Transit survey from Brisbane to Tonga by R/V *Melville* of the Scripps Institution of Oceanography during Westward Expedition Leg 06, 1994: Post-cruise report

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SUMMARY

A transit survey between Brisbane (Australia) and Nuku'alofa (Tonga) was conducted by the Scripps Institution of Oceanography's R/V *Melville* during the 9-day period 30 August to 8 September 1994. The survey was part of Westward Expedition Leg 06. The primary objective of Leg 06 was the deployment about 30 ocean bottom seismographs (OBSs) in the Lau Basin region for a study of the seismic structure and dynamics of an oceanic island arc, subducting slab and backarc spreading centre.

Sea Beam 2000 swath-bathymetry and acoustic backscatter (sidescan) imagery, as well as underway gravity and magnetic profile data were collected along the 3700 km Brisbane-Tonga transit route.

The survey covered part of the steep continental slope northeast of Brisbane, the summit area of Recorder Seamount, part of the southern Kenn Plateau margin, the Middleton Basin, the western and southern flanks of Gifford Guyot, the northern Lord Howe Rise and central New Caledonia Basin, the central Norfolk Ridge, the northern North Norfolk Basin, the Cook Fracture Zone and the central part of the South Fiji Basin, the middle of the Lau Ridge and the central Lau Basin.

On nearing Tonga, during the final part of the transit, 5 OBSs were successfully deployed at 4 sites (1 site on the Lau Ridge and the other 3 in the central Lau Basin) to the south of the proposed main OBS transect.

The survey revealed:-

(i) Deeply-incised, NW-trending canyons on the steep western margin of the northern Tasman Basin. The canyons are controlled by a bedrock structural grain imparted during the mid Cretaceous by tectonism that produced widespread folding and reverse faulting in the adjacent Maryborough Basin.

(ii) Recorder Seamount, a submarine hot-spot volcano, rises from a flat abyssal plain at ~4600 m to a rounded summit at less than 600 m below sea-level. Its flanks, which slope at ~18°, appear fault-controlled.

(iii) Bedrock/basement ridges project above the slopes on the southern margin of Kenn Plateau.

(iv) The flanks of ?volcanic Gifford Guyot are steep (~11°) and gullied.

(v) The seabed on the upper part of Lord Howe Rise is mainly undulating and featureless (?sedimented). The summit area is crossed by a few roughly N-trending channels or small-scale fault-bounded graben.

(vi) The 100-km wide Norfolk Ridge rises steeply 3000 m above flat-lying abyssal plains of the New Caledonia and North Norfolk Basins. Volcanic cones and other edifices on top of the Ridge are evidence of relatively young volcanism (?2-3 Ma, as on Norfolk Island).

(vii) The Cook Fracture Zone is marked by a spectacular terrain of blocky ridges and troughs with about 1000 m relief.

(viii) The floor of the South Fiji Basin at 4000-4600 m depth is mainly sediment covered, but its volcanic origin is revealed by the many cones, seamounts and ridges that protrude (often several hundred metres) through the basin floor.

(ix) Present-day backarc spreading in the southern/central Lau Basin is taking place at the Eastern Lau Spreading Center, and not farther west towards the middle of the basin. The Sea Beam sidescan images show the axial zone of the spreading centre as a distinct dark, highly reflective band (?exposed fresh basalts) that is 4-7 km wide and trends ~010° (NNE).

INTRODUCTION

In August 1994, the R/V *Melville* (Appendix 1), of the Scripps Institution of Oceanography at the University of California, was berthed in Brisbane. Its next research assignment was Leg 06 of the Westward Expedition (a series of *Melville* research cruises in the southern Pacific and Southeast Indian Oceans). Leg 06 was a scientific program proposed by LeRoy Dorman and John Hildebrand (both of Scripps) that aimed to study the seismic structure and dynamics of an oceanic island arc, subducting slab and backarc spreading centre using tomographic imaging techniques. The Tonga region was selected for this experiment as it was an ideal setting for the study because of the high seismicity associated with subduction of the Pacific plate at the Tonga Trench and beneath the adjacent active Lau backarc basin. Leg 06 would involve the setting of an extensive ocean bottom seismograph (OBS) array that would use Benioff zone eathquakes as a source array.

The transit from Brisbane to the main study area around Tonga provided an opportunity to collect underway geophysical (gravity and magnetics) data, as well as swath-bathymetry and backscatter imagery using the *Melville*'s hull-mounted Sea Beam 2000 seafloor mapping system. Since a considerable part of the transit would pass through Australian territorial waters, the author was invited to participate in the transit leg as marine geoscientist and Australian representative.

The ship left Brisbane on 30 August and arrived in Nuku'alofa (Tonga) nine days later on 8 September 1994. The onboard personnel (Appendix 2) included 14 scientists, engineers and technicians.

The route taken (Figures 1 and 2, Table1) involved a voyage of about 3700 km. Some deviation from the direct route was made to investigate parts of the northern Tasman Basin margin. It was intended to run the transit line just south of New Caledonia, to coincide with a proposed deep seismic transect (joint AGSO/French project FADESE); however official French approval to collect data in New Caledonian waters was not received in time and so the transit was run farther south, across the central Norfolk Ridge. Five OBSs were deployed in the Lau Basin area at 4 sites (Figure 2) before finishing the transit at Nuku'alofa.

The port call in Nuku'alofa lasted only a few hours, long enough for transfer of some personnel and conduct of other cruise-related business, before the ship left at about midday on the same day (8 September) to complete the rest of Leg 06.

SURVEY SYSTEMS ON R/V *MELVILLE*

Details of the scientific and navigation equipment on the ship are provided in Appendix 3. Also provided (Appendix 4), 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 Sea Beam 2000 seafloor mapping system, the Geometrics magnetometer and the Bell gravity meter.

Information on the Sea Beam 2000

The Sea Beam 2000 aboard the R/V *Melville* is a 12 kHz, 121-beam swath-mapping system (Asada, 1992; Miller and 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 total angular swath width is 120°, so that a strip of seafloor 3.4 times the water depth is mapped. The maximum effective swath-width in deep water (~4000 m) is about 15 km. Sea Beam 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 and GLORIA. The sidescan has a swath-width comparable to the bathymetric swath and 1024 pixel across-track resolution. In water depths of about 3000 m the backscatter data are sampled at 10 m intervals in the cross-track direction.

The system will operate in conditions of up to ±10° roll and ±7.5° of pitch.

The acquisition computer, requiring 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 array processors.

REGIONAL GEOLOGICAL SETTING AND TECTONICS

The geology and the tectonic evolution of the region traversed by the transit survey (northern Tasman Basin, Lord Howe Rise, New Caledonia Basin, Norfolk Ridge, Norfolk Basin, South Fiji Basin and Lau Basin) have been discussed by Burns and Andrews (1973), Willcox et al. (1980), Kroenke (1984), Eade (1988), Shaw (1990) and Hawkins (1994). Plate reconstructions of the region for the Cretaceous-Cainozoic have been made by Walley and Ross (1991) and Walley (1992).

In the Early Cretaceous, prior to the breakup of eastern Gondwana, the New Zealand - New Caledonia region was part of a convergent margin. Most of the region was emergent at this time. Extension along the eastern Gondwana margin began in the late Early Cretaceous, with widespread terrestrial sedimentation taking place. The New Caledonia Basin is believed to have opened in the mid Cretaceous (~95 Ma). Seafloor spreading in the Tasman Sea (Weissel and Hayes, 1977; Shaw, 1978) during the Late Cretaceous to early Eocene (~86-55 Ma) was accompanied by regional subsidence and transgression.

Rifting and seafloor spreading of the eastern Australian margin during the Cretaceous has recently been interpreted in terms of a continental margin detachment model (Etheridge et al., 1989; Lister et al., 1991). The model interprets a detachment system underlying the whole region, with the Lord Howe Rise and Norfolk Ridge composed of extended upper continental crust and thinned lower crust / upper mantle. Small intervening basins, such as the New Caledonia Basin, may be in part floored by highly-thinned lower continental crust. The crustal thickness beneath the Norfolk Ridge is 21 km (Shor et al., 1971), which is greater than for a volcanic arc and somewhat thinner than for typical continental crust. Based on crustal thickness, seismic character and magnetic signature, Eade (1988)

concluded that the Norfolk Ridge is likely to be of continental or continental margin origin. Norfolk and Philip Islands, on the central Norfolk Ridge, were formed by Pliocene volcanic activity dated at 3.1-2.3 Ma (Jones and McDougall, 1973; Aziz-Ur Rahman and McDougall, 1973).

Cessation of seafloor spreading in the New Caledonia Basin (perhaps coincident with Tasman Basin opening), may have led to the onset of east-dipping subduction along the western side of the north Norfolk Ridge. Backarc basins developed in New Caledonia and to the east of the Norfolk Ridge creating the North and South Norfolk Basins (Walley and Ross, 1991). Launay et al. (1982) and Eade (1988) suggest the North and South Norfolk Basins opened from ~85-75 Ma. However, other interpretations - including those of Rigolot (1989) and CPCEMR (1991) - indicate an Eocene age, with the implication that opening of these basins occurred immediately after the end of spreading in the Tasman.

East-dipping subduction resulted in opening of backarc basins northeast of New Caledonia between the Early and late Middle Eocene. Convergence increased from the late Middle Eocene to Early Oligocene, and following a change in plate boundary configuration, the marginal basin development ceased and newly-formed oceanic crust was obducted from the northeast onto New Caledonia (Brothers and Lillie, 1988). Transpression and associated dextral strike-slip movement along the western Norfolk Ridge is inferred (Rigolot, 1989).

The northerly-trending linear Tasmantid and Lord Howe Seamount chains are submarine volcanoes produced by the Cainozoic transit of the Australian plate over fixed mantle hotspots (McDougall and Duncan, 1988). Recorder Seamount of the Tasmantid chain has an estimated age of about 26 Ma, while that of Gifford Guyot of the Lord Howe chain is 15 Ma (CPCEMR, 1991). Parts of these seamounts were mapped during the cruise (Figure 1).

The South Fiji Basin opened between 36-26 Ma (Malahoff et al., 1982) as a backarc basin to an arc along either the Three Kings Rise (Kroenke and Eade, 1982) or the Colville-Lau Ridge.

The Lau Basin is an active backarc basin separating the inactive Lau Ridge remnant volcanic arc from the Tonga Ridge. Crustal extension that formed the Lau Basin began in the late Miocene at ~6 Ma (Hawkins, 1994). Initially extension was by rifting (forming basin-range type structures) accompanied by magmatism. This was followed by seafloor spreading, promoted by propagating rifts. Seafloor spreading began ~4-5.5 Ma and propagated southwards forming the Eastern Lau Spreading Center; a second propagator was generated ~1.5 Ma forming the present Central Lau Spreading Center.

SCIENTIFIC PROGRAM AND DATA ACQUIRED

The main scientific program of Westward Leg 06 was described by Dorman and Hildebrand in the Scripps Westward Expedition (August 1994 - March 1995) Cruise Prospectus. The program, as it stood just before the cruise, called for the deployment of about 30 OBSs in the Lau Basin region (Figure 3). Most of the OBSs were to be deployed along a W-E transect from the central Lau Basin, across the Tonga Trench and onto the Pacific plate as far east as Niue. The remaining OBSs (about 8 or 9) would be spread over the Lau Basin to

the north and south of the transect. The OBS network would be supplemented by a number of land seismographs located on islands in the region.

The transit route (Figures 1 and 2) followed the steep continental slope northeast of Brisbane, crossed the summit area of Recorder Seamount, followed part of the southern Kenn Plateau margin, crossed the Middleton Basin, skirted the western and southern flanks of Gifford Guyot (southern seamount), crossed the northern Lord Howe Rise and central New Caledonia Basin, crossed the central Norfolk Ridge, the northern North Norfolk Basin, the Cook Fracture Zone and traversed the central part of the South Fiji Basin, crossed the middle of the Lau Ridge and criss-crossed the central Lau Basin.

Underway gravity and magnetics profile data and Sea Beam 2000 swath-data were collected along the entire length of the 3700-km transit from Brisbane to Nuku'alofa. Successful XBT soundings were made at 5 stations. Locations of these and corresponding temperature and inferred sound velocity profiles are given in Appendix 5. Profiles of free-air gravity, magnetic anomaly and bathymetry for the Brisbane to South Fiji Basin part of the transit are presented in Appendix 6.

On nearing Tonga, during the final part of the transit, 5 OBSs were successfully deployed at 4 sites (Table 2; Figure 2) to the south of the proposed main OBS transect (Figure 3).

CRUISE NARRATIVE

The time and nature of significant events that occurred during the cruise are indicated below. Days are local time periods (i.e. 0000-2400 hrs local); times are in GMT (Z), unless specifically shown as being local. Further detail of events is provided in the underway watch log (Appendix 7).

Tuesday 30 August

R/V *Melville* left Brisbane's Cairncross Wharf at 1300 hrs local (= 0300Z). After the Pilot left the ship off Caloundra, the ship headed east across the continental shelf and the acquistion systems were made ready for data collection during the transit to Tonga. Began collecting Sea Beam 2000, magnetics and gravity data on the outer shelf and northwards along the SE Queensland continental slope.

Wednesday 31 August

Surveying along the southern margin of Kenn Plateau. At ~2000 hrs local, alarm was caused by the sound of knocking on the hull in the vicinity of ship's main thrusters. It was suspected that fishing gear had become entangled underneath the ship, since a fleet of fishing ships and floats (?longlines) had been passed earlier. Speed was reduced to 8 knots overnight; an inspection dive was planned next morning.

The Sea Beam data were patchy and generally poor quality, with often only 20-30 of the 121 beams recording. Soft sediment on the seafloor may have caused the poor returns.

Thursday 1 September

In the morning, the inspection dive revealed that half a shark and fishing line were fouled under the ship. These were cut loose, and the ship's speed was increased to the usual ~12 .5 knots. About 1 1/2 hours later, ship's speed was again reduced as a minor fire in the engine room was investigated. Normal speed was resumed about 30 minutes later.

After crossing over the western and southern flanks of Gifford Guyot, the ship headed due east at 27° 08'S. Sea Beam data quality was satisfactory. Typically about 80 beams were recording returns; occasionally this increased to 90-100 of the 121. At ~1900 hrs local, the sidescan recorder began recording. It had not been operational since the start of the survey. It was brought to life by resetting the dip-switches at the back of the recorder for external timing.

The western side of Lord Howe Rise was crossed.

Friday 2 September

The transit line continued over the central part and eastern flank of the Lord Howe Rise. XBTs were deployed several times but all failed.

In the evening the weather deteriorated, with 30 knot winds and very rough seas.

At midnight the top of the Norfolk Ridge was crossed. Water depth here was ~ 600 m. Numerous volcanic cones could be seen in the swath data and the magnetic profile was very disturbed, confirming the presence of relatively shallow volcanics.

Saturday 3 September

Rough to very rough seas, with winds to 30 knots from the south.

XBT sounding successful. The sidescan data were very good quality; generally depths were recorded from 60-100 beams, and occasionally the beam count was as high as 117 (out of 121).

During the day, the ship crossed the eastern Norfolk Ridge, North Norfolk Basin, Cook Fracture Zone and entered the South Fiji Basin.

Sunday 4 September

Crossing of the South Fiji Basin continued. Seas rough.

The Sea Beam performed very well. Sidescan data quality was very good and the beam count was typically 100-121.

Monday 5 September

Seas moderated slightly, but were still rough on a moderate swell.

The ship crossed the NE South Fiji Basin and then onto the Lau Ridge. The first OBS was deployed on the Ridge at 1630 hrs local. After precisely locating the position of the OBS on the ocean floor by running a set of N-S and E-W lines with the 12 kHz transponder active, the ship was again underway (at ~2000 hrs local) to the next OBS site in the central Lau Basin.

Tuesday 6 September

OBS#2 was launched at ~1030 hrs local just west of the Lau Basin spreading axis. The ship then proceeded east to cross and survey the active Lau Basin spreading centre (ELSC). The ship then headed NW for the transit to OBS Site 3. On the way, the ELSC was again crossed and mapped.

Wednesday 7 September

OBS#3 was successfully deployed at Site 3 at 1301Z (6/9/94). The ship then transited to Site 4, crossing the Lau spreading centre on the way. A fire and boat drill was held at 1230 hrs local. An OBS was launched at Site 4 soon after (at 2338Z (6/9/94)). A second OBS was launched at the same site at 0010Z.

Seas were moderate with a moderate swell during the day. Seas abatted to slight towards nightfall. Weather fine. Tofua and Kao were visible to the ENE from Site 4. A small plume of 'smoke' issued from the Tofua caldera signifying some low-level fumarole/volcanic activity.

The ship left Site 4 at ~1530 hrs local and headed SW to survey across the Lau spreading centre, en route to Nuku'alofa for a port call next morning.

Thursday 8 September

Melville sailed into Nuku'alofa, Tonga. Ship berthed at Queen Salote Wharf at 0940 hrs local; customs clearance completed at 1005 hrs local.

PRELIMINARY RESULTS

The swath-data showed the continental slope northeast of Brisbane to be very steep and rugged. Water depths increased from 1000 m just beyond the shelf edge to 4000 m at the lower slope over a distance of only 20 km. The mid and lower slope along this part of the northern Tasman margin (off Brisbane - Fraser Island) trends N-S and is cut by a number of deep NW-trending canyons. The most spectacular of these, crossed at 26° 28'S / 154° 04'E, 26° 19'S / 154° 07'E and 26° 04'S / 154° 11'E, are 2-5 km wide and incised to depths of several hundred metres, and 500 m or more in places. The canyons are structurally controlled, following the same NW-NNW trend of structures mapped beneath the wide shelf and in the adjacent Maryborough Basin (Hill, 1994). These structures were produced during a period of compressive tectonics in the mid Cretaceous.

Water depth at the base of the continental slope on the western side of the northern Tasman Basin is about 4600 m. An unusual 200-m deep seafloor low was recorded at ~4000 m

depth at the base of slope near the mouth of a moderate-size canyon. This local low, about 1.5 x 3 km in size and located at 25° 28'S / 154° 10'E, may be relief created by a large submarine landslide sweeping down from higher up the slope. The depression could be a landslide gouge or a local low in a pile of landslide debris. Evidence of large-scale mass movements has been recorded along much of the steep margin of the northern Tasman Basin (Hill, 1994).

Recorder Seamount, the summit area of which was crossed at 25° 11'S / 154° 57'E, is a large submarine volcano that forms part of the N-S trending Tasmantid hot-spot chain (McDougall and Duncan, 1988). It rises steeply from the surrounding flat abyssal plain (at 4350 m depth to the west and 4650 m to the east). Minimum depth recorded was ~600 m. The seamount appears to be elongate in a NE direction, probably due to structural control on flank mass wasting. Gradients on the mid flanks are about 18°. The top of the seamount, at 1200 m depth and shallower, is rounded in overall shape but the surface texture is rough.

At 24° 58'S / 156° 12'E, Kenn Plateau rises fairly steeply from the flat abyssal plain at 4550 m depth to depths of about 3400 m over a distance of ~14 km, beyond which the gradient of the slope decreases and then flattens out at about 2600 m depth. A narrow (4-km wide), locally NW-trending ridge is located at 24° 50'S / 156° 42'E. The top of it is at ~2300 m depth. Its rugged surface suggests basement/bedrock outcrop or volcanics.

The upper part of the saddle (depth ~2900 m) between Kenn Plateau and Dampier Ridge to the south is mainly gently undulating (?sedimented). A steep, N-trending, 700-m high ridge rises from the eastern flank of the saddle. This ridge was crossed at 26° 03'S / 158° 07'E. The adjacent Middleton Basin has a flat floor at 3550 m depth.

The Sea Beam swath covered the western and southern flanks of Gifford Guyot, from the surrounding plain at ~3300 m to as high as 1600 m depth on its flanks. The flanks of this ?volcano are steep (~11° slope) and gullied.

On the survey line, the Lord Howe Rise culminates at 1150 m depth at 27° 08'S / 162° 50'E. The western flank is undulating and relatively featureless. The summit area is crossed by several 30-m deep, NNW-NNE trending channels or small-scale graben. The eastern flank of the Rise is convex in shape; its lower slope has a rough surface and is relatively steep (2.3°). At 27° 07'S / 164° 25'E there is a break in slope and the seafloor generally flattens out, though several broad, 300-m high hills are present at the base of the slope. The adjacent floor of the New Caledonia Basin is about 150 km wide (in this area) and flat-lying at 3600 m depth.

The western flank of the Norfolk Ridge is very rugged and steep. Along the survey line, it rises from the floor of the New Caledonia Basin at 27° 08'S / 166° 42'E and peaks at a local high rising to 550 m below sea-level at 27° 08'S / 167° 12'E. A number of conical hills about 200 m high occur in the summit area, either clustered together or as isolated edifices. They appear dark in the sidescan imagery (high backscatter) and are undoubtedly volcanic. Such features were observed in an earlier N-S swath-mapping crossing of this region, particularly near Norfolk Island (Hill, 1993).

A 30-km wide, flat-lying and sedimented area lies perched at 800 m depth immediately east of the apex of the Norfolk Ridge. Beyond this, the eastern flank of the ridge drops steeply across a series of N-NNW trending ridges and troughs to a depth of about 3000 m, then more gradually to the floor of the North Norfolk basin at 3350 m depth. The flat floor of this basin terminates on its eastern side at a NNW-trending ridge several hundred metres high, which is topped by a 200-m high flat-topped conical volcano (26° 58'S / 168° 29'E).

The seafloor terrain east to about 170° 00'E is very rugged. The Cook Fracture Zone, at the eastern end of this rugged zone and centred at about 26° 45'S / 169° 35'E, is marked by a spectacular terrain of blocky ridges and troughs with about 1000 m relief. The terrain has a distinct NW-trending grain.

The floor of the South Fiji Basin lies at 4000-4600 m depth and is mainly sediment covered. There is, nevertheless, considerable evidence of its volcanic origin in the the many volcanic structures such as cones, seamounts and ridges that rise, often several hundred metres, above the basin floor.

The active spreading centre in the Lau Basin west of Tofua/Tongatapu was clearly and unequivocally displayed in the Sea Beam data, particularly the sidescan. The fresh and exposed basalts and related co-axially-trending structures of the active 'ridge' were highly reflective and appeared almost black in the sidescan display, in contrast with the lighter, grey tones away from the axial region where the seafloor is blanketed by pelagic sediments.

The Lau spreading centre was crossed twice just east of OBS Site 2 and twice just west of OBS Site 4 (Figure 2). In both cases, it showed a trend of approximately 010°.

Near OBS Site 2, the axis was crossed at 21° 23'S / 176° 22'W and at 21° 18.5'S / 176° 20.5'W. The dark, unsedimented band in the imagery was about 7 km wide and corresponded with local positive seafloor relief of about 400 m, within a broad rift graben in water depths of ~2100 m. In this area, the deepest part of the basin is located west of the axis. Near OBS Site 4, the axis was crossed at 19° 56'S / 176° 04.5'W and at 20° 03'S / 176° 08'W. Here the unsedimented axial band was about 4 km wide (perhaps narrower at this location due to eruptions of ash from volcanoes of the Tofua chain located just to the east). The spreading axis was again located within a broad rift graben (2600 m depth), but this time it coincided with a local topographic low in the seafloor of about 100 m.

The present-day spreading centre in the southern Lau Basin appears to correspond closely with the Valu Fa Ridge and its extension to the NNE. Our data support the contention that spreading is taking place at the Eastern Lau Spreading Center (ELSC) as mapped by Parson et al.(1990) and Parson and Hawkins (1994). It has been suggested (Ruellan et al., 1994) that the main spreading centre in the southern Lau Basin corresponds with an axial ridge (to the west of the ELSC), but this is now unlikely.

The Sea Beam bathymetry and sidescan images revealed a diversity of interesting volcanic features and structures on the seafloor in the Lau basin. This was not unexpected, considering that it is a young backarc basin adjacent to a very active volcanic arc and that the region is one of the most seismically active in the world. Though it is beyond the scope of this report to describe in detail all the seafloor features seen in the survey data, it is

noteworthy that a large and remarkably symmetric submarine volcano, with summit crater, was observed at 20° 12'S / 176° 26'W.

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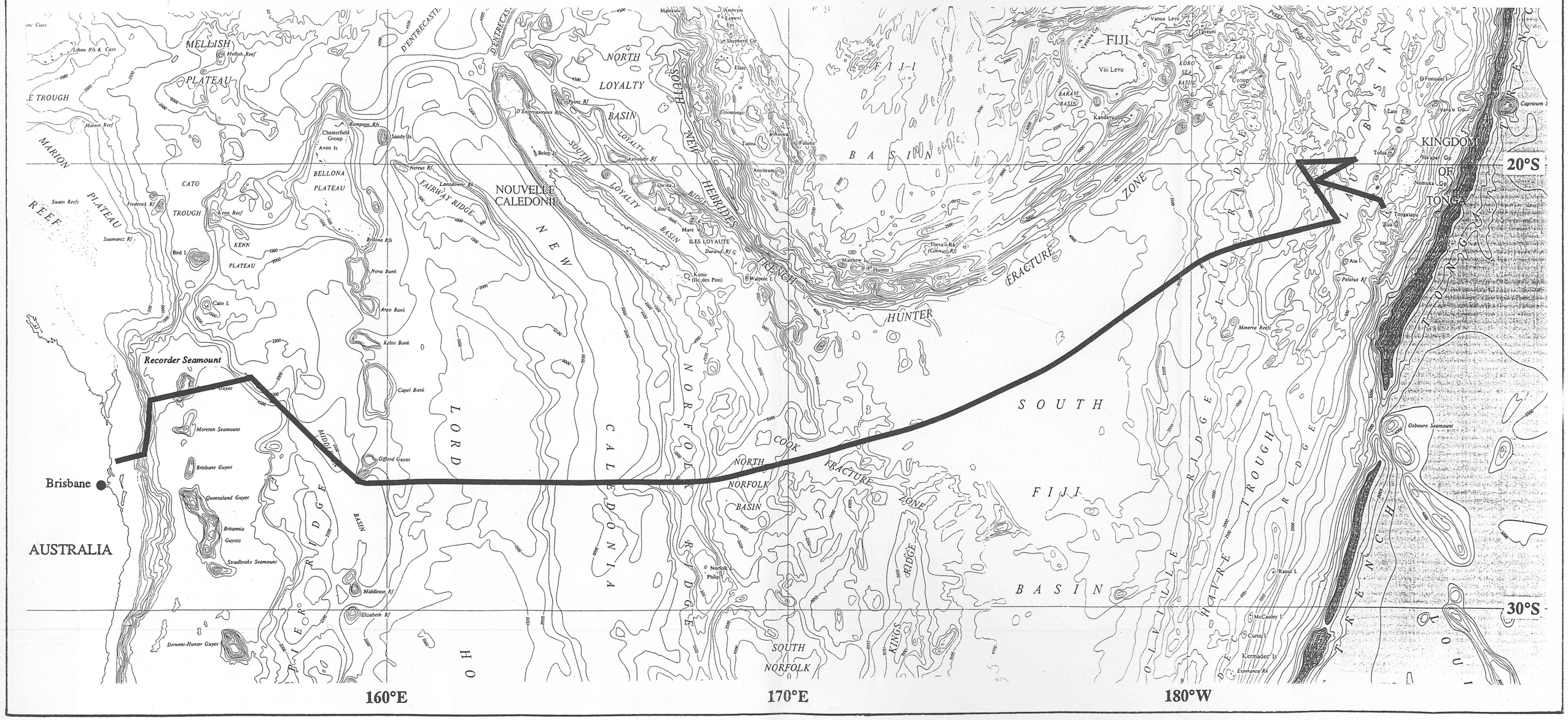
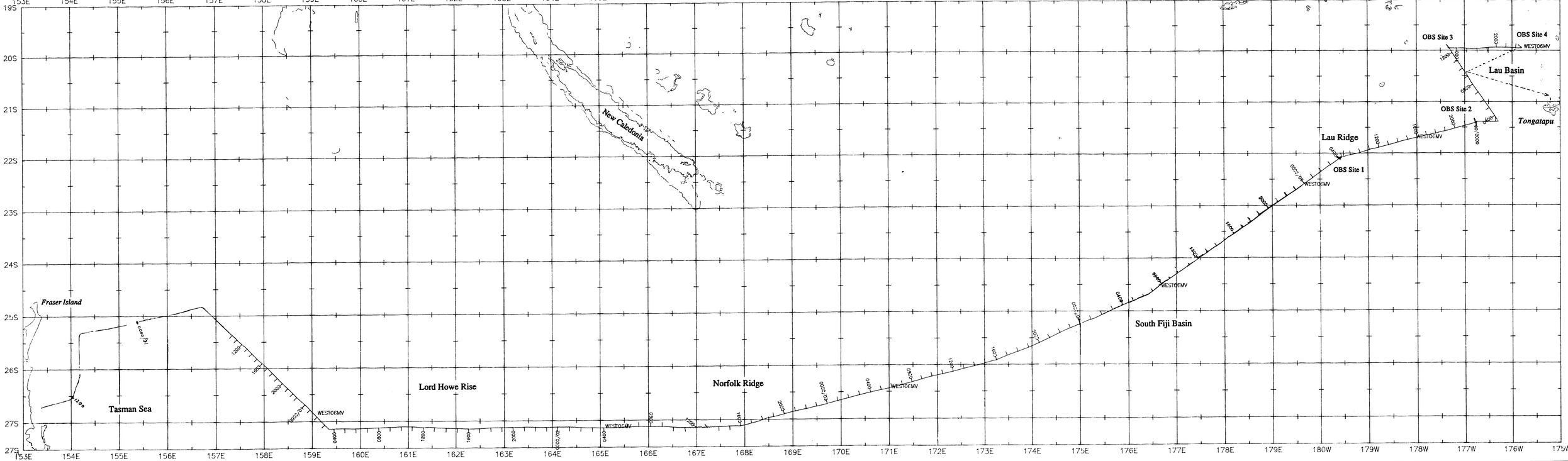


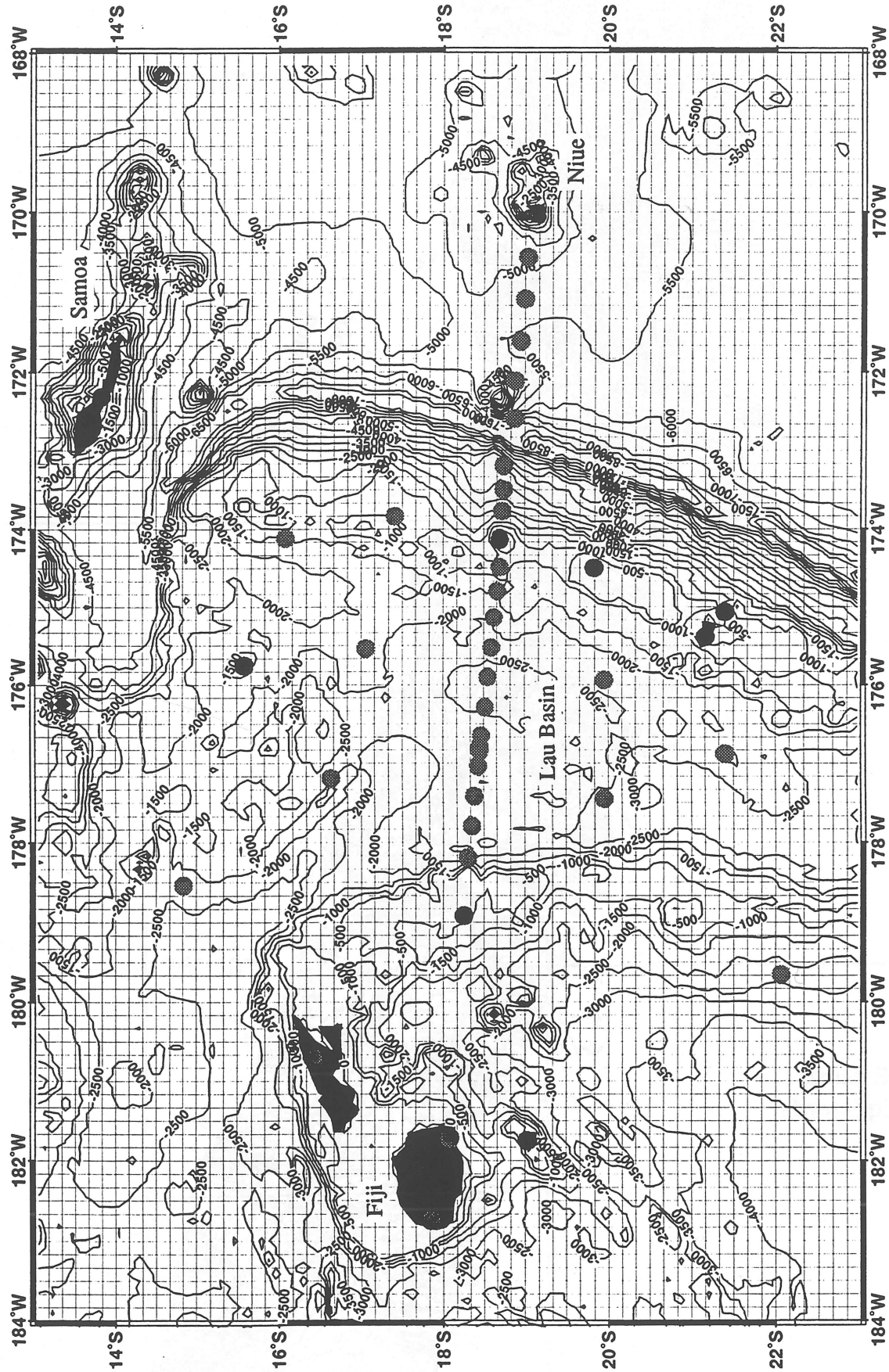
FIGURE 1. R/V *Melville* Brisbane-Tonga transit survey location. Bathymetry base map with contours at 500 m interval after Kroenke et al. (1983).



WEST06MV TRACK PLOT

R9501503

FIGURE 2. Preliminary time-annotated track map. Annotation is in hours GMT / day of month (at 0000 GMT); ticks on the hour.



Onshore stations: solid circles
OBS sites: stippled circles

FIGURE 3. Proposed OBS sites and onshore seismograph stations in the Lau Basin region.

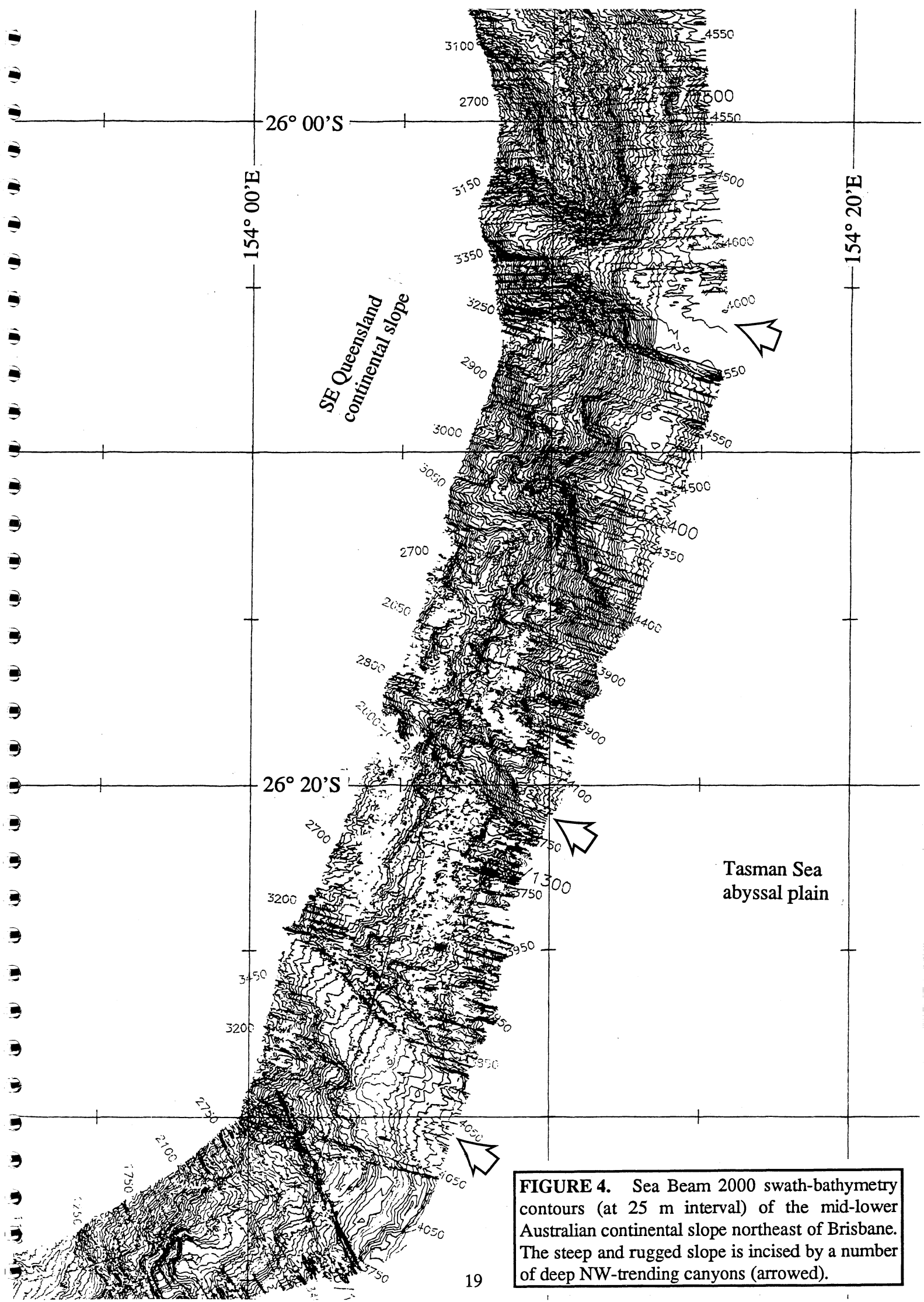


FIGURE 4. Sea Beam 2000 swath-bathymetry contours (at 25 m interval) of the mid-lower Australian continental slope northeast of Brisbane. The steep and rugged slope is incised by a number of deep NW-trending canyons (arrowed).

TABLE 1
Way-points (Australian and adjacent waters)

Way-point	Latitude / Longitude	Course to next W-P	Distance (nautical miles), next W-P	Remarks
1	26° 43.0'S 153° 10.6'E	077	48.0	Pilot station off Caloundra
2	26° 32.0'S 154° 02.0'E	019	25.3	-
3	26° 08.0'S 154° 11.0'E	000	48.0	-
4	25° 20.0'S 154° 11.0'E	078	143.4	-
5	24° 50.0'S 156° 45.0'E	135	194	-
6	27° 08.0'S 159° 21.0'E	090	453.0	-
7	27° 08.0'S 167° 50.0'E	076	301.3	-
8	25° 55.0'S 173° 15.0'E	066.7	190.0	-
9	24° 40.0'S 176° 27.0'E	54.9	271.4	-

TABLE 2
Ocean Bottom Seismograph Sites in the Lau Basin (Brisbane-Nuku'alofa leg)

OBS No.	Site No.	Launch time GMT	Latitude	Longitude	Water depth (m)
1 (Nelson)	1	0436 5/9/94	22° 04.64'S	179° 33.80'W	1856
2 (Helmut)	2	2238 5/9/94	21° 24.04'S	176° 45.93'W	1700
3 (SNAG)	3	1301 6/9/94	19° 57.00'S	177° 19.78'W	2841
4 (SNAG)	4	2338 6/9/94	19° 57.00'S	175° 49.17'W	2398
8 (SNAG)	4	0010 7/9/94	19° 57.00'S	175° 49.17'W	2399

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:	2944
Propulsion:	Diesel electric, twin Cort Z-drives (shrouded) One for'ward retractable thruster
Motors:	3 x 1500 HP (1070 kW), 1 x 800 HP (500 kW)
Official Number:	CF 0719 XS

APPENDIX 2
Shipboard Personnel

Scripps Institution of Oceanography

LeRoy Dorman ---------- Chief Scientist (seismologist)
John Hildebrand ---------- Seismologist (co-chief scientist)
Spahr Webb ---------- Seismologist
Christopher Bradley ---------- Seismologist / programmer
Wayne Crawford ---------- Post-doctoral seismologist
Sharon Escher ---------- Programmer
Allan Sauter ---------- Electronics engineer
Javier Porras ---------- Graduate student, seismology
Robert Sohn ---------- Graduate student, seismology
Kimberly Williams ---------- Graduate student, marine geology
Robert (Bob) Wilson ---------- Resident Marine Technician
Todd Porteous ---------- Computer engineer

Washington University, St Louis

Douglas Weins ---------- Seismologist

AGSO

Peter Hill ---------- Geophysicist and Australian observer

Ships Crew

Eric Buck ---------- Master

John Manion ---------- Chief Mate

David Murline ---------- Second Mate

(total of ~20 in ships crew)

APPENDIX 3
Scientific and Navigation Equipment

Swath-mapping
Sea Beam 2000 system
Calcomp 965A 4-pen colour plotter (ships track and bathymetry contours, real-time monitor)
Hitachi Model HM-4119-S video monitor - part of Sea Beam control console and displaying real-time sidescan imagery)
NEC MultiSync 3D VGA colour QC monitor displaying beam amplitude and cross-track bathymetry per ping (cross-track / status display)
Zeta 912 contour plotter: strip-chart colour pen recorder displaying real-time bathymetry contours (8 pen)
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 GPS Surveyor 4000AX (2 sets)
Trimble 10X GPS (on Bridge)
Ashtech GPS Receiver XII (differential - not used on this cruise)
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-5, 1830 metres depth
Sippican MK9 processor

Data Logger (1 second navigation and geophysical data logged)
Sun 630MP system
MMP hard-disks, 2 x 4.5Gb (total hard-disk storage 12 Gb)
DAT and Exabyte drives, 2 x 9-track ½" tape drives (GCR CacheTape)

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 4
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

Information supplied by Bob Wilson.

APPENDIX 5
XBT Temperature and Sound Velocity Profiles
Stations 1-5

(Following 5 pages)

R/V Melville WEST06MV 24° 58.18' S 156° 08.52' E 03:49:32 Z (GMT)

(graphical displays not available for this station)

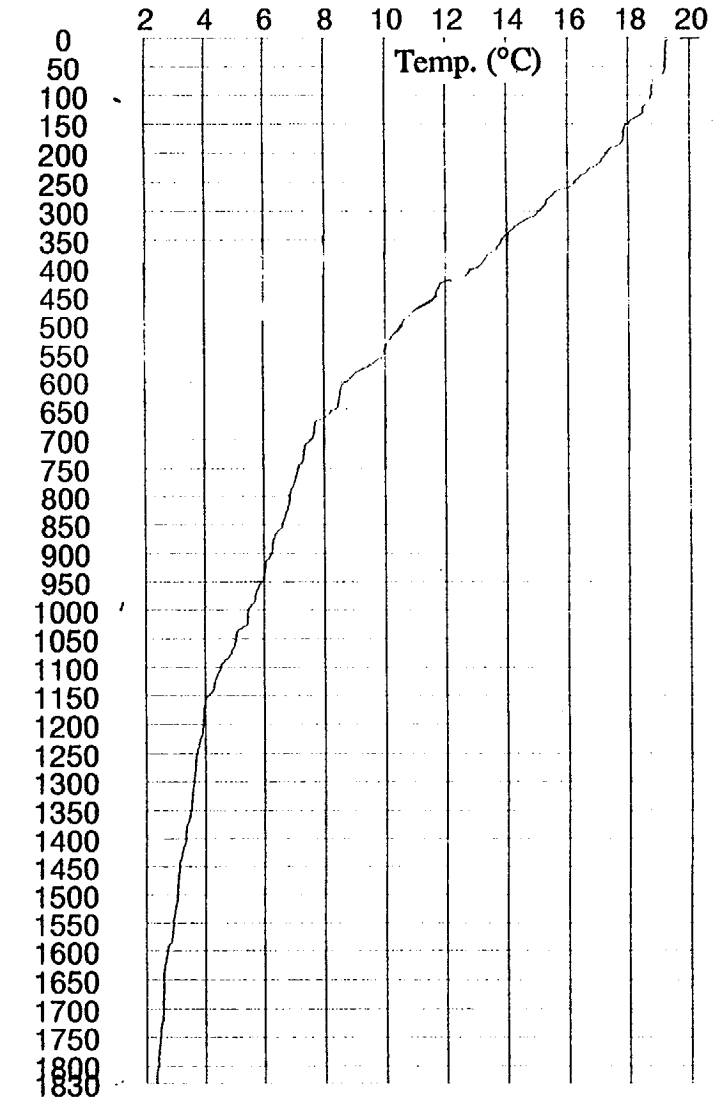
Depth (m), sound velocity (m/s)

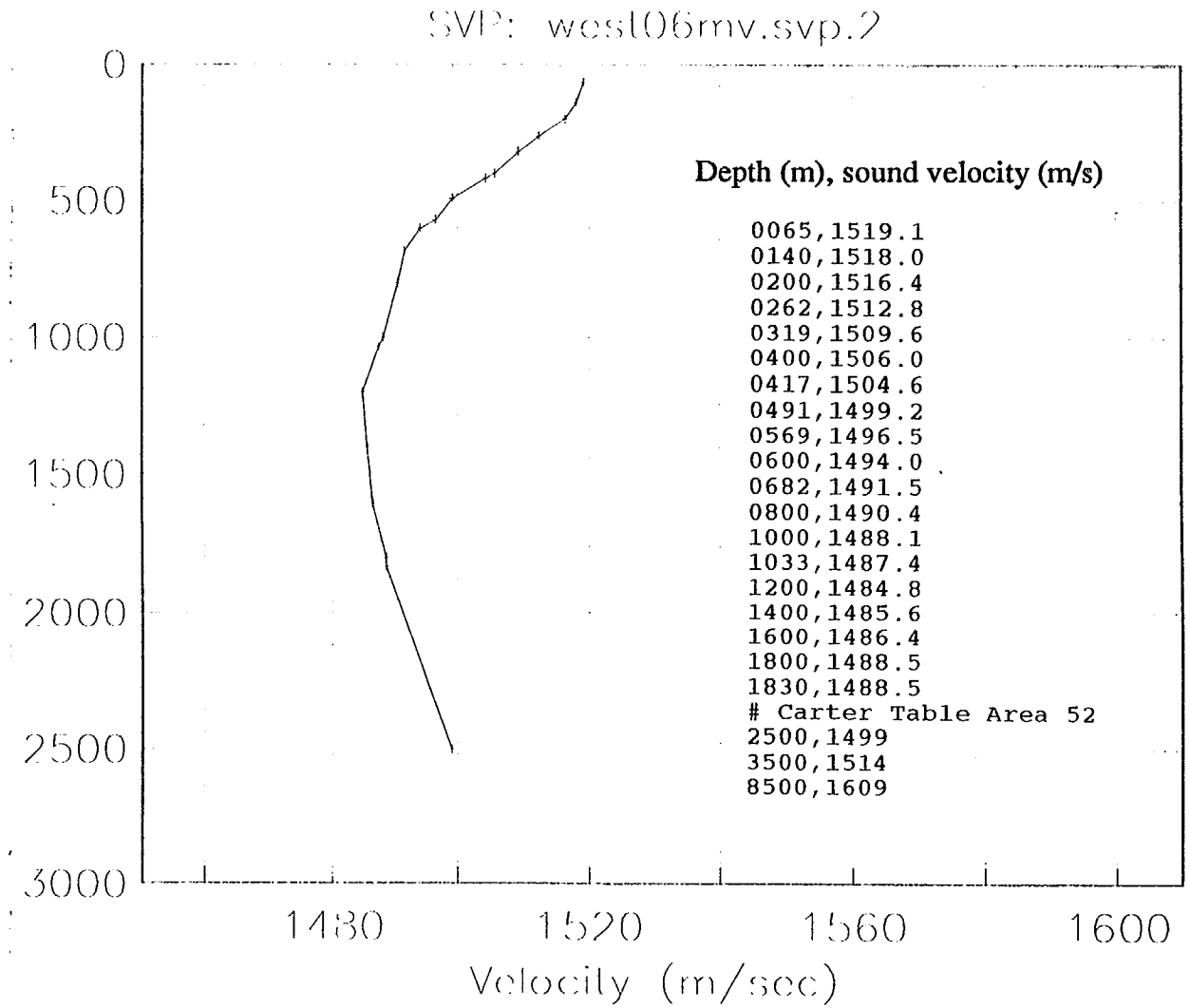
```
0079,1526.9
0167,1524.6
0200,1524.1
0278,1523.2
0344,1517.8
0400,1514.2
0507,1505.8
0600,1498.1
0702,1493.0
0800,1490.0
1000,1487.3
1177,1489.0
1196,1488.5
1200,1487.7
1225,1487.3
1340,1486.7
1400,1486.9
1600,1488.1
1717,1489.7
1800,1489.3
# Carter Table Area 52
2500,1499
3500,1514
8500,1609
```

STATION 1

31 August 1994

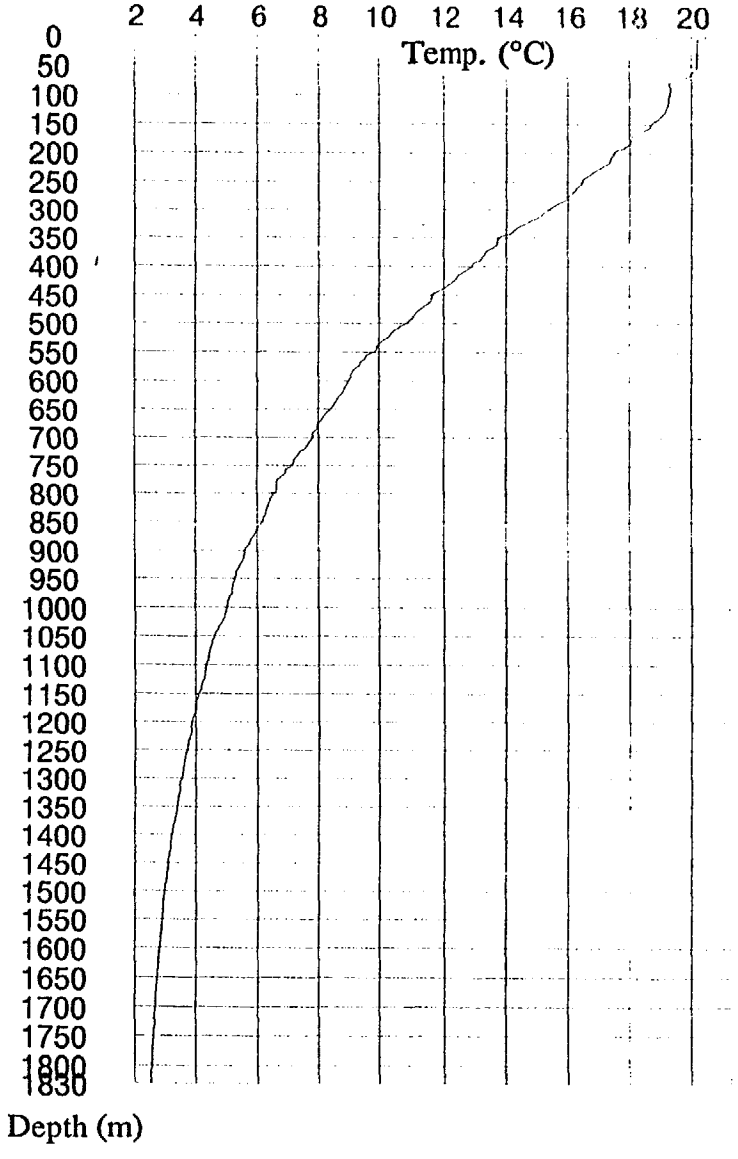
T-5 R/V Melville WEST06MV 26°44.192 S 169°38.131 E 23:43:35

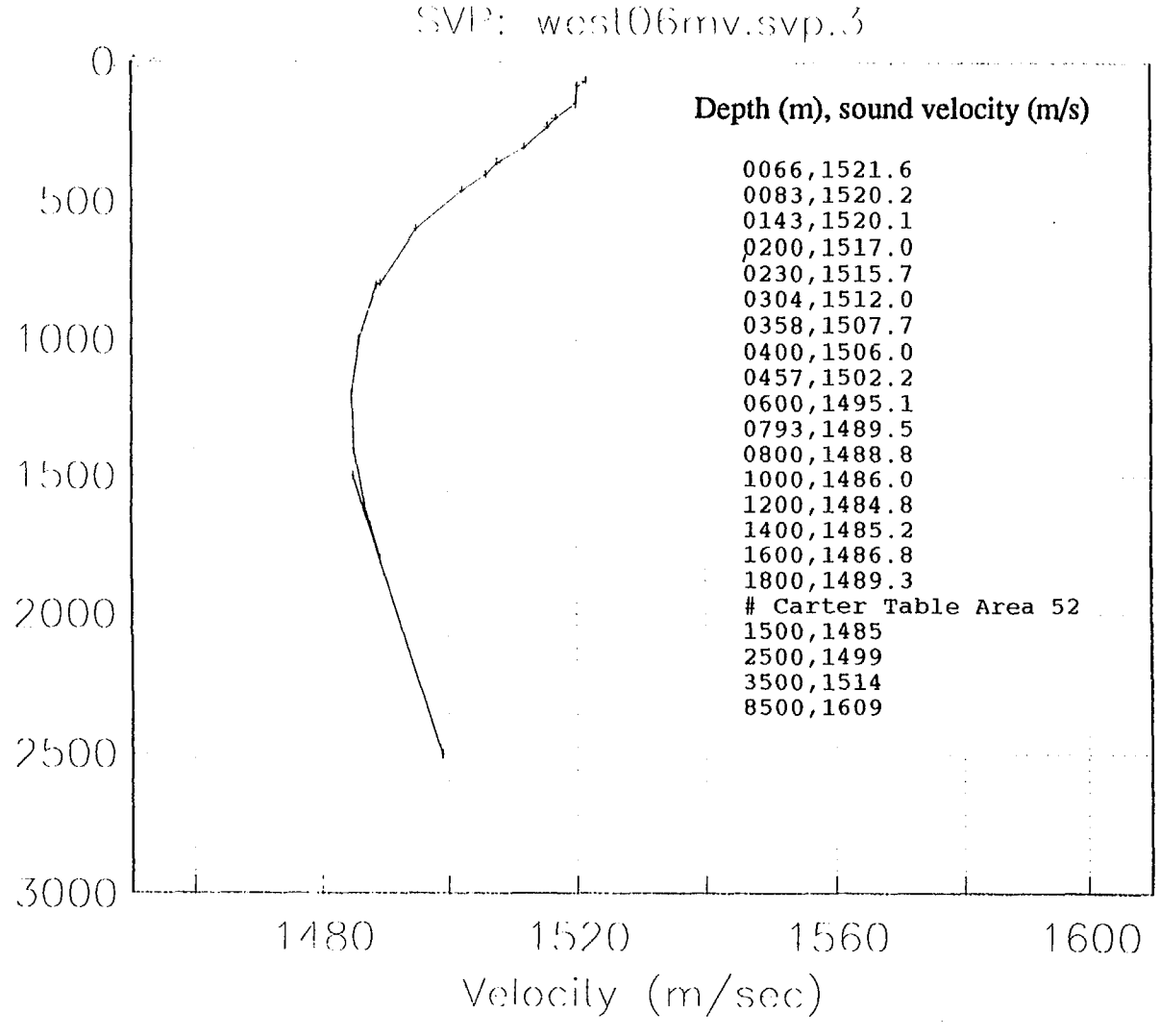




STATION 2
2 September 1994

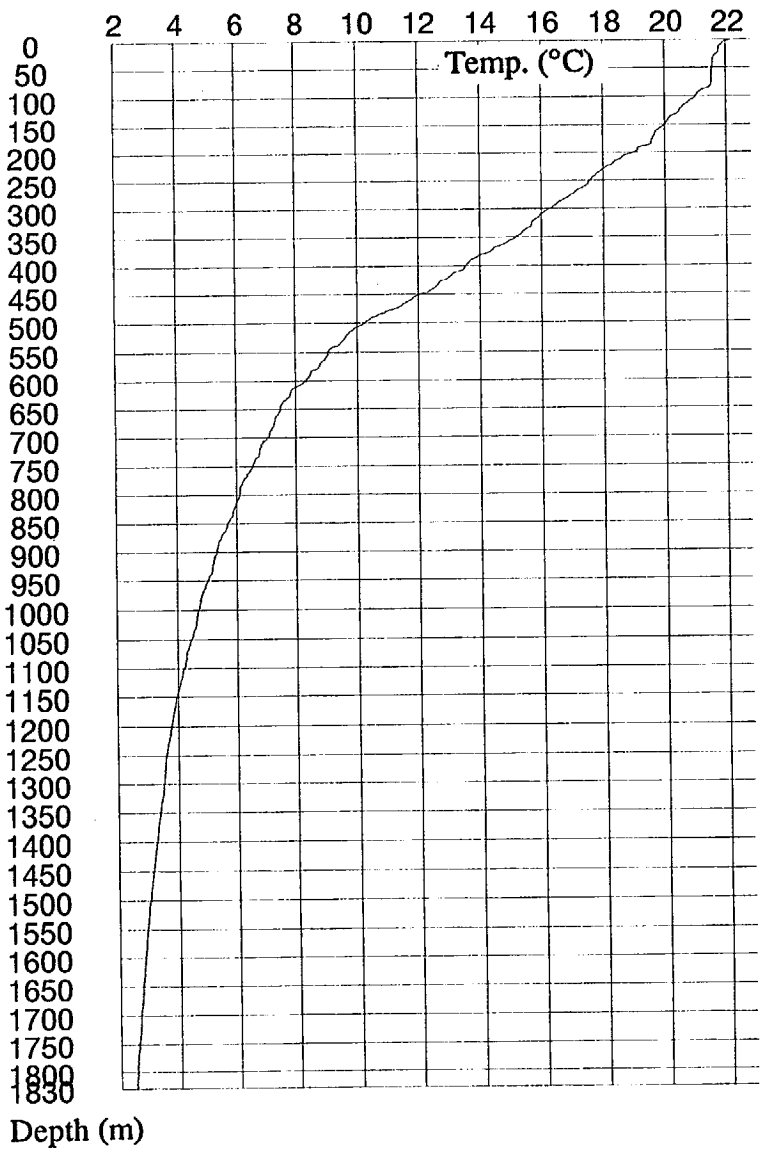
T-5 R/V Melville WEST06MV 25°09.757 S 175°12.211 E 01:14:03

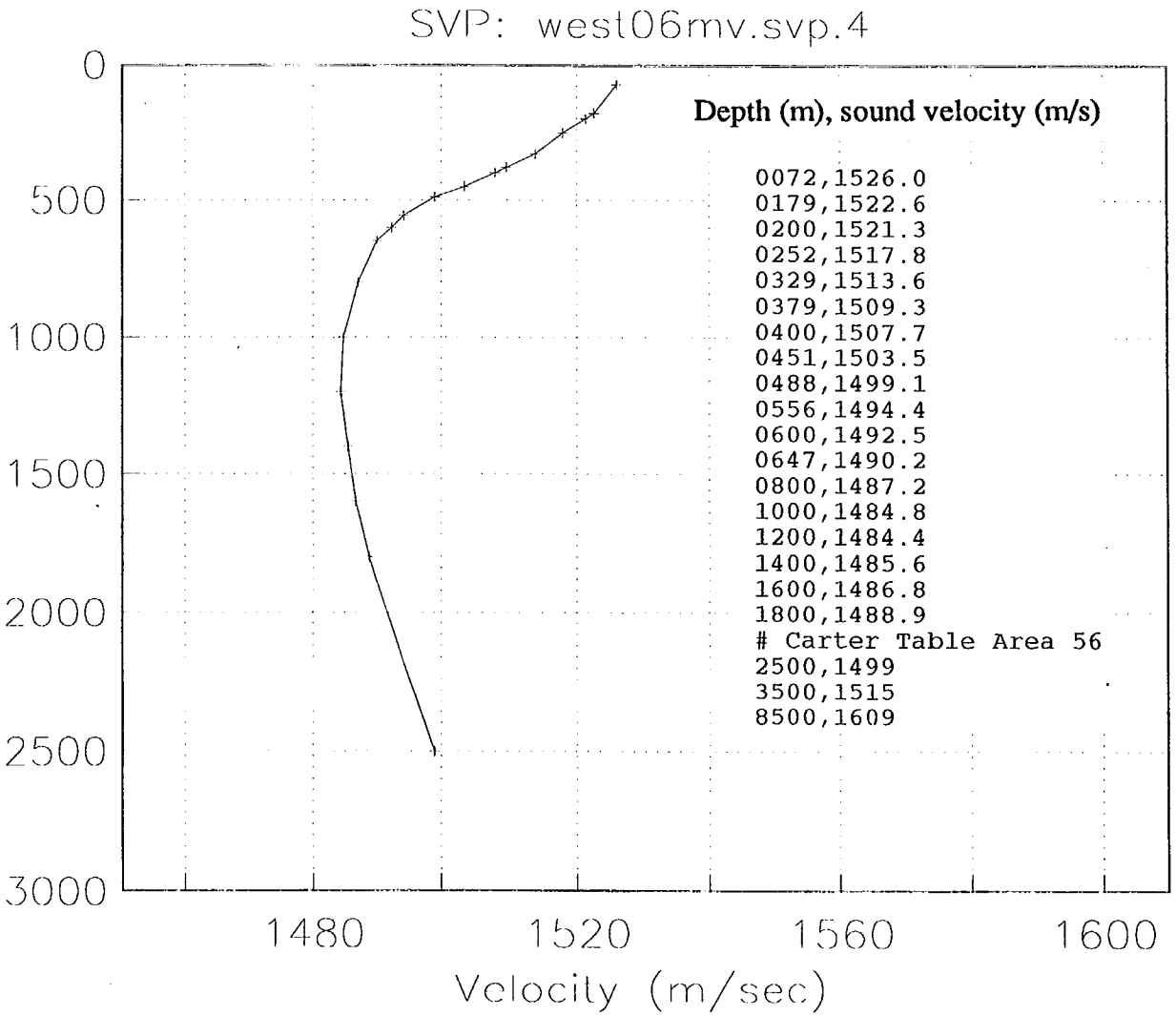




STATION 3
4 September 1994

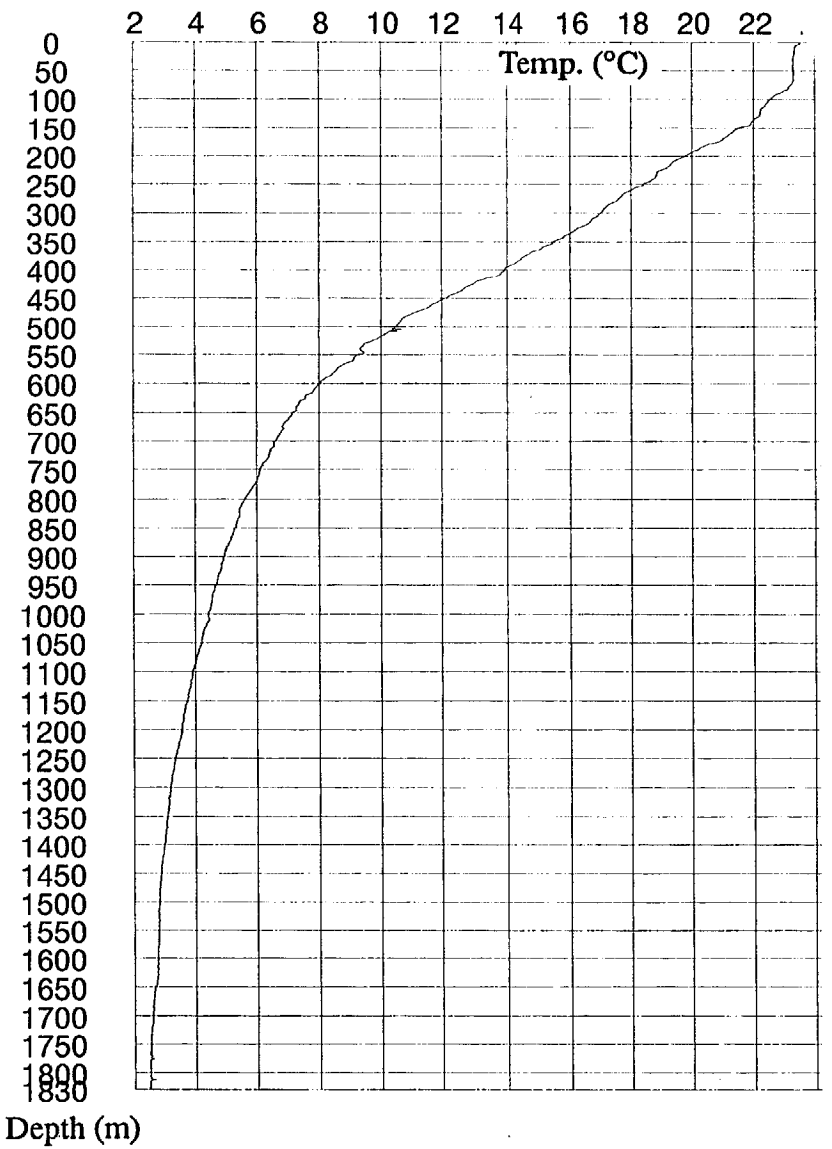
T-5 R/V Melville WESTO6MV 22°24 S 179°55 E 01:41:17

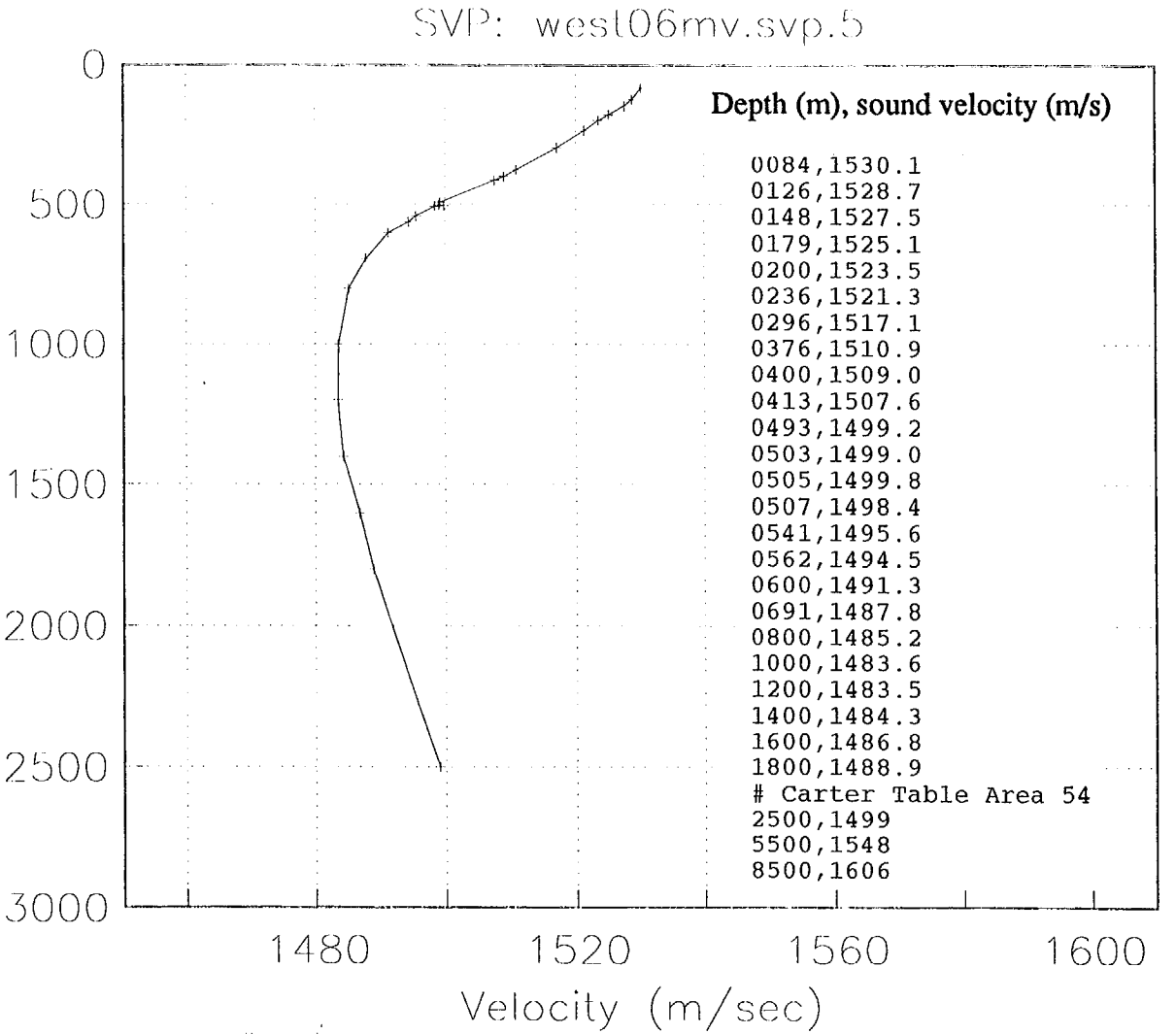




STATION 4
5 September 1994

T-5 R/V Melville WEST06MV 19°56.786 S 175°47.944 W 22:59:22

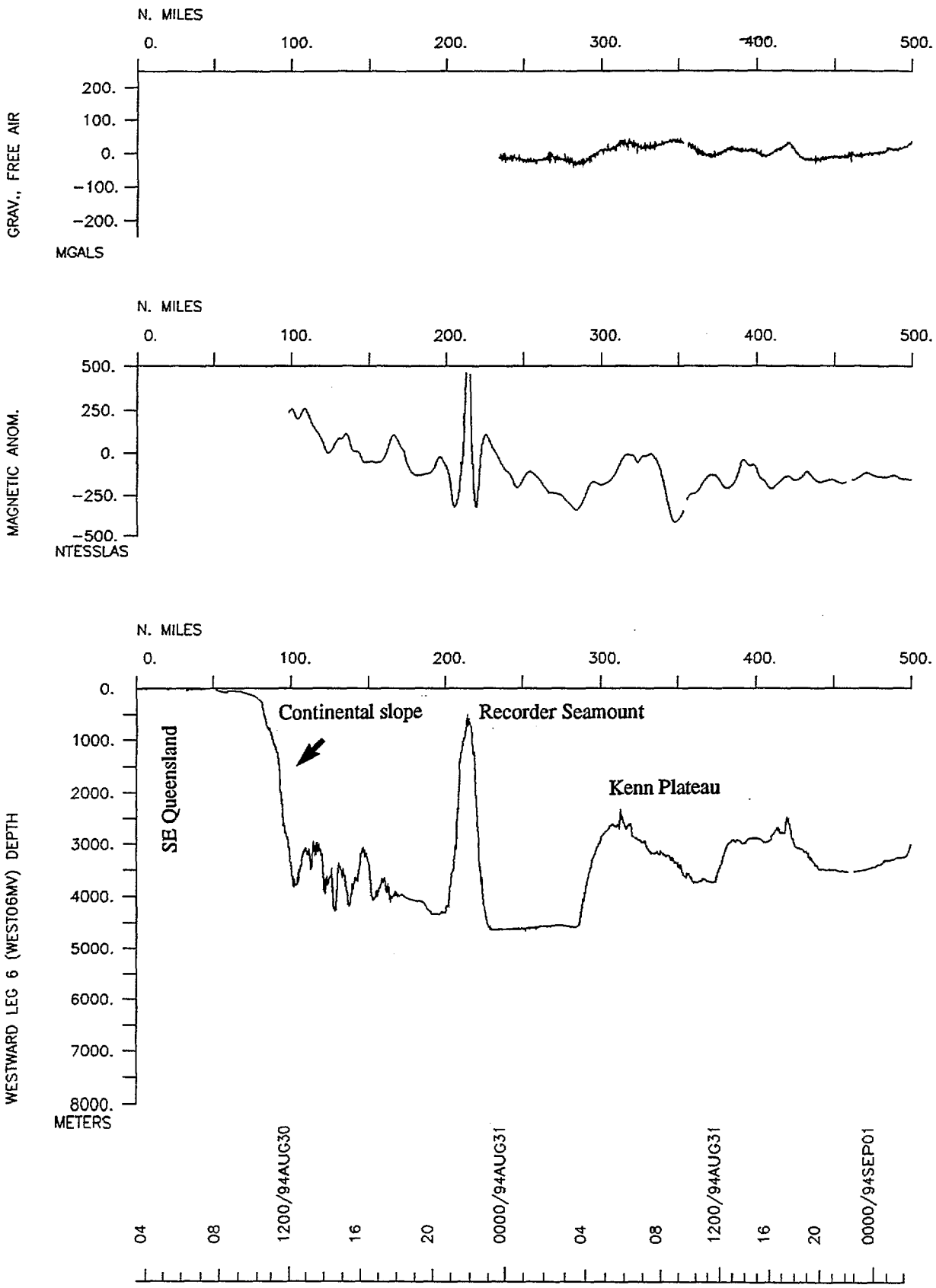


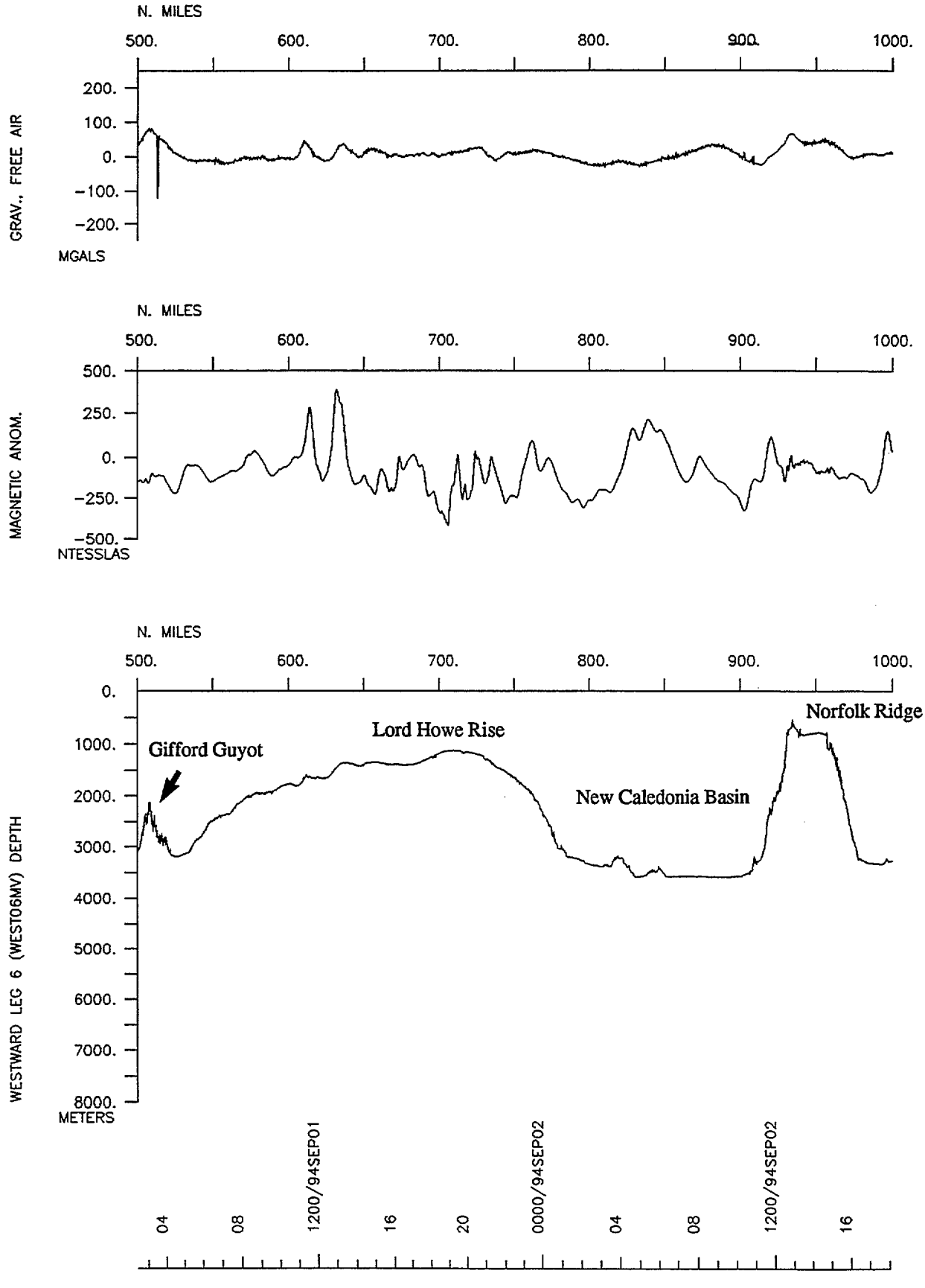


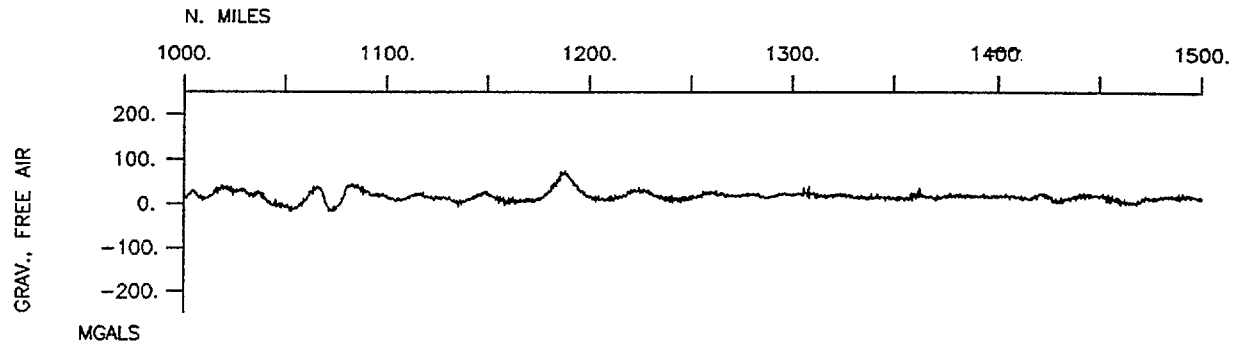
STATION 5
6 September 1994

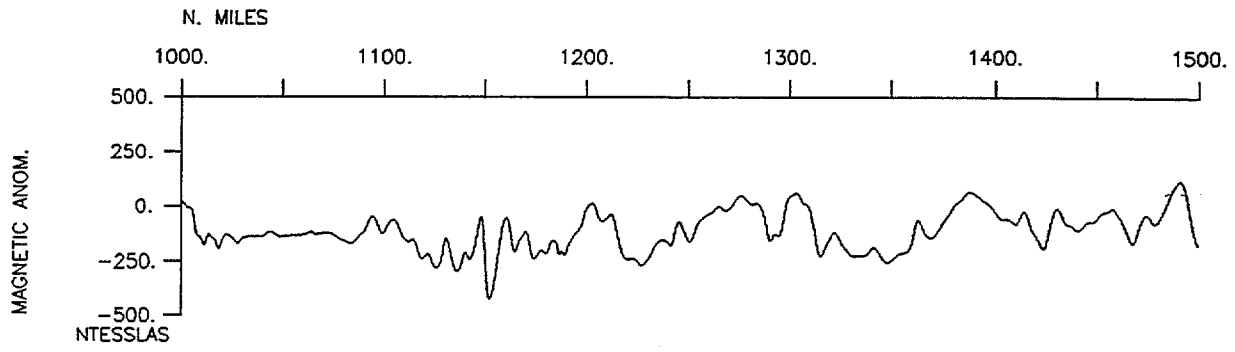
APPENDIX 6
Free-air gravity, magnetic anomaly and bathymetry profiles for the Brisbane to South Fiji Basin part of the transit

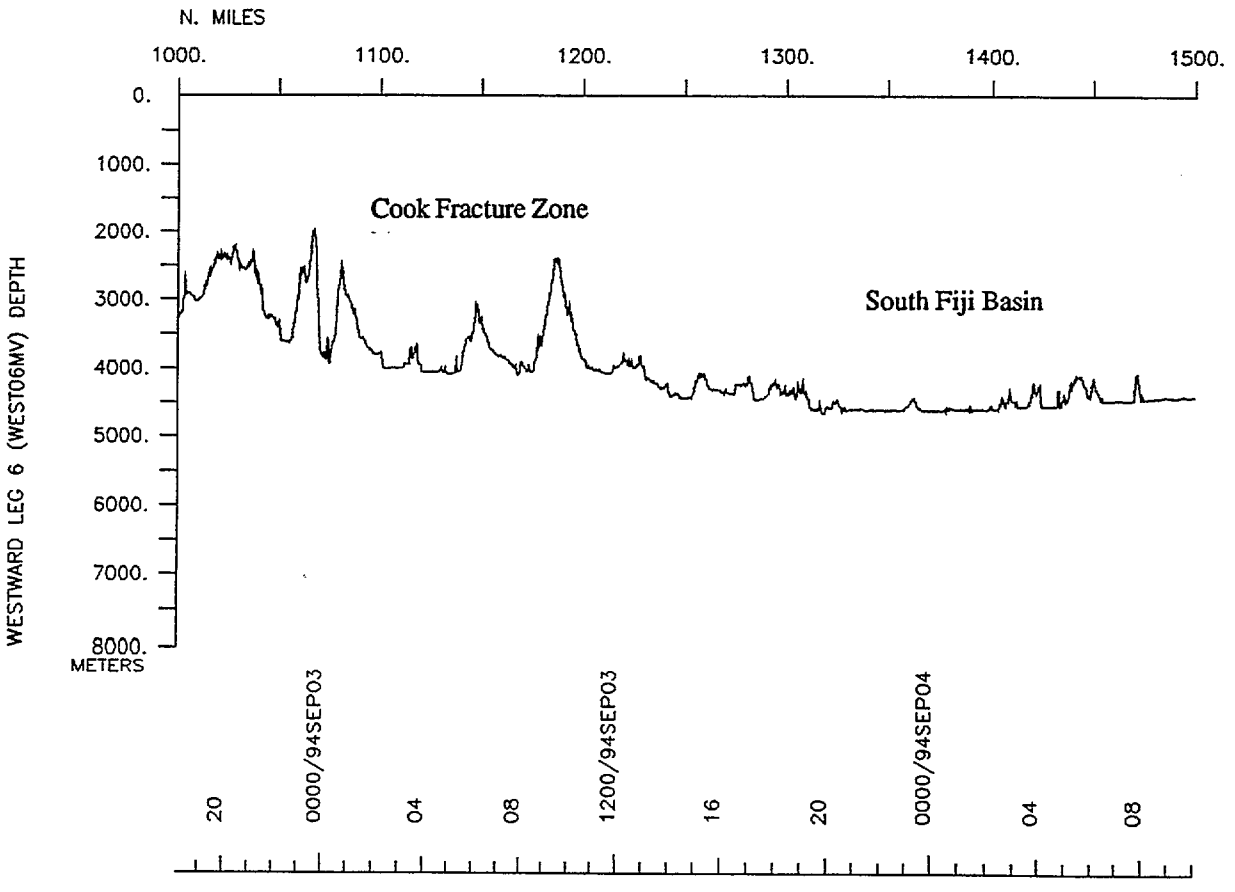
(Following 3 pages)


N. MILES
0.
100.
200.
300.
400.
500.
GRAV., FREE AIR
200.
100.
0.
-100.
-200.
MGALS
N. MILES
0.
100.
200.
300.
400.
500.
MAGNETIC ANOM.
500.
250.
0.
-250.
-500.
NTESSLAS
N. MILES
0.
100.
200.
300.
400.
500.
WESTWARD LEG 6 (WEST06MV) DEPTH
0.
1000.
2000.
3000.
4000.
5000.
6000.
7000.
8000.
METERS
Continental slope
Recorder Seamount
SE Queensland
Kenn Plateau
04
08
1200/94AUG30
16
20
0000/94AUG31
04
08
1200/94AUG31
16
20
0000/94SEP01


N. MILES
500.
600.
700.
800.
900.
1000.
200.
100.
0.
-100.
-200.
GRAV., FREE AIR
MGALS
N. MILES
500.
600.
700.
800.
900.
1000.
500.
250.
0.
-250.
-500.
MAGNETIC ANOM.
NTESSLAS
N. MILES
500.
600.
700.
800.
900.
1000.
0.
1000.
2000.
3000.
4000.
5000.
6000.
7000.
8000.
METERS
WESTWARD LEG 6 (WEST06MV) DEPTH
Gifford Guyot
Lord Howe Rise
New Caledonia Basin
Norfolk Ridge
04
08
1200/94SEP01
16
20
0000/94SEP02
04
08
1200/94SEP02
16


N. MILES
1000.
1100.
1200.
1300.
1400.
1500.
200.
100.
0.
-100.
-200.
GRAV., FREE AIR
MGALS


N. MILES
1000.
1100.
1200.
1300.
1400.
1500.
500.
250.
0.
-250.
-500.
MAGNETIC ANOM.
NTESSLAS


N. MILES
1000.
1100.
1200.
1300.
1400.
1500.
0.
1000.
2000.
3000.
4000.
5000.
6000.
7000.
8000.
METERS
WESTWARD LEG 6 (WEST06MV) DEPTH
Cook Fracture Zone
South Fiji Basin
20
0000/94SEP03
04
08
1200/94SEP03
16
20
0000/94SEP04
04
08

APPENDIX 7
Underway Watch Log

(Following 12 pages)

SIO UNDERWAY WATCH LOG

CRUISE: WEST LEG: 06 SHIP: MELVILLE CHECK OPERATIONS PAGE 1

DATE (DAY, MO, YR): 30-08-94 TIME ZONE (SHIP): 12KHZ ✓ 3.5KHZ SEIS. PROF MAG ✓ GRAV. ✓

(ON CSE 95 @ 3 KTS.)

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	MIN.	N/S	LONGITUDE DEG.	MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE	COMMENTS AND OBSERVATIONS
				TYPE	ELPS.		ELEV.	AZM.						
0300	0038		0300	27	26.80	S	153	04.7	E					Depart Brisbane (W. Bay)
0754	0048			26	45.67		153	12.49						Sea Bird Operational
0900	0062		0900	26	41.18	S	153	26.83	E	0903	075	12.3	CC	(W. Bay)
0930	0114			26	39.36		153	33.83						
1008	0249		0930	26	37.33	S	153	41.86	E	1012	072	5.2	CS	Deployed Magnetometer
1030	0470	#1		26	36.79		153	44.12		1035	072	12.2	CS	Begin Mag Roll 1, time 10:41, value 53118
1100	0894	53146	1100	26	35.83	S	153	49.09	E					Begin sidescan, roll #1
1130	1685	53181		26	34.49		153	55.9						
1200	3060	53314	1200	26	32.25	S	154	01.25	E	1205	015	12.9	CC	
1230	3654	53211		26	27.00		154	03.96						
1300	3153	53179	1300	26	21.85	S	154	05.76	E					
1330	3111	53030		26	16.77		154	07.54						
1400	3913	52439	1400	26	10.3	S	154	09.97	E	1425	357	12.0	c/c	Kimberly on Watch
1430	4152	52482		26	05.3		154	11.24						
1500	3526	52410	1500	25	59.61	S	154	10.68	E	1500	000	12.5	c/c	
1530	3946	52625		25	53.81		154	10.38		1544	000		c/c	
1600	3237	52564	1600	25	47.92	S	154	10.53	E					
1630	3536	52467		25	42.1		154	10.64						
1700	3978	52407	1700	25	36.5	S	154	10.67	E					
1730	3784	52455		25	30.0		154	10.66						
1800	3966	52429	1800	25	24.14	S	154	10.56	E	1820	078	13.0	c/c	
1830	4020	52336		25	19.28		154	13.29						
1904	0798	52147	1900	25	13.66	S	154	19.52	E					
1930	4111	52130		25	17.9		154	25.54						
2000	4335	52131	2000	25	10.45	S	154	31.7	E					Sun's up
2030	4308	52155		25	15.30		154	38.13						L. Dorman dive / flow bucket
2100	3796	51949	2100	25	14.02	S	154	43.92	E					
2130	1234	52073		25	0.44		154	51.23						Recorder / Sea mount 1
2200	754	52287	2200	25	11.08	S	154	57.61	E					
2230	3355	51990		25	09.90		155	04.04						Peter on watch
2300	4542	52113		25	08.71		155	10.34						~2250 Start wander at mount 3 - smooth
2330	4639	51798		25	07.66		155	16.12						
31/8/94 0000	4629	51875		25	06.33		155	22.51						
0030	4617	51760		25	05.18		155	28.61						
0100	4618	51782		25	04.10		155	34.86						
0136	4591	51764		25	02.65		155	42.71		0212	130		°C	New post [illegible]

SIO UNDERWAY WATCH LOG | CRUISE: WESTWARD | LEG: 06 | SHIP: MELVILLE | CHECK OPERATIONS | PAGE 2

DATE (DAY, MO, YR): 31-08-94 | TIME ZONE (SHIP): | 12KHZ ✓ | 3.5KHZ | SEIS. PROF. | MAG. | GRAV. ✓

TIME GMT	DEPTH FM ☐ MT ☐	MAGNETICS	TIME	LATITUDE DEG	MIN.	N/S	LONGITUDE DEG.	MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE	(ON CSE ___ @ ___ KTS.) COMMENTS AND OBSERVATIONS
				TYPE	ELPS.		ELEV.	AZM.						
0200	4563	5165 9	0200	25	01.49		155	49.10		0218	078	12	c/c	Back on course after avoiding fishing vessel
														BOAT DRILL
0300	4558	5152 0	0300	24	57.87		156	03.17		0310				
0330	4587	5142 3		24	58.33		156	10.11						
0400	3898	5148 7		24	56.75		156	17.17						XBT at ≈ 0350 Coming up onto main Plateau
0430	3093	5151 2		24	54.87		156	24.26						
0500	2759	5147 5		24	53.12		156	31.24						0506 New SVP input (based on Rent XBT)
0530	2615	5152 3		24	50.72		156	39.57						
0600	2627	5156 2		24	49.49		156	44.52		0600	135		c/c	
0630	2955	5157 8		24	53.10		156	49.59		0630	138		c/c	SEABEAM CLOCK IS 106 sec fast. Wiens watchstanding
0700	2935	5162 0		24	58.80		156	54.81						
0730	3178	5164 9		25	01.73		156	58.54						
0800	3199	5157 2		25	05.35		156	02.19						
0830	3278	5132 7		25	01.02		157	07.68						Seabeam clock 112 s. fast
0900	3432	5135 4		25	14.19		157	10.90		0903	135		c/c	
0930	3606	5153 7		25	19.09		157	16.42						
1000	3749	5158 7		25	22.63		157	20.63		10:03		5	c/s	Thruster Problem
1030	3689	5164 5		25	24.74		157	23.57		10:40		8.5	c/s	
1100	3721	5170 A		25	27.37		157	26.19						Seabeam clock 118 s. fast
1130	3742	5173 1		25	29.49		157	28.57						
1200	3476	5171 1		25	32.23		157	32.03						
1230	3093	5168 5		25	34.0		157	35.68						
1300	2925	5173 3		25	37.88		157	39.31						
1330	2926	5182 0		25	40.16		157	41.65						
1400	2978	5190 8	1400	25	43.0	S	157	44.0	S					Seabeam clock 1305. fast
1430	2864	5189 9		25	46.4		157	47.7						Kimberly on Watch
1500	2878	5186 8	1500	25	48.5	S	157	50.9	S					
1530	2961	5184 9		25	51.6		157	54.26						
1600	2930	5182 1	1600	25	54.2	S	157	57.8	S					
1630	2760	5164 9		25	56.9		158	00.4						
1700	2783	5197 7	1700	25	59.23	S	158	03.6	S					
1730	2515	5195 6		26	02.2		158	06.9						
1800	2959	5194 3	1800	26	05.9	S	158	10.8	S					
1830	3102	5177 7		26	08.2		158	13.2						
1900	2978	5202 5	1900	26	11.2	S	158	16.4	S					
1930	2992	5200 1		26	15.6		158	21.2						

SIO UNDERWAY WATCH LOG | CRUISE: Wast+Ward | LEG: 06 | SHIP: R/V Melville | CHECK OPERATIONS | PAGE 3

DATE (DAY, MO, YR): 31/08/94 | TIME ZONE (SHIP): +10 | 12 KHZ ✓ | 3.5 KHZ | SEIS. PROF | ✓ MAG. | ✓ GRAV. ✓ | (3)

TIME GMT	DEPTH FM ☐ MT ☑	MAGNETICS	TIME	LATITUDE DEG	MIN.	N/S	LONGITUDE DEG.	MIN.	E/W	TYPE	ELPS.	ELEV.	AZM.
2000	3488	5200	2000	26	16.4	S	158	22.5	E				
2030	4491	5203		26	19.6		158	25.7					
2100	3495	5206	2100	26	22.8	S	158	29.4	E				
2200	3527	5204		26	25.9		158	33.1					
2200	3535	5208	2201	26	28.4	S	158	35.9	E				
2300	3526	5213	2300	26	32.95		158	40.76					
2330	3499	5219		26	37.07		158	45.86					
1/9/94 0000	3457	5220	0000	26	41.02		158	50.92					
0033	3321	5222		26	45.67		158	56.11					
0105	3317	5224		26	47.37		158	57.75					
0130	3277	5226		28	50.88		159	01.54					
0200	3259	5227	0200	26	54.09	S	159	05.759	E				
0230	3018	5230		26	59.30		159	10.36					
0300	2186	5232		27	03.68		159	15.31					
0330	2886	5240		27	08.30		159	20.48					
0400	2945	5233		27	08.31		159	26.78					
0430	3188	5224		27	08.14		159	33.40					
0500	3145	5237		27	08.07		159	40.15					
0530	2935	5237		27	08.23		159	47.22					
0600	2717	5231		27	08.24		159	54.01					
0630	2493	5223		27	08.01		160	01.25					
0700	2395	5224		27	07.75		160	08.12					
0730	2250	5224		27	07.48		160	16.9					
0800	2085	5224		27	07.28		160	22.94					
0830	1999	5230		27	07.07		160	29.27					
0900	1957	5224		27	06.84		160	36.93					
0940	1902	5211		27	06.43		160	46.18					
1000	1806	5213		27	06.20		160	51.58					
1130	1759	5214		27	06.21		160	57.73					

COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE
2206		4	c/s
2220		0	c/s
2230		8	c/s
2240		4	c/s
2250		12	
2300		12.6	
0036		4	c/s
		8→12	c/s
		12.7	
		12.6	
		12.6	
0332	090		c/c
		12.6	
		12.7	
		12.6	
0855	091	13.0	c/c

(ON, CSE 135 @ 8 KTS.)

COMMENTS AND OBSERVATIONS

Kimberly on Watch
(speed slow for starboard screw)
time error @ 1553
Peter Hill on watch
2205 Mag. off – slowing further to retrieve Remus
2220 Sea Beam off (while instrument dive in progress)
2230 Speed increased. 1 shark on line fouled under ship. Cut line
2240 Re-deploying mag.
2250 Mag back on.
2300 Sea Beam back on IFX time error 157 sec
Zeta plotter (bathy.) – new one – on and working.
0036 Slowing down / bring in mag. Mag off at 0037 Fishing problem
Mag back on, speeding up
On flank of Clifford Seamount
Turning to 090°
Seabeam time error 182 sec
Wiens on Watch
Seabeam time error 185 sec
Seabeam timing error 187 sec

SIO UNDERWAY WATCH LOG | CRUISE: Westward | LEG: 06 | SHIP: R/V Melville | CHECK OPERATIONS | PAGE 4

DATE (DAY, MO, YR): 01/09/94 | TIME ZONE (SHIP): +10 | 12 KHZ ✓ | 3.5 KHZ | SEIS. PROF. | MAG. | GRAV. ✓

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	MIN.	N/S	LONGITUDE DEG.	MIN.	E/W	TYPE	ELPS.	ELEV.	AZM.	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE	COMMENTS AND OBSERVATIONS (ON CSE 94 @ 12.8 KTS.)
1130	1629	524061	1130	27	06.75	S	161	11.69	E						94	12.8		Wiens on watch
1200	1654	520333		27	07.21		161	19.68										
1230	1617	520417	1230	27	06.8	S	161	26.68	E									
1300	1450	524775		27	07.15		161	32.30										
1330	1360	520897	1330	27	07.62	S	161	40.09	E									seabeam time error 186 sec.
1400	1490	518500		27	07.8		161	47.46										Kimberly on Watch
1430	1363	518974	1430	27	08.1	S	161	54.5	E									
1500	1349	517725		27	08.2		162	01.5										
1530	1379	519669	1530	27	08.8	S	162	08.4	E					1543	090	12.8	C/C	
1630	1404	518666		27	08.8		162	21.9										
1700	1392	519277	1700	27	08.4	S	162	29.1	E									
1730	1337	518455		27	08.2		162	35.6										
1800	1250	516355	1800	27	07.8	S	162	42.6	E									
1830	1151	514961		27	07.6		162	51.7										New chart
1900	1127	516077	1900	27	07.5	S	162	56.4	E									
1930	1128	517923		27	07.4		163	03.3										
2000	1152	515331	2000	27	07.3	S	163	0.1	E									
2100	1290	515600		27	07.24		163	24.73								13.0		Peter relief on
2130	1468	516022	2130	27	07.13		163	31.93										
2203	1545	513991		27	07.32		163	39.39								13.1		
2230	1642	514114		27	07.46		163	45.62										Reseat SEABEAM clock - Time err now 2 ord @ ~2240
2300	1786	515755		27	07.52		163	52.55								13.0		
2330	1766	516922		27	07.33		163	59.28										
2/9/94 0003	2337	515099		27	07.15		164	07.11								13.0		
0030	2609	515233		27	07.25		164	13.41										
0103	3032	513311		27	07.27		164	21.60								13.1		
0134	3200	512300		27	07.51		164	29.07										
0203	3267	511847		27	07.86		164	36.14								12.8		0207 XBT drop (planned to 5,500m but dubious - not used)
0238	3362	512022		27	08.30		164	44.42										
0300	3384	512477		27	08.19		164	49.58								13.1		
0333	3374	512037		27	08.32		164	57.69							091		C/C	
0400	3219	512977		27	08.35		165	04.12								13.2		
0440	3520	515116		27	08.18		165	14.00										
0500	3583	514388		27	08.05		165	18.48								13.0		
0530	3490	515255		27	07.89		165	25.49										Wiens on watch
0600	3413	514384		27	07.58		165	33.86										

SIO UNDERWAY WATCH LOG	CRUISE: West 06 LEG:	SHIP: Melville	CHECK OPERATIONS	PAGE 5
	DATE (DAY, MO, YR): 2-9-94	TIME ZONE (SHIP): +11	12 KHZ | 3.5 KHZ | SEIS. PROF | MAG. | GRAV.	

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	LATITUDE MIN.	N S	LONGITUDE DEG.	LONGITUDE MIN.	E W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE
				TYPE	ELPS.		ELEV.	AZM.					
0630	3575	5131000	0637	27	07.23		165	42.04			90	13.0	
0700	2567	5711289		27	06.88		165	49.17		0705	91		c/c
0730	3569	5110589	0730	27	08.91		165	55.54					
0800	3581	5111579		27	06.99		166	02.26					
0830	3578	5109999	0830	27	07.07		166	09.55					
0900	3586	5090933		27	07.05		166	16.96					
0930	3582	5094943	0930	27	07.42		166	23.40					
1000	3570	5085616		27	08.14		166	32.0					
1030	3528	5076363	1030	27	08.39		166	38.57					
1100	3293	5109116		27	08.50		166	45.47					
1130	2890	5110009	1130	27	08.26		166	52.78					
1200	2033	5098484		27	07.77		166	00.50					
1230	1488	5082211	1230	27	08.53		167	06.57					
1300	615	5088313		27	08.54		167	13.24					
1330	0828	5094811	1330	27	09.8	S	167	21.7	E				
1400	0801	5084442		27	07.7		167	27.6		1420	096		c/c
1430	0792	5076484	1430	27	07.5	S	167	33.9	E				
1500	1164	5077111		27	07.3		167	43.3		1510	100		c/c
1530	1678	5069911	1530	27	06.9	S	167	47.9	E				
1600	2552	5060422		27	8.9		167	54.5		1629	081		c/c
1630	3229	5062828	1630	27	05.7	S	168	01.5	E				
1700	3811	5049999		27	04.1		168	08.5					
1730	3817	5054747	1730	27	02.4	S	168	15.3	E				
1800	3281	5075010		27	00.3		168	22.3					
1830	2749	5055774	RED	26	58.4	S	168	28.8	E				
1900	2999	5036011		26	56.8		168	36.4					
1930	2600	5035514	M30	26	55.2	S	168	42.7	E				
2000	2401	5063440		26	54.2		168	48.5					
2030	2276	5072663	2030	26	52.4	S	168	56.2	E				
2100	2519	5024877		26	50.88		169	03.46					
2134	3053	5021818	2134	26	48.51		169	10.68					
2200	3256	5018242		26	48.53		169	16.12					
2230	3611	5014111	2230	26	47.13		169	22.86					
2300	3058	5010909		26	45.78		169	29.28					
2330	2397	5008111		26	44.58		169	36.11					
0000	3816	5004742		26	42.96		169	43.00					

COMMENTS AND OBSERVATIONS

Wiens watchstanding

rough sea

Kimberly on Watch

Navigation Bad: satellite removed

Peter Hilton

2323 increased ping power from 0 → 3 db

2345 XBT deployment. Good one.

SIO UNDERWAY WATCH LOG | CRUISE: WESTWARD | LEG: 06 | SHIP: MELVILLE | CHECK OPERATIONS | PAGE 6

DATE (DAY, MO, YR): 3/9/94 | TIME ZONE (SHIP): +11 | 12KHZ | 3.5KHZ | SEIS. PROF | MAG. | GRAV.

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	LATITUDE MIN.	N/S	LONGITUDE DEG.	LONGITUDE MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE	COMMENTS AND OBSERVATIONS (ON CSE ___ @ ___ KTS.)
				TYPE	ELPS.		ELEV.	AZM.						
0030	3588	4978	0030	26	41.33		169	48.42						Entered sound vel profile #2, 00:44 GMT
0100	2949	4996		26	39.67		169	56.46						
0130	3557	4996	0130	26	38.10		170	03.30						
0200	3756	4983		26	36.69		170	09.65				12.5		
0230	4014	4988	0230	26	35.11		170	16.25						
0300	4002	4979		26	33.48		170	23.04		0259	081		c/c	
0332	3863	4970		26	31.88		170	30.48						
0404	4063	4962		26	30.42		170	37.71						
0430	4057	4954		26	29.12		170	43.54						
0500	4080	4954		26	27.86		170	50.15				12.0		
0530	4055	4951		26	26.65		170	56.55		0545	071		c/c	
0600	3340	4952		26	24.42		171	06.69						
0630	3495	4924		26	23.68		171	09.89				12.6		
0700	3826	4952		26	21.94		171	17.33						
0730	3915	4938		26	20.57		171	22.91						
0800	3904	4942		26	19.01		171	29.37						
0830	4051	4927		26	17.61		171	35.09						Changed Calcomp plotter contour interval to 50m
0900	3[illegible]30	4925		26	16.11		171	40.64						
0930	2435	4921		26	14.07		171	48.30						
1000	3240	4925		26	12.53		171	55.04						
1035	3869	4934		26	11.18		171	02.40						
1100	4030	4927		26	10.12		172	07.75						
1130	4064	4923		26	08.93		172	13.41						
1200	3972	4905		26	07.42		172	20.47						
1230	3968	4896		26	05.79		172	27.82						
1300	3953	4891		26	04.1		172	33.5						Kimberly on Watch
1330	4021	4889	1330	26	02.8	S	172	40.3	E					
1400	4239	4891		26	01.7		172	46.3						
1430	4440	4893	1430	26	00.1	S	172	53.5	E					
1500	4392	4891		25	58.3		173	00.6		1523	081		c/c	
1530	4523	4892	1530	25	56.3	S	173	07.9	E					
1600	4323	4897		25	54.8		173	14.6		1601	071		c/c	
1630	4376	4892	1630	25	52.2	S	173	21.4	E	1625	073		c/c	
1700	4224	4898		25	49.7		173	26.2						
1730	4487	4897	1730	25	47.4	S	173	35.1	E					
1800	4240	4659		25	45.2		173	41.1						

SIO UNDERWAY WATCH LOG | CRUISE: Westward | LEG: 06 | SHIP: R/V Melville | CHECK OPERATIONS | PAGE 7

DATE (DAY, MO, YR): 03-09-94 | TIME ZONE (SHIP): +11 | 12 KHZ | / 3.5 KHZ | SEIS. PROF. | MAG. | / GRAV. /

TIME GMT	DEPTH FM ☐ MT ☑	MAGNETICS	TIME	LATITUDE DEG	MIN.	N/S	LONGITUDE DEG.	MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE
				TYPE	ELPS.		ELEV.	AZM.					
1830	4395	4872	1830	25	43.0	S	173	49.9	E				
1900	4360	4863		25	40.7		173	55.6					
1930	4597	4840	1930	25	38.2	S	174	02.0	E				
2000	4654	4837		25	35.6		174	09.3					
2030	4556	4829	0030	25	32.6	S	174	15.4	E				
2100	4606	4820		25	30.01		174	21.84					
2130	4627	4816		25	27.04		174	28.47					
2200	4615	4808		25	24.20		174	34.71					
2230	4609	4804		25	21.52		174	40.93					
2300	4580	4802		25	18.96		174	47.70					
2330	4565	4807		25	16.63		174	54.03				12.0	
4/9/94 0000	4625	4799		25	14.22		175	00.41					
0030	4611	4803		25	11.60		175	07.02				12.2	
0100	4615	4806		25	09.49		175	13.11		0051	070		c/c
0130	4590	4803		25	06.98		175	20.46		0121	063		c/c
										0149			
0200	4623	4792		25	03.97		175	27.00				12.4	
0230	4563	4781		25	01.00		175	33.56					
0300	4484	4784		24	58.19		175	40.22				12.2	
0332	4556	4767		24	55.48		175	47.13					
0400	4337	4753		24	52.20		175	52.76		0403	070	12.5	c/c
0430	4565	4766		24	50.52		175	59.68					
0500	4405	4754		24	48.12		176	05.98					
0530	4109	4748		24	45.81		176	12.51					
0600	4297	4746		24	43.36		176	19.57		0627	055		c/c
0700	4469	4737		24	37.26		176	31.29					
0730	4476	4721		24	33.73		176	36.29		0752	057		c/c
0800	4458	4727		24	29.68		176	41.88					
0830	4446	4719		24	26.05		176	47.16					
0900	4422	4712		24	22.39		176	52.18					
0930	4423	4723		24	18.96		176	58.71					
1030	4429	4689		24	10.66		176	12.32					
1100	4404	4684		24	07.45		177	17.51					
1130	4389	4695		24	04.31		177	22.46					
1200	4391	4691		24	00.94		177	27.76					
1230	4342	4666		23	57.01		177	33.99					

(ON CSE 077 @ 13 KTS.)

COMMENTS AND OBSERVATIONS

K. on Watch

Peter on watch

Entered XBT #3 velocity profile

Wiens on watch

SIO UNDERWAY WATCH LOG | CRUISE: West 06 LEG: | SHIP: R/V Melville | CHECK OPERATIONS | PAGE 8

DATE (DAY, MO, YR): 4-09-94 | TIME ZONE (SHIP): +11 | 12KHZ | 3.5KHZ | SEIS. PROF. | MAG. | GRAV.

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	LATITUDE MIN.	N/S	LONGITUDE DEG.	LONGITUDE MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE	COMMENTS AND OBSERVATIONS (ON CSE 50 @ 12.5 KTS.)
				TYPE	ELPS.		ELEV.	AZM.						Kimberly on Watch
1300	4349	4660	1300	23	42.1	S	177	50.1	E					
1400	4097	4652		23	46.2		177	50.6						
1430	4065	4647	1400	23	42.4	S	177	56.4	E					
1500	4073	4641		23	39.2		178	00.9						
1530	4010	4650	1500	23	35.7	S	178	06.6	E					
1600	3950	4628		23	32.4		178	12.19						
1630	3911	4629	1600	23	28.7	S	178	18.3	E					
1730	3942	4617		23	20.7		178	25.4						
1800	3746	4610	1800	23	18.8	S	178	33.7	E					
1830	3720	4591		23	15.0		178	39.2						
1900	3622	4591	1900	23	11.4	S	178	44.2	E					
1980	3617	4605		23	07.4		178	49.7						
2000	3602	4599	2000	23	03.14		178	55.62						Peter on watch
2030	3551	4587		22	59.54		179	00.95						
2100	3481	4572	2100	22	55.91		179	06.73						
2130	3466	4564		22	52.29		179	12.27						
2200	3502	4552	2200	22	49.01		179	17.81						2228 EPC ROLL #1 off
2230	3445	4565		22	45.65		179	23.61						2248 EPC ROLL #2 on
2300	3420	4570	2300	22	42.44		179	29.11						
2330	2673	4561		22	38.99		179	34.24						
5/9/94 0000	2601	4554	0000	22	35.20		179	39.94						
0030	3168	4550		22	31.86		179	45.15						
0100	3266	4545	0100	22	28.14		179	50.72				12.7		
0130	3094	4544		22	24.72		179	55.77						0135 XBT #4 deployed
0200	3054	4552	0200	22	21.17		179	58.76						
0230	2826	4543		22	16.98		179	52.65						0235 XBT #4 vel. profile entered
0300	2650	4514	0300	22	13.60		179	46.97						
0330	2120	4512		22	10.16		179	41.49			052		c/c	
										0359		4	c/s	Pulling in mag. prior to deploying OBS #1
0400	1888	—		22	06.46		179	36.20						deploying OBS #1 Peters on watch
0430	1855	—		22	04.49		179	32.57						0436: 1885m 2204.63 17933.502 OBS #1
0500	1954	—		22	05.15		179	33.75						0442 Seabeam off
0600		—		22	07.04		179	34.45						going back to OBS site
0630		—		22	07.21		179	34.49						begin logging acoustic replies from OBS #1
0700		—		22	05.35		179	33.73						
0730		—		22	04.19		179	34.31						

SIO UNDERWAY WATCH LOG | CRUISE: West 06 | LEG: | SHIP: R/V Melville | CHECK OPERATIONS | PAGE 9

DATE (DAY, MO, YR): 5-9-94 | TIME ZONE (SHIP): +12 | 12KHZ | 3.5KHZ | SEIS. PROF. | MAG. | GRAV.

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	LATITUDE MIN.	N/S	LONGITUDE DEG.	LONGITUDE MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE
				TYPE	ELPS.		ELEV.	AZM.					
0800	1862	4510	0800	22	06.46	S	179	32.75	W		070	11.5	c/c
0830	1926	4501		22	03.13		179	27.55					
0900	1827	4503	0900	22	01.84	S	179	21.80	W				
0930	1774	4491		22	00.75		179	16.00					
1000	1656	4496	1000	21	59.22	S	179	09.43	W				
1040	1447	4488		21	58.18		179	01.19					
1100	1320	4481	1100	21	55.74	S	178	57.87	W				
1130	0789	4481		21	54.66		178	52.55					
1200	0590	4476	1200	21	53.38	S	178	46.67	W				
1230	1072	4465		21	51.9		178	40.8					
1300	0831	4483	1300	21	50.4	S	178	34.7	W				
1330	1385	4465		21	48.8		178	28.7					
1400	0917	4453	1400	21	47.3	S	178	23.1	W				
1430	1972	4458		21	45.7		178	17.3		1430	082		c/c
1500	2068	4470	1500	21	44.4	S	178	11.5	W				
1530	2620	4437		21	40.8		178	53.7					
1700	2367	4435	1700	21	38.9	S	177	46.6	W				
1730	2437	4438		21	38.1		177	42.3					
1800	2119	4429	1800	21	37.0	S	177	36.5	W				
1830	2416	4403		21	35.6		177	30.7					
2005	2476	4426	2005	21	30.88		177	11.30					
2030	2396	4423		21	29.56		177	06.00					
2100	1926	4404	2100	21	27.91		176	59.80					
2130	1703	4399		21	26.38		176	53.26					
2200	1717	4414	2200	21	24.39		176	46.79		Reducing to 4 kts			
										2215	270		c/c
2233	1724			21	24.03		176	46.05					
2300	1687			21	24.08		176	45.37					
2330	[illegible]			21	24.05		176	44.65					
6/9/94 0000	[illegible]	4411	0000	21	24.07		176	46.25					
										0013	135		c/c
0030				21	24.86		176	46.41		0053		0	
0100	1752			21	23.35		176	45.61		0057			
		4406								0112			

(ON CSE ⓪ KTS.)

COMMENTS AND OBSERVATIONS

0759 - Seabeam on - depart for site #2

Kimberly Williams

Peter on watch

2201 Mag. off approaching OBS #2 site

2213 Mag. on board

2238 OBS #2 dropped released (1038 local)

2359 Mag. back on

0024 Mag. back in (aboard) to disable OBS

Hydrophone over side

Sea Beam back on

Mag recording again.

SIO UNDERWAY WATCH LOG | CRUISE: WEST06 | LEG: | SHIP: | CHECK OPERATIONS | PAGE 10

DATE (DAY, MO, YR): 6-9-84 | TIME ZONE (SHIP): +12 | 12KHZ | 3.5KHZ | SEIS. PROF | MAG. | GRAV.

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	LATITUDE MIN.	N/S	LONGITUDE DEG.	LONGITUDE MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE	(ON CSE ___ @ ___ KTS.) COMMENTS AND OBSERVATIONS
				TYPE	ELPS.		ELEV.	AZM.						
0130	20377	43902	0130	21	23.24	S	176	39.85	W					
0200	24771	44044		21	23.27		176	33.73						
0230	23571	44035	0230	21	23.33		176	27.43				11.9		
0301	22599	44025		21	23.31		176	20.80		0316	326		c/c	176° 22.8' highly reflective ridge
0330	24499	43911	0330	21	21.08		176	18.88						
0400	23331	43913		21	16.18		176	22.43						Wiens on watch
0430	23422	43926		21	11.61		176	25.84						crossed ridge again at 176° 21'
0500	21113	43883		21	07.38		176	28.91						
0535	21163	43958												
0600	20972	43868		20	57.82		176	35.96						
0630	23225	43780		20	53.75		176	39.14						
0700	26888	43810		20	48.15		176	43.11						
0723											328		c/c	
0730	26033	43491		20	44.69		176	46.32						
0800	22936	43424		20	41.12		176	48.96						
0830	22933	43469		20	34.84		176	53.24						
0900	23466	43385		20	30.42		176	55.96						
0930	27366	43554		20	25.47		176	59.92						
1000	28220	43429		20	20.13		178	03.72						
1030	32551	43253		20	15.92		177	06.22						
1100	28566	43862		20	12.23		177	08.79						
1130	28441	43282		20	06.82		177	12.69						
1200	25022	43219	1200	20	02.4	S	177	15.6	W					Kimberly on watch
1232	28827	——		19	57.8		177	16.6						mag in for station #3
1300	28440	——	1300	19	57.0	S	177	19.7	W					on station
1530	25114	43269		19	57.1		177	13.6						1520 underway
1600	24421	43386	1600	19	57.2	S	177	10.2	W					
1630	20977	43397		19	57.1		177	03.1						
1700	27044	43314	1700	19	57.5	S	176	57.0	W					
1730	27471	43823		19	57.8		176	50.7						
1800	24880	42977	1800	19	57.6	S	176	43.8	W					
1830	22504	42966		19	57.3		176	32.3						
1900	20773	43097	1900	19	56.78		176	31.93						(1900 Z ≡ 0800 hrs local) Peter on watch
1930	22441	43004		19	56.31		176	25.26						
2000	20699	43209	2000	19	56.23		176	19.80						
2100	26561	42919		19	56.22		176	07.47						

SIO UNDERWAY WATCH LOG | CRUISE: WESTWARD LEG: 06 | SHIP: MELVILLE | CHECK OPERATIONS | PAGE 11

DATE (DAY, MO, YR): 6-9-94 | TIME ZONE (SHIP): | 12KHZ | 3.5KHZ | SEIS. PROF. | MAG. | GRAV.

TIME GMT	DEPTH FM ☐ MT ☒	MAGNETICS	TIME	LATITUDE DEG	LATITUDE MIN.	N/S	LONGITUDE DEG.	LONGITUDE MIN.	E/W	COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE	COMMENTS AND OBSERVATIONS (ON CSE ___ @ ___ KTS.)
				TYPE	ELPS.		ELEV.	AZM.						
2130	2655	42904	2130	19	56.36		176	01.53						
2203	2446	43019		19	56.82		176	54.80						
2230	2398	43157	2230	19	57.00		175	49.74				11.0		
2304	2394	4		19	56.76		175	48.98		2250		4	c/s	Mag aboard at 2255 XBT #5 launched
														OBS #4 deployment at site at 2311 same time
2330	2395			19	57.00		175	49.21				0		OBS #4 released at 2339 19°56.886's 175°49.174 W
7/9/94 0000	2399			19	57.00		175	49.18						On station at 2398m
														OBS #8 deployment at site 0010 at
														2399m 19-57.5, 175-49 W
0033				19	57.00		175	49.16						
0056				19	57.00		175	49.19		0056	270	6	c/s	
0130				19	55.82		175	49.24			45	6		
										0225	015	6		Mag. going out On and running at 0233
														Sea Beam on at 0230
0236	2480	43107		19	56.27		175	48.45						0242 Entered sound velocity profile from XBT cast
0300	2379	42927		19	57.80		175	53.08		0250	247	11.5	c/c	
0330	2580	42974		20	00.03		175	58.36		0346	244		c/c	
0400	2645	43163		20	01.9		176	03.46						
0500	2592	43122		20	07.22		176	11.60						
0530	2613	43264		20	09.87		176	18.44		0559	247		c/c	
0610	2010	43515		20	12.15		176	25.28						
0630	2348	42951		20	13.96		176	29.45						
0710	2367	43365		20	16.94		176	36.44						
0730	2576	43405		20	18.35		176	40.54						
0800	2633	43444		20	20.13		176	45.42						
0830	2350	43351		20	21.98		176	51.15						
0900	2666	43237		20	23.87		176	56.15		0925	110	11.2	c/c	
0930	2842	43651		20	27.16		176	59.68						
1030	2476	43351		20	28.82		176	48.13						
1100	2794	43453	1100	20	29.8	S	176	42.6	W					
1130	2458	43346		20	30.8		176	37.3						
1200	2170	43527	1200	20	32.3	S	176	32.6	W					
1230	2192	43385		20	33.3		176	25.6						
1300	2306	43528	1300	20	34.7	S	176	19.4	W					
1330	2596	43398		20	36.7		176	12.9						

SIO UNDERWAY WATCH LOG

CRUISE: Westward LEG: 06

DATE (DAY, MO, YR):

SHIP: R/V Melville

TIME ZONE (SHIP): +13

CHECK OPERATIONS PAGE 12

12 KHZ | 3.5 KHZ ✓ | SEIS. PROF. | MAG ✓ | GRAV. ✓

(ON CSE 110 @ 12.7 KTS.)

TIME GMT	DEPTH FM ☐ MT ☑	MAGNETICS	TIME	LATITUDE DEG	LATITUDE MIN.	N/S	LONGITUDE DEG.	LONGITUDE MIN.	E/W	TYPE	ELPS.	ELEV.	AZM.
1400	25119	434909	1400	20	38.8	S	176	04.3	W				
1420	24620	432119		20	41.6		176	01.2					
1500	23663	430788	1500	20	43.6	S	175	52.7	W				
1530	23602	434599		20	45.6		175	47.6					
1600	17105	434499	1600	20	47.3	S	175	41.9	W				
1630	15443	433288		20	49.1		175	34.8					
1700	18599	433992	1700	20	50.7	S	175	28.1	W				
1730	78885	—		20	52.1		175	23.6					
1800	14556	—	1800	20	53.6	S	175	18.5	W				
1830	09862	—		20	55.7		175	14.3					

COURSE/SPEED CHANGES TIME	CSE GYRO	SPD. KNOT	CODE
1416	113		C/C

COMMENTS AND OBSERVATIONS

Mag roll #1 end at 1708