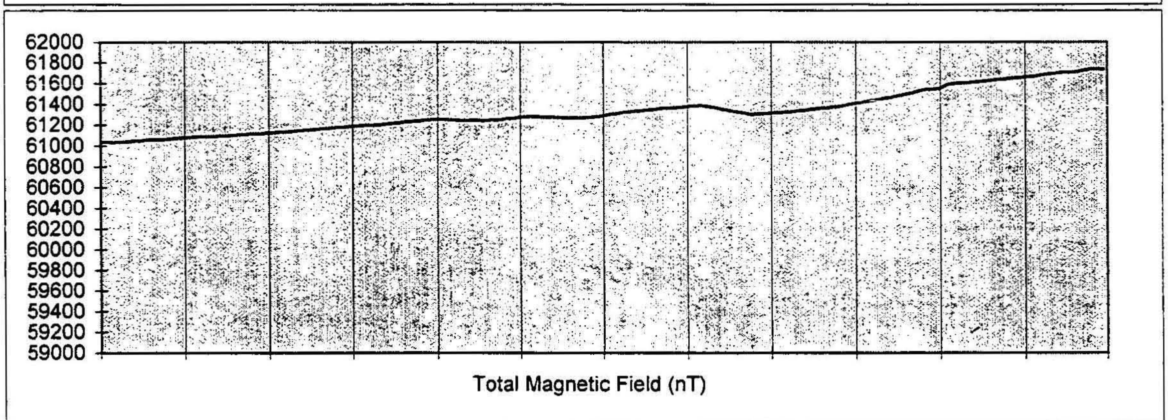


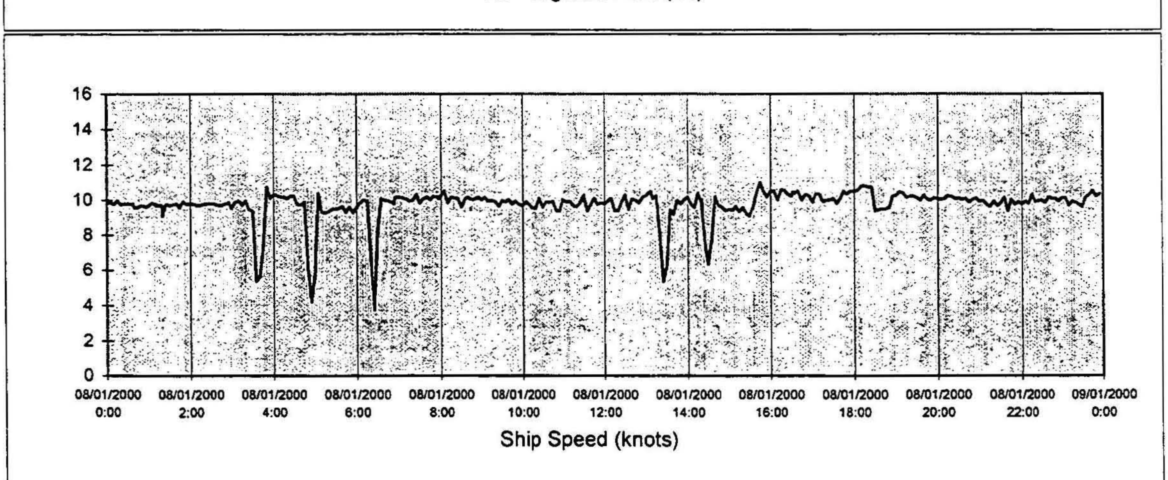


AUSTREA-1 Survey Charts
08/01/2000

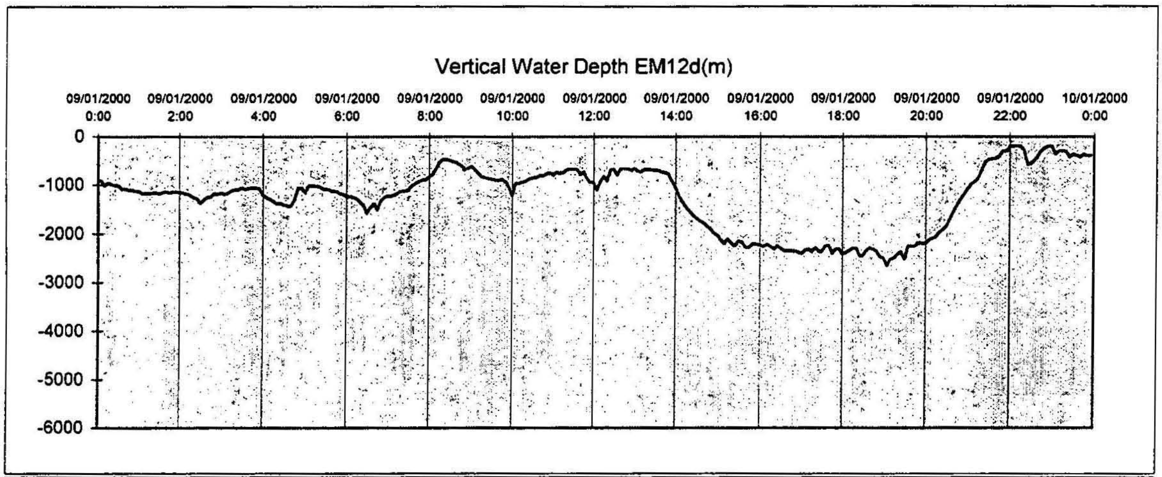


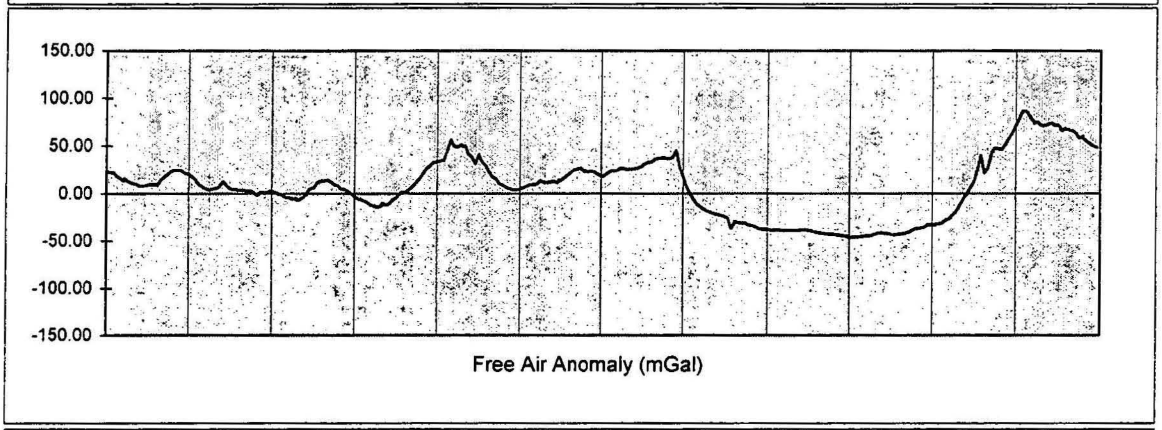


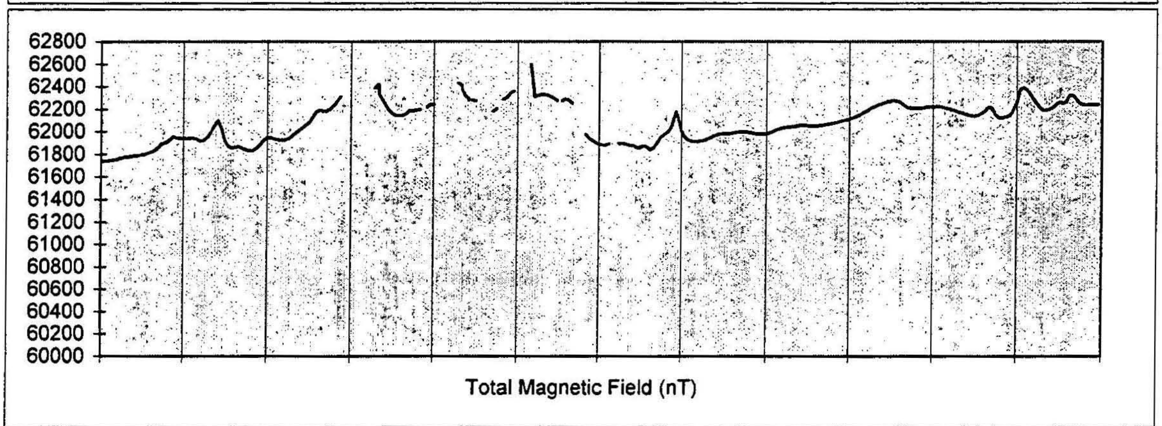


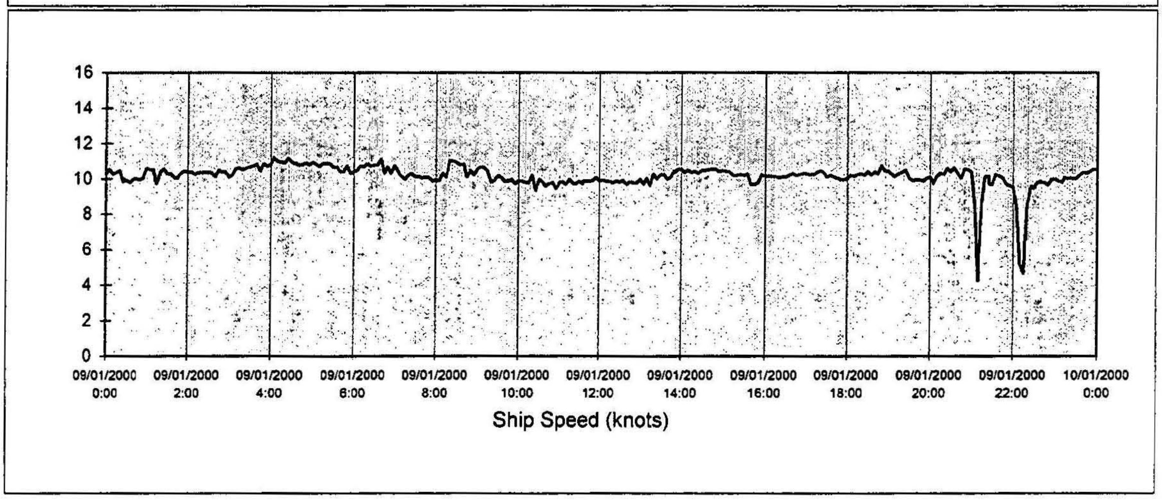


AUSTREA-1 Survey Charts
09/01/2000



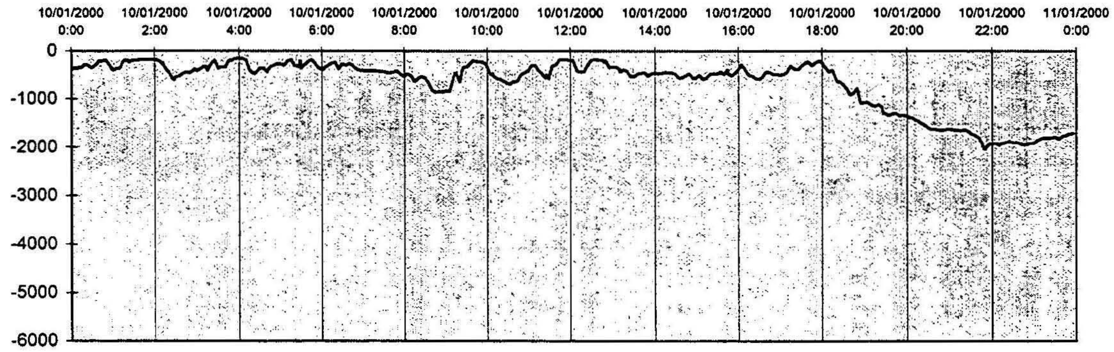


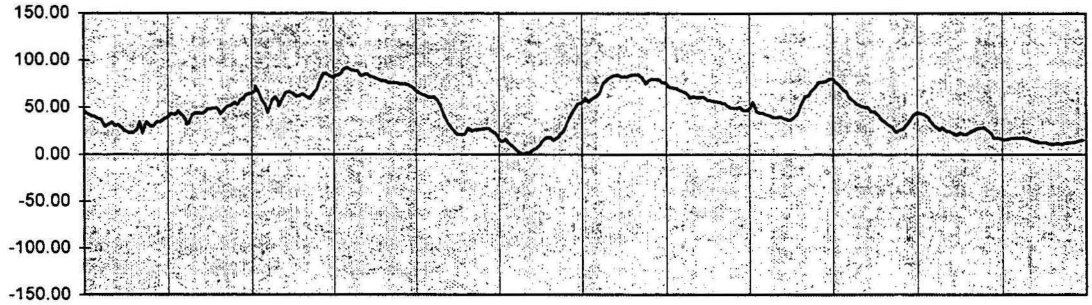




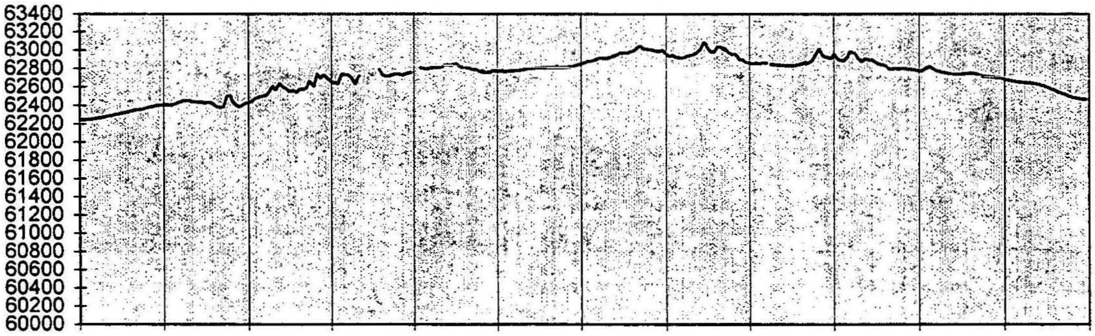
AUSTREA-1 Survey Charts
10/01/2000

Vertical Water Depth EM12d(m)

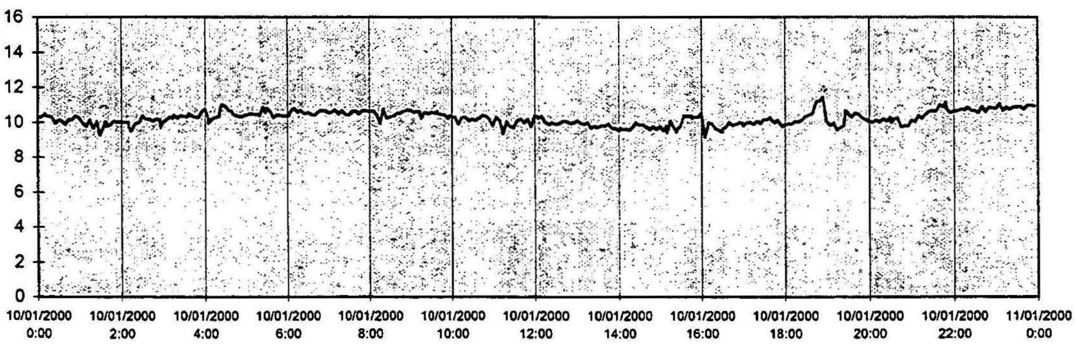




Free Air Anomaly (mGal)

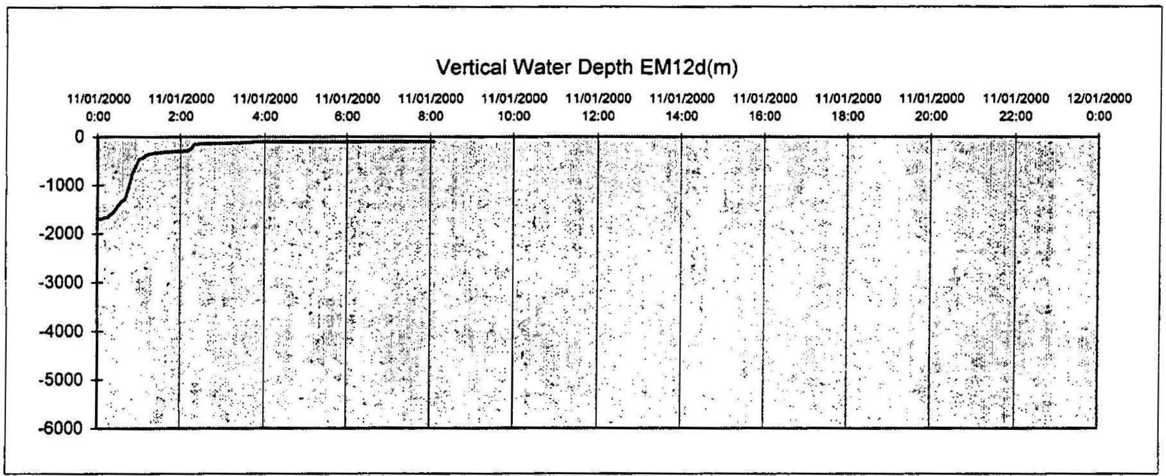


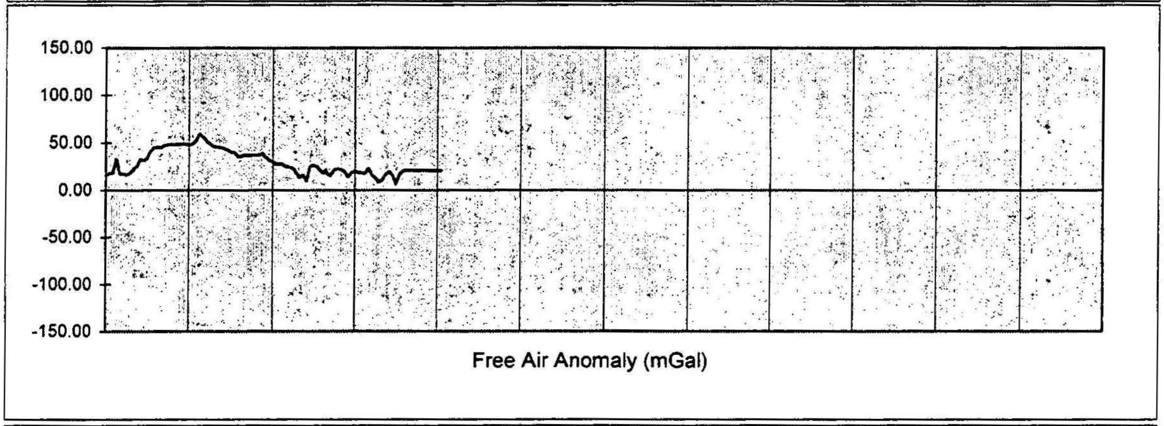
Total Magnetic Field (nT)

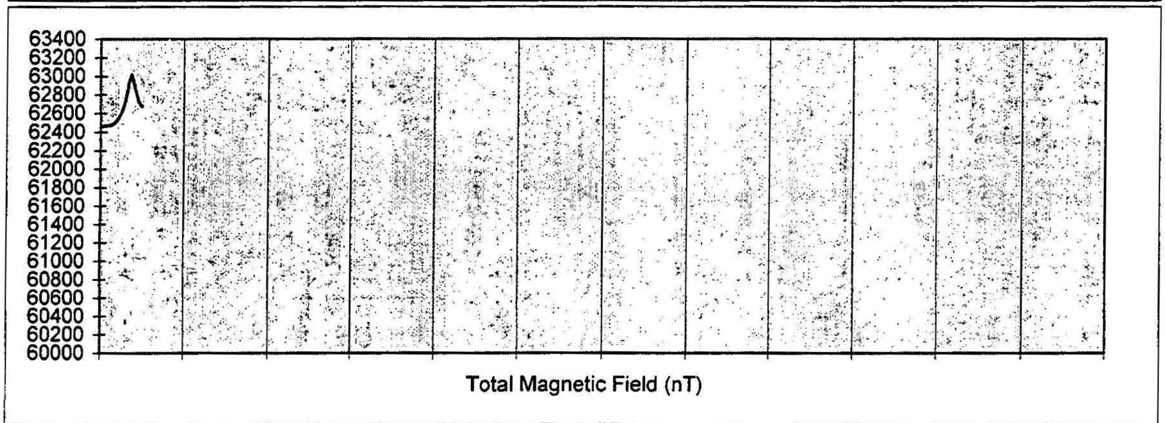


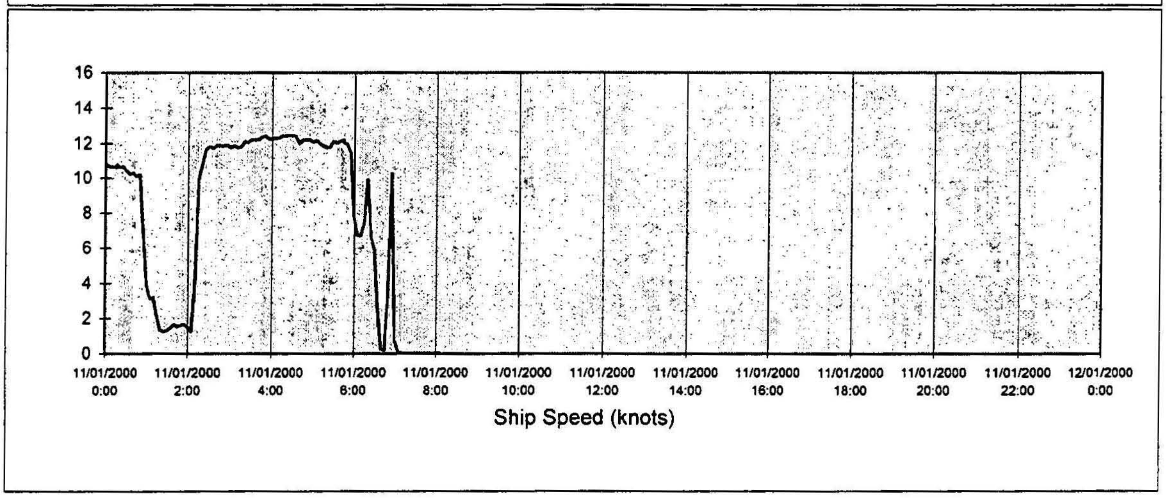
Ship Speed (knots)

AUSTREA-1 Survey Charts
11/01/2000

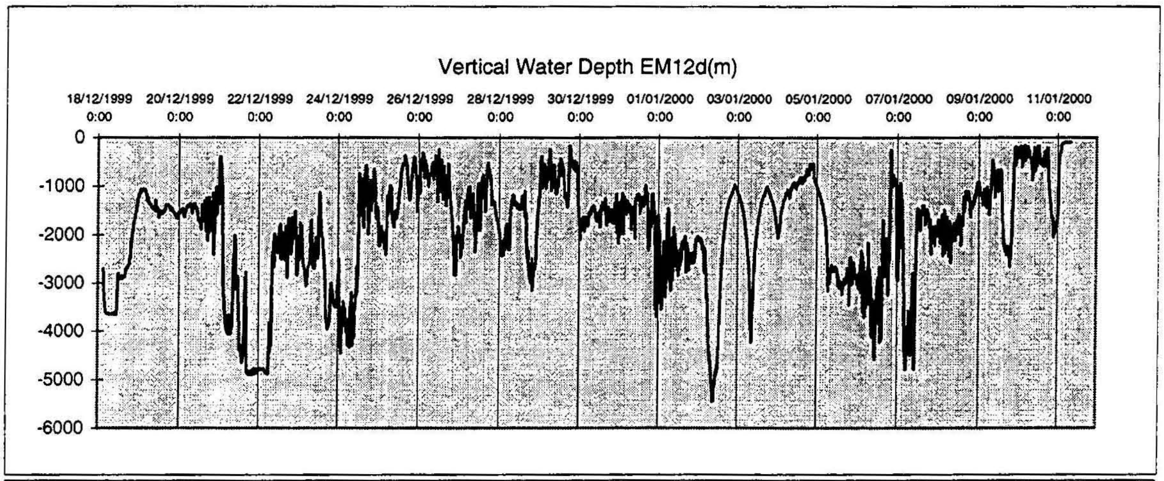


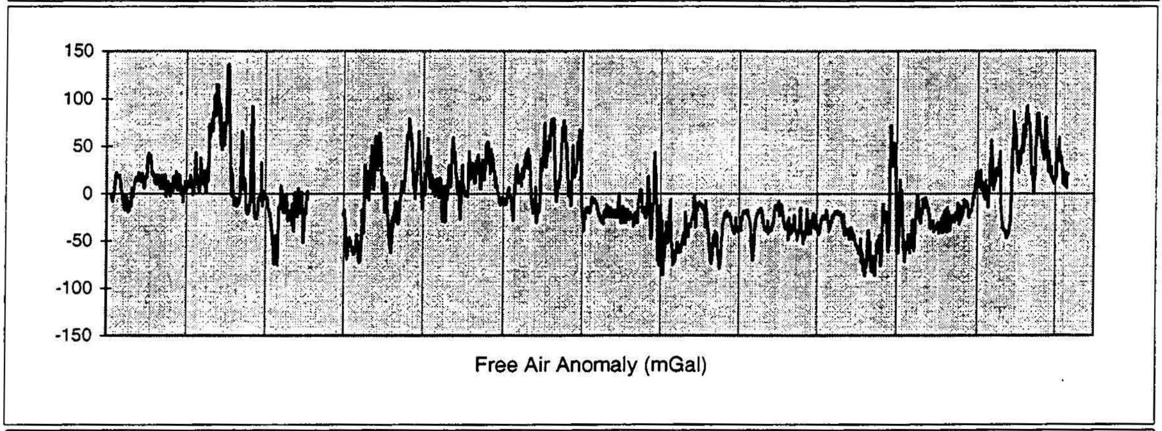


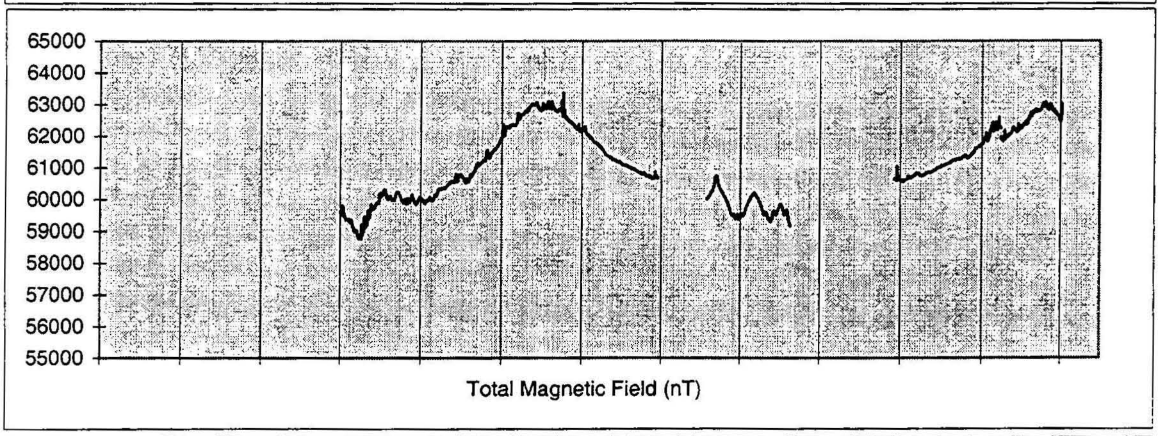


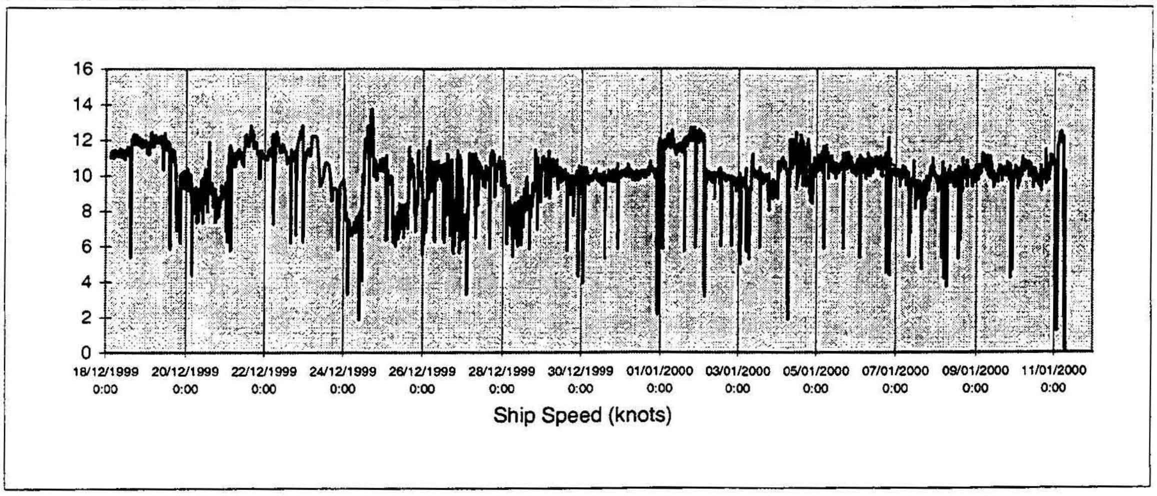


AUSTREA-1 Survey Charts
ALL DAYS









APPENDIX 13.
Compressed Profiles for Entire Cruise (All Days)

APPENDIX 14.
Log of 3.5 kHz Facies and Correlating Backscatter Imagery

Location:	***Noumea - Sydney***				
Date	**UT Time**	**Latitude**	**Longitude**	**3.5 kHz Echo Type**	**Imagery Description**
18/12	0:30	22 30.955	166 08.374	IIB	Dark outcrop in places mostly light sed. cover.
	4:00	23 05.472	165 43.705	IB - overlying IIBa. A flat IB echo/transparent zone/undulating IB echo.	No more outcrop. Continuous light grey sediment cover.
	11:35	24 15.843	164 53.274	IIIC	Dark band extending across swath until 12:10 then light grey. Initial IIIC echo shows as outcrop then it grades to a IIA echo decreasing in outcrop.
	13:15	24 31.475	164 41.967	IIA - Often disturbed by small hyperbolae but does not show in imagery.	Consistant light grey sediment cover. No outcrop.
	23:30	26 11.988	163 28.923	IIB - Some areas of high relief but mainly flat.	Generally unchanged. Some small dark outcrop patterns correlate with areas of high relief.
19/12	3:30	26 51.003	163 00.227	IIA - Sub-bottom reflectors are difficult to distinguish. (IIA/IIB)	Unchanged. Outcrop in areas of high relief.
	10:30	28 00.922	162 08.722	IIIA - Probable seamount. 4.5km at base. 300m high.	Shows as a circular outcrop in imagery. Very noisy.
	10:40			Continue with IIA echo	
20/12	3:30	30 25.086	160 19.806	IIB - no sub-bottom reflectors.	Light grey, no outcrop very noisy.
	13:30	31 37.333	159 21.207	IIIA - Lord Howe Island	Numerous dark outcrop patterns protruding the light grey sediment cover.
21/12	00:30-01:40			IIB - This lies in the shallow channel between LH and Ball's Pyramid.	Very little sedimentation. All outcrop.
				Other than this short channel all the terrain is characterised by a IIIA echo.	
	6:20	32 00.691	158 13.518	IB - extends for 35km and a penetration of upto 50m is reached.	The imagery shows, as is expected, a clean section free of outcrop.
	8:00	32 05.153	157 54.323	IIB	Shows a light grey section with frequent outcrop patterns.
	12:55	32 19.560	156 51.761	IIIC - Hyperbolae are small and tend to define the sea floor but are not regular enough to be classed as a IIID echo.	Very little sedimentation. Almost completely outcrop. Note: 3.5 kHz lost between 15:10 - 17:00.
	17:00	32 32.867	155 53.853	IB - Long continuous sub-bottom reflectors, interrupted by isolated large hyperbolic domes upto 150m high. A penetration of 65m is achieved.	The imagery correlates well with the 3.5 kHz showing the thick sediment sections as long light grey sections and the protruding domes showing as discrete outcrop.

22/12	6:00	33 10.990	153 07.912	IIIA - very rugged topography. Approaching the continental shelf.	Numerous large outcrop patterns.
	9:30	33 25.572	152 23.490	IIIC - Hyperbolae are smaller and more compact than above echo	This change in character is seen in the imagery with a distinct decrease in the amount of outcrop.
	12:20	33 53.207	152 02.701	End Of Roll	

Location:	*NSW South Coast*				
Date	**UT Time**	**Latitude**	**Longitude**	**3.5 kHz Echo Type**	**Imagery Description**
22/12	12:36	33 55.891	152 00.652	IIIC - Most hyperbolae are smaller than 100m and consistant, however they are often interupted by large hyperbolae greater than 200m.	Outcrop occurs in deeper parts with a sediment cover in shallower parts. A series of canyons where there is no sedimentation in the scoured channel but sediment accumulates on the flanks of the canyon.
	20:10	35 06.557	151 15.570	IIB/IIIC - Hybrid. Long sections of IIIC separated by short sections of IIB.	In areas corresponding to the IIB echo the imagery appears dark grey indicating a small amount of sediment cover. This is likely a partially sedimented slope.
	22:20	35 28.615	150 57.964	IIBa - A short section separated by IIIC.	This appears as varying shades of grey indicating varying sediment thickness. The homogenous zone is likely due to debris, slump or a mass flow deposit down the slope.
	22:40	35 32.142	150 55.204	IIIA - Hyperolae are now larger than the IIIC character previously. This is due to the extreme topography on the shelf edge.	As before the shollower secions appear to have some sediment cover whereas the deeper channels are darker indicating protruding outcrop.
23/12	9:00	37 22.617	150 26.762	IIIC	Some continous narrow bands of outcrop across the swath. Likely to be small channels.
	13:00	38 00.538	150 13.759	IIB - short section about 10km.	Imagery is fairly dark but there is no outcrop.
	13:30	38 07.026	150 10.072	IIIA - very large hyperbolae. Extreme topography.	Increased outcropping. Large dark patches that cover half the swath width.
	15:00	38 23.398	150 01.177	IIIC - this topography is not as extreme as IIIA	There is no outcrop. The IIIC echo has a sediment cover which contrasts with the IIIA echo previously.
	17:20	38 39.943	150 01.395	IIIC - rugged topography.	Large outcrop patches but most has a sediment cover. Veneer of ooze or clay.
	20:40	38 12.902	150 14.356	Printer Problem	Imagery shows increased outcrop during this period. Probably a IIIA echo type (?)
	22:00	38 03.587	150 19.758	IIIC - this corresponds with a sudden increase in depth of 750m. (canyon)	Still mainly sediment covered with minimal outcrop.
24/12	3:10	37 21.055	150 36.843	Printer Problem	Possibly continues with same echo (?)
	11:40	36 24.243	150 32.620	IIIA - very large hyperbolae. Extreme topography. Sudden increase in depth of 1.9km over 15km. Scarp (?)	Becomes very noisy and has a very narrow swath width in places. Difficult to interpret.
	18:40	37 37.086	150 22.203	IIB - possible basement high.	Broken up outcrop. Very noisy.

24/12	19:40	37 46.710	150 16.905	IIIC - very rugged topography.	Strong outcrop reflections.
	21:00	37 59.265	150 10.036	IIB - 22km long	Swath width narrows greatly. Shows the high has a thin sediment cover over a basement high.
	22:00	38 08.843	150 04.610	IIIC	Some outcrop. Mostly has a veneer of sediment.
	23:20	38 20.276	149 54.223	End of Roll - Begin Gippsland data	

Location:	*Gippsland - Tasmanian East Coast*				
Date	**UT Time**	**Latitude**	**Longitude**	**3.5 kHz Echo Type**	**Imagery Description**
24/12	23:20	38 20.216	149 54.223	IIB - No sub bottom reflectors, fuzzy.	Dark grey, no outcrop.
	23:50	38 24.793	149 50.453	IIA - A few broken sub bottom reflectors not seen in the IIB echo.	This change is supported in the imagery by grading to a lighter shade of grey.
25/12	0:20	38 29.142	149 46.812	IIIC	Some outcrop. Mostly has a veneer of sediment.
	1:10	38 35.331	149 37.334	IIA - A few broken sub bottom reflectors not seen in the IIB echo. Some interspersed small hyperbolae.	No visible outcrop. Constant light grey pattern.
	2:40	38 32.292	149 23.084	IIIC - very small hyperbolae getting larger towards 4:30.	Change marked by a sudden increase in outcrop. 5:15 - 6:30 shows outcrop that covers entire swath. Numerous occasions where the depth changes by 1km during this period. Very rough topography.
	6:30	38 24.488	149 00.439	End of Roll	
	6:40	38 24.274	149 03.512	IIBa	Corresponds to a topographic high and shows as a very dark region possibly due to a debris flow.
	7:50	38 24.274	149 11.764	IIIC - very steep increase in depth.	Imagery is undistinguishable from above.
	9:40	38 27.696	149 28.310	IIB	Imagery has changed from above, now shows mostly sediment coverd topography with occasional banding of outcrop across swath.
	20:50	38 12.614	149 47.936	End of Roll	
	21:20	38 10.757	149 48.057	IIB	mostly sediment covered some large outcrop. Note only 400m depth.
	22:50	38 20.923	149 30.033	IIIC	Increased outcropping. Probable canyon.
26/12	1:10	38 16.122	149 32.952	IIB	Mostly sediment covered. Very shallow - off the scale. Some profile lost 2:22 - 3:00
	3:20	38 13.965	149 33.839	IIIC	Corresponds to a section of outcrop in imagery. Probable canyon.
	3:50	38 10.885	149 30.374	IIB - Some underlying hyperbolae in places but not very strong.	Very dark but not quite outcrop therefore there is some sediment cover.
	6:10	38 21.821	149 14.016	IIBa - Looks like faulted blocks with overlying transparent zone.	This section shows no outcrop but is still very dark.
	8:40	38 22.711	148 43.093	IIIC - small hyperbolae that form a trough and high pattern.	The highs show in the imagery as outcrop.
	10:00	38 32.707	148 33.090	IIB - Rounded relief.	A sediment covered section. Almost no outcrop. Very shallow (350 - 400m)
	11:10	38 45.099	148 30.409	IIIC	A lot of outcrop. Distinct change from previous facies.

	12:00	38 45.102	148 22.006	IIB - A topographic high about 250m high and 8km long.	The imagery shows less outcrop for this 8km.
	12:20	38 46.465	148 21.518	IIIC	Increased outcrop as seen previously.
	13:30	38 48.307	148 30.206	IIB - Again a topographic high (450m depth)	It is again seen as a narrow band free of outcrop.
	13:50	38 52.000	148 32.000	IIIC - very rugged topography.	Increased outcrop.
	14:50	38 59.021	148 40.887	IIB - as previous IIB echo. This high is 35km long	Again an area of no outcrop.
	17:00	39 12.332	148 47.539	IIIC - as previous IIIC echo.	Increased outcrop.
	17:50	39 15.799	148 43.971	IIB - Some faint sub-bottom reflectors that are often not parallel and discontinuous.	A long section of light grey with increasing swath width with depth.
	21:10	39 26.111	149 08.068	IIIC	The following few facies changes are repeated numerous times with corresponding changes in imagery. Ie IIIC echo type results in increased outcrop.
	23:30	39 47.929	149 05.967	IIB	
27/12	0:40	39 41.545	149 01.196	IIIC	
	3:20	39 23.357	149 01.056	IIB	
	4:10	39 22.537	148 55.097	IIIC	
	9:55-10:20	40 12.458	149 04.339	IIIC	Very steep canyon marked in imagery by a band of outcrop across swath.
	13:50	40 49.734	148 50.211	IIB - Sharp base reflector with small underlying hyperbolae.	
	15:20	41 04.735	148 48.278	IIIC large hyperbolae marking rugged topography.	
	17:40	41 19.877	148 40.897	IIB - Possible prograding sediment draped over large basement block. The echo becomes more 'fuzzy' as you progress.	Shows as very long unchanged section with no outcrop. Very light grey indicating good sediment cover.
	22:50	42 11.106	148 46.070	IIA - Occurrence of sub-bottom reflectors often broken by IIIC type hyperbolea.	As above.
28/12	2:00	42 42.116	148 39.274	IIIC	Marked change from above. A lot of outcrop.
	11:40	43 49.150	147 56.410	IIB - This echo just begins before end of roll. Looks to continue.	
	12:40	43 56.364	147 51.744	End of Roll.	

Location:	*Southern - Western Tasmania*				
Date	**UT Time**	**Latitude**	**Longitude**	**3.5 kHz Echo Type**	**Imagery Description**
28/12	12:50	43 57.464	147 50.929	IIB	Visible outcrop.
	15:00	44 07.620	147 28.427	IIIC	Sharp band of outcrop across swath.
	18:10	44 32.661	147 26.189	IIA	Large swath width with mostly fine sediment and small patches of outcrop.
	19:00	44 39.769	147 34.036	IIIC - very short section that occurs during a very tight turn.	Wide band of outcrop across swath. Posible canyon?
	19:30	44 43.319	147 38.282	IIA - Often broken by IIIC type echo.	Contrasts with previous echo type. No outcrop only fine sediment.
	22:00	44 19.810	147 36.925	IIIC	Section of mostly outcrop and narrowing swath width.
29/12	1:00	44 09.002	147 02.281	IIB/IIIC Likely a partially sedimented slope.	The next few facies changes in the 3.5 kHz, alternating IIIC and IIB facies, are indistinguishable in the imagery. It can be described by mostly outcrop with small isolated patches of sediment.
	1:30	44 07.951	146 55.055	IIIC	
	2:30	44 07.217	146 41.332	IIB	
	5:30	43 58.189	146 02.724	IIIC	
	6:10	43 51.812	145 59.375	IIB	Relatively no outcrop. Good sediment cover.
	11:10	43 15.000	145 18.000	IIIC	Large outcrop.
	13:20	42 57.700	145 01.887	IIBa - Homogenous drape over irregular topography.	Similar to previous IIB. Very little outcrop. Shows that even with such variations in topography the homogenous layer, due to slump or mass flow deposit, is thick enough to prevent outcrop.
	18:10	42 21.698	144 50.475	IIBa - Here the drape is much thinner. Maybe a change in sediment.	The imagery shows this section as being outcrop. Possibly a basement high.
	20:10	42 04.961	144 40.312	IIB	Still very dark.
	21:00	41 57.471	144 35.610	IIA	Uncharacteristically shows up as very dark in imagery.
	23:30	41 41.814	144 18.327	IIIC - Appears to have a thin drape of sediment.	The sediment drape does not appear in imagery. Still shows as outcrop.
30/12	21:00	38 56.682	141 41.324	IIA	Good sediment cover.
	22:00	38 53.441	141 29.183	IIA/IIIC - Short sections of IIA echo type are highs and are bounded by blocks of outcrop, IIIC echo type.	
31/12	0:20	38 43.000	141 03.700	IIA - Topographic high about 22km long.	
	1:30	38 36.604	140 51.548	IIIC	Large outcrop blocks seen across swath.
	3:10	38 27.000	140 33.000	IIB - rough surface with small irregular underlying hyperbolae.	Lack of outcrop, homogenous section of sediment cover - grey.

31/12	4:40	38 18.632	140 08.203	IIA/IIIC	Some outcrop with intermittant smooth sediment cover.
	5:30	38 13.998	140 08.197	IIB As seen at 3:10	Lack of outcrop besides one very large discrete block at 6:00. Otherwise consistant grey cover.
	9:50			IIIA	Very deep canyon - extends across swath as outcrop.
	15:40	37 19.007	138 19.839	IIIA	Not the amount of outcrop expected to accomapy this echo type. Some thin streaks of outcrop presant.
	16:00	37 17.743	138 15.947	IIB	
	17:30	37 12.054	137 58.091	IIIA	Large outcrop patterns, very rough topography.
	19:20	37 04.696	137 35.999	IIB/IIIC	
	21:40	36 55.602	137 08.703	IIIA	Very dark a lot of outcrop.
1/1	0:40	36 44.538	136 36.075	IIB/IIIC	Undistinguishable from above facies.
	1:10	36 42.265	136 29.298	IIIA	As previous IIIA.
	5:40	36 11.930	135 39.575	IIB/IIIC	Distinguishable. Less outcrop. Topographic high with sedimentation.
	6:10	36 07.662	135 34.503	IIIC	Sudden increase in swath width. The rough character probably due to a scarp.
	7:50	35 53.163	135 17.331	IIIA	Extreme. Streaks of outcrop across swath begins a series of very large canyons.

Location:	*Transit to GAB - GAB Survey*				
Date	**UT Time**	**Latitude**	**Longitude**	**3.5 kHz Echo Type**	**Imagery Description**
1/1	9:40	35 42.789	134 56.731	IIIC	Mainly sediment covered with thin bands of outcrop across swath - small canyons.
	11:10	35 42.687	134 35.420	IIB/IIIC	Series of larger canyons marked by incresed outcrop, still shows patches of sediment in places.
	12:00	35 42.616	134 23.556	IIIC	Topographically flat zone is well sedimented but a large canyon appears as outcrop.
	12:50	35 42.524	134 11.766	IIB/IIIC	Alternating well sedimented sections separated by bands of outcrop across swath which correlate to large canyons in the bathymetry.
	14:10	35 42.434	133 52.378	IIB - Still quite rough, some hyperbolae breaking the surfaceregularly but IIB echo is more dominant.	Consistant long grey region, well sedimented, free of outcrop. Banding does occur but not frequently.
	21:10	35 33.707	132 11.644	IIIC	Deep canyon ~ 350m
	22:10	35 28.898	131 59.885	IIB	Well sedimented section. Very little outcrop.
2/1	1:40	35 09.736	131 12.966	IIB/IIIC	Increased outcrop but still mainly sediment covered.
	2:40	Start of New Roll		Entering GAB marine park.	
	3:10	35 02.761	130 55.851	IIIA	Appears as a circular outcrop pattern.
	3:40	35 01.463	130 52.830	IIIC	Less outcrop, some sedimentation.
	4:50	35 08.890	130 49.159	IIIA	Almost entirely outcrop. Large outcrop seen in previous IIIA continues SW where the track cuts across obliquely.
	6:10	35 22.120	130 49.077	IIIC	Still mainly outcrop.
	7:30	35 35.260	130 48.924	IIB	Distinctly less outcrop, larger sediment patches.
	8:10	35 41.500	130 48.940	IIB/IIIC	Undistinguishable from above facies.
	10:20	35 40.642	130 42.607	IIIC	Increase in outcrop so that it almost covers entire swath again.
	13:50	35 08.000	130 38.500	IIB	Sudden stop to outcrop. Very light to medium grey - narrowing swath width.
	17:00	34 37.578	130 45.490	IIA	The following facies are undistinguishable from above in the imagery.
	21:20	33 56.003	130 47.347	IIB	
	23:50	34 01.062	130 42.798	IIA	
3/1	3:40	34 37.258	130 40.005	IIB	
	5:00	34 49.724	130 37.401	IIID	
	6:10	34 59.000	130 33.800	IIA	Again grades back to a very light grey before the outcrop of the following IIIC facies.
	7:20	35 08.668	130 30.864	IIIC	Moderate amount of outcrop - small canyon.

	9:40	35 06.169	130 22.483	IIB	Sudden stop to outcrop. Very light to medium grey - narrowing swath width.
	10:40	34 56.603	130 26.329	IIID	The following facies are undistinguishable from above in the imagery.
	11:10	34 51.970	130 28.753	IIB	
	13:10	34 32.000	130 34.500	IIA	
	16:40	33 58.746	130 38.878	IIB	
	19:00	33 54.983	130 35.816	IIA	
	23:10	34 33.000	130 28.400	IIB	Slightly darker grey in this region - coarse sediment.
4/1	2:20	34 27.137	130 23.841	IIA	Consistant light grey.
	3:00	34 20.097	130 25.892	IIB	Slightly darker grey in this region but overall the same as previous.
	4:00	34 09.555	130 27.764	IIA	
	9:20	33 45.390	130 44.337	IIB	The IIB echo represents a coarser sediment, this is reflected in the imagery by being slightly darker.
	10:30	33 41.998	130 43.979	IIA	
	13:20	33 39.111	130 45.641	IIB - Relatively flat.	Becomes increasingly darker - almost outcrop. Therefore must be very coarse sediment.
	17:20	33 33.497	130 46.198	IIA - Very faint broken reflectors, some IIB	
5/1	0:20	33 55.925	130 51.237	IB - Subbottom reflectors continuous and sharp.	
	4:10	34 37.407	130 51.028	IIB - No subbottoms.	Increasing darkness.
	6:00	34 57.157	130 49.418	IIIC	First outcrop appears.
	6:40	35 04.412	130 50.964	IIIA	Large piece of data missing due to the extreme topography.
	8:20	35 15.597	131 05.864	IIIC	Greatly reduced outcrop. Now the outcrop is in the form of bands across swath.
	18:30	35 50.497	133 07.044	IIA - Very faint reflectors often disturbed by hyperbolae.	Very light grey section. Therefore well sedimented and clear of outcrop.
	19:30	35 50.512	133 20.465	IIIA	Band of outcrop across swath - Canyon.
	19:50	35 50.534	133 24.951	IIA	As previous IIA.
	20:10	35 50.544	133 29.418	IIB - Often marked relief. Some hyperbolae breaking the surface.	Similar to IIA appearance but with some outcrop visible.
	21:25	35 50.655	133 45.600	IIIA - Very short rugged interval.	Faint band of outcrop across swath, mostly sedimented.
	21:45	35 50.670	133 49.000	IIB	As previous IIB.
	22:20	35 50.740	133 57.200	IIB/IIIC - Short sections of IIB.	Banding of outcrop across swath - not as dark as previous.
	23:30	35 50.879	134 12.451	IIIC	Patches of outcrop that don't form complete bands.
6/1	0:50	35 50.960	134 59.326	IIB/IIIC	As previous but some banding occurs.

6/1	3:10	35 50.710	134 59.326	IIIA	Broad bands of outcrop.
	5:50	36 09.495	135 24.738	IIB/IIIC	Appears as a very broad band of outcrop which thins across swath.
	6:30	36 12.812	135 32.239	IIIA	A lot of outcrop. Some banding. Approaching a series of canyons.
	10:40	36 45.170	136 07.150	IIB/IIIC	Much more sediment. Outcrop less pronounced, no banding.
	11:50	36 48.066	136 21.750	IIIA	Increasing outcrop. Banding presant. Very large canyon at 15:00.
	15:40	36 59.174	137 10.127	IIB/IIIC	Short period with little outcrop. Then a broad band of outcrop covering entire swath.
	18:20	37 11.658	137 40.101	IIIA	Swath widens at this point. Canyon marked by outcrop.
	19:50	37 05.762	137 51.635	IIIC - Very shallow ~ 260m	Swath very narrow. Appears very dark grading to a lighter IIB.
	21:20	37 01.287	137 38.628	IIB - Relatively flat.	Consistant dark grey. Lighter than IIIC above.
	23:00	36 54.964	137 18.746	IIA	As above.
	23:50	36 51.363	137 09.290	IIIA	Another line across the series of canyons seen earlier.
7/1	5:10	37 05.491	136 51.825	IIB/IIIC	Corresponds to a broad band of outcrop across swath. Large canyon.
	6:50	37 07.318	137 11.417	IIIA	Separated from above by a section clear of outcrop. Very long section of outcrop.
	11:10	37 19.375	137 50.778	IIIC	Outcrop almost disappears and swath narrows.

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	17:00	37 37.987	138 47.634	IIB/IIIC	No outcrop besides a band at 19:45
	21:40	38 02.851	139 33.880	IIA	Very consistant light grey section.
	22:20	38 07.719	139 40.183	IIA/IIIC	Begins with a patchy band of outcrop across swath.
	23:50	38 15.153	139 57.009	IIB/IIIC	Slightly more outcrop than above.
8/1	1:00	38 21.846	140 08.674	IIA/IIIC	Begins with a patchy band of outcrop across swath.
	2:50	38 30.372	140 28.262	IIA	very clear section. No outcrop.
	3:20	38 33.100	140 33.400	IIIA	Dark broken band across swath - 2 Large canyons.
	4:50	38 40.813	140 48.355	IIA/IIIC	Long sections of clear swath with a single band of outcrop across - canyon.
	6:10	38 47.390	141 00.951	IIIC	very wide, deep canyon. 1750-2500m
	7:00	38 51.700	141 08.600	IIB	One patch of outcrop correlates to a steep slope. The rest appears to be dark grey.
	8:50	38 59.805	141 29.616	IIA/IIIC	Some long dark periods as seen above separated by shorter light sections (IIA).
	10:40	39 05.542	141 51.734	IIIC	Light grey background with patches and outcrop banding -frequent. A small seamount at 19:10, circular in imagery.
	21:40	40 10.960	143 10.537	IIB/IIIC	The background sediment appears darker (coarser) - amount of outcrop is similar to above.
	23:20	40 26.298	143 18.865	IIB	Dark as above, but outcropping decreases.
9/1	1:20	40 45.196	143 28.284	IIB/IIIC	Much lighter than above. Some outcrop.
	3:10	41 00.109	143 43.652	IIB	Light as above. Virtually no outcrop.
	4:00	41 07.138	143 50.786	IIA	Light and dark patches. Not a consistant grey as expected with IIA.
	6:20	41 27.244	144 10.779	IIA/IIIC	Increased outcrop.
	7:00	41 32.966	144 16.460	IIB/IIIC	Not much outcrop but darker overall.
	8:20	41 40.506	144 26.935	IIA	Half swath appears darker than the other . No features.
	9:30	41 29.874	144 19.310	IIB	Very dark. Circular feature at 09:55 - canyon.
	10:50	41 19.491	144 08.768	IIA	Much lighter. Very little outcrop
	11:50	41 11.973	144 00.387	IIB/IIIC	Swath becomes wide, almost entirely outcrop - canyons.
	12:30	41 06.765	143 55.049	IIA	Still very dark. Appears flat in bathymetry.
	13:00	41 02.896	143 51.064	IIB	Begins very dark, swath widens and it becomes much lighter with no outcrop.
	16:20	41 14.718	143 39.463	IIB/IIIC	Consistant grey, relatively light. Very little outcrop. 19:00-19:45 Some outcrop.
	20:40	41 42.825	144 17.912	IIA - Steep rise but subbottom reflectors still visible.	Some outcrop streaks parallel to track. Track is parallel with canyon direction.

	21:40	41 42.910	144 28.525	IIB - Occasional faint subbottom reflectors occur but IIB is the dominant character.	Very shallow ~ 225m. Swath becomes narrow and noisy - very dark.
10/1	8:30	43 19.841	145 25.780	IIIC	Swath widens and there is much outcrop.
	9:20	43 24.022	145 35.147	IIB - Regularly interrupted by hyperbolae.	Swath narrows again and appears as previous IIB.
	18:20	44 07.328	147 08.419	IIIC	Very dark outcrop patterns cover swath.
	19:30	44 07.525	147 25.105	IIB	Swath widens, outcrop increases but still similar to above.
	21:30	44 02.981	147 51.571	IIB/IIIC	Outcrop decreases with longer light grey sections.
11/1	1:00	43 33.020	148 00.566	IIB	Swath becomes narrow and dark.
	3:00	End of Survey			