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AGSO Cruise Report: Cruise 210

THE "*SOJOURN 7*" SWATH-MAPPING CRUISE OF R.V. *MELVILLE* OFF EASTERN TASMANIA AND IN THE GIPPSLAND BASIN

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1. SUMMARY

The R.V. *Melville* left Hobart at midday on 10 April and arrived in Melbourne at 1400 on 17 April 1997, on AGSO Cruise 210, a cruise dedicated largely to swath-mapping, and to a lesser extent to magnetic and gravity profiling. Altogether 1900 nautical miles (3450 km) of swath-mapping and magnetic data were acquired east of Tasmania and in the Gippsland Basin, and 1950 nautical miles (3550 km) of gravity data (Figure 1). Swath-mapping coverage overlapped slightly, to give 100% coverage of both bathymetric contouring and acoustic imagery.

We were fortunate to experience good weather, and the result was excellent SeaBeam 2000 swath-mapping data. Average wind speed seldom exceeded 25 knots, and wave heights did not exceed 2 metres. On two occasions high winds and swell of 3-4 metres came from the southwest or west-southwest, and the result was reduced SeaBeam data quality.

Two-thirds of the work was dedicated to the Tasmanian margin and the rest to the Gippsland Basin. As we wanted to get regional coverage from the deepwater swath-mapping system, which has a swath width of 3.5 times water depth, the bulk of the work was concentrated in water 2000-4200 m deep. In two areas, a fisheries area off St Helens in Tasmania, and in the western and southwestern Gippsland Basin, we came into water shallower than 1000 m.

The *Tasmanian* work had three elements, a regional survey of the outer continental margin between 42°30'S and 39°S (east of Hobart to northeast of Flinders Island), a short survey of a jarosite refinery residue dump site southeast of Hobart, centred on 148°15'E, 43°45'S, and the survey of the fisheries area, centred on 148°50'E, 41°20'S.

The regional survey showed the continental margin to be lightly sedimented and complex geologically, with structures related to Late Cretaceous breakup of East Gondwana being very obvious on the margin in general, and at the foot of the slope in particular. Major offsets in the foot of the slope trend 15-40°, 90° and 110°. Canyons are well developed along much of the margin, and appear to have formed soon after break-up, and to be relatively inactive now. Detailed studies of the data will greatly increase our understanding of the geological history of the margin, and allow targeted sampling and seismic profiling in the future.

The survey of the jarosite dump area, in 1900-4500 m water depth, revealed the details of the bathymetry, down current (SSE) and down slope (ESE) of the dump site. In combination with earlier current modelling, and pre-existing biological, geological and chemical study of cores, it allows the question of jarosite dispersion and its effects on bottom fauna to be more fully addressed.

The survey of 600 km² of an area off St Helens and St Patrick's Head (centred on 148°50'E, 41°20'S) was designed to help the orange roughy fishery and fisheries research. Water depths are 800-1600 m, and the sea floor is generally hard and fairly flat. Scarps formed by resistant flat-lying strata form protective habitats for orange

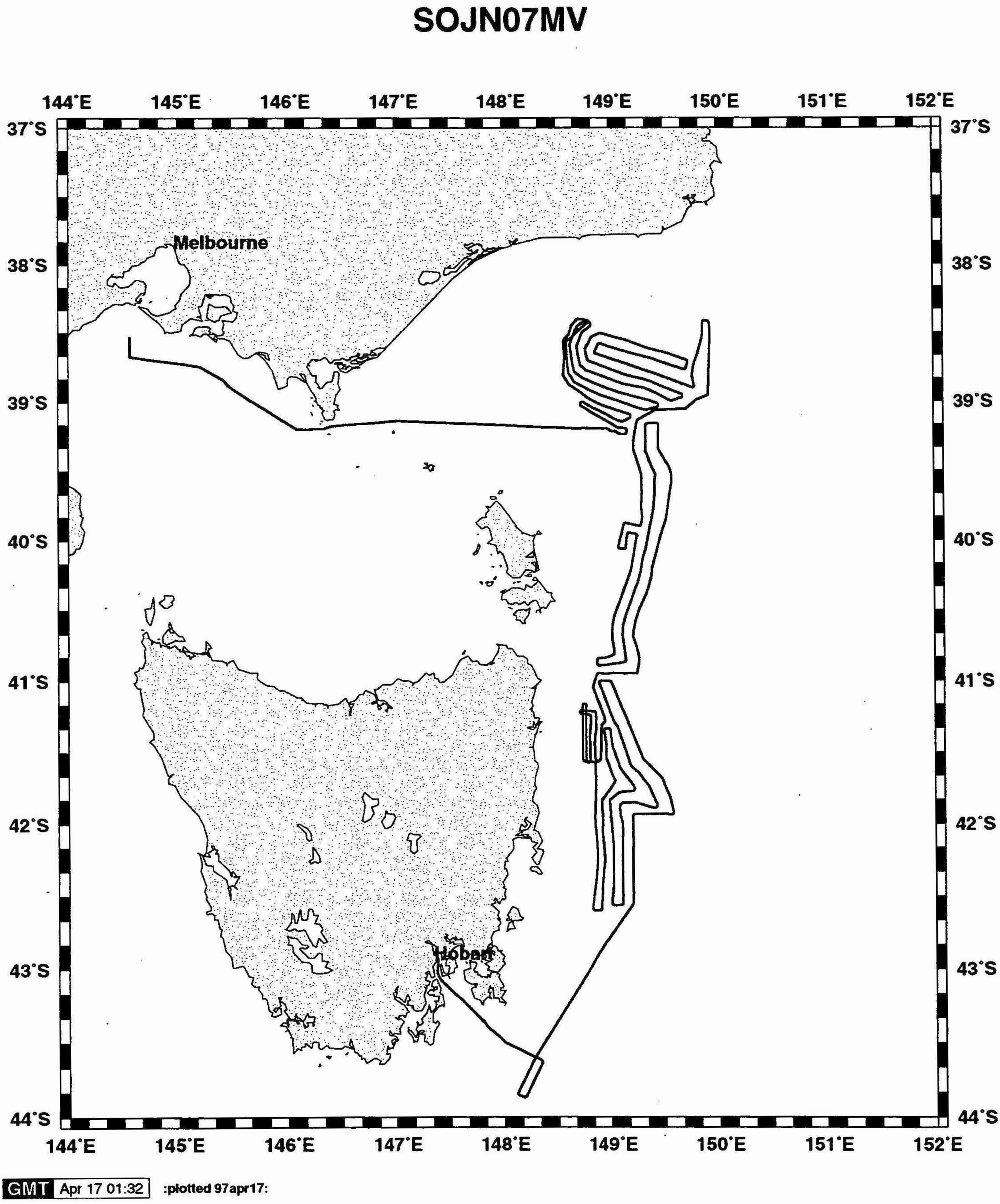

Figure 1. R.V. *Melville's* east Tasmania/Gippsland *Sojourn 7* survey location

roughy, and the submarine volcanic cone of St Helen's hill, a major fishing ground during spawning, was mapped in detail. It rises from sea bed 1000 m deep to less than 600 m. Two smaller volcanic cones were mapped in deeper water, and are potential fishing grounds.

The survey of the deepwater *Gippsland Basin* took in the Bass Canyon, running east-southeastward from the continental shelf of Bass Strait between Victoria and Tasmania to debouch on the abyssal plain at 4000 m water depth, and its flanks. Coverage was limited on the north slope, but virtually complete to 1000 m at its western end and to 2000 m on its southern flank. It provided exquisite detail of the main canyon, which lies within a structural graben, and the feeder canyons that come in from all sides. Structural and lithological control of the canyons is very clear, and follow-up sea floor sampling should determine whether or not they are inactive at present.

Numerous core sampling sites in the canyons, and dredge sampling sites for older Cainozoic rocks on the canyon walls, were located. A sampling research cruise of R.V *Franklin* was carried out in 1998, and this first accurate map greatly increased its efficiency. The results from the two cruises will provide a great deal of tectonic and stratigraphic information about the basin, of value to the petroleum exploration industry.

2. INTRODUCTION

From 10 to 17 ~~March~~ April 1997, the Australian Geological Survey Organisation (AGSO) chartered the 85 m Research Vessel *Melville* from Scripps Institution of Oceanography on a cooperative scientific basis, to map the sea bed east and northeast of Tasmania including the deep water part of the Gippsland Basin. The vessel was equipped with the SeaBeam 2000 multibeam sonar system, capable of swath-mapping the morphology and roughness of the sea bed in a swath 3.5 times as wide as the water depth. The central beam gave a 12 kHz bathymetric profile. Other equipment employed included a magnetometer and gravity meter. Navigation, by military standard GPS using the P code, had an accuracy of about 5 m. Detailed ship's tracks for the survey, from south to north, are shown in Figures 2-5.

The aims of the cruise were to determine the morphology and sea bed character of selected areas, to aid in tectonic, basin and sedimentological studies, to aid the fishing industry, and to provide critical information for future seismic profiling and geological sampling. Satellite gravity images, and sparse bathymetric and seismic profiles, were used to plan the survey.

2.1. Geological setting and tectonics

The offshore continental margin of southeasternmost Australia consists of the eastern Tasmanian margin, and the margin east of Bass Strait between Victoria and Tasmania (Figure 1). In most of the Cretaceous it was within East Gondwana, with the Lord Howe Rise welded to Australia. Rifting probably began in the Early Cretaceous. Heating and uplift in the Eastern Highlands at about 95 Ma (O'Sullivan *et al.*, 1995) must have been accompanied by a period of stretching and rifting of continental crust,

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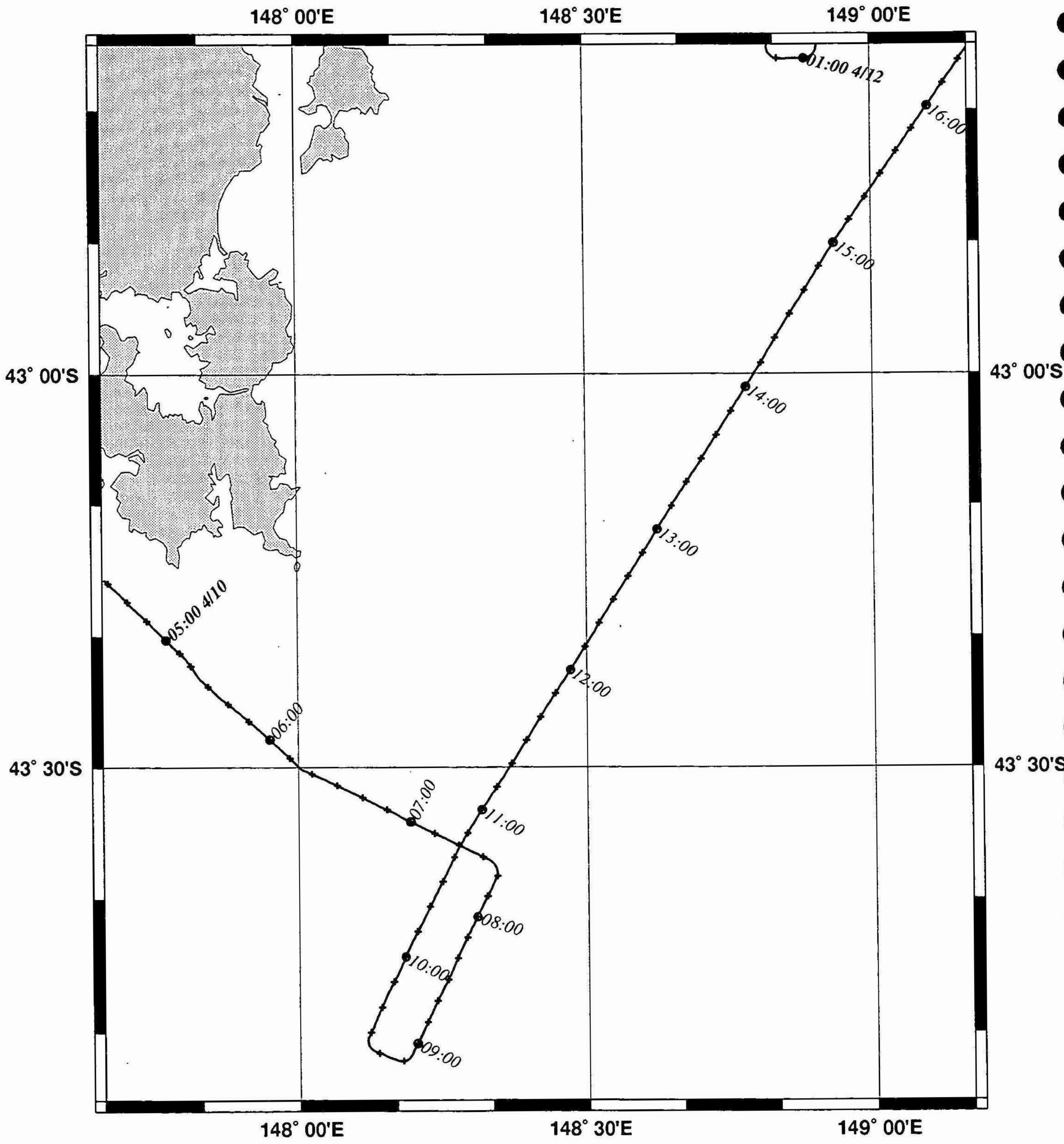

Figure 2. Time-annotated track map for the southern area. Annotation is in hours GMT / day of month (at 0000 GMT); ticks on the hour.

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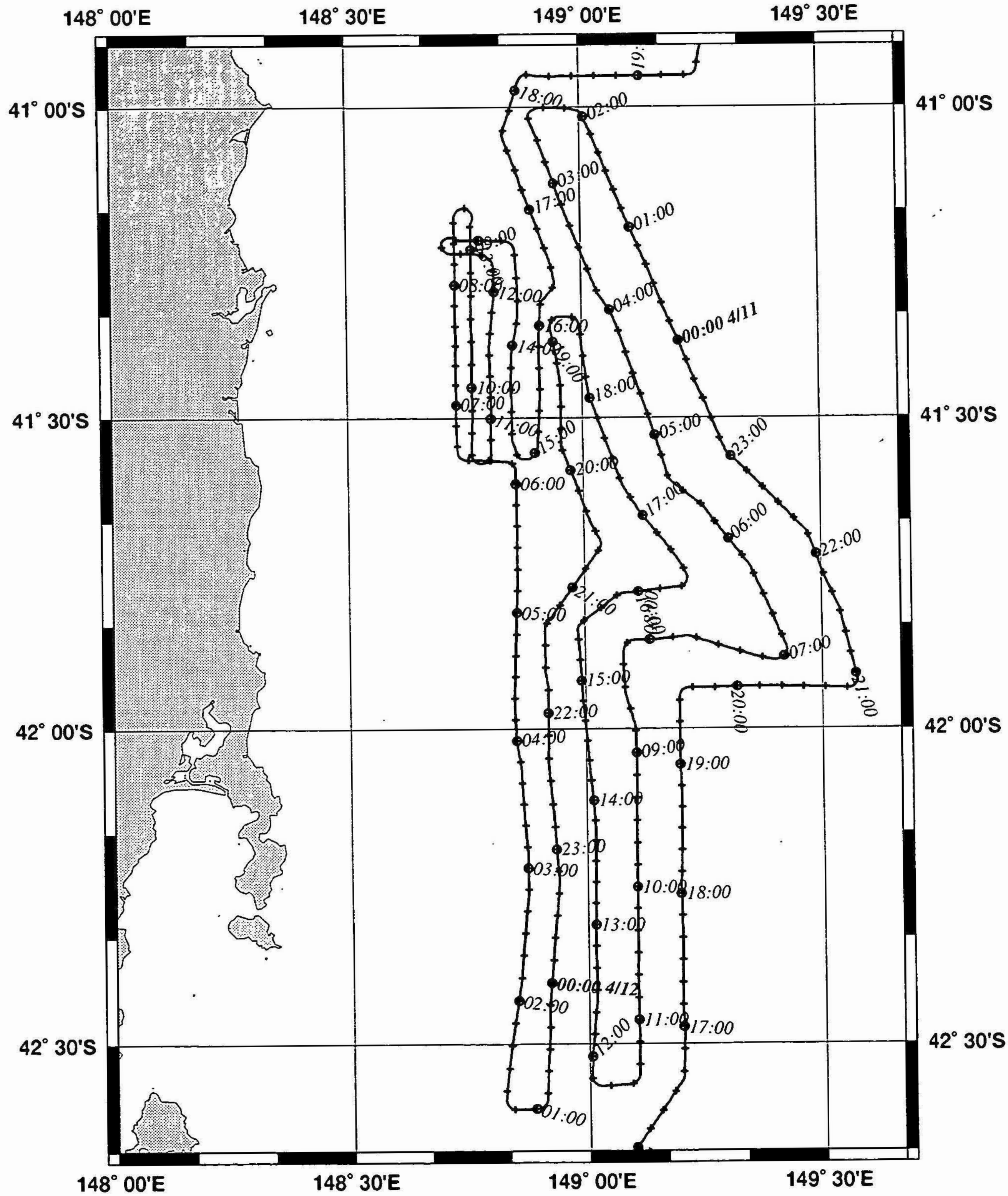

Figure 3. Time-annotated track map for the southeastern area. Annotation is in hours GMT / day of month (at 0000 GMT); ticks on the hour.

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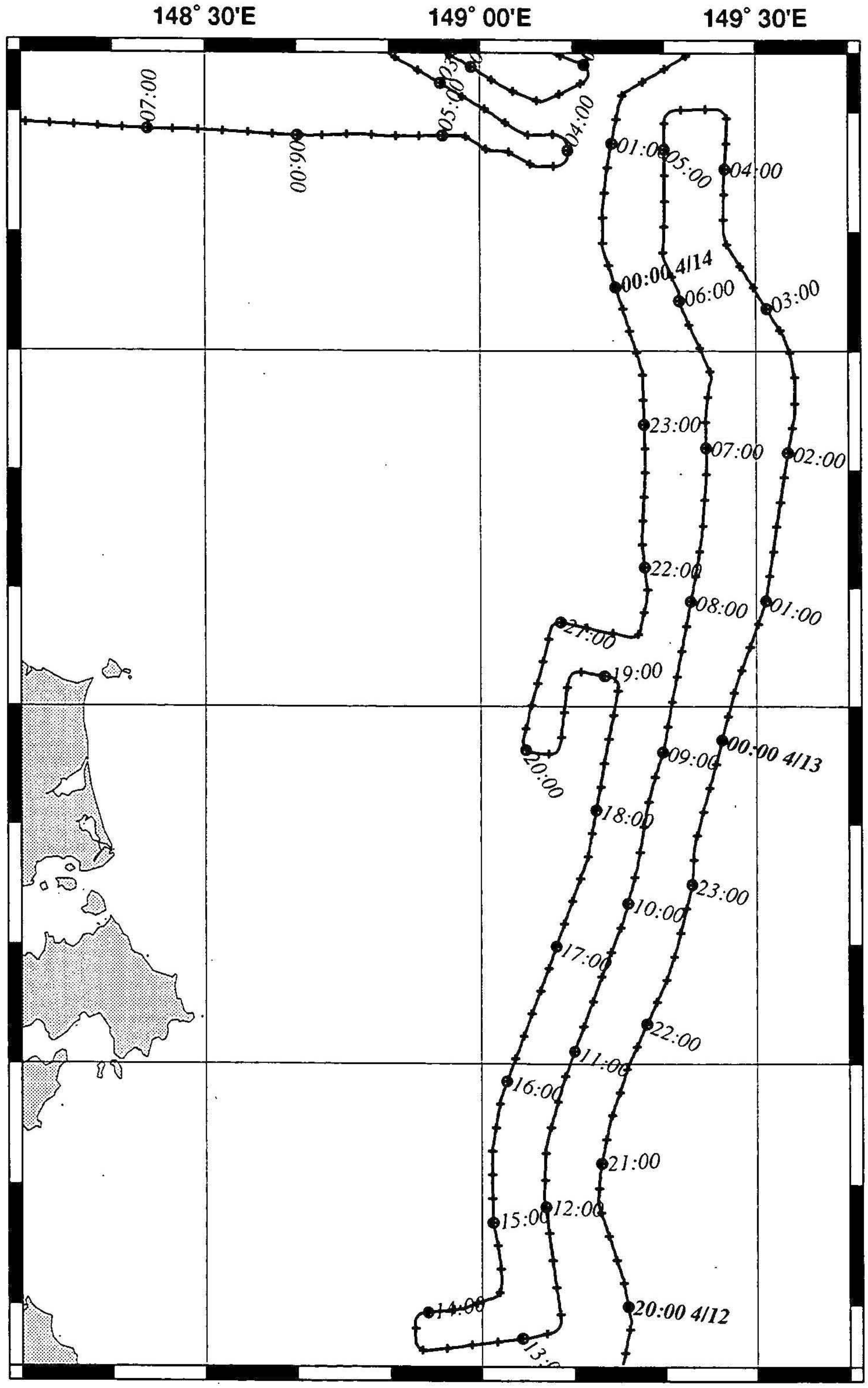

Figure 4. Time-annotated track map for the central area. Annotation is in hours GMT / day of month (at 0000 GMT); ticks on the hour.

GIPPSLAND_sojn07mv_track

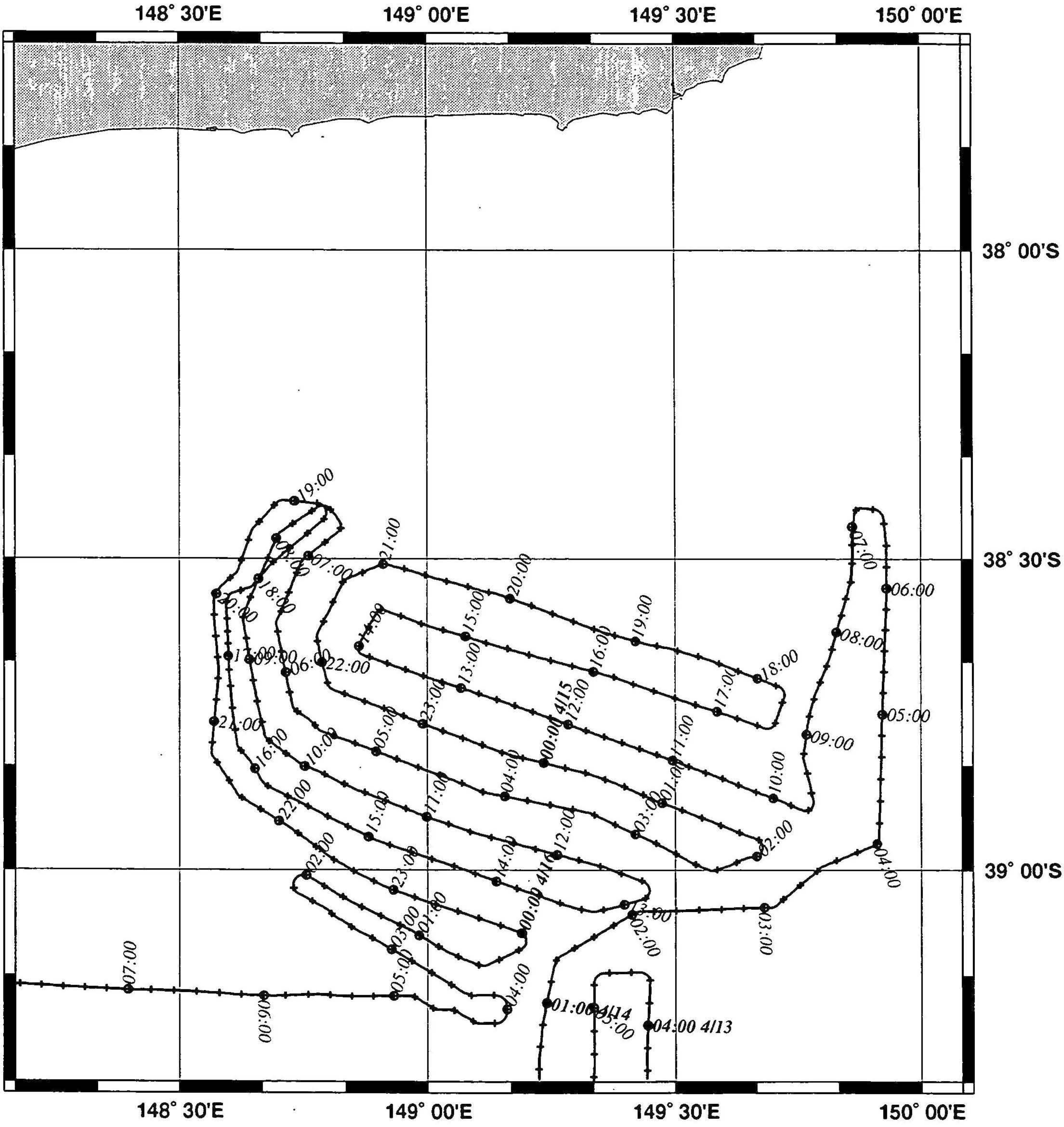

Figure 5. Time-annotated track map for the Gippsland area. Annotation is in hours GMT / day of month (at 0000 GMT); ticks on the hour.

which gave way to the commencement of the opening of the Tasman Sea in the Late Cretaceous at about 80 Ma (Hayes & Ringis, 1973; Weissel & Hayes, 1977). The margin subsided as the Tasman Sea opened, and initial erosion of the highlands, in the Late Cretaceous and Early Tertiary, deposited substantial quantities of sediment on oceanic crust. The East Tasman Plateau moved eastward in the Late Cretaceous, opening the East Tasman Saddle between it and Tasmania (Royer & Rollet, 1997).

The eastern margin of Tasmania has a continental shelf that was mapped out to 300 m water depth by the Department of National Mapping, using closely spaced echosounder profiles. It is bounded by the 200 m contour and is generally 20 to 30 km wide, but broadens to 60 km wide northeast of Flinders Island. The shelf continues across Bass Strait, with a large embayment of the 200 m contour to the west, before it swings around parallel to the Victorian coast where it is 50 km wide. Geological sampling has shown that it is mostly covered by bryozoal sand (Davies, 1979; Marshall & Davies, 1979; Jones & Davies, 1983) and it is likely that this is swept down the continental slope on occasions.

The continental slope off Tasmania was known only from scattered echosounder and reflection seismic profiles and occasional seabed sampling. The slope between the 200 m and 4000 m contours is 50-80 km wide, and generally appears to be heavily sedimented in the upper half, but with numerous outcrops in the lower half. Canyons are present in places.

In the Gippsland Basin of Bass Strait, the slope was better known, with considerable data coming from the petroleum exploration industry and from scientific surveys (Megallaa, 1993). This region is dominated by the Bass Canyon, which forms a trough trending 105°, and with relief of as much as 3500 m in all, and has localised steep walls that are 500 m high in places. Tributary canyons are widespread.

The abyssal plain is poorly known, but generally lies between 4000 m and 4600 m. In places the morphological boundary is clear, but in others it is transitional.

The Gippsland Basin contains thousands of metres of Cainozoic and Cretaceous sediments, but the poorly known sedimentary basins off eastern Tasmania are apparently less than 1000 m thick (Cameron & Pinchin, 1974).

2.2. Previous studies

A number of reflection seismic profiles cross the east Tasmanian margin, but none of these are high-quality deep seismic lines. In 1971, the Bureau of Mineral Resources (now AGSO) recorded fifteen east-west profiles, spaced 20 nautical miles apart, as part of Survey 15 of the Continental Margin Survey (Cameron & Pinchin, 1974), using a 120 kilojoule sparker system. Shell Petroleum used the R.V. *Petrel* to collect five regional lines in 1972.

In the Gippsland Basin there is a plethora of reflection seismic lines recorded by petroleum exploration companies in shallow water, but most modern multichannel regional lines have been acquired by BMR/AGSO as Surveys 40, 68 and 90. These lines were tied to exploration wells, and interpreted on that basis (Willcox *et al.*, 1992).

All these data, or the cruise reports, were examined briefly before the cruise to establish the general framework of the area, and to help plan the swath-mapping to cross areas where older rocks came to the surface. We prepared a compilation of regional bathymetry and satellite gravity (Sandwell & Smith, 1994) as other planning aids.

In the 1970s, BMR carried out a methodical program of geological sampling on the continental shelf that showed that it is dominated by bryozoal sand (Davies, 1979; Marshall & Davies, 1979; Jones & Davies, 1983).

The only relevant DSDP site is Site 283 (43°54.60' S 154°16.96' E), drilled to a depth of 592 m on the abyssal plain about 250 km east of the East Tasman Plateau, in 4756 m of water. It recovered entirely abyssal sediments above heavily altered and un-dated pillow basalt (Kennett, Houtz *et al.*, 1975A). The sedimentary sequence consists of about 13 m of Plio-Pleistocene zeolitic clay, 163 m of Late Eocene siliceous ooze, 139 m of Middle Eocene silty clay, and 273 m of Paleocene silty clay with some chert. The site was located over a magnetic anomaly interpreted as Chron 32. The sediment age does not conflict with the Late Cretaceous (Maastrichtian) age arising from the magnetic identification.

2.3. Acknowledgements

We gratefully acknowledge the efforts of Bob Knox and others at Scripps Institution of Oceanography (SIO) in finding ways and means to allow this research cruise to go ahead at very short notice. This involved re-scheduling of the vessel and making scientific support staff and technicians available for the work. We are grateful to all the ship's crew for making us welcome and providing the basis for a successful cruise. Special mention should be made of the ship's deck officers - Captain Eric Buck, First Mate Murray Stein, Second Mate Eric Wakeman and Third Mate Anja Marneweckie - for their wonderful support.

The scientists and technical staff all worked well together: Chief Scientist and SeaBeam processor Stu Smith (SIO), Principal Investigator Neville Exon (AGSO), geophysicist Peter Hill (AGSO), geologist Jock Keene (University of Sydney), electronics engineer Ron Moe (SIO), and technician Ron Comer (SIO). Peter Butler of AGSO is thanked for producing Appendix 5, and George Bernardel for reviewing the document.

3. SURVEY SYSTEMS ON R/V *MELVILLE*

Details of the scientific and navigation equipment on the ship are provided in Appendix 2. Also provided (Appendix 3), are the positions of the sensors of the various acquisition systems on the ship relative to the navigation origin. The main geophysical systems operated during the transit cruise were the SeaBeam 2000 seafloor mapping system, the Geometrics magnetometer and the Bell gravity meter. The XBT water velocity profiling is outlined in Appendix 4. Profiles of magnetic and gravity data are shown in Appendix 5. Weather conditions are summarized in Appendix 6.

All digital and paper data (including the handwritten cruise log) are held in the AGSO data base, and at SIO; much of the data is also held by the University of Sydney.

3.1. Information on the Sea Beam 2000

The SeaBeam 2000 aboard the R/V *Melville* is a 12 kHz, 121-beam swath-mapping system (Asada, 1992; Miller & Capell, 1993). The transmit beam-width is 2° fore-and-aft (at the -3 dB points), while the receive beam-width is approximately 2° athwartship. The system will operate in conditions of up to ±10° roll and ±7.5° of pitch.

The total angular swath width is 120°, so that a strip of seafloor 3.4 times as wide as the water depth is mapped. The maximum effective swath-width in deep water (>4500 m) is about 15 km. SeaBeam 2000 also collects backscatter data which can be processed to produce amplitude and textural data similar to that produced by sidescan systems such as SeaMARC II/HMR1 and GLORIA. The sidescan has a swath-width comparable to the bathymetric swath and 1024 pixel across-track resolution. During this cruise, the backscatter data were generally sampled at 15 m intervals in the cross-track direction when operating in relatively deep water (2-4 km depth). Optimum pixel size is inversely proportional to water depth, so during the cruise a range of pixel sizes from 2 to 15 m were employed. The ping interval is automatically adjusted to match water depth. In depths of about 2900 m for example, the ping interval is 11 seconds.

The acquisition computer, dealing with a real-time multi-tasking environment, consists of an Intel 80486 microprocessor running at 33 MHz and using 8Mb of RAM. The digital signal processing algorithm, requiring high data transfer rates and large computational capabilities, uses a number of Texas Instrument TMS320C30-based digital signal processors.

4. CRUISE RESULTS

4.1. Jarosite dump

Jarosite is the end product of zinc refining in Hobart and is a clay to silt sized powder rich in heavy metals. This material is dumped in approximately 2000 m of water on the continental slope southeast of Hobart, in a circle of two nautical mile radius about 43°36.6'S, 148°14.5'E. In the past 20 years about 4 million tonnes of jarosite has been dumped at the site by Pasminco EZ, the owner of the refinery. It is believed that currents carry the bulk of the jarosite well to the south, but some may reach the bottom near the site and be carried down the slope by turbidity currents. Such currents would be concentrated in canyons, and Dr Peter Harris of the Antarctic and Southern Ocean Climate Cooperative Research Centre in Hobart asked us to carry out a swath-mapping survey of the area of the site, and to its east (down slope) and south (down current). Harris and physical oceanographers from CSIRO were studying the situation for Pasminco, and an accurate map was a high priority for their work. The results recently have been submitted for publication (Harris *et al.*, in prep.). Dumping ceased in 1998.

Four hours of survey time were invested in three swaths in the dump area (Figure 6) and a rectangular area was fully mapped, elongated NNE-SSW along the slope and centred on 148°15'E, 43°45'S. The area is about 40 km long and 15 km wide, and covers water depths of 1900-3500 m. The slope increases with increasing depth, from about 2° at the top to about 7° at the bottom. A few small canyons are present, the deepest less than 200 m deep. Some of them run ESE down the slope and others southward along geological structures. The majority of them head within the survey region where the slope steepens. There is no doubt that the canyons are capable of carrying sediments down them as turbidites or gravity slides, and hence of transporting jarosite if it is present.

This work is complementary to the core studies being carried out in Hobart, and should lead to a better understanding of how the jarosite is dispersed.

4.2. Tasmanian fishing grounds

Off the east coast of Tasmania, demersal (bottom) fishing for orange roughy (*Hoplostethus atlanticus*) is an important industry. To the south of St Helen's hill is another area off St Patrick's Head from which orange roughy is fished. In correspondence and discussions with Nic Bax, Tony Koslow and Rudy Kloser of CSIRO Division of Marine Research in Hobart, we agreed to swath-map some of the area of both grounds as an aid to fishing and fisheries research.

Similar swath-mapping, carried out by AGSO from R.V. *L'Atalante* in 1994 (Exon, Royer & Hill, 1996), had proven of considerable benefit to the orange roughy fishery south of Tasmania, where swath-mapping better defined known grounds and discovered potential new grounds (Koslow & Exon, 1995; Exon, Hill & Koslow,

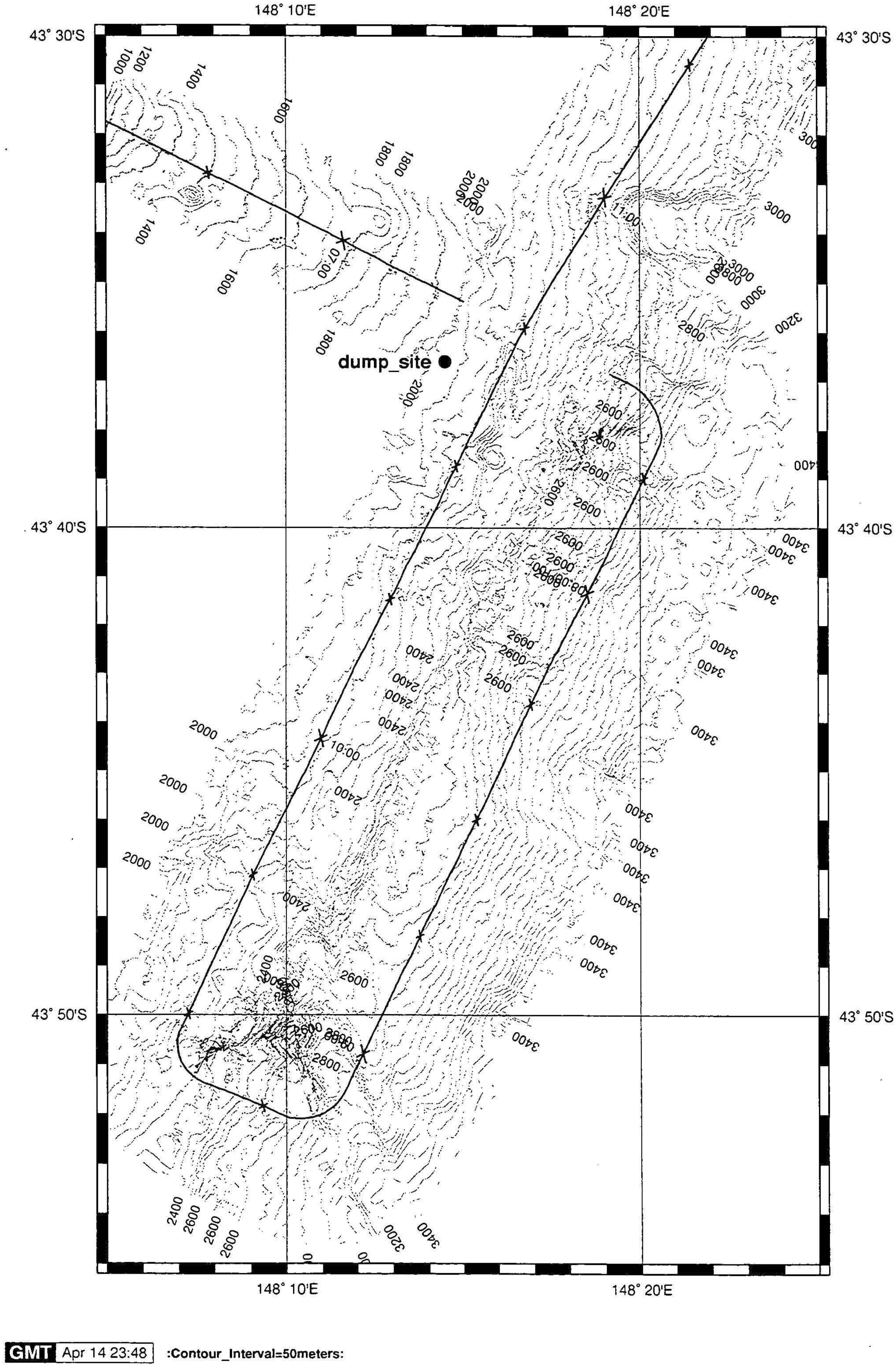

Figure 6. Track map and bathymetric contours in metres for the jarosite dump site, southeast of Hobart.

1996; Hill, Exon & Koslow, 1998). Each fishing ground is a volcanic seamount, and a number of seamounts discovered were included in a temporary Marine Protected Area, so that research could be carried out on their benthos and habitats. A substantial area is to be included in the "Tasmanian Seamounts Marine Reserve" in 1999.

According to Kloser *et al.* (1996), almost half the Australian catch of roughy is taken from the single spawning aggregation on St. Helen's hill (a small conical volcanic seamount off northeast Tasmania) in July and August each year (the only such aggregation known in Australia). At its peak in 1994 nearly 20,000 tonnes was landed in a season. According to Nic Bax (pers. comm.), there are major questions in the spawning behaviour of orange roughy that are critical in estimating their abundance and determining appropriate management strategies. The new bathymetric map of the area, far better than those prepared from single beam echosounders, will be most useful in interpreting existing and future fisheries data.

The area off St Patrick's Head has been shown by CSIRO studies to slope down gently eastward from 600 m to 1400 m, and to contain numerous pinnacles 30-40 m high and 200 m across the base. These pinnacles provide protection to fish and snare demersal trawls, so an accurate map of their distribution and shape would be of benefit to fishermen and researchers.

We surveyed a rectangular area elongated north-south, of 40 km by 15 km, centred on 148°50'E, 41°20'S, and extending from about 41°10'S to 41°35'S, and from 148°43'E to 149°04'E (Figure 7). Water depths were 850-1800 m. The area slopes down to the east at 3-5°, and is generally fairly flat. However, it is cut by shallow depressions running downslope to the east.

The imagery indicates that the sea bed consists of (or in places is shallowly underlain by) hard flat-lying strata with the possibility of basalt flows in the northern third. The bathymetry and imagery indicate that erosion has exposed low scarps and ridges in places, generally running east-west, particularly in the northern third of the area. In some areas NW to WNW trending joints are very apparent. We interpret the strata as consisting of lithified shelf limestones of Miocene age, like those commonly exposed elsewhere on the southern margin of Australia, and Quilty & Telfer (1994) have described Middle Miocene shelf limestones recovered from the area. These have subsided to their present depth some time after deposition. The overlying sediment is probably a veneer of carbonate sand carried down from the shelf. Small dark circular areas visible on the imagery are probably low Miocene bioherms. In the south there is a prominent ridge trending southeast, ending abruptly eastward in a bluff. Rough topography is associated with this ridge, indicating that hard rock exposures are widespread. There are valleys on each side of this ridge which join at the bluff (41° 33'S, 148° 45.5'E), and then trend eastward down the slope as a canyon. Several isolated pinnacles occur on the south side of this canyon and two have relief of 200m.

The volcanic seamount of St Helen's hill is a perfect cone at 41°13.8'S, 148°45.6'E. It rises from about 1000 m water depth at its base, where its diameter is about 3.5 km, to its top at about 600 m. There are some small rises at its foot that are probably volcanic vents, and there is a small possible volcanic flow on its western and northern side where the topography is rougher and more reflective. A highly reflective flat circular

St_Helens_Fishing_area

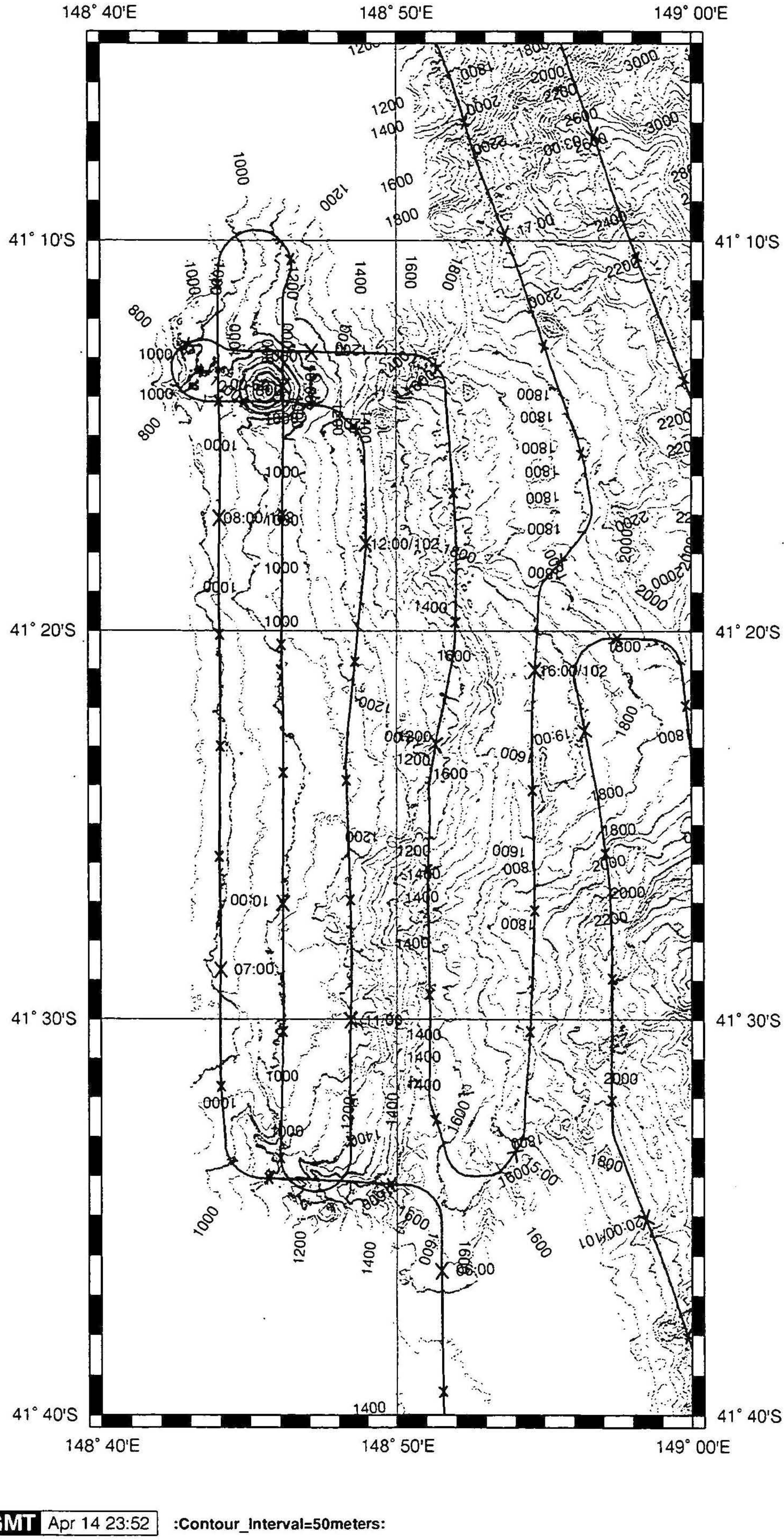

Figure 7. Track map and bathymetric contours in metres for the St Helen's hill fishing ground. The volcanic seamount in the northwest is St Helen's hill, rising from 1000 m to 600 m.

feature on its north side may be a lava lake. There are broad depressions on both the north and south sides that continue downslope, the southern one becoming a canyon that continues to the foot of the slope. If the adjacent limestones are indeed Middle Miocene in age, the volcanism is younger than 15 million years old. Another small cone, less than 200 m high and rising to about 1200 m, lies about 6 km east of St Helen's hill, at 41°14.5'S, 148°49.8'E.

In terms of fisheries' potential, the hard ground and occasional rocky rises should support an abundant benthos, which in turn would support the food chain that provides suitable conditions for orange roughy. The small cone east of St Helen's hill was the only seamount discovery that was new to us. It may have some limited fisheries potential.

4.3. Tasmanian outer margin: southeast and central east

The continental shelf out to the 300 m isobath off east Tasmania is 20-40 km wide. In the southeast, the continental slope falls to the East Tasman Saddle (between the Tasmanian mainland and the East Tasman Plateau), which lies at a depth of 3400 m and is located about 60 km out from the shelf edge. Off the central 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 a depth of about 4200 m. The continental slope in this area is about 80 km wide in the south, and narrows to about 40 km in the north.

A total of 31 hours of survey time was devoted to this region (Figure 3). This period excludes the jarosite dump survey, but includes the transit to the northeast from the dump, and the survey of the fishing grounds off St Helen's (see section 4.2). A large part of the continental slope between 41° 00'S and 42° 40'S, from its upper part to the abyssal plain, was mapped. The primary aims were (i) to establish the structural grain of this part of the margin and how it relates to breakup tectonics, and (ii) to map the structure of bedrock outcrop on the eastern margin of a possible basin that trends north-south and lies beneath the upper continental slope off the Freycinet Peninsula. The existence of this basin was inferred from the presence of a major elongate gravity low observed in ERS-1 satellite gravity imagery covering this offshore region and also in seismic profiles of early-1970s surveys shot off central east Tasmania (BMR Continental Margin Survey 15, and Shell *Petrel*). Later work showed that this basin extends from about 41° 40'S to about 42° 40'S (Hill *et al.*, 1998).

Prior to the *Melville* survey, the Australian Hydrographic Office had made a request that we investigate an anomalous sounding on Chart AUS 355. This point is located 65 km off Maria Island, at 42° 49.8'S 148° 56.5'E, and is shown as 500 fathoms (914 m) with adjacent depths of about 3000 m. We crossed this point during the transit from the jarosite dump to the survey area off central east Tasmania. There was no evidence of a local high in the swath-bathymetry (Figure 8). On the contrary, the seafloor at this point is almost flat at 2950 m, with just a gentle slope to the southeast. We conclude that the point sounding on AUS 355 is spurious, and have informed the Hydrographer accordingly.

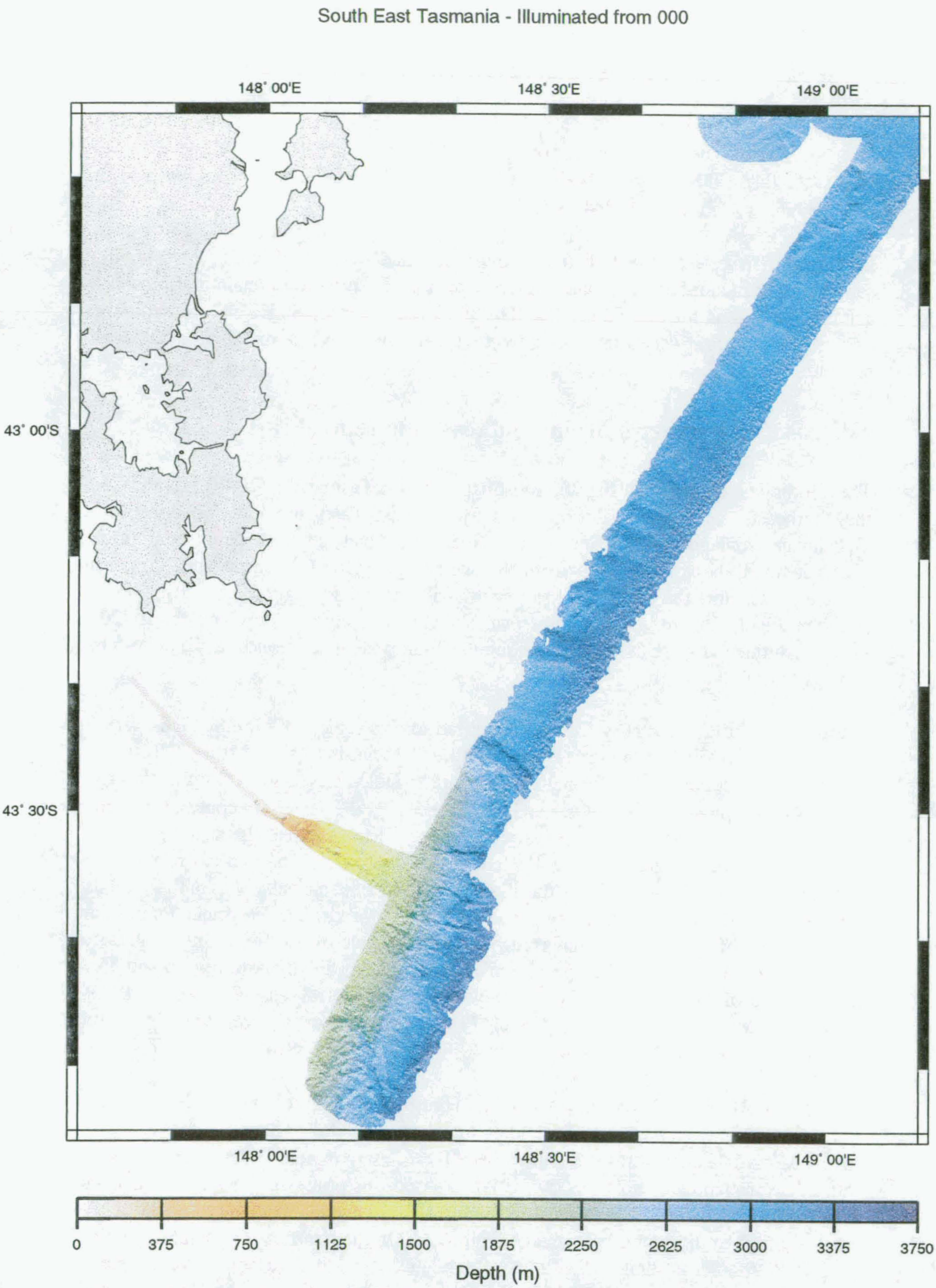

Figure 8. Shaded relief map of the transit swath through the southern area. Note the various canyons.

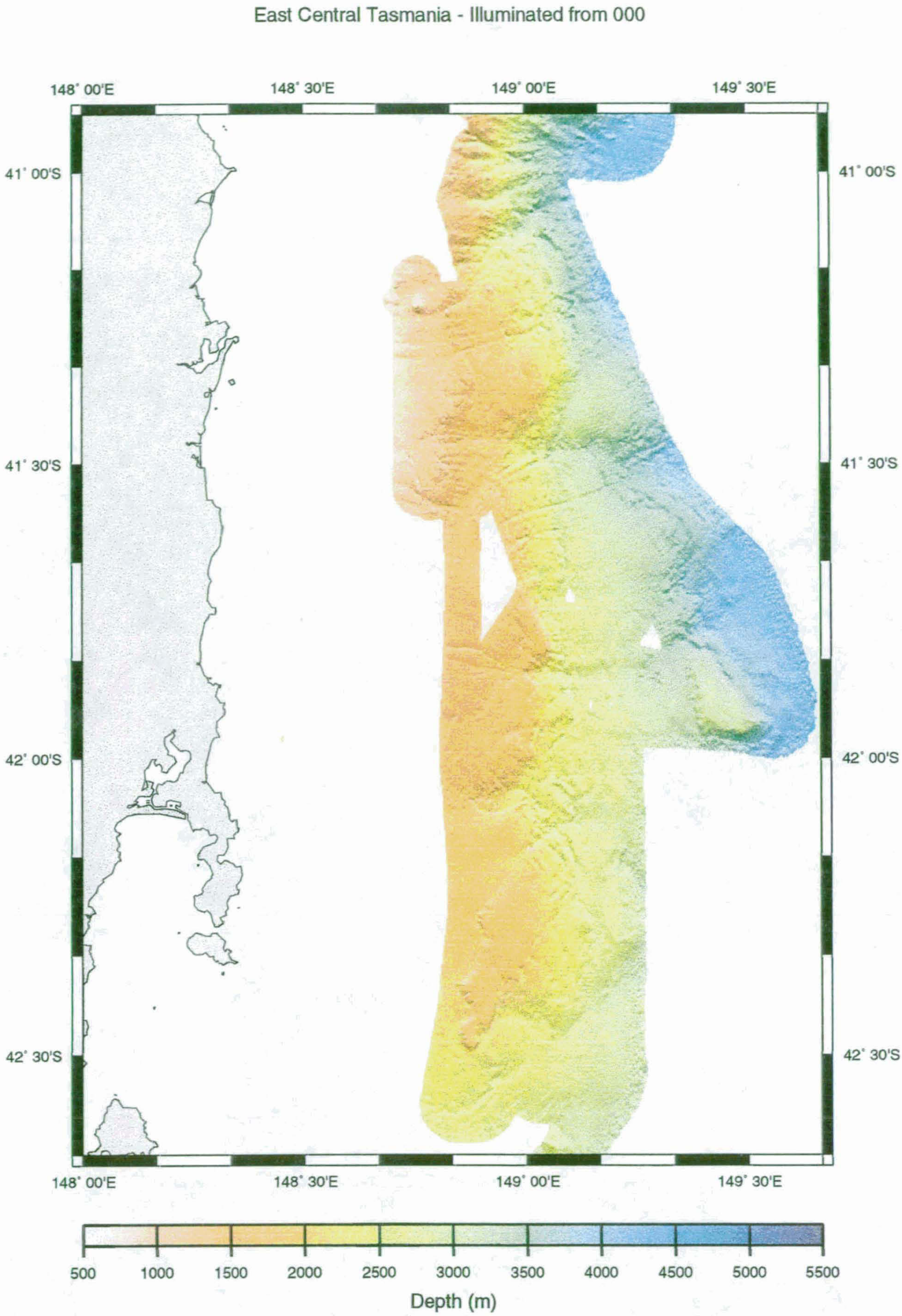

Figure 9. Shaded relief map of the southeastern and central area. Note the offsets of the foot of the continental slope, the large block above the abyssal plain near 42°S, the fault/joint patterns, and the absence of large canyons. Note also the north-south scarp at about 2000 m.

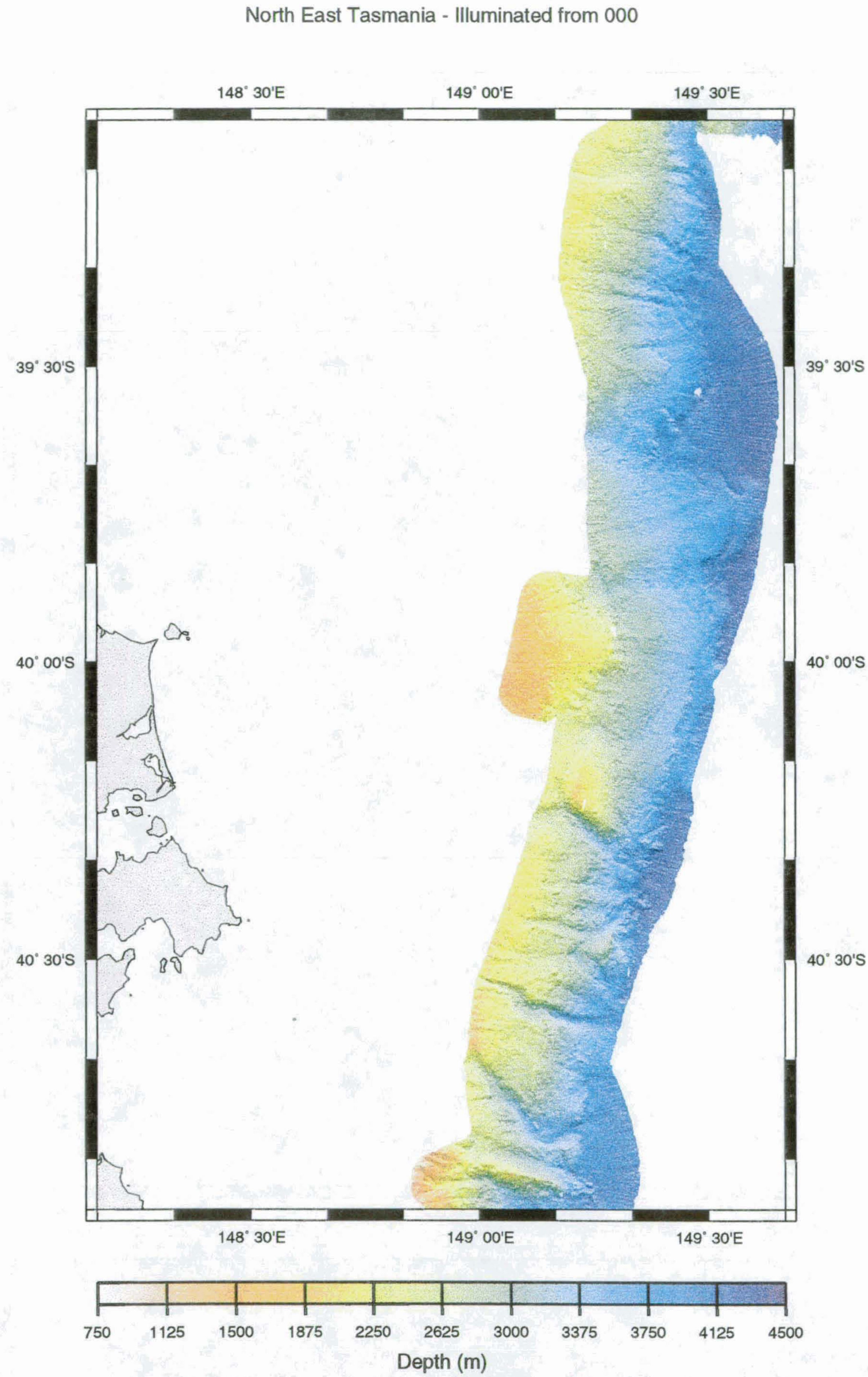

Figure 10. Shaded relief map of the northeastern area. Note the offsets of the foot of the continental slope in the north, the fault/joint patterns, and the large canyons in the south.

Gippsland Basin - Illuminated from 000

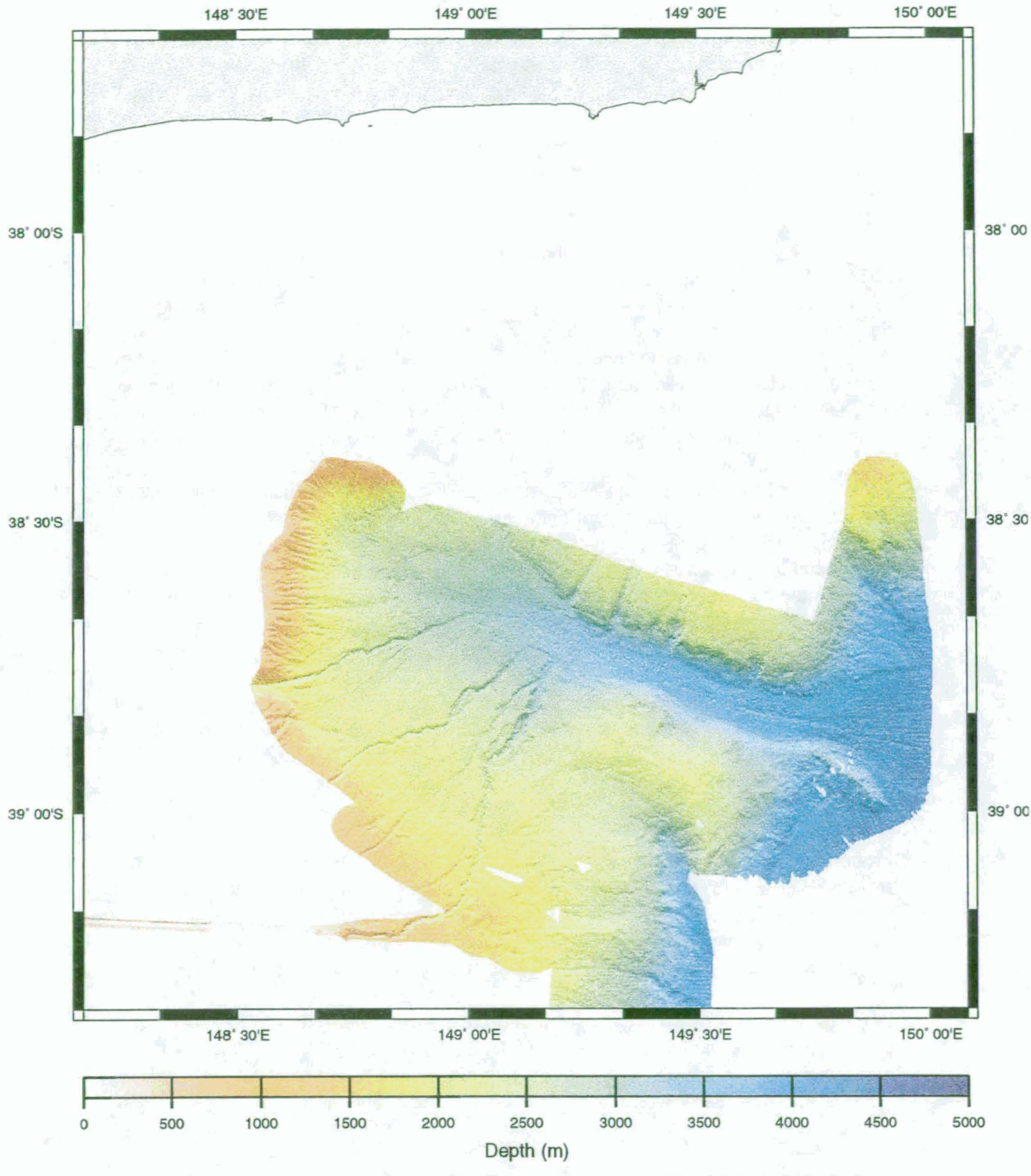

Figure 11. Shaded relief map of the Bass Canyon in the Gippsland area. Note the offsets of the foot of the continental slope, the main and subsidiary canyons, and the ridges and runnels on the steep slope in the west.

The transit line (Figures 2 & 8) passed over the base of slope on the Tasmanian side of the East Tasman Saddle, with seafloor depths in the range 2200-3400 m and the seabed sloping gently to the southeast. The seabed is mainly fairly featureless and undulating. The undulating topography may have been produced by downslope movement of late Cainozoic sediment sheets, reshaped by ocean currents and minor erosion by turbidity flows originating at the shelf edge. A large downslope canyon, about 250 m deep and 2 km wide, is located at 43° 26'S 148° 26'E. A 300-m deep erosional embayment was mapped between the canyon and the jarosite dump, and is further evidence that the lower slope in this area has been sculptured by erosional forces.

The margin off southeast and central east Tasmania (Figures 3 & 9) was mapped in a series of 5 passes, roughly oriented north-south, plus a more tightly spaced set of lines in the relatively shallow (~1000 m depth) St Helens and St Patricks fisheries area. Satellite gravity images were used to good effect in planning the layout of the survey. A major gravity ridge is located over the continental slope, about 55 km offshore, between St Helen's and Freycinet Peninsula. A significant local gravity high is located a further 35 km east, right on the inferred COB. When surveyed, all gravity highs were found to correspond to elevated, fault-bounded basement blocks.

The survey of the margin extended from the flat-lying and sedimented abyssal plain at 4000 m depth to about 900 m depth in the north (fisheries area, discussed earlier) and to roughly 1600-2000 m towards the southern end. The topography is irregular in the central and southern parts, dominated by local highs, often with steep rugged flanks; while in the far north, the continental slope is very steep, rugged and incised by canyons. On a broad scale, the continental slope appears to descend in a series of steps. These steps seem to occur particularly at about the 2200 m and 3400 m isobath levels.

The large triangular-shaped block at the COB in the central east of the survey area is 20 km long and 10 km across. Its steep flanks are clearly fault-bounded. The longest, northeast-facing flank is oriented normal to the direction of seafloor spreading in the adjacent Tasman Basin. It is apparently a continental rift block that was emplaced at ~80 Ma when seafloor spreading commenced.

Pronounced structural trends are also observed in the swath-bathymetry (especially the shaded-relief imagery) of the basement ridge in the southern part of the area. These trends are northeast, parallel to the transform direction in the Tasman Basin, and north-northwest, roughly parallel to the spreading fabric and late rift direction. The seafloor west of the ridge, over the sedimentary basin, is smooth and slopes gently to the south.

In the northern part of the area, a strong northeast structural trend is also observed on the southeast side of the broad basement high located southeast of St Helens hill. A number of shallow (50-100 m deep), but long (30 km or more) canyons cut down the slope in this area. The longer ones trend east-northeast, but shorter sets show an east-west trend.

St Helen's hill, 400 m high, is the only large volcanic cone mapped in the area. A number of small cones (up to ~200 m high) occur in the far north, including two to the east of St Helen's hill.

4.4. Tasmanian outer margin: northeast

An area along the outer continental margin off northeast Tasmania, elongated north-south, was mapped over about 32 hours (Figures 4 &10). This area is about 220 km long and 30 km wide, and was mapped as three swaths, with the outermost swath located along the foot of the continental slope. Water depths generally are in the range 2000-4000 m. One additional small survey was made in water depths of about 1500-2000 m, over the morphological expression of a gravity high, just east of the main survey.

The regional grain of the margin is north-south to NNE-SSW, with slopes down to the east varying from quite gentle to about 7°, with some steeper scarps in places. The survey shows that there is a marked change in the character of the margin north and south of 40°15'S.

4.4.1. Southern area

Between 40°15'S and 41°S, the margin is concave eastward overall, and is cut by four major canyons and a number of small ones, all with steep walls. These canyons are onlapped by abyssal plain sediments at their feet, so are no longer active. Between the canyons the surface falls eastward, but is rather irregular. In detail, the margin consists of four north-south trending segments cut by three east-west trending offsets that southward displace the margin back to the west (Figures 9 & 10). The northern and southern offsets correspond to major canyons. Five small cones, less than 200 m high, are probably all Tertiary volcanoes.

The northernmost major canyon apparently heads in about 2000 m water depth, and runs southeastward. The greatest depth of incision is about 700 m against a northern high. It falls steeply near its head, flattens out in its mid reaches, and drops off steeply again between 3400 and 3800 m. Below 3800 m it no longer has a clearcut channel to the abyssal plain at 4200 m.

The area extending south from this canyon to the next major one is cut by half a dozen small canyons that head in about 2200 m water depth, and run down to the abyssal plain at 4200 m. Maximum incision is about 200 m. Two canyons deviate around a major block on the lower slope that rises steeply from 4200 m to almost 2000 m. It clearly consists of very resistant rocks. The overall trend of the lower slope is north-south. The major canyon to the south heads in about 1900 m and is of variable trend, width and fall, depending on the bounding lithology. Its maximum incision is about 500 m, in an area of hard rocks between 2900 m and 3400m. It debouches on the abyssal plain at a depth of 4000 m.

The area between this canyon and the next major canyon to the south falls steadily to the east and is cut by only one minor canyon. The southern canyon, like the one to the north, is of variable trend, width and fall, depending on lithology. It heads in water shallower than 2000 m, and debouches on the abyssal plain at 4000 m. Between it and the southernmost canyon are rocks that trend north-south, overlain by a east-west ridge at about 40°51'S. This ridge is about 20 km long, rises up to 800 m above its surrounds, and consists of resistant rocks, very likely basalt or dolerite. The magma may have come up along an east-west fault that displaces the continental margin about 10 km to the west, going south. To the south is a broad canyon complex with canyons heading in less than 1000 m of water, cutting in up to 600 m in places, and amalgamating in a broad valley more than 10 km wide at about 3200 m. The valley gives way to the abyssal plain at 4000 m.

The general impression is of a Palaeozoic terrain with a north-south grain, that was thinned by stretching before Late Cretaceous breakup, and cut by east-west strike-slip faults at the same time. The area sank beneath the sea in the Early Tertiary and was modified by canyons that probably followed old river channels. These canyons became inactive in the Early Tertiary when erosion of the highlands and sediment supply dropped off.

4.4.2. Northern area

The northern area generally lacks steeply incised canyons. Overall it is convex to the east, and can be split into two major segments separated by a large embayment at 39°40'S.

The southern segment is limited to the south by the northernmost canyon described above, and to the north by the embayment. The lower slope is very straight, trending 15°, and lies on a gravity lineament (visible in satellite imagery) that extends at least 800 km into the Tasman Sea. Water depths are generally in the range 2500 m to 4200 m, but a short survey was carried out in a small adjacent area to the west where the minimum water depth is 1400 m. The average slope is 2°, but the sea bed is terraced, with four scarps visible above the abyssal plain.

Next to the canyon in the south is a 15 km long high block, elongated north-south, that rises steeply from 3000 m in the west to 2000 m at its crest. It corresponds to a gravity high and may well be a granitic batholith. The small western survey area also corresponds to a topographic high above a gravity high. In the northern part of the segment is a small embayment about 400 m deep and trending east-west, that does not seem to be structurally controlled.

The southern segment ends at the southern slope of the major embayment at 39°40'S, the slope trending 300°. The broad southern embayment is up to 800 m deep and its northern side trends 30°. To the north the overall trend is north-south, but two embayments cut the lower slope, and small canyons also complicate the topography. There is another somewhat smaller embayment at 39°20'S, about 400 m deep, the southern side of which trends 330° and the northern side 40°. These embayments appear to be fault controlled. Between 39°S and 39°05'S there is a major fault controlled canyon with its head in 2800 m water depth at 149°25'. It is up to 700 m deep and runs south-southeast to 4200 m water depth. It is bounded to the north by an elongated ridge trending east-west, with its crest at 2300 m.

The general impression is of simple, layer cake geology, consisting largely of Late Palaeozoic or Mesozoic sediments, with an overall north-south strike. This was complicated during Late Cretaceous rifting and break-up, by rift faults trending 330° and strike-slip faults trending 15-40°. When the rifted and thinned area sank beneath the sea in the Early Tertiary, canyons developed from pre-existing streams in the north, but lack of such streams in the south meant that canyons did not form.

4.4.3. Conclusions

The northeast margin off Tasmania consists of two geological provinces, a southern one lying east of Tasmania between Cape Naturaliste and the strait between Cape Barren and Flinders Islands (40°15'S to 41°S), and a northern one east of Bass Strait (between 39°S and 40°15'S). The southern province is complicated geologically, with older deformed rocks, intrusions and extrusions present. Geological structures appear to trend north-south, 15°, and east-west. Canyons and one major embayment are features. The northern province is much less complicated geologically, probably consisting of shallowly dipping Late Palaeozoic and Mesozoic sediments. The margin is cut by faults trending 330° and 15-40° that define two major embayments. Canyons are rare but there are two major embayments in the margin.

The region was probably uplifted prior to Late Cretaceous rifting, and sank beneath the ocean after breakup. It has been little sedimented since, probably because the early flood of eroded sediments bypassed the area down canyons, and there was little terrigenous input thereafter. The Eastern Australian Current flows south along the margin now and prevents pelagic sedimentation. The result is that pre-Tertiary rocks form much of the sea bed. Pre-rift, rift and break-up structures are all exposed at the sea bed.

4.5. Gippsland Basin

4.5.1. Geological Background

The large wedge of sediments which has accumulated in the last 40 million years in the Gippsland Basin is unusual for the eastern continental margin of Australia adjacent to the oceanic crust of the Tasman Sea. Most of the margin represented by the continental slope is sediment starved. However, in the Gippsland Basin there is a partly filled "failed arm" of the Tasman Sea triple junction. The unfilled section in the east is the Bass Canyon, a broad structurally controlled canyon with many tributaries. This canyon system has acted as a conduit for sediment to the deep sea floor since break-up some 80 m.y. ago. The filled section to the west contains several kilometres of section ranging in age from Late Cretaceous through to Recent and forms the continental shelf and extends onto land. The underlying rocks, considered to be unprospective for petroleum, consist of volcanogenic sandstones of Early Cretaceous age.

There has been little published work carried out on the offshore Seaspray Group (Oligocene to Quaternary carbonate dominated sediments) of the Gippsland Basin. The most recent study of the offshore Seaspray Group by Bernecker *et al.* (1997) concerns the shelf and provides the foundation for a more detailed study. The underlying Latrobe Group has been well studied onshore, and to a lesser extent where it continues beneath the shelf and contains major hydrocarbon reservoirs. Again little is known beyond the shelf edge.

Deposition related to the present day Gippsland Basin extends from onshore several hundred kilometres out onto the abyssal sea floor. The surface processes active in the marine environment are both erosional and depositional. Erosion results from gravity slumping, mass wasting and turbidity currents, as well as from biological activity and currents. Gravity processes, along with possible turbidity currents, transport sediment down canyons and onto the abyssal plain, where most deposition occurs. This has been the principal form of sedimentation in the basin in the recent past, and is in addition to the background settling of pelagic organisms and fine detritus. The relative importance of the two components, erosion and deposition, in the modern environment is not known. The Gippsland Basin is an ideal region to study these processes as there is a modern source of shelf sediment, namely carbonate-producing organisms, to feed the canyons, and there is active erosion of the slope. This sediment is fed into the canyon heads by strong currents on the shelf. Elsewhere on the Australian margin, most canyon heads are starved of sediment and are considered inactive.

In the marine part of the basin the morphology and surface geology of the shelf area is relatively well known, with BMR surveys of sediment type and bathymetric surveys by the Division of National Mapping. However, this is not the case for the deeper water. Seismic surveys by both AGSO and industry have elucidated the internal structure of the basin, particularly on the shelf where most of the hydrocarbon exploration has occurred, but relatively few lines extend down the slope and onto the abyssal plain. These seismic data have also provided bathymetry, but there are no bathymetric maps available at a scale of 1:250 000 or better for the areas beyond the shelf. There is also very little high-resolution surface data available past the shelf edge, with the exception of small areas of confidential side-scan sonar data collected for potential gas field development at Blackback. A limited amount of unprocessed Seabeam data collected by HMAS Cook in the 1980s provides a tantalising insight into the sea floor structures and processes in the region (Keene, 1996).

4.5.2. Significance

The Tertiary sediments of the Gippsland Basin are of enormous economic importance to Australia. Awareness of the lithological make up of the Seaspray Group will aid in developing a velocity model for seismic interpretation. The large lithological variation within the buried Tertiary submarine canyon complex of the Seaspray Group severely distorts the seismic time expression of underlying structures (Maung & Cadman, 1992; Feary & Loutit, 1998). This has hindered accurate structural interpretation of the underlying Latrobe Group, the principal petroleum reservoir sequence of the Gippsland Basin.

In terms of Australian plate history through the mid to Late Tertiary, the Gippsland shelf has acted as a subsiding continental shelf and upper slope, upon which have been deposited wedges of sediment that record the major events and environments of this period.

The significance of the Gippsland continental slope, surveyed during this cruise, lies with its impact on petroleum resources:

1. Rocks of hydrocarbon-producing age outcrop in the canyons down the slope, and once pin-pointed by swath mapping could be accurately sampled for dredging (Keene *et al.*, 1998). This will provide a time and environmental window into the past history of the eastern part of the basin. Both are fundamental information required for oil exploration.
2. Outcrop of mid to Late Tertiary carbonates will indicate the role that the slope, and erosion versus deposition, play in the accumulation and internal architecture of prograding wedges. This is essential for sequence stratigraphic analysis.
3. The fabric of the outcrop strata will assist with a structural interpretation of the basin, another requirement for oil exploration.
4. The swath mapping will assist with future pipeline or cable laying in this difficult terrain. Detailed mapping and engineering studies over a small area of the seabed down to 600m have been required for the Blackback field in the northwest part of the canyons. With exploration and development extending into deeper water, a detailed bathymetric map is required both for the monitoring organisation and the developer.
5. Fisheries are an important industry on this continental slope and the management of this resource requires detailed bottom topography.

4.5.3. Preliminary Results

The Gippsland Basin area was mapped over a period of 53 hours (Figures 5 & 11). This allowed almost complete coverage in depths of 2000 to 4000 metres, and large areas in the south and west extended up to 1000 m, and small areas to 400 m or less. The survey extended out onto the abyssal plain and depths of 4400 m. The area mapped, of 100 x 80 km, is approximately 8,000 sq km.

The area mapped is dominated by the Bass Canyon. The mapping shows the significance of structural control on the shape of the sea floor, particularly in the lower slope. The regional grain is 110°and 020° in the older rocks at the base of slope. This structural control defines both the continental margin facing the east, and the slope and canyons within the basin.

The Gippsland area surveyed can be divided into six contrasting geomorphic areas on a regional scale:

1. **The abyssal plain and associated channels below 4000m** extend out from the entrance of Bass Canyon. The isobaths here indicate a very low channel gradient at the canyon entrance and extending out for the 20 km mapped. The sedimented plain extending out from the base of the slope is actually a broad depression with contours veeing up the canyon. Within this broad topographic feature there are two

distributary channels, one trending east and the other southeast. The southernmost channel appears to meander and hug the southern side of the canyon at the entrance, before heading southeast beyond the continental slope. These channels are less than 50 m deep and 1 km wide.

2. **The lower slope near the canyon entrance** is characterised by a rectilinear pattern of outcrop at the base of slope and this structural control is continued down onto the sedimented areas beyond the break in slope. As well as the primary orientations of 020° and 110° there are isobath strikes of 160° and 080°. A large, hitherto undescribed, lozenge-shaped block extends the southern wall of the canyon. This feature has isobaths striking 125° and 145°. It has no significant magnetic or gravity signature and is probably rotated Cretaceous or older rocks. It rises from 4200m to 3200m and has dimensions of 15 x 4 km. This block is joined to the main continental slope by a narrow saddle (water depth of 3400 m).

   On the northern side the continental slope is steep from 2800m down to the base of the slope at 3800m. The lower 400m are particularly steep. There is the possibility of slumped material below 3800m. Twenty kilometres northeast of the Bass Canyon entrance is a large canyon running southeast, which divides upslope into two canyons. The continental slope continues to the northeast out of the survey area.

3. **The canyon floor** is a linear feature starting at the 4000 m isobath and trending to the west-northwest (290°). The floor is flat and relatively narrow (7 to 10 km) for the first 40 km westward from the entrance, and then opens out to 20 km wide for another 40 km, before forming a large semicircular amphitheatre at the 2800 isobath. Channels from tributary canyons can be recognised on the floor and they appear to meander and have levees, and join to form the one channel running out of the amphitheatre. This is on the order of 20 m deep and 500 m wide, and follows the northern side of the canyon until near the entrance where it branches.

4. **The western slope at the head of Bass Canyon** is a unique feature of the area, with a steep slope falling from 800 m to 1800 m in 4 km, and consisting of a uniform series of parallel ridges and runnels. There are some 40 ridges and runnels over a distance along slope of 40 km. Each of these runnels is 50 to 150 m deep and has relatively smooth sides and floor, running directly down slope. They continue to the north where the slope changes orientation to 110°. This area is bounded on the south by a large tributary canyon, one of four that are a feature of the slope to the south.

   The ridges and runnels are erosional features dictated by the steep slope and the inability of sediment to accumulate. They most likely formed during sea level lowstand and are now draped with a veneer of hemipelagic sediment between exposures of Late Tertiary rocks, based on the interpretation of the surface reflectivity. The role of currents on this slope today is unknown. Below 1800m the slope decreases and the runnels coalesce into three broad valleys which continue for 18km before joining as one at 2800m and trend down the axis of the canyon at 110 degrees.

5. **The northern slope** was only mapped up to 2200m. Isobaths on this slope are generally oriented 110°. Five box canyons cut the lower slope and are oriented 020°. They are wide and steep sided in the lower slope and narrow and shallow above the 2600 m isobath. The lower slope is particularly steep for the first 20 km from the entrance and would provide rock outcrop for dredge targets particularly in the canyons. Parts of the slope appear to have slumped and form distinct crown scarps.

6. **The southern slope** was mapped with continuous coverage up-slope for 40 km and along slope for 50 km. The eastern part is characterised by steep slopes, with no canyons for the first 25 km from the entrance. Further west are more gentle slopes, with three major canyons and two lesser canyons for the next 25 km. This divides the slope into two distinct parts. The eastern part rises steeply to a narrow plateau at 2300 m, 20 km east-west and 3 km north-south. The plateau is joined on the southwest to the main continental slope by a narrow saddle at 2400 m water depth. Between 3200 and 3800m the isobaths fall 600 m in two kilometres; they trend 110° and 020° on this structurally controlled slope. Rotational slumps are quite common and are recognised by their shape on the bathymetry and on the backscatter image. Unusual depressions may be formed by the underlying geology and have not been filled with hemipelagic sediments. Many low ridges do not have canyons associated with them but do give the appearance of being current swept as the depressions are on their upslope side. To the south the plateau descends into a structurally controlled canyon striking 110°, and then 160° in the steep lower slope.

   To the west of the plateau there is a broad uniform slope, gently rising from the Bass Canyon floor at 3000 m to the shelf edge some 80 km to the southwest. Backscatter image and isobaths define low parallel ridges, trending roughly east-west, over large areas of this slope. These ridges are sediment covered but reflect harder rocks beneath. They have a dramatic impact on the thalweg of the three major canyons on the slope. The canyons are relatively narrow, 500-800m wide, and 150-200m deep with flat floors. Over short distances they are incised over 500m and are still only a kilometre wide. They are box-shaped in cross section with rock outcrop on the sides.

   The easternmost of these canyons was mapped for 20 km eastward from a surface depths of 600m where the canyon floor was at 1000 m. This canyon is deflected by a prominent and most significant ridge which probably represents a major fault. The canyon breaks through this ridge and steps down along several ridges as it continues its eastern direction, before being deflected to the north by what could be a major change in near-surface lithology. This also corresponds to a local gravity high. The canyon descends 70 km to the north, where it joins the main Bass Canyon at 3200 m.

   The two canyons to the west are similar, and were each mapped for nearly 40 km as they trend northeast. The bathymetry, and the backscatter image, both show what appear to be meanders in each of these canyons but they are actually structurally controlled changes in channel course. The canyons follow the up-slope side of harder ridges until they break through and then follow the next, lower, ridge. The two minor canyons are strongly incised above 1800m, but below 2600 m they widen out into broad and shallow channels.

5. CONCLUSIONS

Altogether 1900 nautical miles (3450 km) of swath-mapping and magnetic data were acquired east of Tasmania and in the Gippsland Basin, and 1950 nautical miles (3550 km) of gravity data (Figure 1), in somewhat more than seven days at sea. The emphasis was on methodical swath-mapping of the sea bed in this poorly known area. We produced excellent maps of bathymetry and seabed imagery at an initial scale of 1:250,000. We were thankful for the excellent weather, a very pleasant contrast to the wild gales faced by *Melville* and her crew on the previous cruise south and southwest of Tasmania. The two short blows that we did experience did not seriously affect the data, and we met all our objectives.

The offshore Tasmanian region was probably uplifted before Late Cretaceous rifting, and sank beneath the ocean after breakup. The evidence gathered on this cruise indicates that it has been little sedimented since, probably because an early flood of eroded sediments bypassed the area down canyons, and there was little terrigenous input thereafter. The Eastern Australian Current flows south along the margin now and hinders pelagic sedimentation. The result is that pre-Tertiary rocks form much of the sea bed. Pre-rifting, rift and break-up structures are all exposed at the sea bed.

The surveying shows two physiographic provinces from 42°30'S to 41°S, separated by a coast-parallel steep slope at 2000-2500 m. Small canyons meander on the sedimented upper slope, but follow basement structures across the unsedimented lower slope. The deeper, outer province (2500-4000 m) forms the continental margin out to the foot of slope (roughly COB), which was markedly offset during continental breakup, with rift direction NW-NNW, and transfer direction NE-ENE. However, the 2000-2500 m slope has much smaller offsets; perhaps both because transfer faults die out landward, and because a Miocene carbonate platform has built outward.

Off central east Tasmania (42°30'S to 41°40'S), consisting of the Carboniferous to Triassic Tasmania Basin and Devonian granites of Freycinet Peninsula, faults trend 30-45° and 320-330°. Further north (41°40'S to 41°S), off the northeast Tasmanian block of mid Palaeozoic turbidites and Devonian granites, faults trend 70-80° and 330-340°. East of Furneaux Islands (41°S to 40°15'S), the area is geologically complex, with old deformed rocks, intrusions and extrusions, and structures trending 0°, 15° and 90°. Canyons are larger than in the south, suggesting feeding by larger rivers, and are mostly structurally controlled. The area northeast of Furneaux Islands (40°15'S to 39°S) is much less complex, probably consisting of shallowly dipping pre-Tertiary sediments. Canyons are small. Faults trend 330° and 15-40°, and there are two major embayments at the foot of the slope.

Two short surveys were carried out for specific purposes off Tasmania, a survey of a dump site for the refinery residue jarosite, southeast of Hobart, and a survey of the orange roughy fishery off St Helen's. Both surveys were successful in producing high quality, detailed maps of the sea bed, for practical and research purposes.

The area mapped in the Gippsland Basin is dominated by 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. Its floor, 7-8 km wide, is relatively flat with a gentle dip to the east. Primary structural orientations are 020° and 110° (roughly parallel and normal to the margin).

Since the cruise a variety of work has been carried out using these and other results:
- A preliminary geophysical study of the east Tasmanian margin including a seismic interpretation, and gravity and magnetic modelling (Kivior, 1997)
- A detailed study of the structure and development of the east Tasmanian and Gippsland continental margin, using the multibeam and seismic data (Hill *et al.*, 1998)
- A study of sedimentation and continental slope processes near the jarosite dump off Hobart (Harris *et al.*, in prep.)
- A sampling cruise in Bass Strait that included dredging of the slopes of Bass Canyon (Keene *et al.*, 1998)

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APPENDIX 1

Information on Research Vessel *Melville*

Owner: United States Government
Operator: Scripps Institution of Oceanography
Built: Bay City, Michigan, 1969
Home Port: San Diego, California
Call Sign: WECB
Length Overall: 85 metres
Beam: 14 metres
Draft: 5 metres
Gross Tonnage: 2516
Net Tonnage: 754
Displacement Tonnage: 2944
Propulsion: Diesel electric, twin Cort Z-drives (shrouded)
One forward retractable thruster
Motors: 3 x 1500 HP (1070 kW), 1 x 800 HP (500 kW)
Official Number: CF 0719 XS

APPENDIX 2

Scientific and Navigation Equipment

Swath-mapping
Sea Beam 2000 system
Calcomp 965A 4-pen colour plotter (ships track and bathymetry contours, real-time monitor)
Sun Model C video monitors (2) - one part of Sea Beam control console and the other displaying real-time sidescan imagery and bathymetry waterfall plot
NEC MultiSync 3D VGA colour QC monitor displaying beam amplitude and cross-track bathymetry per ping (cross-track / status display)
EPC 9200 20-inch thermal strip-chart recorder displaying sidescan imagery and 12 kHz vertical profile

Magnetics
Geometrics G801 marine proton magnetometer
Hewlett-Packard 7130A strip-chart recorder

Gravity
Bell Aerospace Textron BGM-3 gravity meter
Lacoste & Romberg land gravity meter G-611 (for ship-shore ties)

Navigation
Trimble Tasman P-Code GPS Receiver
Trimble GPS Surveyor 4000AX (2 sets)
Ashtech GPS 3DF Receiver XII (Attitude heading/pitch/roll into ADCP)
Speed log - EDO sonar doppler system Model MRQ-4015D
Gyrocompasses - Sperry MK-37 and Mk-23
Datawell Hippy 120-C Mark II sensor (pitch, roll and heave (from vertical acceleration integrated twice)) - input to Sea Beam 2000

XBTs (expendable bathythermographs)
Sparton (of Canada) XBT-5DB, 1830 metres depth
Sippican MK9 processor

ADCP (acoustic doppler current profiler)
RD Instruments, RD-VM 150 series (150 kHz, to ~400 m depth)

Data Logger (1 second navigation and geophysical data logged)
Twin Sun 630MP system (1 for data acquisition and 1 for post processing)
MMP hard-disks, 2 x 3.1, 4 x 9.0 Gb (total hard-disk storage 42 Gb)
DAT (4mm) and Exabyte (8mm) drives, 1 x 9-track ½" tape drives (GCR CacheTape)

Time Synchronization (GPS derived)
Bancomm Tymserve 2000 NTP Time Server
Provides time synchronization over the network and IRG-B co-ax

Geological Sampling / Deep Tow (not used on this cruise)
Trawl winch with traction drive, 2 drums each filled with 13,000 metres 9/16" wire
(0.680" deep-tow electo-mechanical cable also available)

APPENDIX 3

Acquisition Geometry on R/V *Melville*

Locations are relative to a ship's co-ordinate system (ahead, port, up) in metres with the origin (0,0,0) at the waterline directly below the GPS antenna.

Equipment	Ahead (m)	Port (m)	Up (m)
GPS antenna	0	~1	29.1
Sea Beam receiving array	24.2	+/-5	-5.0
12 kHz transducer (fwd)	15.9	~2	-5.0
12 kHz transducer (skeg)	-23.7	0	-5.0
3.5 kHz transducer	-17.0	~-2	-4.0
ADCP transducer	-10.6	~2	-5.0
Doppler log transducer	15.9	~2	-5.0
Gravity meter	-7.2	~-1	0.0
Magnetometer sensor	-351	~3	-50

APPENDIX 4

XBT sound velocities used for swath-mapping corrections

Six expendable bathythermographs (XBTs) were used to correct the sound velocities used in building the swath-mapping data set. The first was taken on the previous *Sojourn 6* cruise, west-southwest of Tasmania, and the remainder on the present *Sojourn 7* cruise. Details of the five stations are provided in Table 1.

TABLE 1: SIX XBT STATIONS USED FOR *SOJOURN 7* SWATH-MAPPING

Number	**Latitude (S)**	**Longitude (E)**	**Measured to**	**Used for correction From or To**
SOJN6MV.svp.04	50°48.249'	143°20.577'	1830 m	To 0420Z/10Apr 97
SOJN7MV.svp.01	43°38.764'	148°20.214'	1050 m	Fr 0826:27Z/10Apr 97
SOJN7MV.svp.02	41°17.252'	149°01.739'	1694 m	Fr 0442:04Z/11Apr 97
SOJN7MV.svp.03	39°27.165'	149°31.732'	1830 m	Fr 0339:19Z/13Apr 97
SOJN7MV.svp.04	38°38.916'	149°55.600'	1830 m	Fr 0630Z/14Apr 97
SOJN7MV.svp.05	33°45.746'	148°45.811'	1830 m	Fr 0622Z/15Apr 97

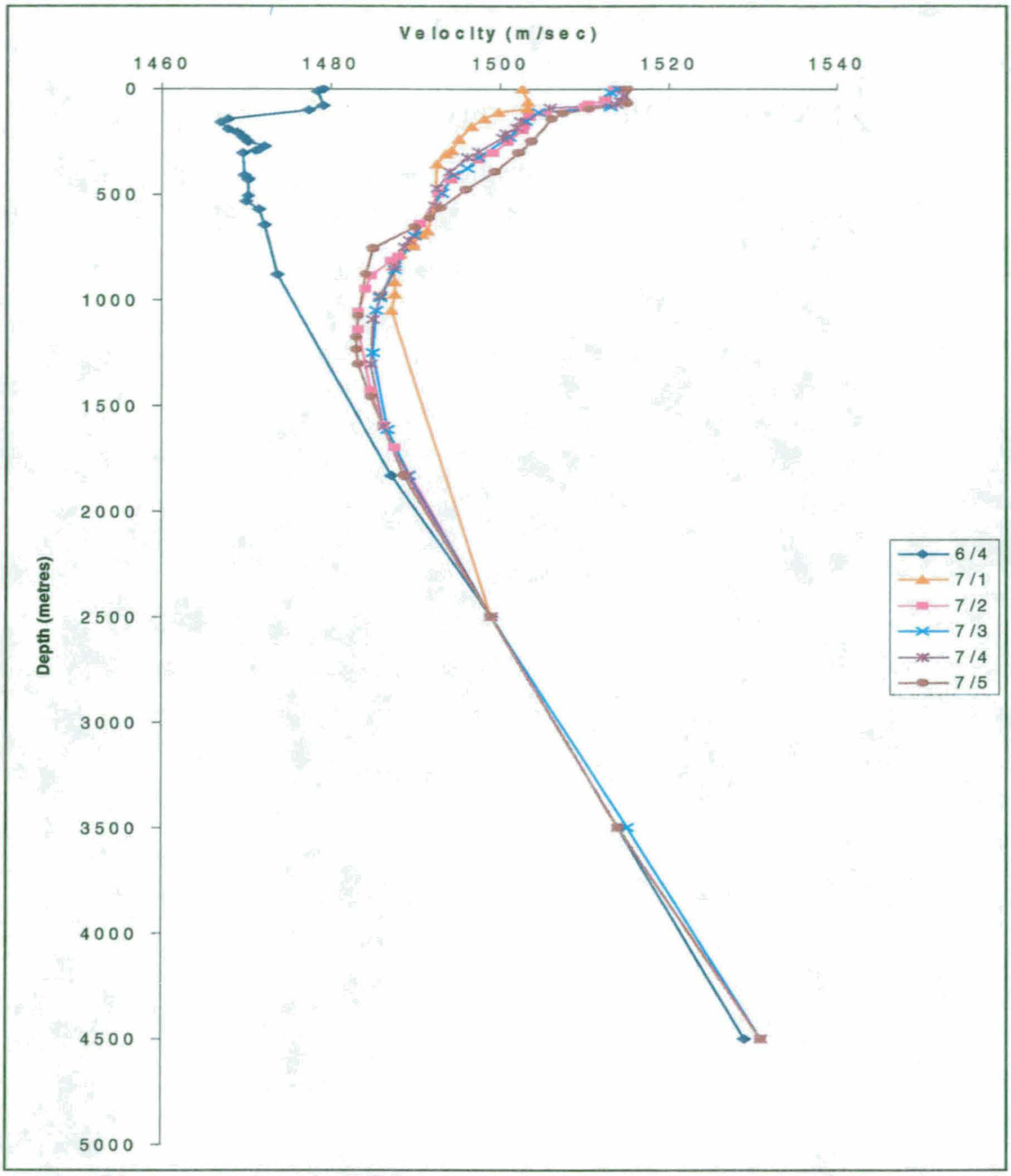
The XBTs measured temperature against pressure until the linking wire broke, these were converted automatically to temperature against depth, and the resultant curves are held in AGSO's cruise data base. The velocity:depth values, calculated on the basis of the temperatures and assumed salinities, are shown in Table 2. Below the depth covered by the XBT readings, Carter Tables were used to produce assumed velocities.

The curves of velocity:depth show that there was little variation across the area mapped, so that there should be little mismatch between lines, with the exception of the curve recorded on the previous cruise used for the first few hours out of Hobart (6/4). In fact, a marked mismatch was apparent in lines using values from 6/4 and 7/1 in the region of the jarosite dump off Hobart.

TABLE 2: XBT VELOCITIES AGAINST DEPTH

SOJN06MV.svp.04		SOJN07MV.svp.01		SOJN07MV.svp.02		SOJN07MV.svp.03		SOJN07MV.svp.04		SOJN07MV.svp.05	
Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
1479.0	0.0	1502.7	0.0	1513.6	0.0	1514.0	0.0	1514.6	0	1515.0	0.0
1478.4	10.9	1503.3	61.3	1512.4	51.1	1513.2	15.0	1514.7	30.7	1515.0	67.4
1479.0	81.0	1503.4	95.2	1510.6	72.9	1513.1	83.7	1514.1	60.6	1510.5	95.9
1477.4	99.3	1499.8	110.8	1510.0	86.4	1504.7	113.5	1513.8	73.5	1507.5	114.9
1467.9	144.6	1498.2	145.3	1505.5	111.5	1503.1	152.7	1505.9	91.2	1506.1	145.3
1466.9	158.8	1496.7	178.3	1503.6	133.8	1501.2	227.4	1502.4	152	1503.8	247.5
1467.9	193.8	1495.2	239.4	1503.0	175.0	1497.4	324.9	1502.1	183.7	1502.3	302.2
1468.9	206.6	1494.2	290.2	1502.8	194.5	1496.3	376.0	1500.7	210.6	1499.5	391.2
1469.6	229.4	1493.5	308.9	1501.0	252.2	1494.4	410.4	1500.3	234.1	1496.0	476.3
1470.1	247.5	1492.6	358.8	1499.2	300.9	1493.2	497.3	1497.5	299.6	1492.9	565.9
1472.1	271.5	1492.2	554.8	1497.5	332.9	1490.0	696.2	1496.1	326.2	1491.7	612.8
1471.5	284.9	1491.5	676.9	1494.2	432.2	1487.5	856.2	1494.1	392.5	1490.0	656.2
1471.0	290.9	1490.8	691.7	1492.7	497.3	1485.9	989.5	1492.6	473	1484.9	756.0
1469.5	304.2	1489.8	732.3	1490.5	640.7	1485.4	1045.9	1492.2	550.9	1484.0	879.1
1469.8	409.1	1489.7	746.4	1487.9	794.4	1484.9	1250.6	1489.3	719.4	1483.3	1072.1
1470.2	424.3	1488.1	780.4	1487.2	813.6	1486.7	1610.4	1488.7	750.9	1482.9	1175.0
1470.1	431.5	1487.4	842.9	1484.8	882.3	1489.2	1830.0	1487.5	838.4	1483.0	1232.9
1470.2	506.4	1487.5	916.5	1484.1	945.5	1499.0	2500.0	1485.7	979.5	1483.2	1301.4
1469.9	532.6	1487.5	973.8	1483.2	1052.8	1515.0	3500.0	1485.0	1090.1	1484.7	1455.6
1471.4	569.8	1487.2	1050.3	1483.1	1140.4	1531.0	4500.0	1484.8	1304.4	1488.6	1830.0
1472.1	642.6	1499.0	2500.0	1484.7	1428.0			1486.3	1595.1	1499.0	2500.0
1473.7	878.5	1514.0	3500.0	1486.2	1590.9			1489.1	1830	1514.0	3500.0
1487.2	1830.0	1531.0	4500.0	1487.5	1694.5			1499.0	2500	1531.0	4500.0
1499.0	2500.0			1499.0	2500.0			1514.0	3500		
1514.0	3500.0			1514.0	3500.0			1531.0	4500		
1529.0	4500.0			1531.0	4500.0						

Carter Table velocities used below the lines.



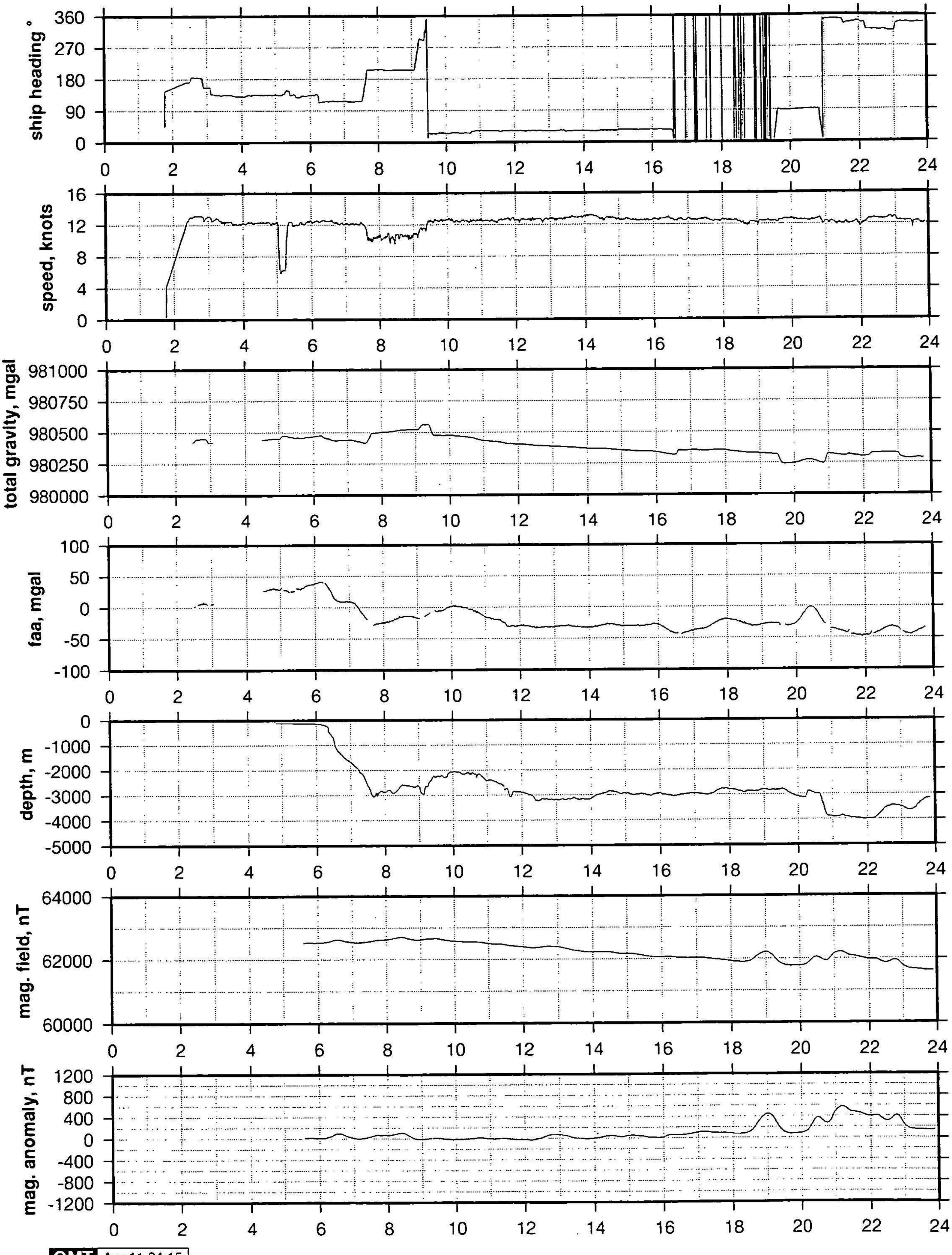
Graph of velocity against depth for six stations used to correct swath-mapping data on *Sojourn 7* cruise.

APPENDIX 5

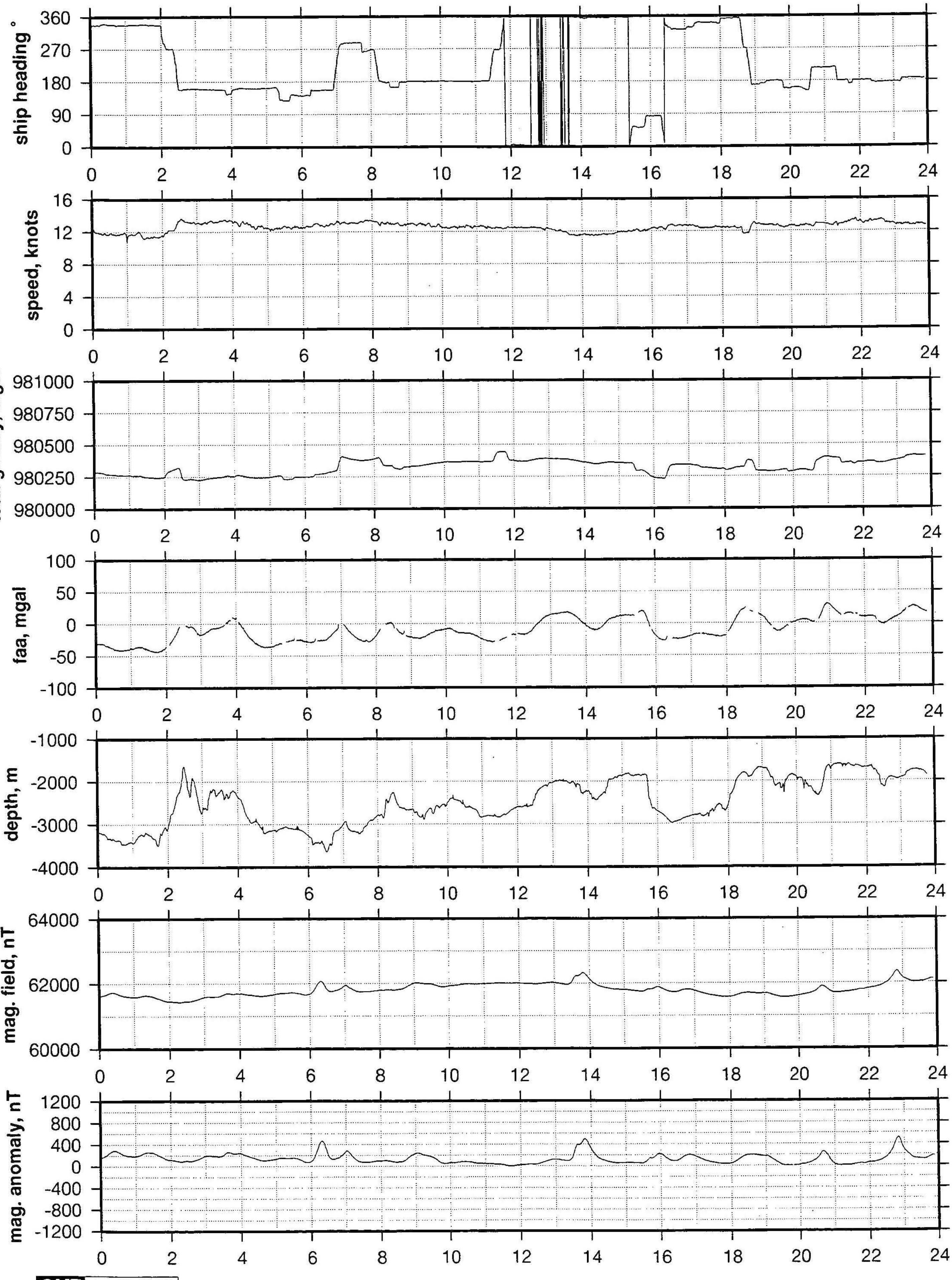
Data profiles for the seven days of the Sojourn 7 Cruise

These data profiles show ship's heading, ship's speed, total gravity, free air gravity, depth, magnetic field, and magnetic anomaly, for the seven days of the cruise, April 10 to April 17.

U/W data SOJN07MV 97apr10

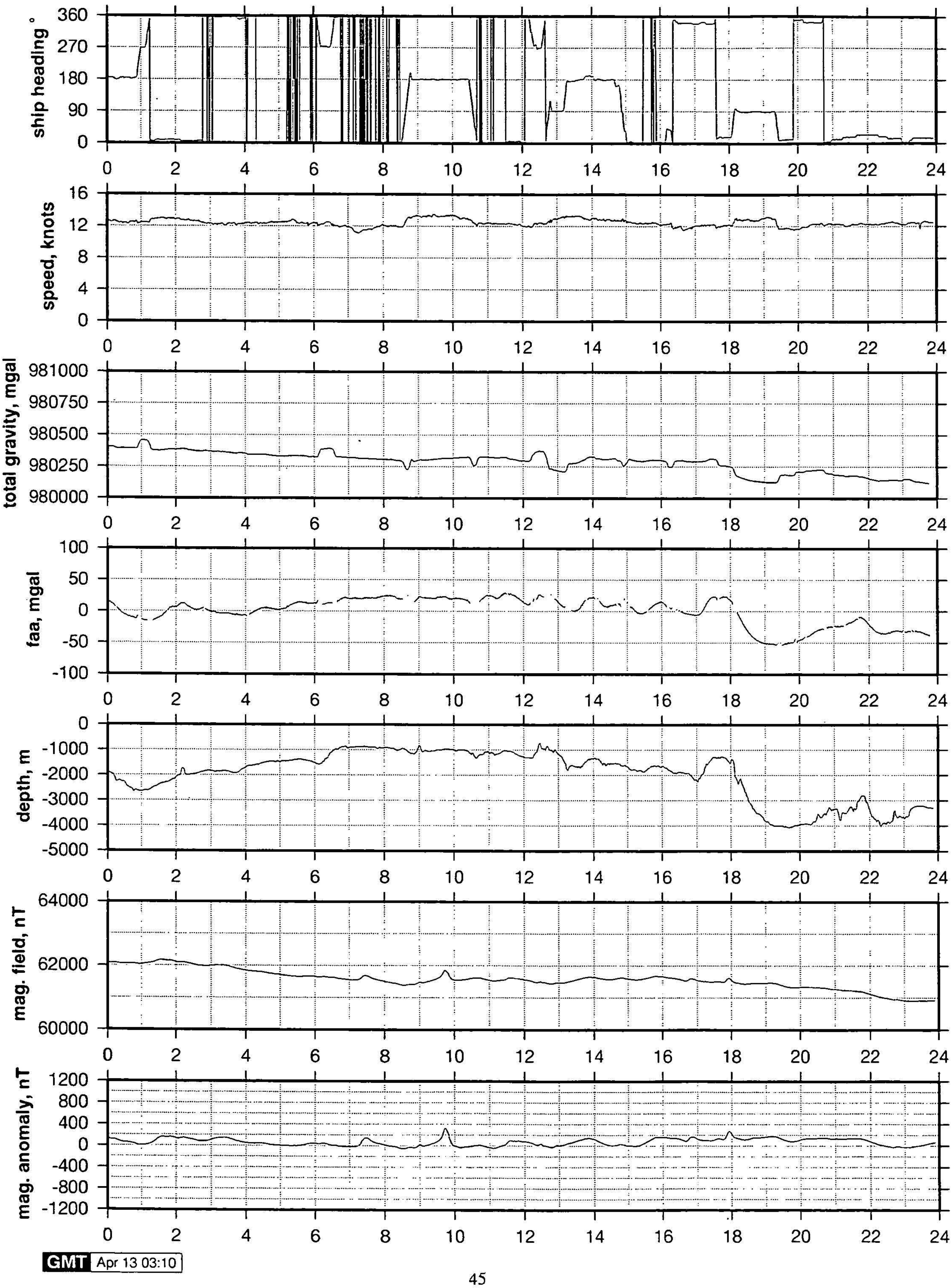


U/W data SOJN07MV 97apr11

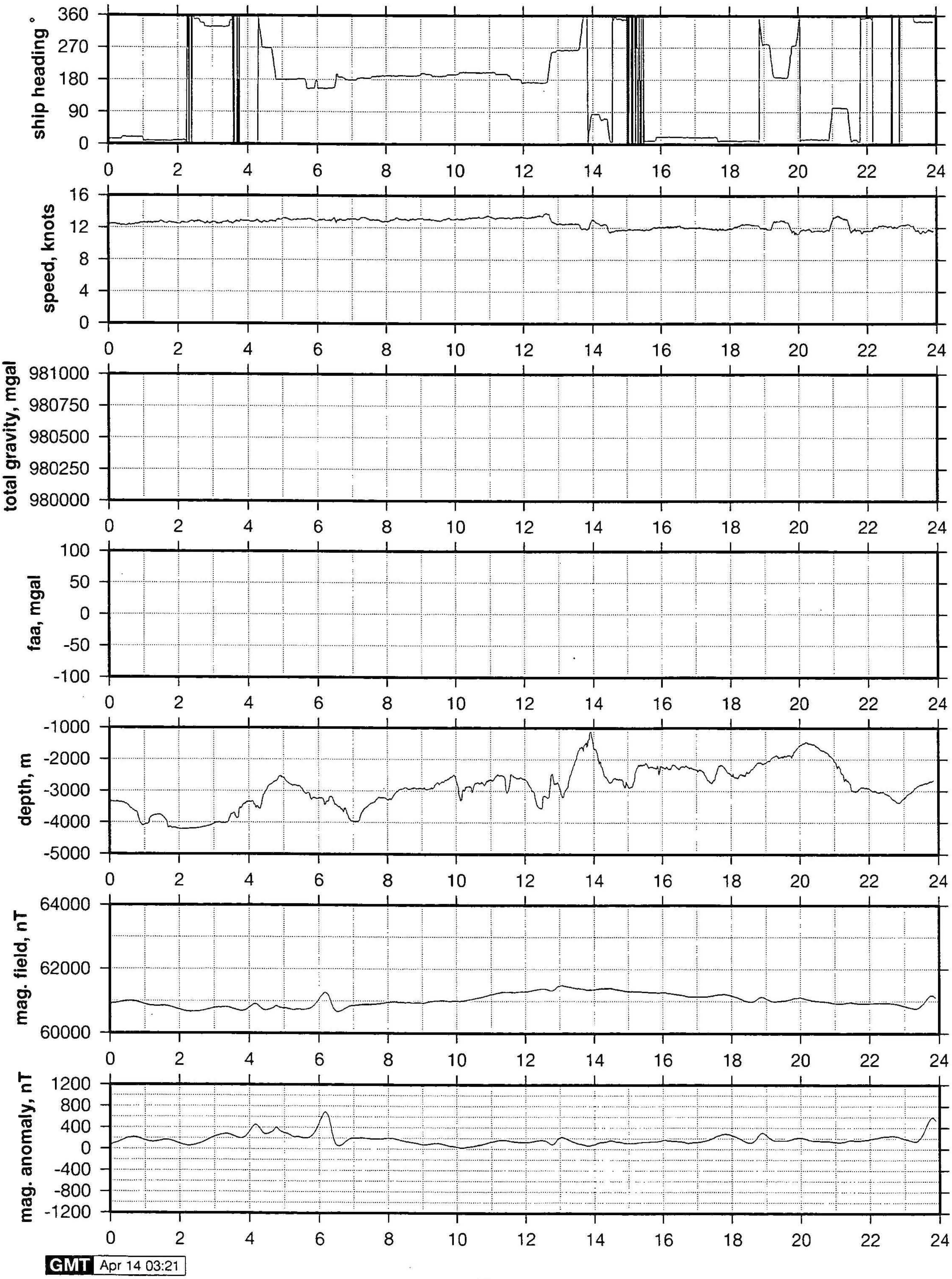


GMT Apr 12 03:26

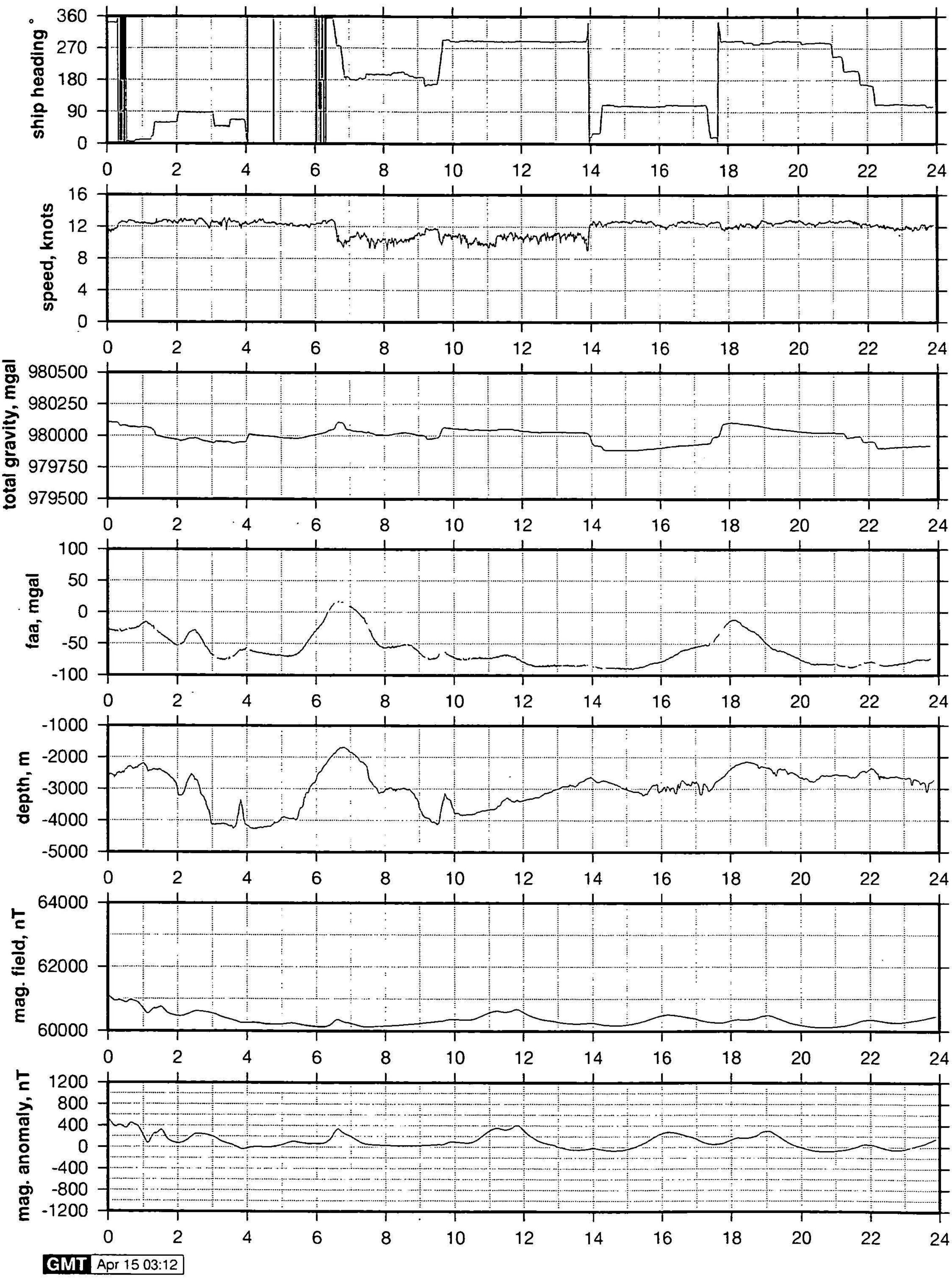
U/W data SOJN07MV 97apr12



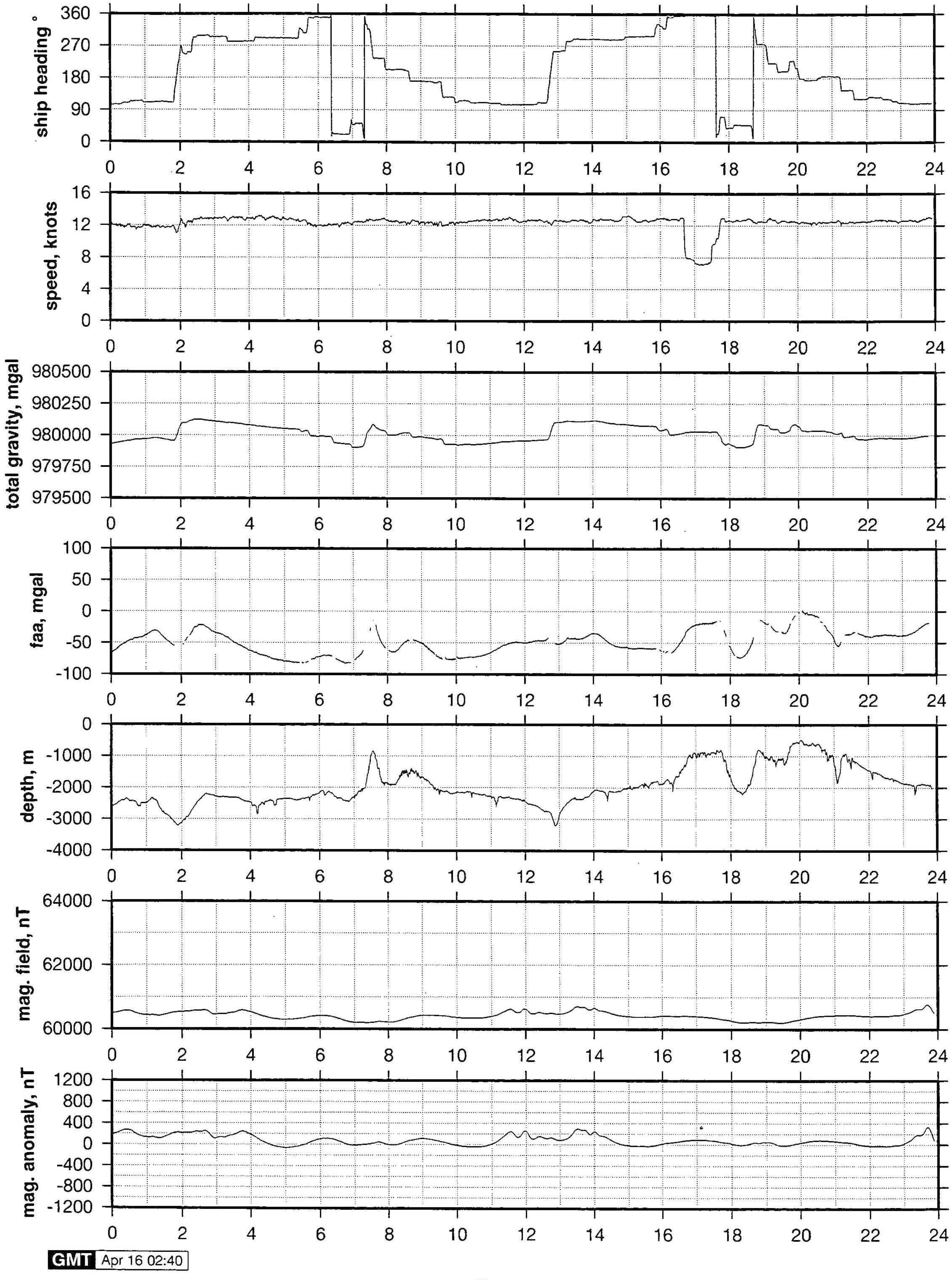
U/W data SOJN07MV 97apr13



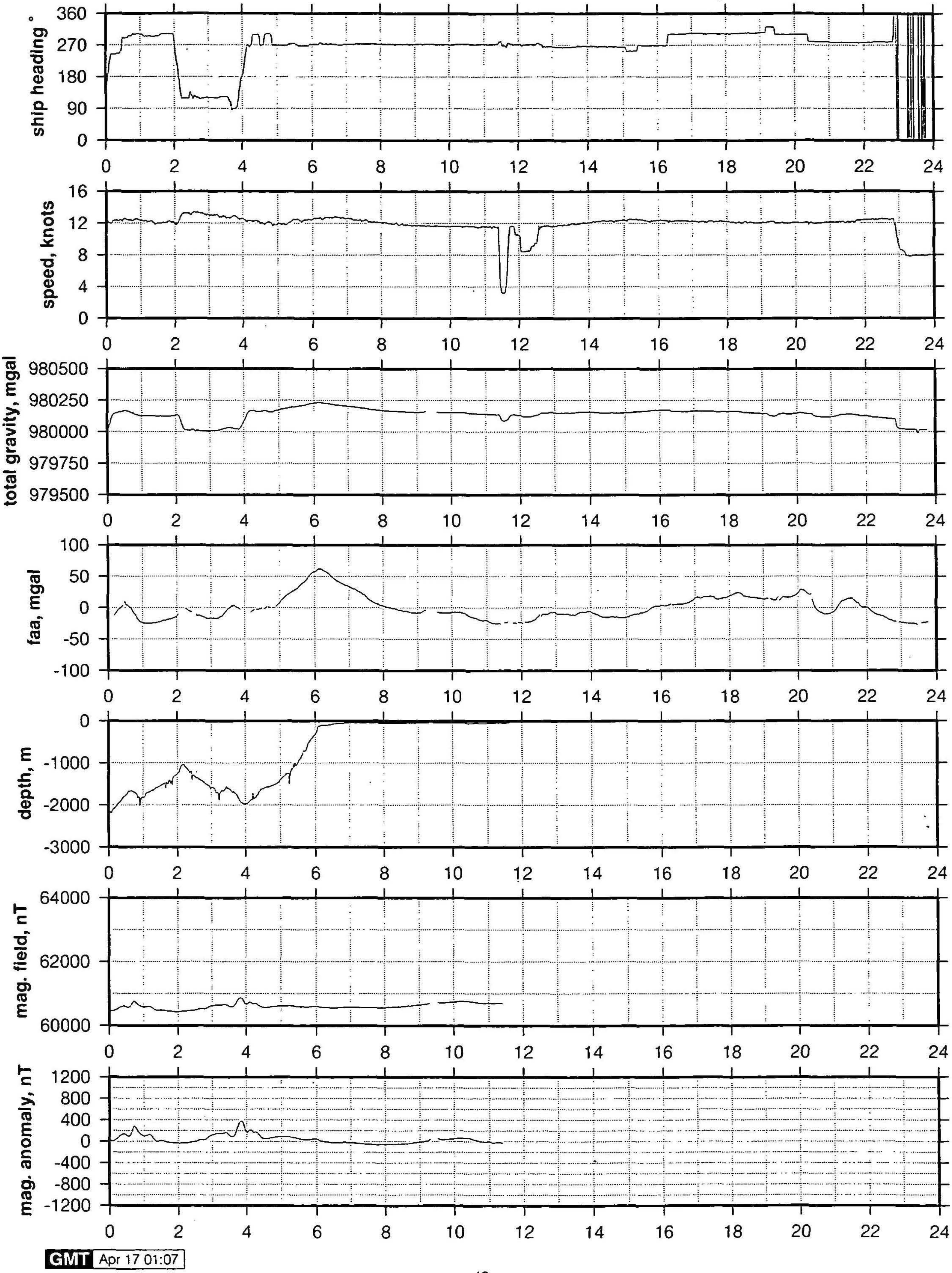
U/W data SOJN07MV 97apr14



U/W data SOJN07MV 97apr15



U/W data SOJN07MV 97apr16



APPENDIX 6

Weather conditions during Sojourn 7 cruise

We were fortunate to experience good weather, and indeed often calm weather, during the cruise with maximum temperatures around 15°C, and conditions sunny or lightly overcast. One morning was foggy. As the table shows, the wind speed only exceeded 20 knots on two occasions, at the very start of the cruise on JD100, and on JD 104. Even then average wind speed seldom exceeded 25 knots, with gusts up to 35 knots. Wave heights peaked at those times but did not exceed 2 metres. The largest swells reached heights of 4 metres on JD 100 and at least 3m on JD 104: the rest of the time the swell did not exceed 2 metres. The directions of both high winds and large swell coincided, and were from the southwest or west-southwest.

TABLE: WIND AND WAVE CONDITIONS DURING MELVILLE SURVEY

Julian day (JD)	Time	Wind direction	Wind speed (kn)	Sea direction	Sea height (ft)	Swell direction	Swell height (ft)
100	0400	0	0	0	0	175	2-6
100	0800	230	20	230	3	220	10-15
100	1200	230	18	230	3		
100	1600	0	0	0	0		
100	2000	020	4	0	0	200	4-6
101	0000	350	6	0	0	200	4-6
101	0400	020	5	020	2	210	2-4
.101	0800	350	15	350	2	180	4-6
101	1200	350	8	350	2		
101	1600	350	8	350	2		
101	2000	340	12	340	2	200	5-6
102	0000	0	0	0	2	340	4-6
102	0400	015	4	015	2	340	2-3
102	0800	330	18	330	2	350	2-3
102	1200	330	12	330	2		
102	1600	340	5	340	2		
102	2000	290	10	290	2	210	3-4
103	0000	350	6	350	2	050	4-6
103	0400	350	5	350	2	035	2-3
103	0800	350	10	350	2	030	2-4
103	1200	350	8	350	2		
103	1600	310	14	310	2		
103	2000	260	20	260	2	260	5-7
104	0000	240	24	240	4	260	6-8
104	0400	240	22	240	6	240	8-9
104	0800	235	25	235	6	250	8-10
104	1200	215	20	215	6		
104	1600	200	10	200	2		
104	2000	150	16	150	2	230	4-6
105	0000	115	8	115	2	150	6-8
105	0400	140	5	140	2	200	4-5
105	0800	055	6	055	2	170	4-6
105	1200	090	4	090	2		
105	1600	300	9	300	2		
105	2000	230	8	230	2	150	3-5
106	0000	260	10	260	2	260	3-5
106	0400	260	10	260	2	260	3-4
106	0800	240	14	240	2	260	3-4