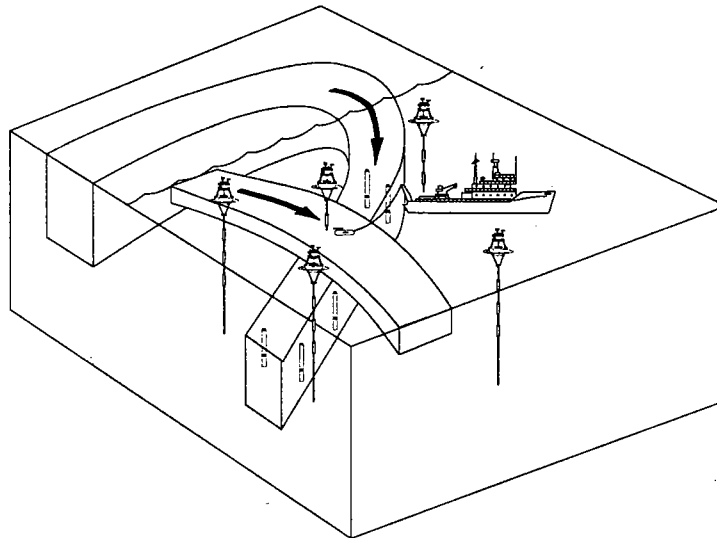




The Subduction Experiment



Cruise Report

R/V *Oceanus*

Cruise Number 250 Legs 1 and 2

Subduction 2 Mooring Deployment and Recovery Cruise

25 January – 26 February 1992

by

Richard P. Trask

Nancy J. Brink

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Neil McPhee

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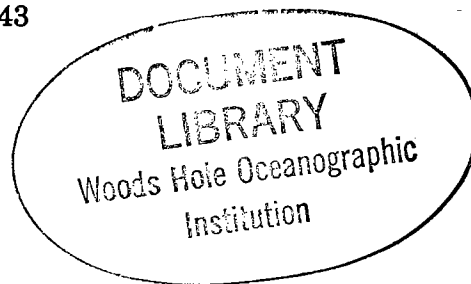
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Woods Hole, Massachusetts 02543**

March 1993

Technical Report

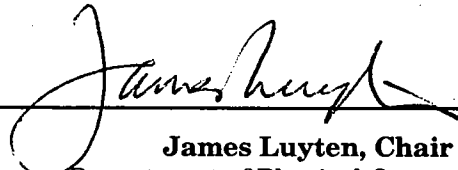


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Department of Physical Oceanography

Abstract

Subduction is the mechanism by which water masses formed in the mixed layer and near the surface of the ocean find their way into the upper thermocline. The subduction process and its underlying mechanisms were studied through a combination of Eulerian and Lagrangian measurements of velocity, measurements of tracer distributions and hydrographic properties and modeling.

An array of five surface moorings carrying meteorological and oceanographic instrumentation were deployed for a period of two years beginning in June 1991 as part of an Office of Naval Research (ONR) funded Subduction experiment. Three eight month deployments were planned. The moorings were deployed at 18°N 34°W, 18°N 22°W, 25.5°N 29°W, 33°N 22°W and 33°N 34°W.

A Vector Averaging Wind Recorder (VAWR) and an Improved Meteorological Recorder (IMET) collected wind speed and wind direction, sea surface temperature, air temperature, short wave radiation, barometric pressure and relative humidity. The IMET also measured precipitation. The moorings were heavily instrumented below the surface with Vector Measuring Current Meters (VMCM) and single point temperature recorders.

Expendable bathythermograph (XBT) data were collected and meteorological observations were made while transiting between mooring locations.

This report describes the work that took place during R/V Oceanus cruise number 250 which was the second scheduled Subduction mooring cruise. During this cruise the first setting of the moorings were recovered and redeployed for a second eight month period. This report includes a description of the instrumentation that was deployed and recovered, has information about the underway measurements (XBT and meteorological observations) that were made including plots of the data and presents a chronology of the cruise events.

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Section 1: Introduction

R/V Oceanus cruise number 250, Leg 1 departed Woods Hole, Massachusetts, on 25 January 1992 to recover and redeploy five surface moorings as part of the Office of Naval Research (ONR) funded ASTEX and Subduction Experiments. This cruise involved personnel and equipment from both the Woods Hole Oceanographic Institution (WHOI) and Scripps Institution of Oceanography (SIO). Appendix 1 lists the cruise participants.

The first setting of Subduction moorings were deployed in June/July 1991 during Oceanus cruise number 240 (see Trask and Brink, 1993 for details). The first setting has been referred to as Subduction 1. The Subduction 1 moorings were recovered and replaced with 5 new surface moorings during Oceanus cruise 250. The deployment schedule for the entire experiment is shown below (figure 1). Table 1 lists the Subduction 1 mooring positions and the dates they were deployed and recovered. Table 2 lists the deployment positions and dates for the second setting (aka Subduction 2). In addition to the initial deployment and first turnaround cruise a second turnaround cruise in October 92 and the final recovery cruise in June 93 are shown.

This report has in addition to this introduction two other sections. The second section describes the mooring program including the instrumentation that was deployed and recovered, as well as the underway measurements that were made including the XBT and meteorological observations. The third section is a chronology of the entire cruise.

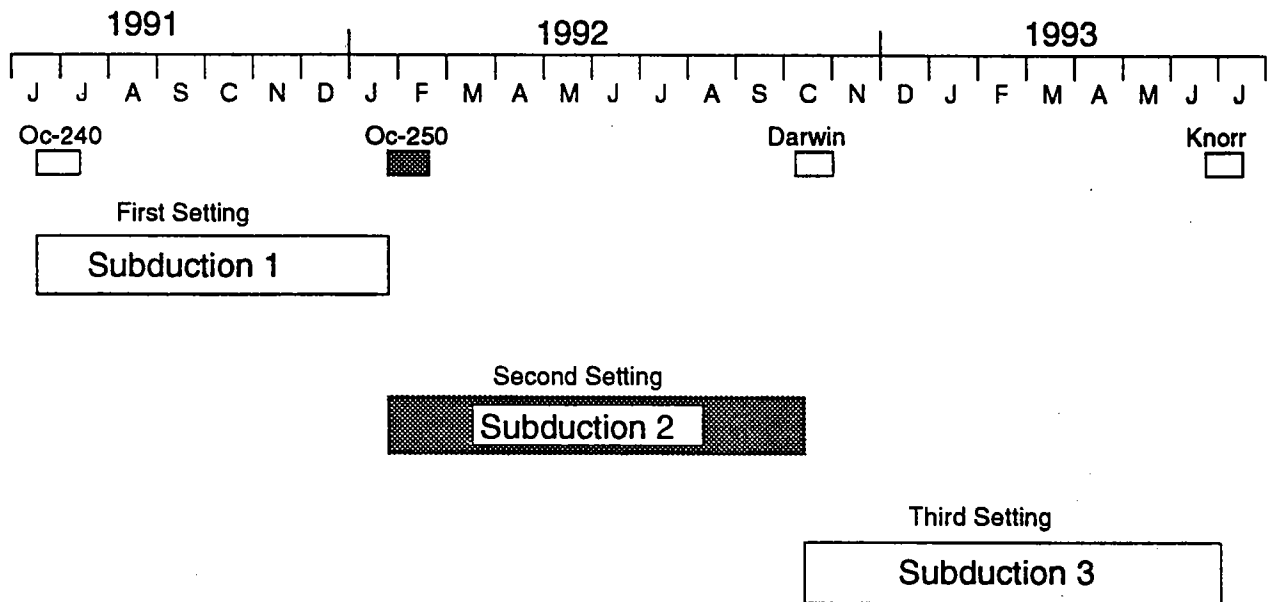


Figure 1. Mooring and Cruise Schedule

**Table 1. Subduction 1
Mooring Deployment and Recovery Information**

Buoy	Mooring #	Deployment Time (UTC)	Recovery Time (UTC)	Position (GPS)
NE	914	18 Jun 1991 1642	14 Feb 1992 2315	33° 00.07'N 21° 59.75'W
C	915	23 Jun 1991 0026	11 Feb 1992 1120	25° 31.90'N 28° 57.17'W
SW	916	25 Jun 1991 1312	2 Feb 1992 0727 4 Feb 1992 1844 *	18° 00.03'N 33° 59.96'W
SE	917	29 Jun 1991 0137	30 Oct 1991 0000 8 Feb 1992 0843**	18° 00.13'N 22° 00.00'W
NW	918	3 Jul 1991 1323	15 Sept 1991 2035 23 Feb 1992 1022***	32° 54.61'N 33° 53.50'W

* SW Mooring broke free on 3 November 1991. Top 110m recovered 2 February 1992
remainder of mooring recovered 4 February 1992.

** SE Mooring broke free on 10 October 1991. Top 50m recovered on 30 October 1991
remainder of mooring recovered 8 February 1992

*** NW Mooring broke free on 3 August 1991. Top 400m recovered 15 September 1991
remainder of mooring recovered 23 February 1992

**Table 2. Subduction 2
Mooring Deployment Information**

Buoy	Mooring Number	Deployment Time (UTC)	Position (GPS)
SW	924	05 Feb 1992 1318	17°59.93'N 34°00.65'W
SE	925	09 Feb 1992 0244	17°59.72'W 22°00.29'W
C	926	12 Feb 1992 1915	25°31.95'N 28°57.23'W
NE	927	20 Feb 1992 1547	33°01.98'N 22°00.27'W
NW	928	23 Feb 1992 2328	32°54.42'N 33°53.35'W

Section 2: The Mooring Program

A. Moorings and Buoys

The goal of the mooring program conducted during Oceanus cruise number 250 (Oc-250) was to recover five moorings that were deployed during Oceanus cruise 240 leg 3 in June/July of 1991, and deploy replacement moorings. The five surface moorings deployed in 1991 included two WHOI discus buoy moorings designated the Northeast and Central moorings and three SIO toroid buoy moorings designated Southwest, Southeast and Northwest. The names of the moorings denote their relative placement in the moored array. Figure 2 shows the location of the individual moorings.

In August 1991 the Northwest mooring parted and the toroid buoy and upper mooring components went adrift. The drifting buoy was subsequently recovered on 15 September during R/V Endeavor cruise number 228. Failure of the Southeast mooring occurred on 10 October 1991. The toroid buoy from this mooring was recovered by the Soviet Research Vessel Mendeleev on 30 October 1991. This was followed by the failure of the Southwest surface mooring which occurred on 3 November 1991. The first stop of Oceanus cruise 250 was to recover the toroid buoy from the Southwest mooring which had drifted 642 miles to the southwest. Appendix 2 describes the SIO mooring designs for Subduction 1 and details the improvements made for Subduction 2.

Since all three of the SIO moorings had failed during the first setting, major design changes were made before the second setting. In addition, the complement of surface buoys was changed such that four of the five moorings deployed during Oc-250 had a WHOI 10' diameter discus buoy as their primary flotation at the surface. The fifth mooring had a SIO 7'6" diameter toroid buoy (from the first setting) for its surface flotation. Additional buoyancy was provided to the toroid by means of a large boat fender that was inserted in the center hole of the toroid and inflated. Figure 3 schematically shows the five Subduction 1 moorings and the distribution of the subsurface instrumentation. Figure 4 shows the five Subduction 2 moorings and their distribution of instrumentation.

Meteorological instrumentation was mounted to both the toroid and discus buoys. A two part aluminum tower was attached to both buoy types. The top half, which had the meteorological sensors, marine lantern and satellite antennae was the same for both buoy types so as to minimize the differences between buoys and to facilitate assembly. The lower half was specific to the buoy type and acted as an interface between the buoy hull and the tower top. The tower tops were separate assemblies so that they could easily be replaced with new units containing freshly calibrated sensors when the moorings were recovered and redeployed.

The two additional discus buoys and one toroid buoy deployed during Oc-250 were prepared in Woods Hole and loaded on Oceanus. These buoys serviced the first three moorings encountered. The toroid was used for the Southwest mooring and the discus' were used on the Southeast and Central moorings. The Central and Northeast discus' deployed in 1991 which were still on station were recovered and taken into Madeira where they were serviced and made ready for use on the Northeast and Northwest moorings. A port stop in Madeira was necessary because the ship could not carry all the equipment for the entire cruise due to deck space and weight limitations. Previous arrangements had been made to ship the equipment needed for the rest of the cruise to Madeira so that it was there when the Oceanus arrived.

Figure 2. Oceanus 250 ship track and mooring locations.

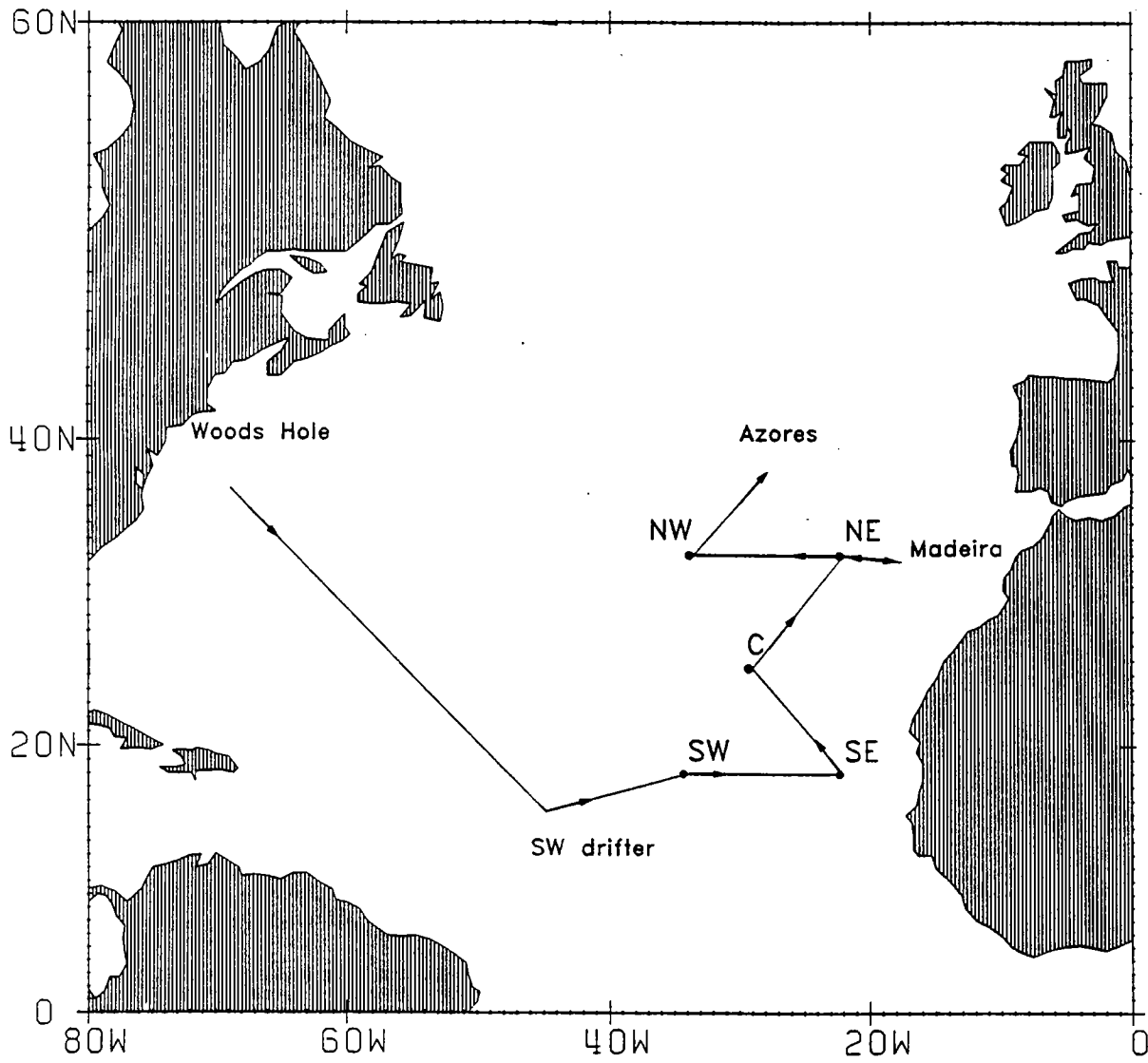


Figure 3. Instrument Positions on the Subduction 1 Moorings

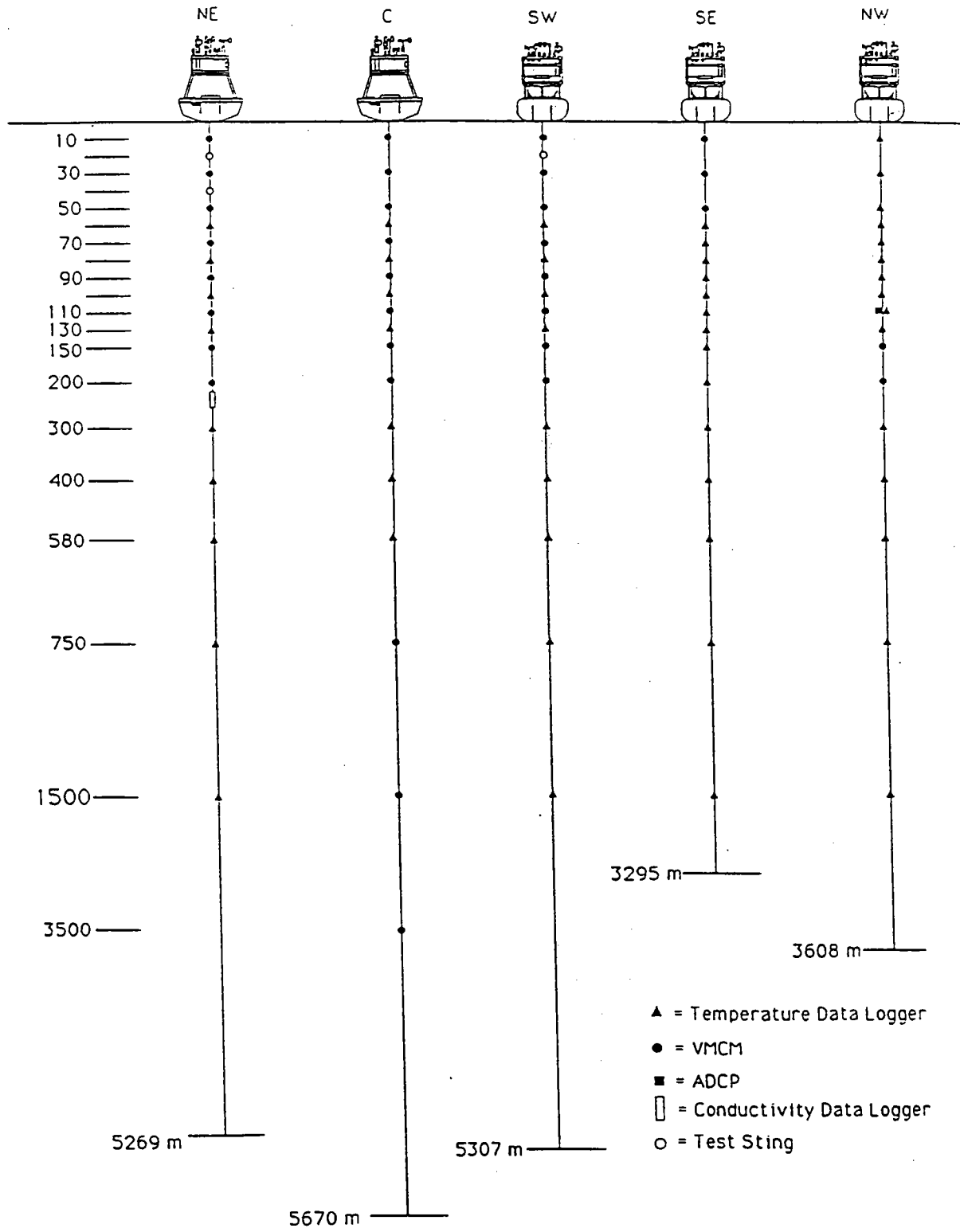
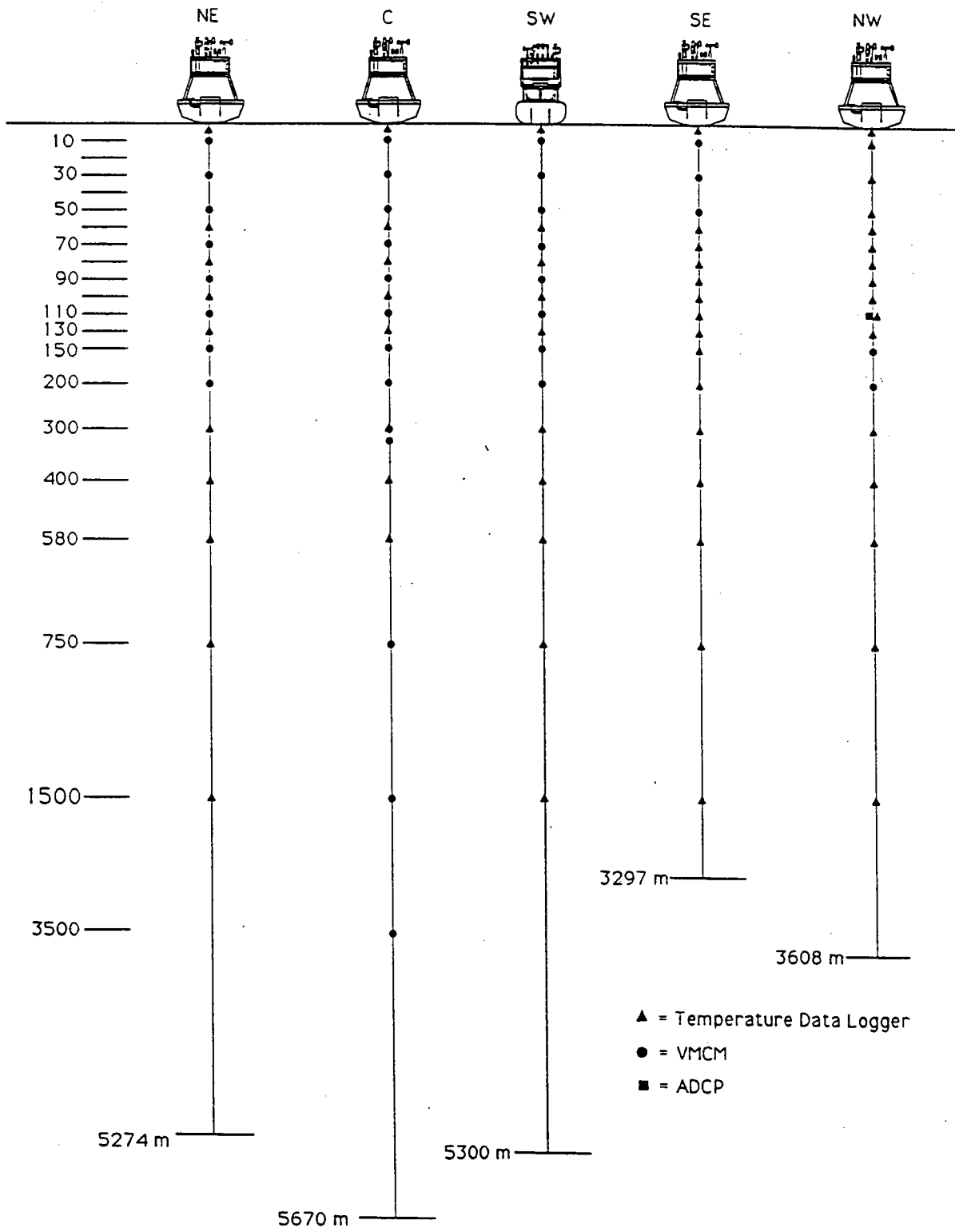


Figure 4. Instrument Positions on the Subduction 2 Moorings



B. Instrumentation

A total of 102 recording instruments were deployed on the five Subduction 2 moorings. There were 9 meteorological packages, 34 current meters, 58 temperature data loggers, and one Acoustic Doppler Current Profiler. The specific instrumentation deployed and recovered from the first Subduction setting is shown in table 3. The instrumentation on the second setting is shown in table 4.

Meteorological Instrumentation

Each discus buoy was outfitted with two separate meteorological instruments. One system was a Vector Averaging Wind Recorder (VAWR) which recorded measurements of wind speed and direction, air temperature, relative humidity, barometric pressure, sea surface temperature, shortwave radiation, and longwave radiation. Additional information about the VAWR can be found in Trask *et al.*, (1989). The other meteorological package was an IMET system which made measurements of the same variables as the VAWR plus precipitation. The IMET systems on the second Subduction deployment did not have longwave radiation sensors. Both the VAWR and IMET systems individually recorded all data internally as well as telemetered their data via Argos. The VAWR stored its data on cassette tape every 15 minutes and the IMET system recorded on optical disk every minute.

For both the discus and toroid buoys the VAWR sensors (except sea temperature) and electronics with battery pack were attached to the tower top. The sea surface temperature sensors for both the VAWR and IMET systems were attached to the buoy bridle approximately 1 meter below the surface. All other meteorological sensors were placed at the same heights on the tower tops as in Subduction 1 (see Trask and Brink, 1993). During the second Subduction setting the Southwest toroid did not have an IMET system. The IMET sensors on all the discus buoys were configured the same and mounted on the tower top. The IMET electronics and rechargeable batteries were housed in the discus buoy water tight instrument well.

Details regarding the IMET performance during the first setting can be found in Appendix 3.

Prior to deployment the air and sea temperature sensors as well as the relative humidity sensors were calibrated at WHOI. The calibrations of the barometric pressure sensors were checked and if found out of specification were returned to the manufacturer for recalibration. The shortwave and longwave radiation sensors were calibrated by the manufacturer. The wind direction sensor readings were compared with a known bearing to a fixed target. Details of the direction comparison tests can be found in Appendix 4.

Current Meters

A total of 34 Vector Measuring Current Meters (VMCM) provided by both WHOI and SIO were deployed on the five Subduction 2 surface moorings. The 22 WHOI VMCMs were a modified version of the EG&G Sea Link instrument whereas the 12 SIO VMCMs were built by Scripps personnel. The sampling interval of the WHOI VMCMs was 7.5 minutes, and for the SIO VMCMs it was 15 minutes.

The WHOI VMCMs incorporated several changes to the standard EG&G Sea Link product. These included different propeller bearings, a different plastic for the propeller blades, an external temperature pod for faster temperature response, and a redesigned the instrument cage. The cage redesign and external temperature pod is described in Trask *et al.*, (1989) as is some historical information on propeller bearings and blade materials.

**Table 3.
Subduction 1 Instrumentation**

Depth	NE	C	SW	SE	NW
VAWR IMET	V-704WR	V-722WR	V-720WR	V-721WR	V-121WR
10	VM-041	VM-035	SVM-04	SVM-12	S-3285
20	TEST STING1			TEST STING2	
30	VM-021	VM-033	SVM-07	VM-007	S-3315
40	TEST STING3				
50	VM-039	VM-024	SVM-06	SVM-16	S-3294
60	W-3274	W-3309	S-3314	W-3297	W-3262
70	VM-032	VM-012	SVM-22	S-3282	S-3313
80	W-3265	W-3308	W-3279	S-3270	S-3260
90	VM-022	VM-038	SVM-02	S-3298	S-3261
100	W-3288	W-3296	W-3303	S-3284	W-3258
110	VM-030	VM-009	SVM-05	S-2425	ADCP
130	W-3269	W-3280	S-2427	S-2432	S-3277 S-2434
150	VM-028	VM-037	SVM-20	S-2418	SVM-11
200	VM-018	VM-016	SVM-13	S-2424	SVM-10
206	COND				
300	W-3300	W-3289	S-2435	S-2433	S-2421
400	W-3305	W-3283	S-2437	S-2422	S-2431
580	W-3268	W-3271	W-3341	W-3290	W-3272
750	W-3286	VM-015	S-2436	S-2426	S-2420
1500 3490 3500	W-3293	VM-034 TENS 1029 VM-011	W-3287	W-3259	W-3273

W-# = WHOI Brancker Temperature Recorder
 S-# = SIO Brancker Temperature Recorder
 VM-# = WHOI Vector Measuring Current Meter
 SVM-# = SIO Vector Measuring Current Meter

**Table 4.
Subduction 2 Instrumentation**

Depth	NE	C	SW	SE	NW
VAWR IMET	V-380WR	V-712WR	V-713WR	V-707WR	V-717WR
1	W-3507	W-3506	W-3665	W-3704	W-3508
10	VM-034	VM-002	SVM-01	SVM-03	S-3709
30	VM-027	VM-023	SVM-16	VM-010	W-3274
50	VM-036	VM-020	SVM-08	SVM-17	W-3288
60	W-2539	W-2541	S-3285	W-3279	W-3296
70	VM-014	VM-013	SVM-15	S-3707	W-3309
80	W-2542	W-2534	W-3263	S-3261	W-3269
90	VM-045	VM-019	SVM-14	S-3706	W-2536
100	W-3280	W-2537	W-3291	S-3714	W-2540
110	VM-035	VM-008	SVM-12	S-3710	ADCP-195 W-2535
130	W-3265	W-2538	S-3310	S-3294	S-3313
150	VM-009	VM-026	SVM-11	S-3715	SVM-09
200	VM-011	VM-025	SVM-18	S-3708	SVM-21
300	S-3260	VM-017	S-3713	S-3712	S-3276
310		VM-031			
400	S-3711	W-2533	S-2430	S-2423	S-3277
580	S-3298	W-3262	W-3299	W-3303	S-3316
750	S-2426	VM-029	S-2429	S-2434	S-3282
1500	S-2427	VM-001	W-3258	W-3341	S-3284
3500		VM-003			

W-# = WHOI Brancker Temperature Recorder
 S-# = SIO Brancker Temperature Recorder
 VM-# = WHOI Vector Measuring Current Meter
 SVM-# = SIO Vector Measuring Current Meter

For the Subduction experiment the WHOI VMCMs in the upper 100 meters were outfitted with cages that had 3/4" cage rods. The deeper instruments had cages with 1/2" cage rods. All cages had a single cross brace to support the sting between the two sets of propellers.

An alternative propeller bearing chosen for use in the Subduction experiment was an all silicon nitride ball bearing (SiNi balls and races with a Duroid ball retainer) available from Miniature Precision Bearing (MPB), of Keene, New Hampshire, as part number J0001-809. This was selected over the typical stainless steel bearing based on previous test results, actual deployments and the fact that the eight month Subduction deployment would be 30% longer than most previous deployments.

The same type of VMCM propellers used in the first setting of the Subduction experiment were used again for the second setting. They were made of an unpigmented Delrin 100 ST which is impact modified. See Trask and Brink (1993) for more details about the bearing and blade materials.

The Subduction 1 VMCMs that were recovered during Oc-250 were in excellent condition with respect to propeller bearings and blades. None of the propellers had broken blades and the silicon nitride bearings were like new. They were in such good condition after the first 8 month deployment that two of the four instruments (VM009 and VM011) that had to be turned around at sea and redeployed used their original stings that had previously been in the water for eight months during Subduction 1. The other two instruments (VM034 and VM035) that were turned around at sea had new stings installed.

The data tapes from seven WHOI VMCMs recovered from the first setting of the Central and Northeast moorings were impossible to read with the equipment aboard ship. The problem was related to a bad batch of certified data cassettes. The data tapes that could not be read had the same code printed on the cassette whereas the readable data tapes had different codes. Five of the seven instruments affected by the bad cassette tapes were on the Central Subduction 1 mooring. They were VM033 at 30 meters, VM038 at 90 meters, VM037 at 150 meters, VM016 at 200 meters and VM015 at 750 meters. The Northeast mooring had two instruments with bad cassettes; VM032 at 70 meters and VM030 at 110 meters. The details of this problem are described in the cruise chronology by mooring.

Temperature Loggers

A total of 58 temperature data loggers manufactured by Richard Brancker Research Ltd. were provided by both WHOI and SIO for the five Subduction moorings. The locations of the loggers are shown in figure 4 and table 4. The loggers provided by WHOI were attached to the mooring line using a hinge type clamp that was tightened around the wire. The SIO clamping arrangement consisted of two 2 piece monel blocks which had been machined to accept the mooring wire. The two pieces were clamped around the wire with .25" hardware.

Several different models were deployed. The SIO 2000 series instruments sampled at 30 minute intervals. The WHOI 2000 series instruments which were modified for extra memory sampled at 15 minutes, and both the SIO and WHOI 3000 series instruments sampled at 15 minutes. The SIO 2000 series instruments had SIO fabricated pressure cases and endcaps.

A total of 15 temperature loggers recovered during Oc-250 leaked a small quantity of water, and the data could not be read. In response to this problem while at sea the instruments that were deployed for the second setting had a vacuum drawn during assembly to better seat the O-rings. This procedure was adopted from SIO whose nearly identical temperature loggers did not display the problem as severely. In addition, the endcaps were tightened considerably more than previously deployed units using a large adjustable wrench. The performance of the temperature

loggers recovered from the first setting is described in the Section 3 of this report by mooring on which they were deployed.

ALACE Floats

A total of 11 SIO Autonomous LAgrangian Circulation Explorers were deployed during Oc-250. Details of those deployments can be found in Appendix 5 of this report.

C. Underway Measurements

Expendable Bathythermographs (XBT)

Three hundred XBTs were deployed during Oc-250. The T-7 probes were purchased from Spartan of Canada. XBT data was logged on a NEC APC IV which had a Spartan data acquisition microprocessor card installed. The digital data was simultaneously logged in memory and plotted on the screen. In all there were very few probes that failed to produce reasonable data.

R/V Oceanus transited from Woods Hole to the drifting Southwest buoy before reaching the Subduction site, during this time XBTs were dropped every four hours. Following the deployment of the Southwest mooring XBTs were made hourly. The details of the XBTs can be found in Appendix 6.

Meteorological Observations

From the time the ship left Woods Hole meteorological data from a shipboard IMET system mounted on the bow mast were recorded on optical disk. The IMET sensors included wind speed and direction, seawater temperature (made in the seawater intake of the main engine), barometric pressure, air temperature, relative humidity, precipitation and shortwave radiation. Minute data was logged to a dedicated PC with optical disk. The data was also displayed on the PC monitor.

Manual meteorological observations were also taken hourly on the hour. The manual observations consisted of recording the time, GPS position, ship's speed, ship's heading, wind speed and wind direction from the bridge readout, barometric pressure from the bridge, wet and dry bulb temperatures from a Bendix psychrometer, sea surface temperature from a bucket thermometer, cloud type, and visual cloud cover estimates. Relative humidity was computed using a conversion program on the MacIntosh computer. In addition the corresponding ship mounted IMET data displayed on the PC monitor were also recorded by hand. Information on the shipboard IMET system and a comparison of the data collected with the manual observations is presented in Appendix 7.

Acoustic Doppler Current Profiler

Velocity and temperature data were collected by an Acoustic Doppler Current Profiler mounted in the hull. See Appendix 8 for a summary of the data files collected.

Section 3: Cruise Chronology

Oceanus cruise number 250 departed Woods Hole on Saturday, 25 January 1992 at 1130 UTC. The purpose of the cruise was to recover and redeploy an array of five surface moorings deployed in June/July 1991 as part of the ONR funded ASTEX and Subduction Experiment. This was the second of four scheduled mooring cruises planned for this experiment. Details of the cruise are described below by mooring. For an abridged version of the cruise chronology see Appendix 9.

Southwest Mooring

The Oceanus arrived at the drifting toroid buoy at 0515 UTC on Sunday, 2 February 1992 at position 15°13.09'N, 44°47.48'W. The buoy's marine lantern was first sighted at a distance of approximately 5 miles. After a brief opportunity for fishing the buoy and parted mooring were brought aboard. Figure 5 is a schematic of the mooring as it was deployed in June 1991. An XBT (#44) was taken while along side the buoy prior to recovery. A total of 6 SIO Vector Measuring Current Meters (VMCMs at 10m, 30m, 50m, 70m, 90m, and 110m), 2 WHOI Brancker temperature recorders (80m, 100m) and 1 SIO Brancker temperature recorder (60m) were recovered. The last item to be recovered was the 110 meter current meter which did not have a shackle in the bottom bale. The top bale of the 110 meter VMCM had a shackle and bolt but had lost its nut and cotter pin. The titanium pin in the lower bale of the 110 m VMCM was extremely worn. In addition to the load cage wear the VMCM sting (orthogonal propeller assembly) was missing from the instrument which caused the instrument to flood. Both WHOI Brancker temperature recorders (#3279 at 80 m and #3303 at 100 m) as well as the SIO Brancker (#3314 at 60 m) were opened and the data read without any problem. The VAWR meteorological package recorded data the entire time the buoy was on station but failed on 30 November 1991.

With the upper part of the mooring aboard the Oceanus got underway at 0730 UTC for the original Southwest mooring site at 18°00.03'N, 33°59.96'W. The ship arrived at the site on 4 February 1992 at 1152 UTC. Upon arriving at the site the location of the anchor was checked by ranging on the acoustic release from approximately 2 miles away. The range obtained confirmed the original anchor position obtained during the setting cruise in June/July 91. The ship was then positioned one-half mile down wind of the anchor position and the release was fired at 1235 UTC. Confirmation of release was not detected right away. A continual decrease in slant ranges indicated that the release was rising. Slant ranges to the release were monitored the entire time the mooring was coming to the surface. The ship continued to drift away from the site and had to be repositioned to the location where the release was fired several times. A set of 4 glass balls was sighted at 1332 UTC. One by one the clusters of 4 balls were spotted strung out in line with the wind direction. All but two clusters were sighted. The ship then cautiously proceeded parallel to the mooring until the large bottom cluster of 12 balls was spotted. Recovery of the bottom of the mooring was initiated at 1430 UTC. By 1843 UTC the entire parted mooring was on board. The uppermost part of the mooring was a cluster of 3 glass balls (one of the original four was missing and those remaining had cracked hardhat flanges), a shackle with master link and the top shackle with no bolt in place. The top shackle was originally attached to the bottom of the 110m VMCM that was recovered below the drifting buoy. The entire mooring was therefore recovered.

The lower part of the mooring contained 4 SIO Brancker Temperature Recorders (at 130m, 300m, 400m, 750m), 2 SIO VMCMs (at 150m and 200m) and 2 WHOI Brancker Temperature Loggers (at 580m and 1500m). WHOI temperature logger #3287 at 1500m and SIO temperature logger #2436 at 750m had several drops of water inside when the instruments were opened. The water appeared to have just entered the pressure case sometime during recovery since there was no indication of corrosion. The data however could not be read from these instruments. This

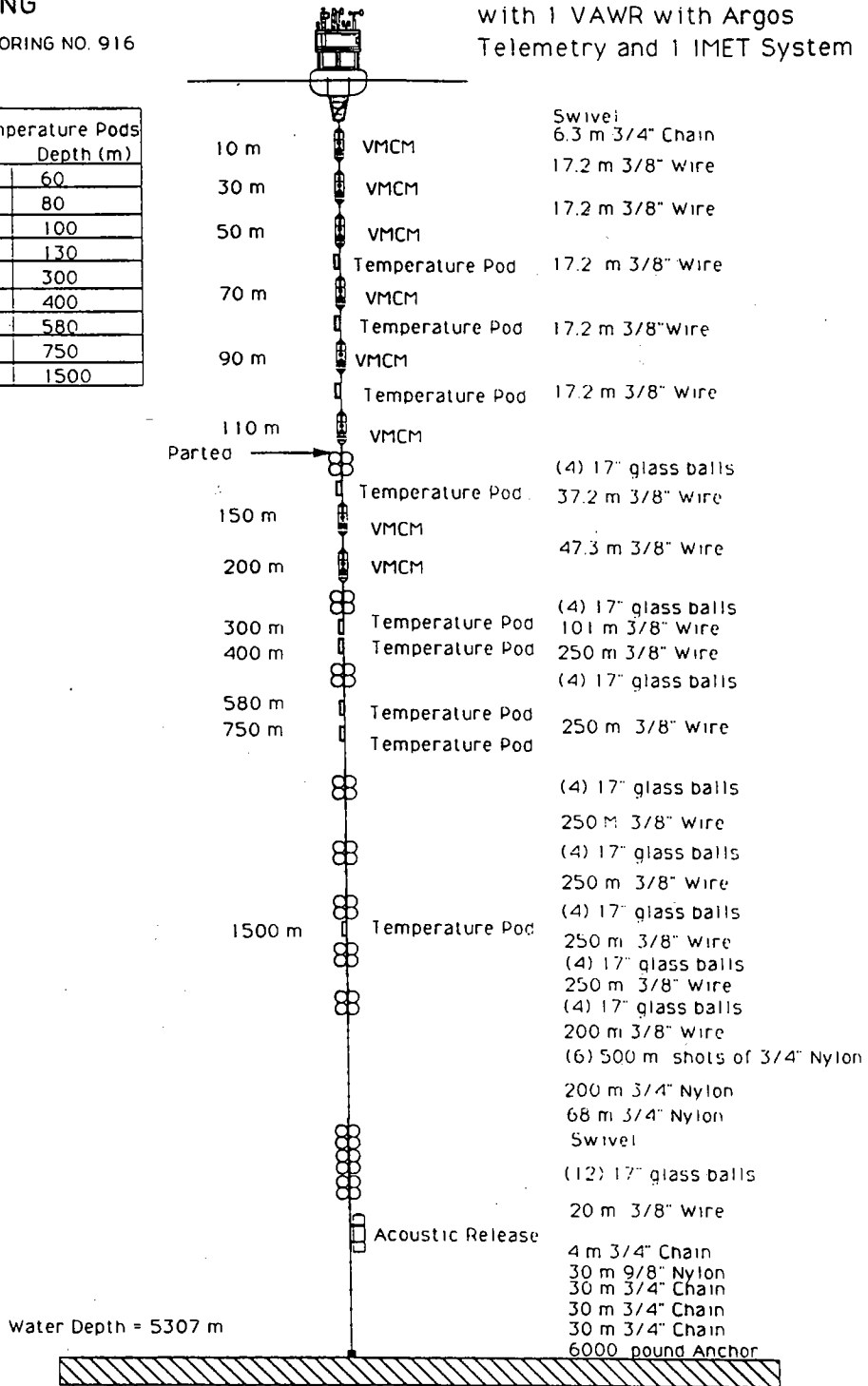
Figure 5. Subduction 1 Southwest Mooring Schematic

**SOUTHWEST SUBDUCTION
MOORING**

WHOI MOORING NO. 916

SIO Toroid Buoy
with 1 VAWR with Argos
Telemetry and 1 IMET System

Temperature Pods	
No	Depth (m)
1	60
2	80
3	100
4	130
5	300
6	400
7	580
8	750
9	1500



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particular SIO Brancker that leaked had an SIO fabricated pressure case and endcaps. Inspection of the pressure case face seals revealed markings in the anodizing. The same pressure case design as that used by Brancker was also used to fabricate the SIO pressure case. All SIO purge plugs were not the standard Brancker issue. SIO replaced the Brancker purge plug with one fabricated of Ertalyte (P.E.T.).

With the mooring aboard attention was turned to preparing for redeployment. The deck was cleared and off-spooling the wire on the winch was begun. Simultaneously three acoustic releases were wire tested using the CTD winch. Two SIO releases and one WHOI release were tested to a depth of 1000 meters. These operations were followed by rewinding the wire and nylon for the next mooring. The mooring schematic for the second setting of the Southwest mooring is shown in figure 6. Due to space limitations on the TSE winch drum only the upper 3200 meters of wire and nylon were wound on the winch. While the winding was taking place the ship was positioned 7 miles to the south southwest. This was downwind of the target and slightly south to compensate for a small northerly current.

The deployment of the upper instrumentation (10m and 30m VMCMs) and buoy (in that order) went quite smoothly. With the buoy in the water the ship initially had just enough way on to maintain steerage. As more instrumentation and wire were deployed the speed through the water was increased to .5 knot and then to 1.0 knot. Mid-way through the deployment the mooring was towed while 1800 meters of nylon and 500 meters of polypropylene were wound onto the winch. During towing the ship's speed was decreased to .7 knot due to an increase in the tension in the nylon. This speed was maintained as the remainder of the mooring was deployed.

With the reduction in the ship's speed, progress over the bottom was slower than expected. The mooring had been cut for deployment in water similar to the original water depth of 5307 meters. The plan was to continue to tow until the water depth was within 40 meters of the planned depth. Unfortunately during our approach the water was several hundred meters shallower than what was needed. Towing had to continue at a slow pace until the design depth was obtained. As the ship approached the original target the water depth increased for a sufficient distance to permit the deployment of the mooring. The anchor was deployed at 1318 UTC on 5 February 1992.

Following the anchor deployment the ship was repositioned to watch the toroid buoy ride through the water as the anchor went to the bottom. The toroid behaved considerably different during this deployment than it had in previous deployments in June/July 91. In comparison with the Subduction 1 toroid deployments the speed through the water was much less (.7 kt), the toroid was not heeled over as much, and it did not submerge.

Two hours of intense meteorological observations were made as the buoy settled into position. Meteorological observations were obtained by hand held and bridge mounted sensors and logged with the IMET data every 15 minutes. At the same time the VAWR Argos transmissions were received directly from the buoy via the Telonics receiver aboard ship. These data were compared at the end of the two hour period. All observations compared well. These observations are used as a final check of instrument performance before leaving the site.

An acoustic release survey followed. Three positions were selected approximately 2-3 miles away from the suspected anchor location. From each position a horizontal range to the release was obtained. Figure 7 shows the results of the survey which located the anchor of the Southwest mooring (WHOI Mooring number 924) at $17^{\circ}59.93'N$ and $34^{\circ}00.65'W$. Following the survey the acoustic release was disabled and confirmation obtained. The anchor fall back for this mooring was 238 meters or 4.5% of the water depth. The water depth at the site was 5300 meters corrected. The total depth correction was +50 meters (+3 transducer depth + 47 Matthew's correction) and the sound speed used was 1514 m/sec.

Figure 6. Subduction 2 Southwest Mooring Schematic

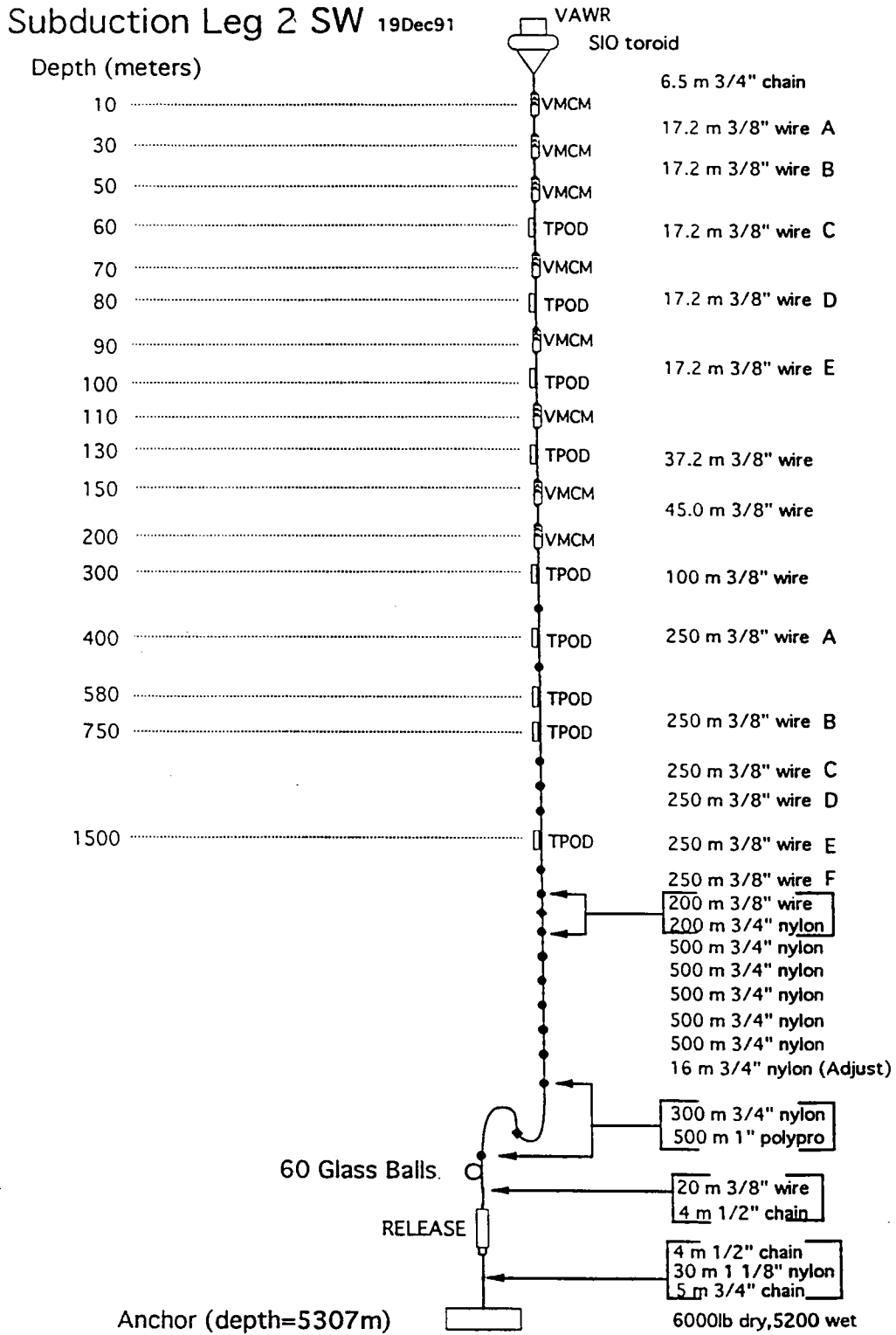
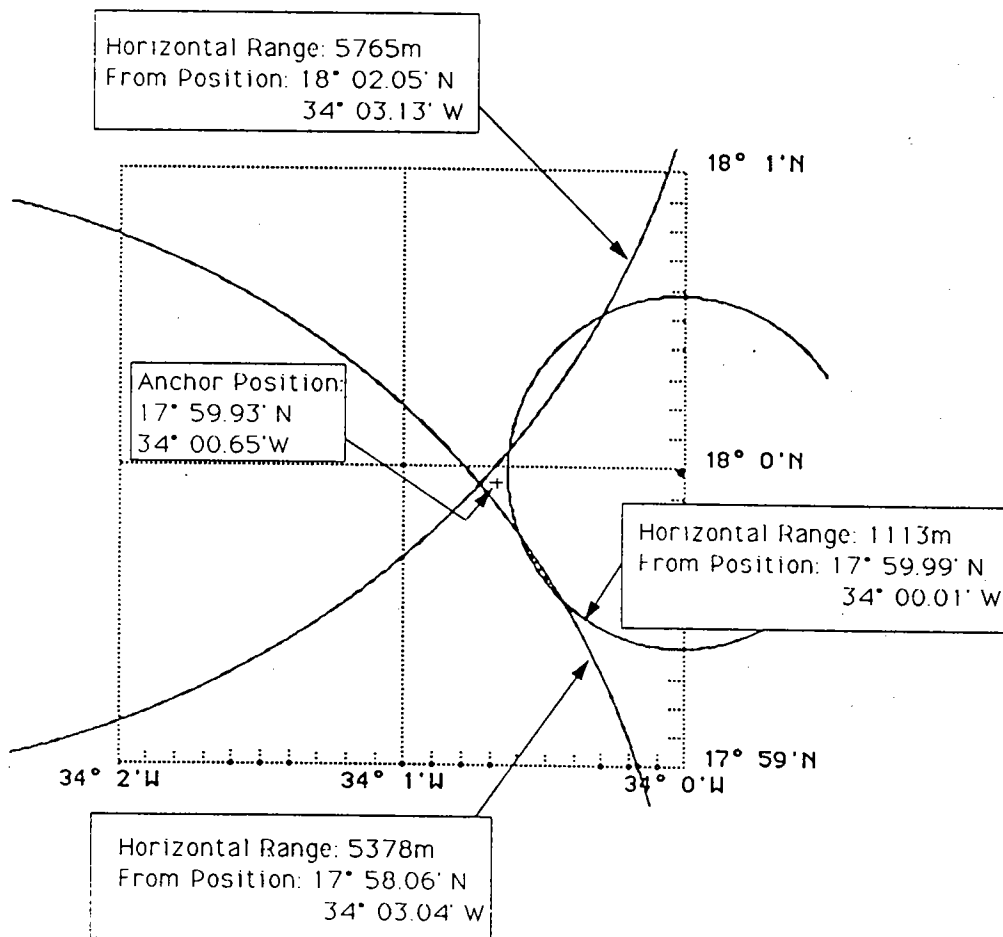


Figure 7. Subduction 2 Southwest Acoustic Release Survey

Subduction 2
Southwest Mooring
Mooring Number 924
Acoustic Release Survey
5 February 1992



The ship immediately got underway for the Southeast mooring location (18°N and 22°W) at 1750 UTC 5 February 1992. The meteorological watch was resumed and hourly XBTs were started at 1900 UTC.

Southeast Mooring

Oceanus arrived at the Southeast site at 0507 UTC on 8 February 1992. This mooring shown in figure 8 was originally set on 29 June 1991 and had parted on 10 October 1991. Since all that remained were the subsurface components with no recovery aids such as a flashing light we waited until daylight to release it.

While we waited a three point acoustic release survey was conducted. The results of that survey showed that the release was within 150 meters of the position determined when the mooring was set. Also during the wait for daylight time was spent determining the set and drift of the ship which would aid in the deployment.

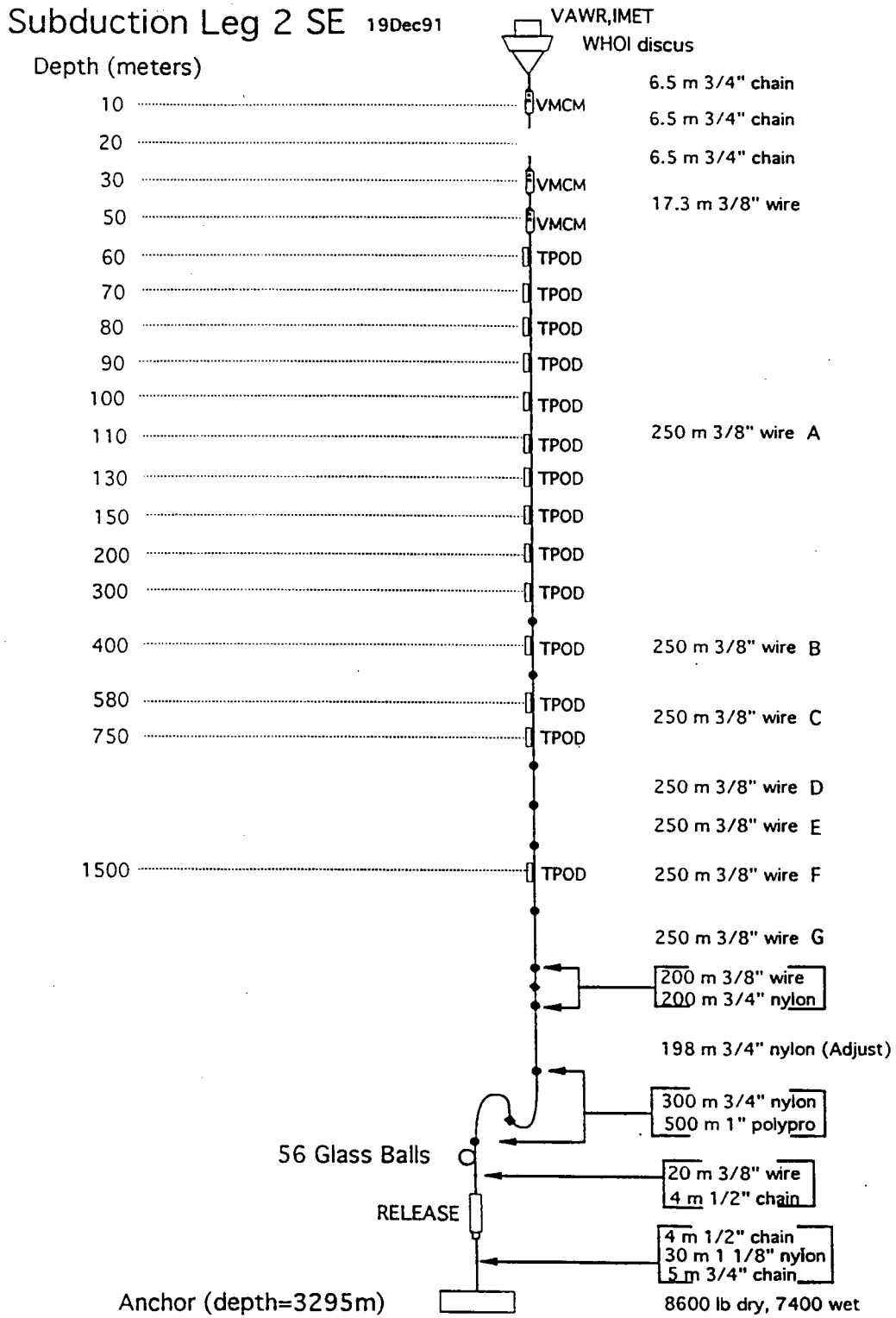
The acoustic release was fired at 0853 UTC 8 February 1992 and the mooring was sighted at 0936. Recovery was initiated at the release end of the mooring and proceeded very smoothly. The entire mooring was on board by 1155 UTC. The last component to be recovered was a cluster of three glass balls (one was missing) the top of which had no shackle or master link. These balls were originally just below the 50m VMCM which had been recovered with the top of the mooring in October 1991.

All three WHOI Brancker temperature loggers recovered from this mooring (#3297 at 60m, #3290 at 580m, and #3259 at 1500m) appeared to have taken on small drops of water during recovery and the data could not be read from the instruments. The failure mode appeared to be the same as that seen at the previous mooring. The SIO Brancker temperature loggers did not leak and their data could be read from memory. The SIO Branckers were a combination of loggers with SIO fabricated pressure cases and Brancker fabricated cases. Both types worked equally well. The SIO instruments with the 2000 series serial numbers had the SIO fabricated pressure cases.

The deck was cleared, glass balls transferred, and the discus buoy was moved into deployment position. A test lowering of three acoustic releases followed along with the off spooling of the recovered mooring and the rewinding of the new mooring. The SIO mooring schematic for the second setting of the Southeast mooring is shown in figure 9. While the wire was being wound one shot was found to have a serious tendency to twist and kink. It was unclear whether the problem was in the wire or in the manner in which it was wound onto the winch. The winding setup was from the tensioning payout cart through a 4" block and then onto the winch. The angle between the wire from the cart and the wire going onto the winch was less than 45°. This same winding arrangement had been used for the Southwest mooring without any noticeable damaging effects to the wire. The bad shot of Southeast wire was replaced and two blocks were used to route the wire onto the winch. No further problems were seen with the remaining shots of wire. All the wire shots and the wire to nylon shot were wound on the winch. The remaining part of the mooring was wound while the mooring was in tow.

Deployment of the Southeast mooring began at 2224 UTC on 8 February 1992. The ship was positioned 4 miles to the southwest of the target. This starting position was downwind and slightly to the north to compensate for a southerly drift experienced earlier. The deployment went along quite smoothly. Since the bottom was very flat and exact positioning was not important the deployment proceeded right through to anchor drop without any towing except that which was needed to wind the remainder of the mooring onto the winch. The anchor was deployed at 0244 UTC on 9 February 1992.

Figure 9. Subduction 2 Southeast Mooring Schematic



Following the deployment, four hours were spent taking meteorological observations every 15 minutes while standing by the surface buoy. An acoustic release survey was then conducted. The results of that survey are shown in figure 10. The anchor position for the **Southeast mooring (WHOI Mooring number 925)** was **17°59.72'N, 22°00.29'W**. The anchor fall back for this mooring was 311 meters or 9.4% of the water depth. The water depth is 3297 meters corrected (total correction = +4 meters) and the sound speed used was 1501.8 m/sec. At the conclusion of the release survey the ship got underway for the Central mooring site.

Central Mooring

The R/V Oceanus arrived at the Central mooring site at 1100 UTC on 11 February 1992. Figure 11 is a schematic of the first setting of the Central mooring. At a distance of approximately 1.5 miles an acoustic range to the release was taken to ascertain whether the anchor was in the same position as when it was deployed. The range obtained confirmed the original anchor position. The ship then got into position to make an approach for recovery. With the buoy just off the bow of the ship the release commands were sent and confirmation of release received. The ship then moved in for recovery. The buoy appeared in good condition and came aboard without any damage.

Half way through the recovery the mooring was stopped off and towed in order to off-spool the wire on the winch. The total recovery operation took 7 hours and 10 minutes. The bottom cluster of glass balls had a number of broken super-ribbed hardhats in the flange that attaches to the chain. There were, however, no broken glass balls.

There was a minimal amount of growth on the buoy which indicated that the antifouling paint worked well during the eight months the buoy was in the water. On some sections of the hull the paint had worn away and it was unclear whether the same application of paint would work for a much longer deployment. The same was noticed with the VMCMs that were recovered. All the VMCMs appeared in good condition. All propeller blades were intact, propellers were freely spinning and propeller bearings did not exhibit any noticeable wear. The Brancker temperature logger clamps were however difficult to remove from the wire. This was believed to be due to the dimensions specified for the delrin bushings. This problem was rectified by adjusting the bushing dimensions so as to increase clearances where needed.

The VAWR and IMET meteorological packages recorded full data records for the deployment of the Central mooring. Five VMCMs (at 10m, 70m, 110m, 1500m, and 3500m) worked throughout the deployment, one VMCM recorded less than a full data tape (50m) and five VMCMs (at 30m, 90m, 150m, 200m and 750m) had data tapes which were unreadable with the equipment on board ship. Close inspection of the five cassette data tapes that were unreadable indicated that they had the same manufacturers code printed on the cassette housing. The code was 2931-3823. The readable tapes had different codes. Numerous attempts at reading the cassette tapes were unsuccessful.

Three Brancker temperature recorders (at 60m, 100m, and 130m) had full data records, one (at 80m) had a partial record, and three instruments (at 300m, 400m, and 580m) flooded with a small quantity of water and could not be read.

Half of the glass balls and hardhats from this mooring were turned around with new chain and hardware. The other half were taken from the already refurbished glass balls that were brought from Woods Hole. The mooring was off-spooled and the new mooring components were wound onto the winch beginning with the wire to nylon shot. The buoy bridle and bridle mounted instruments were given a coat of anti-fouling paint. At the completion of the preparatory work a decision was made to rest for the remainder of the evening and begin the deployment after breakfast the following day.

Figure 10. Subduction 2 Southeast Acoustic Release Survey

Subduction 2
Southeast Mooring
Mooring Number 925
Acoustic Release Survey
8 February 1992

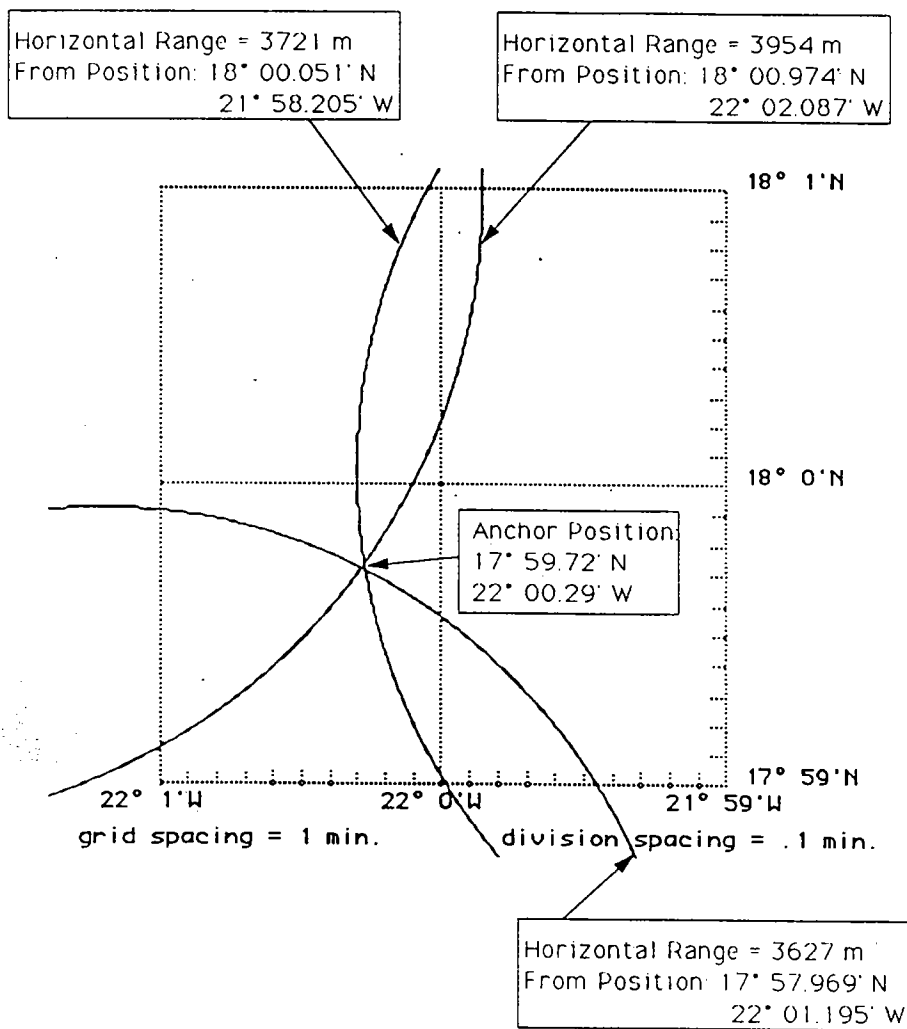
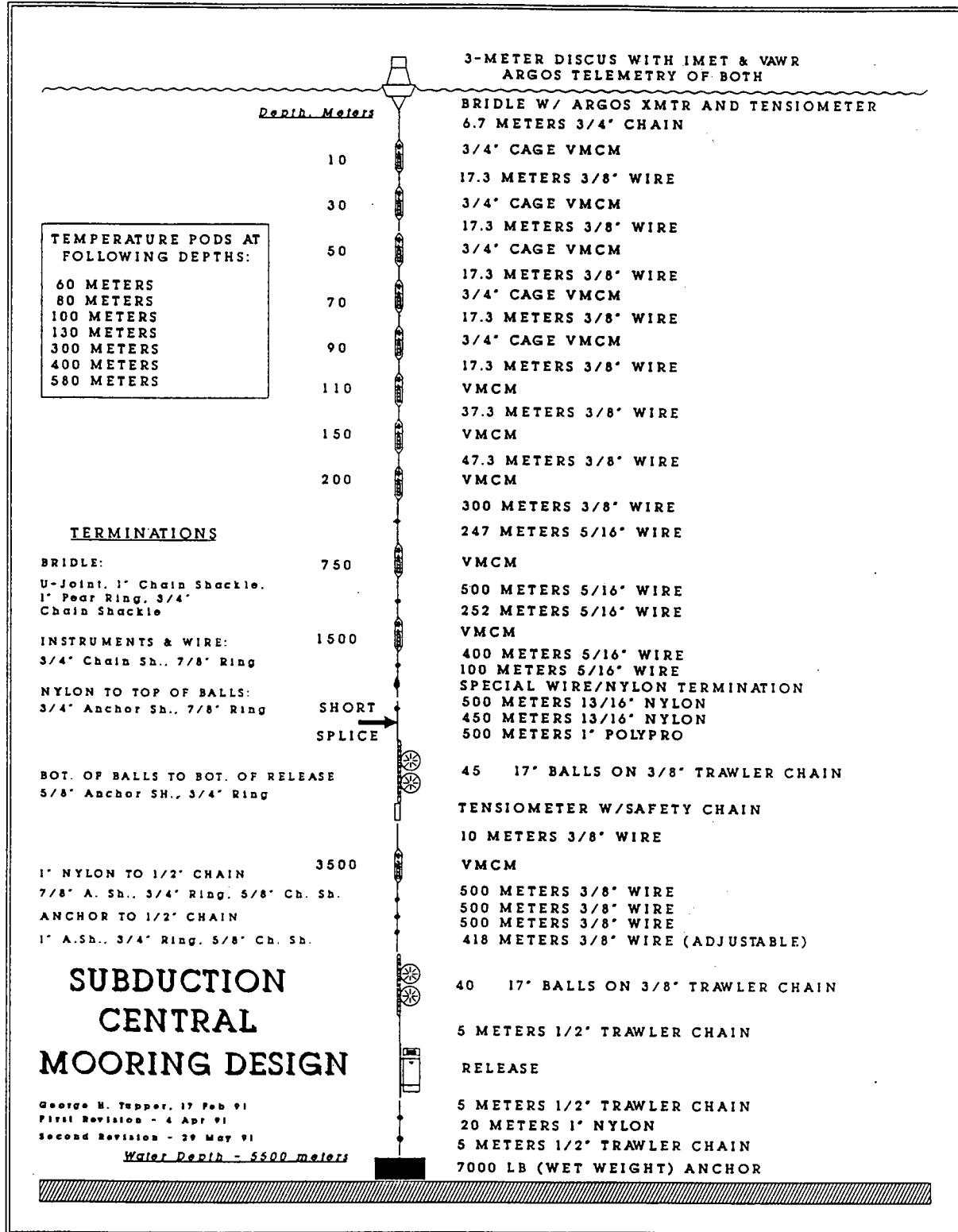


Figure 11. Subduction 1 Central Mooring Schematic



The deployment of the second setting of the Central mooring (figure 12) began at 1037 UTC on 12 February 1992. The ship was positioned 5 miles downwind (east-southeast of the site) and proceeded at an average speed of about .6 knots over the bottom. After the wire to nylon shot was deployed it was necessary to tow the mooring for about 2 hours while the remainder of the mooring was wound onto the winch. The last cluster of balls were deployed along with the release and the mooring was towed for about 30 minutes until the appropriate water depth was obtained. The anchor was deployed at 1915 UTC, 12 February 92.

Following the deployment an acoustic release survey was conducted. The results of that survey are shown in figure 13. The anchor position for the second setting of the **Central mooring (WHOI Mooring number 926)** was **25°31.95'N, 28°57.23'W**. The mooring anchor fell back 778 m or 13.7% of the water depth from its anchor drop position. The corrected water depth was 5670 (total correction = +70 meters) and the sound speed used was 1518 m/sec. The release used on the Central Mooring was a Model 323 which did not have the disable option.

The ship then returned to within .25 miles of the surface buoy. Meteorological observations were made every 15 minutes until 0100 UTC 13 February 92 at which time the Oceanus got underway for the Northeast mooring. Hourly meteorological observations were resumed and hourly XBTs were started at 0200 UTC.

Northeast Mooring

The ship arrived at the Northeast mooring at 2253 UTC on 14 February 92 . Figure 14 is a schematic of the first setting of the Northeast mooring. At a distance of approximately 1.5 miles an acoustic range to the release was made to ascertain whether the anchor was in the same position as when it was deployed. The range obtained confirmed the original anchor position. The ship then got into position to make an approach for recovery. With the buoy just off the bow of the ship the release commands were sent. The ship then moved in for recovery. The buoy was brought aboard without any problems.

There were considerably more goose neck barnacles on the underside of the Northeast buoy than was observed on the Central buoy and the VMCM at 10m also had quite a few growing on it as well. The VMCMs at 10m and 30m and the test sting at 20m had the majority of growth. The tension in the mooring line remained high throughout the recovery presumably due to the drag caused by the cluster of 61 glass balls at the bottom of the mooring. The bottom of the mooring with glass balls and the release was brought on board at 0541 UTC. Aside from two shredded glass ball hardhats that appear to have had glass balls that imploded at depth there were no other broken glass balls.

The IMET package produced a readable data record for the entire deployment. The VAWR however produced a short record having failed on 30 October 1991. Two VMCMs (at 70m and 110m) from the Northeast mooring had cassette data tapes with the same code as the five that were recovered from the Central mooring and could not be read with the equipment on board the ship. Two Brancker temperature recorders (at 80m and 130m) had readable data, five instruments at 300m, 400m, 580m, 750m, and 1500m flooded with small quantities of water and two temperature recorders at 60m and 100m failed to record any data at all.

Following the recovery of the Northeast mooring the Oceanus got underway for Madeira. The ship arrived in Funchal, Madeira, at 0800 UTC on 16 February 92. Work was immediately begun to turnaround the two recovered buoys and instrumentation for deployment on the Northeast and Northwest moorings. Tower tops were removed from the buoys and packed for surface shipment back to Woods Hole. The tower bottom from the Northeast had several cracked welds where the legs intersect the intermediate triangle. This was a one piece unit that had to be repaired in Madeira in June 1991 after being damaged during shipment. One of the welds that was cracked had previously been repaired. The cracked tower bottom was removed and replaced with a newer

Figure 13. Subduction 2 Central Mooring Acoustic Release Survey

Subduction 2
Central Mooring
Mooring Number 926
Acoustic Release Survey
12 February 1992

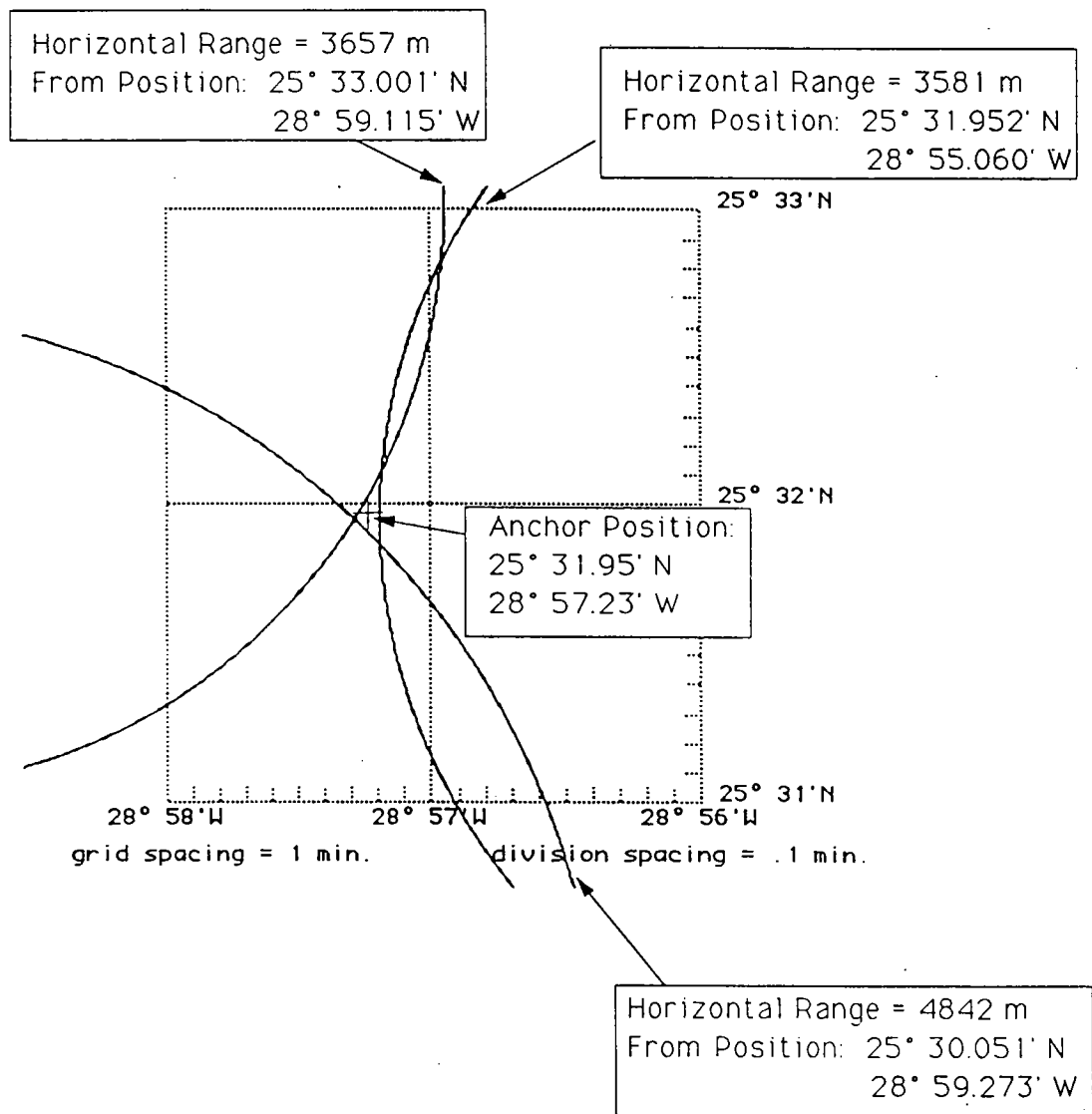
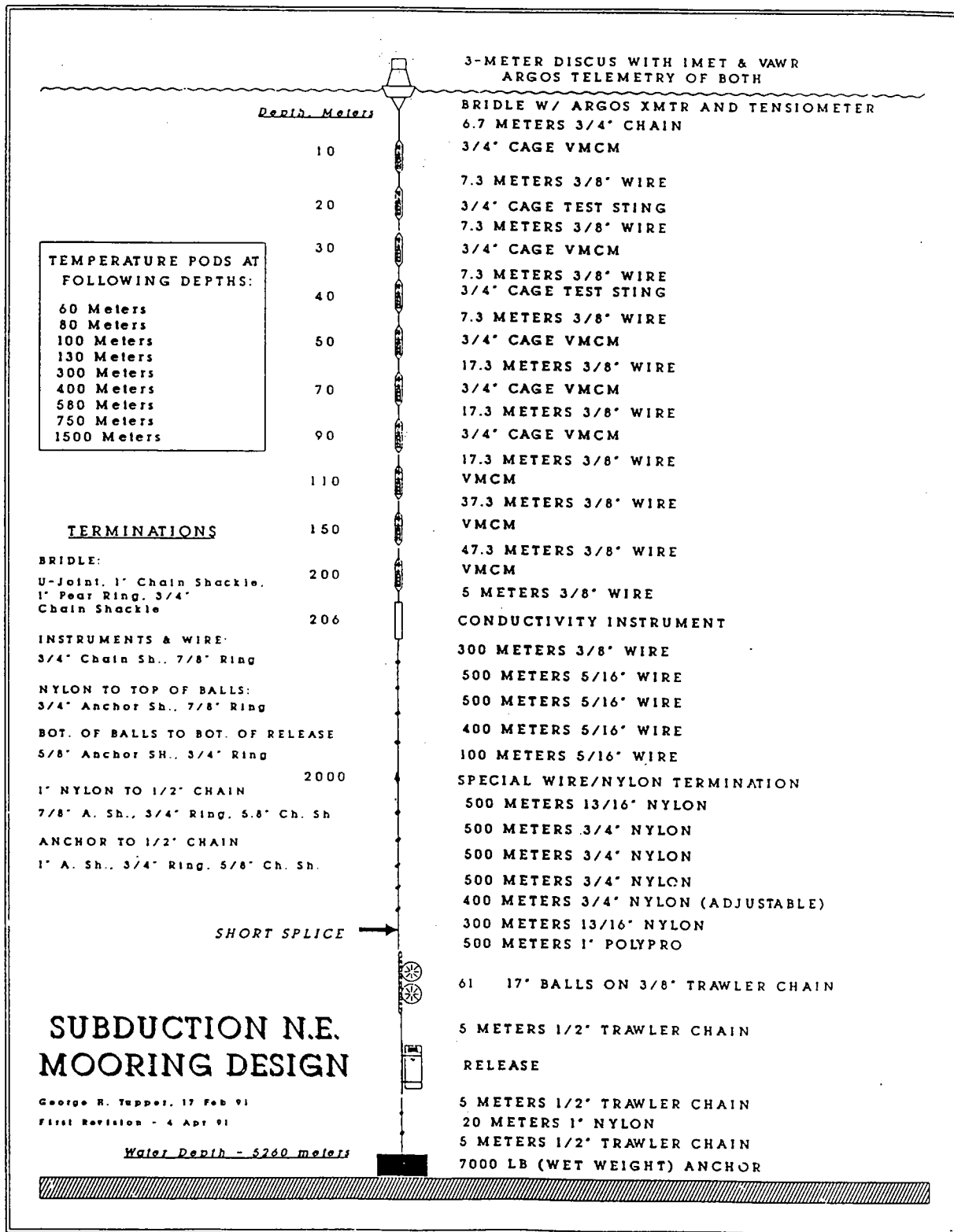


Figure 14. Subduction 1 Northeast Mooring Schematic



design with independent legs and intermediate triangle. The cracked tower bottom was again repaired and gussets welded in the vulnerable areas. The repaired bottom was a spare in the event that the primary unit was damaged during deployment.

New VAWR Argos transmitters were installed in the buoy wells as were new marine lantern batteries. New fully instrumented tower tops were installed and the meteorological instruments checked out and cabling secured. The IMET LOPACS was working satisfactorily and therefore not changed. The storage batteries were also checked out and they too were found to be in good condition and not replaced.

Five VMCMs (four plus one spare) were turned around for deployment on the Northeast mooring. Two of the four instruments reused the stings that had been previously deployed for eight months. Their condition upon recovery was like new so a decision was made to reuse two of them. The inventory of Brancker temperature recorders was reviewed and a strategy of where to place the remaining WHOI units and SIO units was developed. Instruments were painted with antifouling paint as were the buoy hulls.

The Southwest toroid buoy that was recovered early in the cruise was loaded into a 40 foot container along with a spare toroid anchor, two tower tops, recovered current meters and releases, used wire rope and nylon, and used hardware. The new wire, nylon and anchors for the Northeast and Northwest moorings which had arrived in the same container were loaded onto the ship. The upper part of the Northeast mooring was wound onto the winch. The remaining reels were secured on deck. In all there were three full days of work getting everything ready for the second leg.

The Oceanus departed Madeira at 0800 UTC on 19 February 1992 enroute to the Northeast mooring. The ship arrived at the Northeast site at 0600 UTC on 20 February 92. As the ship approached the site a brief depth survey was conducted. While on location the set and drift of the ship was established to determine the start position for the mooring work. While steaming into the wind (northeast) at approximately 1 knot the ship was set to the northwest. A start position four miles to the southeast of the target was decided upon.

The deployment commenced at 0915 UTC and proceeded very smoothly. Figure 15 is a schematic of the second setting of the Northeast mooring. The buoy and upper instrumentation went in the water without any problems. Several shots of nylon and the nylon-to-polypropylene shot were wound onto the winch about half way through the deployment. During the deployment of the acoustic release the protective cage around the transducer head was damaged. A replacement was substituted and the deployment continued. Since the bottom was very flat and it was not necessary to hit any particular target the mooring anchor was deployed as soon as it was prepared. The anchor was deployed at 1547 UTC on 20 February 1992.

After the mooring had settled out an acoustic release survey was conducted. The results of that survey are shown in figure 16. The anchor position for the second setting of the **Northeast mooring (WHOI Mooring number 927)** was **33°01.98'N, 22°00.27'W**. This position is slightly to the north of the original site so as to give some distance between it and a Kiel mooring located at 32°55.3'N, 22°08.17'W. The Northeast mooring anchor fell back 393 meters or 10.9% of the water depth. The corrected water depth at the Northeast site was 5274 meters (total correction = 54 meters) and the sound speed was 1515 m/sec.

Following the acoustic survey, meteorological observations were taken every 15 minutes for four hours while the ship was within .25 miles of the surface buoy. The Oceanus then got underway for the Northwest buoy at 2152 UTC on 20 February 1992. Hourly XBTs were resumed at 2300 UTC.

Figure 15. Subduction 2 Northeast Mooring Schematic

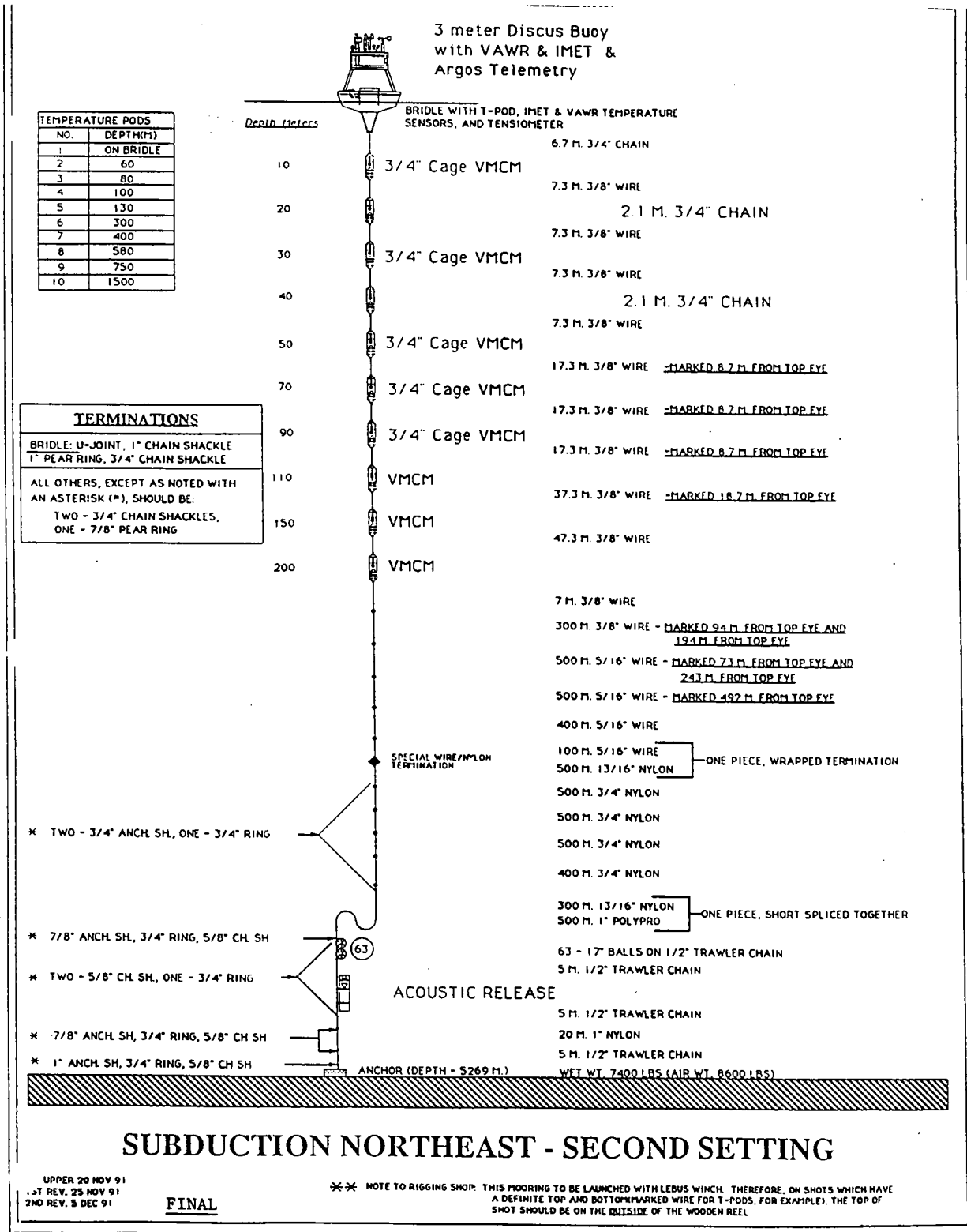
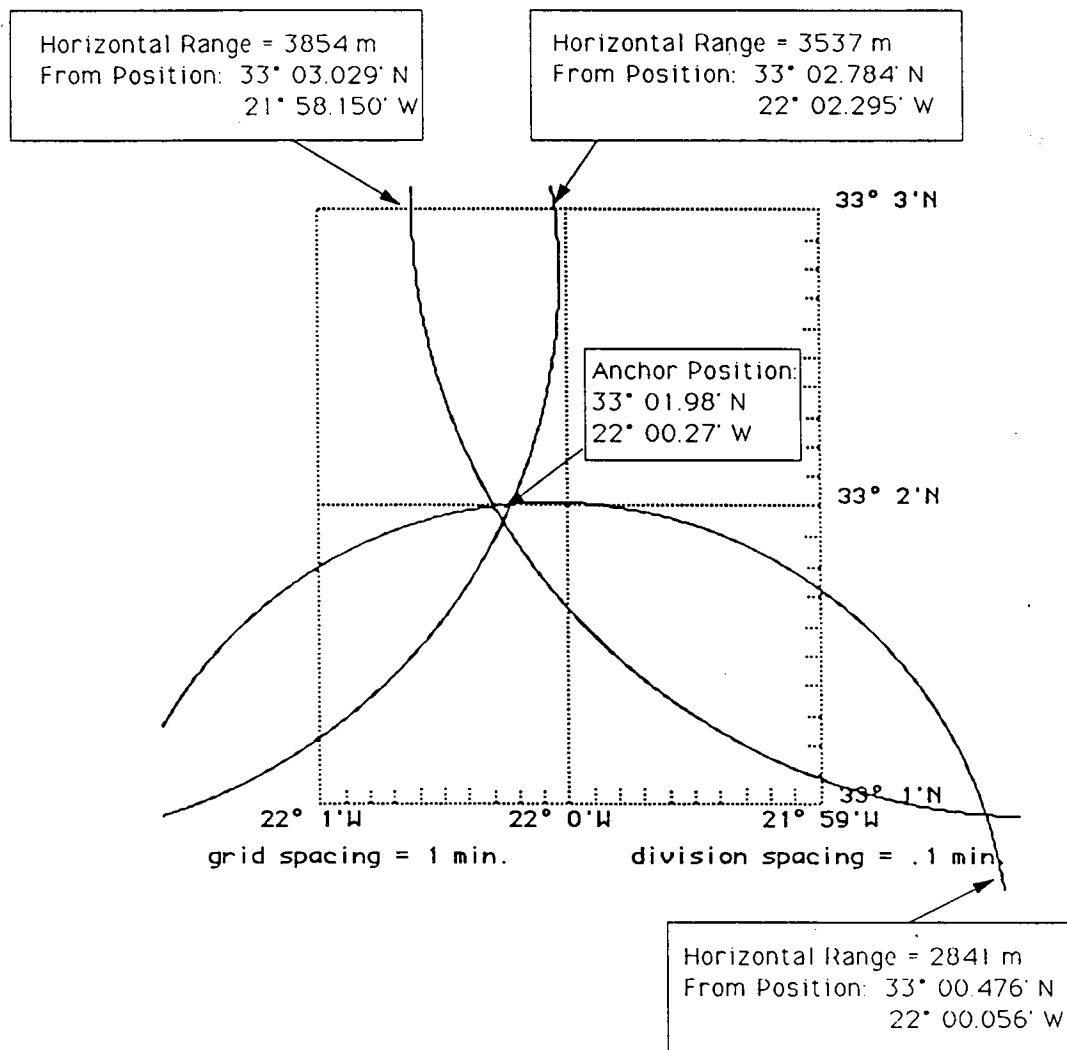


Figure 16. Subduction 2 Northeast Mooring Acoustic Release Survey

Subduction 2
Northeast Mooring
Mooring Number 927
Acoustic Release Survey
20 February 1992



Northwest Mooring

The ship arrived at the Northwest mooring site at 0230 UTC on 23 February 1992. Since this mooring had parted in August 1991 there was nothing on the surface and it was preferable to wait until daylight before recovery was attempted. While waiting the ship interrogated the release to determine if it was still operable and to see if it was in the same location as when deployed. The release responded without any trouble and was in the same position. A depth survey was conducted to determine the depth variability in the immediate target area. The new mooring design for the northwest site permitted a ± 60 meters depth window around the design depth without producing any significant effect on the mooring's performance. The area within those limitations was identified as the "strike zone". Deployment anywhere within the "strike zone" would be permissible. Time was also spent determining the set and drift of the ship at the drop site and the start position.

With daylight the ship was positioned .3 miles downwind of the anchor position and the release was fired at 0854 UTC. The mooring was sighted at 0909 UTC and was completely recovered by 1119 UTC. Figure 17 is a schematic of the failed mooring. The upper most part of the recovered mooring consisted of a cluster of four glass balls at 500m and above that a wire rope swage with boot and about 3" of wire. The wire appeared as if it had been bent back on itself before parting. Presumably the wire took a turn around the balls, was damaged and then failed.

Two WHOI temperature loggers at 580m and 1500m and one SIO temperature logger at 750m were the only instruments recovered from the parted Northwest mooring during Oc-250. The two WHOI loggers (#3272 at 580m and #3273 at 1500m) leaked a small quantity of water and the data could not be read. The SIO instrument had readable data.

With the mooring aboard the wire on the winch was off-spoiled, glass balls were transferred to the ball container and the new mooring was wound onto the winch.

A set and drift exercise conducted during the off-spooling and winding indicated that the ship should be positioned to the southeast of the site and steam to the west. A slight northerly current would set the ship to the northwest. The ship was positioned 4 miles downwind of the mooring site to begin deployment.

Figure 18 shows the new mooring design for the second setting of the Northwest mooring. The deployment began at 1756 UTC on 23 February 1992. The upper temperature instruments and buoy were deployed very smoothly. During deployment it was discovered that the 37.2 meter shot of wire was wound onto the winch up side down. The shot was recovered and reversed and redeployed. Later in the deployment there was concern that the 80 meter shot with 7 temperature recorders attached may be inverted. If it is the temperature recorder depths will be recalculated. A recommendation for the future is to mark the top and bottom of critical wire shots that have instruments spotted at particular depths along its length.

The mooring was towed for approximately 45 minutes while the nylon-to-polypropylene shot was wound onto the winch. Deployment resumed and the mooring was again towed with the glass balls and release outboard. The anchor was deployed at 2328 UTC on 23 February 1992.

After the mooring had settled out an acoustic release survey was conducted. The results of that survey are shown in figure 19. The anchor position for the Northwest mooring (WHOI Mooring number 928) was $32^{\circ}54.42'N$, $33^{\circ}53.35'W$. The Northwest mooring fell back 298 meters or 8.3% of the water depth. The water depth at the site was 3590 meters corrected (total correction is +13 meters). The sound speed was 1505.4 m/sec.

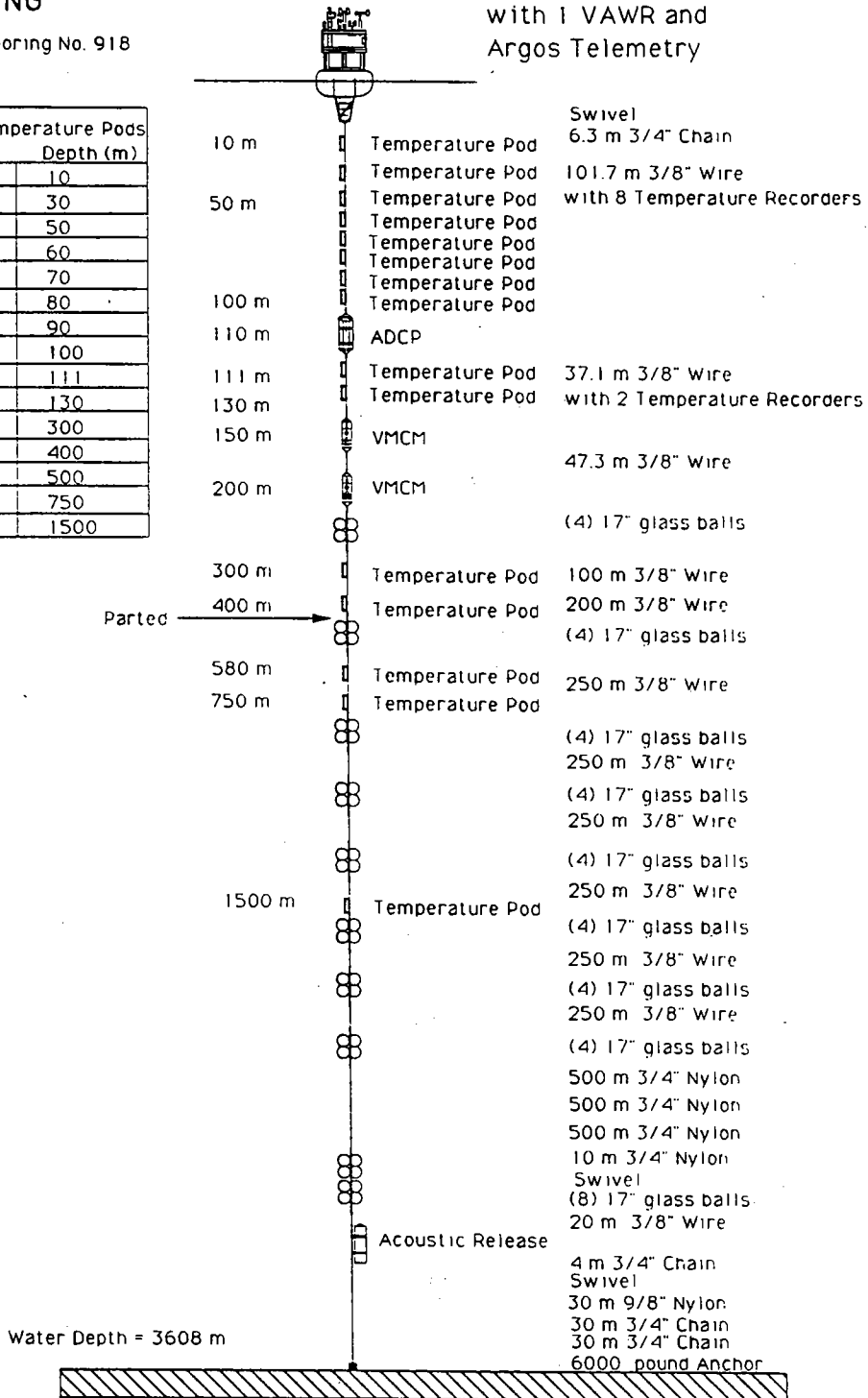
Figure 17. Subduction 1 Northwest Mooring Schematic

**NORTHWEST SUBDUCTION 1
MOORING**

WHOI Mooring No. 918

SIO Toroid Buoy
with 1 VAWR and
Argos Telemetry

Temperature Pods No	Depth (m)
1	10
2	30
3	50
4	60
5	70
6	80
7	90
8	100
9	111
10	130
11	300
12	400
13	500
14	750
15	1500



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Figure 18. Subduction 2 Northwest Mooring Schematic

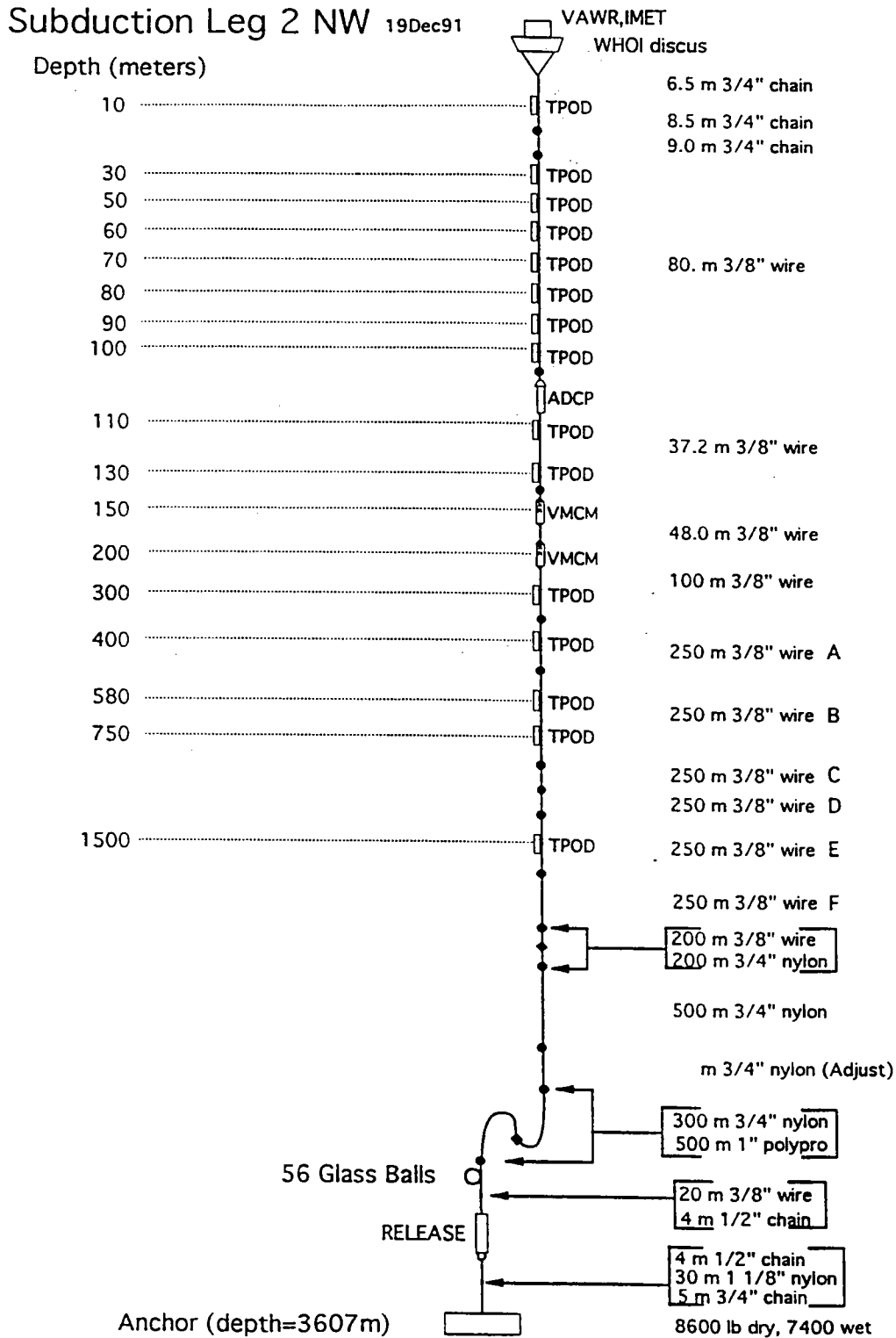
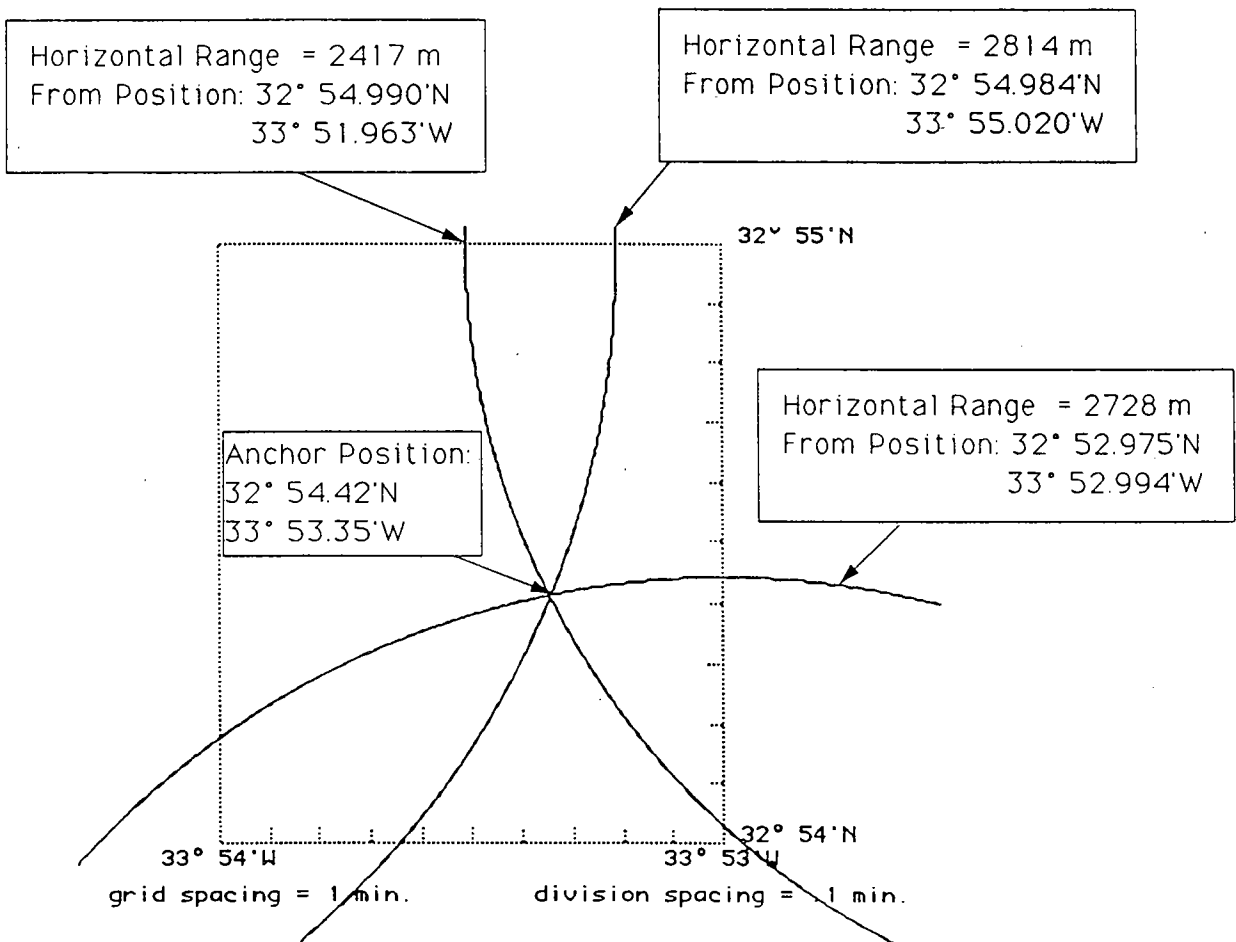


Figure 19. Subduction 2 Northwest Mooring Acoustic Release Survey

Subduction 2
Northwest Mooring
Mooring Number 928
Acoustic Release Survey
23 February 1992



Meteorological observations were taken every 15 minutes for four hours while the ship was positioned .25 miles downwind of the buoy. At 0545 UTC 24 February 1992 the ship got underway for Ponta Delgada, Azores. Hourly XBTs were resumed at 0900 UTC with the last XBT deployed at 2000 UTC. The ship arrived in the Azores on 26 February 1992 at 0900 UTC.

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Trask, Richard P., and Nancy J. Brink, 1993: The Subduction Experiment, Cruise Report, R/V Oceanus Cruise Number 240, Woods Hole Oceanographic Institution Technical Report, WHOI-93-12, 77 pp.

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We are grateful for the skill of Captain Paul Howland and the friendly assistance provided by all the crew members of the R.V Oceanus. Will Ostrom was instrumental in preparing the buoys for deployment and in supervising the recovery and deployment operations during the cruise. Glenn Pezzoli from Scripps Institution of Oceanography was helpful both on deck and in evaluating several instrumentation problems. Bob Weller's attention to detail prior to and throughout the cruise greatly benefited the project as instrumentation was prepared. Long hours spent by Nan Galbraith in the noisy lower lab of the Oceanus upgrading software and processing data is also greatly appreciated. We sincerely thank Mary Ann Lucas for her help in preparing this report.

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Appendix 1 Cruise Participants

Robert A. Weller, Chief Scientist	(WHOI)
Richard P. Trask	(WHOI Research Specialist)
William Ostrom	(WHOI Senior Engineering Assistant)
Bryan Way	(WHOI Engineering Assistant)
Paul Bouchard	(WHOI Engineering Assistant)
Neil McPhee	(WHOI Engineering Assistant)
Nancy Pennington	(WHOI Senior Research Assistant)
Nan Galbraith	(WHOI Information Systems Associate)
Lloyd Regier	(SIO Design Engineer)
Glenn Pezolli	(SIO Development Technician)

Appendix 2

SIO Mooring Design

The Instrument Development Group (IDG) of Scripps Institution of Oceanography prepared three surface moorings and provided the associated instrumentation for the first Subduction deployment. In Subduction 2 these moorings were recovered, the data extracted from the instruments, and the moorings and instruments were redeployed for another eight months.

SUBDUCTION 1 SURFACE MOORINGS

The IDG surface moorings were supported by a toroid buoy with a diameter of 2.4 meters. A triangular tower on top of the buoy supported IMET and VAWR instruments measuring meteorological variables. Solar panels were used to provide power for the IMET package and the associated ARGOS satellite transmitters which relayed the data to shore-based observers. An auxiliary lead-acid battery pack was installed in the bridle beneath the buoy to provide power during periods of low solar energy. These additions to the IDG toroid weighed a total of 1900 pounds which left the buoy with a reserve buoyancy of only 4200 pounds with which to support the mooring. By comparison, a similarly loaded WHOI discus buoy has a reserve buoyancy of 8700 pounds.

As these moorings were being designed, several key mistakes were made in an attempt to make these moorings survive the high currents which often characterize regions near fronts. The effective scope of the mooring was increased by adding 60 to 90 meters of 3/4 inch chain to the bottom of the mooring just above the anchor. This improved the holding power of the anchor by making the force on the anchor more horizontal. However it increased the weight of the anchor by so much that the toroid was incapable of supporting the mooring if it drifted into deep water. The increased anchor weight also increased the falling velocity of the anchor during launch.

The second mistake was that flotation, rather than being concentrated near the anchor, was distributed throughout the wire rope in the upper part of the mooring. This reduced the tension at the base of the surface float and thus made the mooring capable of standing large currents. But it also decreased the drag near the anchor which further increased the fall velocity of the anchor.

Some of the ramifications of these design errors became apparent as the moorings were deployed. The low static tensions at the base of the surface toroid, which were needed to make the overloaded buoy withstand the expected currents, gave little righting moment to the surface float. Thus the mooring had to be paid out very slowly. The multitude of flotation elements in the wire rope section resulted in multiple catenaries of wire hanging beneath the floating glass balls. One could not simultaneously maintain sufficient way on the ship to keep the catenaries from tangling without increasing the danger of capsizing the surface buoy. When the anchor was deployed, the terminal velocity of the very heavy, low drag anchor was truly astounding and resulted in the buoy being towed across the surface at speeds near 4 knots. This raised the drag-induced tension in the mooring and stretched the nylon sections much more than had been anticipated. Once the anchor had settled into the bottom, the stretched nylon began to contract. But the buoy was still out at the limits of its watch circle and was only barely at the surface. As the nylon contracted and the force on the buoy became more vertical, it pulled the buoy under the surface a few meters for a few minutes. It slowly surfaced as the buoy moved closer to the anchor position. The short term submergence of the buoy had a rather disastrous effect on the meteorological instruments.

Ultimately the folly of the mooring design became more evident as the moorings parted and began drifting around the Atlantic Ocean. The upper portion of the Northwest mooring (NW) was recovered by Woods Hole personnel onboard R.V. Endeavour. Part of the Southeast (SE)

mooring was recovered by the Russian vessel Mendeleev and another portion was recovered from the shoals of the Cape Verde Islands by a local tug boat and diver. The upper portion of the Southwest mooring (SW) was recovered by R.V. Oceanus during Oc-250. The remaining portions of all three moorings were also recovered by Oceanus in this cruise. Ultimately all the pieces of all the moorings were recovered and examined to discover the causes for the failures. It appears that the moorings failed for two different reasons.

The NW mooring parted in a wire rope section about .3 meter away from a set of glass balls at 500 meters depth. The jacket on the rope was scratched and the wire itself bent in a tight radius which indicates that it may have tangled on a shackle during deployment. When the anchor was dropped, the wire was damaged when it kinked around this shackle and then ultimately failed a month later.

The SW and SE moorings failed in a different manner. Both these moorings parted at the base of a current meter to which was attached a set of glass balls. In both cases the set of glass balls was the shallowest set in the mooring, at 50 meters in one case and 110 meters in the other. In both cases some of the termination hardware, shackles or master links, were missing and the glass balls were heavily damaged. Both of these current meters were also severely damaged and the stings holding their propellers were missing. The explanation for this failure mode lies in the dynamic response of the mooring to wave-induced motion of the surface buoy. As waves move the buoy up and down, the wire rope attached to the buoy is moved vertically. The wire itself has very little drag and can't stretch so the vertical motion propagates downward through the mooring until the current meter just above the first set of glass balls is reached. The current meter is being yanked up and down by the wire from above. However, by design, the mooring tension is very low, too low to accelerate the glass balls downward sufficiently to keep the current meter from capsizing from its normal vertically upright position. When the crest of the next wave pulls the surface float upwards, the current meter is suddenly pivoted upwards, the slack is taken up with a slam, and the connection between the current meter and the glass balls is stressed impulsively. After several thousand such cycles, the hardware is hammered to extinction and fails.

MOORING IMPROVEMENTS FOR SUBDUCTION 2

As the fundamental cause for the mooring failures was the inadequate displacement of the surface toroid, in the Subduction 2 redeployments, two of the surface toroids were replaced by WHOI discus buoys which have an additional 4000 pounds of reserve buoyancy. No discus or other float was available to replace the third toroid. Rather than attempt to patch together a way to increase the displacement of the toroid, we reduced the load on the toroid by removing the IMET package and its associated lead-acid battery package. This reduced the payload by 700 pounds. However because of concerns that the toroid might capsize during a deployment in heavy seas, a lead counter weight was added to the base of the buoy bridle; this decreased the net payload to about 450 pounds less than that of the Subduction 1 configuration. An additional 1200 pounds of buoyancy was added by installing a ship's fender inside the central well of the toroid.

On all three moorings the glass balls were concentrated in a single mass above the release and anchor. Rather than getting extra scope during periods of high current by lifting a heavy chain off the bottom, a WHOI inverse catenary mooring design was used. A long section of buoyant line provided the extra line needed to increase the scope without creating opportunities for the line to snag on hardware terminations. This required the installation of two special terminations which had been developed at WHOI, a wire-to-nylon junction and a nylon-to-polypropylene junction. These terminations have proved successful in several WHOI moorings in rather difficult environments where more conventional approaches have failed. While the Subduction 1 moorings had a slack scope of .96, the Subduction 2 toroid mooring had a slack scope of 1.01. The extra scope also provided a greater tolerance for irregularities in the bottom profile. The glass ball buoyancy was increased on all moorings so that the entire mooring would float in water of infinite

depth. All of the glass ball flotation was installed directly above the acoustic release and anchor. This reduced the holding power of the anchor but allowed the surface buoy to remain afloat should it hop into deeper water.

The deployment of the Subduction 2 moorings went without incident. The NW and SE moorings were supported by WHOI discus buoys. Only the SW mooring had a SIO toroid. When the SW mooring was deployed, the speed of the toroid through the water was a more sedate 1-2 knots which resulted from the reduced effective weight and increased drag of the anchor caused by moving the glass balls to just above the anchor. As the SW toroid was settling into position, there were several anxious minutes as the toroid rode very low in the water until it had moved from the periphery of its watch circle to a position closer to the anchor. Once it had settled, the toroid was riding very much like it had in previous deployments where it had survived 20 foot seas and 50 knot winds in the Gulf of Alaska.

Appendix 3 IMET Buoy Systems

Subduction 2 IMET/LOPACS status

The first turnaround of the Subduction buoys involved replacing the Southeast and Northwest toroids with discus buoys and "turning around" the existing discus buoys at the Central and Northeast positions. The Southwest buoy remained a toroid and was not fitted with an IMET system. This report will deal with the status of the recovered IMET modules and LOPACS and problems or fixes with the newly deployed systems.

Two complete buoys with IMET/LOPACS systems were assembled and tested at Woods Hole. The LOPACS used in these buoys were primarily assembled from existing spares and previously used ARAMP boards. Care was taken to ensure that the components were all properly modified to current standards. Two tower tops were also assembled to be used as replacements for those on the presently deployed discus'. Post assembly testing of the buoys and tower tops was completed and they were loaded aboard the Oceanus.

2 Feb. 1992: The first to be recovered was the Southwest toroid. It had broken free of its mooring and was drifting. It had also gone subsurface after anchor launch last June. IMET ARGOS transmissions from this buoy had ceased just after this but had resumed a week later. The transmissions were only half frame but contained some reasonable data. After the buoy was recovered and set on deck the LOPACS enclosure was opened and a visual inspection made. The only sign of water having gotten in was a slight bit of corrosion on the main power connectors on the power regulator boards. The lights were observed to flash on the 485/232 converter indicating the system was still working. However when an attempt was made to monitor/communicate with the system via the external console cable the LOPACS began to experience hang-ups, i.e. the program would begin to run but stop after the first minute of module interrogation, it could not be restarted by keyboard commands so module status could not be checked at that time. It was possible to exit the program during initialization to check the Date/time. This was 20 secs faster than the standard (Heath GC-1000).

The Optical disk was easily removed for analysis. An initial check showed files were still being written the morning of recovery. Further investigation revealed that no short files were written from 25 June (launch) until 2 July. (See pg. 1, appendix).

It does not appear that much of the data written to optical is usable. A better understanding is gained by looking at the plots of the data but briefly it seems that only SWR returned good data until it quit in January.

After the tower top was removed and set on the lab van for transit to Madeira a cable was run from it to the main lab and each module interrogated via Procomm with the following results:

WND: Answered all commands o.k. Compass and vane outputs varied as expected. The propeller was pretty much frozen with salt and would not spin freely.

HRH: Answered all commands o.k. Values pretty much in agreement with Ships' IMET system and varied in test mode. (ship: 81.4%/ 23.183 deg; buoy: 84.8%/23.284 deg)

TMP: Answered all commands (ship: 23.234 deg; buoy:23.389 deg).

LWR: Answered all commands, output seemed reasonable, varied in test mode.

PRC: Answered all commands, raw values are all negative, no change when water was added to sensor.

SWR: No response.

SST: Checked in main lab. Disassembled and found no sign of water. Had problems when communications were attempted, almost seemed as if the program were stuck in a loop. Removed program eprom and reinitialized and it began working o.k.

PTT: All responses good, power out > 1W, went to multiple id's and full frames when commanded.

These modules will be examined more closely and recalibrated but it seems that the initial submergence caused some problems which need to be better understood.

Both Junction boxes were clean and dry and the battery voltages were between 12.30 and 12.45.

There is no explanation at present for the inability to communicate with the LOPACS after recovery but this may be due to either the physical jarring of the buoy during recovery or it's angle while secured on deck.

All the modules and brackets were secure and intact, the only obvious problem being the wind prop.

9 Feb. 1992: Deployed new Southeast Discus. This was one of the buoys which had been assembled and tested at Woods Hole. It worked properly when powered up. Observed and checked disk writes. ARGOS transmissions were good on all 4 id's. Rechecked 0 and nominal load of 700 lbs on tension. Post deployment meteorological observations and ARGOS monitoring compared well.

11 Feb. 1992: Recovered Central discus. ARGOS transmissions were received when the buoy was in range (Woods Hole had reported that no transmissions had been received from Service ARGOS since 4 Feb.). Communications were established via ext. con. cable with LOPACS and Subduct.exe was observed to be running properly with only SST not responding. A check of Date\Time showed the following discrepancy:

LOPACS time: 2/13/92 16:53:16

Std time: 2/11/92 16:55:00

This shift occurred 1 week after deployment and had been noticed via ARGOS at that time. The clock/backup battery voltage was 3.02v at recovery with 3.0 v being nominal. This could possibly be due to a recently found artwork mistake on the LOPACS memio board which had the clock driven watchdog circuit tied to the battery side of the isolation diode instead of the backplane 5 vdc. But I feel that while this is a possibility it is remote. This shift had not been observed in any other LOPACS with the same board error.

There were no missing files and data quality appeared good. Problems were noted with the following modules:

SST: Ceased functioning 27 July. When disassembled it was found to contain about 1/4 cup of water. This water had set in the bottom of the module so there was not much corrosion on the boards themselves but the wires to the Sea-Con connector were quite corroded and the power wire had separated from its' solder cup.

SWR: Quit 4 Nov. Had been working fine until then. Have not investigated yet.

General: Sensor J-box was clean and dry.

Solar J-box had a little water in it and some corrosion but since the regulators are encapsulated it was still working. The O ring and mating surface were intact, the lid was tightly fastened and the Woodheads and cable stoppers were tight and undamaged. It is possible the water could be coming through the cable from the panels and this will have to be looked at.

Gel Cells: Voltages were between 12.4 and 12.7.

This buoy was to be turned around and used as the Northwest (a change in plan as it was originally to become the Northeast). Since the LOPACS had worked properly, the time shift notwithstanding, it was readied for reuse. This involved modifying the artwork on the memio and adc boards, installing new Subduct.exe eproms, and memory back up batteries. A close physical

inspection at this time showed no signs of corrosion or damage. It was connected to the tower top still on the lab van for burn-in. No problems were noted.

The original Central discus PTT was inspected and reprogrammed to become the new Northwest PTT.

12 Feb. 1992: Deployed Central Discus. This was the other complete buoy which had been assembled and tested at Woods Hole. After it was restarted the PTT began to occasionally cease transmitting but then restart. A complete system power cycle would always return it to proper operation but it would again cease after a few hours. The PTT which had been recovered from the Southwest and had worked properly for the last 8 months was prepared, reprogrammed and installed. No further ARGOS problems were noted.

Pre-deployment checks of modules, disk operation and tension were all good.

Post deployment via ARGOS showed a good intercomparison with VAWR and meteorological observations. The tension appeared high however.

15 Feb. 1992: Recovered the Northeast Discus. ARGOS transmissions since last October seemed to indicate the LOPACS was resetting itself at irregular intervals. Analysis of the optical disk showed some files missing followed by short files in a manner which indicated that disk drive hangups were causing the resets. This, however, did not result in much data lost and all of the modules performed through to the end.

The LOPACS time was 1 min. 52 secs behind the standard time. There were no signs of corrosion or damage to the LOPACS. This buoy was to be redeployed as the Northeast. The optical disk drive and controller board were replaced in the LOPACS in addition to the previously mentioned turn around requirements.

The on deck tension check indicated a problem with the system. A shorting plug was installed at the input to the LOPACS a/d and the signal via ARGOS did go to 0. When the cable from the buoy well to the tension cell itself was rung out an open was found in the common lead. The cable was replaced but tension was still not responding properly. Temporarily connected the spare cell with good results. The old cell was removed and replaced with the spare.

General: Sensor J-box was clean and dry.
 Solar J-box had about same amount of water as Centrals.
 Again there were no obvious paths for water entry.
 Gel Cells: Voltages were between 12.25 and 12.40.

This buoy was redeployed 20 Feb. The shipboard meteorological observations compared well with the ARGOS transmitted IMET data.

(23 Feb. 1992: Deployed Northwest Discus)

General Notes: As with the previously returned Southwest toroid all the buoy hardware was in good shape. The solar panels were secure and undamaged as were any exposed cables. None of the brackets showed any cracked welds or loose fastenings.

Appendix 4 Wind Direction Comparison Tests

Part of the preparation of the meteorological packages includes checking the wind direction sensors. This consists of placing each buoy on a test station that can be rotated through 360° and directing the wind vane to a fixed target at 60° intervals. The direction is then computed from the instrument compass and vane direction data.

The test site in Woods Hole was located at the southern corner of the Clark - South Laboratory parking area. This site showed little horizontal or vertical spatial variation in the magnetic field. The tower tops (3 of which were on buoys) were mounted each in turn on a wooden and masonite turntable, and the direction of a tree near the Clark building was measured from six orientations. At each of the six positions the wind vane was aligned to the tree by eye and locked in position. The data was then read directly from the instrument. In the case of the VAWR the compass and vane positions are added to obtain the wind vane direction in oceanographic convention (i.e. the wind direction of flow from the north is 180°). The magnetic bearing to the tree from the test site is 309.0° . Figures A4-1 to A4-5 show the results of those spin tests for the Subduction 2 VAWR and IMET direction sensors.

Figure A4-1. Wind Direction Comparison Test for Subduction 2 Southwest Buoy.

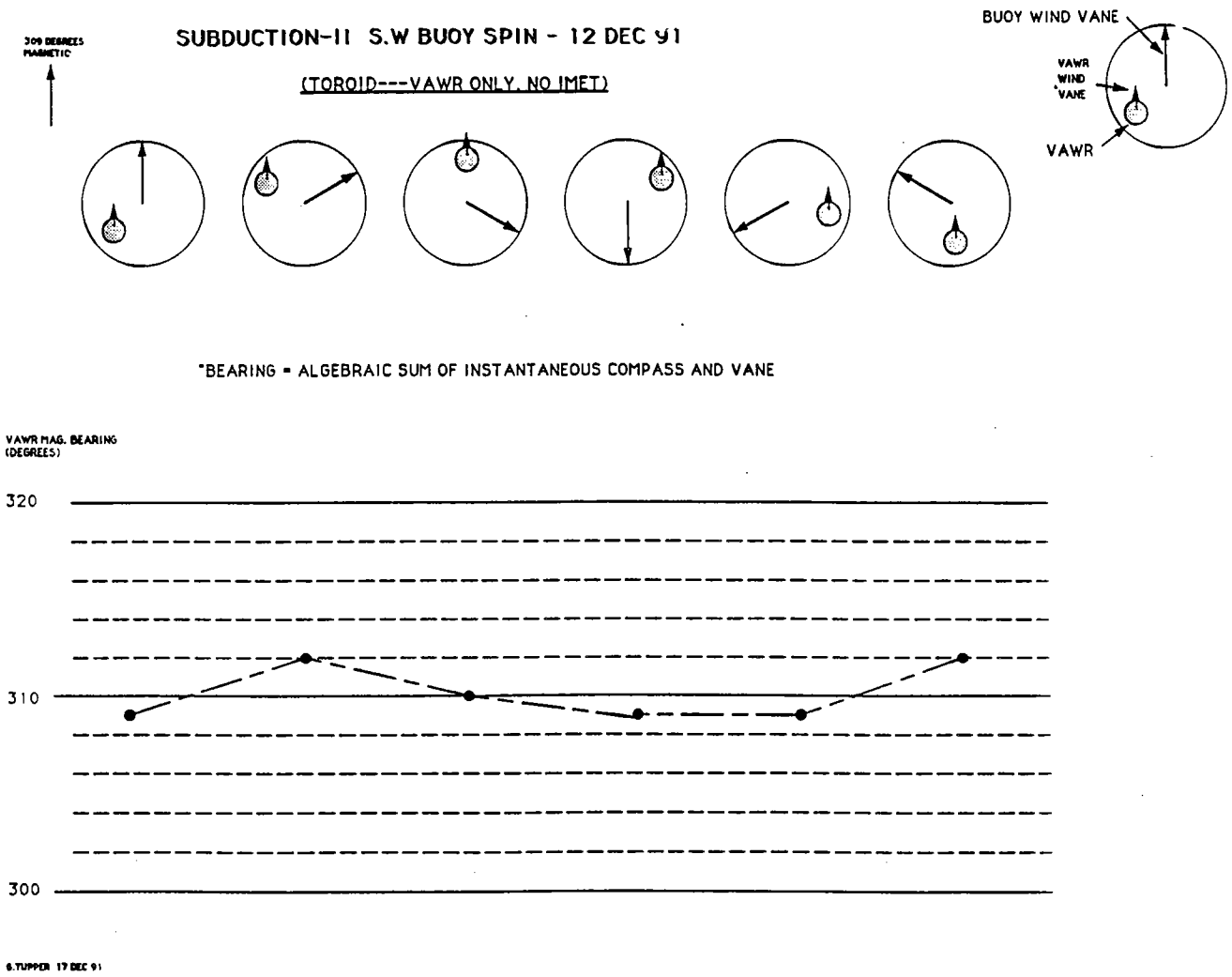
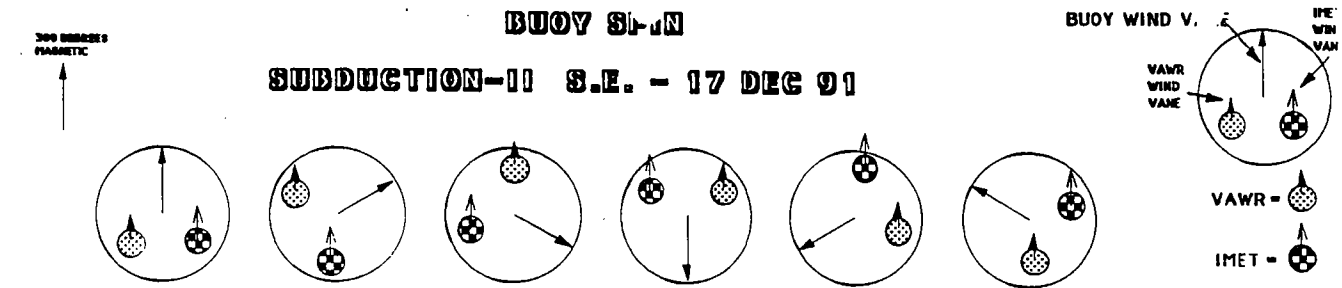
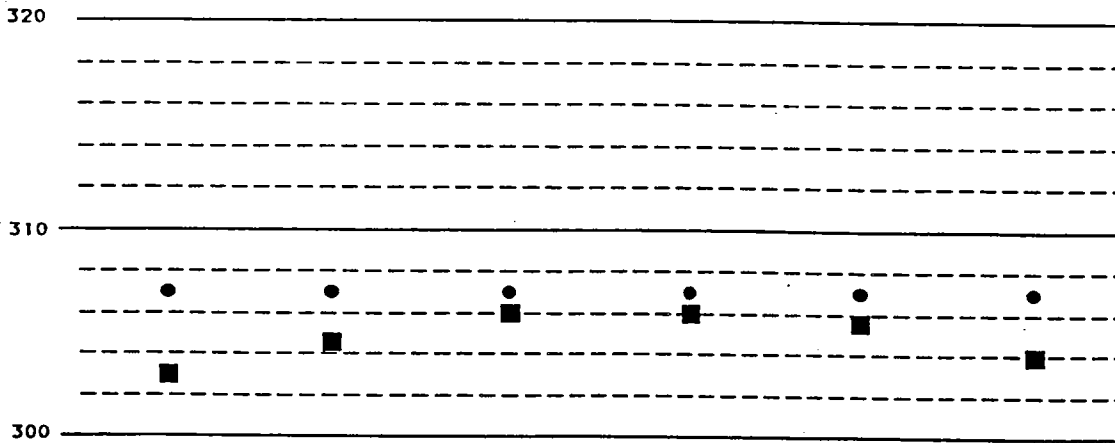


Figure A4-2. Wind Direction Comparison Test for Subduction 2 Southeast Buoy.



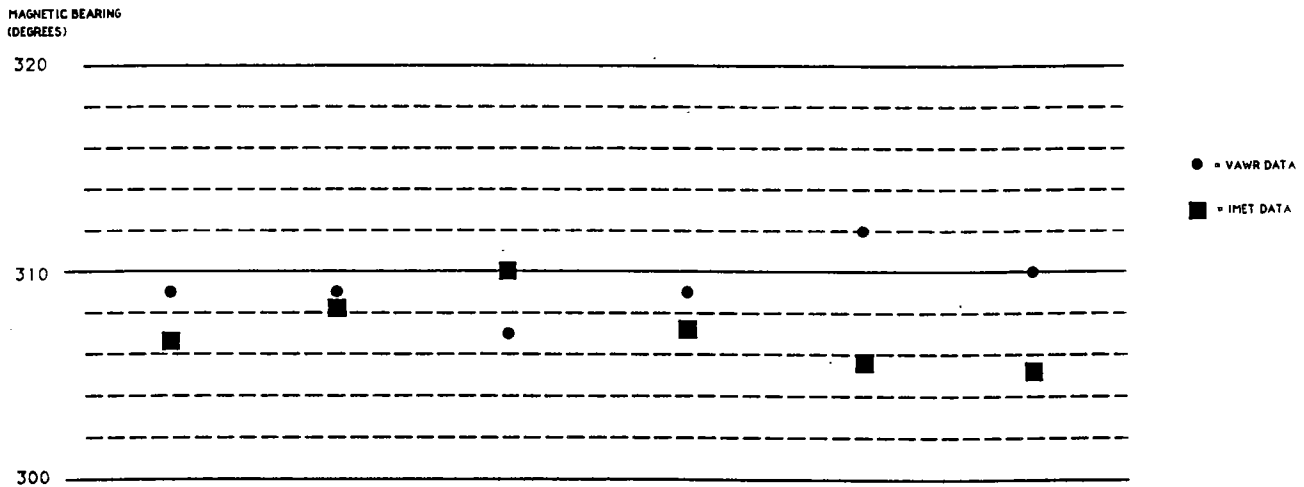
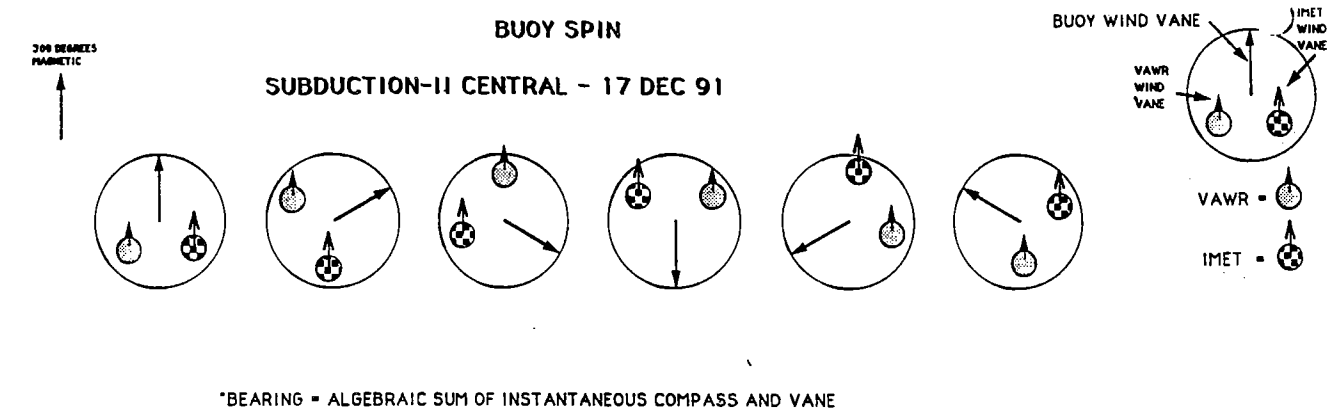
*BEARING = ALGEBRAIC SUM OF INSTANTANEOUS COMPASS AND VANE

MAGNETIC BEARING
(DEGREES)



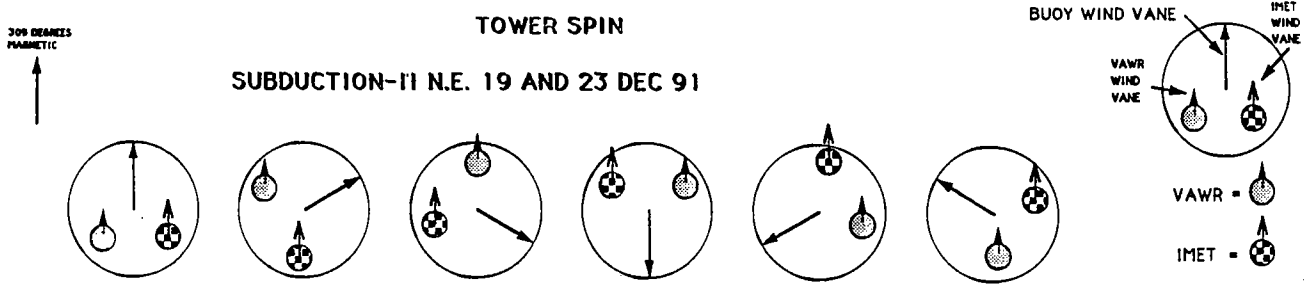
● - VAWR DATA
■ - IMET DATA

Figure A4-3. Wind Direction Comparison Test for Subduction 2 Central Buoy.



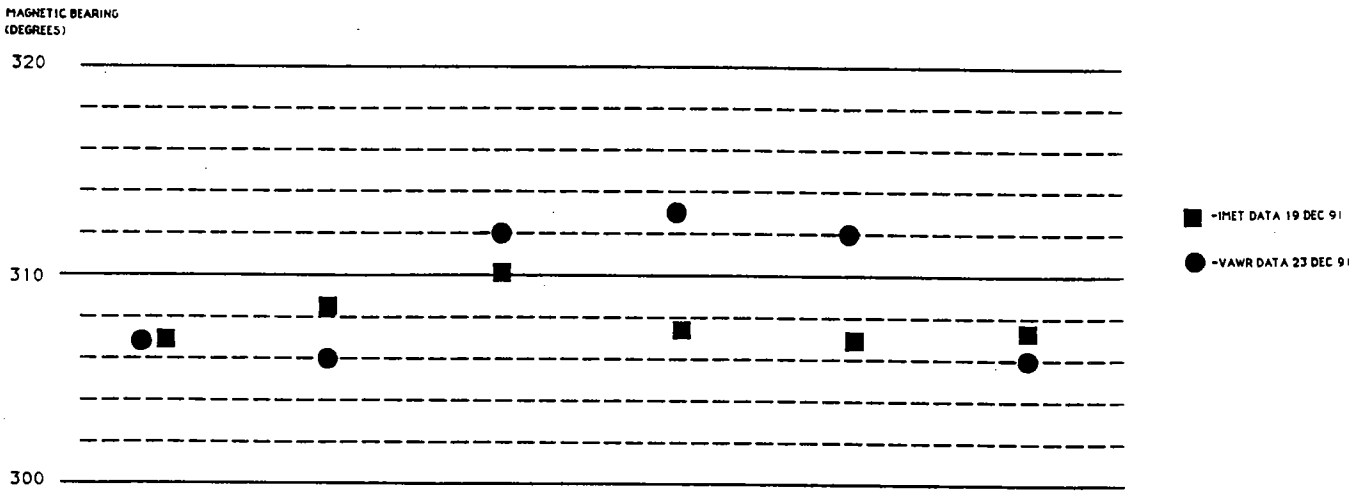
0.TUPPER 17 DEC 91

Figure A4-4. Wind Direction Comparison Test for Subduction 2 Northeast Buoy.



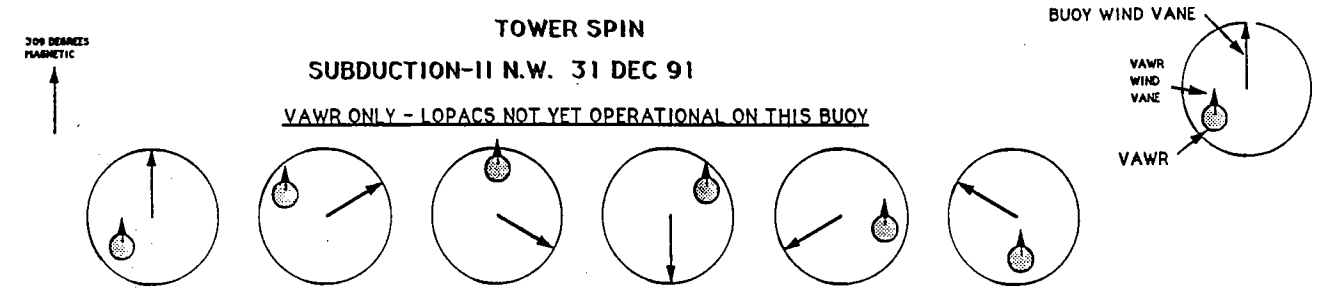
NOTE - VAWR DATA WAS BAD ON THE FIRST SPIN DONE ON 19 DEC 91. THE VANE FOLLOWER WAS REPLACED AND THE TOWER SPUN AGAIN ON 23 DEC. THE IMET DATA IS FROM 19 DEC, THE VAWR FROM THE 23RD.

*BEARING = ALGEBRAIC SUM OF INSTANTANEOUS COMPASS AND VANE



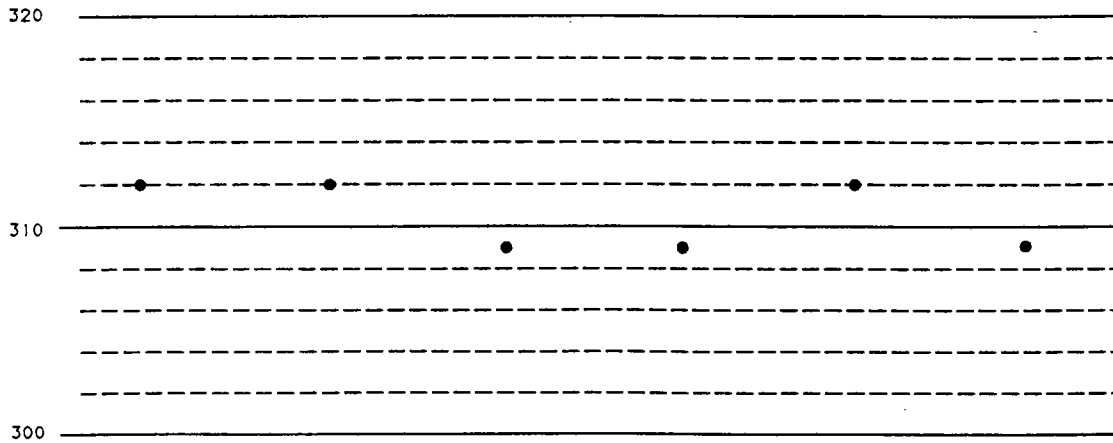
6.TUPPER 19 DEC 91
8.WAY 23 DEC 91

Figure A4-5. Wind Direction Comparison Test for Subduction 2 Northwest Buoy.



*BEARING = ALGEBRAIC SUM OF INSTANTANEOUS COMPASS AND VANE

VAWR MAG. BEARING
(DEGREES)



S.W.A. 31 DEC 91

Appendix 5 ALACE Deployments

ALACE (Autonomous Lagrangian Circulation Explorer) is a freely drifting body that has been ballasted to be neutrally buoyant at a depth of about 400 meters. Periodically it pumps oil from an internal bladder to an external bladder, changing its displacement and causing it to rise to the surface. Any data taken during the previous dive is then relayed to shore using the ARGOS satellite system. Estimates of the average current experienced by the buoy while submerged are computed from ARGOS fixes of the buoy's positions at the start and end of a dive. The buoy remains at the surface transmitting for one day. After retracting the external bladder, it sinks back to its resting depth. Between 50 and 100 dive cycles can be repeated before the batteries are exhausted.

The ALACE's deployed during Oc-250 were of two different types. Ten instruments were deployed which measured the profile of temperature versus depth with a vertical resolution of about 10 meters and a temperature resolution of .02 degree Celsius. These ALACEs repeated their dive cycle every 10 days. A prototype of a "CTD" ALACE was also deployed during Oc-250. It had improved electronics for measuring pressure and temperature and incorporated an inductive cell to measure water conductivity. The vertical resolution was 5 meters near the surface and increased to 10 meters below about 200 meters. The temperature resolution was several millidegrees Celsius. Conductivity and temperature were processed onboard to estimate salinity. Profiles of temperature, pressure, and salinity were transmitted via ARGOS every 14 days. Three ALACEs were deployed along a ray extending from the Central mooring to the Northeast mooring. The other eight instruments were deployed along the ship's track from the Northeast mooring to the Northwest mooring. Table A5-1 details the ALACE units deployed, variables measured, and the time and position of deployment.

**Table A5-1
ALACE Deployment Information**

Serial No.	Data	Time of Deployment	Deployed Position	
			Latitude	Longitude
46	T,P	13 Feb 1319Z	27 27.580°N	27 06.920°W
101	T,P	14 Feb 0116Z	29 24.140°N	25 23.931°W
98	T,P	14 Feb 1328Z	31 24.180°N	23 30.533°W
100	T,P	21 Feb 0413Z	33 00.642°N	23 28.465°W
97	T,P	21 Feb 1010Z	32 59.368°N	24 50.382°W
103	T,P	21 Feb 1613Z	32 59.396°N	26 13.393°W
59	T,P,C	21 Feb 1615Z	32 59.396°N	26 13.393°W
102	T,P	21 Feb 2211Z	32 59.546°N	27 34.365°W
99	T,P	22 Feb 0411Z	32 58.331°N	28 53.129°W
44	T,P	22 Feb 1207Z	32 57.350°N	30 38.513°W
96	T,P	22 Feb 2006Z	32 56.675°N	32 25.669°W

T=temperature, P=pressure, C=conductivity

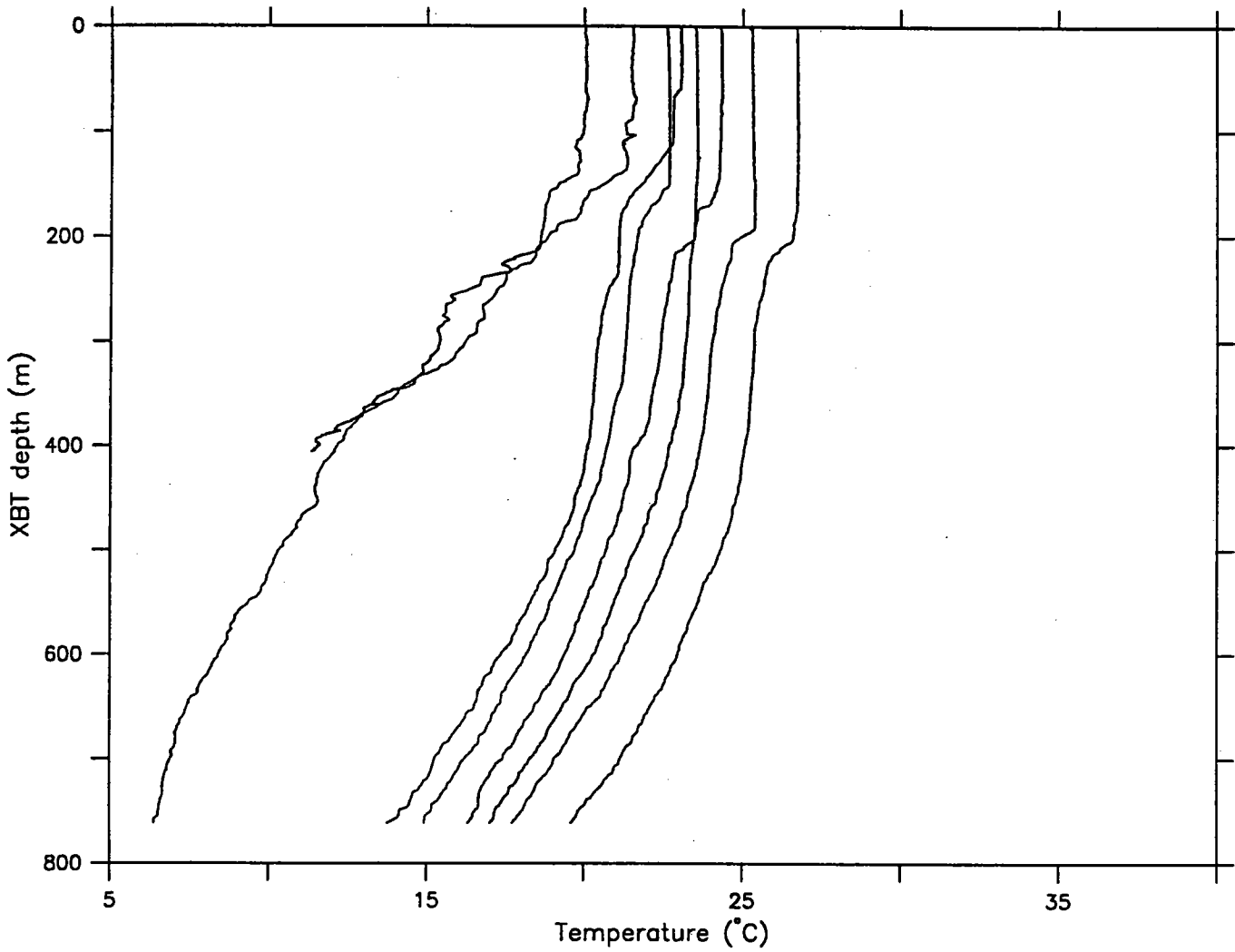
Appendix 6 XBT Data

Three hundred and twelve XBTs were deployed during Oc-250. The T-7 probes were purchased from Sparton of Canada Ltd. The XBT data was logged on a NEC APC IV which had a Spartan data acquisition microprocessor card installed. The digital data was simultaneously logged in memory and plotted on the screen.

Figure A6-1 (a through dd) shows the XBT profiles in groups of ten. Table A6-1 contains the positions and time of the XBTs. Figure A6-2a shows the ship track where the hourly XBTs were dropped. Figure A6-2b through A6-2d are contour plots of XBT temperatures at the surface, 200 meters depth, and 500 meters depth respectively. Figure A6-3 details the location of the XBT sections that appear in Figures A6-4a and A6-4b.

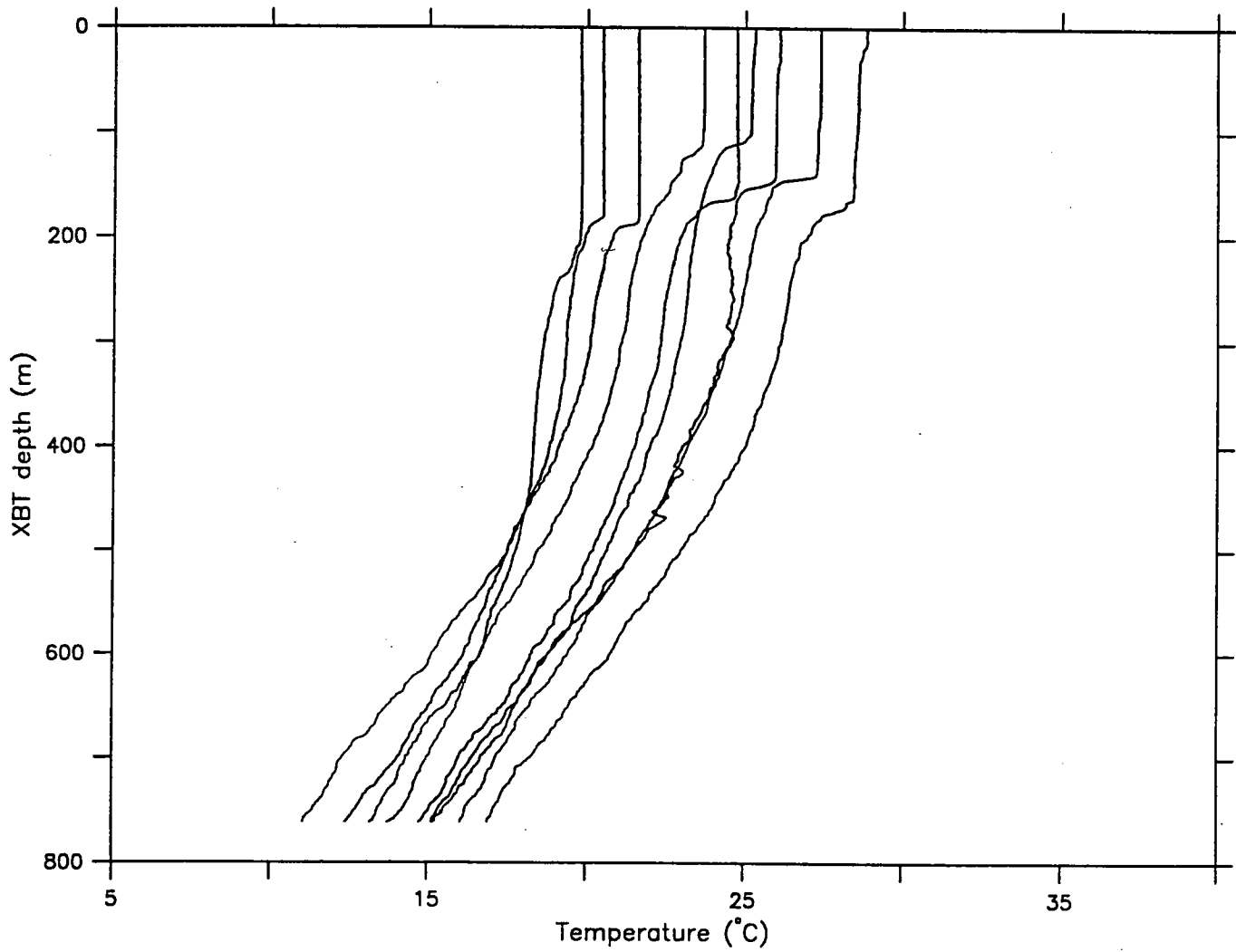
Numbering of XBTs jumps from 223 to 234.

Figure A6-1a. Overplot of XBT Profiles 1-9
Successive Profiles are offset by 1° C.



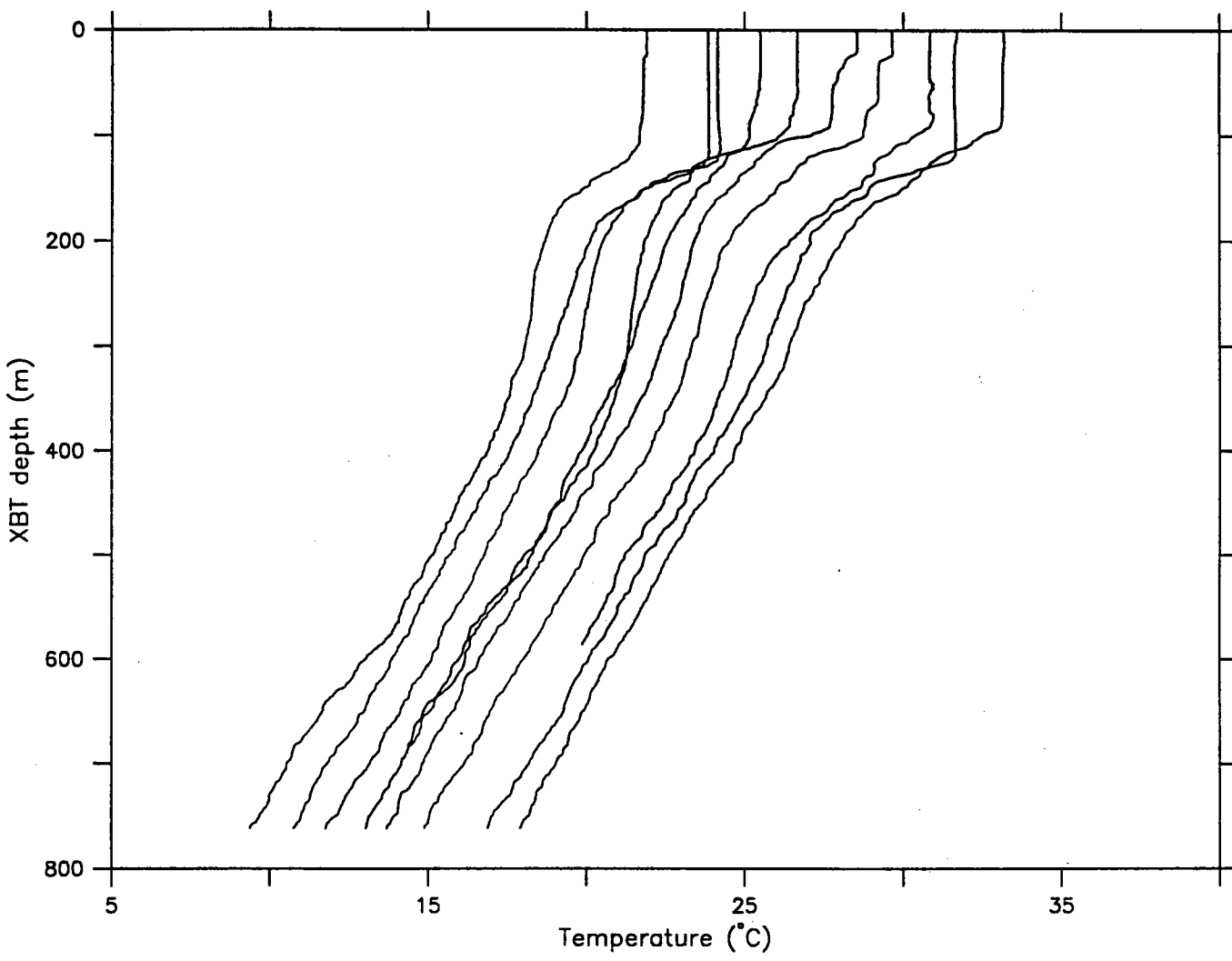
Subduction II XBT start: 1 offset by 1°C

Figure A6-1b. Overplot of XBT Profiles 10-19
Successive Profiles are offset by 1° C.



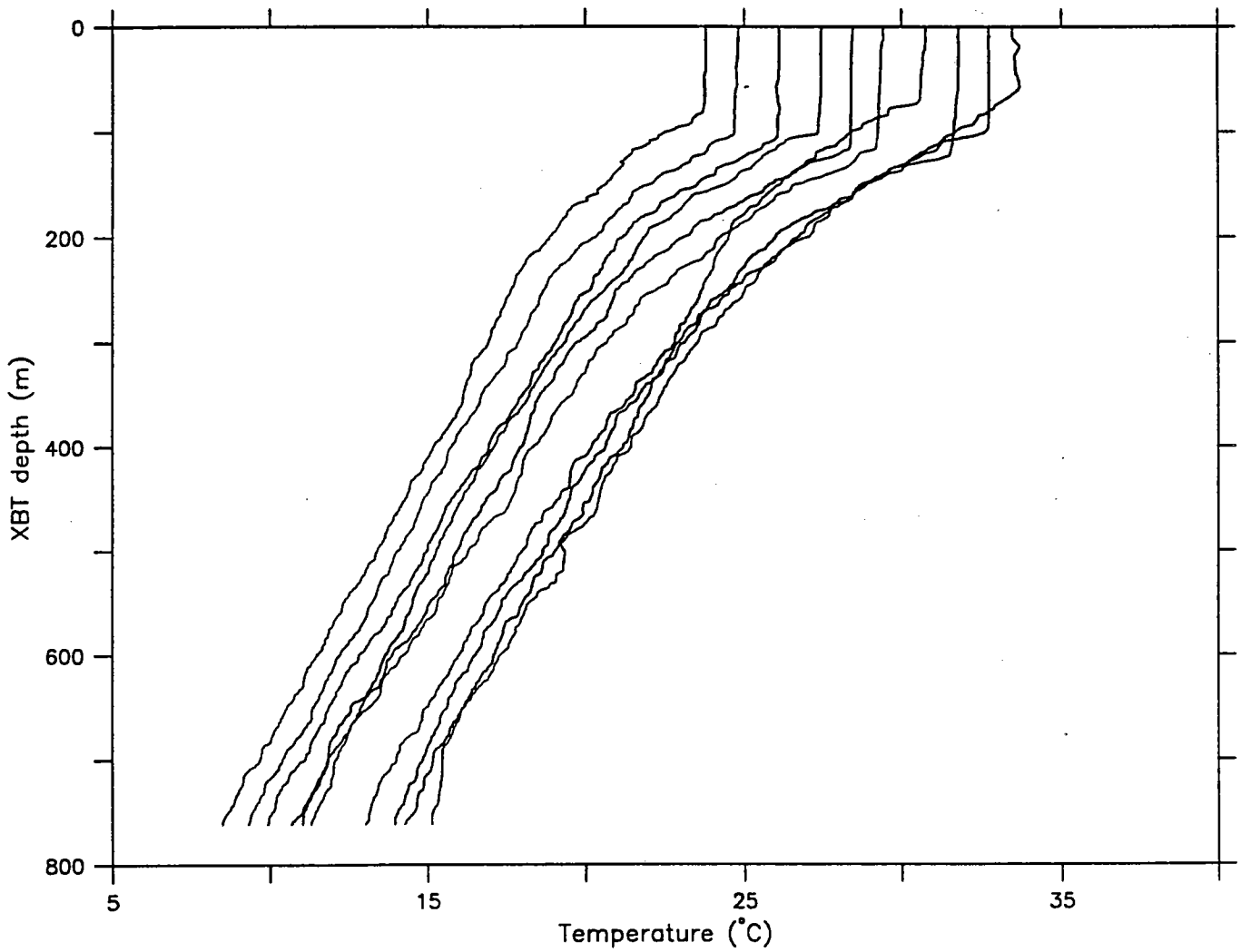
Subduction II XBT start: 10 offset by 1°C

Figure A6-1c. Overplot of XBT Profiles 20-29
Successive Profiles are offset by 1° C.



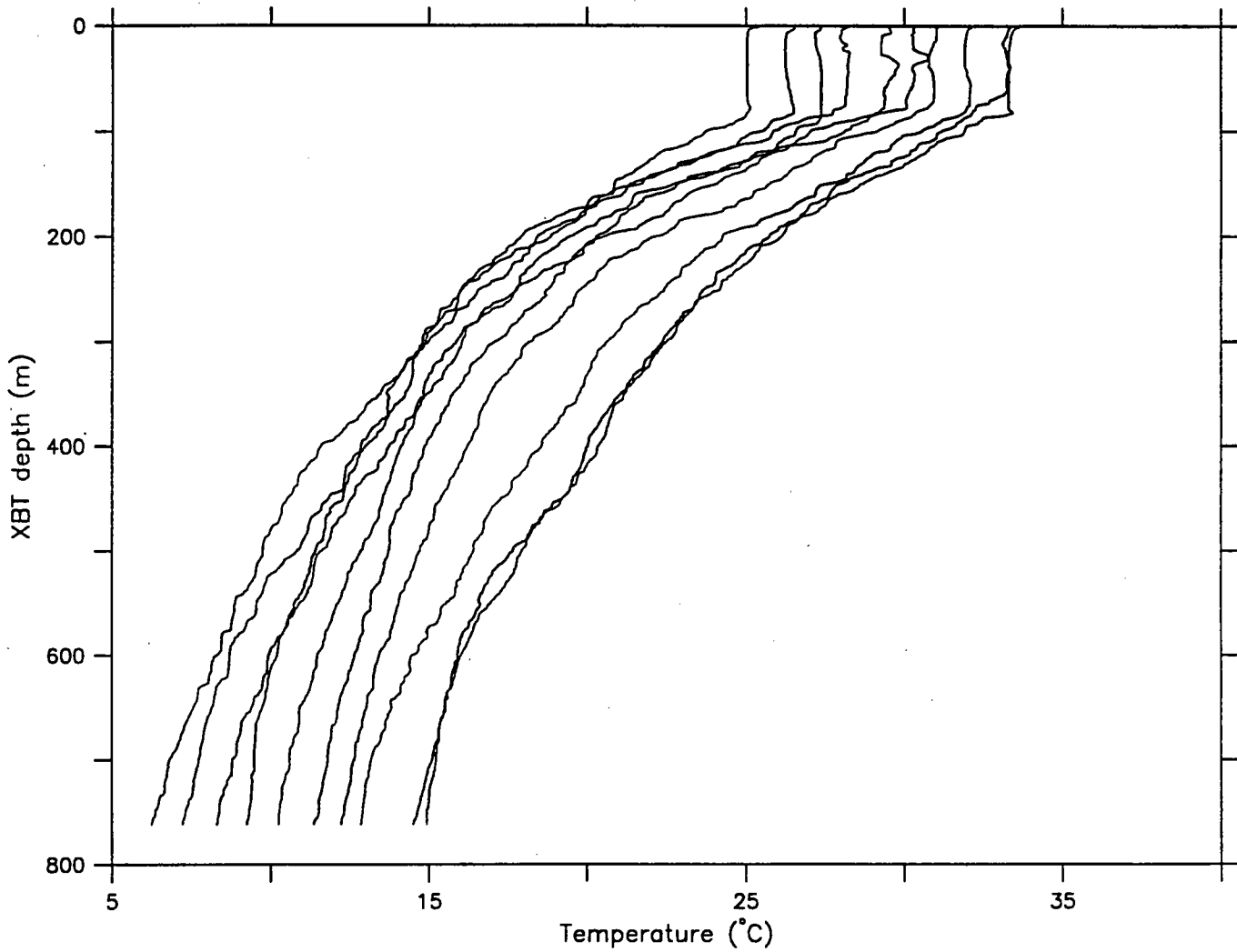
Subduction II XBT start: 20 offset by 1°C

Figure A6-1d. Overplot of XBT Profiles 30-39
Successive Profiles are offset by 1° C.



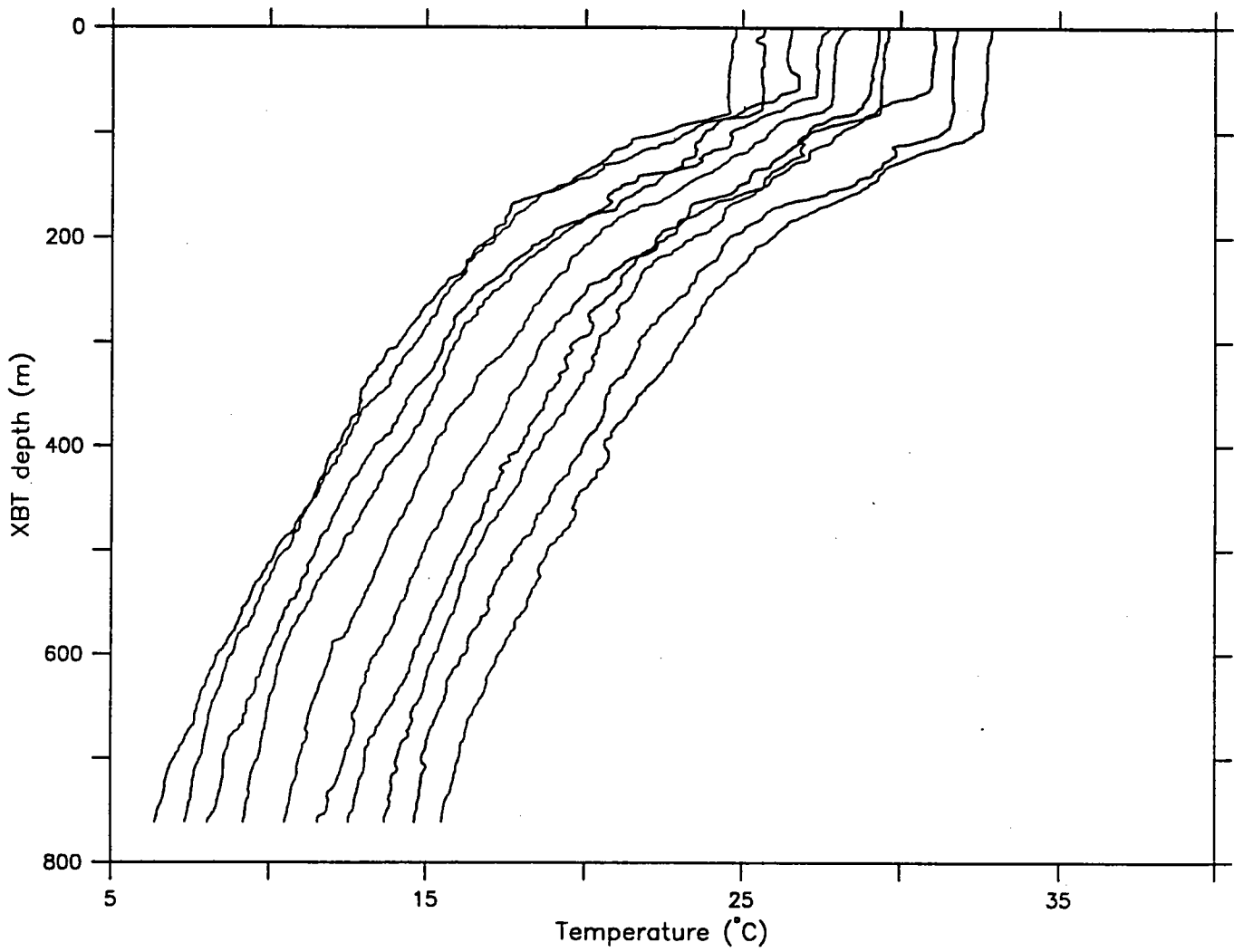
Subduction II XBT start: 30 offset by 1°C

Figure A6-1e. Overplot of XBT Profiles 40-49
Successive Profiles are offset by 1° C.



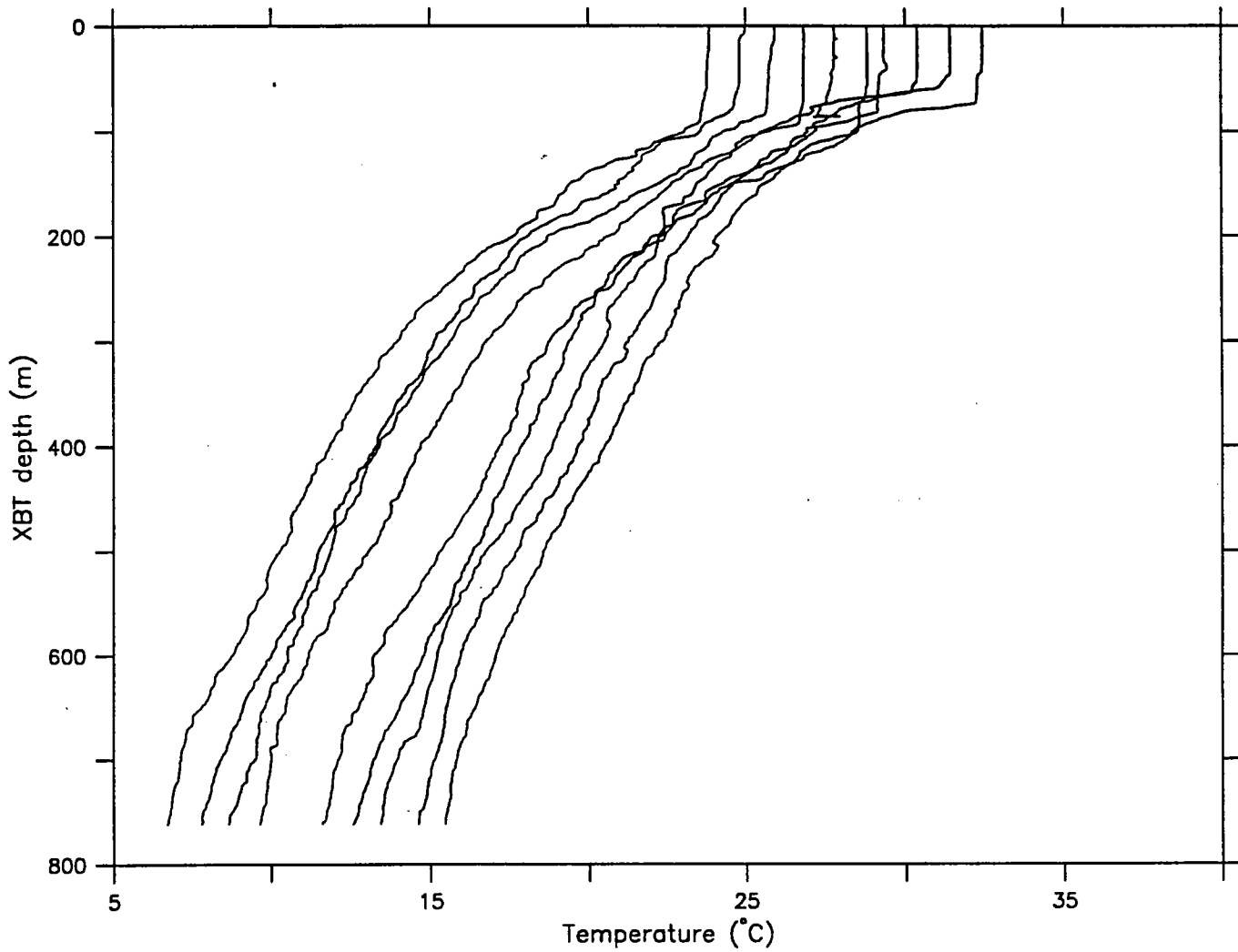
Subduction II XBT start: 40 offset by 1°C

Figure A6-1f. Overplot of XBT Profiles 50-59
Successive Profiles are offset by 1° C.



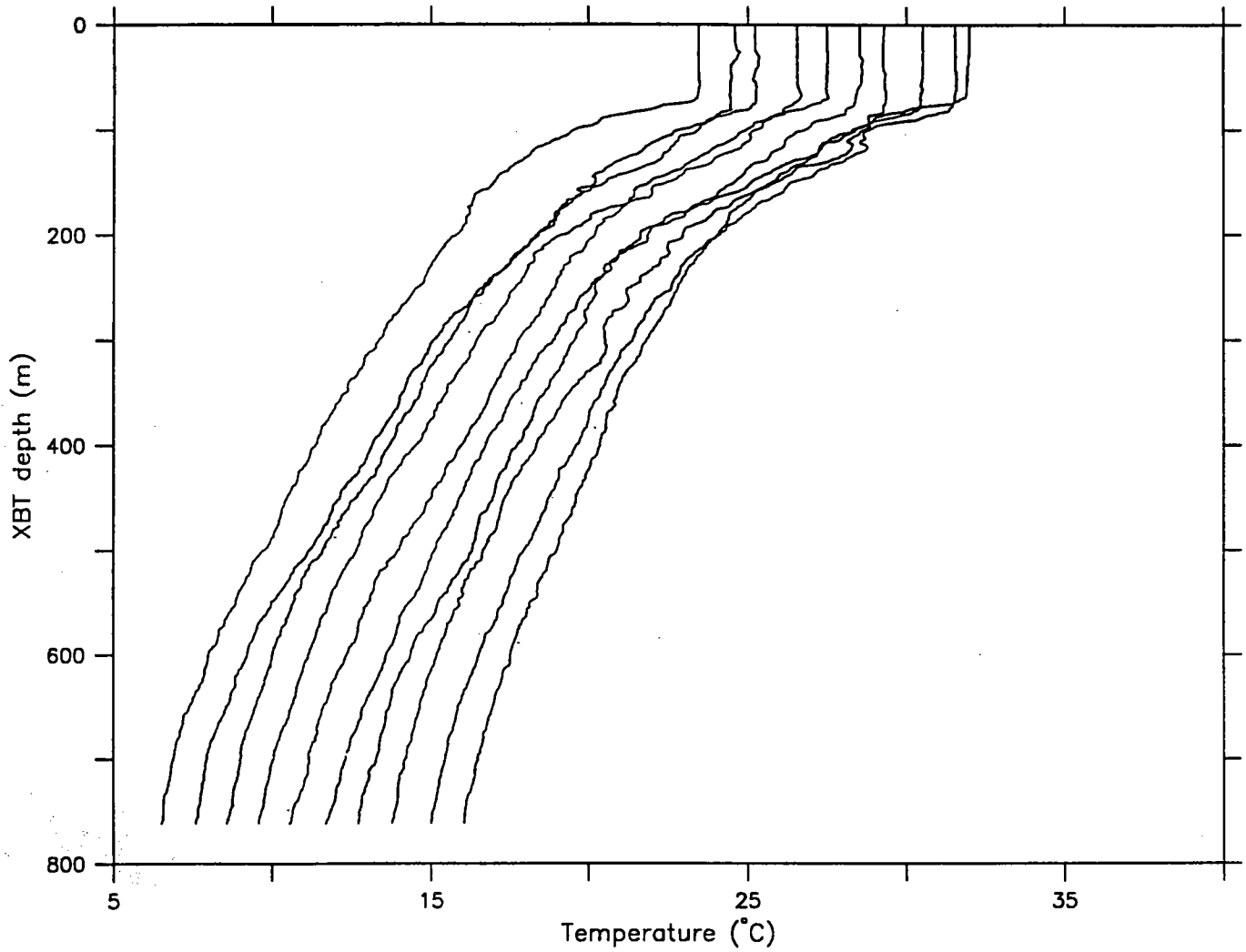
Subduction II XBT start: 50 offset by 1° C

Figure A6-1g. Overplot of XBT Profiles 60-69
Successive Profiles are offset by 1° C.



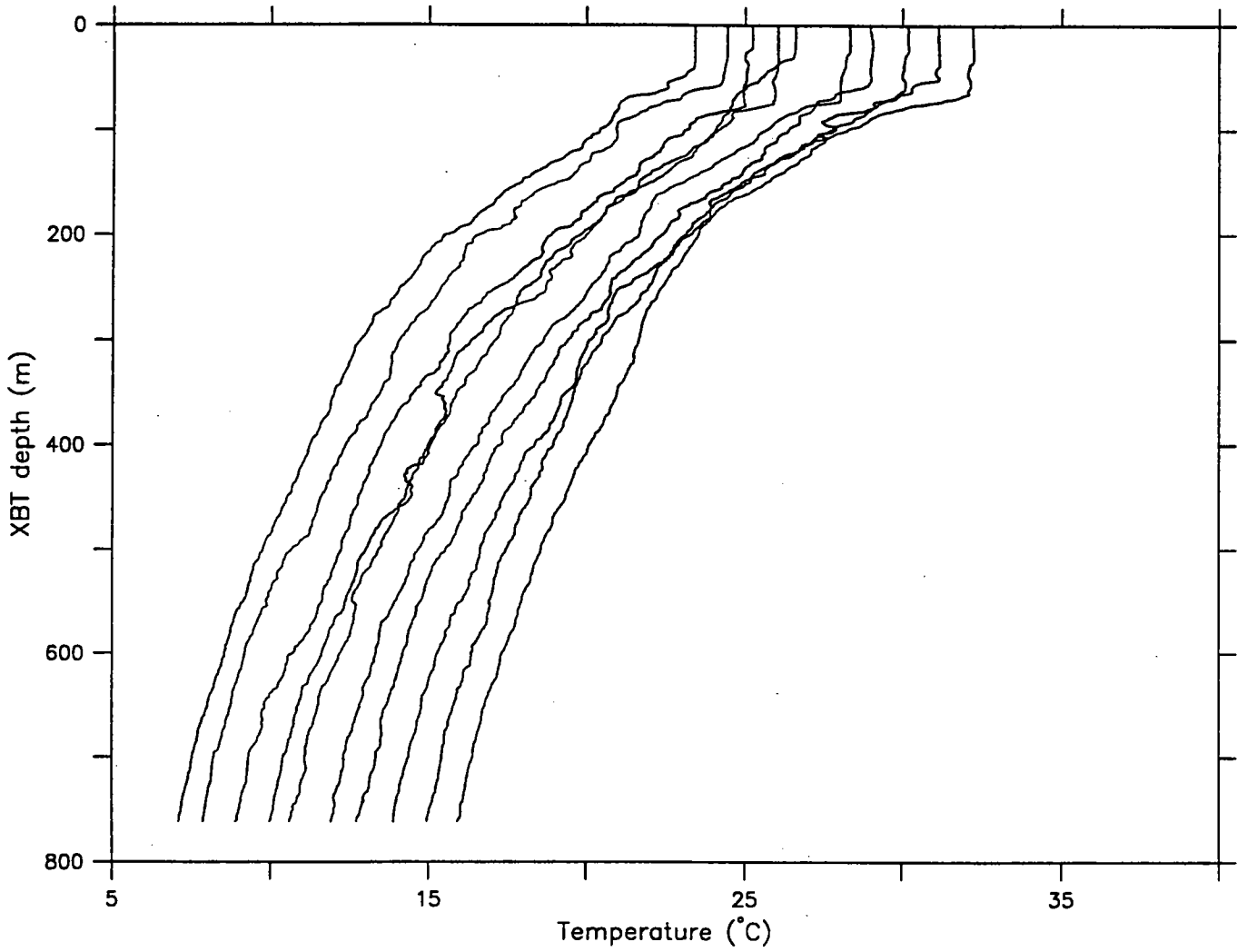
Subduction II XBT start: 60 offset by 1° C

Figure A6-1h. Overplot of XBT Profiles 70-79
Successive Profiles are offset by 1° C.



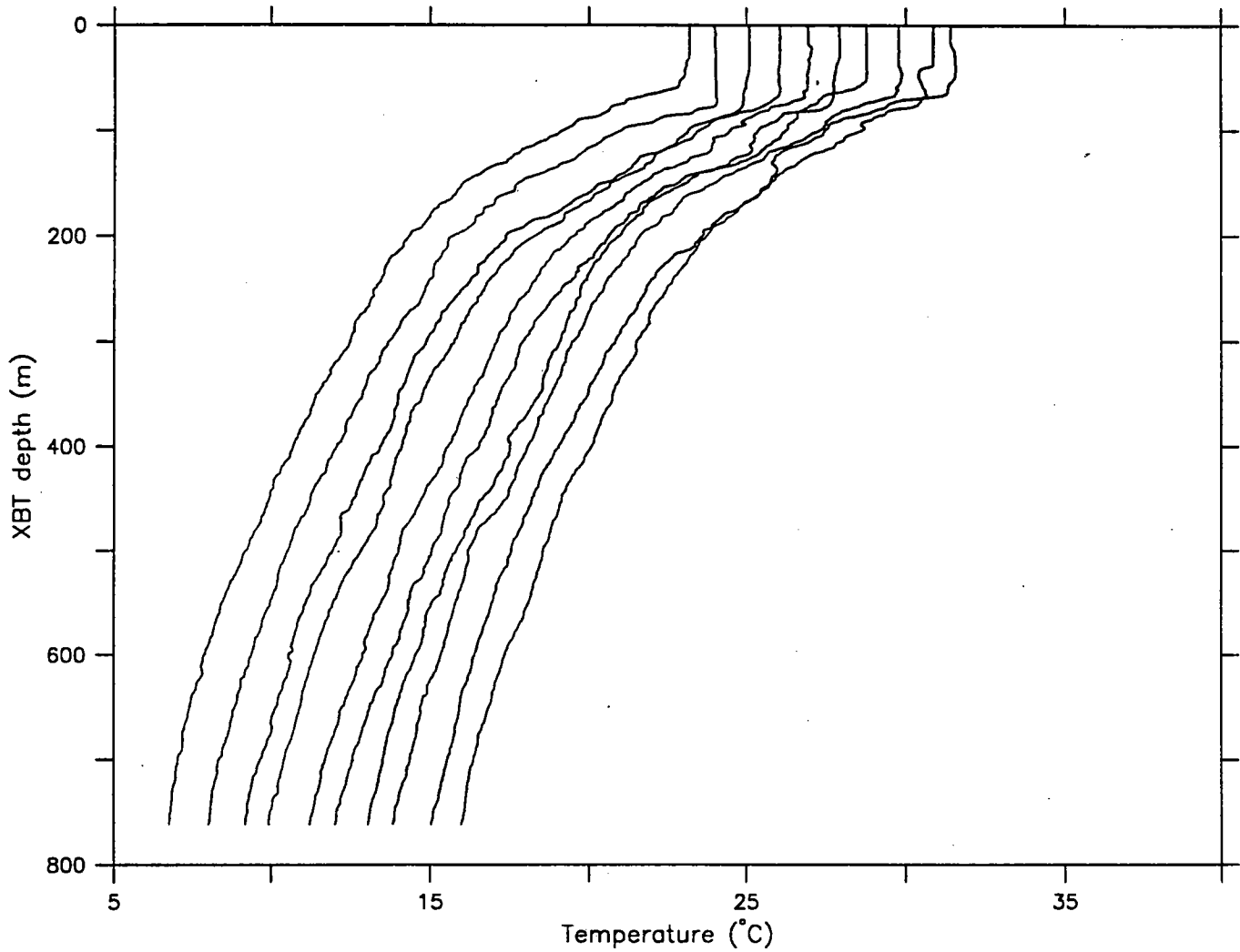
Subduction II XBT start: 70 offset by 1°C

Figure A6-1i. Overplot of XBT Profiles 80-89
Successive Profiles are offset by 1° C.



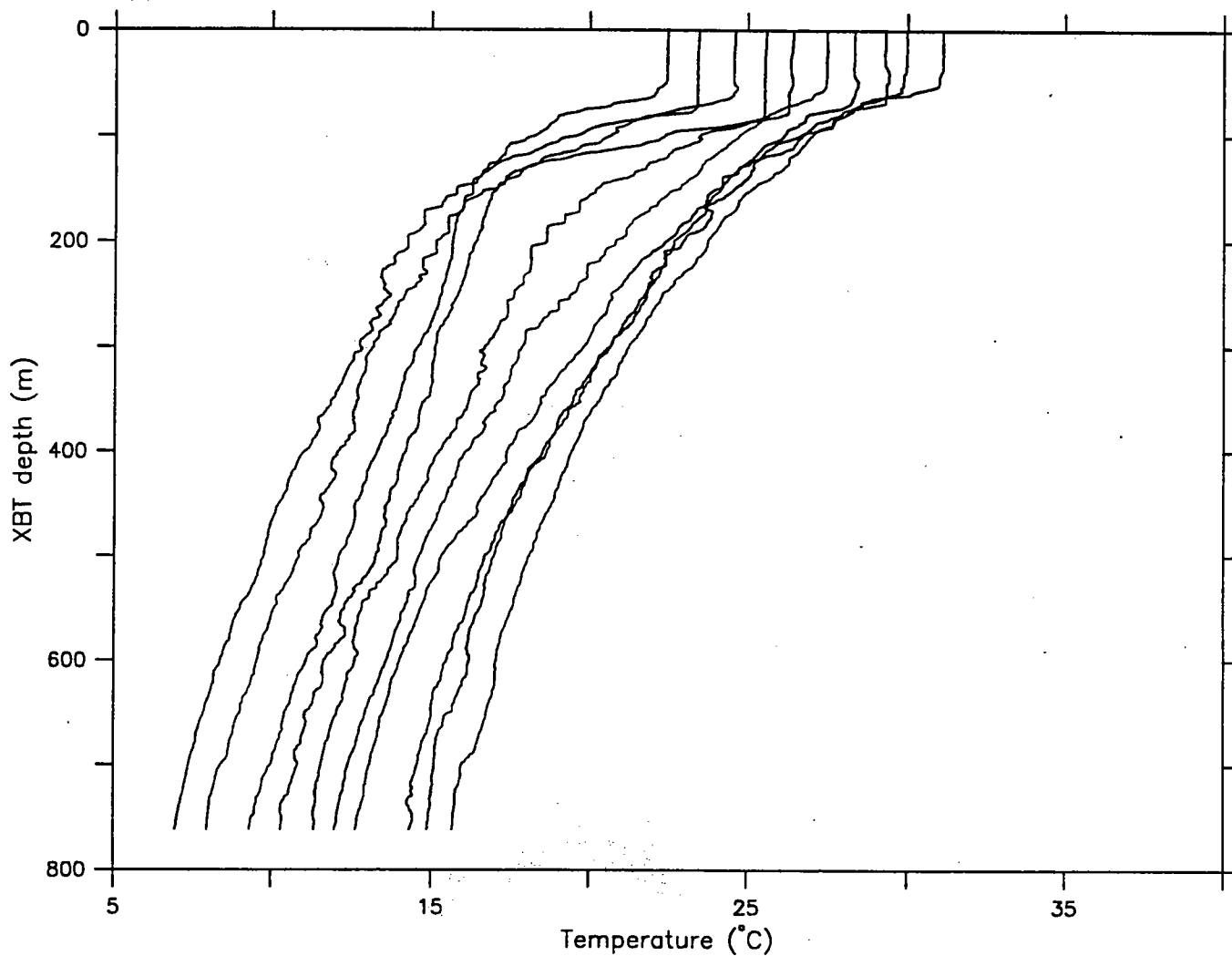
Subduction II XBT start: 80 offset by 1°C

Figure A6-1j. Overplot of XBT Profiles 90-99
Successive Profiles are offset by 1° C.



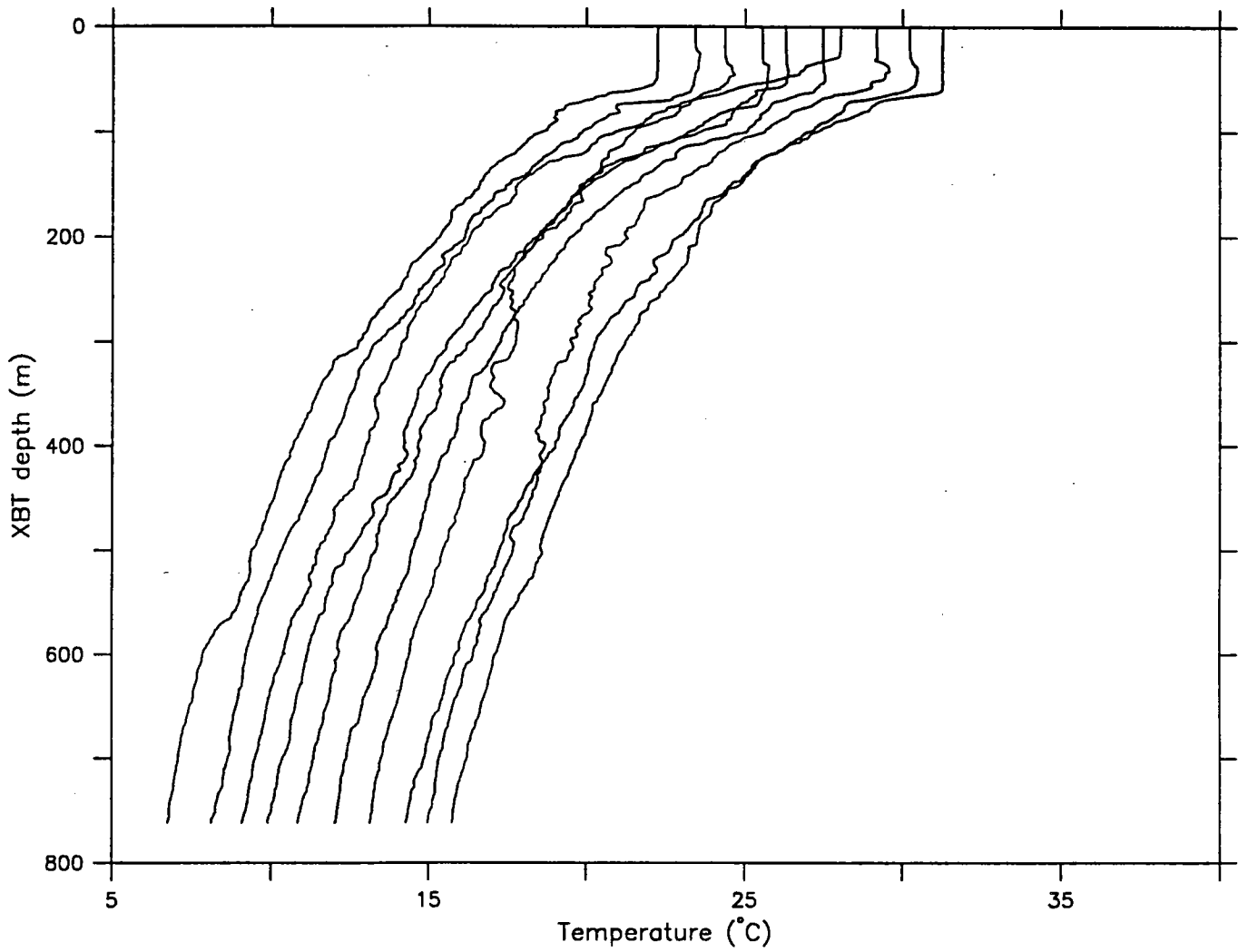
Subduction II XBT, start: 90 offset by 1° C

Figure A6-1k. Overplot of XBT Profiles 100-109
Successive Profiles are offset by 1° C.



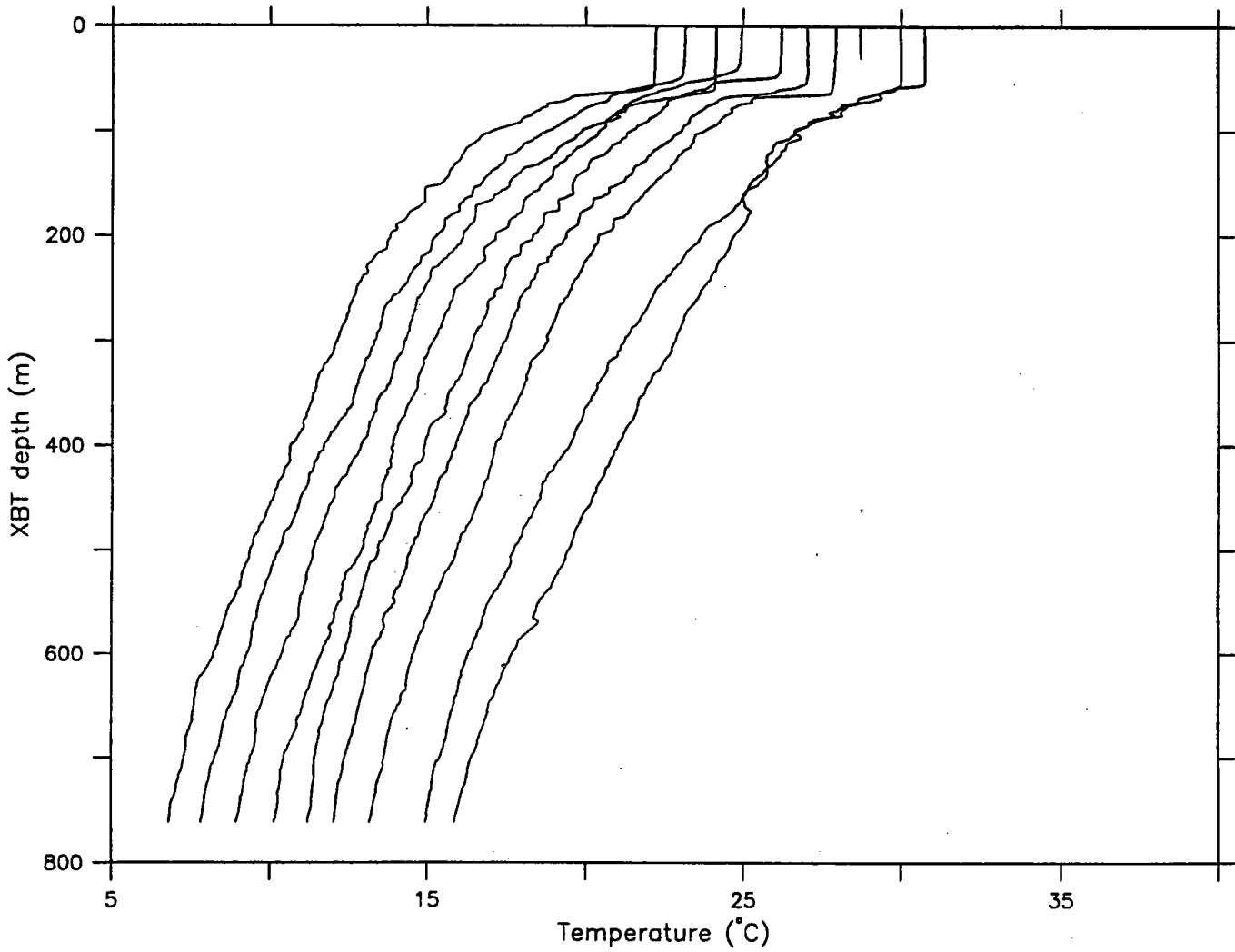
Subduction II XBT start: 100 offset by 1°C

Figure A6-11. Overplot of XBT Profiles 110-119
Successive Profiles are offset by 1° C.



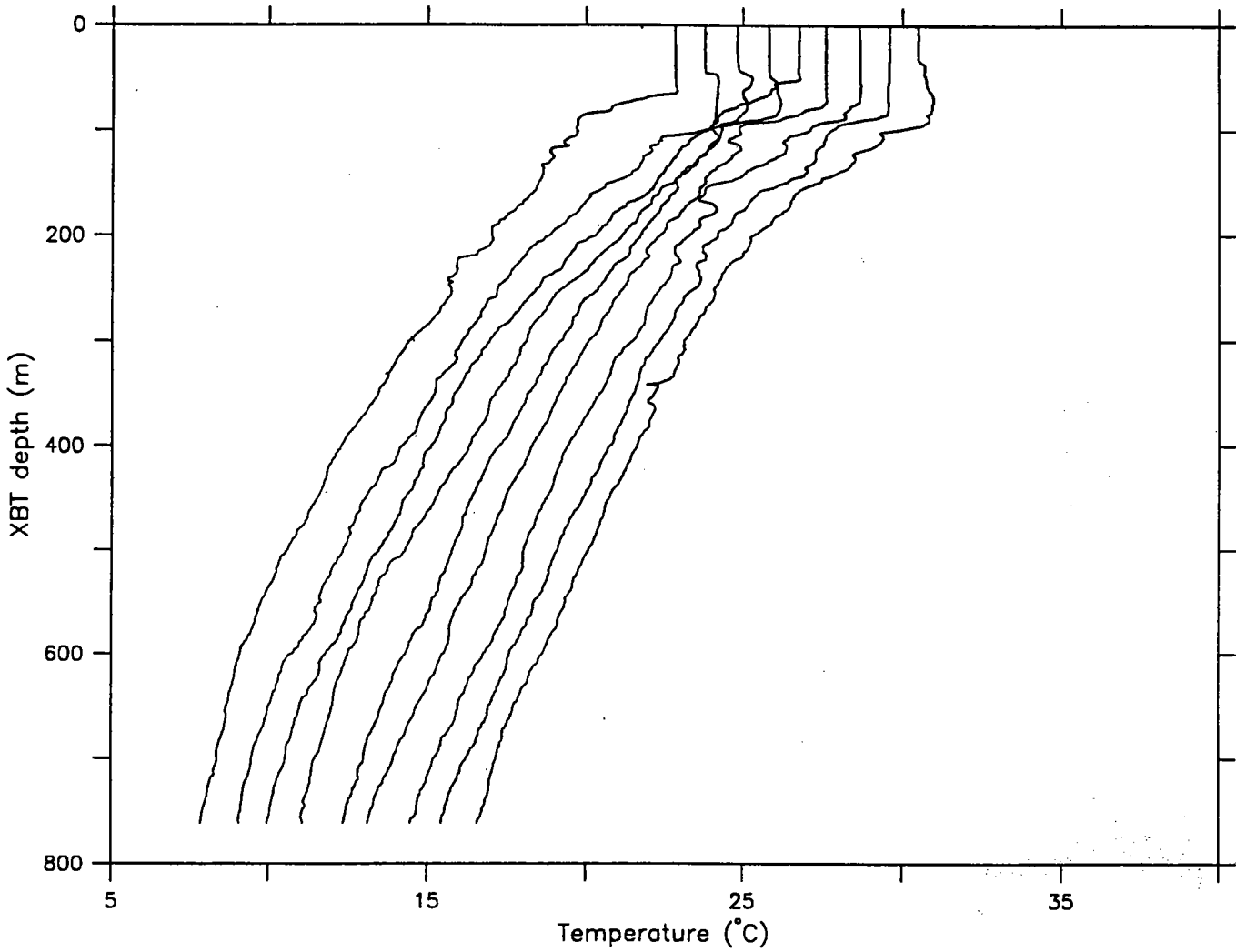
Subduction II XBT start: 110 offset by 1°C

Figure A6-1m. Overplot of XBT Profiles 120-129
Successive Profiles are offset by 1° C.



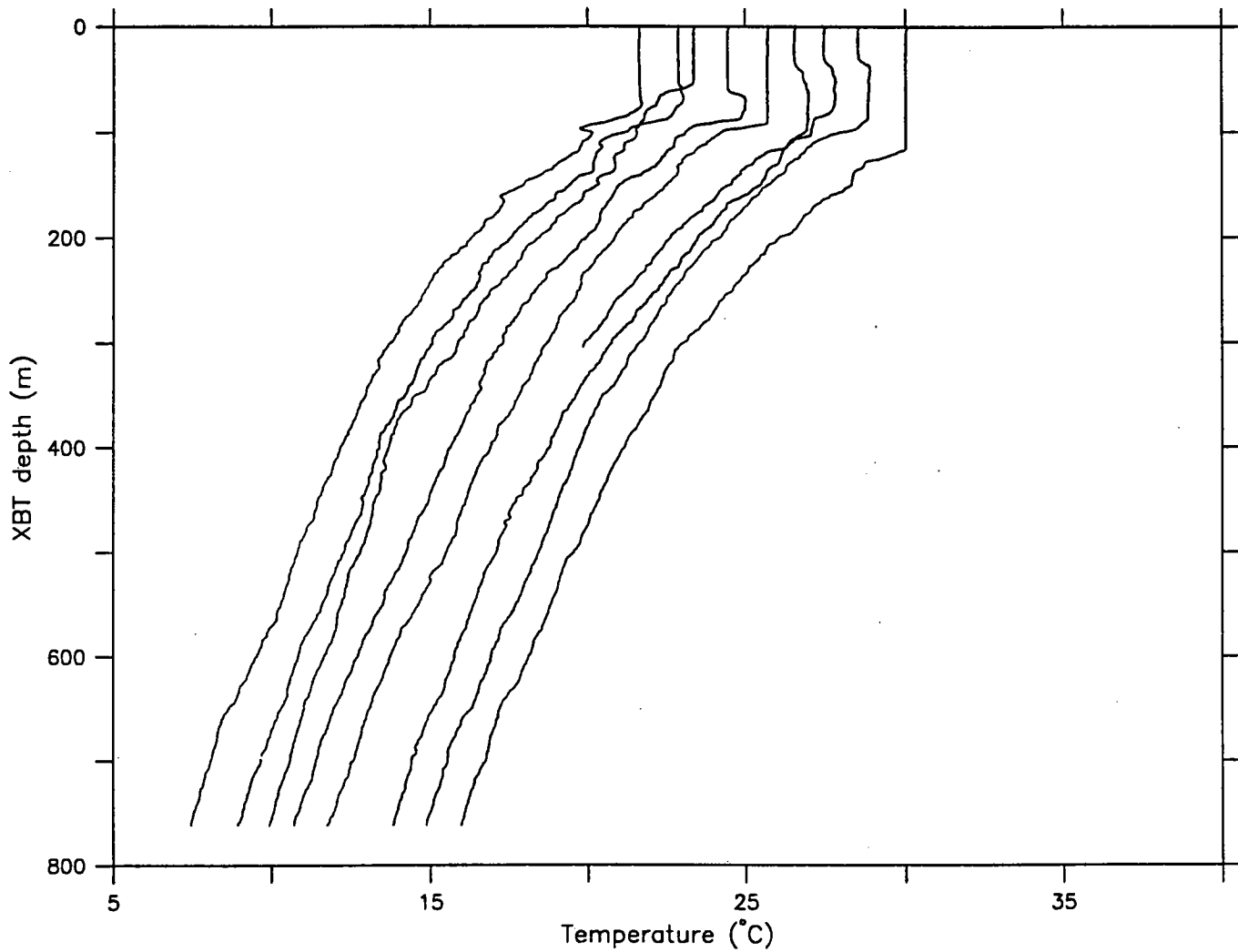
Subduction II XBT start: 120 offset by 1°C

Figure A6-1n. Overplot of XBT Profiles 130-139
Successive Profiles are offset by 1° C.



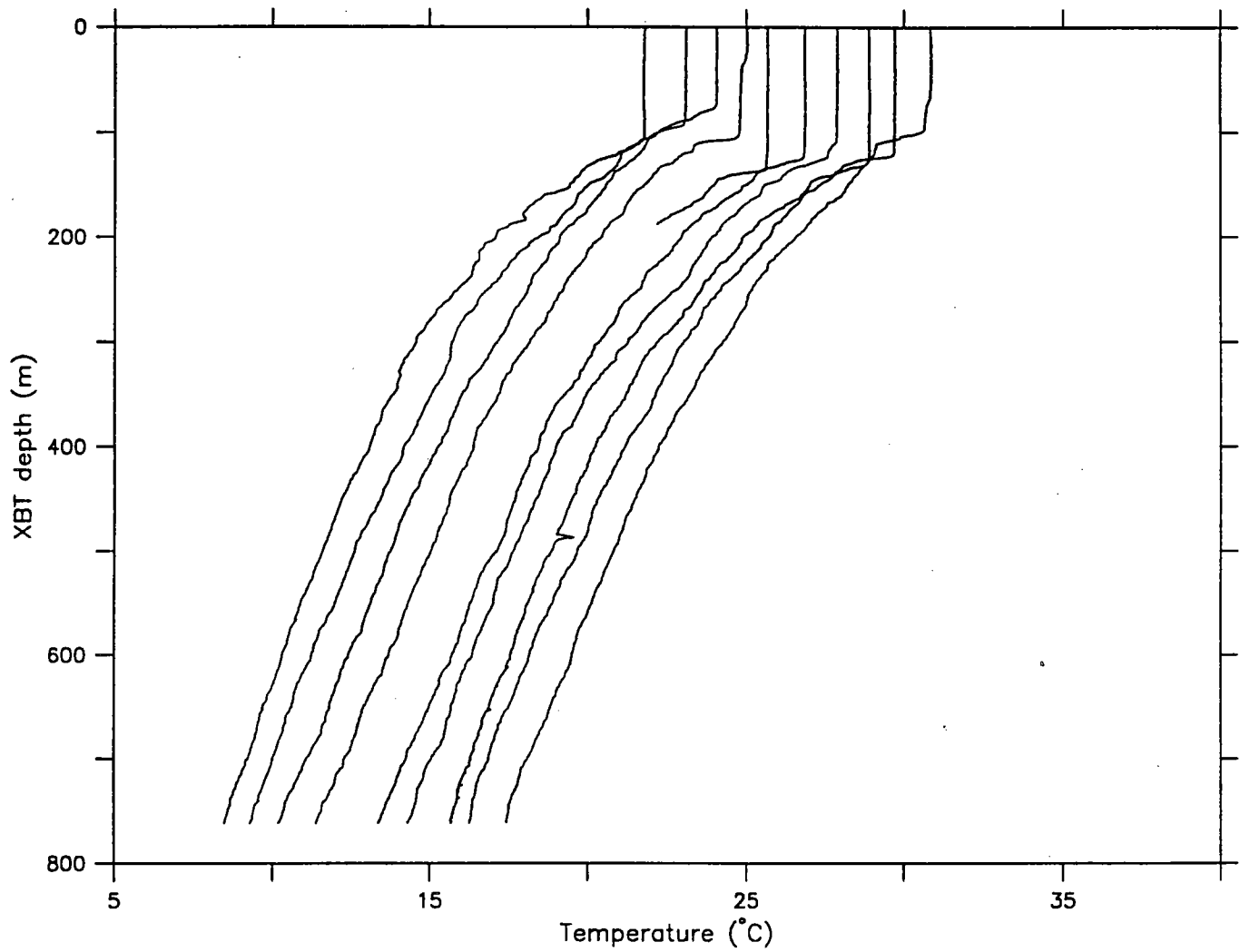
Subduction II XBT start: 130 offset by 1°C

Figure A6-10. Overplot of XBT Profiles 140-149
Successive Profiles are offset by 1° C.



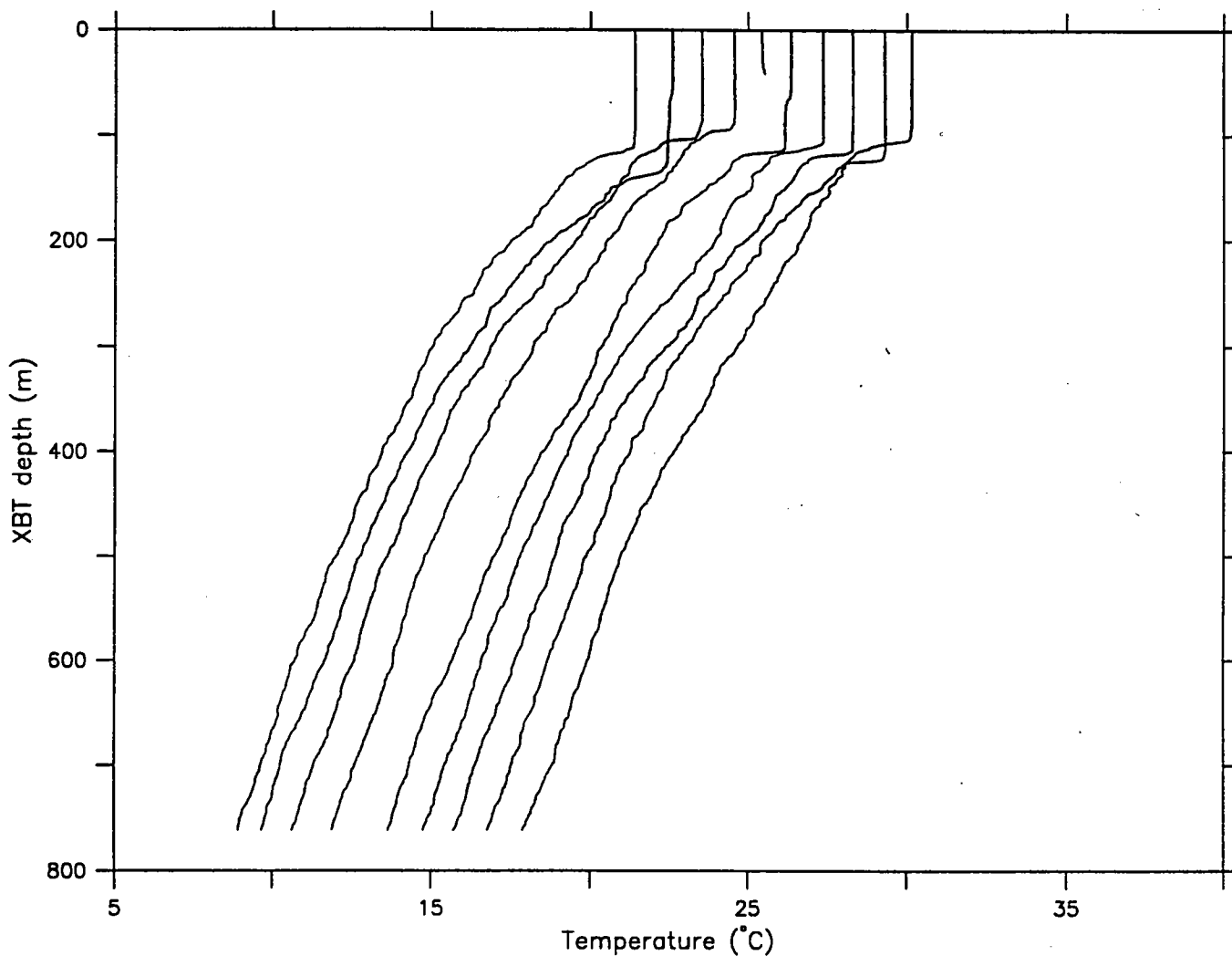
Subduction II XBT start: 140 offset by 1°C

Figure A6-1p. Overplot of XBT Profiles 150-159
Successive Profiles are offset by 1° C.



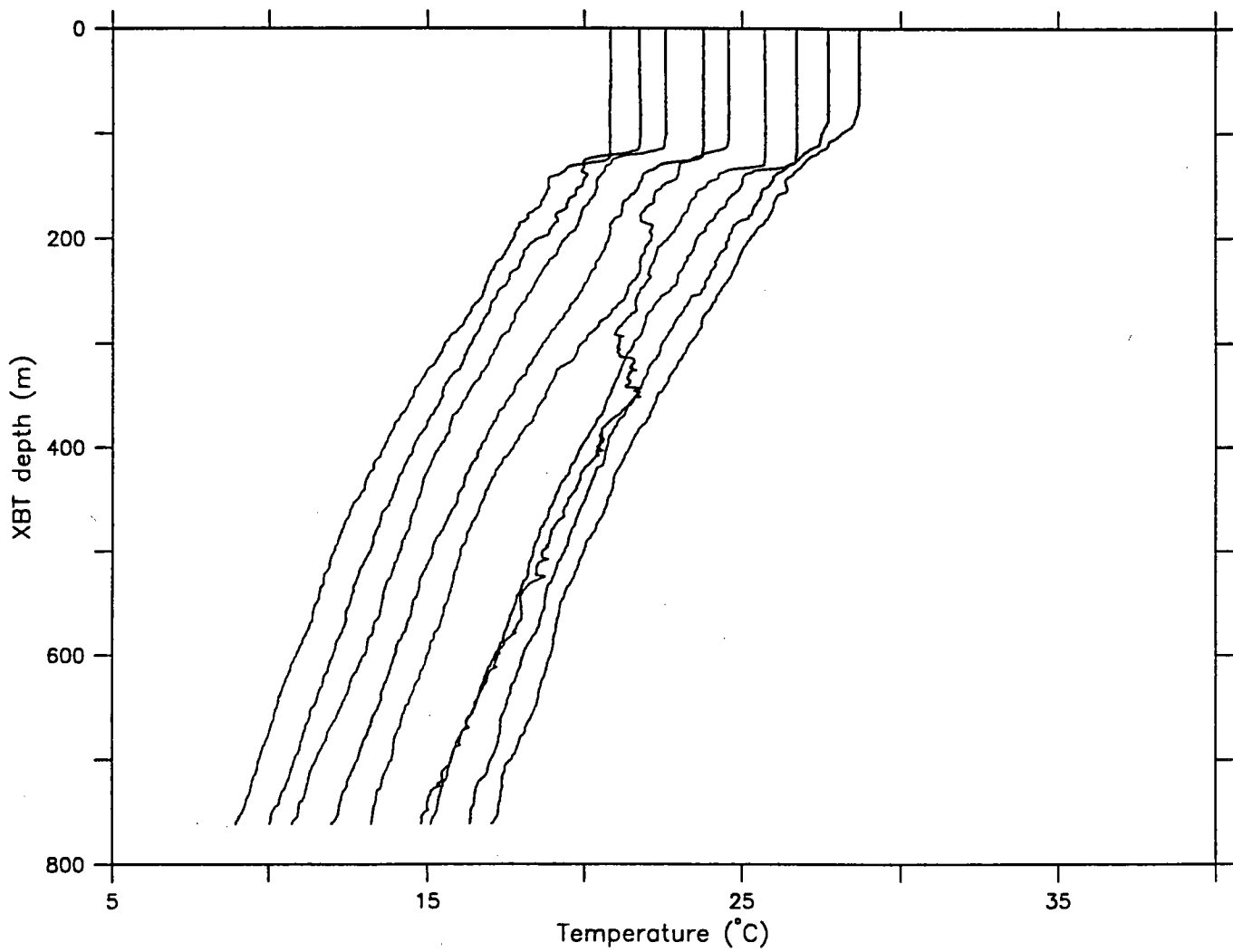
Subduction II XBT start: 150 offset by 1°C

Figure A6-1q. Overplot of XBT Profiles 160-169
Successive Profiles are offset by 1° C.



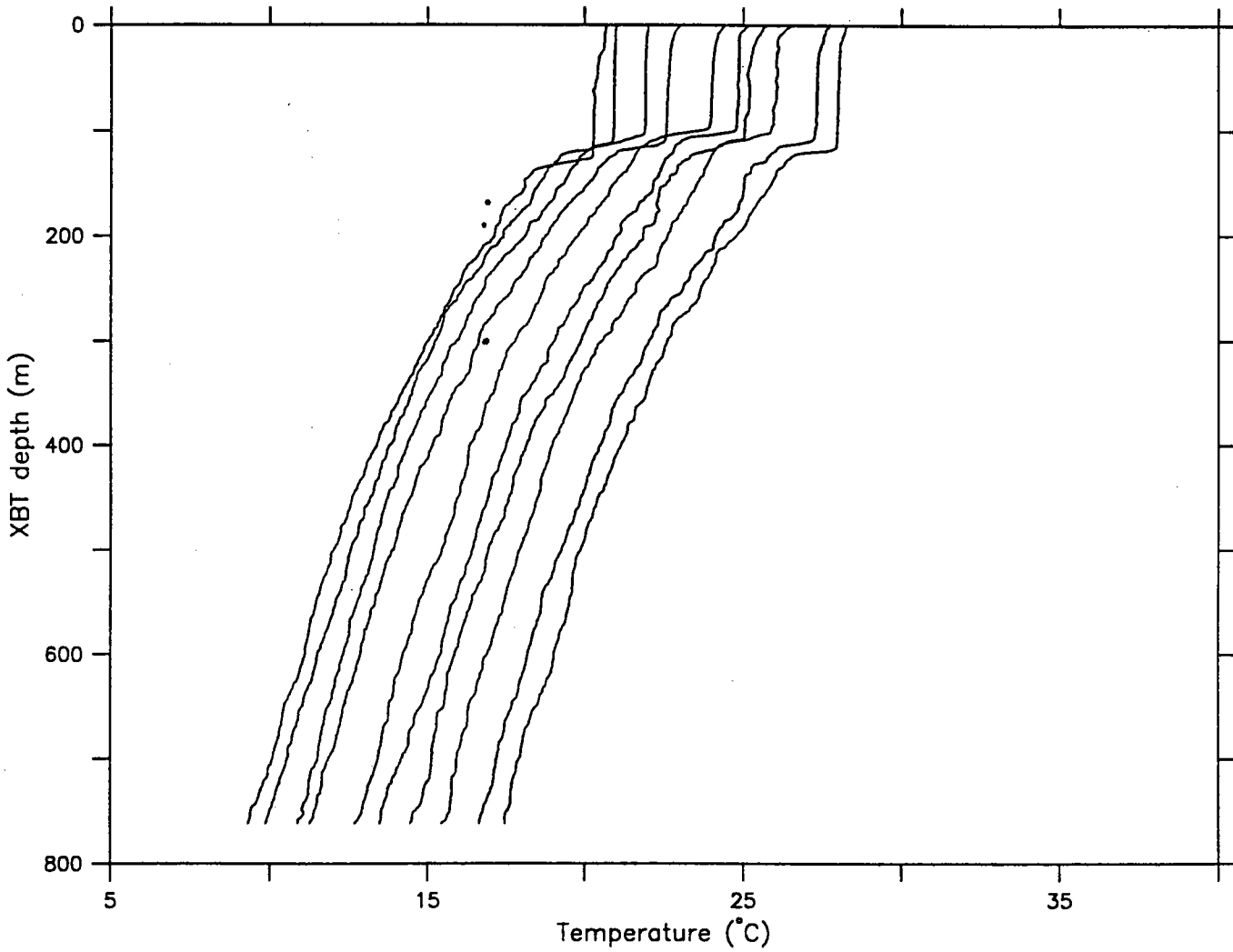
Subduction II XBT start: 160 offset by 1°C

Figure A6-1r. Overplot of XBT Profiles 170-179
Successive Profiles are offset by 1° C.



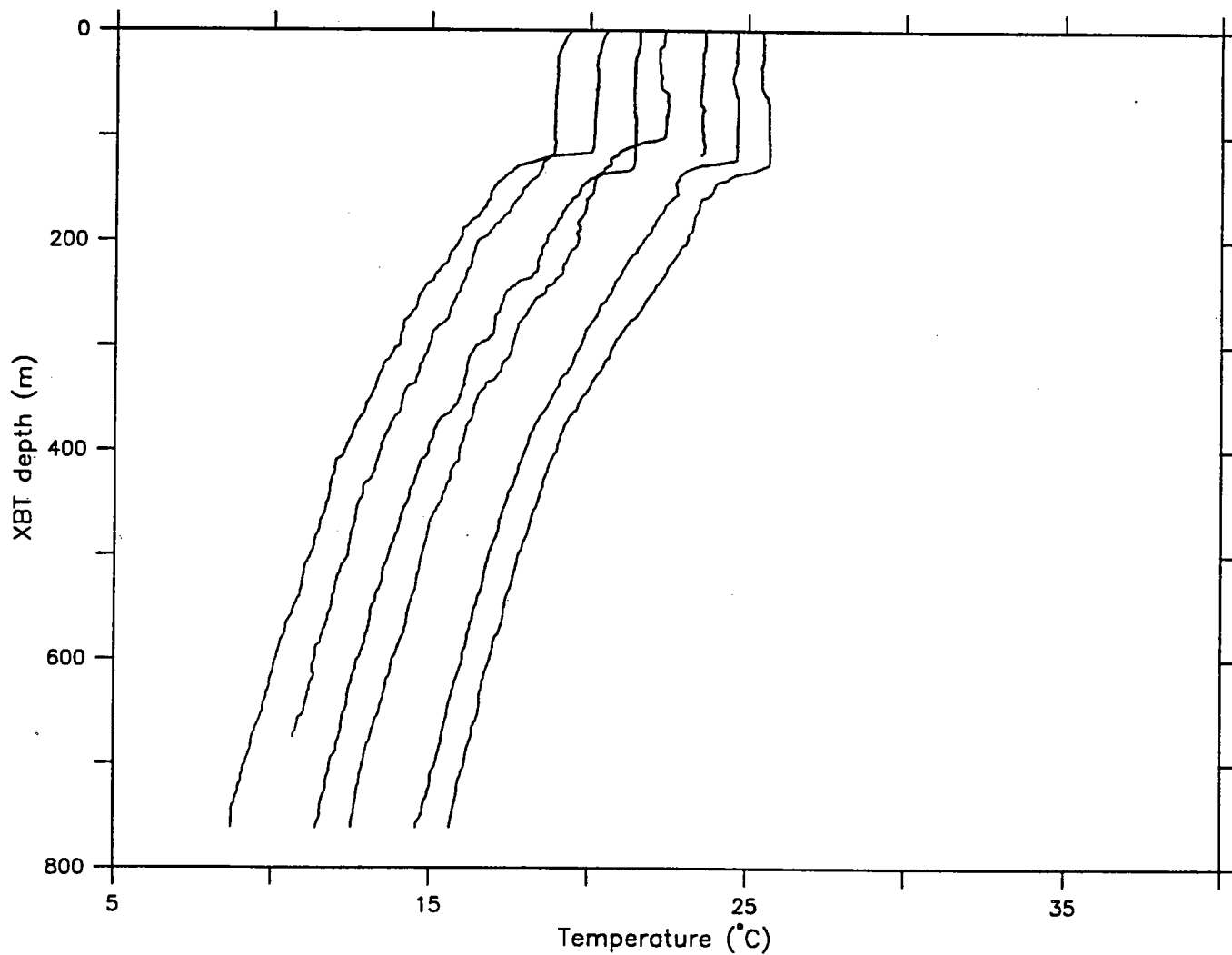
Subduction II XBT start: 170 offset by 1°C

Figure A6-1s. Overplot of XBT Profiles 180-189
Successive Profiles are offset by 1° C.



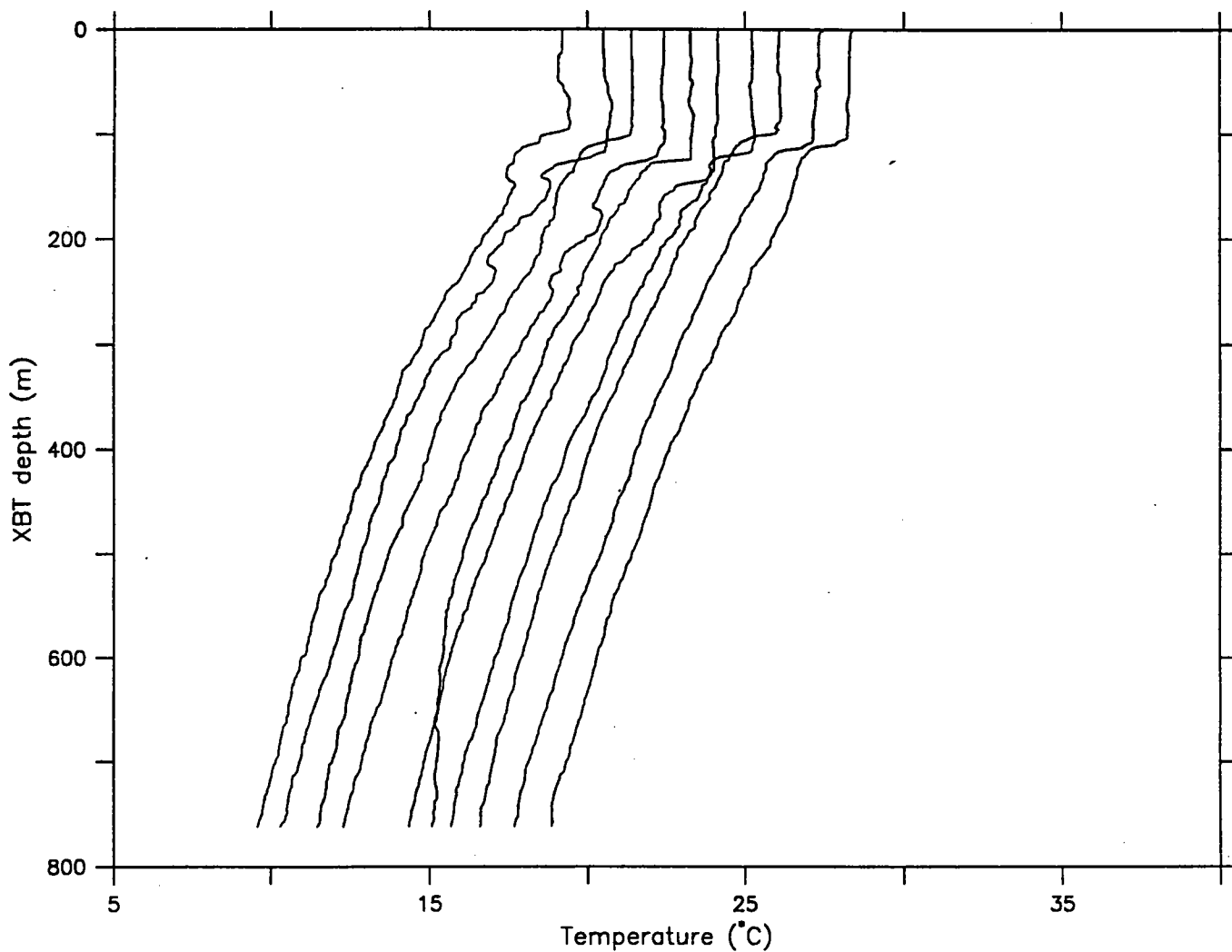
Subduction II XBT start: 180 offset by 1°C

Figure A6-1t. Overplot of XBT Profiles 190-199
Successive Profiles are offset by 1° C.



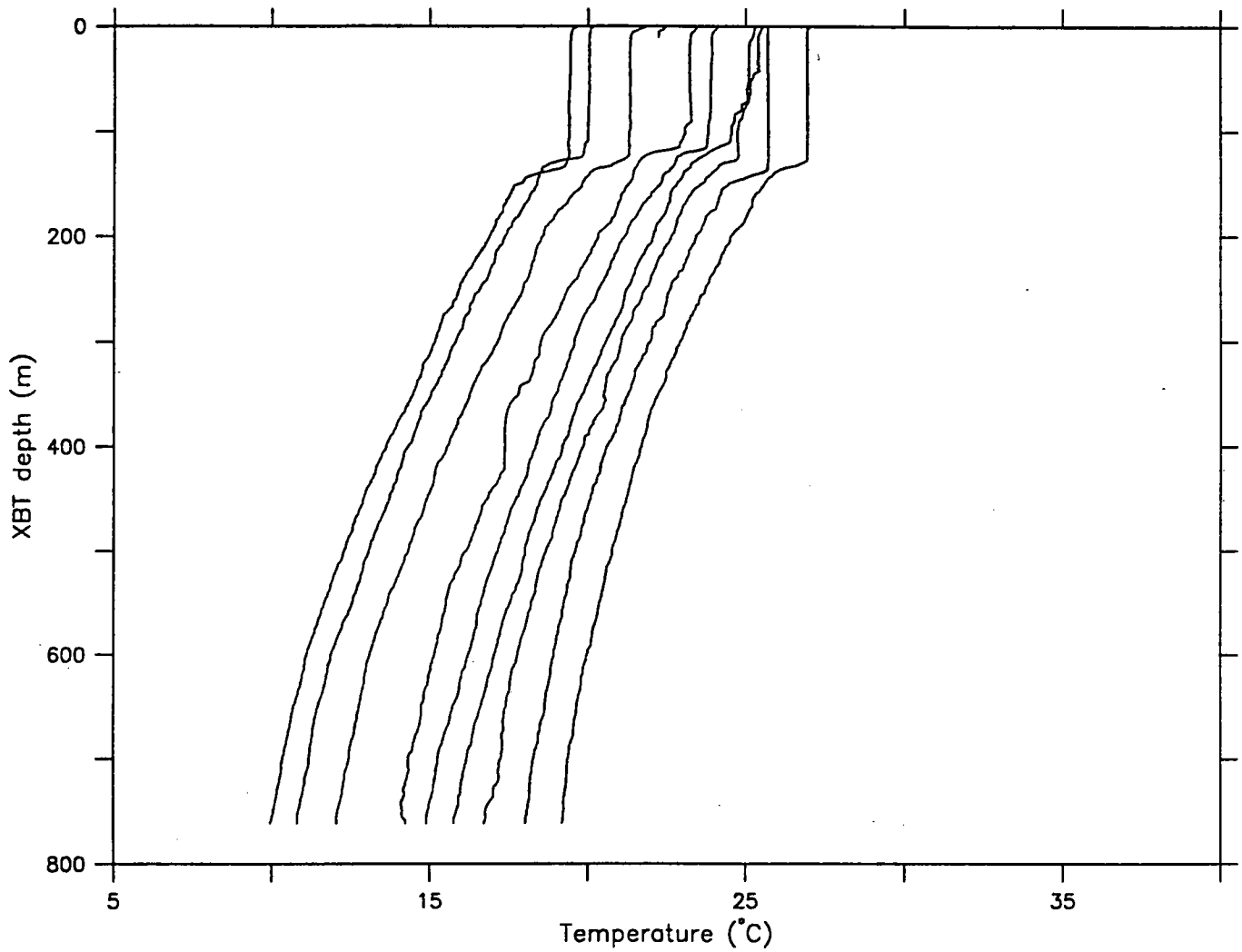
Subduction II XBT start: 190 offset by 1°C

Figure A6-1u. Overplot of XBT Profiles 200-209
Successive Profiles are offset by 1° C.



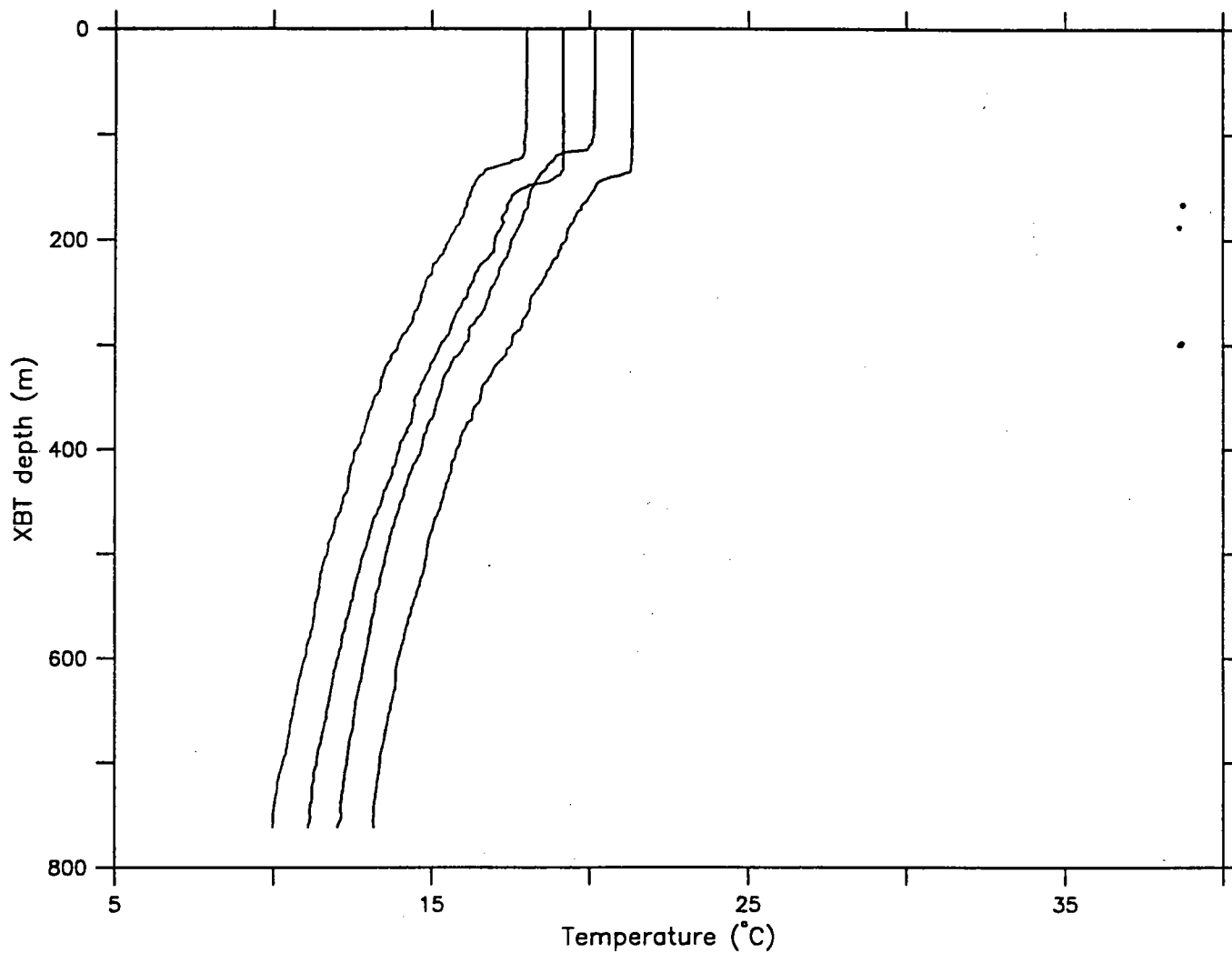
Subduction II XBT start: 200 offset by 1°C

Figure A6-1v. Overplot of XBT Profiles 210-219
Successive Profiles are offset by 1° C.



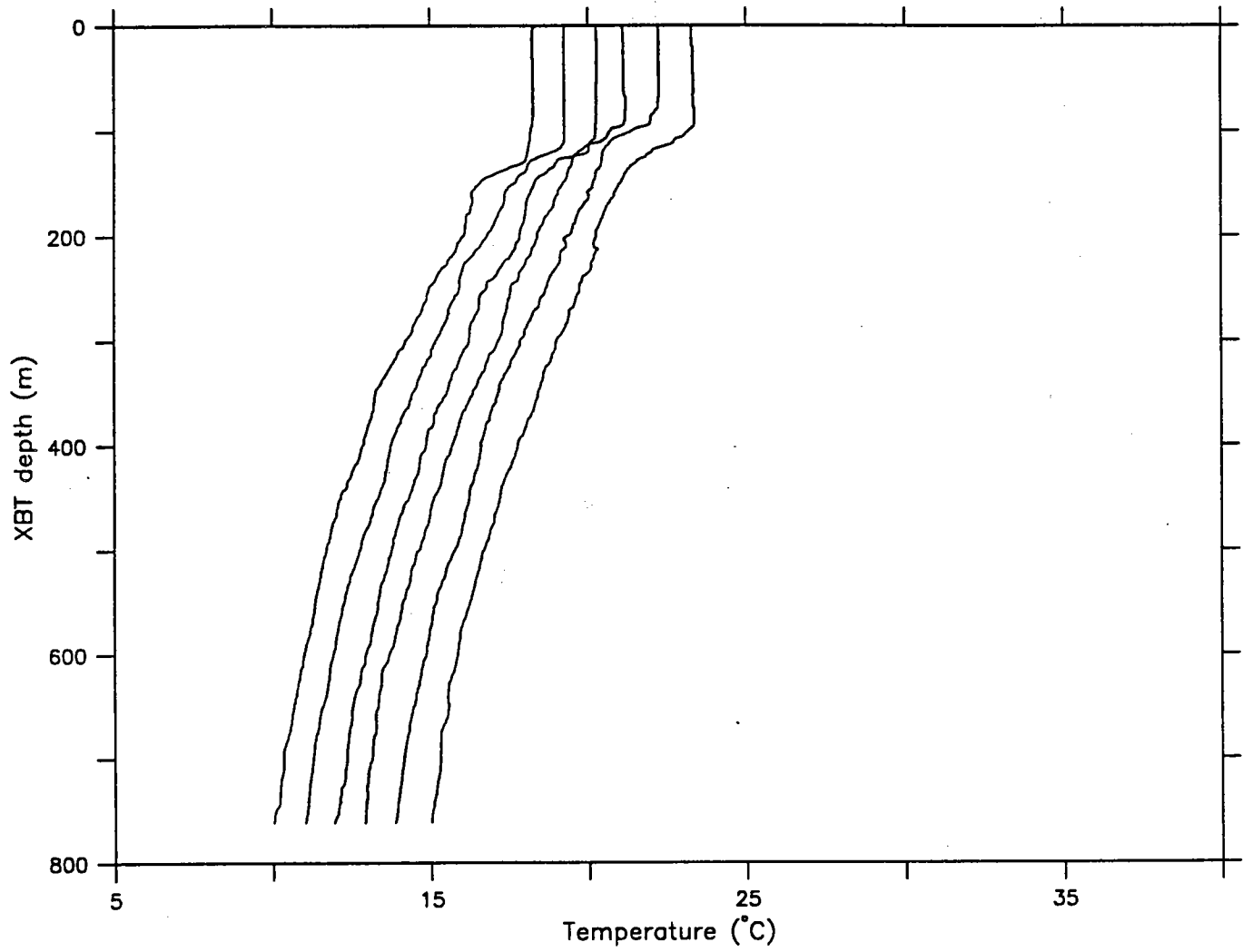
Subduction II XBT start: 210 offset by 1°C

Figure A6-1w. Overplot of XBT Profiles 220-229
Successive Profiles are offset by 1° C.



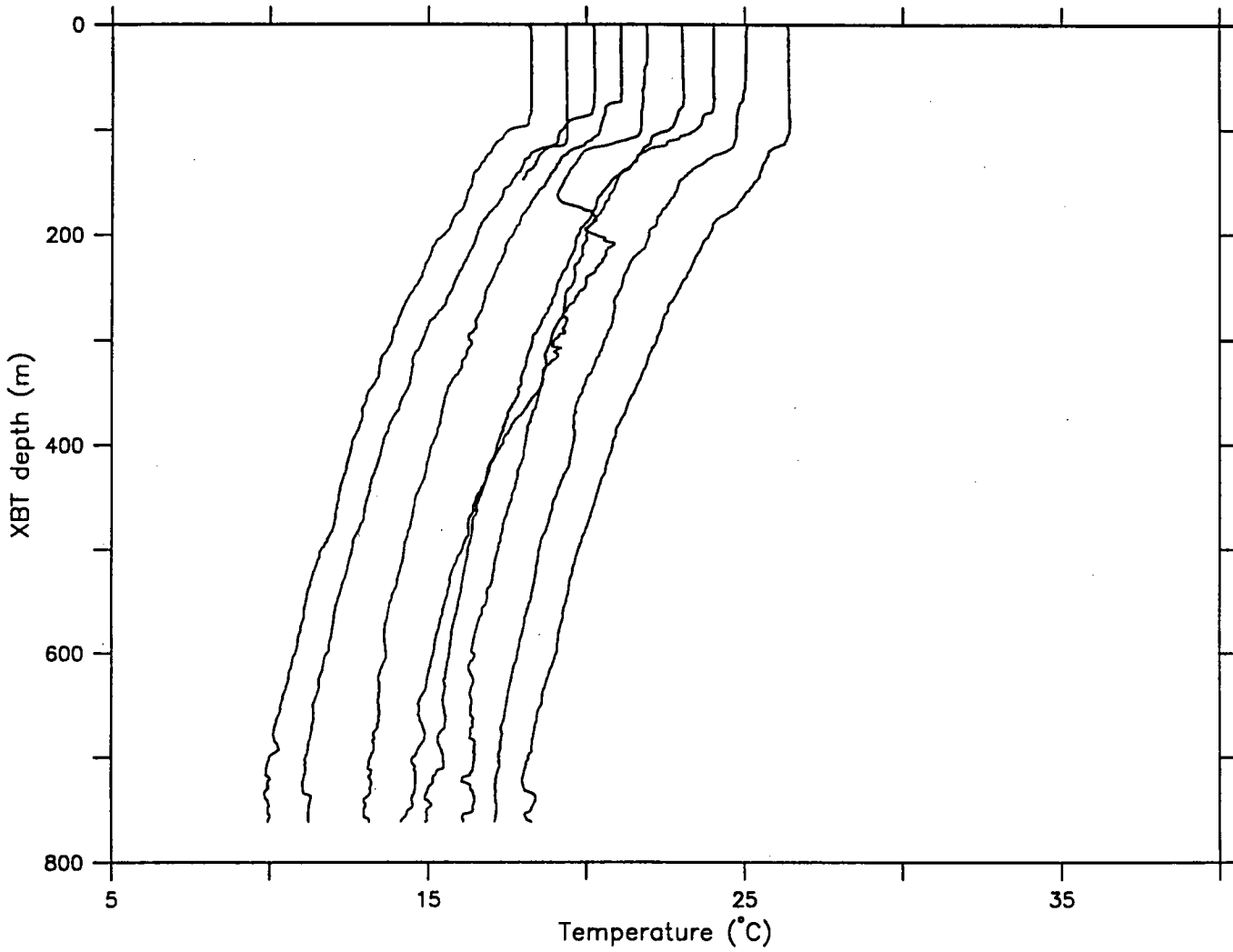
Subduction II XBT start: 220 offset by 1°C

Figure A6-1x. Overplot of XBT Profiles 230-239
Successive Profiles are offset by 1° C.



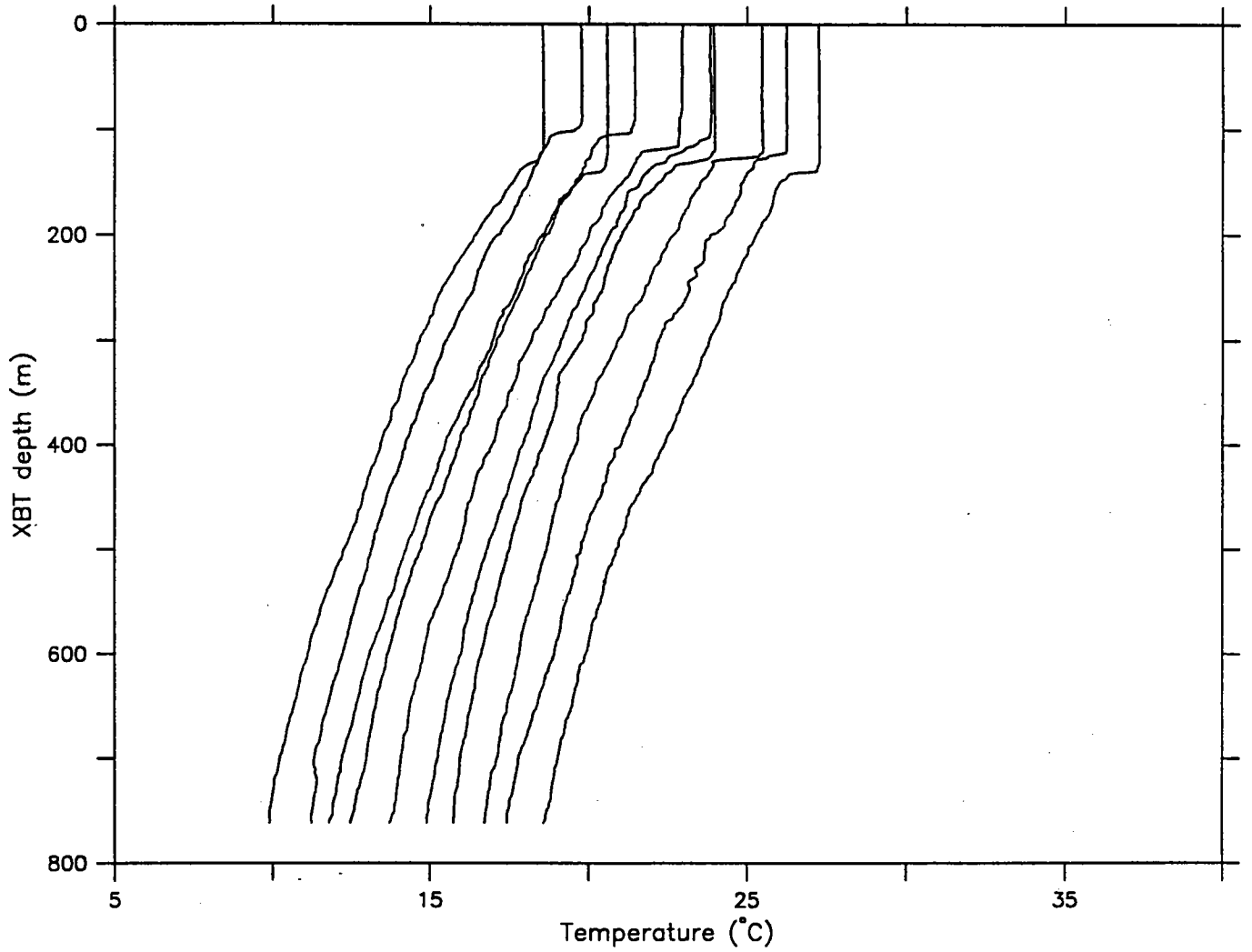
Subduction II XBT start: 230 offset by 1°C

Figure A6-1y. Overplot of XBT Profiles 240-249
Successive Profiles are offset by 1° C.



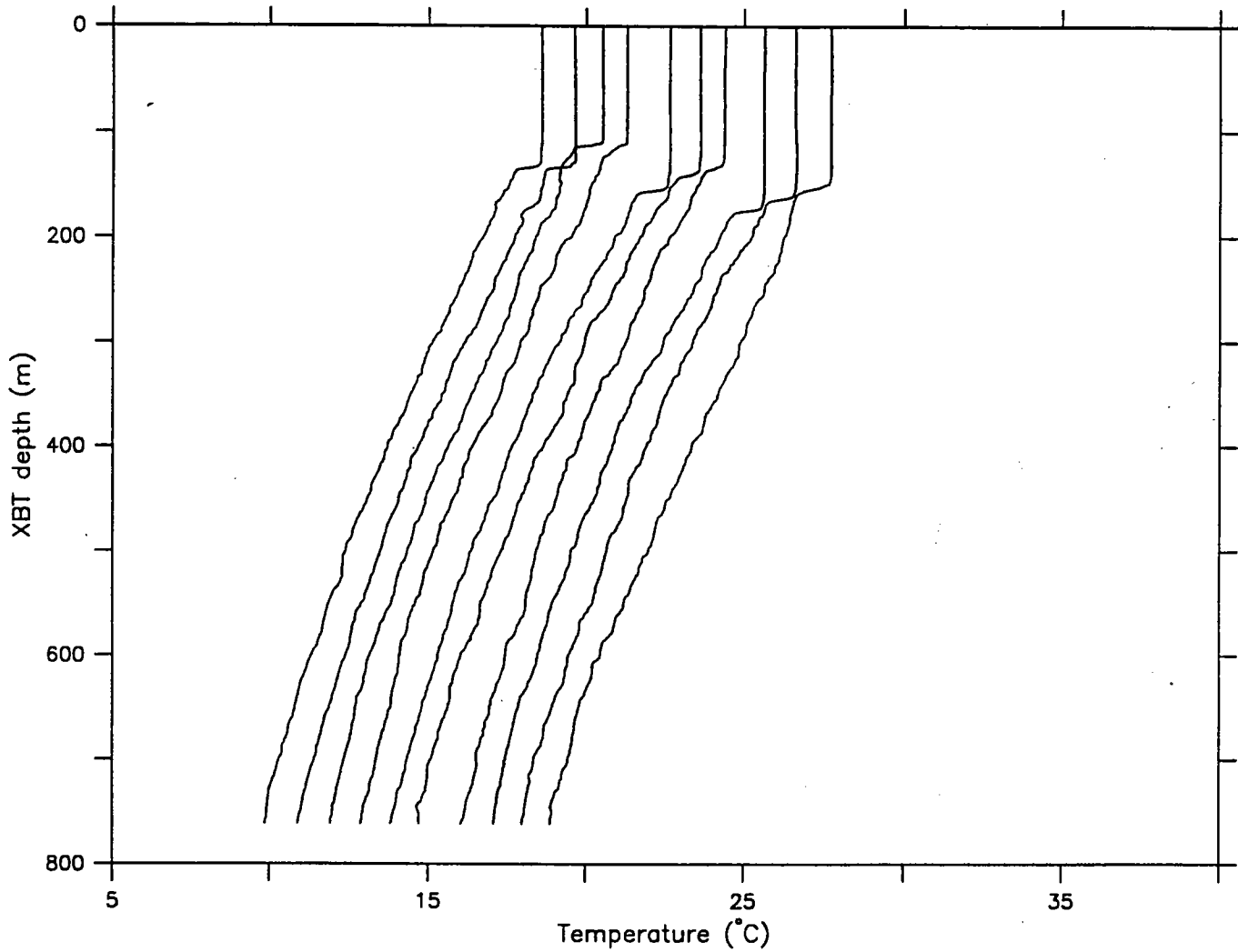
Subduction II XBT start: 240 offset by 1°C

Figure A6-1z. Overplot of XBT Profiles 250-259
Successive Profiles are offset by 1° C.



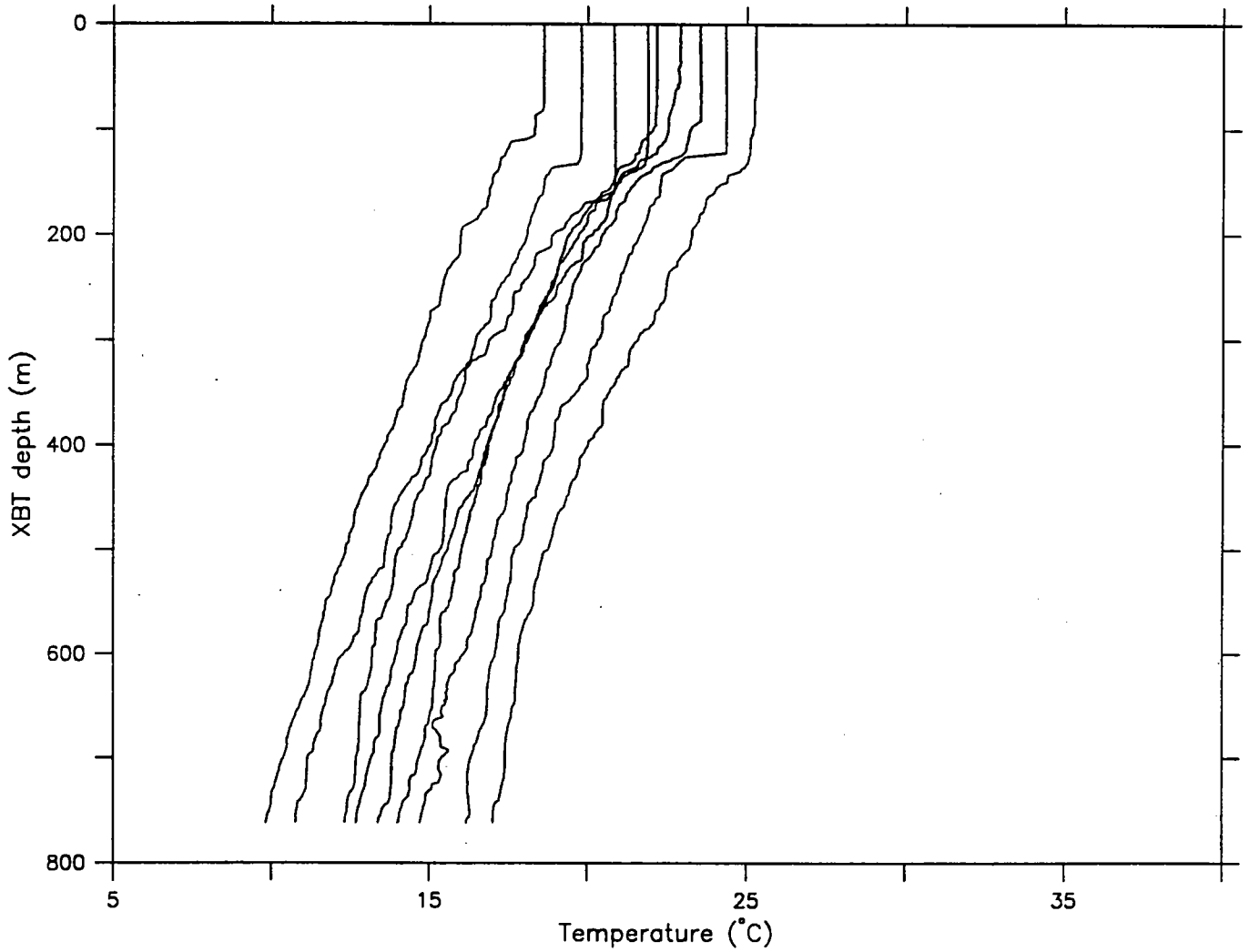
Subduction II XBT start: 250 offset by 1°C

Figure A6-1aa. Overplot of XBT Profiles 260-269
Successive Profiles are offset by 1° C.



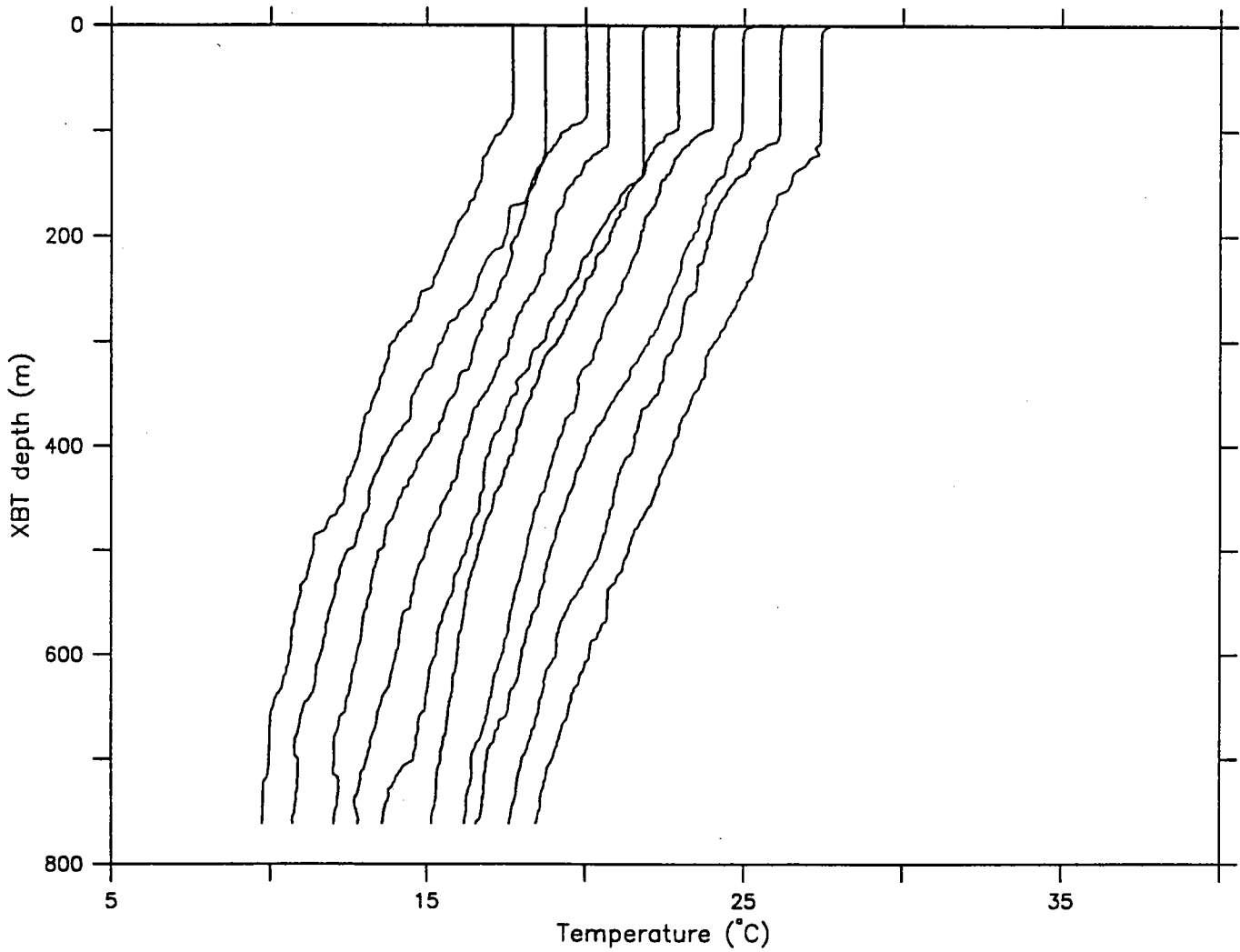
Subduction II XBT start: 260 offset by 1°C

Figure A6-1bb. Overplot of XBT Profiles 270-279
Successive Profiles are offset by 1° C.



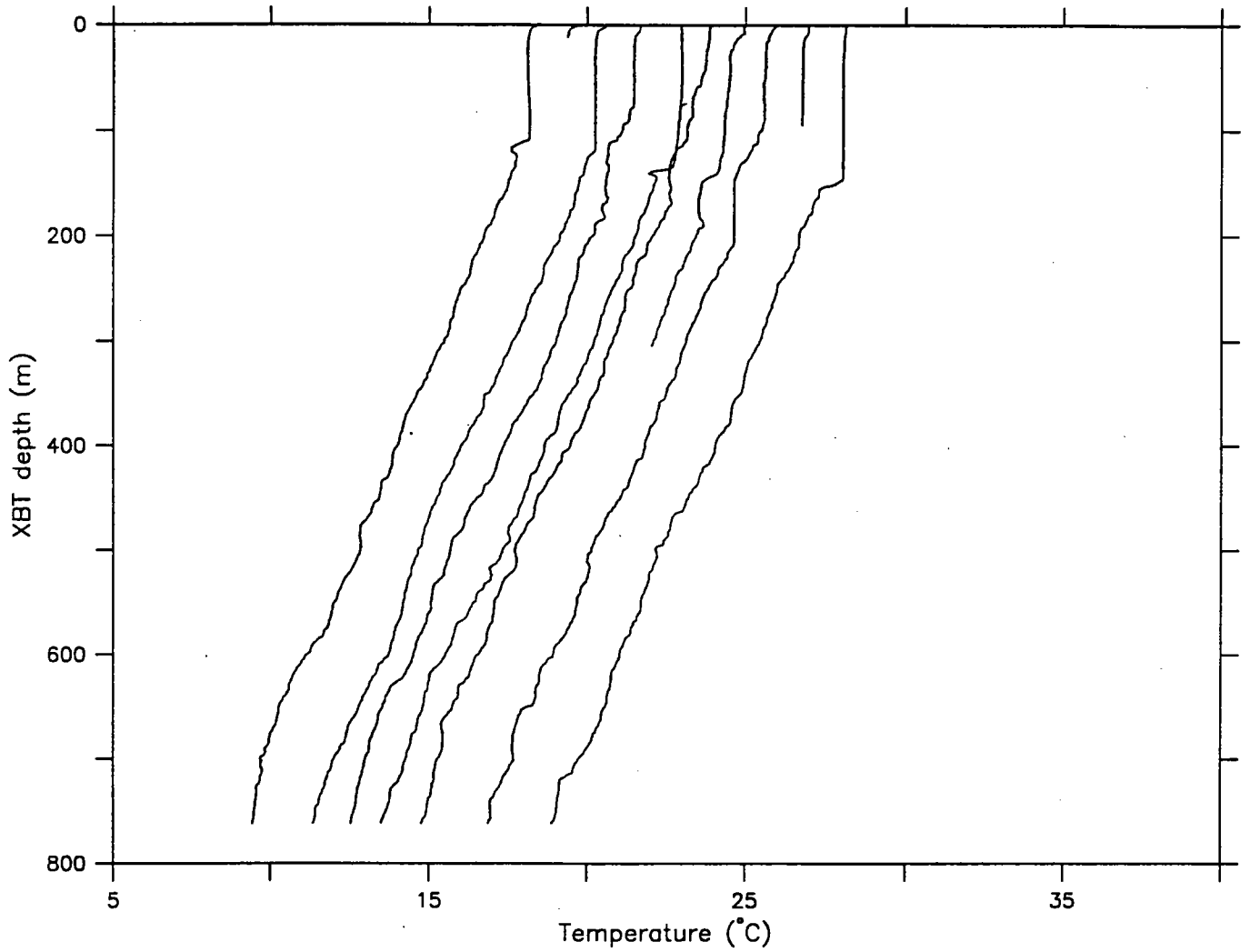
Subduction II XBT start: 270 offset by 1°C

Figure A6-1cc. Overplot of XBT Profiles 280-289
Successive Profiles are offset by 1° C.



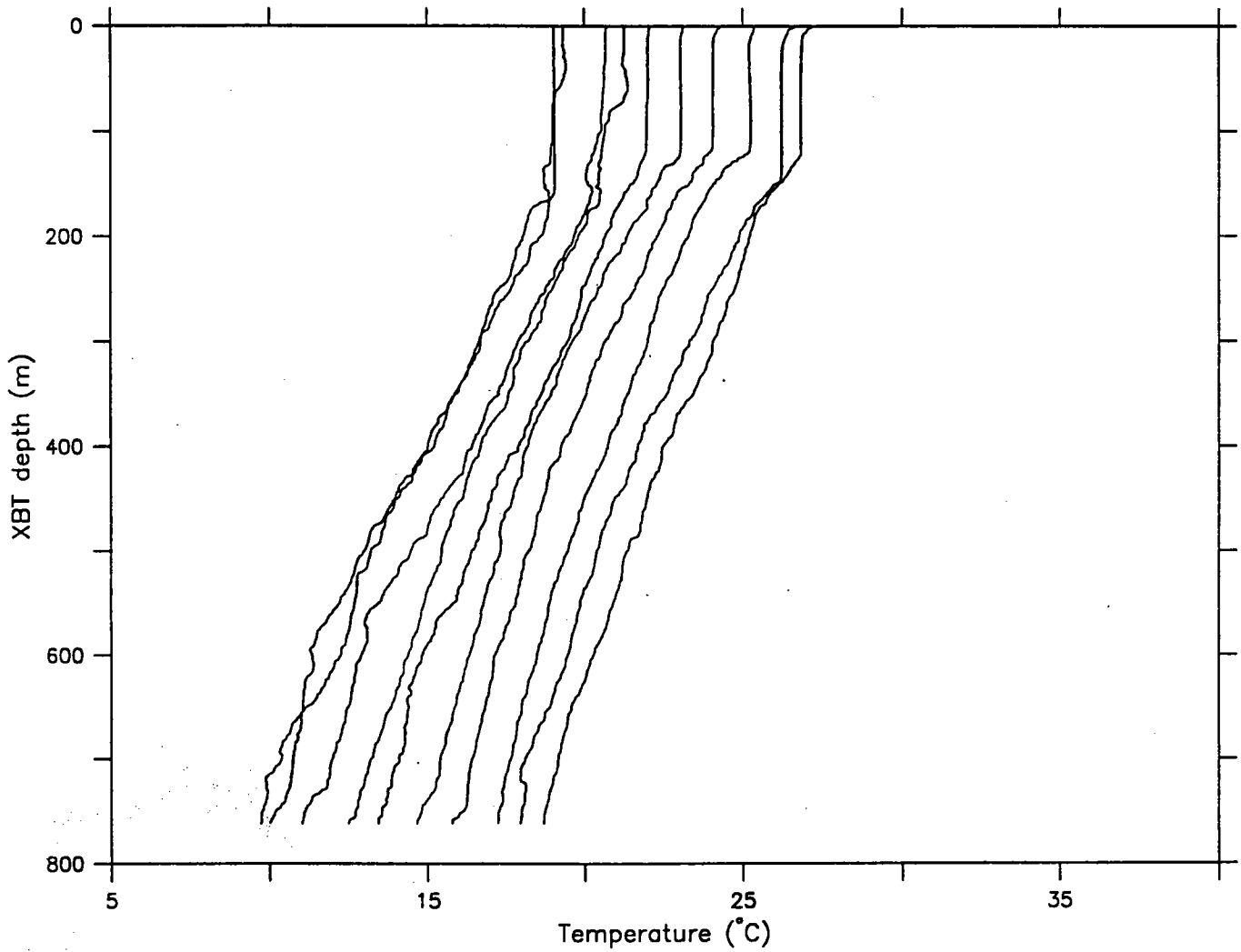
Subduction II XBT start: 280 offset by 1°C

Figure A6-1dd. Overplot of XBT Profiles 290-299
Successive Profiles are offset by 1° C.



Subduction II XBT start: 290 offset by 1°C

Figure A6-1ee. Overplot of XBT Profiles 300-309
Successive Profiles are offset by 1° C.



Subduction II XBT start: 300 offset by 1°C

Table A6-1 XBT Positions

	No. (1992)	Date	Time (UTC)	Position (GPS)	
				Latitude (N)	Longitude (W)
2	26 January	1505	36° 58.13'	68° 38.76'	
3		1900	36° 23.48'	67° 51.20'	
4		2300	35° 52.49'	67° 18.52'	
5	27 January	0300	35° 20.00'	66° 46.41'	
7		0600	34° 58.89'	66° 23.79'	
8		1000	34° 33.51'	66° 04.55'	
9		1400	34° 04.79'	65° 28.75'	
10		1800	33° 36.71'	65° 28.77'	
11	28 January	2200	33° 08.41'	64° 30.86'	
12		0200	32° 30.19'	63° 49.85'	
13		0600	31° 57.15'	63° 00.98'	
14		1000	31° 25.21'	62° 27.39'	
15		1400	30° 53.01'	61° 46.04'	
16		1800	30° 19.38'	61° 46.04'	
17	29 January	2200	29° 46.74'	60° 29.82'	
18		0200	29° 09.02'	59° 47.76'	
19		0600	28° 32.43'	59° 08.44'	
20		1000	27° 58.54'	58° 33.60'	
21		1400	27° 26.06'	57° 58.51'	
22		1800	26° 51.81'	57° 23.39'	
23	30 January	2200	26° 18.09'	56° 48.59'	
24		0200	25° 44.98'	56° 12.29'	
25		0600	25° 11.05'	55° 34.59'	
26		1000	24° 35.07'	54° 58.25'	
27		1400	24° 01.27'	54° 24.93'	
28		1800	23° 27.51'	53° 49.63'	
29	31 January	2200	22° 53.60'	53° 14.80'	
30		0200	22° 17.24'	52° 39.30'	
31		0500	21° 52.02'	52° 13.71'	
32		0900	21° 17.29'	51° 36.35'	
33		1300	20° 40.20'	50° 57.31'	
34		1700	20° 04.69'	50° 21.64'	
35	1 February	2100	19° 28.57'	49° 46.05'	
36		0100	18° 54.62'	49° 07.85'	
37		0400	18° 31.78'	48° 39.01'	
38		0800	17° 59.87'	48° 01.27'	
39		1200	17° 27.97'	47° 25.11'	
40		1600	16° 57.61'	46° 48.47'	
41	2 February	2000	16° 27.50'	46° 09.89'	
42		0000	15° 58.13'	45° 34.24'	
43		0400	15° 23.13'	44° 56.93'	
44		0517	15° 13.09'	44° 47.48'	

45		0800	15° 15.15'	44° 42.26'
46		1200	15° 28.81'	43° 53.88'
47		1600	15° 43.04'	43° 03.13'
48		2000	15° 55.46'	42° 15.77'
49	3 February	0000	16° 06.50'	41° 26.40'
50		0400	16° 19.39'	40° 36.78'
51		0800	16° 32.81'	39° 46.63'
52		1200	16° 46.89'	38° 55.41'
53		1600	17° 01.96'	38° 09.00'
54		2000	17° 12.43'	37° 22.67'
55	4 February	0000	17° 23.94'	36° 30.49'
56		0400	17° 35.98'	35° 39.90'
57		0800	17° 47.65'	34° 50.94'
58		1900	17° 59.82'	33° 49.03'
59		2000	17° 59.75'	33° 37.03'
60		2100	17° 59.40'	33° 24.92'
61		2200	17° 59.39'	33° 12.28'
62		2300	17° 59.56'	32° 59.80'
63	5 February	0000	17° 59.61'	32° 47.51'
64		0100	17° 59.48'	32° 35.15'
65		0200	17° 59.23'	32° 21.75'
66		0300	17° 59.42'	32° 09.34'
67		0400	17° 59.56'	31° 56.80'
68		0500	17° 59.85'	31° 44.32'
69		0600	18° 00.19'	31° 32.07'
70		0700	18° 00.31'	31° 19.66'
71		0800	18° 00.74'	31° 07.71'
72		0900	18° 01.25'	30° 55.86'
73		1000	18° 01.17'	30° 43.09'
74		1100	18° 09.90'	30° 31.42'
75		1200	18° 01.05'	30° 20.44'
76		1300	18° 01.17'	30° 05.71'
77		1400	18° 00.81'	29° 55.06'
78		1500	18° 00.43'	29° 42.92'
79		1600	17° 59.86'	29° 30.42'
80		1700	17° 59.96'	29° 18.58'
81		1800	18° 00.10'	29° 08.83'
82		1900	18° 00.13'	28° 56.54'
83		2000	17° 59.90'	28° 45.05'
84		2100	17° 59.34'	28° 32.59'
85		2200	17° 59.44'	28° 20.44'
86		2300	17° 59.41'	28° 08.41'
87	6 February	0000	17° 59.52'	27° 56.61'
88		0100	17° 59.56'	27° 44.58'
89		0200	17° 59.86'	27° 31.38'
90		0300	18° 00.07'	27° 19.21'

91		0400	18° 00.14'	27° 07.00'
92		0500	18° 00.43'	26° 54.91'
93		0600	18° 00.29'	26° 43.06'
94		0700	17° 59.89'	26° 30.34'
95		0800	17° 59.64'	26° 17.45'
96		0900	17° 59.51'	26° 05.14'
97		1000	17° 59.29'	25° 53.19'
98		1100	17° 59.14'	25° 40.27'
99		1200	17° 59.12'	25° 28.37'
100		1300	17° 59.47'	25° 15.92'
101		1400	17° 59.87'	25° 03.55'
102		1500	18° 00.07'	24° 50.95'
103		1600	18° 00.18'	24° 38.78'
104		1700	18° 00.30'	24° 27.25'
105		1800	17° 59.99'	24° 14.75'
106		1900	17° 59.98'	24° 02.79'
107		2000	18° 00.08'	23° 51.03'
108		2100	18° 00.01'	23° 38.98'
109		2200	17° 59.98'	23° 26.87'
110		2300	18° 00.04'	23° 15.09'
111	7 February	0000	18° 00.72'	23° 03.22'
112		0100	18° 01.16'	22° 51.43'
113		0200	18° 00.97'	22° 38.95'
114		0300	18° 00.63'	22° 26.73'
115		0400	18° 00.15'	22° 14.84'
116	9 February	1000	18° 09.49'	22° 09.70'
117		1100	18° 18.16'	22° 17.06'
118		1200	18° 27.58'	22° 25.19'
119		1300	18° 37.20'	22° 33.18'
120		1400	18° 46.18'	22° 40.96'
121		1500	18° 55.31'	22° 49.02'
122		1600	19° 04.52'	22° 57.37'
123		1700	19° 12.98'	23° 05.51'
124		1800	19° 21.87'	23° 14.40'
125		1900	19° 30.59'	23° 23.05'
126		2000	19° 39.99'	23° 32.36'
127		2100	19° 48.95'	23° 40.95'
128		2200	19° 57.60'	23° 49.28'
129		2300	20° 06.27'	23° 59.68'
131	10 February	0000	20° 14.98'	24° 05.89'
132		0100	20° 24.63'	24° 14.88'
133		0200	20° 33.52'	24° 22.56'
134		0300	20° 42.77'	24° 30.30'
135		0400	20° 51.51'	24° 37.84'
136		0500	21° 00.33'	24° 45.47'
137		0600	21° 08.90'	24° 53.14'

138		0700	21° 17.71'	25° 01.31'
139		0800	21° 26.64'	25° 09.42'
140		0900	21° 35.61'	25° 17.65'
142		1000	21° 44.53'	25° 25.64'
143		1100	21° 53.34'	25° 33.93'
144		1200	22° 02.78'	25° 42.92'
145		1300	22° 12.24'	25° 51.62'
146		1400	22° 21.59'	26° 00.42'
147		1500	22° 30.63'	26° 08.94'
149		1600	22° 39.96'	26° 17.46'
150		1700	22° 48.89'	26° 25.68'
151		1800	22° 58.07'	26° 33.48'
152		1900	23° 07.06'	26° 41.48'
153		2000	23° 16.10'	26° 49.68'
155		2100	23° 25.26'	26° 57.97'
156		2200	23° 34.28'	27° 06.06'
157		2300	23° 43.29'	27° 14.41'
158	11 February	0000	23° 52.28'	27° 22.65'
159		0100	24° 01.54'	27° 31.01'
160		0200	24° 10.39'	27° 39.25'
161		0300	24° 19.17'	27° 47.66'
162		0400	24° 28.47'	27° 56.64'
163		0500	24° 37.24'	28° 04.93'
165		0603	24° 46.99'	28° 14.38'
166		0700	24° 54.97'	28° 22.21'
167		0800	25° 03.58'	28° 30.87'
168		0900	25° 12.47'	28° 39.86'
169		1000	25° 21.26'	28° 48.60'
170	13 February	0200	25° 31.82'	28° 57.79'
171		0300	25° 50.13'	28° 41.05'
172		0400	25° 59.70'	28° 31.93'
173		0500	26° 08.61'	28° 23.42'
174		0600	26° 18.36'	28° 14.25'
175		0700	26° 27.67'	28° 05.35'
176		0800	26° 37.39'	27° 55.96'
177		0900	26° 46.68'	27° 46.90'
178		1000	26° 56.24'	27° 37.48'
179		1100	27° 05.71'	27° 27.80'
180		1200	27° 14.94'	27° 18.77'
181		1300	27° 24.78'	27° 09.33'
182		1400	27° 33.85'	27° 01.39'
183		1500	27° 44.35'	26° 53.33'
184		1600	27° 54.44'	26° 48.75'
185		1700	28° 04.11'	26° 40.43'
186		1800	28° 13.83'	26° 32.16'
187		1900	28° 23.74'	26° 23.02'

188		2000	28° 33.44'	26° 13.50'
189		2100	28° 42.98'	26° 04.06'
191		2200	28° 52.43'	25° 54.82'
192		2300	29° 01.99'	25° 45.39'
194	14 February	0020	29° 15.12'	25° 32.78'
195		0100	29° 22.02'	25° 26.05'
198		0209	29° 32.31'	25° 16.36'
199		0300	29° 40.93'	25° 08.40'
200		0400	29° 50.54'	24° 59.38'
201		0500	30° 00.57'	24° 50.04'
202		0600	30° 10.29'	24° 41.15'
203		0700	30° 20.15'	24° 31.95'
204		0800	30° 30.19'	24° 22.52'
205		0900	30° 39.70'	24° 13.50'
206		1000	30° 49.45'	24° 04.17'
207		1100	30° 59.38'	23° 54.63'
208		1200	31° 09.21'	23° 45.20'
209		1300	31° 19.23'	23° 35.33'
210		1400	31° 29.19'	23° 25.80'
211		1500	31° 38.84'	23° 16.44'
212		1600	31° 49.01'	23° 06.49'
213		1700	31° 58.79'	22° 57.52'
214		1800	32° 09.06'	22° 47.92'
215		1900	32° 18.78'	22° 38.45'
216		2000	32° 28.94'	22° 28.34'
217		2100	32° 38.54'	22° 18.47'

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218	19 February	1200	32° 41.16'	17° 43.91'
219		1300	32° 42.66'	17° 57.06'
220		1400	32° 43.97'	18° 10.17'
221		1500	32° 45.21'	18° 23.96'
222		1600	32° 46.41'	18° 37.47'
223		1700	32° 47.21'	18° 49.43'
234		1800	32° 49.12'	19° 00.29'
235		1900	32° 50.58'	19° 12.60'
236		2000	32° 52.79'	19° 29.25'
237		2100	32° 53.81'	19° 40.43'
238		2200	32° 55.05'	19° 53.40'
239		2300	32° 56.28'	20° 06.92'
240	20 February	0000	32° 57.32'	20° 20.37'
241		0100	32° 58.30'	20° 34.73'
244		0200	32° 59.45'	20° 50.74'
245		0300	32° 59.94'	21° 02.80'
246		0400	33° 00.28'	21° 17.56'

247		0500	33° 00.62'	21° 31.67'
248		2300	33° 00.73'	22° 15.90'
249	21 February	0000	33° 00.10'	22° 30.55'
250		0100	33° 00.03'	22° 44.94'
251		0200	33° 00.26'	22° 58.57'
252		0300	33° 00.56'	23° 12.10'
253		0400	33° 00.54'	23° 25.57'
254		0500	33° 00.77'	23° 38.11'
255		0600	33° 01.05'	23° 52.47'
256		0700	33° 01.10'	24° 07.15'
257		0800	33° 00.87'	24° 20.39'
258		0900	33° 00.16'	24° 34.11'
259		1000	32° 59.43'	24° 48.17'
260		1100	32° 59.13'	25° 01.57'
261		1200	32° 58.97'	25° 15.13'
262		1300	32° 58.81'	25° 29.11'
263		1400	32° 59.05'	25° 43.01'
264		1500	32° 59.48'	25° 56.77'
265		1600	32° 59.43'	26° 10.67'
266		1700	32° 59.84'	26° 23.32'
267		1800	32° 59.89'	26° 36.97'
268		1900	32° 59.89'	26° 50.86'
269		2000	32° 59.68'	27° 05.17'
270		2100	32° 59.48'	27° 18.35'
271		2200	32° 59.52'	27° 31.85'
272		2300	32° 59.68'	27° 44.55'
273	February 22	0000	32° 59.67'	27° 57.68'
274		0100	32° 59.87'	28° 11.10'
275		0200	32° 59.63'	28° 24.53'
276		0300	32° 59.29'	28° 37.61'
277		0400	32° 58.50'	28° 50.68'
278		0500	32° 57.69'	29° 03.48'
279		0600	32° 57.11'	29° 16.01'
280		0700	32° 56.13'	29° 30.32'
281		0800	32° 55.92'	29° 43.44'
282		0900	32° 55.85'	29° 55.68'
283		1000	32° 56.18'	30° 09.27'
284		1100	32° 56.82'	30° 22.80'
285		1200	32° 57.29'	30° 36.59'
286		1300	32° 58.02'	30° 50.36'
287		1400	32° 58.16'	31° 04.16'
288		1500	32° 57.65'	31° 17.89'
289		1600	32° 56.88'	31° 31.38'
290		1700	32° 57.68'	31° 44.15'
292		1800	32° 57.98'	31° 57.18'
293		1900	32° 57.39'	32° 10.24'

294		2000	32° 56.80'	32° 23.91'
295		2100	32° 56.07'	32° 36.69'
296		2200	32° 55.38'	32° 49.96'
297		2300	32° 55.27'	32° 51.88'
299	23 February	0000	32° 54.29'	33° 17.44'
300		0100	32° 54.49'	33° 31.81'
301	24 February	0900	33° 15.55'	33° 15.89'
302		1000	33° 22.88'	33° 03.69'
303		1100	33° 29.87'	32° 51.66'
304		1200	33° 36.25'	32° 40.60'
305		1300	33° 42.22'	32° 30.76'
306		1400	33° 47.84'	32° 21.58'
307		1500	33° 53.38'	32° 12.28'
308		1600	33° 59.37'	32° 02.56'
309		1700	34° 05.06'	31° 53.17'
310		1800	34° 10.86'	31° 43.56'
311		1900	34° 16.68'	31° 33.63'
312		2000	34° 22.62'	31° 24.32'

Figure A6-2 (a-d). XBT survey area during OCEANUS 250 and contour plots.

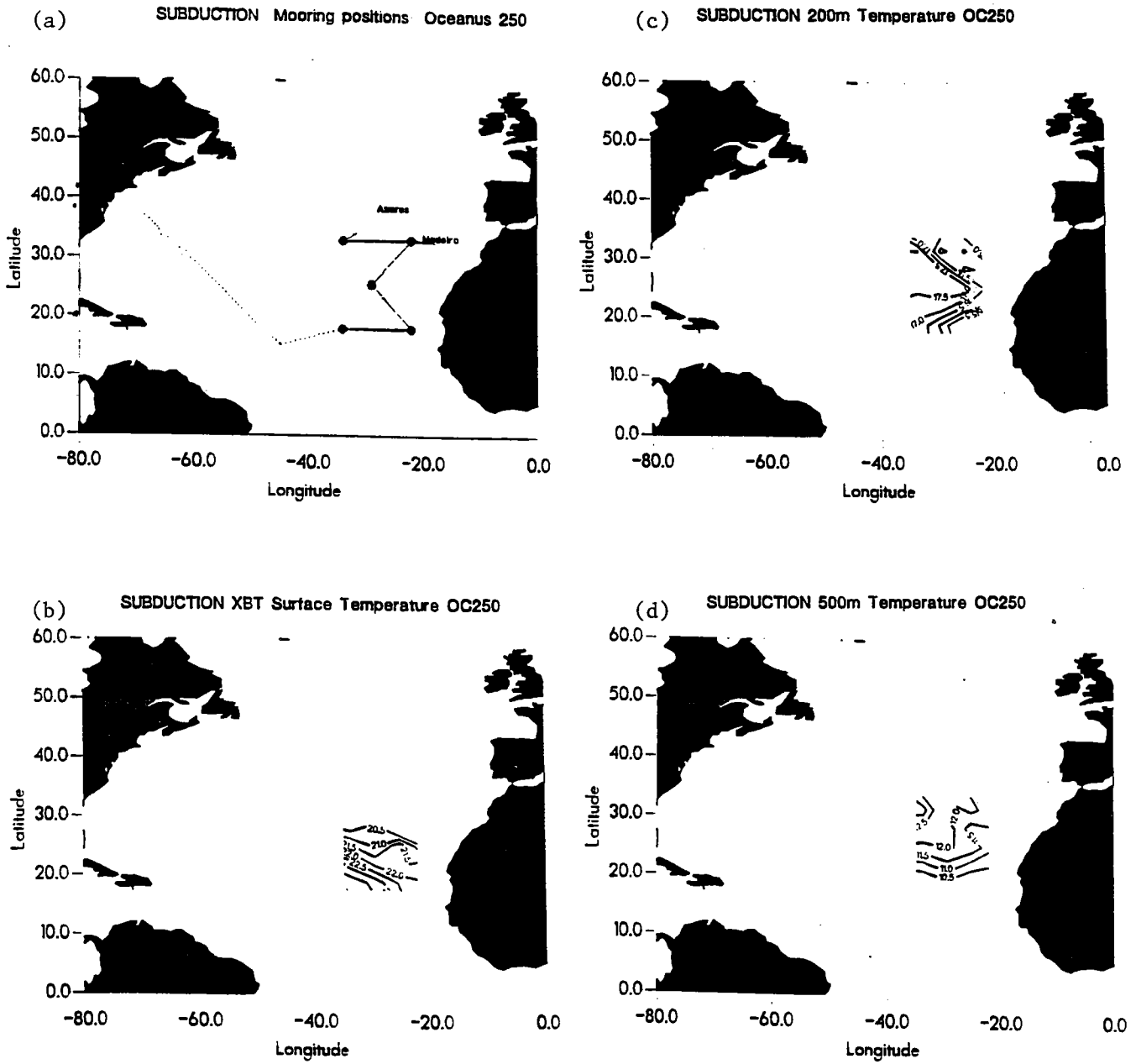
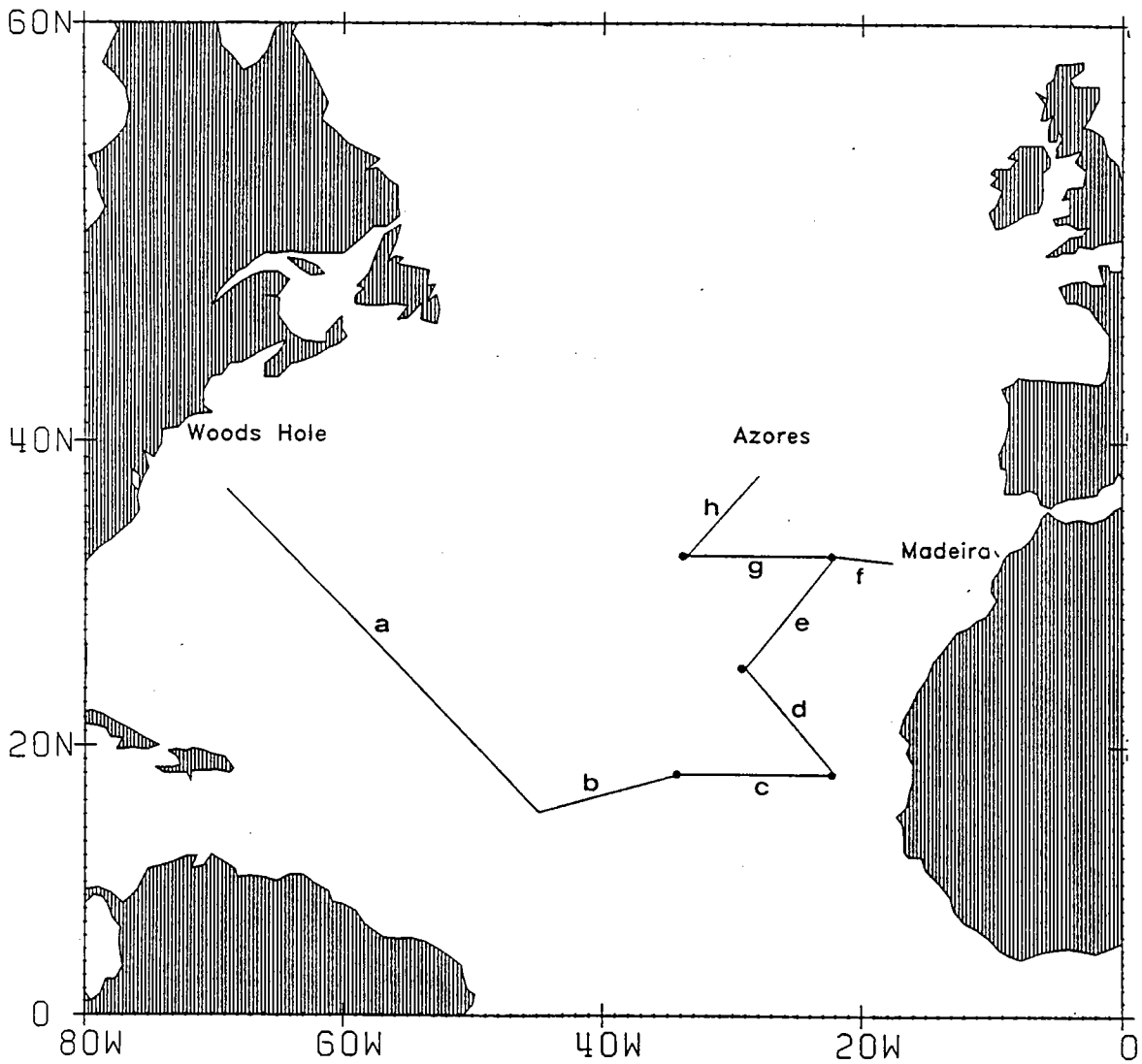


Figure A6-3. XBT section locations.



Section Location	Section letter	XBTS included
Woods Hole to SW drifting buoy	a	1-44
SW drifting buoy to SW anchor site	b	45-57
SW anchor site to SE anchor site	c	58-115
SE anchor site to C anchor site	d	116-169
C anchor site to NE anchor site	e	170-217
Madeira to NE anchor site	f	218-246
NE anchor site to NW anchor site	g	247-300
NW anchor site towards Ponta Delgada	h	300-312

Figure A6-4a. Contoured XBT sections in Subduction array area.

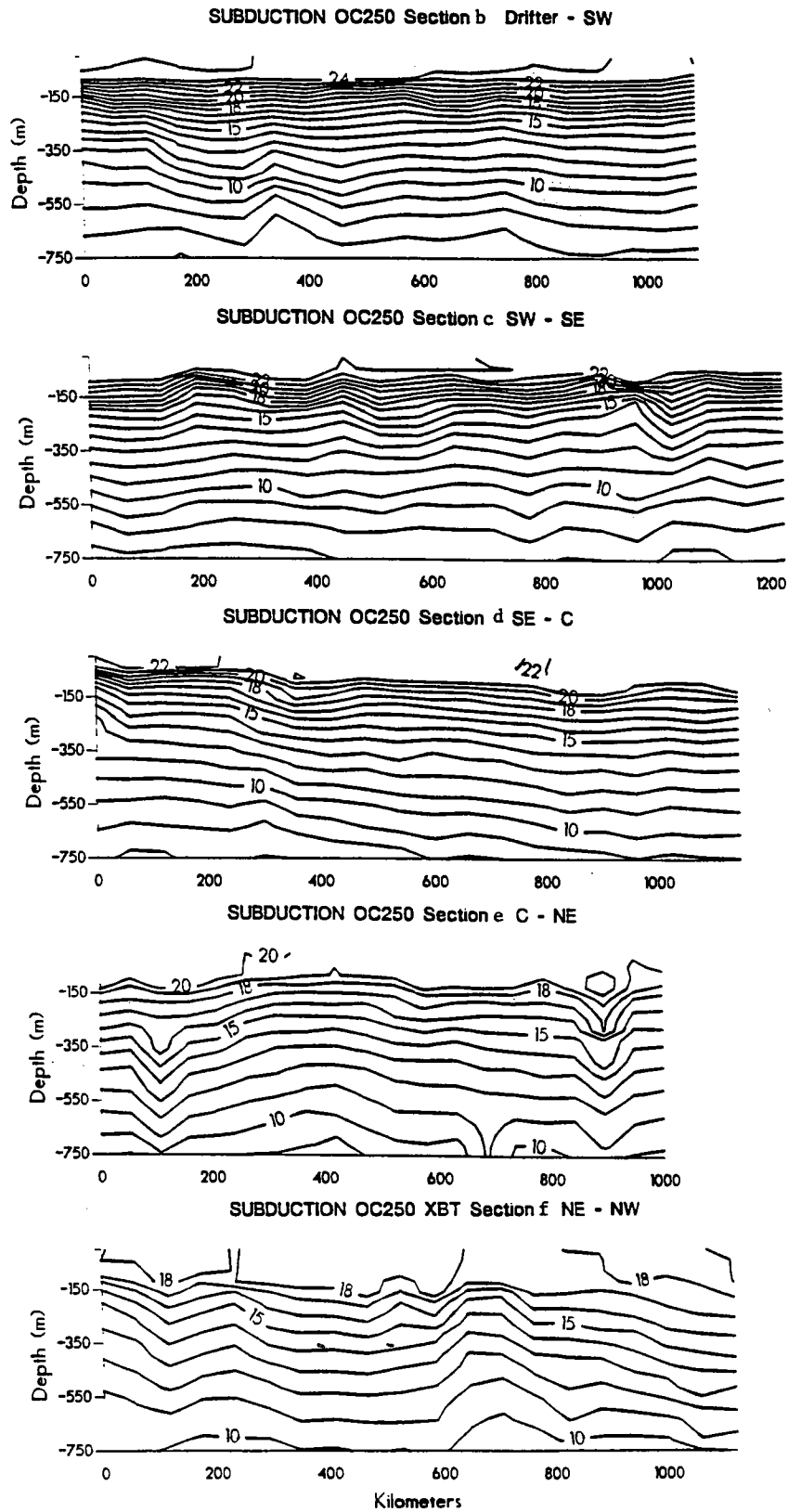
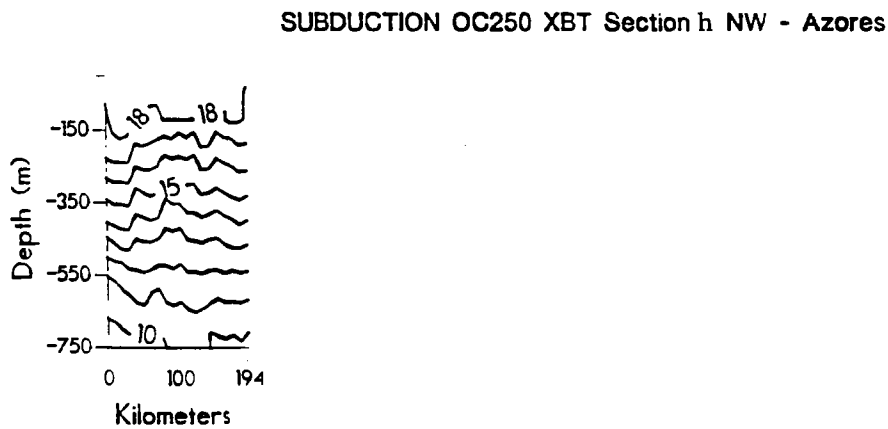
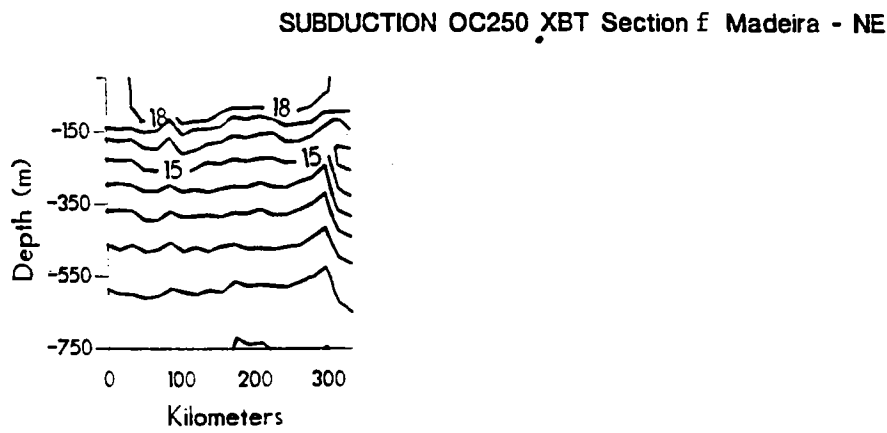
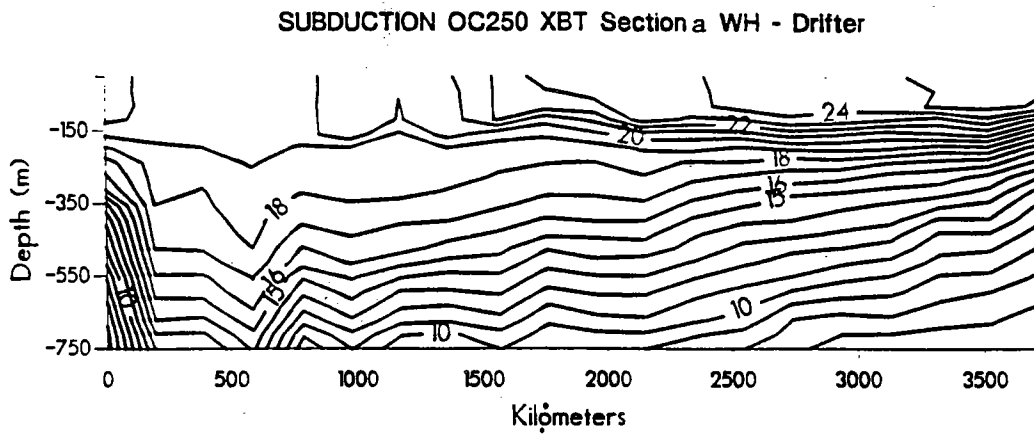


Figure A6-4b . Contoured XBT sections in Subduction transit areas.

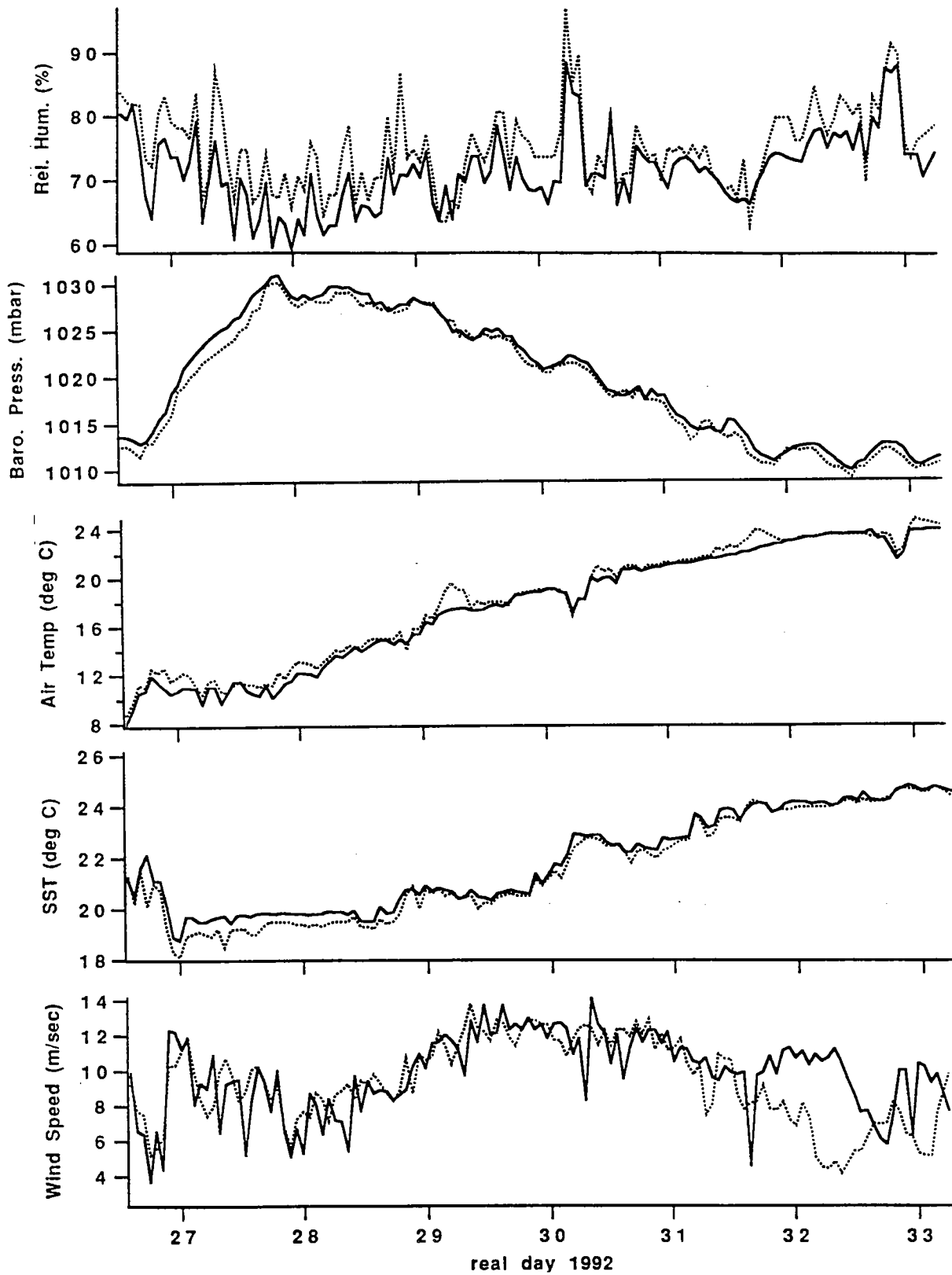


Appendix 7

IMET Shipboard System Comparison with Manual Observations

The following selected data were gathered on Oc-250 to compare the shipboard IMET system with manual observations taken by watch standers. The data are from the transit from Woods Hole to the Subduction SW buoy pickup site at 15°13'N, 44°48'W. Hand held meteorological measurements (dashed line) were made routinely during this time and compared to the IMET data (solid line). Within the accuracy limits of the hand held instruments and sampling locations on Oceanus, the correlation between the data sets is very good. Other short term comparisons between the Oceanus IMET and buoy IMET and VAWR were excellent. The IMET wind sensor measures wind direction relative to magnetic north and later processing will permit direction comparison plots from this unit.

Figure A7-1. IMET Shipboard System Comparison with Manual Observations



Appendix 8

ADCP Data Files

ADCP data was collected continuously during the Subduction II cruise. Processing and plotting of this data will take place in Woods Hole. Note that beginning with adcp.11, the pitch angle was set to 45.

Data were collected on 5 1/4 inch floppy diskettes.

Table A8-1

File	Creation Date and Time		Size(bytes)
adcp.0	Jan 25	15:24	320000
adcp.1	Jan 26	12:14	320256
adcp.2	Jan 27	09:06	320768
adcp.3	Jan 27	23:16	217856
adcp.4	Jan 28	20:43	320512
adcp.5	Jan 29	17:33	320256
adcp.6	Jan 30	14:23	320256
adcp.7	Jan 31	06:38	249856
adcp.8	Jan 31	12:48	93696
adcp.9	Feb 1	09:38	320256
adcp.10	Feb 2	05:44	308992
adcp.11	Feb 3	02:40	320256
adcp.12	Feb 3	23:30	320256
adcp.13	Feb 4	15:40	248576
adcp.14	Feb 5	12:30	320256
adcp.15	Feb 6	09:20	320256
adcp.16	Feb 7	06:10	320256
adcp.17	Feb 7	21:55	242176
adcp.18	Feb 8	18:45	320256
adcp.19	Feb 9	15:35	320256
adcp.20	Feb 10	12:25	320256
adcp.21	Feb 10	20:55	130816
adcp.22	Feb 11	17:45	320256
adcp.23	Feb 12	14:35	320256
adcp.24	Feb 13	11:25	320256
adcp.25	Feb 14	03:40	249856
adcp.26	Feb 15	00:35	320256
adcp.27	Feb 19	16:40	320768
adcp.28	Feb 19	19:20	320512
adcp.29	Feb 20	06:25	170496
adcp.30	Feb 21	03:15	320256
adcp.31	Feb 22	00:05	320256
adcp.32	Feb 22	20:55	320256
adcp.33	Feb 23	06:50	152576

Appendix 9

Chronological Log of RV Oceanus Cruise 250

Jan 25

01130 Oceanus sails heading to drifting SW buoy - approx. 15 N, 45 W

Jan 26

1400 Underway watch begins
 1500 Hourly XBT started
 1600 Fire and Boat Drill

Feb 2

0600 Arrive at drifting SW mooring 15°13.09N, 44°47.78W
 0631-0727 Recover upper 110m of mooring
 0730 Underway to SW anchor position
 0800 Start up XBT and met watch

Feb 4

1158 On station for SW mooring recovery
 1430-1843 Lower portion of the SW mooring recovered
 1900 Begin preparation for redeployment
 Release test
 Unspooling and respooling wire rope and nylon
 Check for surface current
 2200 Begin deployment

Feb 5

1318 Anchor over for Subduction II mooring SW 17°59.978'N, 34°00.513'W
 1330-1530 Intensive meteorological comparison
 1747 Underway to SE mooring
 1800 XBT and met watch started

Feb 7

0949 Recovery of lower section of SE mooring
 1413 Release test
 1630 Begin preparation for redeployment
 Unspooling and respooling wire rope and nylon
 Check for surface currents

Feb 8-9

2241-0244 Deployment Subduction II SE 17°59.72'N, 22°00.92'W
 0315-0715 Intensive Met Observations by buoy
 0731-0846 Release survey
 0900 Underway to C
 1000 XBT and met watch resumed

Feb 11

1040 C Buoy sighted
 1044-1746 Recover Central mooring
 1900 Begin preparation for redeployment
 Unspooling and respooling wire rope and nylon
 Checking for ship drift

Feb 12

1111-1916 Deployment Subduction II Central mooring 25°31.95'N, 28°57.23'W
 2006-2049 Release survey

2145-Feb 13

0045 Intensive Meteorological observations
 0100 Underway to NE mooring
 0200 Resume underway met obs and XBTs
 1319 Deployed ALACE # 46 27°27.41'N, 27°06.98'W

Feb 14

0116 Deployed ALACE #101 29°24.140'N, 25°23.931'W
 1328 Deployed ALACE #98 31°24.180'N, 23°30.533'W
 2247 NE Buoy sighted

2352-Feb 15

0541 NE mooring recovered
 0605 Underway to Madeira

LEG 2**Feb 19**

0800 Leaving Madeira Underway to NE deployment site
 1000 Start underway meteorological observations
 1200 Start hourly XBT survey

20 Feb

0600 Approaching NE anchor site
 0931-1547 Deployment of Subduction II NE Mooring 33°01.98'N, 22°00.27'W
 1747-2147 Intensive Meteorological Observations
 2152 Underway to NW
 2200 Resume underway met watch
 2300 Resume hourly XBT watch

Feb 21

0413 Deploy ALACE #100 33°00.642'N, 23°28.465'W
 1010 Deploy ALACE #97 32°59.368'N, 24°50.382'W
 1613 Deploy ALACE #103 32°59.396'N, 26°13.393'W
 1615 Deploy ALACE with CTD #59 32°59.396'N, 26°13.393'W
 2211 Deploy ALACE #102 32°59.546'N, 27°34.365'W

Feb 22

0411	Deploy ALACE #99	32°58.331'N, 28°53.129'W
1207	Deploy ALACE #44	32°57.350'N, 30°38.513'W
2006	Deploy ALACE #96	32°56.675'N, 32°25.669'W

Feb 23

0941-1022	Recover bottom section of NW mooring	
1816-2328	Deployment of Subduction II NW mooring	32°54.42'N, 33°53.35'W

Feb 24

0024	Release Survey	
0145-0545	Intensive Meteorological Observations	
0545	Underway to Ponta Delgada	
2000	Met and XBT watch suspended	

Feb 26

0900	Arrive Ponta Delgada, Azores	
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