XCP Data From the Pioneer Seamount/NOCAL Experiment

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by

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ABSTRACT

Fifty expendable current profilers (XCPs) were deployed off the California coast from the NOAA ship *McArthur*, 22-29 October 1984. Profiles of relative velocity and temperature were obtained at three sites: over the Pioneer Seamount (37°23'N, 123°25'W), near an Oregon State University (OSU) current meter mooring (38°57'N, 125°W), and across a surface-intensified front (39°07'N, 125°27'W). The goal of this study was to examine the mean and near-inertial fields of motion at the three measurement sites. The experimental design and instrument performance are discussed. Sections of relative velocity and temperature are presented for each of the experimental sites. Station pairs taken half an inertial period apart are plotted together showing the mean and inertial velocity fields.

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I. THE EXPERIMENT

Introduction

To examine the mean and near-inertial fields of motion, profiles of velocity and temperature were acquired at three measurement sites off the California coast using 50 expendable current profilers (XCPs). These measurements were made aboard the NOAA vessel *McArthur* on 22-29 October 1984 during cruise 13 of the Ocean Prediction through Observations, Modeling and Analysis (OPTOMA) Program.* Measurements were made at three sites: over the Pioneer Seamount (37°23'N, 123°25'W), around an Oregon State University current meter mooring (38°57'N, 125°W), and across a surface-intensified front (39°07'N, 125°27'W) (Figure 1).

The Pioneer Seamount location (Figure 2) was chosen to examine the effect of topography on near-inertial motions and the mean flow fields. (See the Appendix for detailed topography in the vicinity of the Pioneer Seamount.)

The current meter and front sites were located within the Northern California (NOCAL) domain of the OPTOMA Program. The NOCAL region is a 100 nm square domain off Pt. Arena where numerous quasi-synoptic maps have been made to test the predictive capabilities of the OPTOMA eddy-resolving numerical ocean model. The OPTOMA program wished to determine the utility of including XCP velocity profiles in its sampling grid.

*This is a joint program (Naval Postgraduate School and Harvard University) sponsored by ONR. The work reported here was conducted on an OPTOMA cruise, but was not a part of that program. Some aspects of our experiment were of interest to OPTOMA, and these are noted in the text.

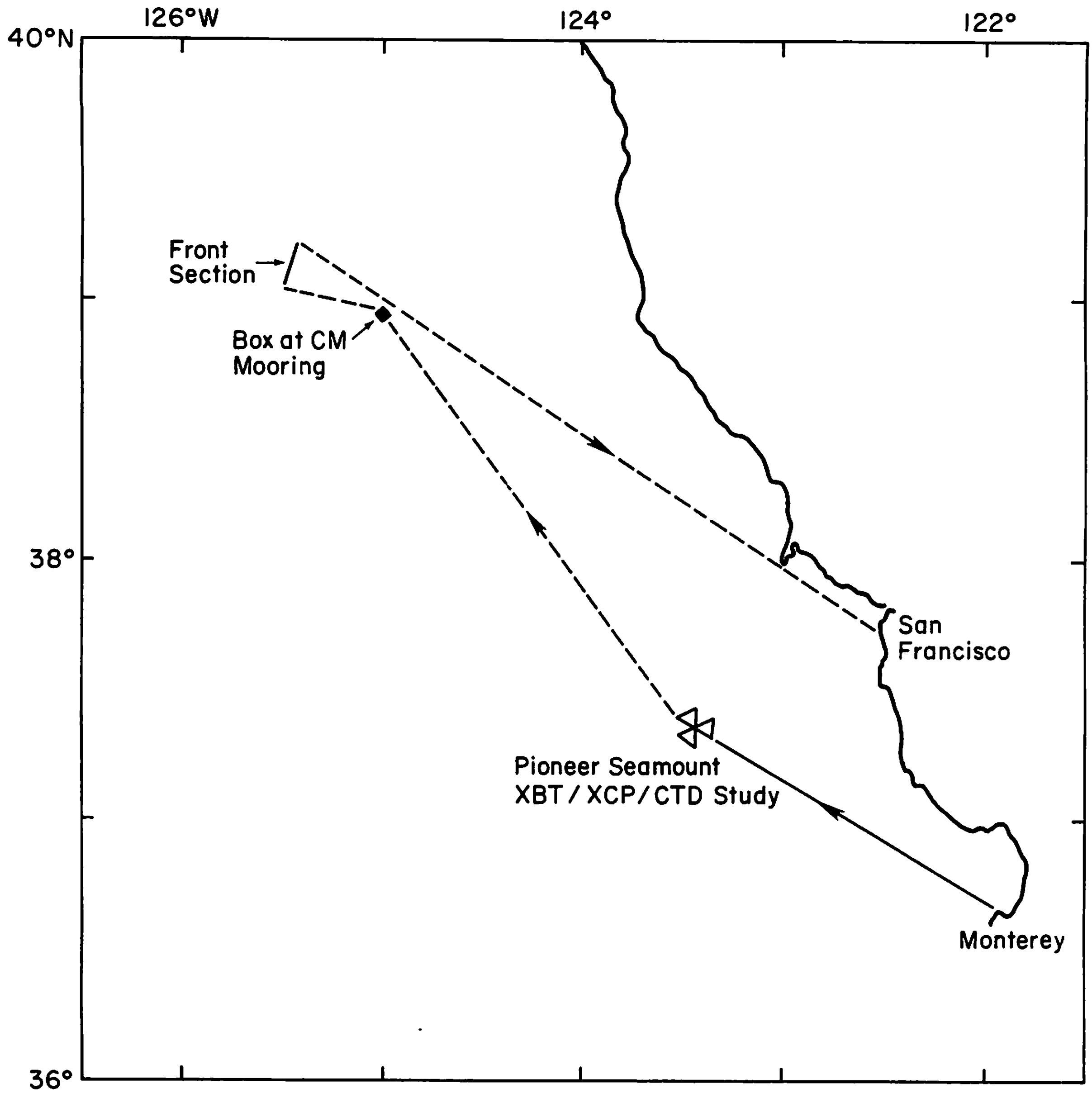
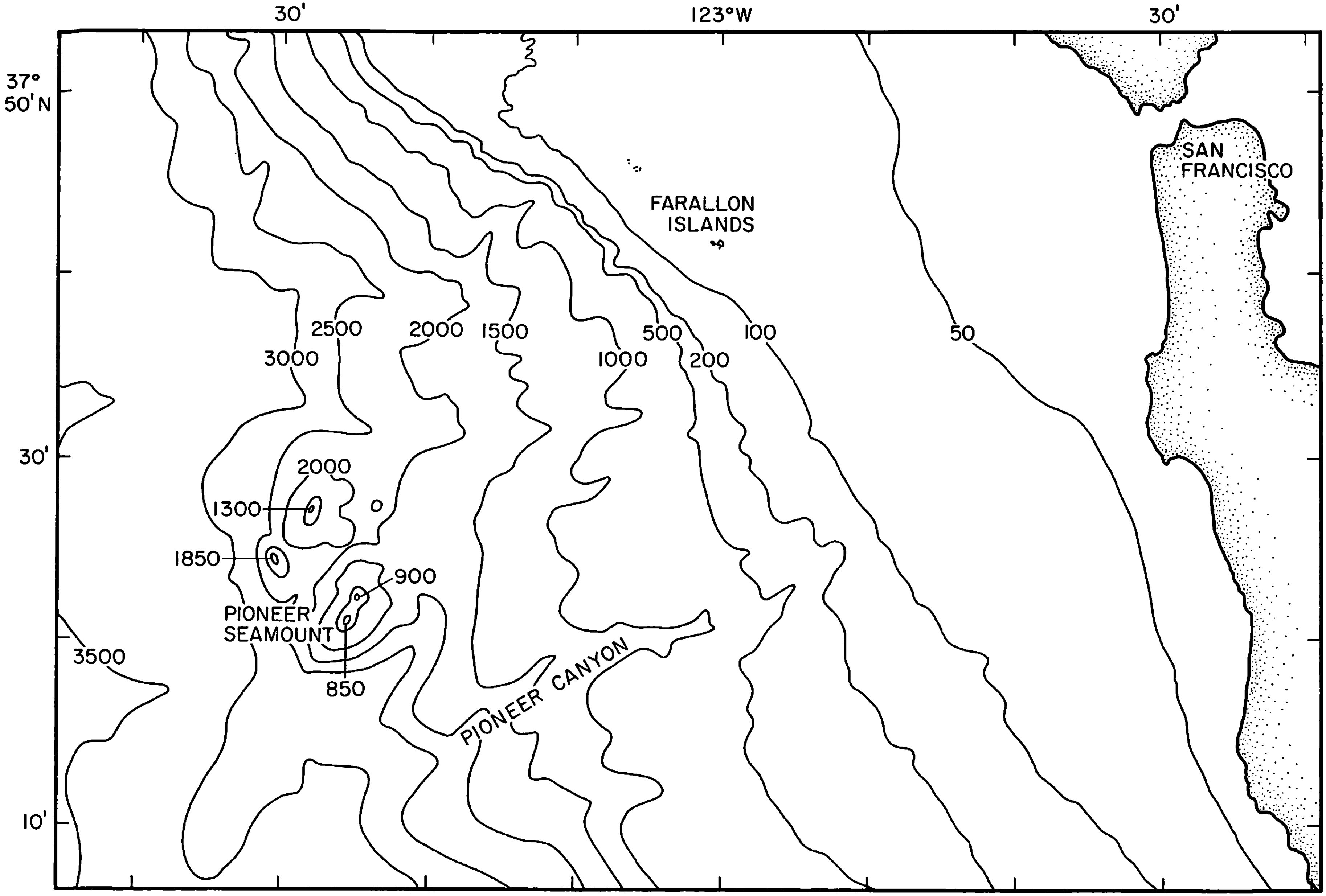


Figure 1. XCP deployment sites off California.



After Chart NOS NJ 10-8 (OCS) Depths in meters

Figure 2. Topography of Pioneer Seamount.

Experimental Design

The goal of the Pioneer component was to acquire a spatially-coherent snapshot of the mean and internal wave temperature and velocity fields in the vicinity of a topographic feature. Sampling over Pioneer comprised two pinwheel patterns. Pinwheel 1 consisted of 21 probe drops on three legs (XCPs 1501-1521). Pinwheel 2 was to be a repetition of pinwheel 1, half an inertial period (10 hours at 37°20'N) later, to allow separation of near-inertial and geostrophic motions. However, failure of the OPTOMA XBT/CTD acquisition system necessitated the ship's return to Monterey for repairs. By the time the *McArthur* returned to Pioneer, over a full inertial day had passed and there was insufficient time to wait an additional half-inertial period. Nine XCPs (1522-1530) were deployed in pinwheel pattern 2, for the most part on two legs. At the same time, three CTD casts were made (Figure 3) to determine the T-S relation in the area. It was thought that a stratified Taylor column might exist over the peak, which might cause horizontal variability in the T-S relation. However, there is no indication of either a stratified Taylor column (Figures 12a-e) or a varying T-S relationship over the seamount, although thermohaline intrusions are present between 220 and 600 m (Figure 4).

At the site of the OSU current meter mooring, 10 XCPs were dropped in a repeated box pattern. The two boxes were taken half an inertial period apart to allow separation of the mean and inertial wave components. Box 1 included XCPs 1531-1535 and box 2 XCPs 1536-1540 (Figure 5).

Two transects separated by 10 hours were made across a surface-intensified front previously detected during OPTOMA cruise 12 on 8-18 October 1984. XCPs 1541-1546 were dropped on transect 1; XCPs 1547-1550 were dropped on transect 2 (Figure 6). These sections also included half-inertial-period pairs. Ten XBT drops and a CTD cast were made on that same line.

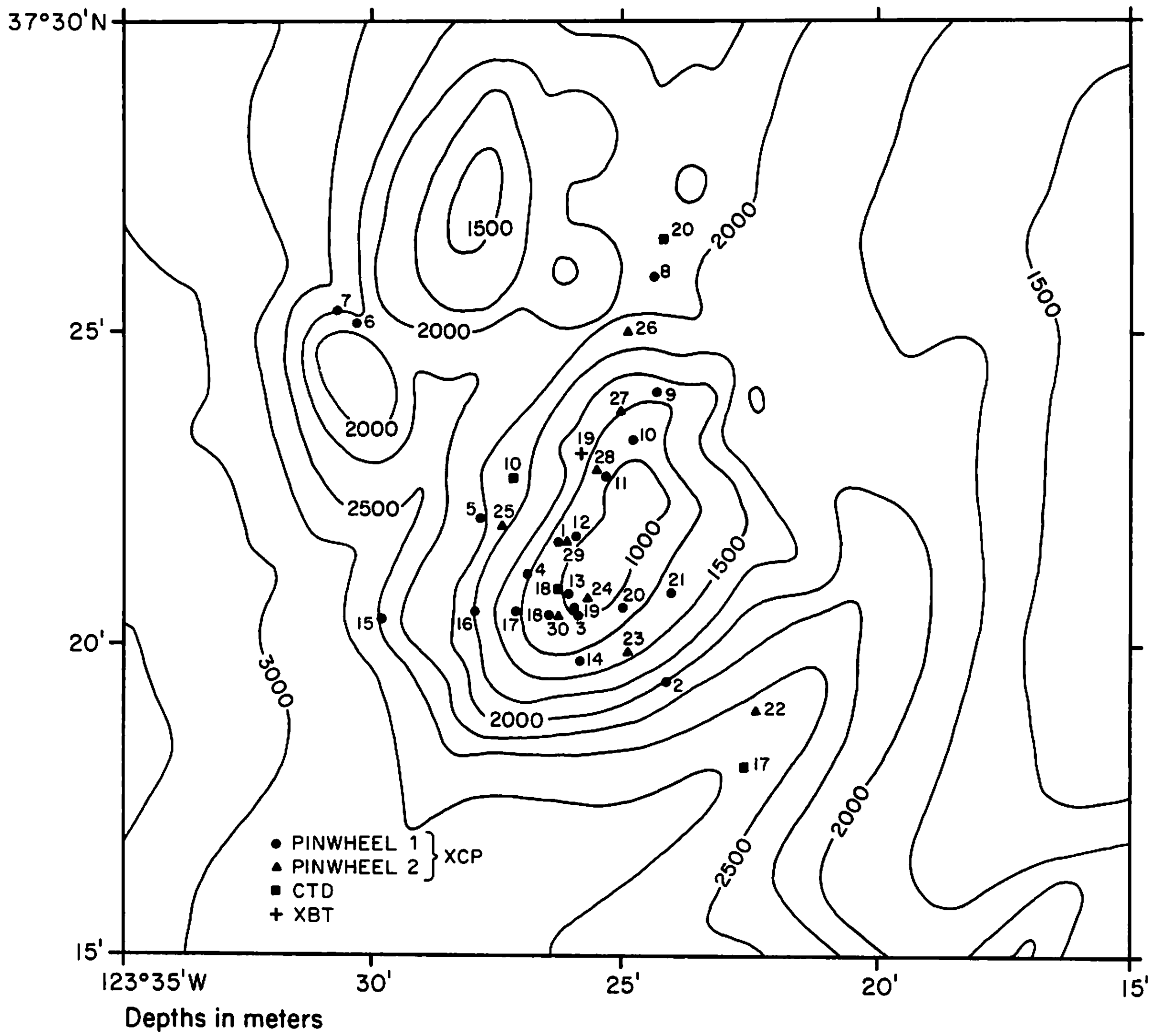


Figure 3. XCP deployment locations for pinwheel patterns 1 and 2 over Pioneer Seamount.

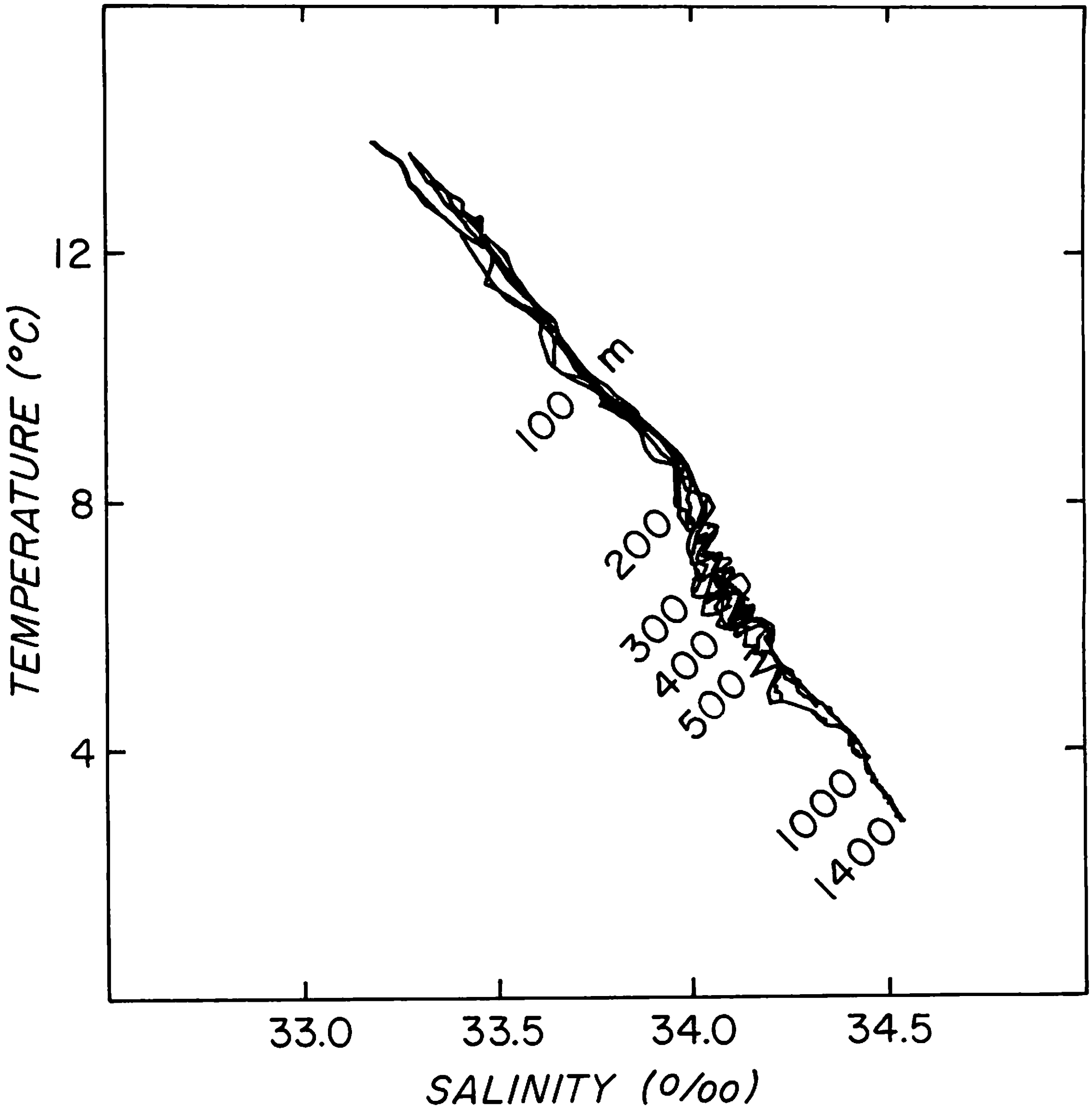


Figure 4. T-S relation for Pioneer Seamount region derived from CTD data.

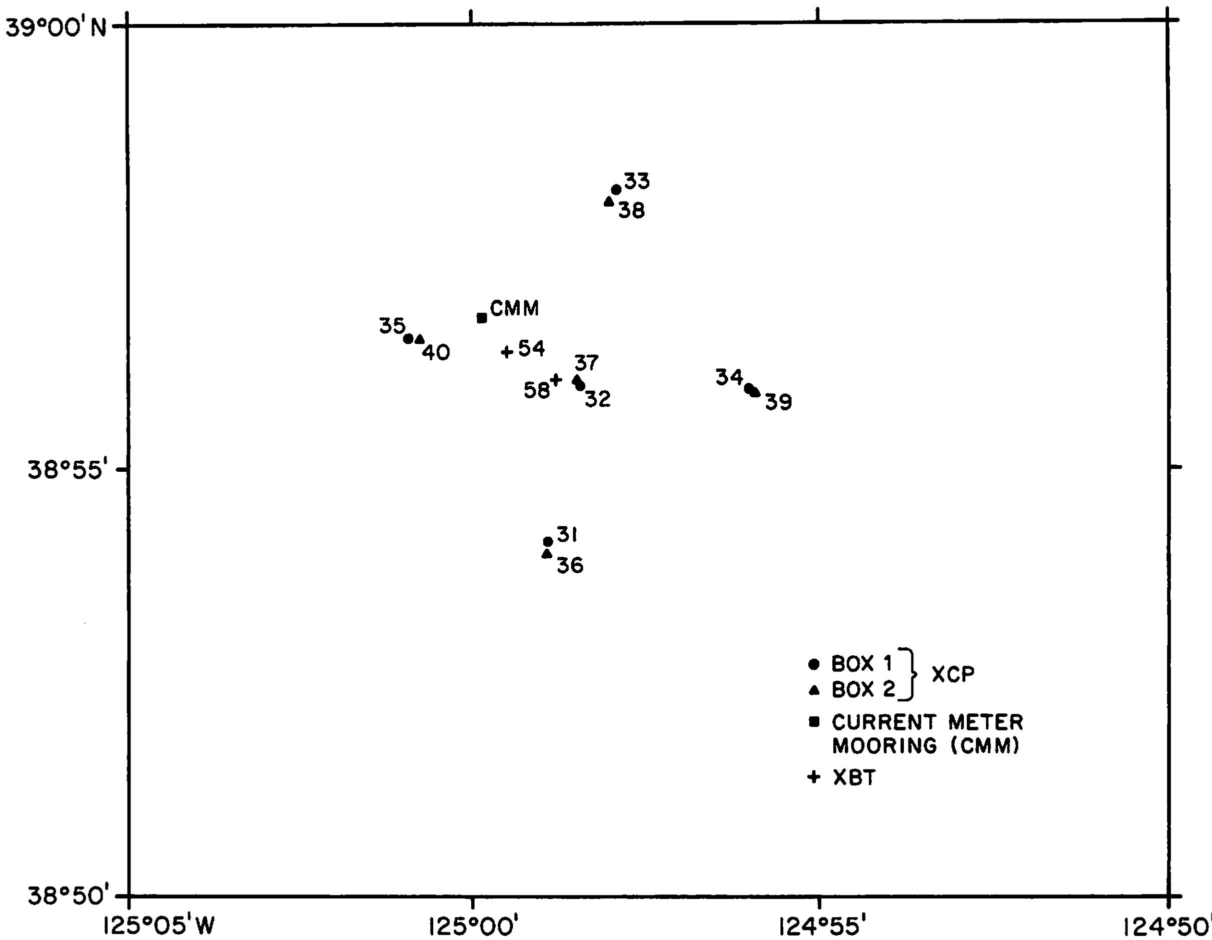


Figure 5. XCP deployment locations for boxes 1 and 2 around OSU current meter mooring.

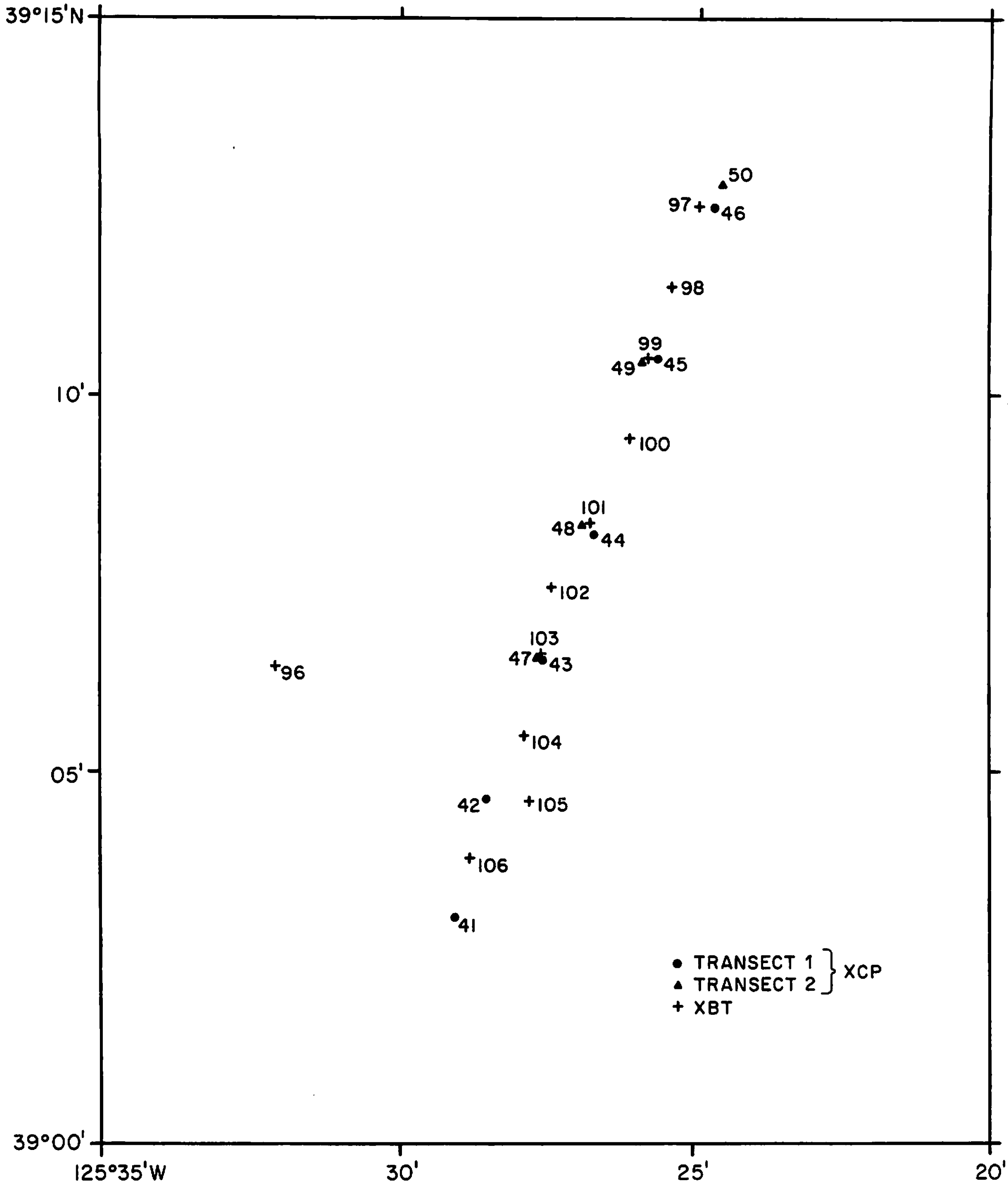


Figure 6. XCP deployment locations for transects 1 and 2 across surface front.

The XCP position information at the three sites is summarized in Tables 1-3 along with ship's speed and heading, and wind speed and heading. Some XBT and CTD information is also given in Tables 1-3 for cross-reference purposes. Knowledge of the bottom depth was crucial for the Pioneer Seamount survey, so it is included in the Pioneer event log (Table 1). Comments on the quality of the XCP drops are provided in the last column of Tables 1-3. Position information for all CTD casts and XBTs is given in Tables A-1 and A-2. The hydrographic data from the OPTOMA program are summarized in Wittmann et al. (1985).

II. BOTTOM TOPOGRAPHY

After the first XCP drop, depth was recorded continuously over the seamount with a PGR fathometer. The bathymetric record is compared with chart bathymetry in Figure 7 for the three legs of pinwheel 1. The PGR record is plotted as a continuous line; breaks indicate bad data. The triangles indicate values read off the bathymetry chart (NOS Chart NJ 10-8). The vertical lines mark XCP drop positions: solid lines denote profiles that hit the bottom, and dashed lines indicate wire breaks or ambiguous drop endings. The three estimates of bottom depth agree reasonably in terms of the overall structure of the topography. The chart bathymetry shows the least agreement, probably as a result of smoothing before the data were contoured.

III. INSTRUMENTATION

The XCP, formerly known as the XTVP (Sanford et al., 1980), is a ship-launched expendable instrument that measures a vertical profile of the relative horizontal velocity and temperature. Velocity determinations are based on the principles of electromagnetic induction which govern the weak electric currents induced by the motion of seawater through the earth's magnetic field. The resulting electric current profile corresponds to the velocity profile (offset by an unknown but depth-independent constant, the barotropic component of the flow). The Mod 7 XCP consists of two major

Table 1. Pioneer Seamount event log.

Instrument Type	No.	Date	Time	Latitude deg min	Longitude deg min	Bottom depth (m)	Ship sp kn	Ship head deg	Wind sp kn	Wind head deg	Comment
					PINWHEEL 1						
											over seamount
XCP	1501	841023	0052	37 21.6	123 26.2	----	5	330	26	000	good
CTD	10	841023	0122	37 22.7	123 27.2	----					
											leg1
XCP	1502	841023	0249	37 19.3	123 24.0	----	5	340	22	000	good to 1050 m
XCP	1503	841023	0348	37 20.5	123 26.0	1170	5	326	28	000	good
XCP	1504	841023	0404	37 21.2	123 27.0	1887	5	330	24	000	good after 100 m
XCP	1505	841023	0426	37 22.0	123 28.0	----	5	330	26	000	good
XCP	1506	841023	0513	37 25.2	123 30.4	1756	5	335	28	000	good
XCP	1507	841023	0529	37 25.3	123 30.7	1298	1	300	24	020	good
											leg 2
XCP	1508	841023	0624	37 25.9	123 24.3	1692	5	200	18	120	good to 1500 m
XCP	1509	841023	0656	37 24.0	123 24.3	1185	5	194	16	125	good
XCP	1510	841023	0714	37 23.2	123 24.7	1551	5	260	24	055	good
XCP	1511	841023	0729	37 22.6	123 25.2	585	5	194	14	120	good
XCP	1512	841023	0744	37 21.7	123 25.8	644	5	180	16	150	fair
XCP	1513	841023	0757	37 20.7	123 25.9	936	5	180	12	150	good
XCP	1514	841023	0814	37 19.7	123 25.8	----	5	192	16	145	good
											leg 3
XCP	1515	841023	0919	37 20.4	123 29.8	----	5	080	20	350	good to 1200 m
XCP	1516	841023	0936	37 20.6	123 28.1	1229	5	078	20	340	good
XCP	1517	841023	0951	37 20.5	123 27.3	----	5	076	20	350	good
XCP	1518	841023	1005	37 20.4	123 26.5	878	5	070	20	350	good to 820 m
XCP	1519	841023	1018	37 20.6	123 25.9	1214	5	070	18	345	good
XCP	1520	841023	1033	37 20.6	123 24.9	2249	5	070	18	350	good
XCP	1521	841023	1049	37 20.8	123 24.1	----	3	040	14	300	good to 1600 m
CTD	17	841024	0415	37 18.0	123 22.6	----	0	320	18	000	
					PINWHEEL 2						
											leg 1
XCP	1522	841024	0441	37 18.9	123 22.2	1756	5	330	20	000	good to 470 m
XCP	1523	841024	0508	37 19.9	123 24.8	----	5	300	18	000	good
XCP	1524	841024	0524	37 20.7	123 25.7	1024	5	320	20	000	fair
XCP	1525	841024	0542	37 21.8	123 27.4	2751	5	315	20	000	good
											leg 2
XCP	1526	841024	0621	37 25.0	123 24.8	1006	5	192	10	090	good to 100 m
XCP	1527	841024	0659	37 23.7	123 25.0	1668	5	180	10	110	good to 900 m
XCP	1528	841024	0715	37 22.7	123 25.4	761	5	180	14	110	good
XCP	1529	841024	0730	37 21.7	123 26.0	----	5	200	12	095	good to 980 m
XCP	1530	841024	0750	37 20.5	123 26.2	1346	5	180	14	095	fair
CTD	18	841024	0848	37 20.9	123 26.1	732	2	290	12	030	
XBT	19	841024	0910	37 23.7	123 25.7	----	11	023	26	320	
CTD	20	841024	1048	37 26.5	123 24.1	1756	1	315	20	315	

Table 2. OSU current meter mooring event log.

Instrument Type	No.	Date	Time	Latitude deg	min	Longitude deg	min	Ship sp kn	head deg	Wind sp kn	head deg	Comment
						BOX 1						
XCP	1531	841026	1037	38	54.1	124	58.9	5	325	16	280	good
XCP	1532	841026	1103	38	55.9	124	58.4	5	040	12	245	good
XCP	1533	841026	1132	38	58.1	124	57.9	5	010	18	280	good
XCP	1534	841026	1213	38	55.8	124	55.9	5	065	18	240	good
XBT	54	841026	1258	38	56.3	124	59.4	5	285	30	005	
XCP	1535	841026	1316	38	56.5	125	01.0	7	285	30	010	good
						BOX 2						
XCP	1536	841026	2039	38	54.0	124	58.9	5	070	16	265	good
XCP	1537	841026	2109	38	55.9	124	58.4	5	070	18	270	good (bad T)
XCP	1538	841026	2133	38	58.0	124	58.0	5	000	16	290	fair
XCP	1539	841026	2157	38	55.8	124	55.8	5	140	16	104	good
XBT	58	841026	2222	38	56.0	124	58.7	5	285	24	045	
XCP	1540	841026	2237	38	56.5	125	00.8	7	295	30	045	good

Table 3. Surface front event log.

Instrument Type	No.	Date	Time	Latitude deg	min	Longitude deg	min	Ship sp kn	head deg	Wind sp kn	head deg	Comment
						LEG 1						
XBT	96	841028	0633	39	06.4	125	32.2	12	157	20	010	
XCP	1541	841028	0659	39	03.0	125	29.1	5	020	08	060	good
XCP	1542	841028	0716	39	04.6	125	28.5	5	040	06	075	good
XCP	1543	841028	0735	39	06.5	125	27.5	5	345	08	270	fair
XCP	1544	841028	0755	39	08.2	125	26.7	5	015	08	320	good
XCP	1545	841028	0824	39	10.5	125	25.7	5	025	04	160	good
XCP	1546	841028	0956	39	12.5	125	24.7	5	015	04	160	good
XBT	97	841028	0917	39	12.5	125	24.9	4	320	10	270	
XBT	98	841028	0940	39	11.5	125	25.4	4	195	20	350	
XBT	99	841028	0955	39	10.5	125	25.8	4	190	18	015	
XBT	100	841028	1010	39	09.4	125	26.2	4	195	14	000	
XBT	101	841028	1026	39	08.3	125	26.8	4	195	18	000	
XBT	102	841028	1039	39	07.4	125	27.4	4	195	18	000	
XBT	103	841028	1052	39	06.5	125	27.6	4	190	16	000	
XBT	104	841028	1106	39	05.5	125	27.8	4	190	16	000	
XBT	105	841028	1119	39	04.6	125	28.3	4	200	14	020	
XBT	106	841028	1129	39	03.8	125	28.8	4	200	16	010	
						LEG 2						
XCP	1547	841028	1735	39	06.5	125	27.6	5	113	20	000	good
XCP	1548	841028	1802	39	08.3	125	26.9	5	030	10	150	good to 850 m
XCP	1549	841028	1823	39	10.4	125	25.9	5	027	10	180	good
XCP	1550	841028	1957	39	12.8	125	24.5	5	150	22	060	good

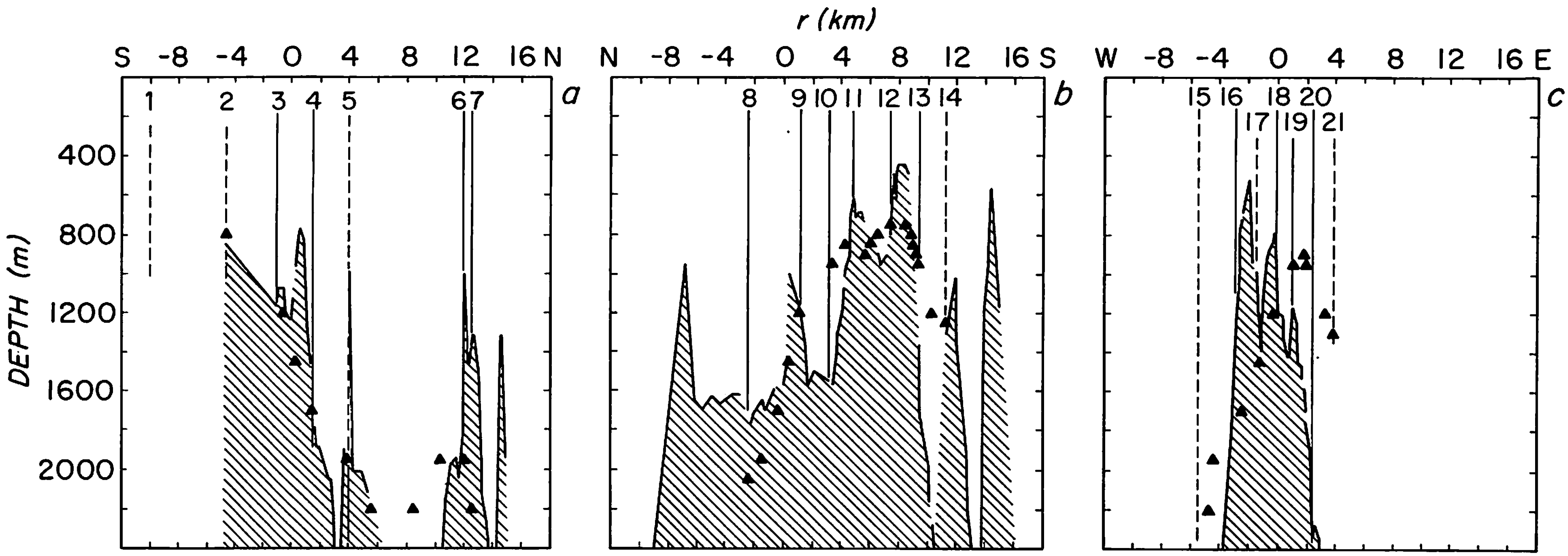


Figure 7. Comparison of PGR bathymetry record with NOS bathymetry chart. Pinwheel 1: a) along leg 1; b) along leg 2; c) along leg 3.

subassemblies: the probe, which descends through the water column; and the buoy assembly which remains on the ocean surface to transmit data via an RF link to the shipboard receiver. Three signals are sent to the receiver: electric field, compass direction, and temperature. This cruise was the first occasion on which we deployed radio-link XCPs from a ship. Previously, a wire link to the shipboard processing system had been used.

The XCP receiving system (Figure 8) consists of a digital receiver developed by Robert Drever (at APL-UW) which receives, amplifies, demodulates, and digitizes the incoming RF signal for direct computer storage. The computer used for this system is an HP9845B, with an HP9885M flexible disc drive and an HP9872A XY plotter. The compass information from the probe and the analog electric field signal are available at front panel connectors of the receiver during deployment. The compass signal is used as a reference signal for a PAR 129A two-phase vector lock-in amplifier. This amplifier synchronously demodulates the electric field voltage into its in-phase (north-south) and quadrature (east-west) components with respect to the compass signal to produce real-time plots, as the probe is falling, of the "velocities" on an HP7064A two-pen XYY recorder. These real-time displays are invaluable for planning changes in deployment methods and sampling strategy in response to observed conditions during the experiment.

IV. OPERATIONS

Fifty Sippican Mod 7 XCPs were deployed during the Pioneer Seamount/NOCAL experiment. All probes were tested before launch for transmitter and probe operation; the results of all tests were good. One nose weight separated from the probe during the pre-launch test, but was reconnected and the probe functioned properly. All probes inflated the antenna float and transmitted the data signal back to the ship without exception. The float holds the buoy assembly and probe on the surface so that the ship can move away before the probe is released, thus minimizing the ship's

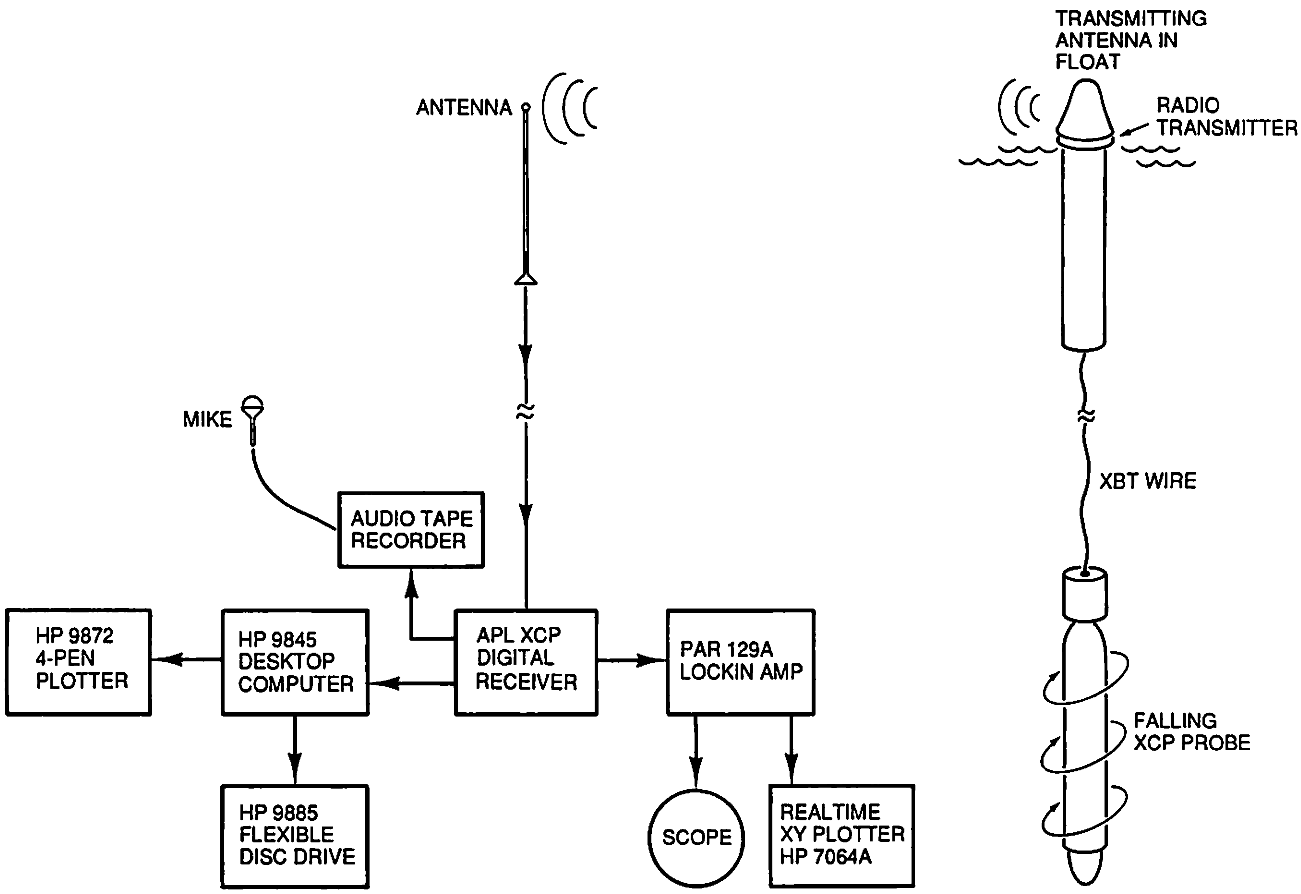


Figure 8. XCP acquisition system.

contamination of the electric and magnetic fields sensed by the probe. The float also supports the antenna in the buoy assembly. One probe appeared to break a wire before reaching the design depth of 1600 m.

The procedure for powering up the XCP to test the transmitter before launching is outlined below.

> Connect +12 to 15 Vdc to the wire located about 9 in. from the transmitter end (Figure 9) and ground to the cast metal housing above the wire. This powers the transmitter only and does not turn on the timer or the air bag.
>
> There is a 3/4 in. x 1/2 in. hole near the nose end of the XCP probe with three contacts (Figure 9). These are the test points. Apply 12 V to turn on the probe:
>
> > nearest to nose, +12 Vdc
> > next (middle point), -12 Vdc
> > nearest tail, ground

This procedure will run a signal to the antenna through the receiver box to the tape recorders. Listen on earphones.

During the first 11 probe drops various techniques were used to optimize the RF signal. Starting with drop 1512, the standard launch procedure was:

> Have the ship steaming at 5 kn at the time of launch.
>
> Launch probe from starboard wing of bridge (located one deck below the receiving antenna).
>
> Slow ship to 1 kn and turn 45° to starboard 1 minute after launch.

The last series of drops, commencing with drop 1544, was done with the ship slowly turning to starboard, ending with the probe 90° off the starboard beam at a distance of no less than 500 m. This procedure gave the best signals.

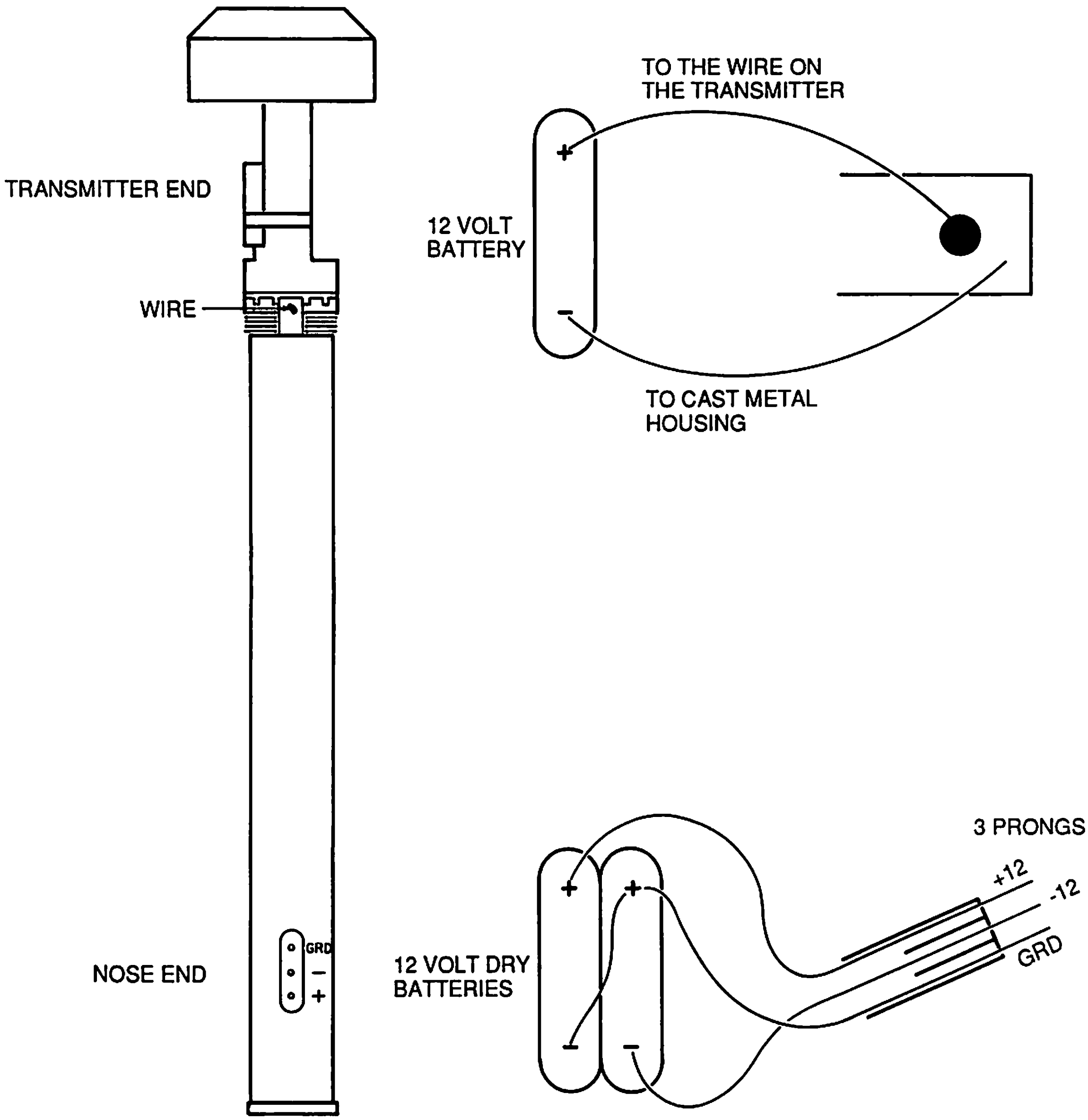


Figure 9. XCP power-up test diagram.

V. DATA

Of the 50 probes, only two failed and even these returned some useful data (drop 1526 was good to only 100 m; temperature data were bad on drop 1537). The nature of the noise in most of the drops implied that much of the bad data was due to loss of radio signal. This problem could have been alleviated by using a directional antenna and placing it higher on the ship. Electrode failure, previously a major problem, appeared to contribute little to degrading the data.

The data acquisition scheme used during this experiment is outlined in Table 4. The incoming signal is recorded on audio tape. In addition, the program DXGETH accepts data from the XCP receiver and stores it on floppy disc. Acquisition takes roughly 5 minutes.

Before the actual processing program can be run, it is necessary to find the components of the earth's magnetic field at the location of the XCP drop. This is accomplished using a program called PADOC which evaluates a spherical polynomial model based on date and position. Next, the processing program KXPROm is implemented. KXPROm is a modified version of DXPRO which is described by Sanford et al. (1982). KXPROm takes files of raw data and produces velocity profile files as it plots. Wild point editing was used in the Pioneer/NOCAL data processing to reduce the influence of outliers on the computed average velocities. The processing sequence is outlined in more detail by Sanford et al. (1982).

VI. VELOCITY SECTIONS

The east (U) and North (V) components of relative velocity are plotted separately as a function of depth (Figures 10a-v). The straight vertical lines indicate XCP drop location in kilometers relative to the rightmost station in each section, which is arbitrarily set at r=10 km. The drop number is annotated below each profile. Section orientation is given by the directions at the top corners of each plot, and the velocity scale is shown in the lower left corner. The bottom topography has been hatched for

Table 4. XCP data acquisition scheme.

Probe	APL-UW XCP Digital Receiver	HP9845B Computer (Specify storage device: Mass storage is "DISC DRIVE")	Tape Recorder
5-10 min. before drop			
Wait for previous probe to stop transmitting	Check that all cables & switches are in place	Wait for previous DXGETH run to finish	Change tape (if necessary)
Log S/N & channel frequency	Set channel freq. switch	Change discs	Add audio header, i.e., drop no., etc.
	Connect channel output to tape recorder	Push RUN	Remove microphone
Power-on probe xmtter →	Listen for quieting on audio	*Program prompts* / *User response* Probe mod? / 7 CONT	
Power-on probe →	Listen for warble on audio	Enter the number of data cycles to take from the digital receiver / 7500 CONT	
Remove all fiber tape from base of probe, rubber band from top of probe, & the two pieces of electrician's tape from electrodes (but leave masking tape)			
Launching			
Launch probe from fantail or side, well away from ship; to avoid contamination (by the ship's electric field) of the upper 100 m of the profile, the ship should be moved at 10 kn for the first 60 s after launching probe	Wait for quieting →	*Program prompts* / *User response* Push CONT to start recording from digital receiver / CONT Computer displays message: "GETTING DATA FROM DIGITAL RECEIVER NOW"	Tape recorder is recording (Avoid overdriving recorder signal; recording level on tape recorder should not go into red zone.)
Drop completion			
		After 3-5 min. of additional acquisition, DXGETH will give *Program prompts* / *User response* Output file name? / _ _ _ _R* Comments? / Enter any comment line After about 3 min., the file will be saved on disc and computer will display "FINISHED"	When probe warble ends, stop recording

*four-digit number plus R (for raw file) the Pioneer Seamount sections. Gaps in the velocity profiles represent bad data. Bad data points are identified by a standard deviation criterion on raw data with respect to a 22-point, triangular-averaged value divided by the square root of the number of input points (VELER). This statistic is taken to be a measure of the white noise contamination of the measurement. Experience has shown that profile accuracy is degraded when VELER exceeds several centimeters per second. In plotting the U and V sections, the upper bound for VELER was 3 cm/s.

The data were plotted subtracting out the flow averaged between 800 and 1000 m. The plots for the Pioneer location are presented first, then those at the OSU CM mooring, followed by the front location.

VII. TEMPERATURE SECTIONS

Sections of temperature as measured by the XCP are plotted as a function of depth in Figures 11a-i. The XCP drop number is annotated below each profile. The leftmost profile is plotted to the temperature scale at the top of the plot. All other drops are successively shifted 2°. The drops comprising the sections are the same as for the velocity component plots with the exception of the boxes, where all profiles for each box are plotted together. The temperature for drop 37 was bad.

Two VELER criteria were used for most of the temperature profiles: VELER <2 above 200 m; VELER <0.8 below 200 m. These criteria were relaxed for drops 22, 24, and 38.

VIII. ISOTHERM SECTIONS

Isotherm sections are plotted as a function of depth in Figures 12a-k in a similar manner to the velocity component plots. The 5 and 10° isotherms are annotated. Solid lines denote whole degrees; the dashed lines in between mark every 0.5° above 6°C and every 0.2° below 6°C. Bottom topography is hatched for the Pioneer sections. There is no indication of strong up- or downbowing of isotherms over the seamount, probably because no current was impinging on the seamount.

IX. HALF-INERTIAL-PERIOD PAIRS

Much of the internal wave energy in the ocean is contributed by near-inertial-period waves. Profiles taken half an inertial period apart often show structure that is nearly 180° out of phase. To evaluate the inertial wave contribution to the velocity profiles, half-inertial period pairs are plotted together. In Figures 13a-d the pairs are plotted as a function of depth, where the vertical lines represent zero and the scales are shown in the lower right-hand corner of each panel. Drop numbers for the pairs are located below the bottom panel. The east component (U) of velocity is plotted in the upper half, and the north component (V) in the lower half. The first drop in the pair is represented by the thick curve; the thin curve denotes the second drop. The velocity components plotted in near-inertial-period pairs were averaged over six points.

It was intended that pinwheel sampling pattern 2 be a repetition of pinwheel pattern 1, half an inertial period later; but the ship had to go into port for repairs, so only one pair (1 and 29) of the Pioneer drops was separated by an odd multiple of half an inertial period. The drops near the current meter mooring and in the front were separated by half an inertial period.

X. HALF-INERTIAL-PERIOD PAIR SUMS AND DIFFERENCES

Sums of half-inertial-period pairs reveal characteristics of the mean flow, while differences highlight the inertial motions. Plotted in Figures 14a-d are sums (top panel) and differences (lower panel) for the pairs shown in Figures 13a-d. The thick line denotes the V component; the thin line is the U component. As before, the straight vertical line is zero, and the scale is shown on the right.

XI. SUMMARY

The Pioneer Seamount/NOCAL experiment was successful in terms of XCP performance and quality of data obtained. Future plans are to assimilate the XCP data set with the other data from the OSU CM mooring site and the frontal region in order to gain an understanding of the dynamics of these two areas.

ACKNOWLEDGMENTS

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We commend the cooperation and skill of the captain of the *McArthur*, Commander Lilly, and the officers and crew who contributed to the success of the XCP work. We are also grateful to Dr. Edward Kelly Jr., chief scientist for the OPTOMA 13 cruise, for facilitating the XCP deployments.

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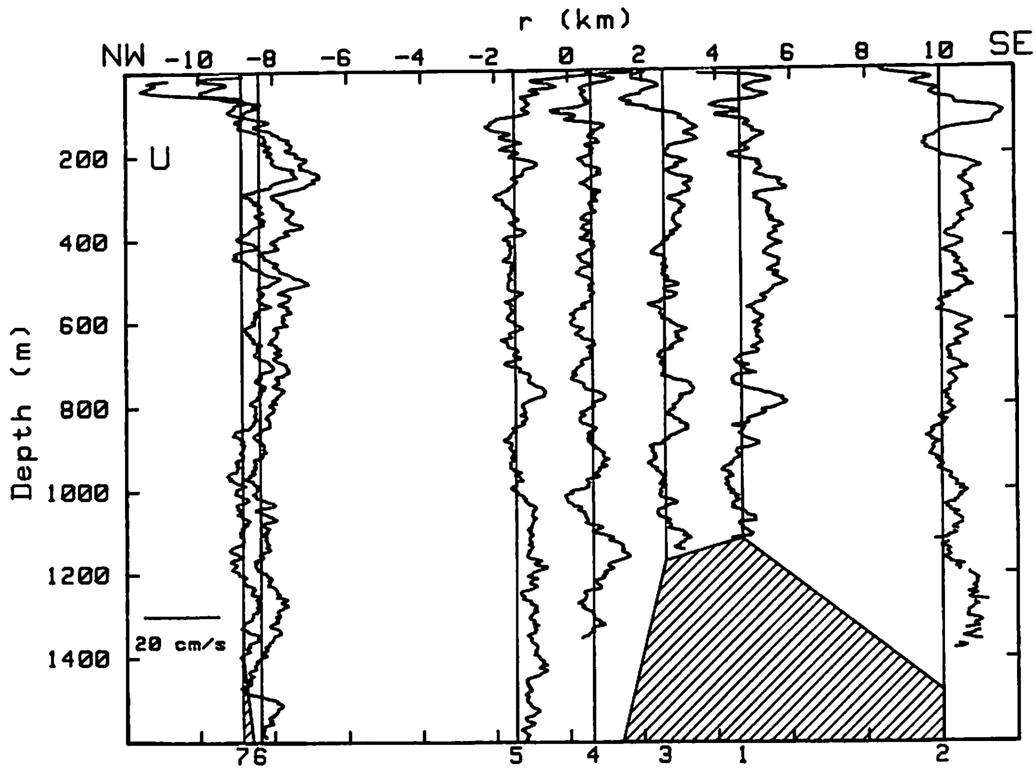

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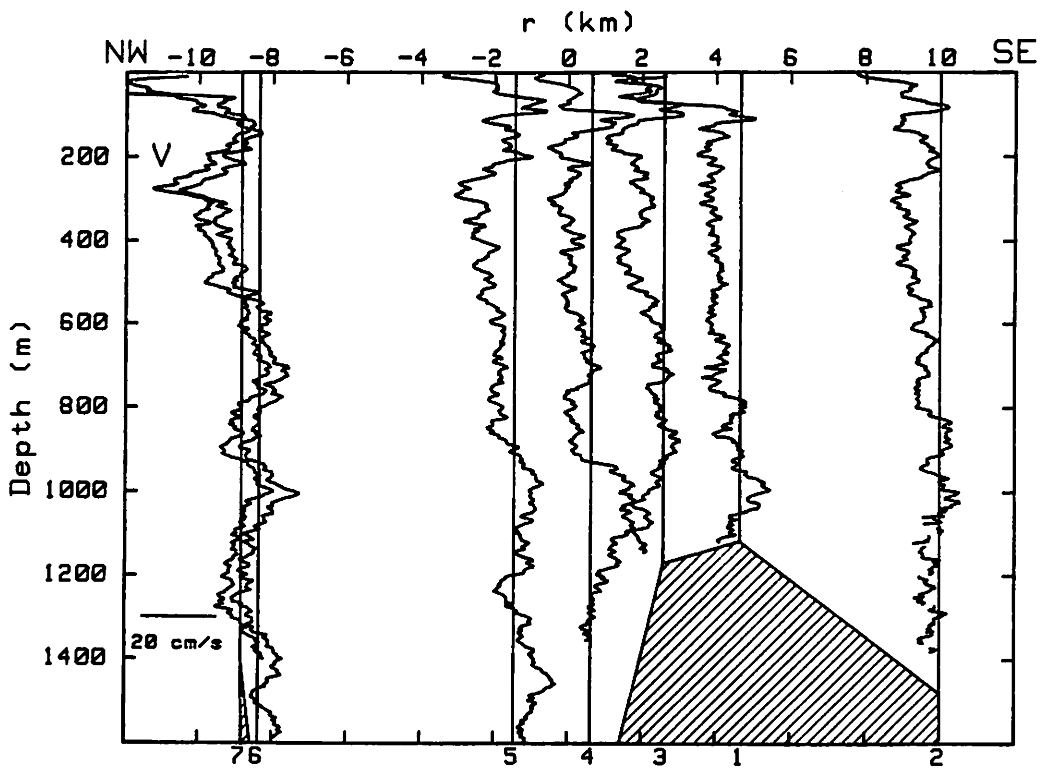

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Figure 10 East (U) and North (V) velocity sections.

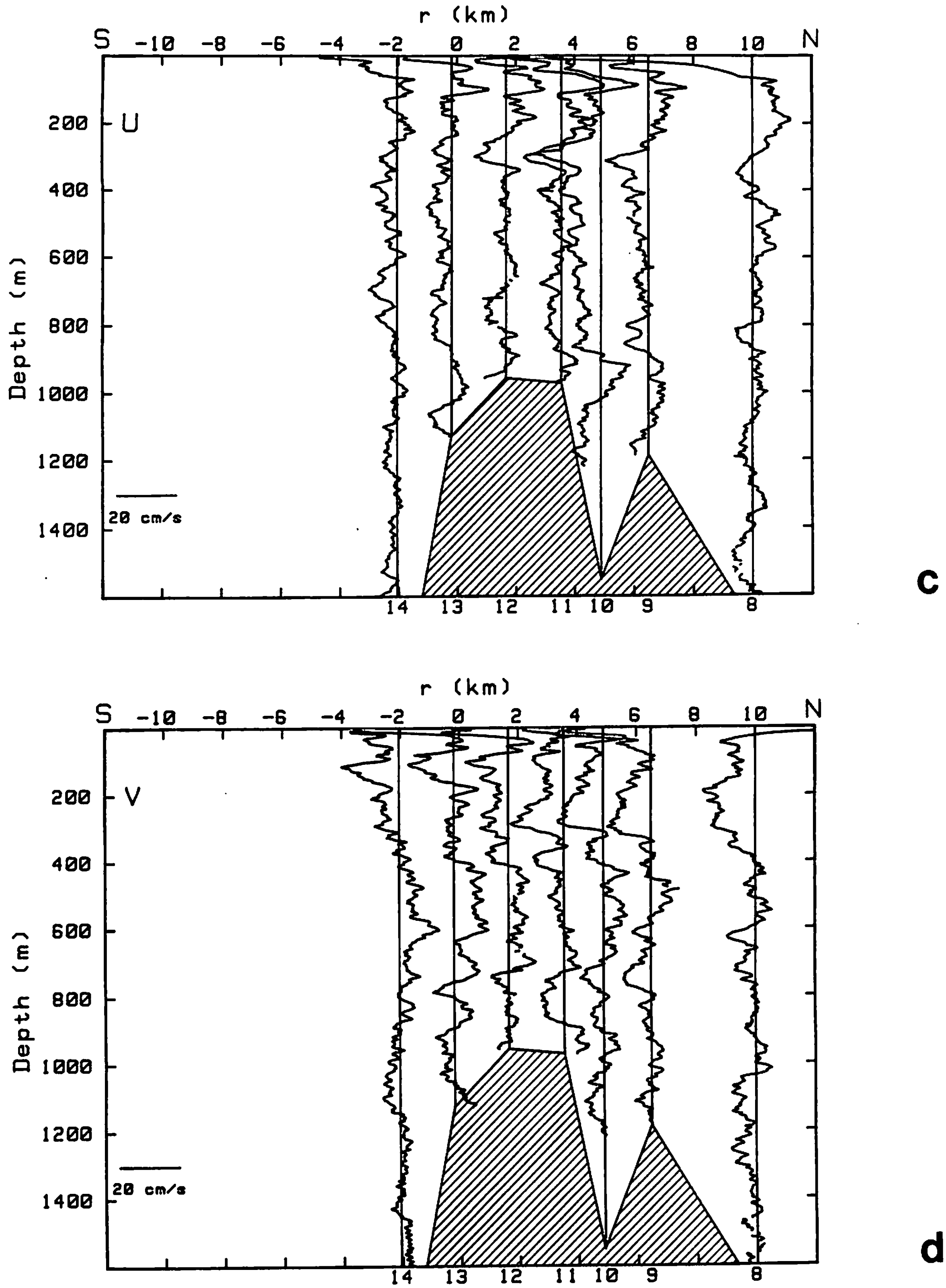
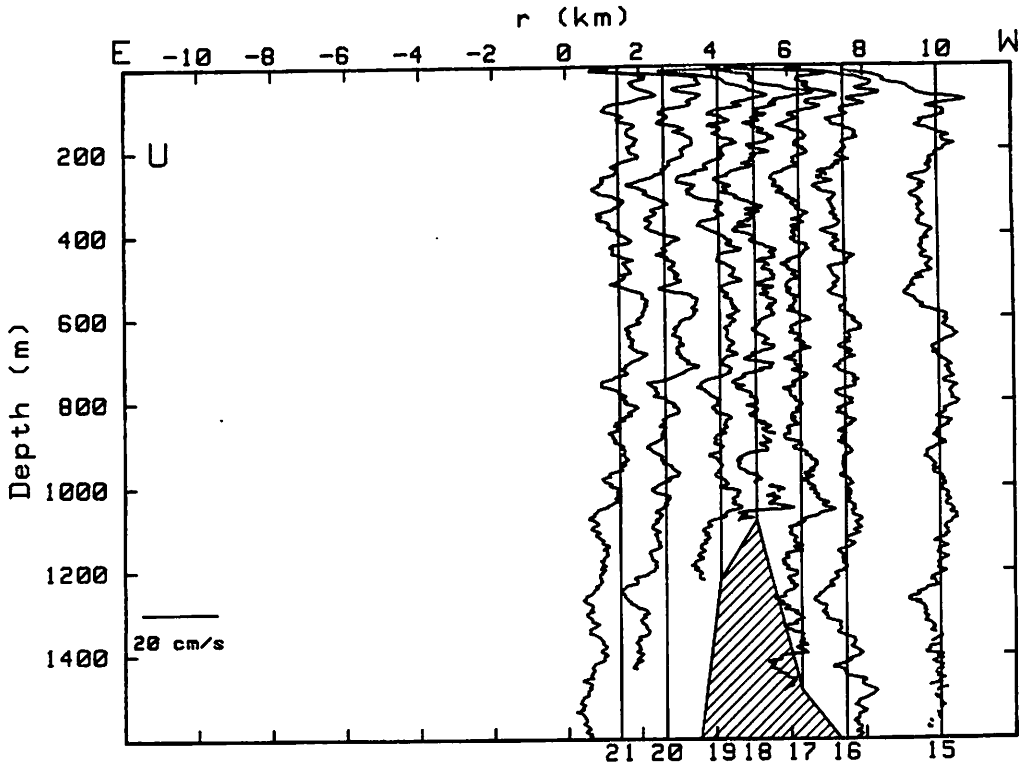


Figure 10. East (U) and North (V) velocity sections (continued).



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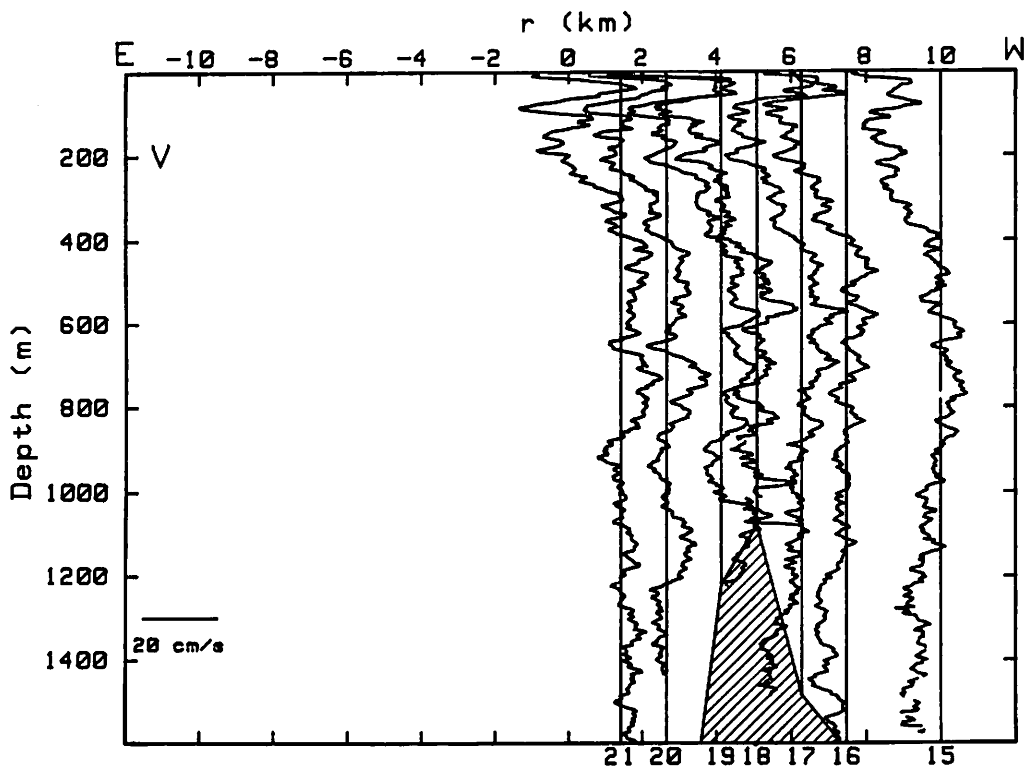

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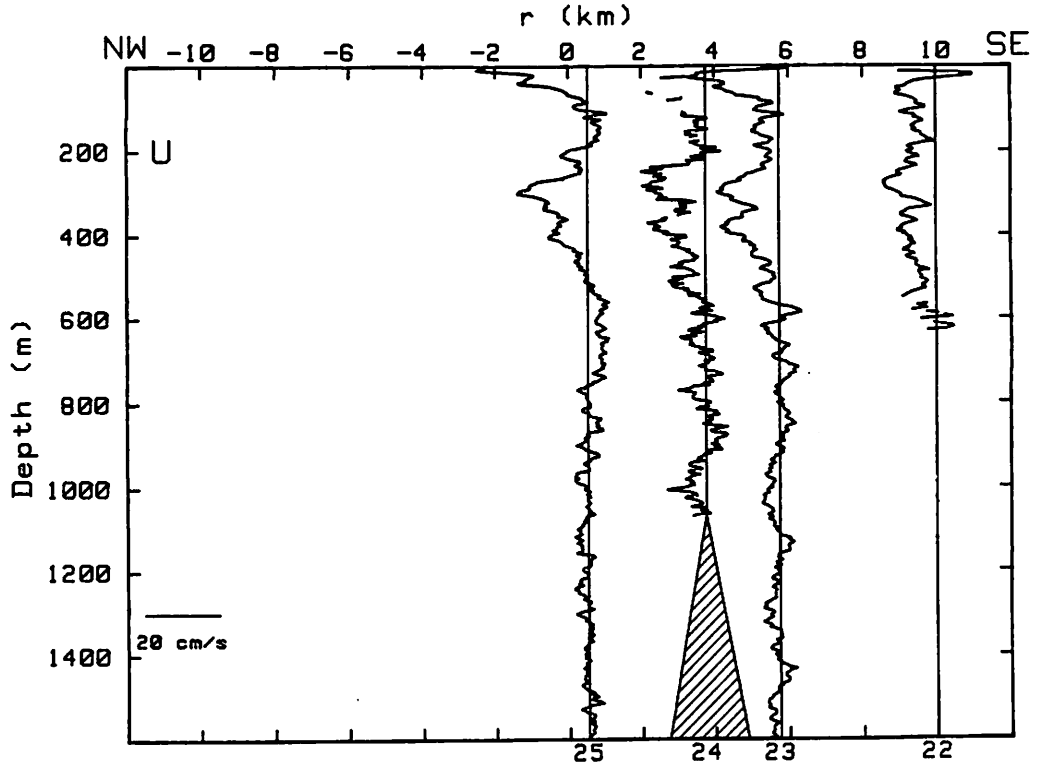
Figure 10. East (U) and North (V) velocity sections (continued).



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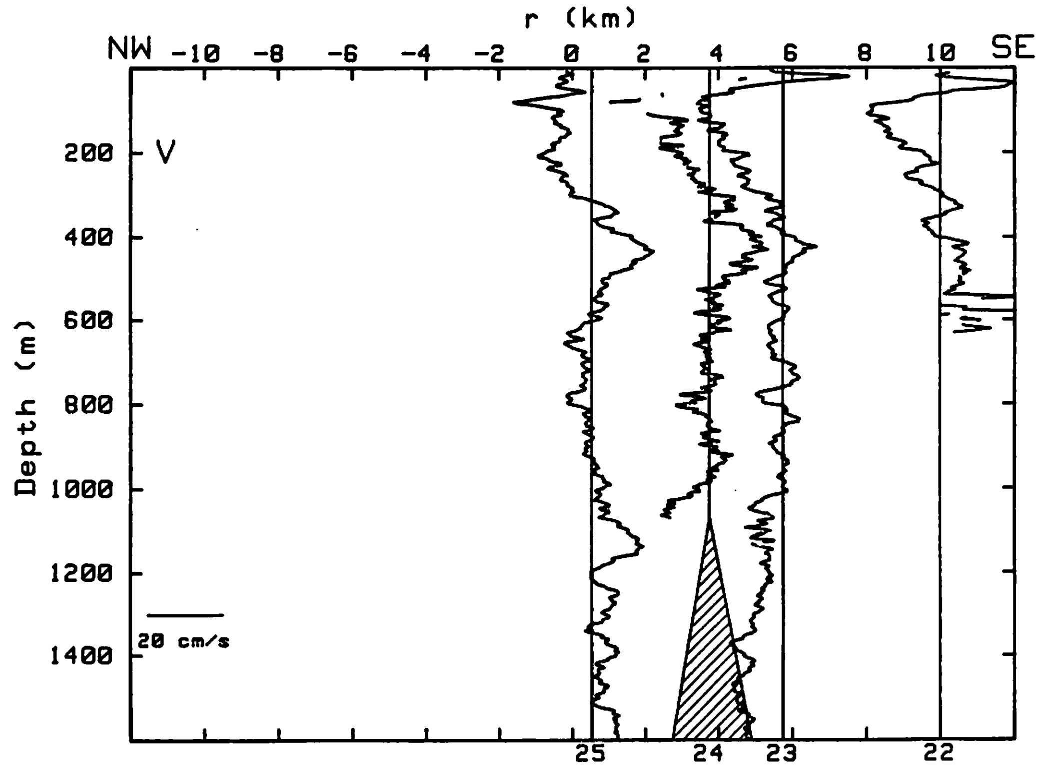

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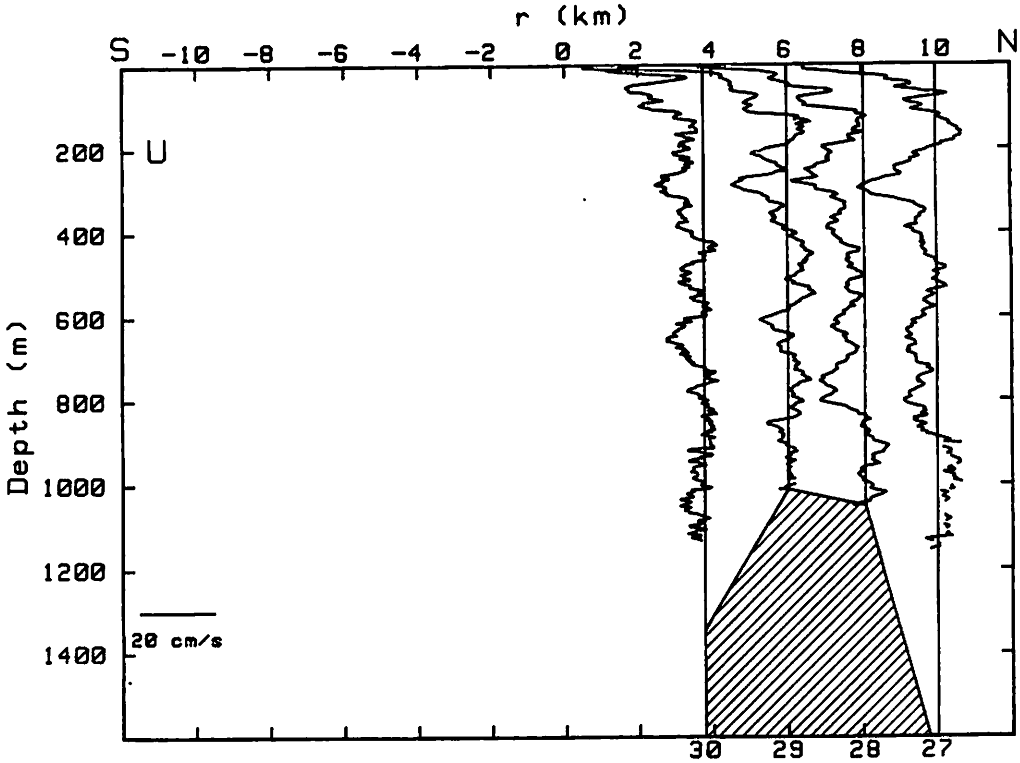
Figure 10. East (U) and North (V) velocity sections (continued).



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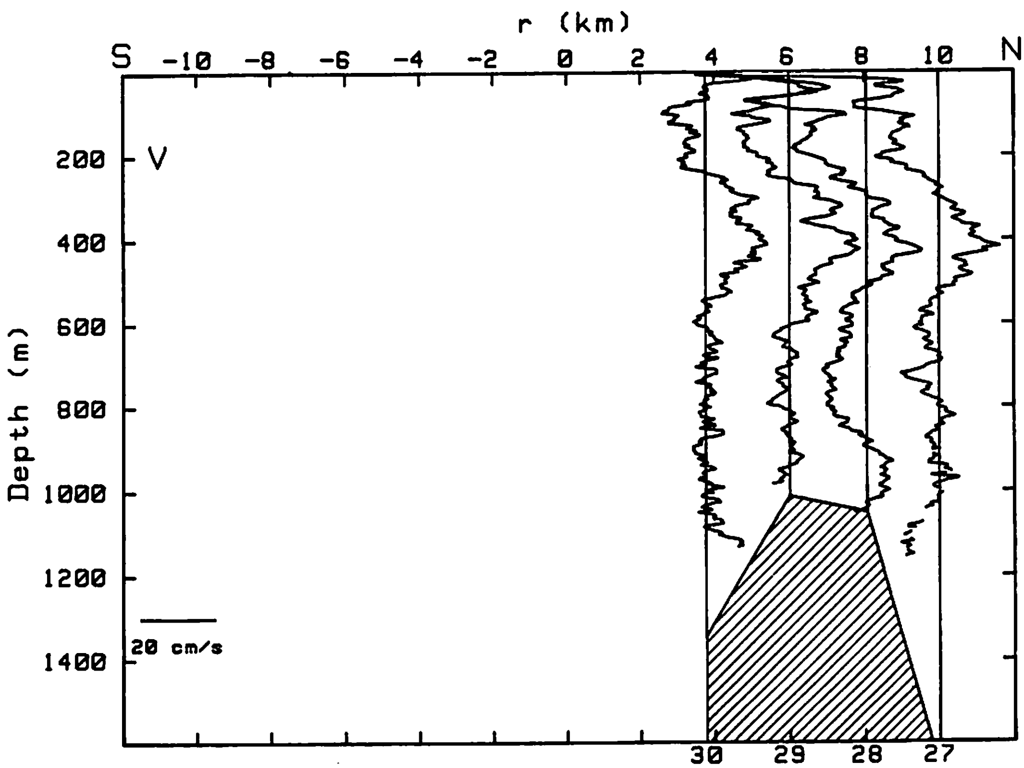

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Figure 10. East (U) and North (V) velocity sections (continued).

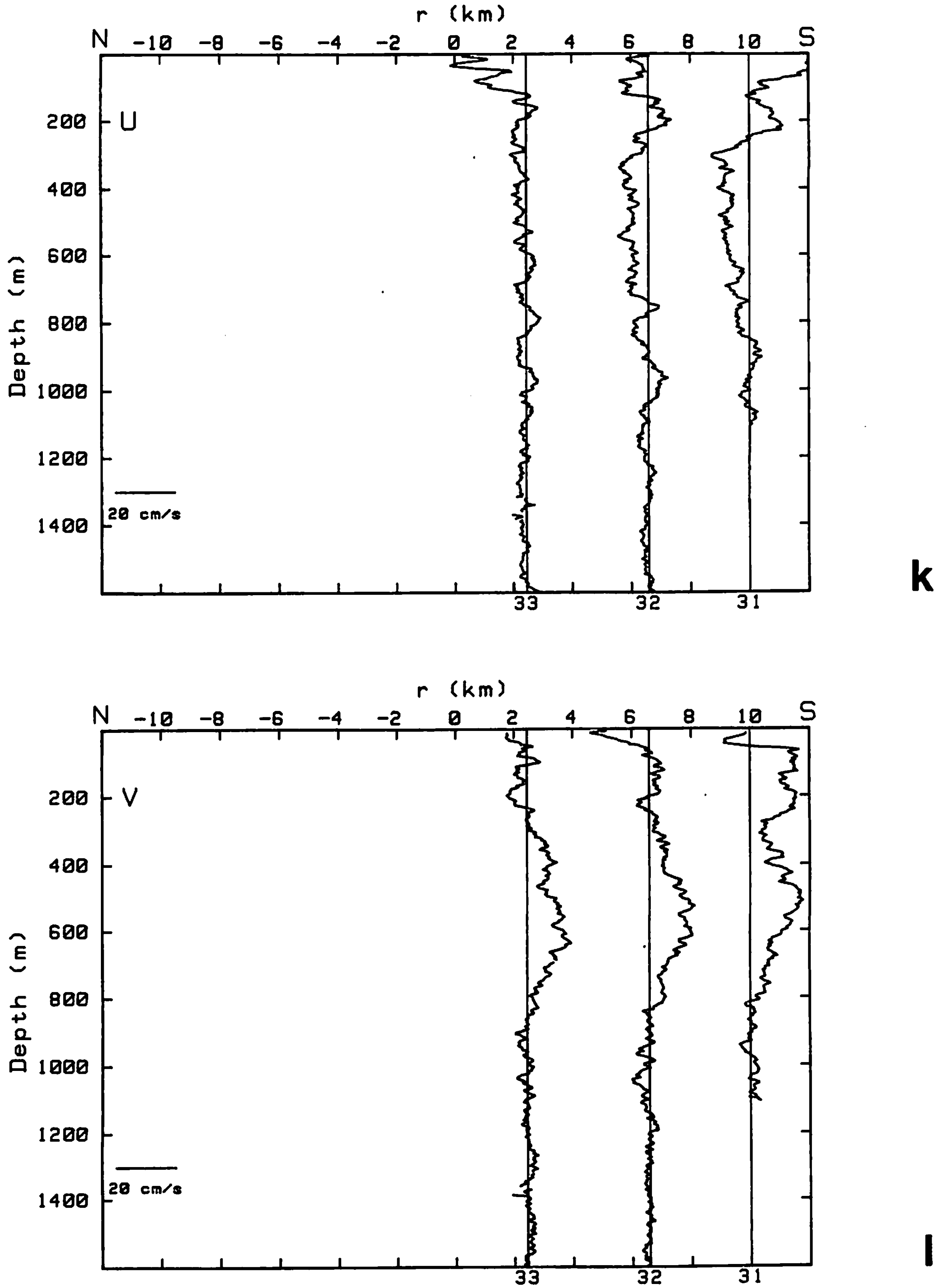
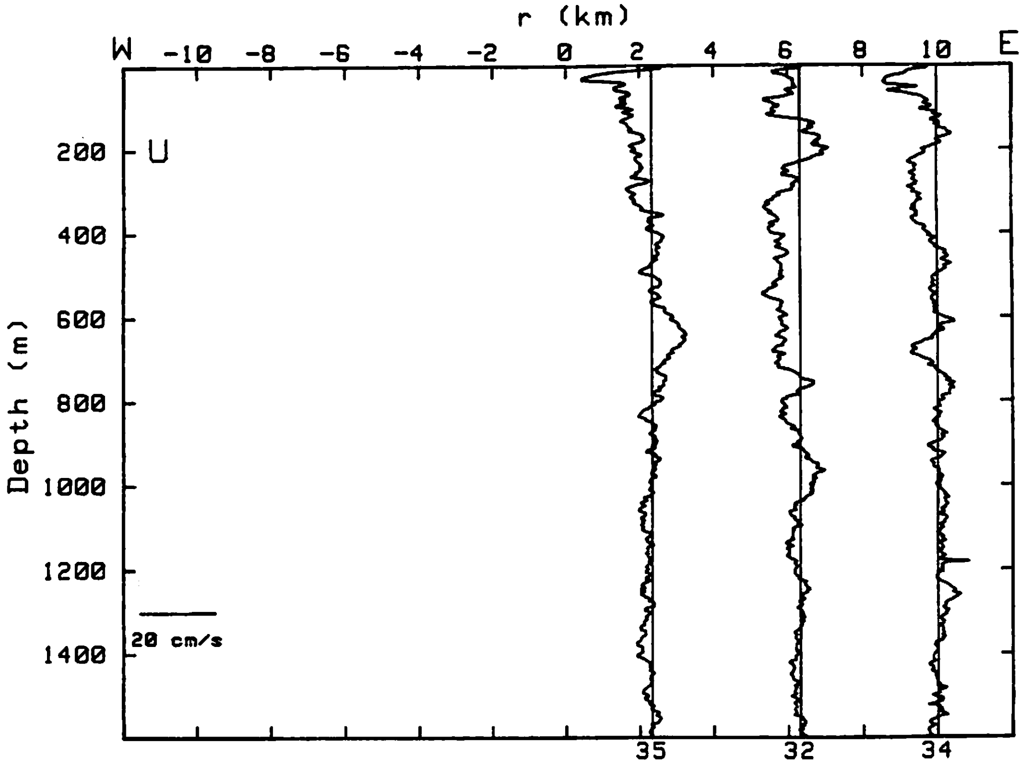


Figure 10. East (U) and North (V) velocity sections (continued).



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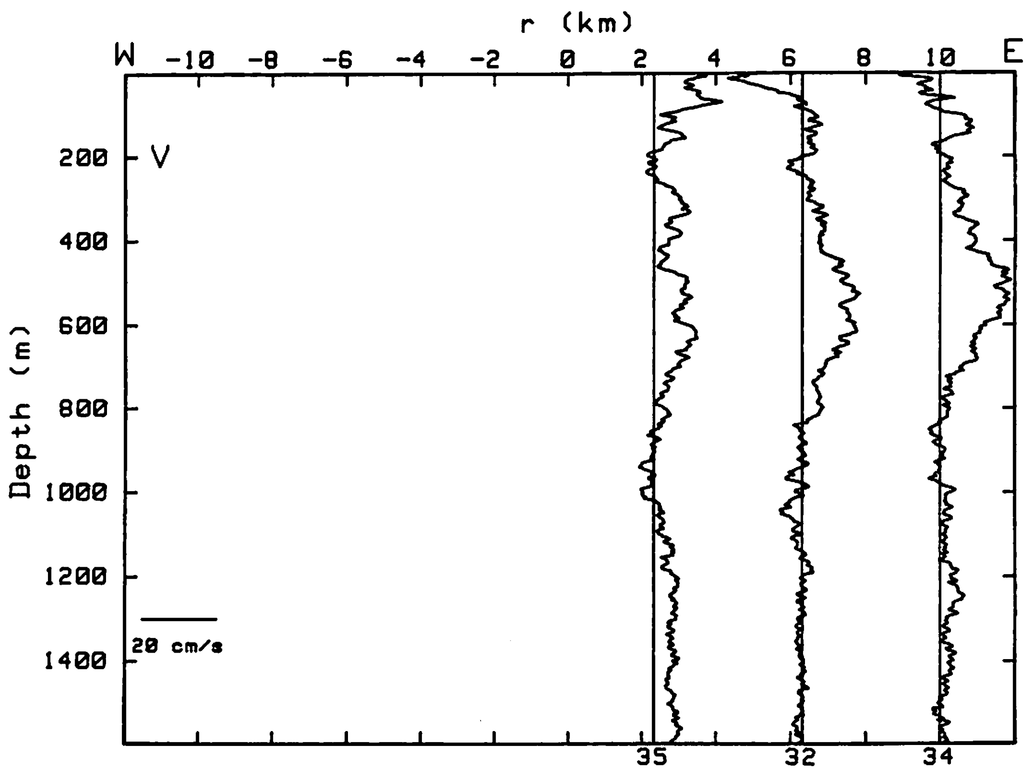

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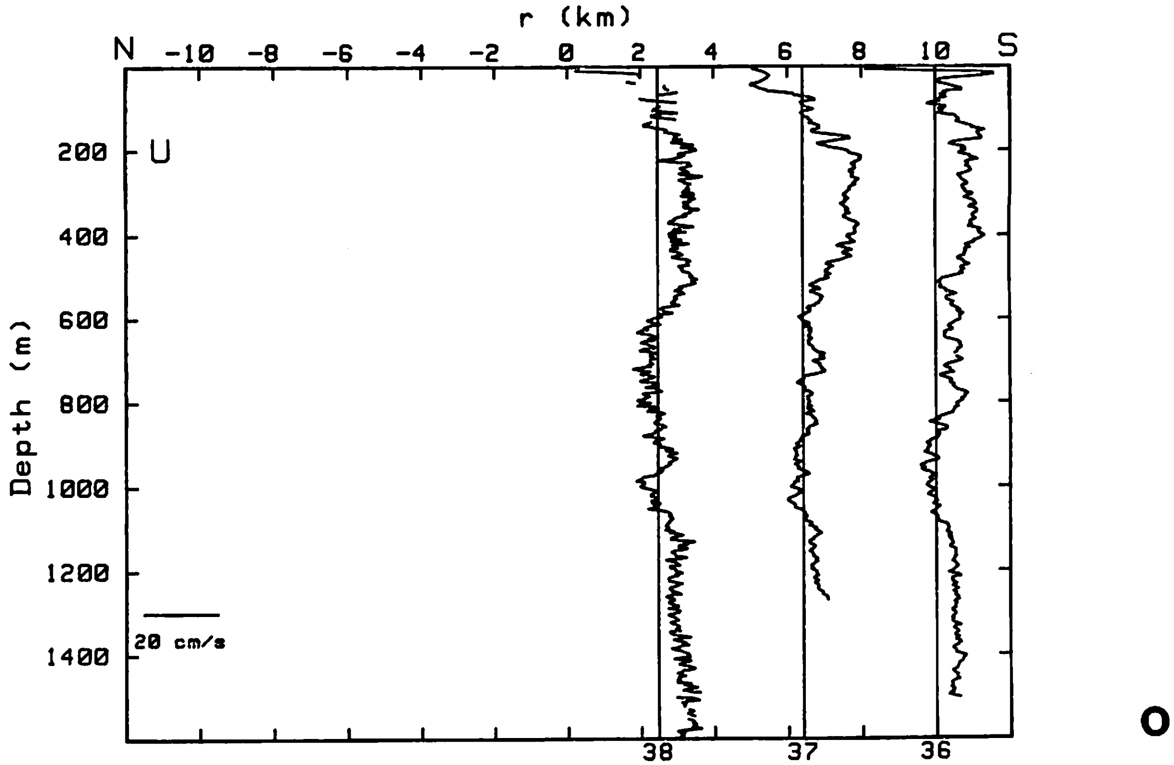
Figure 10. East (U) and North (V) velocity sections (continued).



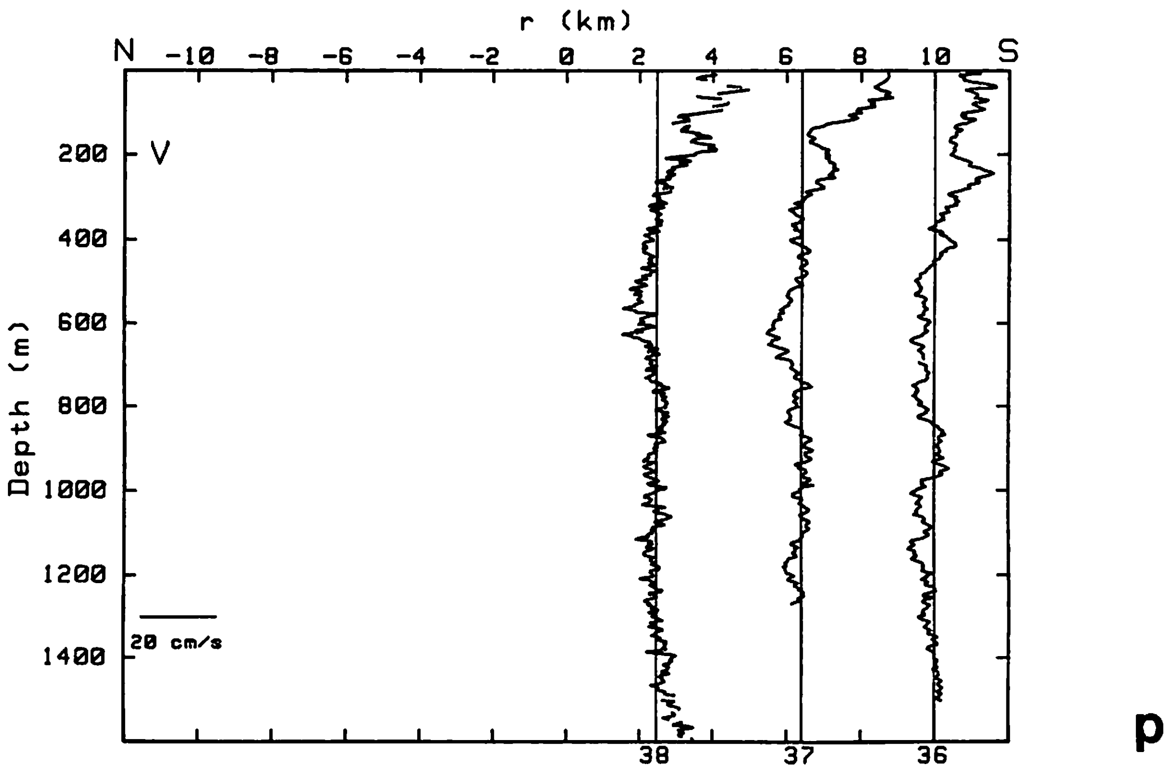
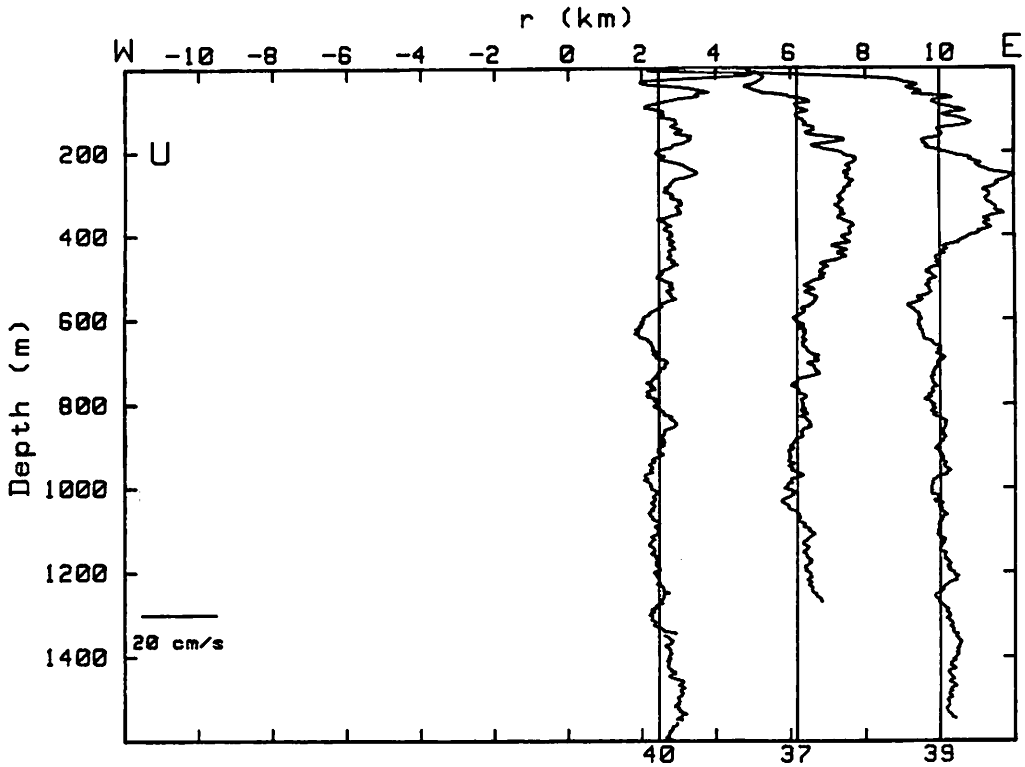


Figure 10. East (U) and North (V) velocity sections (continued).



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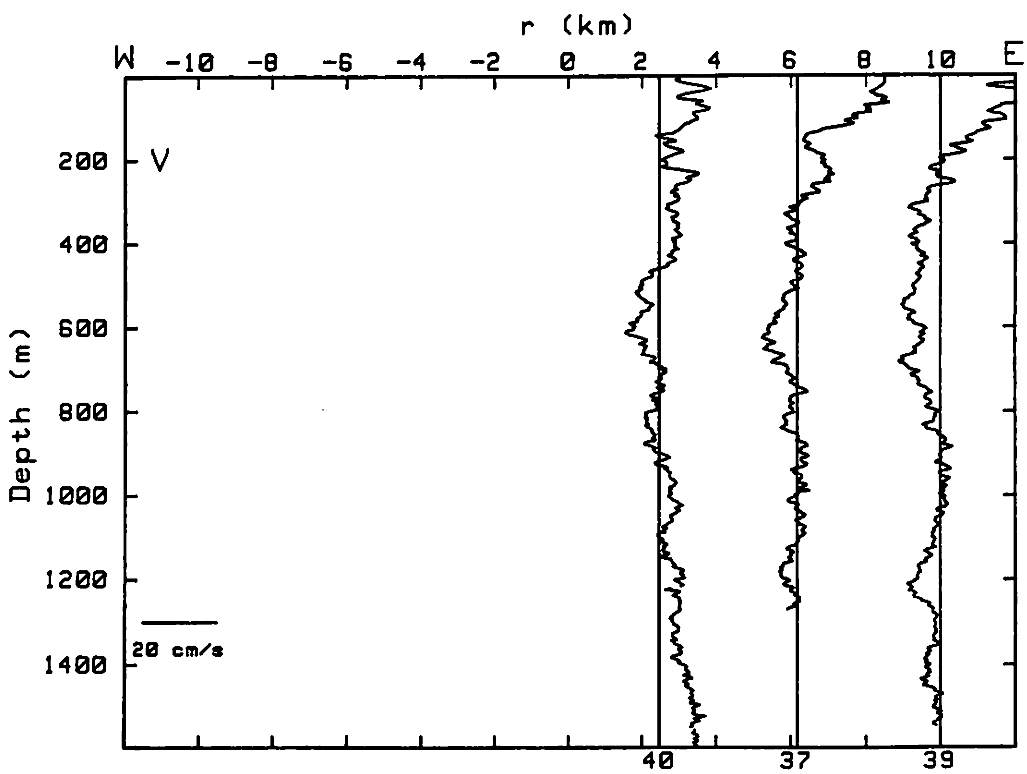

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Figure 10. East (U) and North (V) velocity sections (continued).

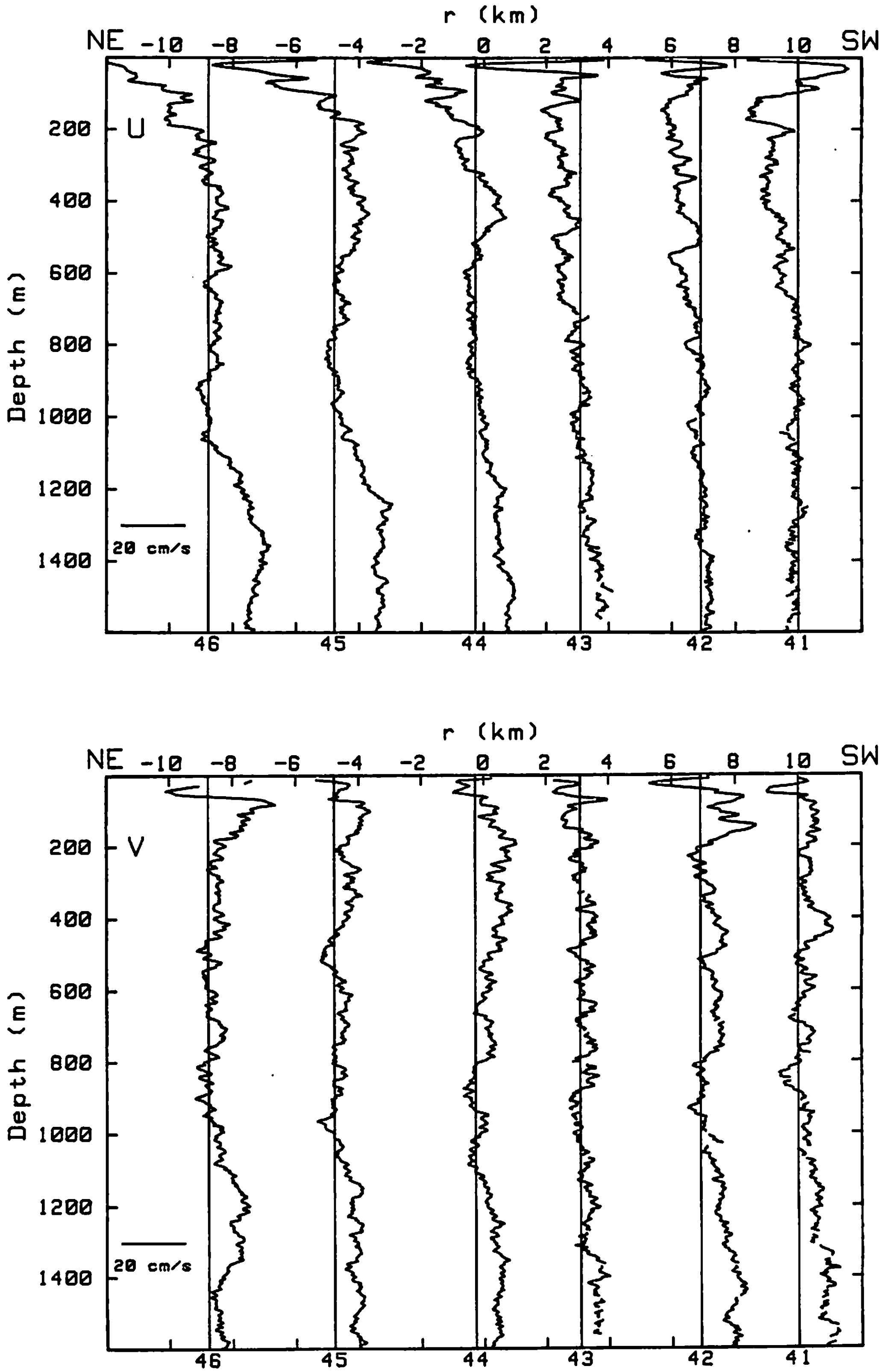

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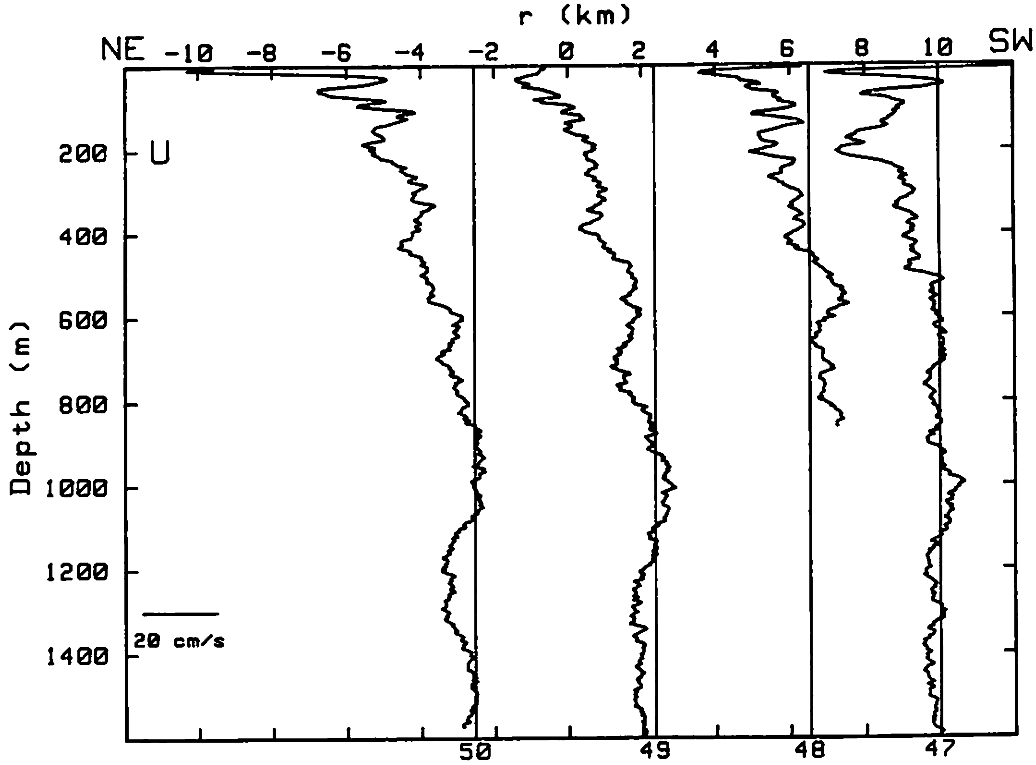
Figure 10. East (U) and North (V) velocity sections (continued).



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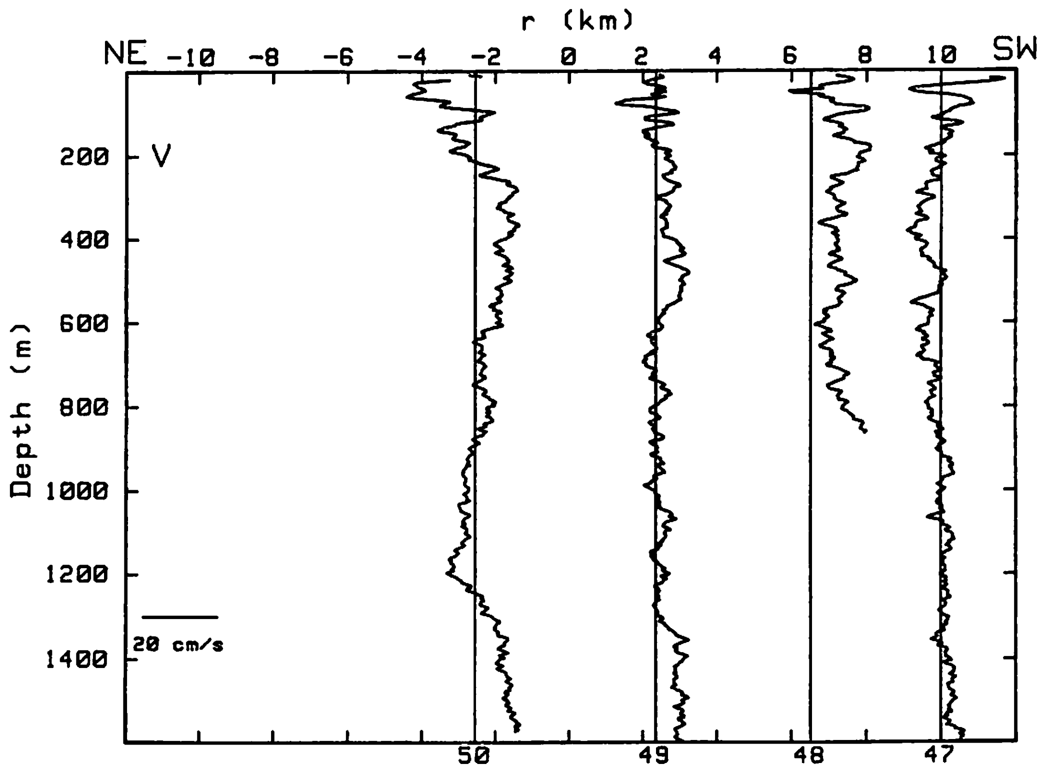

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Figure 10. East (U) and North (V) velocity sections (continued).

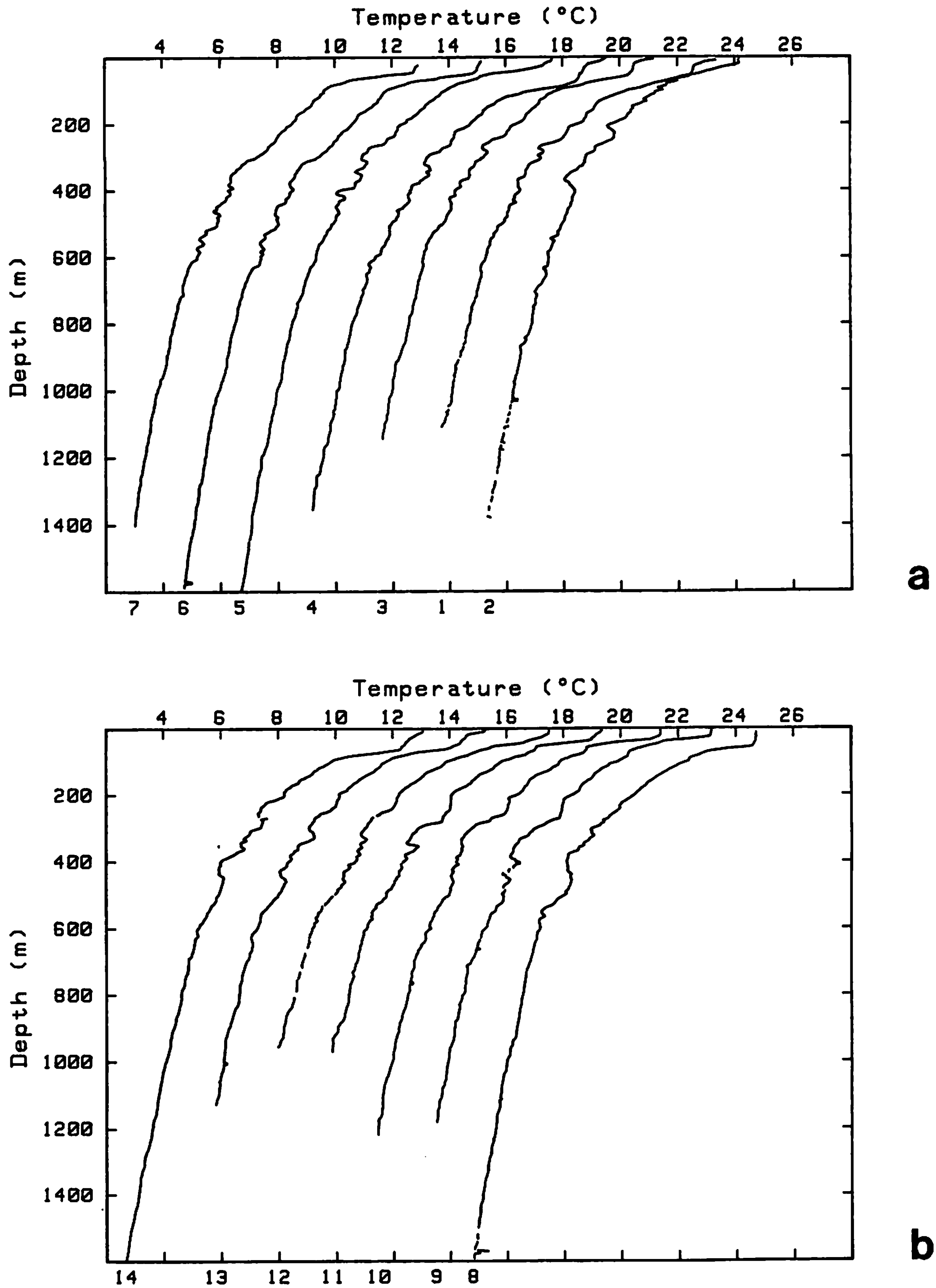
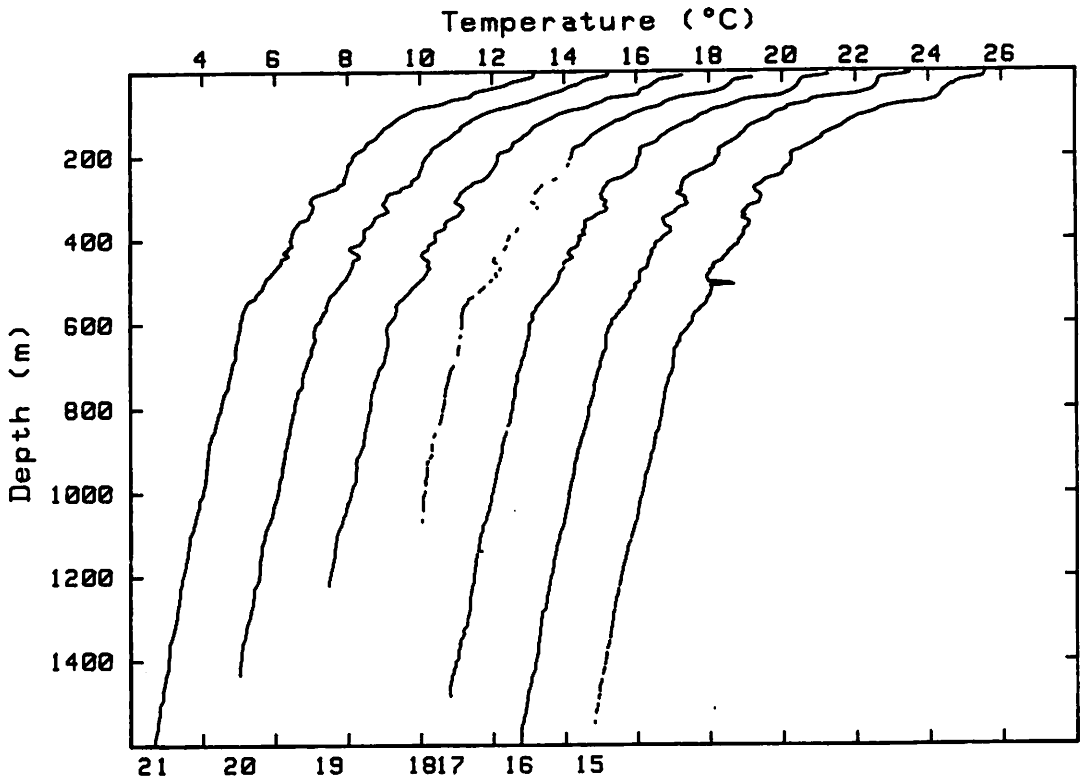


Figure 11. Waterfall sections of temperature.



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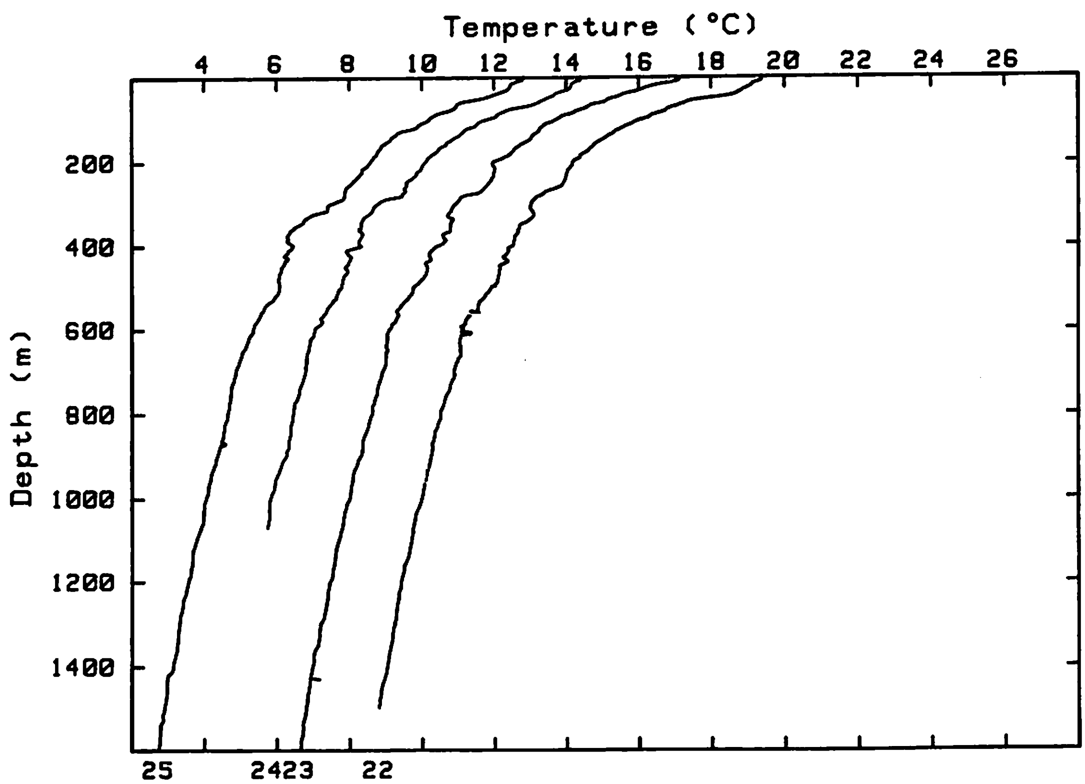

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Figure 11. Waterfall sections of temperature (continued).

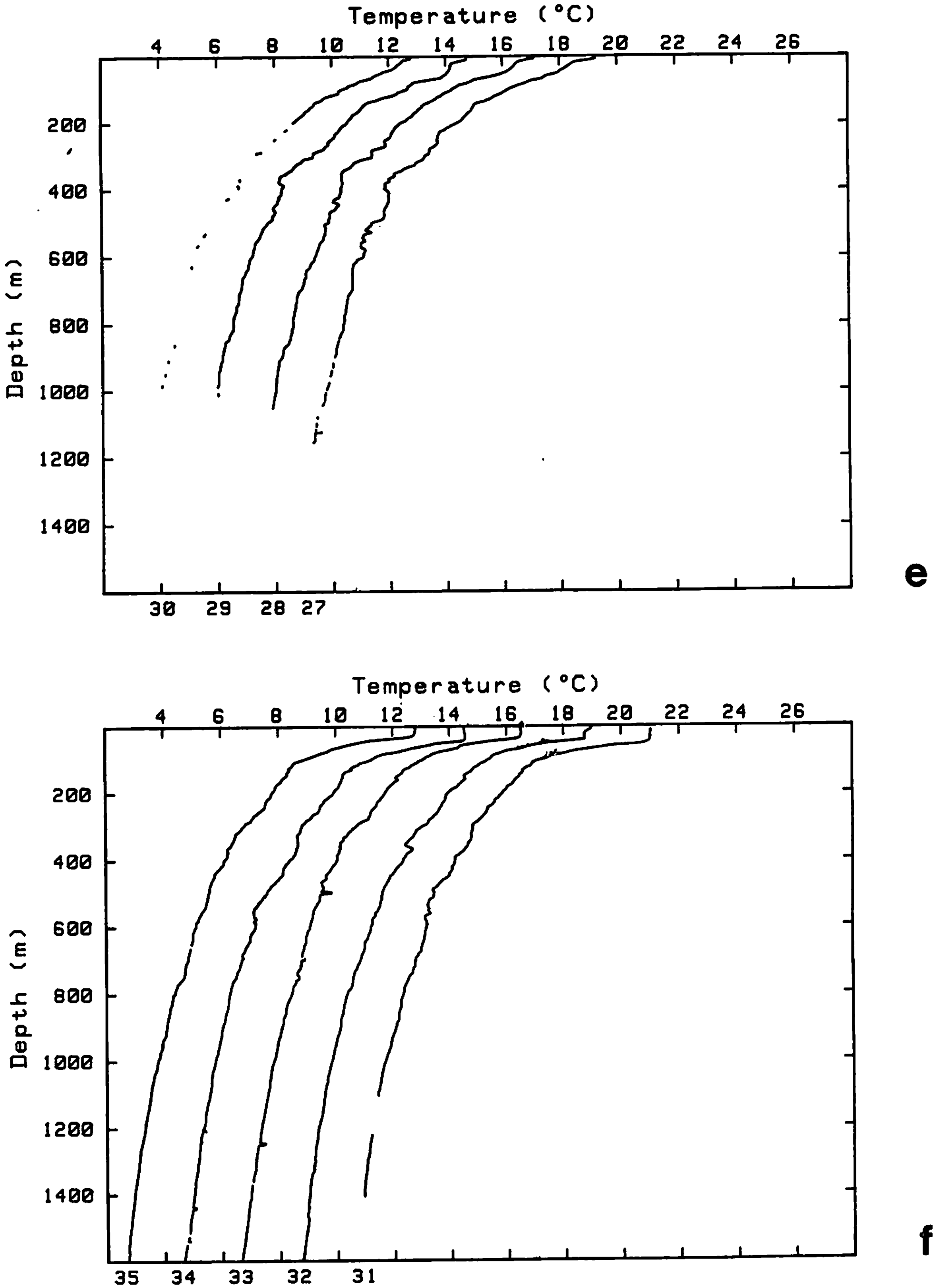


Figure 11. Waterfall sections of temperature (continued).

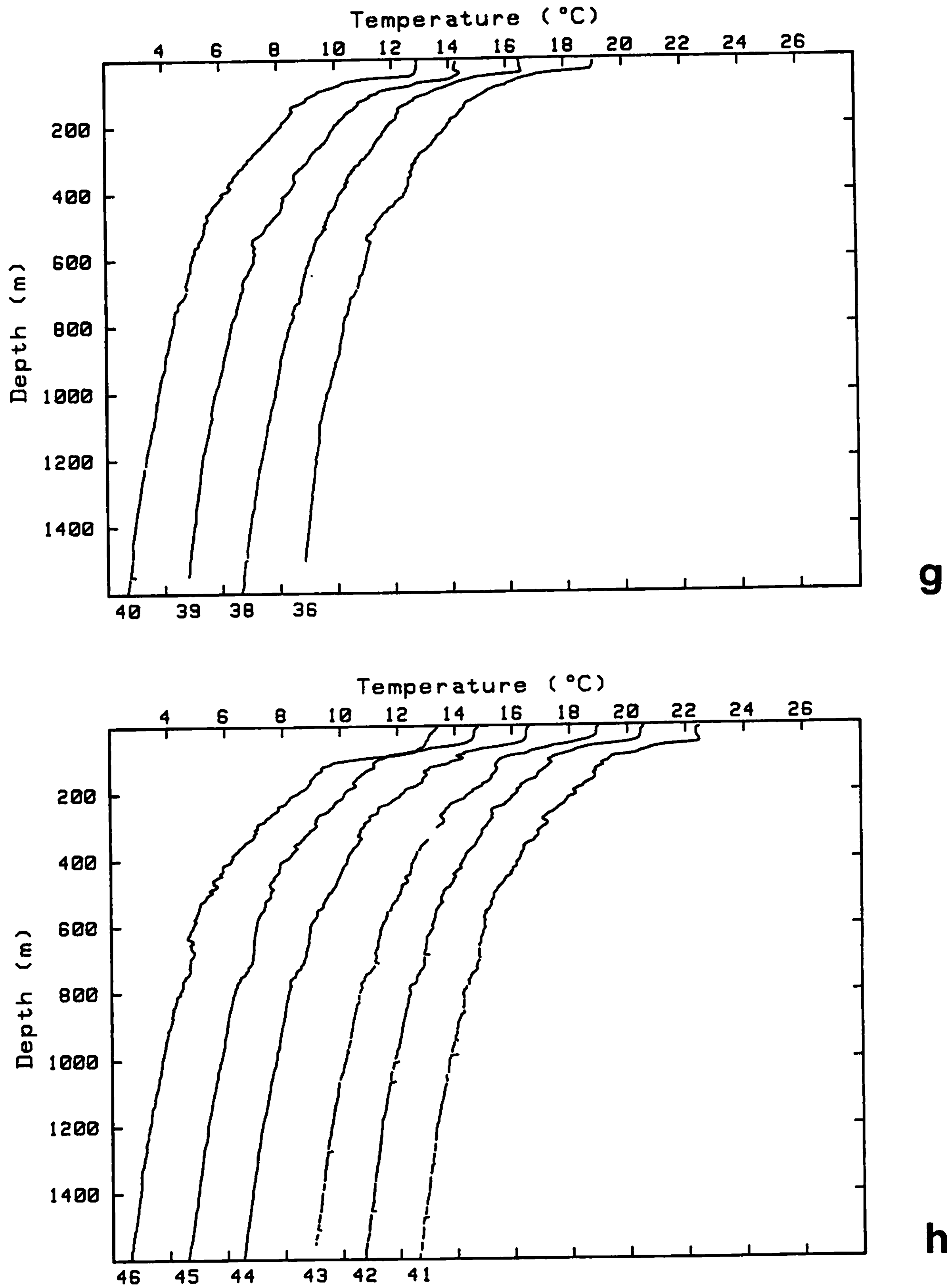


Figure 11. Waterfall sections of temperature (continued).

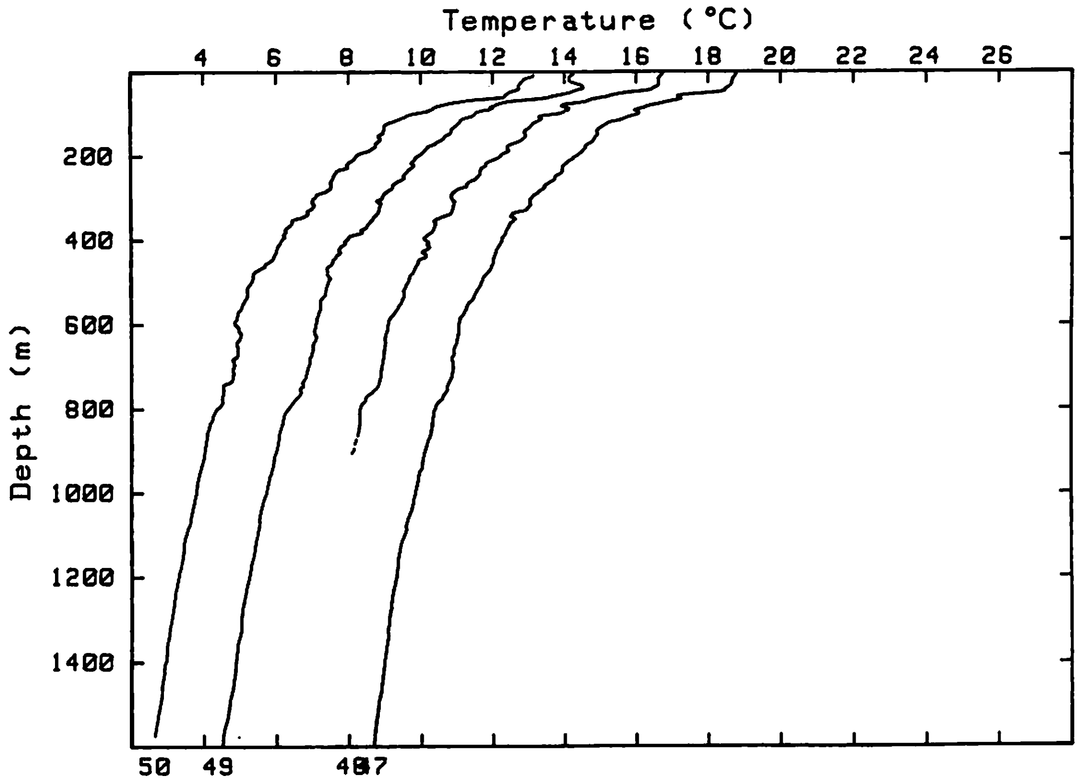


Figure 11. Waterfall sections of temperature (continued).

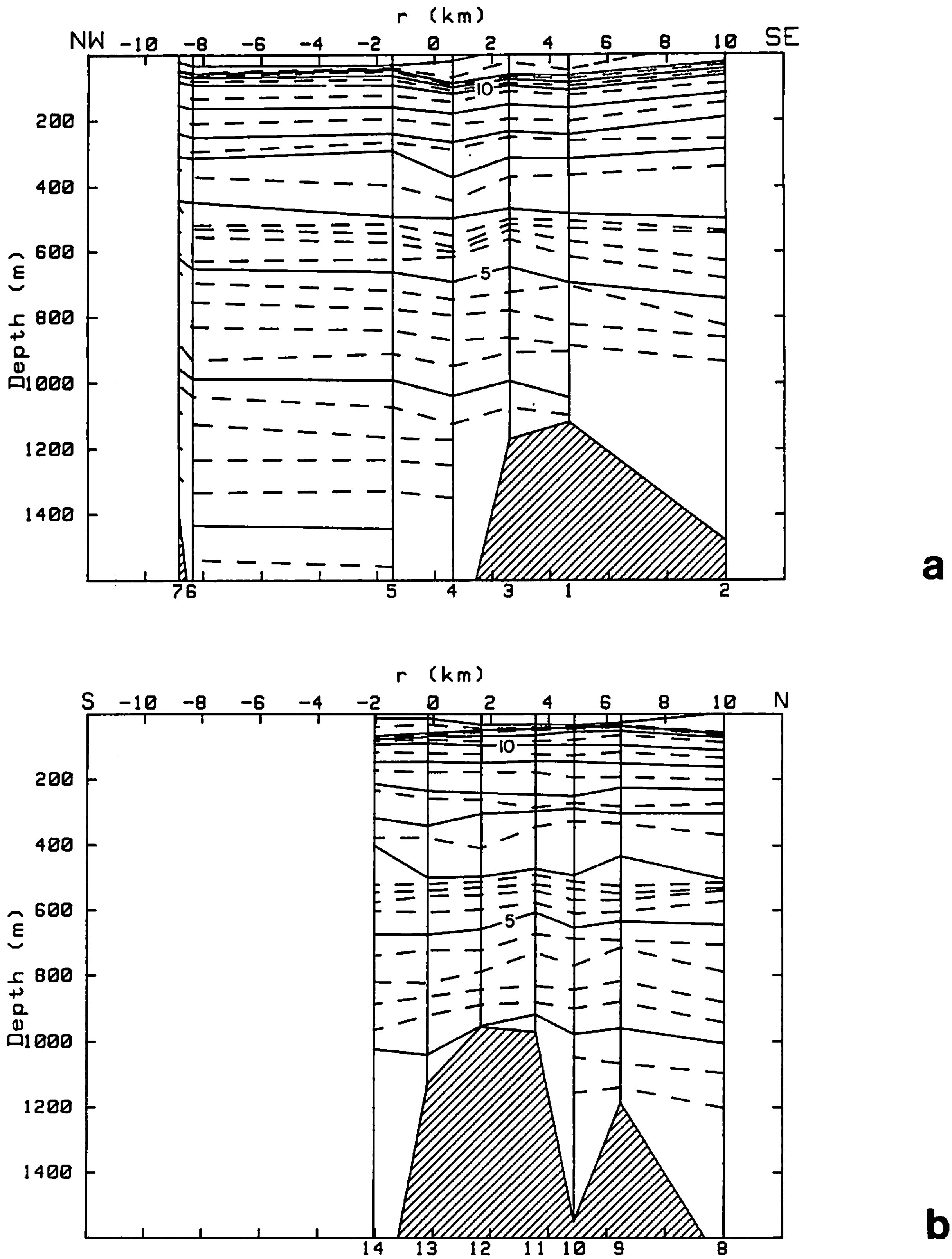
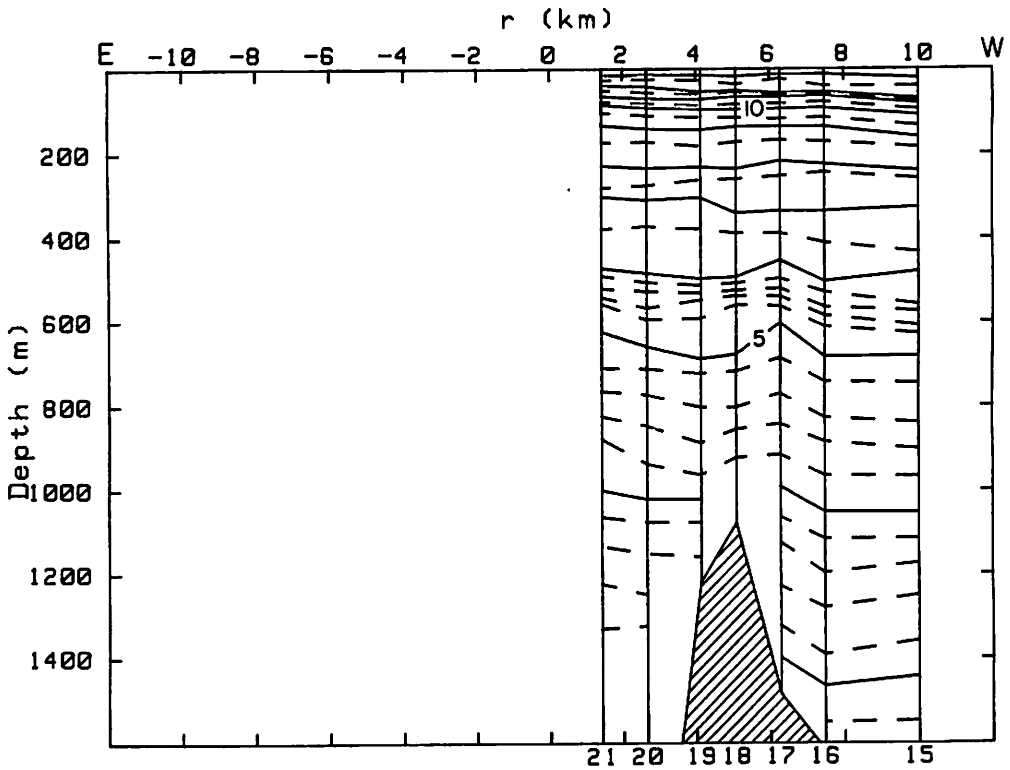


Figure 12. Isotherm sections.



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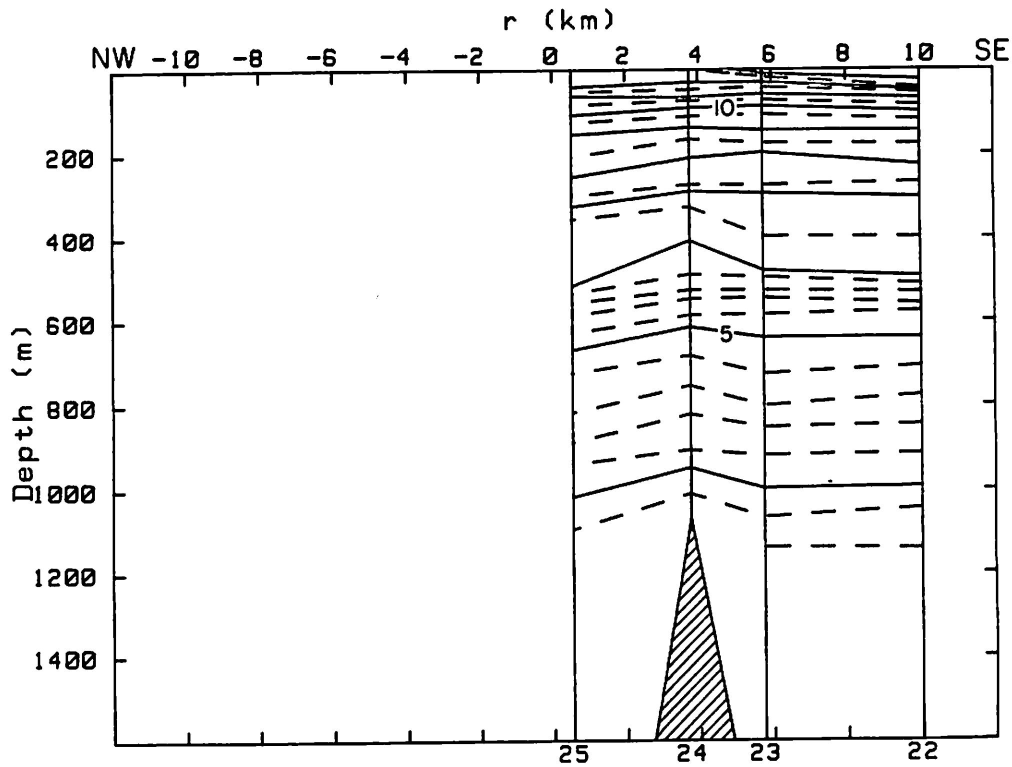

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Figure 12. Isotherm sections (continued).

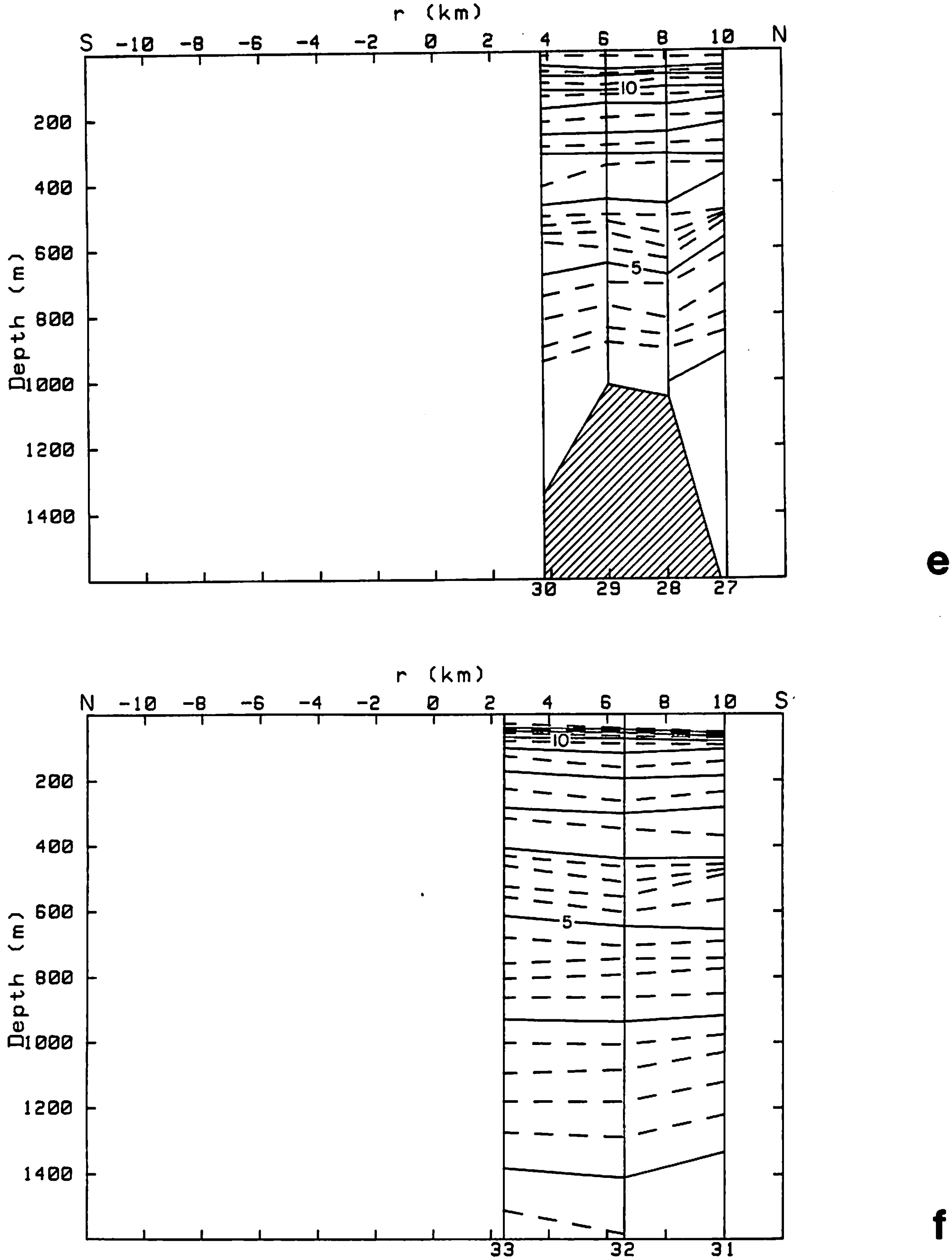
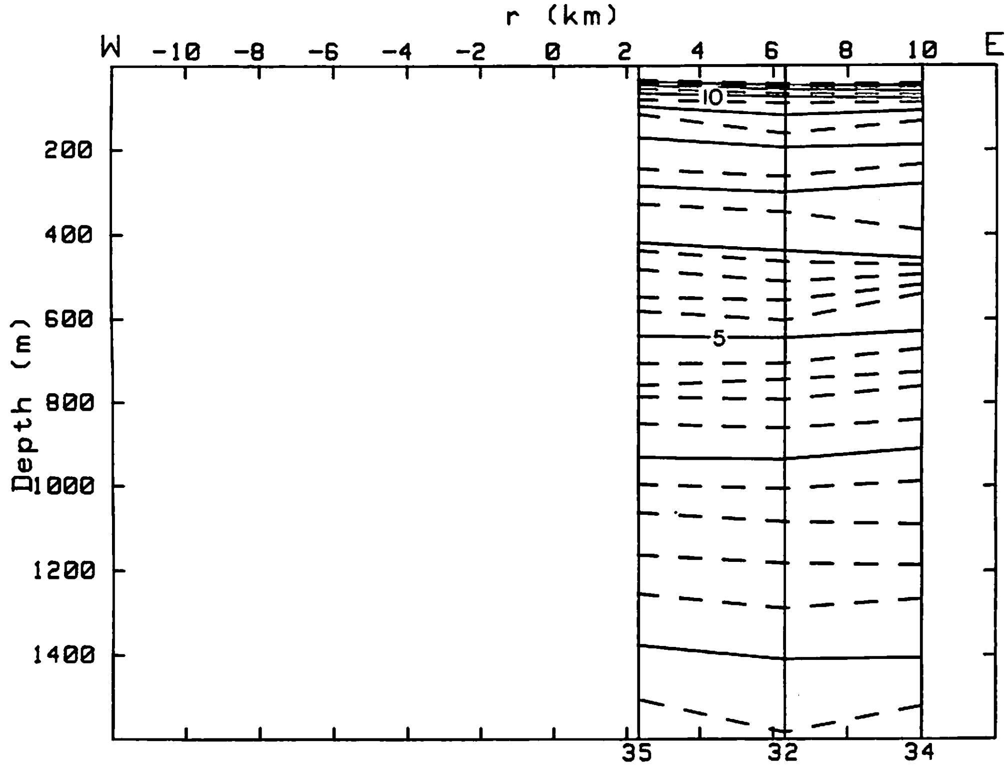


Figure 12. Isotherm sections (continued).



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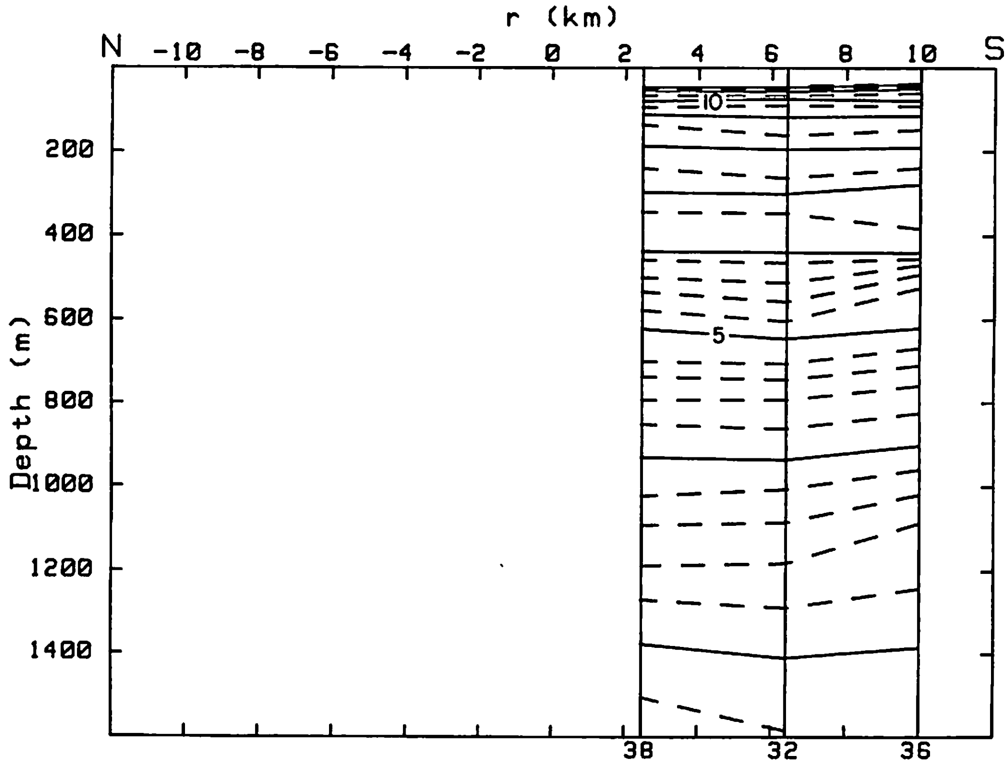

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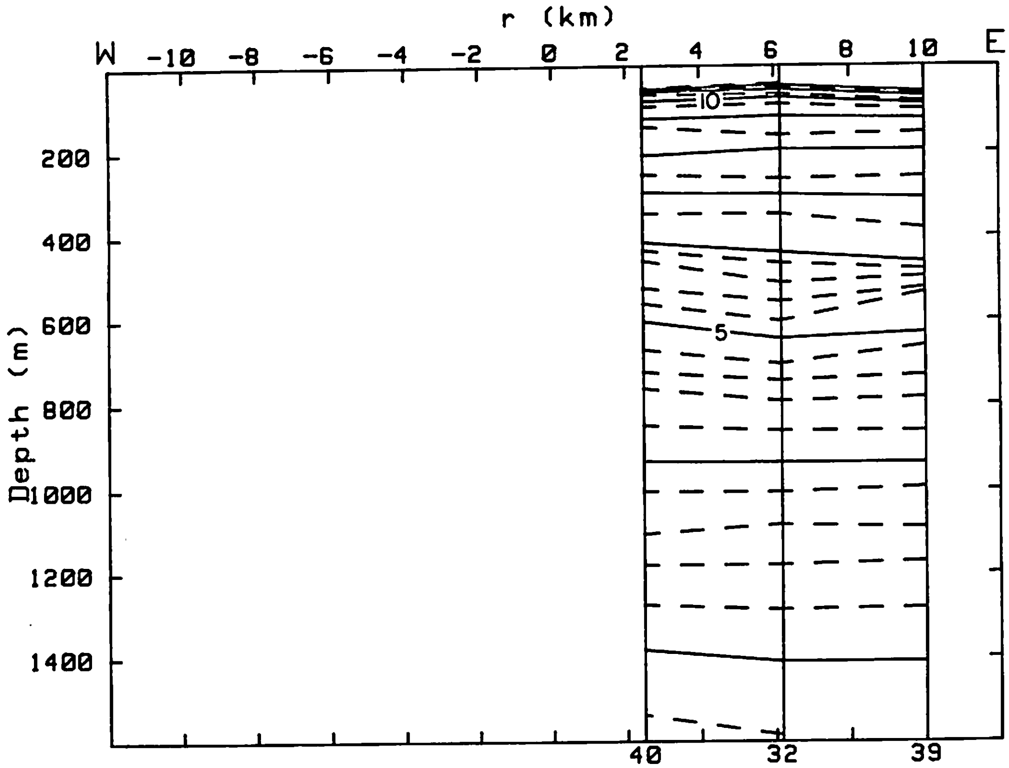
Figure 12. Isotherm sections (continued).



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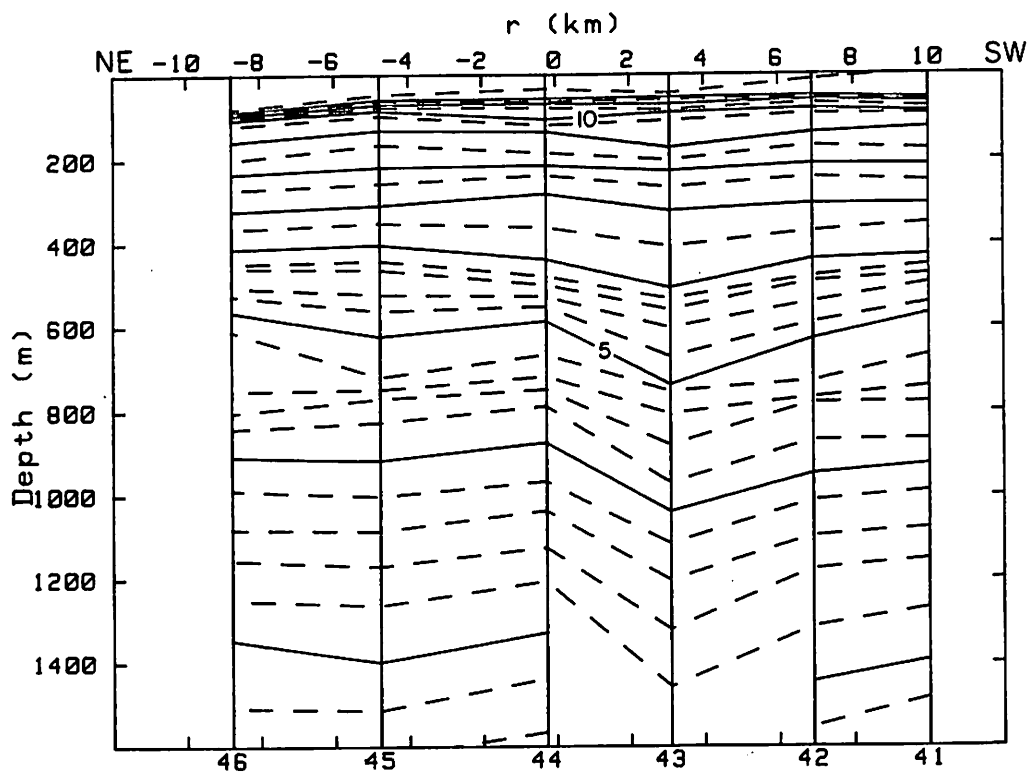

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Figure 12. Isotherm sections (continued).

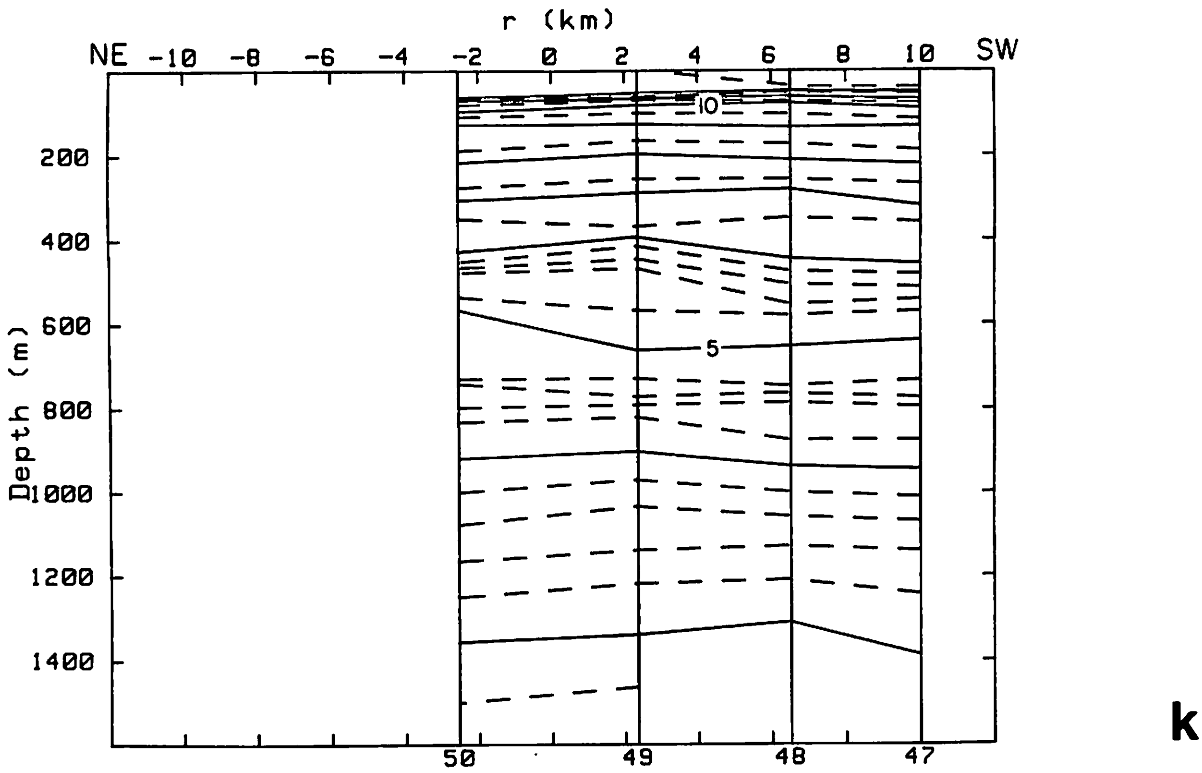

Figure 12. Isotherm sections (continued).

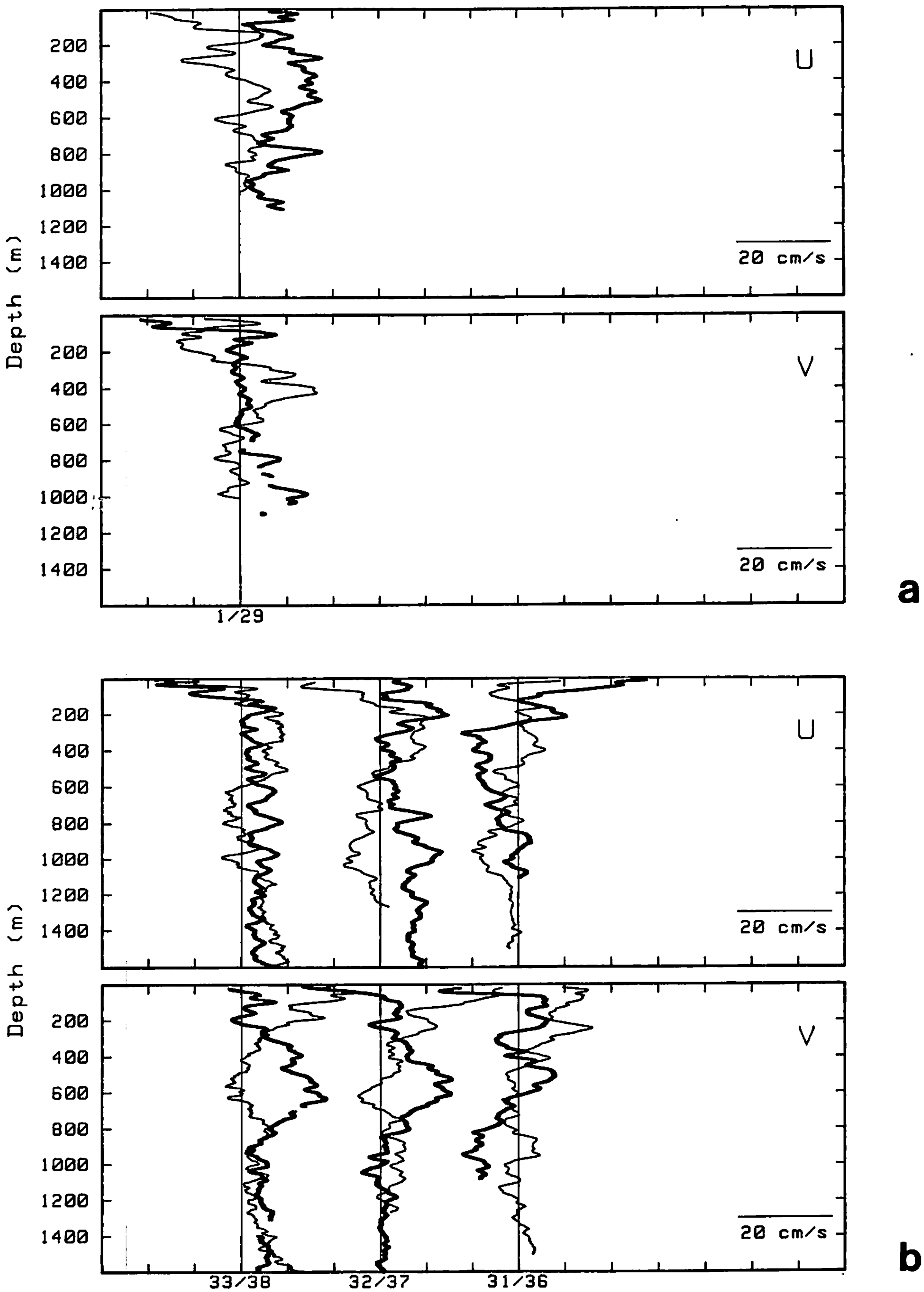

Figure 13. Half-inertial-period pairs, U and V components.

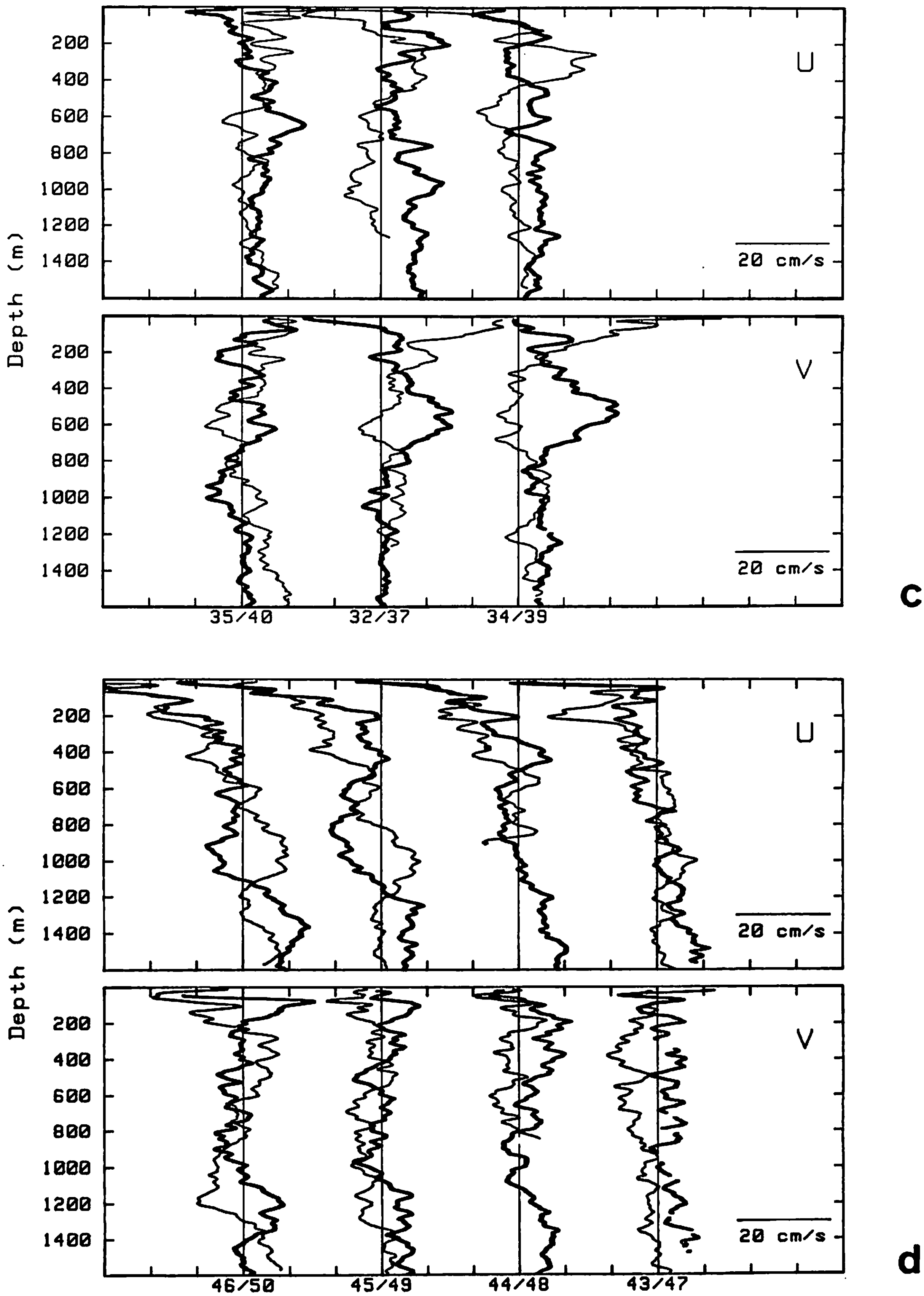

Figure 13. Half-inertial-period pairs, U and V components (continued).

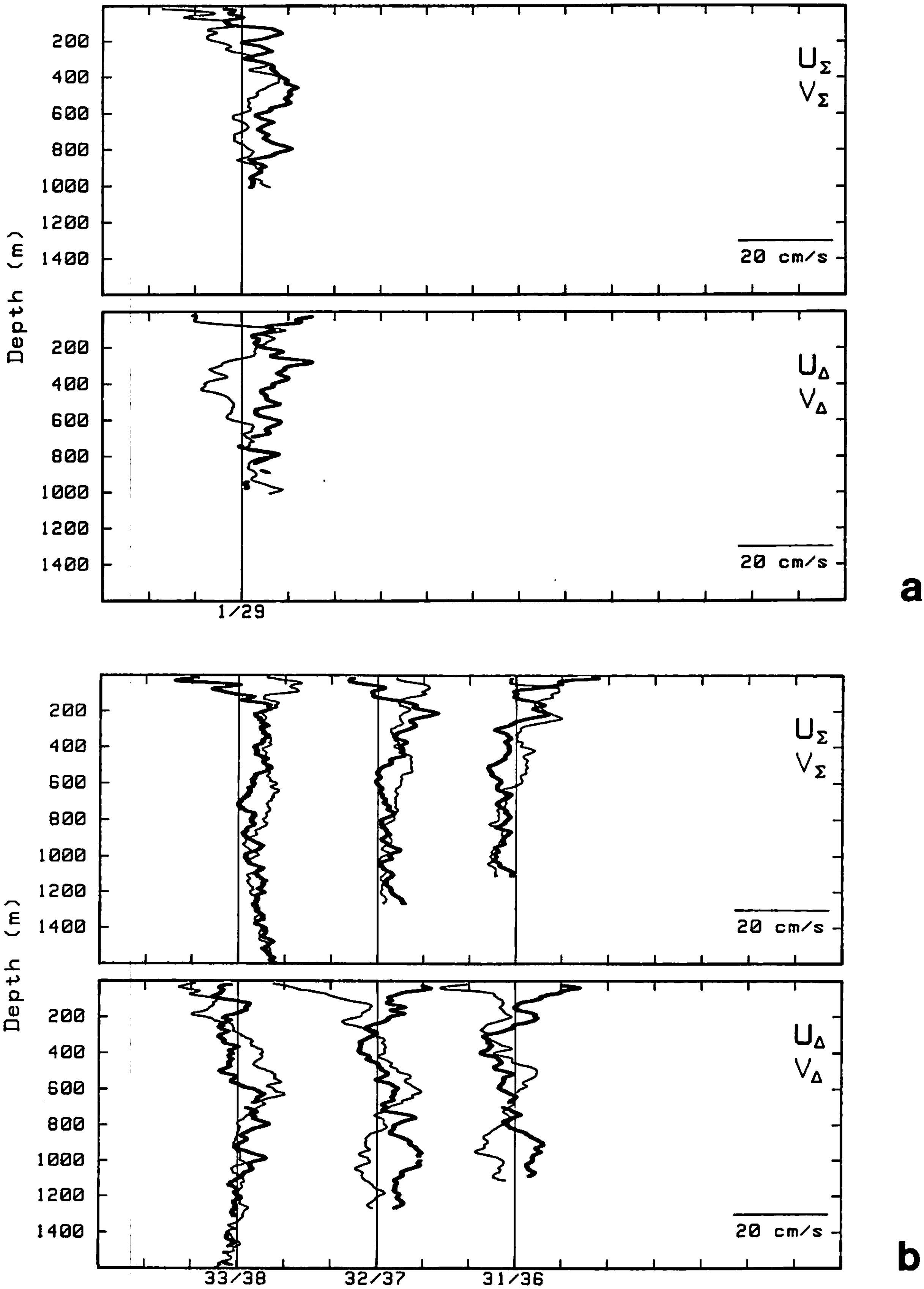

Figure 14. Half-inertial-period pair sums and differences.

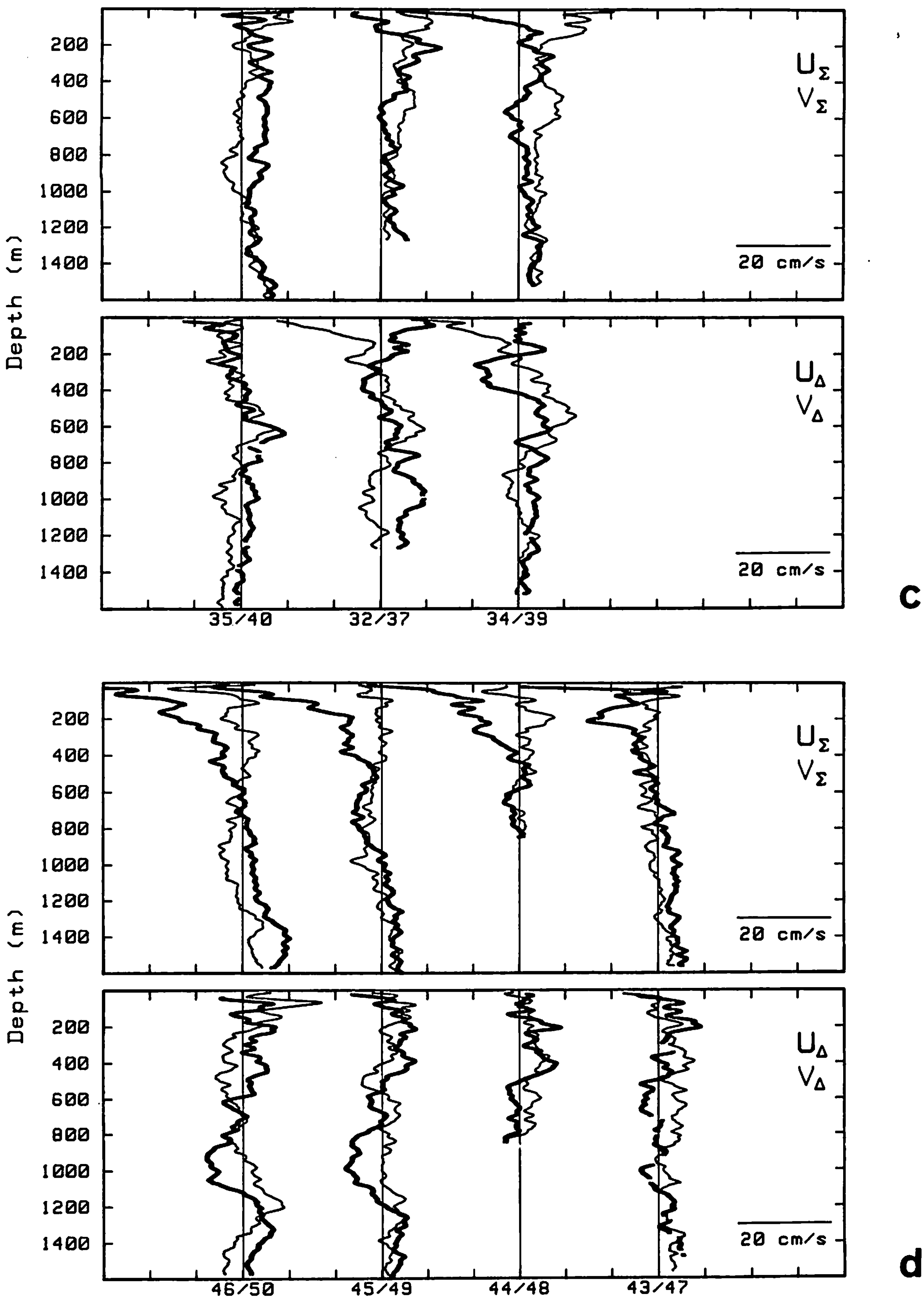

Figure 14. Half-inertial-period pair sums and differences (continued).

APPENDIX

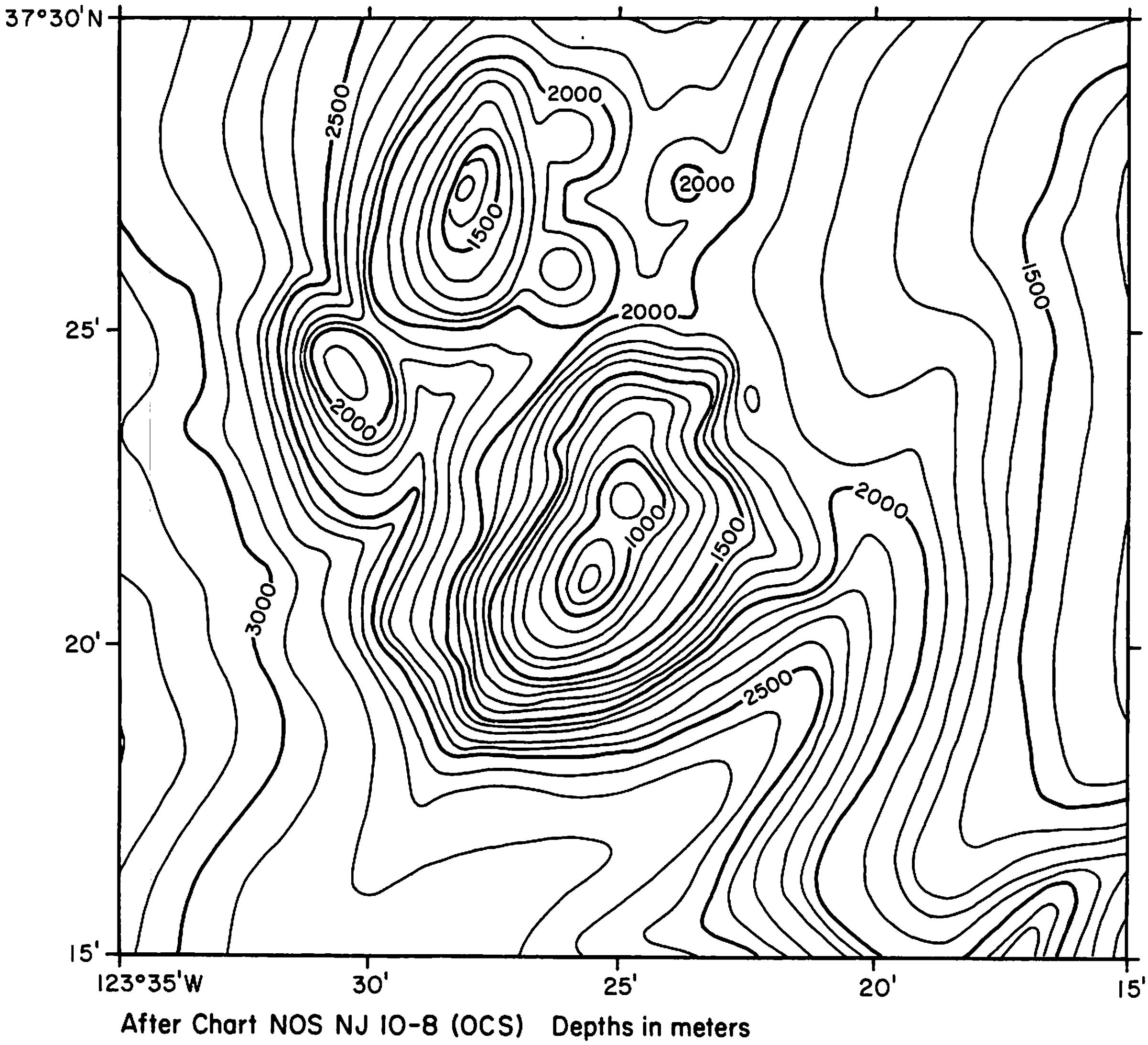

Figure A-1. Detailed topography of Pioneer Seamount.

Table A-1. CTD station positions.

CTD number		Date	Time	Latitude deg	Latitude min	Longitude deg	Longitude min
CTD	3	841022	1919	36	53.6	122	30.0
CTD	10	841023	0122	37	22.7	123	27.2
CTD	17	841024	0415	37	18.0	123	22.6
CTD	18	841024	0825	37	20.9	123	26.1
CTD	20	841024	1013	37	26.5	123	24.1
CTD	44	841025	1955	38	32.4	124	26.6
CTD	46	841025	2235	38	15.9	124	13.2
CTD	48	841026	0128	38	02.3	124	17.2
CTD	50	841026	0444	38	18.4	124	30.2
CTD	53	841026	0911	38	47.6	124	52.3
CTD	55	841026	1521	39	02.1	124	50.0
CTD	56	841026	1702	39	05.4	125	07.2
CTD	57	841026	1911	38	51.0	125	09.3
CTD	80	841027	1836	38	41.2	125	45.9
CTD	107	841028	1602	39	12.6	125	24.3
CTD	112	841029	0012	38	47.4	124	22.0
CTD	138	841101	1411	38	41.1	126	34.9

Table A-2. XBT station positions.

XBT number		Date	Time	Latitude deg	Latitude min	Longitude deg	Longitude min
XBT	1	841022	1724	36	43.8	122	07.7
XBT	2	841022	1816	36	48.9	122	18.6
XBT	4	841022	2030	36	59.0	122	41.6
XBT	5	841022	2127	37	04.7	122	52.8
XBT	6	841022	2224	37	08.4	123	04.8
XBT	7	841022	2322	37	14.5	123	16.1
XBT	8	841023	0003	37	14.5	123	16.1
XBT	12	841023	2250	36	48.4	122	17.9
XBT	13	841024	0115	37	02.2	122	47.9
XBT	14	841024	0122	37	02.8	122	49.3
XBT	16	841024	0028	37	12.3	123	00.0
XBT	19	841024	0910	37	23.7	123	25.7
XBT	21	841024	1152	37	35.9	123	29.9
XBT	22	841024	1302	37	44.2	123	35.5
XBT	23	841024	1426	37	52.9	123	41.1
XBT	24	841024	1547	38	00.9	123	46.5
XBT	25	841024	1805	38	11.9	123	56.0
XBT	26	841024	1949	38	21.0	124	02.0
XBT	27	841024	2144	38	29.5	124	09.0
XBT	28	841024	2341	38	37.3	124	15.0
XBT	29	841025	0201	38	47.8	124	22.7
XBT	30	841025	0344	38	56.1	124	28.4
XBT	31	841025	0531	39	04.9	124	35.4
XBT	32	841025	0702	39	13.0	124	42.2
XBT	33	841025	0836	39	22.0	124	49.0
XBT	34	841025	1039	39	31.1	124	55.9
XBT	35	841025	1147	39	36.2	125	00.2
XBT	36	841025	1321	39	30.8	125	11.8
XBT	37	841025	1409	39	22.2	125	06.1
XBT	38	841025	1457	39	14.3	124	58.9
XBT	39	841025	1603	39	05.4	124	53.8
XBT	42	841025	1758	38	48.4	124	38.9
XBT	43	841025	1841	38	40.9	124	32.9
XBT	45	841025	2125	38	24.0	124	19.9
XBT	47	841025	2352	38	07.0	124	07.0
XBT	49	841026	0031	38	10.8	124	23.7
XBT	51	841026	0628	38	27.0	124	36.7
XBT	52	841026	0739	38	37.0	124	45.0
XBT	54	841026	1257	38	56.3	124	59.4
XBT	58	841026	2222	38	56.0	124	59.0
XBT	59	841027	0122	39	15.5	125	15.0
XBT	60	841027	0240	39	25.1	125	22.4

Table A-2. XBT station positions (continued).

XBT	61	841027	0326	39	16.3	125	25.4
XBT	62	841027	0410	39	07.6	125	28.7
XBT	63	841027	0439	39	01.6	125	31.2
XBT	64	841027	0531	38	52.4	125	24.6
XBT	65	841027	0622	38	43.4	125	18.4
XBT	66	841027	0710	38	35.0	125	10.7
XBT	67	841027	0757	38	26.5	125	04.9
XBT	68	841027	0847	38	15.9	124	57.8
XBT	69	841027	0935	38	09.4	124	51.1
XBT	70	841027	1027	38	01.0	124	43.3
XBT	71	841027	1118	37	51.5	124	37.8
XBT	72	841027	1213	37	54.2	124	49.3
XBT	73	841027	1302	37	56.4	125	01.0
XBT	74	841027	1347	37	58.7	125	11.9
XBT	75	841027	1447	38	08.0	125	19.1
XBT	76	841027	1532	38	15.4	125	25.3
XBT	78	841027	1633	38	25.4	125	32.9
XBT	79	841027	1711	38	31.9	125	38.2
XBT	81	841027	1958	38	49.8	125	52.9
XBT	82	841027	2036	38	56.3	125	57.8
XBT	83	841027	2119	39	03.4	126	03.6
XBT	84	841027	2210	39	11.2	126	10.2
XBT	85	841027	2303	39	04.9	126	00.1
XBT	86	841027	2352	38	58.3	125	50.1
XBT	87	841028	0036	38	52.2	125	41.5
XBT	88	841028	0115	38	59.0	125	41.6
XBT	89	841028	0157	39	06.6	125	44.8
XBT	90	841028	0235	39	12.9	125	46.1
XBT	91	841028	0322	39	21.8	125	47.3
XBT	92	841028	0413	39	26.9	125	37.0
XBT	93	841028	0450	39	20.1	125	39.1
XBT	94	841028	0527	39	13.3	125	36.1
XBT	95	841028	0603	39	06.6	125	33.3
XBT	96	841028	0632	39	00.6	125	32.2
XBT	97	841028	0917	39	12.5	125	24.9
XBT	98	841028	0939	39	11.5	125	25.4
XBT	99	841028	0955	39	10.5	125	25.8
XBT	100	841028	1010	39	09.4	125	26.2
XBT	101	841028	1026	39	08.3	125	26.8
XBT	102	841028	1039	39	07.4	125	27.4
XBT	103	841028	1052	39	06.5	125	27.6
XBT	104	841028	1106	39	05.5	125	27.8
XBT	105	841028	1118	39	04.6	125	28.3
XBT	106	841028	1130	39	03.8	125	28.8
XBT	108	841028	2005	39	07.9	125	12.5
XBT	109	841028	2102	39	02.9	125	00.0
XBT	110	841028	2155	38	57.9	124	47.9

Table A-2. XBT station positions (continued).

XBT	111	841028	2252	38	52.9	124	35.3
XBT	113	841029	0214	38	41.0	124	12.0
XBT	114	841029	0338	38	34.3	124	02.9
XBT	115	841029	0501	38	27.8	123	53.0
XBT	116	841029	0625	38	21.7	123	43.1
XBT	117	841029	0810	38	14.9	123	33.5
XBT	118	841029	0934	38	08.7	123	24.0
XBT	119	841029	1109	38	02.5	123	14.5
XBT	120	841029	1243	37	55.1	123	05.0
XBT	121	841031	2103	37	55.5	123	13.0
XBT	122	841031	2200	37	58.1	123	24.4
XBT	123	841031	2311	38	01.0	123	36.2
XBT	124	841101	0018	38	03.8	123	48.0
XBT	125	841101	0126	38	06.5	124	00.4
XBT	126	841101	0225	38	09.0	124	11.8
XBT	127	841101	0327	38	11.7	124	24.1
XBT	128	841101	0443	38	15.5	124	38.4
XBT	130	841101	0636	38	20.0	125	00.1
XBT	131	841101	0740	38	23.0	125	12.3
XBT	133	841101	0922	38	28.1	125	35.6
XBT	134	841101	1010	38	30.8	125	47.1
XBT	135	841101	1101	38	33.5	125	59.1
XBT	136	841101	1152	38	36.5	126	10.7
XBT	139	841101	1528	38	45.1	126	50.6
XBT	140	841101	1644	38	35.8	126	43.4
XBT	142	841101	1850	38	18.6	126	30.8
XBT	143	841101	2000	38	10.9	126	23.9
XBT	144	841101	2113	38	02.6	126	17.8
XBT	145	841101	2213	37	54.5	126	11.0
XBT	146	841101	2311	37	46.0	126	04.8
XBT	147	841102	0010	37	37.8	125	58.0
XBT	148	841102	0109	37	29.0	125	51.6
XBT	149	841102	0209	37	20.0	125	44.8
XBT	150	841102	0309	37	25.9	125	33.1
XBT	151	841102	0544	37	15.1	125	55.0
XBT	152	841102	0702	37	10.2	126	06.5
XBT	153	841102	0956	37	34.9	125	38.7
XBT	154	841102	1056	37	44.7	125	37.5
XBT	155	841102	1205	37	55.6	125	34.2
XBT	156	841102	1259	38	04.3	125	30.5
XBT	157	841102	1406	38	04.2	125	18.0
XBT	158	841102	1456	38	03.6	125	05.8