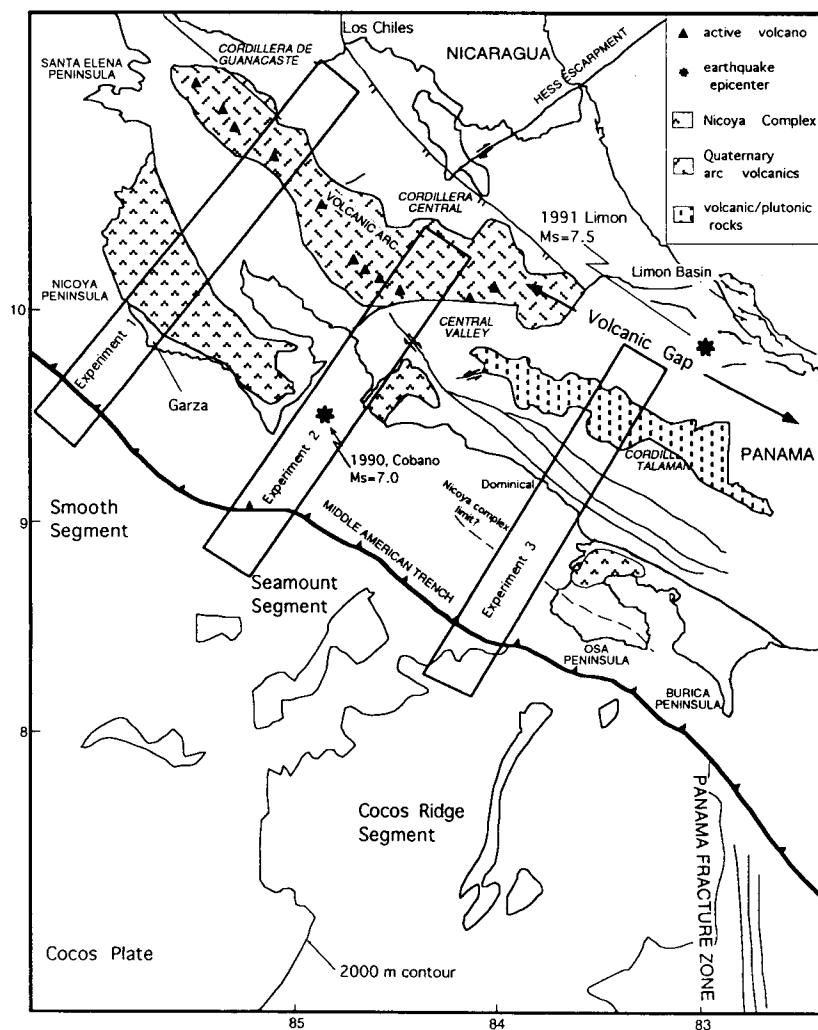


TICOSECT PHASE I

CRUISE REPORT

25 MARCH - 21 APRIL 1995

R/V MAURICE EWING



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I. Abstract. Observation of convergent margins worldwide suggest that the morphology and crustal thickness of a subducting plate may affect the mode of deformation, seismicity patterns, volcanic activity and composition, and elevation of the overriding plate. It has also been proposed that seamounts on the subducting plate may be earthquake nucleation sites or asperities. The goal of this field project and subsequent data analysis is to investigate the upper plate response to three different morphological segments of the Cocos plate that subduct beneath Costa Rica. Work during this cruise includes investigation of a segment of the subducting Cocos Plate that is relatively smooth, one that is dominated by seamounts, and another that is characterized by the thickened crust of the Cocos Ridge. The primary tools used during this cruise are ocean bottom seismic instruments with up to 33 deployed simultaneously. In addition, 30 Reftek seismographs have been deployed at various locations on land by German collaborators from Potsdam and a DFS V deployed by personnel from ICE and UTIG has recorded airgun shots from locations near the coast. The intent of this instrumentation was to record wide aperture and near vertical seismic data along the three representative regional transects. The wide aperture data will be used to establish crustal structure/velocity models across the arc and forearc areas, which are poorly known at present. The resulting models will also be used to process (i.e. migrate) reflected arrivals recorded by the ocean bottom and land instruments to image the plate boundary zone reflections landward into the zone of seismogenic subduction and seaward to tie with existing seismic reflection data. Along all three transects a primary goal is to construct accurate velocity models so that the images of the plate boundary zone produced in this project can be tied to relocated earthquake hypocenters. The hope is that integration of these two data sets could provide a missing link in understanding the transition from aseismic to seismogenic plate motion.

II. Project participants

Participants on R/V Ewing:

Faruq Akbar	UTIG	Austin, Texas
Miguel Avila Ballar	ICE	San Jose, Costa Rica
Ulrich Bartschat	GEOMAR	Kiel, Germany
Jörg Bialas	GEOMAR	Kiel, Germany
Tom Bodine	UTIG	Austin, Texas
Glen Caglarcan	UTIG	Austin, Texas

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Carlos Calderon	UTIG	Austin, Texas
Gail Christeson	UTIG	Austin, Texas
Kirk McIntosh	UTIG	Austin, Texas
Yosio Nakamura	UTIG	Austin, Texas
Stéphane Operto	UTIG	Austin, Texas
Jorge Marino Protti	OVSICORI-UNA	Heredia, Costa Rica
Tom Shipley	UTIG	Austin, Texas
Alexander Stavenhagen	GEOMAR	Kiel, Germany
Alison Teagan	UTIG	Austin, Texas
Mark Wiederspahn	UTIG	Austin, Texas

Ewing Science Staff:

John Di Bernardo
Chuck Donaldson
Carlos Gutierrez
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Onshore participants:

Ken Griffiths	UTIG	Austin, Texas
Hildegard Goedde	GFZ	Potsdam, Germany
German Leandro (and many others)	ICE	San Jose, Costa Rica
Karl Otto	GFZ	Potsdam, Germany
Jens Priebach	GFZ	Potsdam, Germany
Steffen Saustrup	UTIG	Austin, Texas
Albrecht Schulze	GFZ	Potsdam, Germany

R/V Maurice Ewing Officers:

Ian Young	Master
Louis Mello	First Officer
Mark Landow	Second Officer
Jeff Sylvia	Third Officer
Albert Karlyn	Chief Engineer

III. Cruise Narrative

The cruise EW-9502 started in Balboa, Panama and ended in Caldera, Costa Rica. The cruise was divided into three experiments performed in three areas of the Pacific margin of Costa Rica (Figs. 1 and 2). This narrative section briefly summarizes cruise activities to establish the general timing. More detailed information concerning the activities and the timing are included in following sections with detailed shooting and recording information in the appendix.

25 March, 1995. The R/V *Ewing* departed from the pier at Balboa, Panama at about 14:00 (GMT) and after exiting the harbor the *Ewing* dropped off the Panamanian pilot at about 15:30. The transit to Costa Rica took about 50 hours including a stop off southwestern Panama to test the GEOMAR OBH release mechanisms (described below).

27 March, 1995, ~17:30. The *Ewing* arrived at the Experiment 1 area off the central Nicoya Peninsula. OBH and OBS deployment proceeded immediately followed by shooting and instrument recovery over the next five days.

3 April, 1995, 10:17. The final instrument was recovered from Experiment 1 (OBS 10). Begin transit to Experiment 2 area.

3 April, 1995, 21:43. Deployed OBH at station 53 in the Experiment 2 area for airgun array testing.

4 April, 1995, 07:00. Finished array test and recovered OBH.

5 April, 1995, 07:00. Instruments refurbished. Begin deployment at station 27.

5 April, 1995, 20:01. All instruments deployed for Experiment 2 (total of 33).

6 April, 1995, 03:01. Start shooting Experiment 2 on line 239.

13 April, 1995, 23:01. Finished shooting line 240 and Experiment 2.

15 April, 1995, 15:06. Finished instrument recovery for Experiment 2 -- all instruments recovered. Transit to Experiment 3 area.

16 April, 1995, 12:43. Begin deployment for Experiment 3.

21 April, 1995, 01:05. Final instrument recovered and Experiment 3 completed. Begin transit to Caldera, Costa Rica.

IV. Equipment and Instrumentation

Airgun array

In general the airguns performed very well throughout the cruise. At no time did we have to reshoot lines or sections of lines due to airgun problems. The problems that did arise were due to obstacles in the water such as fishing equipment and, in at least one case, a floating tree trunk. The standard Ewing seismic source is a 20-gun, 138 L (8420 in.³) array. The center of the array is 39.6 m behind the stern (Fig. 3) and its depth varies between 6 and 9 m depending on ship speed. We used this standard array for Experiment 1 and Experiment 3 exclusively and for the strike lines in Experiment 2 when outside of the 3D grid area. During the 3D shooting we used a 16 gun, 97 L (5895 in.³) array. We performed an airgun array and shot interval test before Experiment 2 on which we based this selection. A more detailed description of the airgun arrays and the array test are included in the section on Experiment 2.

Navigation and Timing Systems. (Mark Wiederspahn)

The general requirements for navigation and timing systems stem from the need to determine all shot-receiver travel times to a small error relative to 50 meter shot locations and 5 msec sampling. The systems had to be reliable, as all of our shooting schedules were fixed, and a navigation outage would mean loss of data with little opportunity to reshoot it.

Summary. We used a commercial service (RACAL MultiFix) to provide differential GPS (DGPS) corrections via Inmarsat to three separate receivers throughout the cruise. One receiver was able to use four base stations in the region (Panama, Carmen Mexico, Tampa Florida, and Trinidad) with offsets 600-2700 km to provide an improved fix relative to single station DGPS. This consistent and reliable source of positions every second permitted shooting on distance. The single station DGPS receivers obtained corrections from Carmen (1200 km), which had lower errors than Panama (600 km), except when Carmen was offline. We logged four separate GPS systems, including one not differentially corrected. The relative accuracy (within the experiment) seems now to be around 5-10 meters 2D RMS based on multi-station pseudo-range residual errors. The system overall was quite reliable; we experienced only one 5 minute outage during online work. There were a small number of glitches (due to constellation changes?) but these were generally in the few meter range, and compromised a single shot. Each base station failed at least once; Panama was out for many hours over the course of the month. The primary GPS receiver (and its spare!) faulted twice for extended periods, the longest was about 2.5 hours. These seemed to be GPS receiver firmware bugs.

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The reference UTC time for this experiment was provided by GPS also. We recorded the precise time of the gun controller aim point using three independent GPS clocks and a GOES geosynchronous satellite clock. Agreement was generally within 1 msec. This event trigger was transmitted to the land array site using blaster shot boxes over a radio link. The land recorder could be started using this trigger or on exact UTC minute provided by a local GPS receiver/microprocessor system, depending on radio signal conditions. The actual start time of the recording was in either case recorded by local GOES clock time stamp. Each land recorder, OBH and OBS has some way to calibrate its time relative to GPS standard time. In the case of the marine instruments, the precise location is also determined in this process.

A display on the bridge allowed the crew to steer more or less directly down the computer determined line. Generally, we were no more than 20 meters cross track from the desired line; the average of line averages was 4 m. Shotpoint locations down line were generally no more than 10 m from the planned location, except where a navigation software/operator problem occurred. For one line, the actual shotpoint location seems to have been as much as 250 m from the desired location. The location of each shot, although quite precisely known, is incorrect.

We recorded one second navigation from the primary and the secondary receivers, and time stamps for each shot. The raw ascii data was broken into hour files. Each line has a binary file which contains raw and filtered locations for the line and its short run-in and run-out extensions.

The final product of the entire process is a "shot" file for each line, which contains precise time of shot to the nearest UTC millisecond, a source position to the nearest micro-degree (~ 0.1 m) and a Hydrosweep center beam water depth. This file drives all subsequent data extraction from the semi-continuous recordings made by the various digital recorders.

Detailed Navigation Description. Each base station uplinks the DGPS pseudorange corrections to Houston for each satellite it sees above 10 degrees elevation, which sends them on to Aberdeen, Scotland, where monitoring and control for all Racal DGPS operations occurs. From Aberdeen they are uplinked via the Inmarsat West Atlantic satellite, and received by the ship's JRC JUE45-MKII receiver. A Racal supplied down converter, decoder and descrambler and control module provides two RS232 RTCM-104

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output streams, with updates about every 10 seconds. One of these streams contains only a single base station's corrections, and can be sent to any DGPS receiver. The station for this stream is selected by the decoder, and can be switched at any time in case a base station has problems.

The 4 station stream goes to a Compaq 486/66 PC running RACAL MultiFix software, which estimates the best set of corrections and ionospheric model. In coordination with a Trimble 4000-DS 9 channel GPS receiver, it determines the current position. All four solutions are plotted and the offsets from the combined solution are displayed on the screen each second, along with error history ellipses. Other displays give detailed information about the solution, or the constellation.

Although the expectation was that Panama (516-721 km from the work site) would be our best DGPS base station, it was not for two reasons. The precision of the DGPS corrections was often self-described (via UDRE > 1) as poor. The station experienced a number of outright failures during the transit and initial phase of the experiment, so it was selected only if Carmen was down. Carmen, at 1159-1407 km from the work site, should have given less precise fixes than Panama, but this seemed not to be so. Surprisingly, both Tampa (2042 - 2177 km) and Trinidad (2753 - 2740 km) gave quite consistent fixes relative to fixes generated using the closer stations.

The MultiFix software outputs a fix every second to the primary nav computer, which computes filtered velocity and location, and determines the time when the ship will pass over the next pre-determined shot point along a line. If no subsequent nav update changes this estimate, it triggers the Lamont gun system then by sending an "F" to an interface box. This box sends the complicated and precisely timed series of instructions to the DMS2000/ TAGS system, which then fires the guns. The delay in this process is 1.305 seconds. (We did not adjust our fire time for this delay, but should have.) The gun control system fires the guns, adjusting each gun so its pressure pulse occurs at an "aim point". This aim point is the trigger time for time stamps and the radio signal to synchronize other recorders.

The nav computer navigates a shot source location 87.4 meters behind the antenna. This offset does not depend on the ship's gyro, but is a down line offset. We used Lamont's standard antenna to gun offset numbers; we did not verify these. Preliminary attempts to determine source offset or timing error from shooting over an OBH in one direction then

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the opposite indicate no indentifiable bias although this could be due to compensating time and gun location errors.

The secondary nav computer runs the same code as the primary, but accepts fixes from an Ashtec Ranger-7 12 channel receiver being corrected by the single station DGPS stream. If the primary faults the secondary system can be brought on-line within a shot. In any case, it is a constant comparison and verification of the solutions of the primary system. We found it to be within about 2-5 meters cross track or down track from the primary system most of the time.

The pseudorange residuals from either MultiFix or Ashtec receivers, plotted as hourly averages, show a daily variation from about 1 m to about 4 meters. The residuals depend on the number and relative spacing of the GPS satellites, and the best and worst residuals occur at about the same time on any two successive days.

The bridge display is an X terminal which can display either or both of the primary and secondary systems' solutions. The bridge has independent control of scale and display parameters, while working off position data from the nav computer.

The tertiary DGPS receiver is a Lamont Magnavox 4200D receiver, which is logged as part of their standard operation. That system drives a Calcomp 465 belt bed plotter which provides a "minutes behind realtime" track plot, which can be used to verify the correctness of the first two systems. A Trimble model NT200D receiver on the bridge is not differentially corrected, and is used to provide sanity checking for the overall DGPS system solutions. These have not been extensively quality checked, as the usual Lamont navigation deliverables include these.

The ship's Inmarsat A service antenna is a possible single point of failure. It is located above the bridge in an easily serviced area; the mast can obstruct the signal from the satellite at certain ship azimuths. We experienced few problems during the Barbados 3D cruise two years ago, using a very similar DGPS scheme with the same receiver. We did azimuth vs. signal strength tests in the work area, and found adequate signal strength except at 301-309 degrees. The DGPS correction stream did not drop out even though the signal strength would have been marginal for placing a telephone call.

Detailed Timing Description. The gun aim point strobe is sent to several time stampers. The permanently installed Lamont time stampers are a TrueTime model GPS-DC GPS clock, which logs time to a millisecond, and a Datum model 9390 GPS clock, which logs time to microseconds. In addition, we used a TrueTime model GPS-TMD clock (usec) and a TrueTime model 468-DC GOES clock (msec). The interclock delay was determined in several ways, including using a University of Wisconsin GPS trigger box (incorporating a Garmin GPS receiver/clock and a microprocessor) to trigger on a UTC minute and log the time stamps for each clock. We also used this scheme to verify the radio link/blaster box delay to the land array recording site.

The Datum did not work well, and the Lamont TrueTime missed between 5 and 10 events (compared to the UT TrueTime) per day for unknown reasons. The Datum would fail by either latching a time exactly one second too early, or not providing any time at all. When reset by software command, the gun system would fail to trigger any time stamper one shot after the Datum began to work again. The GOES clock, set to a nominal 35 msec travel time delay, was 1 msec consistently later than the UT TrueTime clock. The UT TrueTime is used as a basic time reference except for the few periods when the Macintosh computer logging its output crashed.

We verified that the aim point trigger was within about 1/2 msec of the array acoustic pressure peak by attaching an independent single blast phone to a gun harness and monitoring this signal compared to the aim point trigger

The land array recorder (a 120 channel Texas Instruments DFS-V) was triggered by IO model 200 master/slave encoders over a half-duplex radio link. Motorola model GM300 45w FM radios at 153.05 MHz over a marine VHF band antenna mounted on the ships mast proved to work out to 40 km if the land antenna were high up, above obstacles. In Experiment 1 (Marbella) and the Cobano location in Experiment 2 it worked quite well. It barely worked at all for voice at the Concepcion Experiment 2 site. It was used for triggering only at Cobano for the Experiment 2 shooting. The ARM signal from the IO box was used to start the DFS. Its WIRE_BLAST signal was looped back into FTB and also strobed the local GOES clock to obtain a precise time stamp. A disadvantage of using ARM is that the radio squelch break may not always be exactly the same delay from the time the transmitter starts. For some reason, the FIRE signal from the IO box was not used for this purpose. We don't yet know what the problem was with this configuration.

Navigation Processing. The filtered realtime multistation DGPS corrected location from the binary line file is linearly interpolated in time to find the shot location. In a second pass, the Hydrosweep center beam depth is interpolated and appended to the shot time/location record. So far, it has not seemed necessary to retouch the realtime navigation.

We generated plots of shot distance vs. offset down line, and distance from desired shotpoint to actual shot point to verify the system was working as expected (Figs. 4-13). It was not. The differences seem to stem from a scale distortion in determining the distance cross and down track to a projection of the desired shotpoints on the ellipsoid. This problem was exacerbated by an operations error in setting up the parameters for Experiment 2; Experiment 1 parameters were used instead. The distortion in Experiment 2 seems to be no more than $\pm 5\text{m}$; it is presently unknown why Experiment 1 line 103 was so distorted. These problems are believed fixed for Experiment 3 (Fig. 14-17).

UTIG OBS Description

The instruments we used for recording the seismic signals are the ocean-bottom seismographs (OBS's) designed and built at the University of Texas Institute for Geophysics. They have gone through several upgrades since their first design in the 1970's, and the current version incorporates digital recording with automatic gain ranging to achieve wide dynamic range, use of off-the-shelf computer boards to achieve high reliability, SCSI interface to provide ready adaptability to newer recording devices of increasing capacity, and easy operation through direct communication with a personal computer. Recent improvements specifically to adapt to this experiment include the addition of OAS hydrophones; a capability to select any combination of active channels; use of 500 Mbyte 2.5" disk drives for increased recording capacity, longer battery life and higher reliability; use of alkaline batteries with associated saving in cost of expendables; an addition of a battery monitor to prevent complete exhaustion of the power source; and a modified anchor frame design to reduce volume for shipping and storage.

The current instrument has the following characteristics:

Sensors:	3-component gimballed geophones and an optional hydrophone; may be configured for 1-, 2-, 3- or 4-
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	channel recording in any combination, software-selectable
Pass band:	4.5 - 100 Hz for geophones; 3.0 - 100 Hz for hydrophone
Alias filters:	selectable with plug-in resistor blocks
Filter roll-off:	-24 dB/oct
Sensitivity:	2.1 nm/s with Mark Products L-15B geophones; 1.0 mPa with OAS E-2PD hydrophone
Dynamic range:	126 dB theoretical, 112 dB re rms electronic noise
A/D:	14 bits plus dynamic gain ranging
Sample interval (τ):	1 to 106 ms at 1 ms steps
Number of channels (n_{ch}):	1, 2, 3 or 4
Timing accuracy:	10 ms absolute, with pre- and post-deployment clock calibrations against standard signal and water-wave arrivals
Instrument location accuracy:	10 m or better, from post-cruise analysis of water-wave arrival data
Instrument orientation accuracy:	1°, from post-cruise analysis of water-wave arrival data.
CPU:	80C88
Data acquisition mode:	continuous with short gaps while transferring data to recording device, or triggered with long-term/short-term signal-level comparison
Temporary data memory	512 Kbytes standard, 4 Mbytes optional
Continuous record length:	261,120 τ/n_{ch} [e.g., 8m:42s @ 4 ch. 8 ms] (2,088,960 τ/n_{ch} w/ optional memory)
Transfer rate to recorder	200 Kbytes/s
Data gap:	8.1 s for 512K transfer to Tandberg TDC3660 tape drive; 4.1 s for 512K transfer to Tandberg TDC3820 tape drive; 22 s for 512K transfer to Toshiba MK2224FB or MK2428FB disk drive

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Recording capacity:	155 Mbytes on DC6150 tape; 450 Mbytes on DC6525 tape; 203 Mbytes on Toshiba MK2224FB disk drive; 500 Mbytes on Toshiba MK2428FB disk drive
Storage requirement::	2 bytes/sample plus 0.4% overhead (16-byte header every 4K-block)
Battery life:	2 years dormant; 5 days acquiring data on tape, up to 8 weeks acquiring data on disk
Power source:	24-37 size-D lithium or alkaline batteries or equivalent
Pressure case:	43 cm (17") diameter glass sphere
Weight at deployment:	85 kg (190 lbs)
Weight at recovery:	35 kg (75 lbs)
Overall dimension at deployment:	128 \times 128 \times 145 cm (50" \times 50" \times 57")
Maximum depth of deployment:	7 km
Method of instrument recovery:	timed release from anchor controlled by two independent clocks

UTIG OBS Processing and OBSTOOL (Gail Christeson)

Following recovery and clock calibration the disk drives were removed from the OBS chassis. The disks were then connected to a SUN workstation and the data transferred to a larger disk drive on the workstation. This step required shutting down the workstation each time another OBS disk needed to be dumped. After several OBS disk drives had been dumped, the raw OBS data were written to Exabyte tapes for archival using the tar command. The data still on the SUN disk were then processed to SEG-Y format as described below.

Processing of the UTIG OBS data from raw OBS format to SEG-Y files was done using OBSTOOL, a graphical user interface written by Gail Christeson. Before the original OBS field data can be transformed into final SEG-Y files, the OBS needs to be properly located and a clock correction needs to be calculated. The clock correction is necessary

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because there is significant drift on the OBS internal clock, which needs to be accounted for so that the shot times and recording times are in the same reference frame.

In addition to the raw OBS data, the following information was needed to process the data:

1. Shot file. The shot file consists of the following information: shot_number year julian_day hour minute second latitude longitude depth
Mark Wiederspahn produced the shot files by combining information from the shot time files, navigation files, and Hydrosweep center beam depth files.
2. OBS start-up/clock-calibration capture files. Information from these files, together with the start and end times of data acquisition, were used to do the clock corrections. Yosio Nakamura recorded these files before OBS deployment and after OBS recovery.
3. OBS deployment location, water depth, water velocity. OBS location and water depth were recorded by the watchstanders for each deployment. Water velocities for the shallow instruments (<500 m) were obtained from XBT measurements. Water velocities for the deeper instruments were obtained during the inversion for OBS location and secondary clock correction.
4. Clock and BRG crystal calibration information for each OBS instrument from laboratory measurements. From prior experience, it was known that the temperature of the BRG crystal increases by $\sim 4^\circ$ during data acquisition when writing to tape. If the amount of temperature increase and bottom temperature are known, the calibration information can be used to account for the effect this will have on the clock drift rate.

The processing sequence used during the TICOSECT cruise was:

1. Initial processing (convert from raw OBS data format to raw SEG-Y format).
2. Initial clock correction
3. Make water wave data subset (for OBS location and secondary clock corrections)
4. Pick water wave arrivals
5. Locate instrument, make secondary clock correction
6. Repeat 1-5 for each OBS drop in experiment
7. Final clock correction
8. Create final SEG-Y files

Step 6 was done for 2 reasons. 1) To determine if there was a bias in the secondary clock corrections, which would be indicative of a shot delay (there was no evidence for this). 2) To determine the temperature increase during data acquisition when writing to disk

(this was the first field experiment where the OBS data was written to disk instead of to tape). Analysis of the secondary clock corrections for the OBSs in Experiment 1 indicates that the temperature increase was $\sim 1^\circ$.

GEOMAR OBH (Dr. J. Bialas, U. Bartschat, A. Stavenhagen)

Technical Design. The instrument configuration (Flueh et al., 1995) is sketched in Figure 18. All components are centered around a stainless steel tube. At the top of the tube is a ring for lifting the instrument. Mounted on this ring is a 2 m long flag stick. The buoyant body is made of syntactic foam and consists of two hemispheres, 550 mm in diameter. Between the two hemispheres additional discs can be placed, each of which provides an additional 3.5 kg of flotation. The fixed upper hemisphere is used as the attachment for a flasher, a radio beacon, and the release transponder hydrophone. This hydrophone is connected through the tube to the *MORS RT 601* release transponder, which is located beneath the buoyant body. The release transponder has its own power supply (18 R20 cells) and an additional time release programmable in 0.1 hour steps from 0.1 to 10000 hours for safety reasons. A 2-3 m long wire is used between the anchor (a 40-50 kg piece of railway track) and the release unit to prevent the system from contacting the seafloor. Opposite the release transponder is a 0.8 m long pressure cylinder which contains the *METHUSALEM* recorder and its batteries (up to 54 R20 cells or two rechargeable batteries). The hydrophone is mounted between these two devices. The total weight of the system is about 125 kg without anchor. The descent and ascent speeds are about 1 to 1.5 m/s. In Figure 19 the instrument is shown during recovery at sea.

Electronic Design. The seismic waves are received with the model *E-2SD* hydrophone manufactured by *OAS Inc.* The signals are fed through a very low noise preamplifier (26 dB gain) and a 3 Hz highpass filter before they are stored on the *DELTA t METHUSALEM* seismic recorder.

Before A to D conversion, the four input channels pass through a 30 dB preamplifier, a 5 pole, 50 Hz anti-aliasing Bessel filter, and a programmable gain stage (0, 6, 12, or 18 dB). The input signals are over sampled at 800 Hz and converted with 12 bits plus sign resolution. Subsequent digital decimation filtering increases the resolution to 14 bits plus sign (90 dB S/N ratio). The resulting sampling rate is programmable at 25, 50, 100, or 200 Hz.

After digital filtering, the data is stored into a buffer RAM of 768 kb. Once the buffer is filled one block of data is transferred to the DAT recorder (*AIWA HD-SI*). The recorder uses a modified standard audio DAT recorder, which only has to be switched on for 10 s whenever the buffer is full. This technique greatly reduces power consumption (a SCSI-DAT recorder would need about 2 minutes after power on for self test and repositioning). After every block of data a gap is left on the tape such that no repositioning is needed when the next block is recorded. Using a C180 DAT cassette we can store 1.08 GB of data in the audio format.

The time base is based on a DTCXO with a 0.05 ppm accuracy over temperature. Setting and synchronizing the time as well as monitoring the drift is carried out automatically by synchronization signals (DCF77 format) from a *LENNARTZ ELECTRONICS* GPS-based coded time signal generator.

The *METHUSALEM* is controlled with simple commands via an RS232 interface with a PC. Acquisition campaigns with start and stop times as well as interval definitions can be loaded via the PC and all parameters are stored in EPROM such that they do not change even if the power is switched off. After start of a measurement the data of any channel may be displayed on the PC for system calibration and checkout via the RS232 interface.

Instrument Handling at Sea. The onboard preparation of the instrument before deployment consists of two parts. First, the mechanical adjustments include installation of the hydrophone, recovery facilities, and the release transponder. A check of the power supply for each component is made. Onboard the ship the instruments are maneuvered with a hoist from the instrument container to the point of deployment.

Second, the recording device must be programmed, synchronized, connected to the power supply, and placed into the recorder pressure cylinder. This cylinder is then attached to the instrument and connected to the hydrophone. Finally, the anchor is attached to the release system by opening and closing the release hook. The instrument is then deployed "anchor first" and lowered to about 2 or 3 m below surface. At this point a final test of the release transponder can be performed prior to release of the instrument. The deployment procedure consumes generally less than 15 minutes per instrument.

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The recovery procedure of the OBH is as simple as its deployment. Once the release command has been transmitted, the distance to the ship and thus the pop-up speed can be monitored from the transponder. When the instrument reaches the surface, no further ranges can be read because the transponder hydrophone will be above the water. Thus the final range indicates the distance to the ship. In addition, the radio beacon (and during night hours the flash) are activated. Depending on the weather conditions, the instrument can be collected by a Zodiac or the ship can move sufficiently close to the instrument so that it can be grappled. During the TICOSECT cruise all instruments were collected with R/V *MAURICE EWING* itself (except for two caught by shrimpers) and in general lifted onboard within 20 minutes after they were located by the watch. After the system is lifted onboard the ship, the recorder cylinder is opened immediately to check the recorder and determine the chronometer drift. For safety, the data are copied onto a DAT cassette.

Cruise activities specific to the GEOMAR OBH (Dr. J. Bialas, U. Bartschat, A. Stavenhagen)

During the TICOSECT Phase I expedition off Costa Rica the GEOMAR OBH- group was invited to join the survey onboard the research vessel *MAURICE EWING*. After preparing the OBH- and processing- laboratories during the harbor time in Balboa, Panama, the first location on March, 28 was to test the release systems with their hydrophones in realistic water depths, i.e., more than 3000 m, to discover any damage caused by transportation. Twelve complete release systems were mounted on two test frames and were lowered with the CTD winch to depth (3000 m). Two systems (D629, D649) failed, and, after controlling the components, the depth test was repeated. This time the systems worked well and the releases could be prepared for the first array.

Problems arose with the Lennartz GPS-system that is used for synchronizing the internal clock of the Methusalem recording unit. The system showed available satellites but it could not derive the position or any time information. Various tests with changing the antenna position and cable length or cable paths onboard failed, so at last they were dismantled and the backup unit, a Precitel GPS, was used for the synchronizing procedure. During the Experiment 1 shooting, this system failed too and could not be set up again. Therefore a systematic problem was assumed for the damage of the three GPS but a reason or a solution for this problem could not be found. Another GPS was borrowed from the UTIG OBS group and was used thereafter for synchronizing the systems.

On March 29, 11:51 (local, Costa Rica time) the first GEOMAR- OBH was lowered at its location of the experiment 1. It was decided to use the starboard A-frame and a stern sited winch for deploying the GEOMAR OBH because the weight of a complete mounted system is about 160 kg with a total length of 6 m. OBH stations 1- 20 were deployed alternating with UTIG and GEOMAR OBH on the dip line 101/ 102. On the strike line 103 that was planned with two GEOMAR OBH (positions 21, 22) only station 21 was occupied because the release system of station 22 failed prior to deployment. Therefore only 11 GEOMAR systems were further available for the expedition. From March 30, 12:00 (local) to March 31, 20:00 lines 101, 102 and 103 and 4 land shots were recorded by the deployed OBH.

From March 31, 20:00 (local) to April 1, 07:00 (local) OBH sites 11 to 21 were recovered without any problems or time delays. All GEOMAR systems had recorded the whole deployed time. Directly after the recovery 4 OBH were prepared again for a new deployment.

On position 23 (line 104) a new vertical streamer configuration was deployed. It contains an OBH connected with a 100 m long streamer (40 hydrophones, in four sections, stacked to four channels) that was held by a second buoy. First the streamer buoy was lowered to the water and the streamer cable was given out by hand while it was drifting away from the ship, then the OBH followed and a last test was done to verify that the whole configuration was able to float after releasing. Positions 24 to 26 were deployed with the GEOMAR OBH in the scheduled time and profiling of lines 104 and 105 started on April 1. 19:00 (local).

From April 2, 09:00 (local) to April 3, 05:00 all OBH, including the vertical streamer array, were recovered without any losses. Two of the GEOMAR recorders failed due to recorder errors. Three Benthos flashlights did not work because the depth switch did not turn off the flash and at last the batteries were empty when the systems had to be recovered at night. Sensible maneuvering of the ship following radar signals and with use of the direction finder each of these three systems were found in about 20 minutes.

Experiment 2 combined 33 OBS/OBH in a 3-D array off the southeastern tip of the Nicoya peninsula near Cabo Blanco. Starting the deployments on April 5, 01:00 (local) after the preparation of the systems the array was set up within about half of the

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scheduled time. The GEOMAR OBH were prepared with 4 battery packs each for long time deployments (two weeks). Profiling of the 5 strike and the 3-D lines (201- 237) started on April 5, 21:00 (local).

On April 11, at 06:00 the radio beacon of one unidentified OBH was received on the bridge. One of the GEOMAR OBH was located on a shrimp fishing boat which dragged the OBH from the ocean bottom. A zodiac was brought out and J. Bialas, M. Protti, and the second officer (M. Landow) of the Ewing entered it and went to the fishing boat. The OBH (from station 72) was retrieved without any problems. It turned out that OBH station 72 was recovered two days earlier than scheduled. No damage of the system was found and the recording unit was still working. During the recovery from the fishing boat the R/V *Ewing* continued profiling so that no time losses or course changes occurred.

In the evening of 13 April and the morning of 14 April, after the finish of profiling, the other 10 GEOMAR OBH systems were recovered. All systems recorded the whole deployment time and data losses were not indicated.

After a transit of about 6 hours and one night rest, the deployment of the OBHs for Experiment 3 started in the morning of 16 April. At 06:45 (local) station 100 was deployed. In the following 11 hours the other 10 GEOMAR instruments were lowered at their stations. Again a vertical array was mounted with two floats on the upper side and a frame without floats containing the recording unit and the release system on the lower side. This configuration was intended to avoid torsional effects on the streamer wire while the system rises to the surface.

Seismic Streamer and Recording System (Carlos Calderon and Alison Teagan) The streamer used throughout the TICOSECT project is a French, AMG analog streamer. The streamer and associated sections have a total length of approximately 310 meters consisting of a 90 m tow section, a 25 m stretch section for shock absorption, four active sections, a 25 m stretch section, and a 100 foot tail rope for stabilization. The active sections are a 12.5 m high frequency section, a 25 m medium frequency section and two 50 m low frequency sections. Due to a two channel recording limitation, we recorded only the two 50 m sections. The center of the first 50 m active section is 177.5 m behind the ship and the center of the second is 228 m behind (the center of the airgun array is ~40 m behind the ship so the corresponding source to receiver distances are ~ 137 m and

187 m, respectively). At a speed of 5 knots, the streamer tows at a depth of about 10 m. There is no independent streamer depth control.

As part of the data acquisition system, a pre-amplifier applies a fixed gain to the input signal, the data are filtered with an analog anti-alias filter with a cut-off frequency of 160 Hz, and an analog/digital converter digitizes and sends the data to memory buffers. The data are written from these buffers to 3480 tape units using SEG-D format. Previous to the digitization stage, the two data channels in their analog form are plotted using the thermal plotters in the main lab. There are 8 channels available, but we only recorded 2 channels. Each 3480 contains approximately 1000 shot points (about 40 Mb) each with a 16 second record length sampled at 2 ms intervals.

On board SCS processing. Before processing, the data were converted from SEG-D to SEG-Y format and written to disk files. Next the data were organized into the actual lines of the experiment. This is due to the fact that data have been recorded in turns between lines for the 2-D array of Experiment 2, and for some of the transits between lines in Experiments 1 and 3. The 3480 tapes are labeled with number of experiment, tape number (reel number), and number of shots (file number). The data were first read from tape to disk using SIOSEIS. For this purpose, SIOSEIS had to be modified by Mark Wiederspahn so that the correct channel set containing the seismic data in the DMS 2000 SEG-D format could be read. The data were organized into seismic lines by using the GMT times recorded in the log history or from GMT times obtained from the navigation tapes. Once organized on disk, the data were copied to exabyte tapes. Only one exabyte tape is required to store the two seismic channels for all three experiments.

We did preliminary data processing to some of the seismic lines with SIOSEIS software using the processing sequence below:

- Normal Moveout Correction (NMO) and stack of two-channels
- Mute
- Deconvolution
- Filtering
- F-K Migration

Due to the fact that the data have small offsets, it is expected that the NMO correction will not be very sensitive to detailed variations in the velocity field. To perform the

moveout correction, velocities from a previous survey were used. Next, the data between zero time and the first reflected arrival (sea bottom reflection) were muted. With this purpose a water bottom library was constructed based on the bathymetry, assuming a velocity for the water, or based on first picks from the nearest offset channel (better for deep water). To reduce the effect of the source in the data, and to remove short intrabed multiples, a deconvolution operator was applied to the stacked data. For this, a 200 ms operator obtained from a 2.0 s design window (beginning just above the water bottom) was applied to the data. To reduce high frequency noise, including artifacts introduced by the deconvolution operator a low pass filter with a cut-off frequency of 50 Hz was applied to the data. Also, frequencies lower than 8 Hz are filtered to improve resolution of the seismic section. The cut-off frequencies are designed from filter panels obtained from one of the strike lines of Experiment 2. These cut-offs may vary between Experiments 1-3. Finally, to improve the image defined by shallow reflectors in the stack section, the data were time migrated using an F-K migration operator (Fig. 20). A velocity of 1.5 km/s was selected to perform this operation. By varying this velocity it will be possible to improve the image for the different areas of study, but this provides a good preliminary image especially in the deeper water areas of the survey. In addition to these steps, for data acquired in shallow water, mainly Experiment 2, removal of surface related multiples is necessary in order to unmask the primary reflections. Predictive deconvolution was applied with this purpose prior to migration.

V. Experiment 1 Description and Results

Purpose. The rationale for Experiment 1 is twofold and relies on dense instrumentation and shot spacing: A first goal is to determine a detailed and well constrained crustal scale velocity model that may allow differentiation of prism lithologies. A second goal is to use the reflected arrivals from the ocean bottom and land instruments to construct an image of the plate boundary useful for analysis of the prism geometry and its morphology to seismogenic depths.

Description. Experiment 1 consisted of a dip line shot twice, lines 101 and 102, and three strike lines, 103, 104, and 105 (Fig. 21). Line 101 (102) has a total length of 84 km with 20 instruments positioned along its length; UTIG OBS/OBHs and GEOMAR OBHs occupied alternate stations. The seawardmost eleven instrument stations were at 5 km intervals and the landward nine stations were at 2.5 km intervals. Stations 1 and 2 were seaward of the trench and station 3 was in the trench axis. The landward extension of

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this line was occupied by a DFS V recording system with a 3.6 km spread near the coast and 30 REFTEK seismographs extending up to 140 km from the coast.

Strike line 103 intersects line 101 at station 11. Although this line was intended to have 3 instruments, a malfunctioning release mechanism prevented deployment at station 22. Due to deployment faster than expected line 103 was extended to the NW for a total length of ~70 km (check this).

Strike line 104 included stations 23, 7, and 26 and line 105 included stations 24, 5, and 25. Each of these lines were 48 km long with 12 km station spacing. These lines crossed the lower slope off the Nicoya Peninsula including the area of the UTIG 3D multichannel survey.

Lines 100 and 99 are transit lines along which we continued to shoot the airgun array.

Airgun arrays, shot spacing, and shooting speed. The airgun array used for all of Experiment 1 was the standard Ewing array of 8420 cu.in. The shot spacing was varied to test the importance of noise dissipation between shots. Lines 103 and 101 had shots at 50 meter intervals, line 100 had shots every 75 meters, and lines 102, 104, and 105 had 125 meter intervals. The ship speed was maintained at ~ 4 kt on all lines but 102 on which the speed was increased to 4.5 kt to maintain our schedule.

Results. All instruments that were deployed in this experiment were recovered as scheduled. Preliminary processing of all the UTIG OBS data for Experiment 1 was completed by Gail Christeson a few days following recovery. A few examples of records from Experiment 1 produced by shipboard processing are shown in Figures 22 and 23.

Examples of the GEOMAR OBH data are shown in Figures 24 and 25 show two sections, along lines 101 and 102 from station 1. For display, the data were processed with a distance weighted trace normalization and a bandpass filter of 5-16 Hz. Both sections show clear arrivals up to more than 70 km offset. The data of line 101 should benefit from the dense shot interval of 50 m during later processing. Due to the large shot spacing of line 102 tracing of the events is not disturbed by waterwave arrivals of previous shots.

Apparent velocities are observed from lines 101 and 102 as follows:

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Although these velocities are affected by the dip of the continental slope, its topography and the internal structure, at least 6 different layers could be identified at this stage. This is in good agreement to the model presented by Ye et al. and indicates that the oceanic slab subducting under Nicoya has been covered.

Figure 26 shows strike line 104 recorded by OBH station 23. First arrivals can be traced up to the end of the line at 36 km. At first inspection three sets of events are observed. According to the model of Ye et al. and compared to the estimates drawn from figure 24 and 25, it appears that the strike lines cover only parts of the wedge. It seems that no energy has arrived from the subducting oceanic crust.

offset [km]	apparent velocity [km/ s]
5.44 - 11.17	4.04
11.17 - 22.55	6.9
22.55 - 35.21	9.11
42.60 - 49.54	13.61
49.54 - 56.87	7.56
56.87 - 71.87	15.63

offset [km]	apparent velocity [km/s]
5.46 - 18.65	5.36
18.65 - 30.25	6.30
30.25 - 35.94	8.91

VI. Experiment 2 Description and Results

Purpose. Experiment 2 shares the same goals as Experiment 1 with a stronger focus on determining the plate boundary morphology in the seismogenic zone. Specifically, this experiment is intended to test the hypothesis that subducted seamounts are sites of earthquake nucleation by obtaining 3D coverage of the forearc in the vicinity of the 1990 M=7 earthquake.

Description. Experiment 2 consists of 37 dip lines, 201-237 (azimuth $\sim 40.04^\circ$), and 5 strike lines, 238-242 (Fig. 27). The dielines were spaced at 250 m, the strike lines at 5 km, and they were 35 km and 37 km in length, respectively (except for lines 240 and 241 which were extended 2 km landward while 240 was truncated due to time constraints. The instruments occupied five rows of stations each with 6 instruments such that the row spacing was 5 km and along row spacing was 1 km. The recording capacity of the instruments required that this project last ≤ 8 days and the number of lines and their length, in turn, required that the ship speed throughout this experiment be ~ 5.1 kt.

The 3D shooting was essentially divided into four parts with each part covering half of the grid area at 500 m spacing. The connecting turns were alternately 2 and 2.5 km in diameter in the same direction allowing "moving racetrack" progression through half the grid in 9 lines. After changing turn directions the second half of the grid was covered (Fig. 28). At this point all the odd numbered lines had been shot except for 203 because line 202 had been shot instead by mistake. By repeating the procedure in the reverse direction from 237 toward 201 the even numbered lines were shot. Because we had only limited problems with fishing gear and fishermen, we were able to fill all but a small amount of the missed shots in a 5 hour period. Strike lines 238 and 239 were shot before the 3D shooting and lines 242, 241, and 240 followed the fill in period.

Array and shot interval test. For Experiment 2, six 5-km-long tests were conducted to a single GEOMAR OBH. These tests evaluated reverberation in the shallow water column, energy levels, and spatial aliasing issues for three gun arrays at various shot distances. The arrays tested are shown below:

Volume	55 L	98 L (97 L)	138 L (137 L)
	3365 in. ³	5985 (5895) in. ³	8445 (8335) in. ³

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Guns	10 guns	16 guns	20 guns
Gun No.	in. ³	in. ³	in. ³
1	145	145	145
2	-	-	850
3	305	305	305
4	235	235	235
5	-	520	520
6	-	-	500
7	250	250	250
8	850	850	850
9	540	540	540
10	-	145 (80)	145
11	-	145 (120)	145
12	385	385	385
13	-	850	850
14	250 (120)	250	250
15	-	350	350
16	-	520	520
17	260 (200)	-	260
18	-	350	350
19	-	-	850
20	145	145	145

The tested arrays and shot distance combinations were:

55 L x 50 m	(19 s)	(Fig. 29a)
55 L x 100 m	(38 s)	
98 L x 50 m	(19 s)	(Fig. 29b)
138 L x 75 m	(28 s)	(Fig. 29c)
98 L x 100 m	(38 s)	
138 L x 125 m	(38 s)	(Fig. 29d)

We chose the 98 L array, 50 m shot interval, based on qualitative comparison of the GEOMAR OBH record sections and the results of Experiment 1. Some of the test records are shown in Figure 29. To further tune the array an 80 in.³ and 120 in.³ gun replaced two 145 in.³ guns in the array. The 37 grid lines used 97 L (5795 in.³) while the

strike and dip lines outside of the grid used the standard Ewing array with the two small gun substitutions for a total volume of 137 L (8355 in.³).

Results. Thirty-three instruments were deployed for this experiment and all thirty-three were recovered. Only one instrument, an OBH at station 72, failed to record the entire experiment and that was because it was recovered by a shrimp vessel after about 75% of the lines had been shot. As described above, the instrument was recovered from the shrimper without incident and without delaying the shooting in progress.

Due to the large amount of data, onboard processing and display of the GEOMAR OBH data could only be done for Experiment 1. Examples of the UTIG OBS data are shown in Figures 30-32. Travel time modeling will be done using these data to determine the velocity structure of this area. Subsequent processing will be done to enhance reflected arrivals and then the data will be migrated.

Bathymetry and gravity. Due to the dense ship track coverage over the Experiment 2 area both bathymetry (Hydrosweep center beam) and gravity were gridded and contoured. As expected the free air gravity anomaly closely corresponds to the bathymetry; however, in the NE and SW ends of the gridded area the two trends diverge (Figure 33).

Water column velocity. While shooting the 3D survey and during recovery of instruments we deployed several expendable bathythermographs (XBTs). The XBTs, all deployed in water depths less than 600 m, demonstrated a temperature range of ~6°-32° corresponding to a velocity range of ~1480 m/s-1545 m/s (Figure 34).

VII. Experiment 3 Description and Results

Purpose. Experiment #3 shares the velocity and imaging goals of Experiments 1 and 2, but the circumstances are somewhat different. In this case the study area is on the northern flank of the subducting Cocos Ridge. We expect to be able to measure the crustal thickness of the subducting plate and contrast that with the other areas. This area also encompasses an apparent lithological change or stratification in the forearc. The outer Osa Peninsula and the nearby Caño Island are apparently composed primarily of Eocene and younger accreted sediment. Thus the diplines may cross the upper plate boundary between this type of material and ophiolitic basement (Figure 1). Strike line

304, which comes close to Caño Island is intended to make measurements through the sedimentary accretionary complex and line 303 is more likely to record arrivals through the ophiolitic basement. As in the other experiments a primary goal is to identify the position of the plate boundary. In this case it is of particular interest because a much shallower dip is expected. In fact due to the lack of deep seismicity in this area it has been proposed that the buoyant crust of the Cocos Ridge subducts along the base of the crust of the overlying arc.

Description. The experimental design of Experiment #3 is very similar to Experiment #1. Lines 301 and 302 are along the same line with 301 shot going seaward and 302 in the landward direction (Figure 35). There are two strike lines in this case, lines 303 and 304, and, in contrast to Experiment #1, they are both in shallow water. The intersection points between the strike and dip lines are stations 92 and 87.

Results. A total of 26 instrument deployments were made during this experiment, including three GEOMAR OBHs that were deployed twice. One UTIG OBS failed to surface as programmed at station 94 and is considered lost. Another UTIG OBS was recovered ~2 km from its deployment site although relocation of this instrument during processing indicates that it was in the correct location during data acquisition. Minor damage to the radio beacon of this instrument and mud in its base suggests that it was dragged from its recording position to near its recovery position before release. If so, it is likely due to fishing activities, and we speculate that similar interactions may have caused the loss of OBS 94. The GEOMAR OBH that was deployed at station 101 was harvested by a shrimp fisherman before data were recorded along line 304.

No data from Experiment 3 were processed aboard the R/V *Ewing* due to the brief time from the end of data acquisition to the return to port in Puerto Caldera, Costa Rica. The data from the UTIG OBSs have subsequently been processed to SEG-Y format. An example of the Experiment 3 data is shown in Figure 35.

VIII. Summary

We surveyed three areas of the Pacific margin of Costa Rica during Cruise EW 9502. The primary data collected during this cruise includes data from 81 OBS/OBH deployments, ~90 REFTEK land deployments, and three deployments of a 120 channel DFS V recording system (raw DFS data collected ~25 Gbyte). Both the GEOMAR OBHs and the UTIG OBSs worked very well and the R/V *Maurice Ewing* proved to be

an excellent ship for these operations. The airguns were a very dependable source, requiring no down time, and the ship and crew were adept at the maneuvers required for deployment and recovery. The Racal Multifix differential GPS navigation system was robust and provided consistently excellent positioning data such that navigation was generally within ~ 10 m of the intended track.

IX. References.

- Flueh, E., Ye, S., Stavenhagen, A., Leandro, G., Bialas, J., 1992, Pacomar, Sonne 76, Compilation of seismic data, *GEOMAR-Data-Report*
- Flueh, E., Ye, S., Stavenhagen, A., Leandro, G., Bialas, J., 1993, Pacomar, Sonne 81, Compilation of seismic data, *GEOMAR-Data-Report*
- Flueh, E., Bialas, J., Ye, S., Herber, R., Bergmann, P., Schleisiek-Kern, K. & von Huene, R., 1995, A digital, high capacity ocean bottom recorder for seismic investigations, *submitted to Geophysical Prospecting*
- Hinz, K. and the PACOMAR working group, 1995, Tectonic Structure of the Convergent Pacific Margin Offshore Costa Rica from Multichannel Seismic Reflection Data (SO-81), *submitted to Tectonics*
- von Huene, R., Bialas, J., Flueh, E., Cropp, B., Csernok, T., Fabel, E., Hoffmann, J., Emeis, K., Holler, P., Jeschke, G., C. Leandro, M., Perez-Fernandez, I., Chavarria, S., Florez H., A., Escobedo Z., D., Leon, R., Barrios L., O., 1995, Morphotectonics of the Pacific convergent margin of Costa Rica in: Mann, P. (ed), Geologic and tectonic development of the Caribbean plate boundary in southern Central America, *Geological Society of America,, Special Paper*, 295
- Ye, S., Bialas, J., Flueh, E., Leandro, G., Hinz, K., Stavenhagen, A. and von Huene, R., 1995, Crustal structure of the subduction zone off Costa Rica derived from OBS refraction and wide-angle refraction data, *submitted to Tectonics*

X. Figure Captions

Figure 1. Map of Costa Rica showing TICOSECT transect locations. Detailed caption is provided on figure.

Figure 2. Map of TICOSECT offshore instrument locations with bathymetry and coastlines.

Figure 3. Dimensioned diagram of R/V *Maurice Ewing* indicating ship dimensions, airgun positions, antenna, Hydrosweep, and 3.5 kHz sonar locations.

Figure 4. Line 101 graph of shot distance vs. offset.

Figure 5. Line 101 graph of shot point error versus offset.

Figure 6. Line 103 graph of shot distance vs. offset.

Figure 7. Line 103 graph of shot point error versus offset.

Figure 8. Line 201 graph of shot distance vs. offset.

Figure 9. Line 201 graph of shot point error versus offset.

Figure 10. Line 211 graph of shot distance vs. offset.

Figure 11. Line 211 graph of shot point error versus offset.

Figure 12. Line 215 graph of shot distance vs. offset.

Figure 13. Line 215 graph of shot point error versus offset.

Figure 14. Line 301 graph of shot distance vs. offset.

Figure 15. Line 301 graph of shot point error versus offset.

Figure 16. Line 303 graph of shot distance vs. offset.

Figure 17. Line 303 graph of shot point error versus offset.

Figure 18. Labeled drawing of GEOMAR OBH system.

Figure 19. Picture of GEOMAR OBH being recovered at sea.

Figure 20. Portion of Line 101 single channel seismic reflection data near the trench. Processing includes bandpass filter and FK migration at 1500 m/s. Time range displayed is 3-7.8 seconds, and the shot point range is 800-1350 with a shotpoint interval of 50 m. The vertical exaggeration is ~4.25:1 at the seafloor.

Figure 21. Map showing TICOSECT Experiment 1 instrument locations. GEOMAR instruments are represented by open circles and UTIG instruments by filled circles. Track lines are marked with light lines and labeled. Bathymetry is from data set published by von Huene et al., 1995.

Figure 22. Record section from UTIG OBS 8, Line 102, vertical component. Times reduced at 6 km/s.

Figure 23. Record section from UTIG OBS 14, Line 102, vertical component. Times reduced at 6 km/s.

Figure 24 a, b. Record section from GEOMAR OBH 1, Line 101. Times reduced at 6 km/s.

Figure 25 a, b. Record section from GEOMAR OBH 1 Line 102. Times reduced at 6 km/s.

Figure 26 a, b. Record section from GEOMAR OBH 23, Line 104. Times reduced at 6 km/s.

Figure 27. Map of TICOSECT Experiment 2 showing instrument locations and acquisition lines. As before, UTIG instruments are represented by filled circles and GEOMAR instruments by open circles. Bathymetry is from data set published by von Huene et al., 1995.

Figure 28. Diagram showing intended ship track for Experiment 2 data acquisition.

Figure 29 a-d. Plots of airgun array and shot spacing tests prior to Experiment 2. Further description of the tests is included in the text.

Figure 30. Record section from UTIG OBS 32, Line 213, hydrophone. Times reduced at 8 km/s; displayed offset range 5000 m.

Figure 31. Record section from UTIG OBS 46, Line 229, vertical component. Times reduced at 8 km/s; displayed offset range -12447 m to +22478 m; time range 0-8 s.

Figure 32. Record section from UTIG OBS 32, Line 213, hydrophone. Times reduced at 8 km/s; displayed offset range -17458 m to +17500 m; time range 0-8 s.

Figure 33. Free air gravity anomaly map and bathymetry in Experiment 2 area. The final line spacing of 250 m was sufficient to produce displays of gridded gravity and bathymetry that were collected during the cruise.

Figure 34. Graphs of expendable bathythermographs (XBTs) results from the Experiment 2 area.

Figure 35. Map of TICOSECT Experiment 3 showing instrument locations and acquisition lines. As before, UTIG instruments are represented by filled circles and GEOMAR instruments by open circles. Bathymetry is from data set published by von Huene et al., 1995.

Figure 36. Record section from UTIG OBS 88, Line 301, vertical component. Times reduced at 8 km/s; displayed offset range -26000 m to +9047 m; time range 0-8 s.

XI. Figures

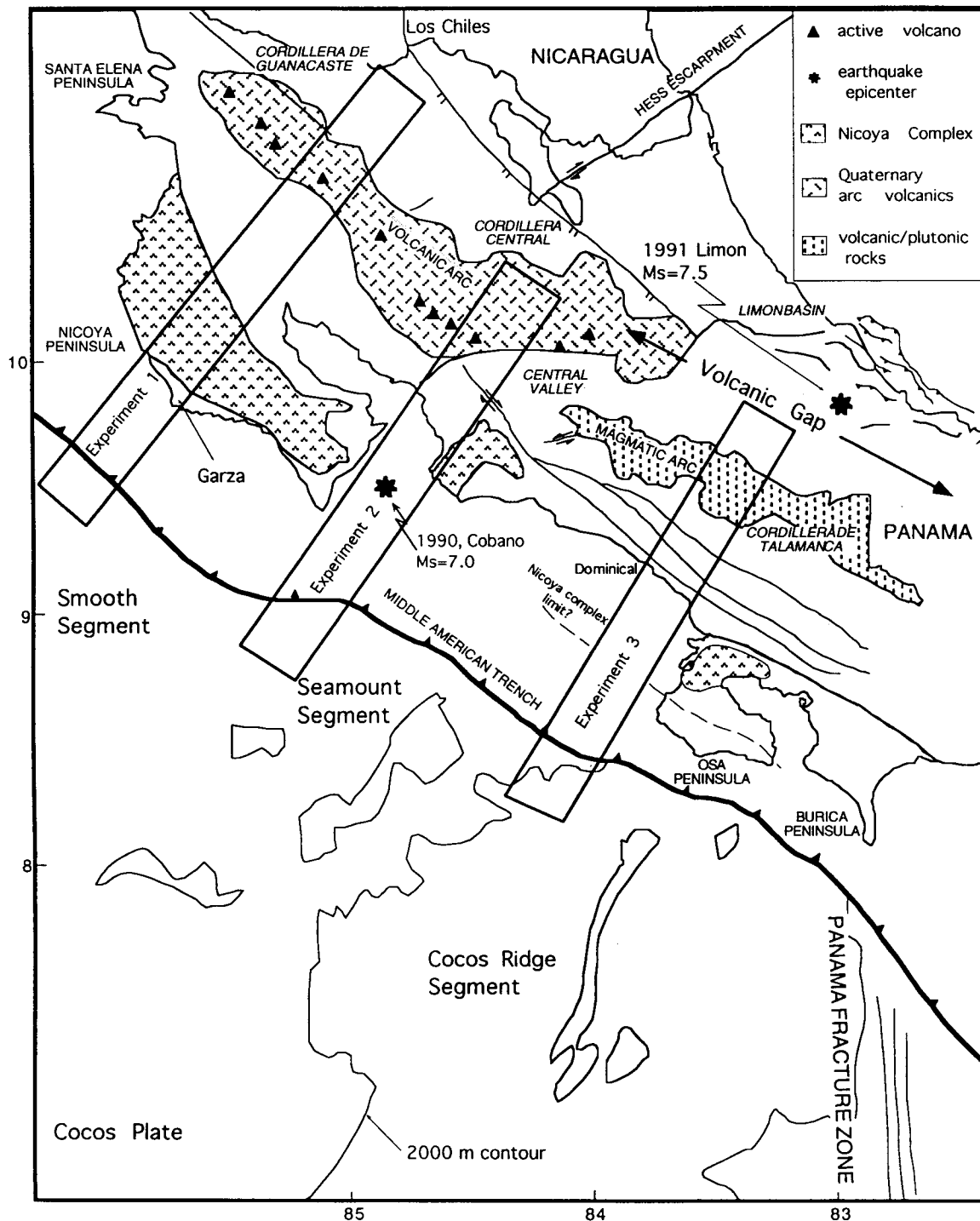


Figure 1. Map of Costa Rica showing the three transects containing TICOSECT Phase I geophysical experiments proposed in this project. Note the varying morphology of the subducting Cocos plate: from NW to SE, smooth, seamount dominated, and Cocos Ridge segments. The 1990, Cobano epicenter is located in the Experiment 2 corridor. The trends of the volcanic centers are deflected eastward in central Costa Rica adjacent to the volcanic gap. The volcanic gap is aligned with the projection of the Cocos Ridge, as is the 1991 Limon epicenter near the Caribbean coast. The dashed line crossing the Experiment 3 corridor and Osa Peninsula is the seaward limit of Nicoya complex ophiolitic rock interpreted by Baumgartner et al. [1989]. Experiment 3 will be a direct test of this interpretation.

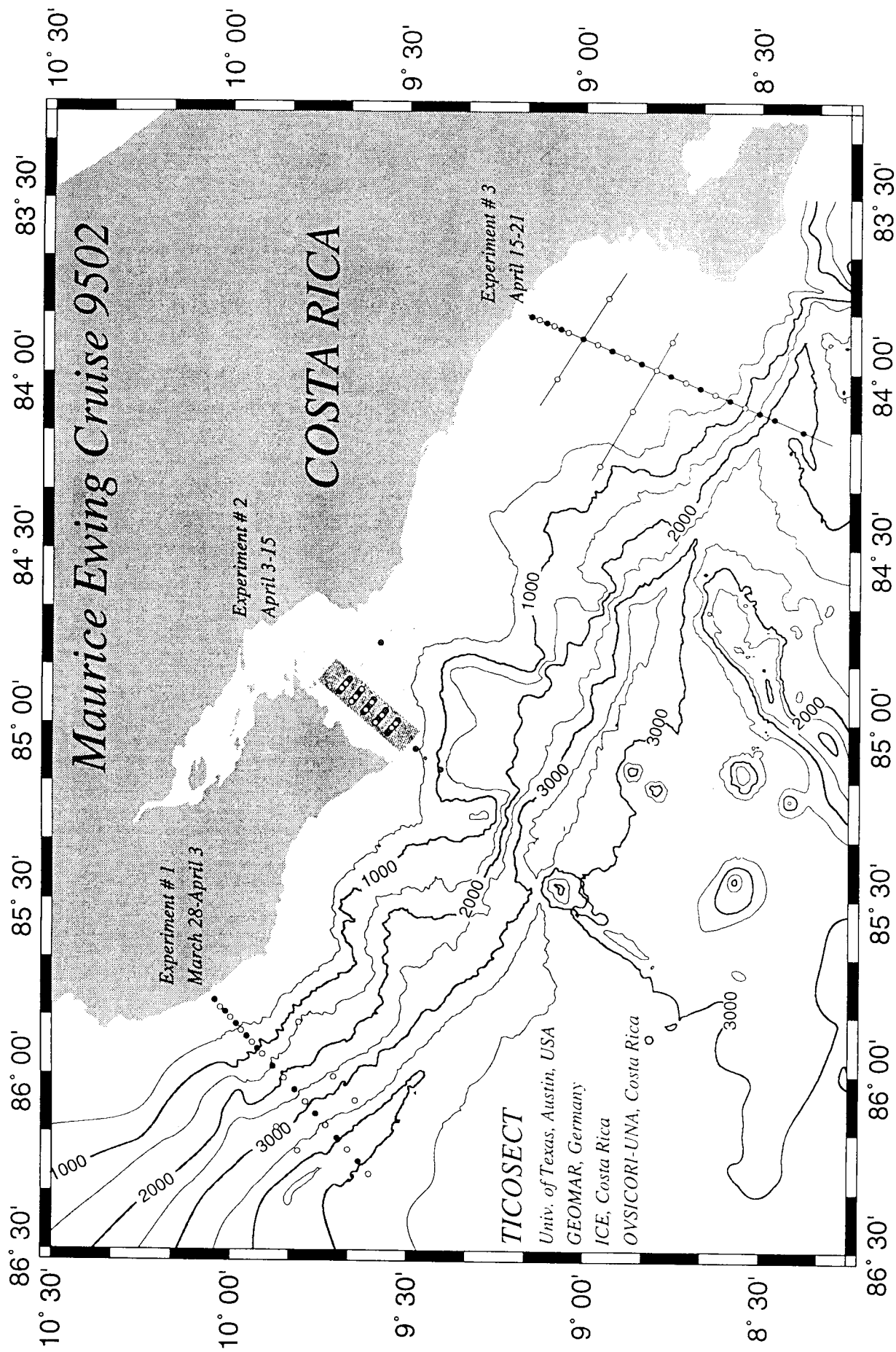


Figure 2

MAURICE EWING SETBACK AND OFFSET DIAGRAM

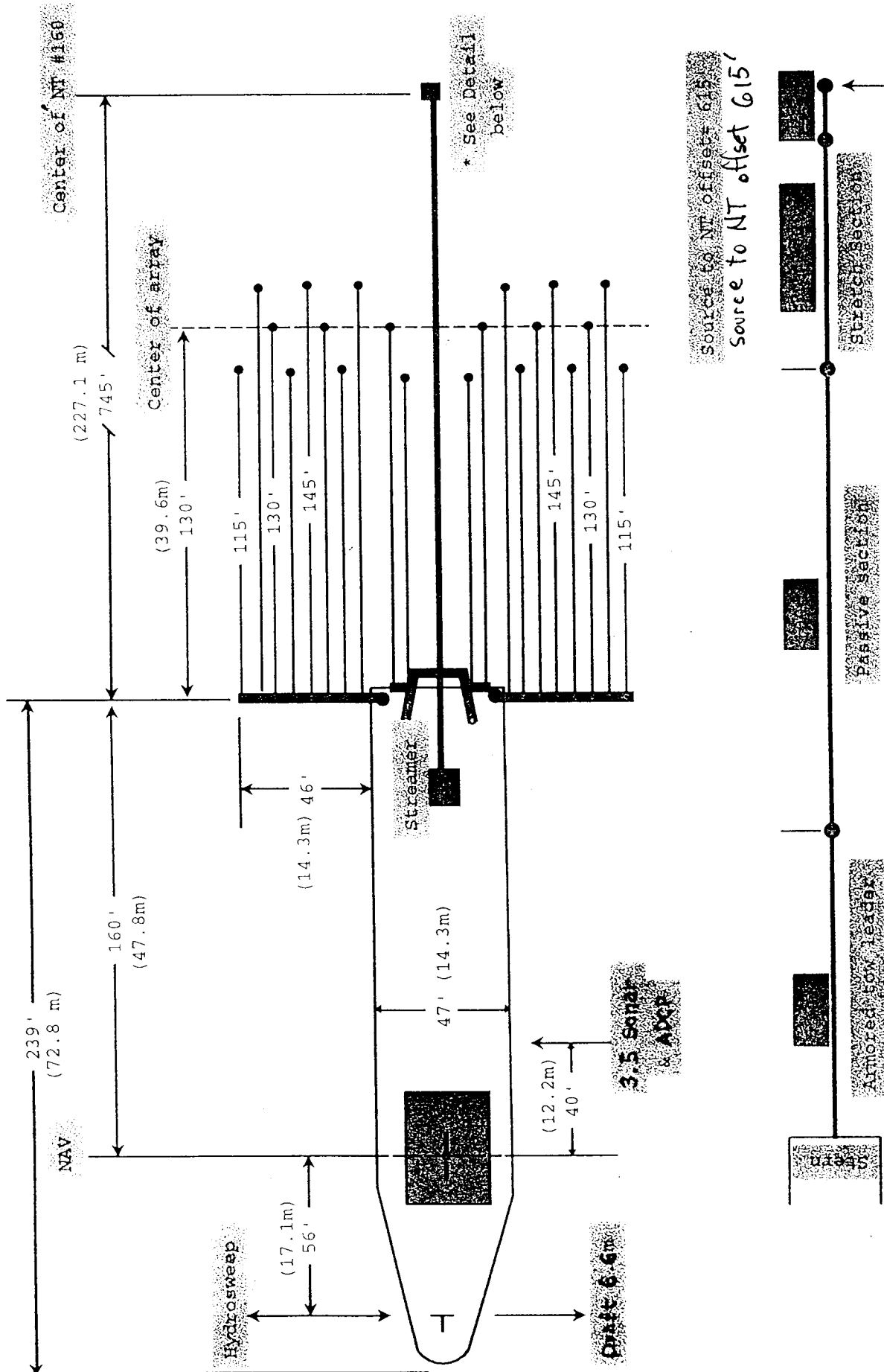


Figure 3

line 101 delta shot

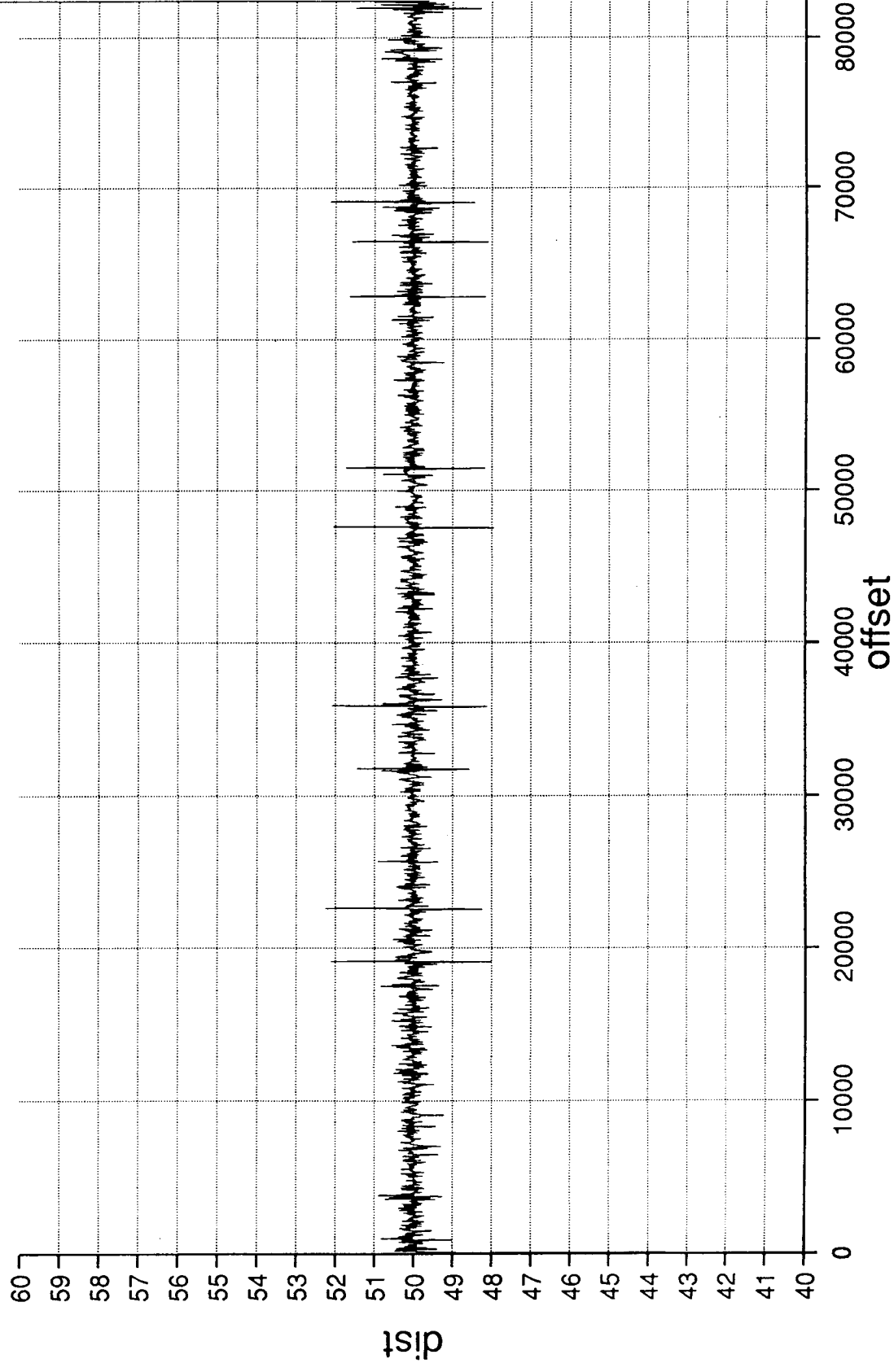


Figure 4

line 101 sp error

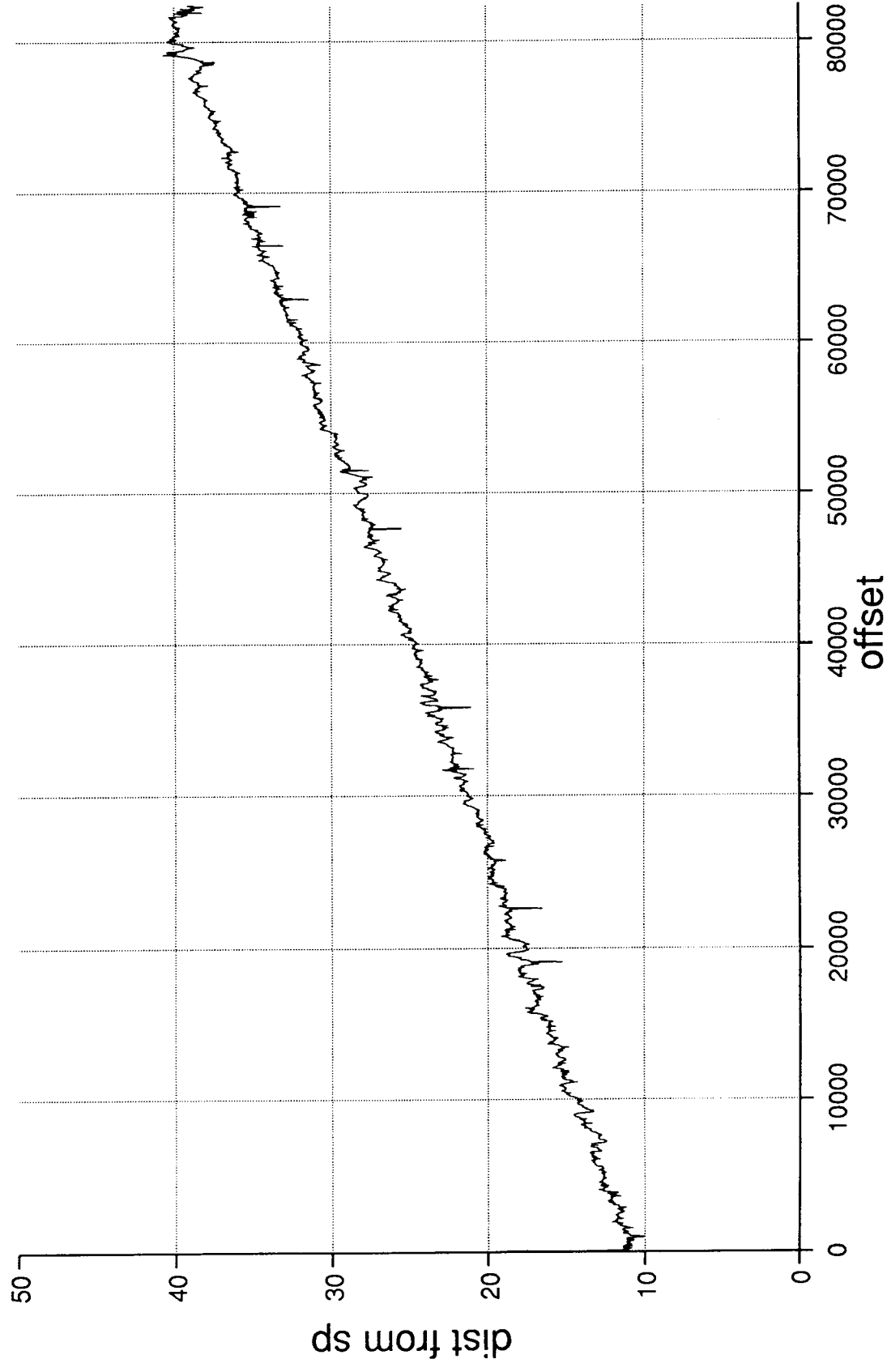


Figure 5

line 103 shot delta

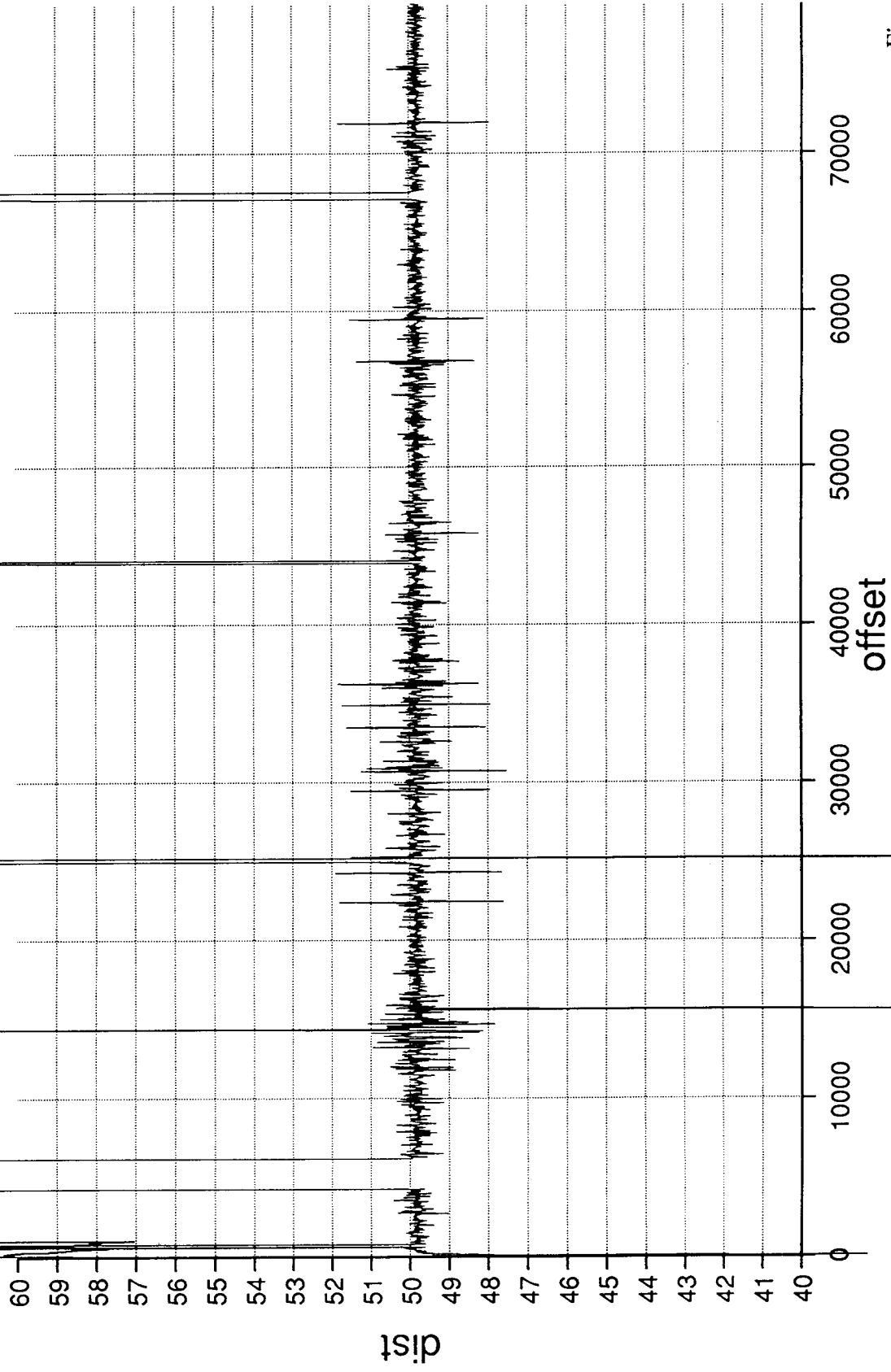


Figure 6

line 103 sp error

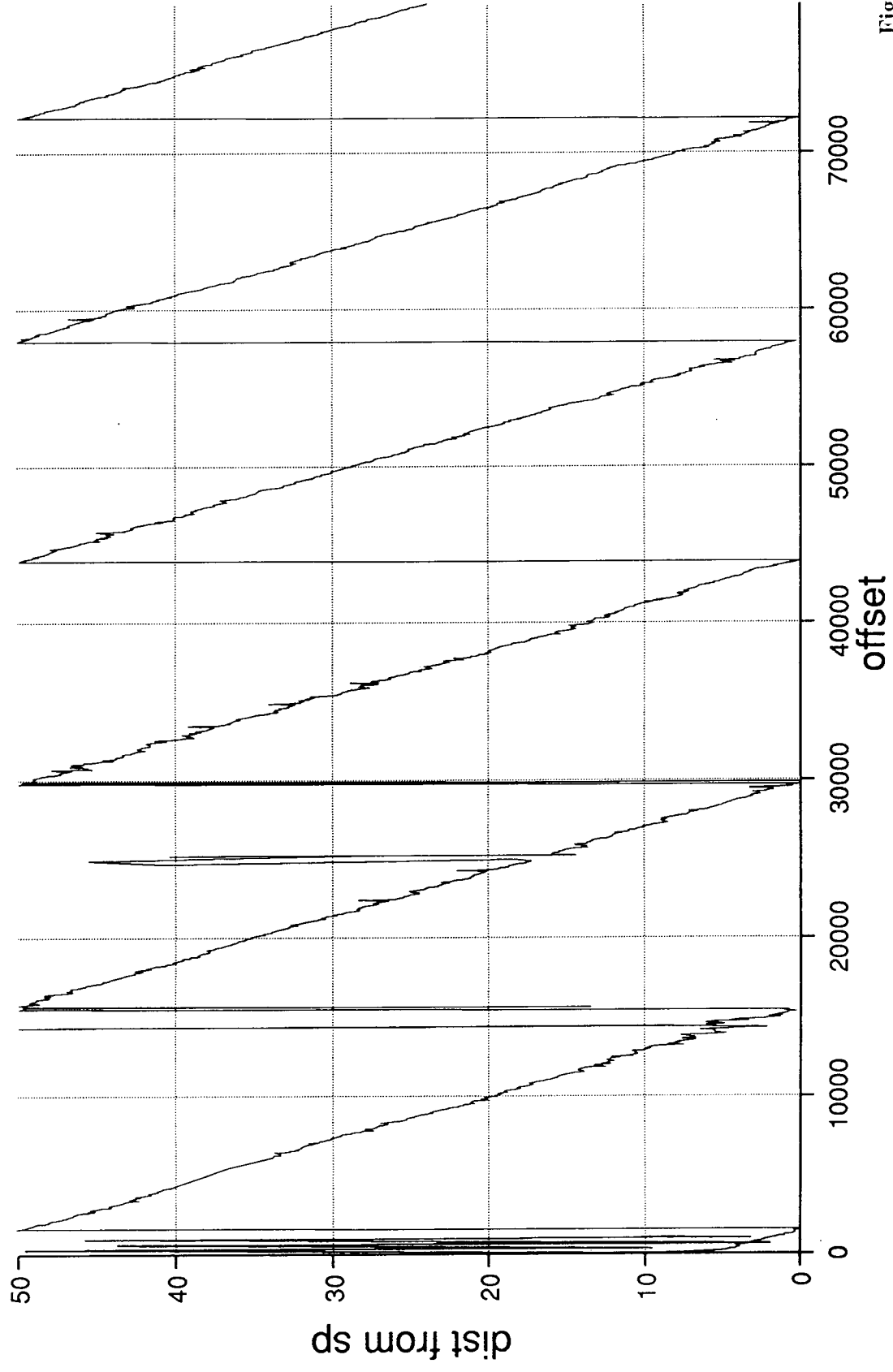


Figure 7

line 201 sp dist

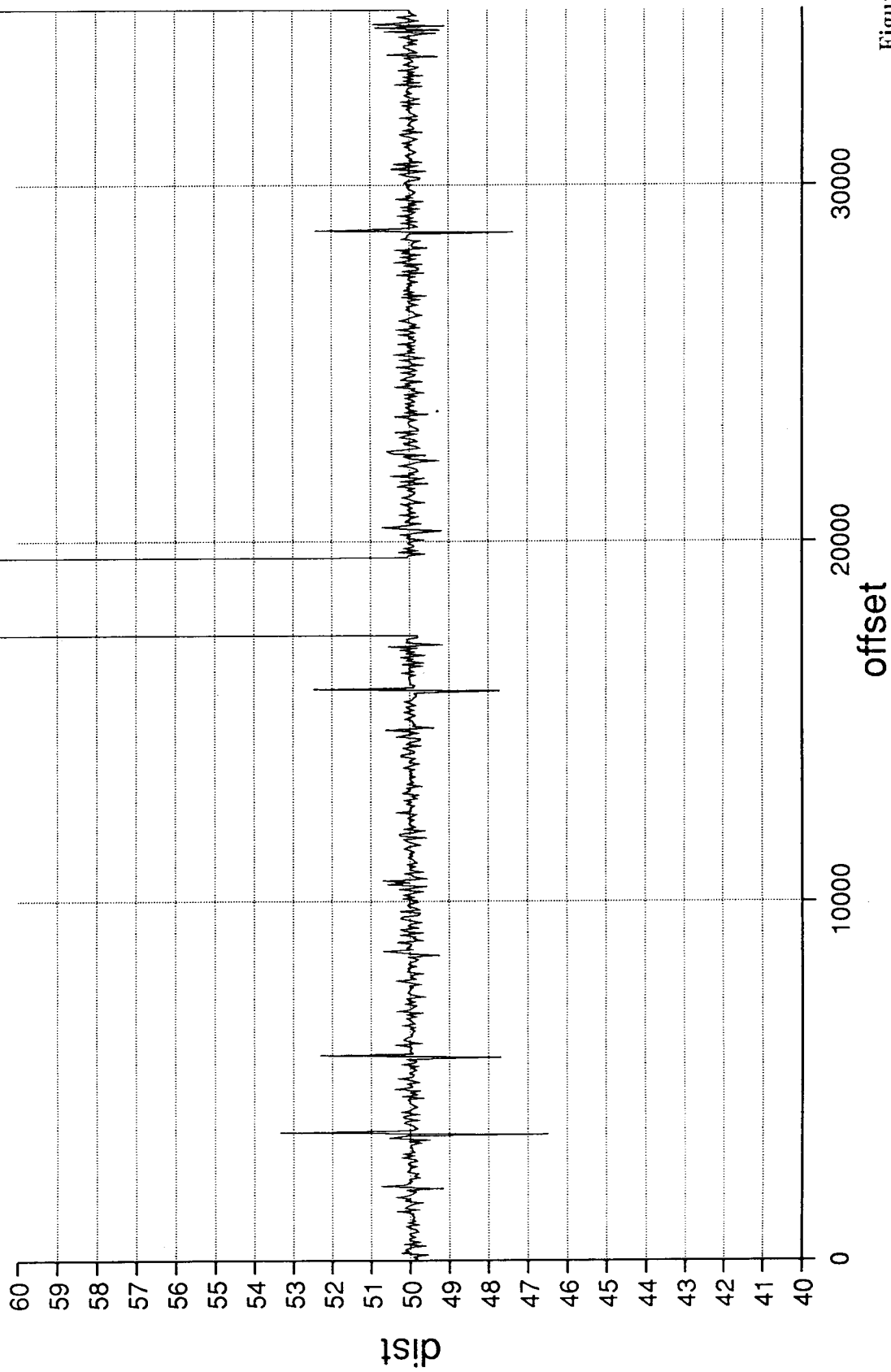


Figure 8

line 201 sp error

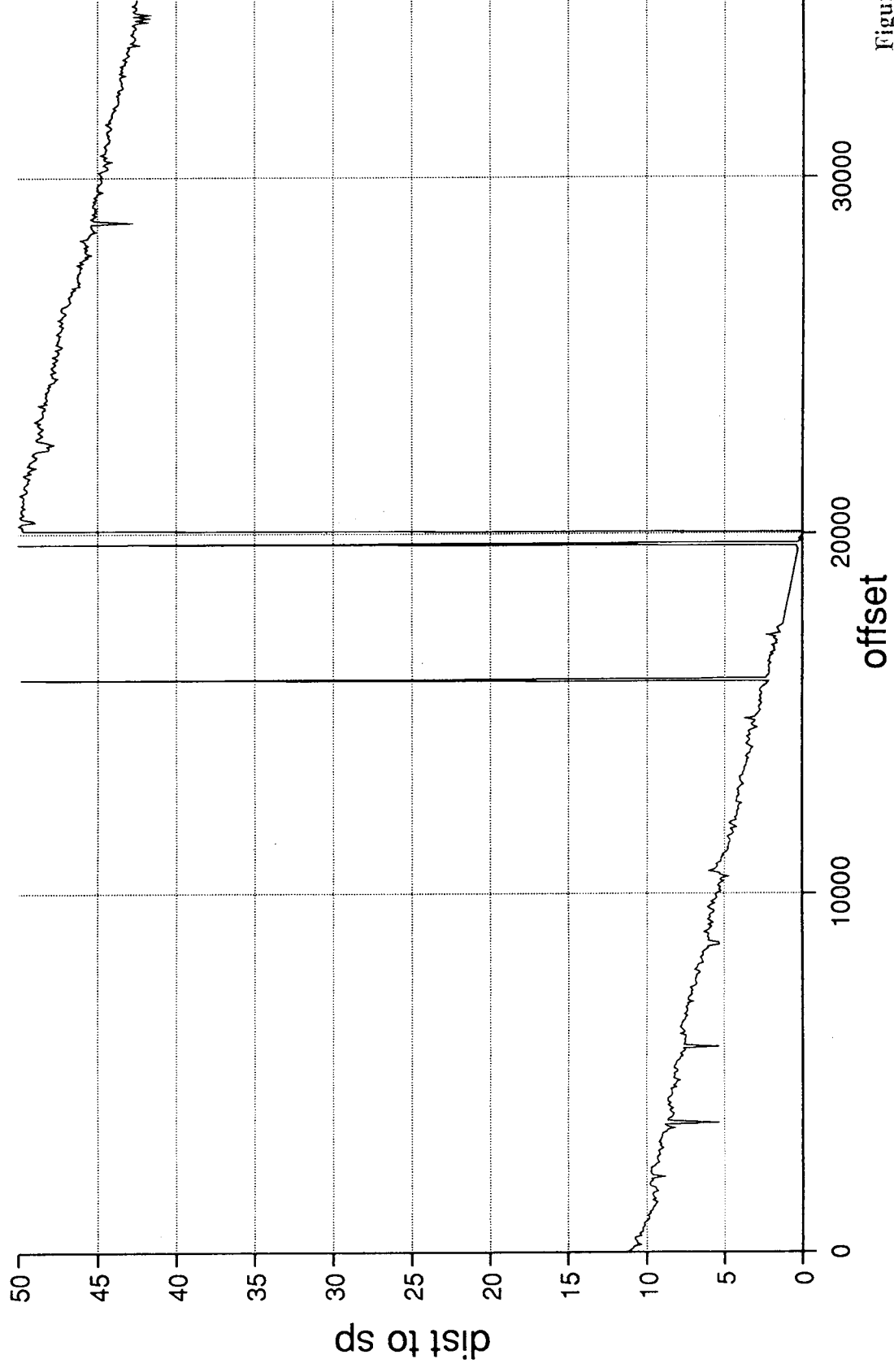


Figure 9

line 211 sp dist

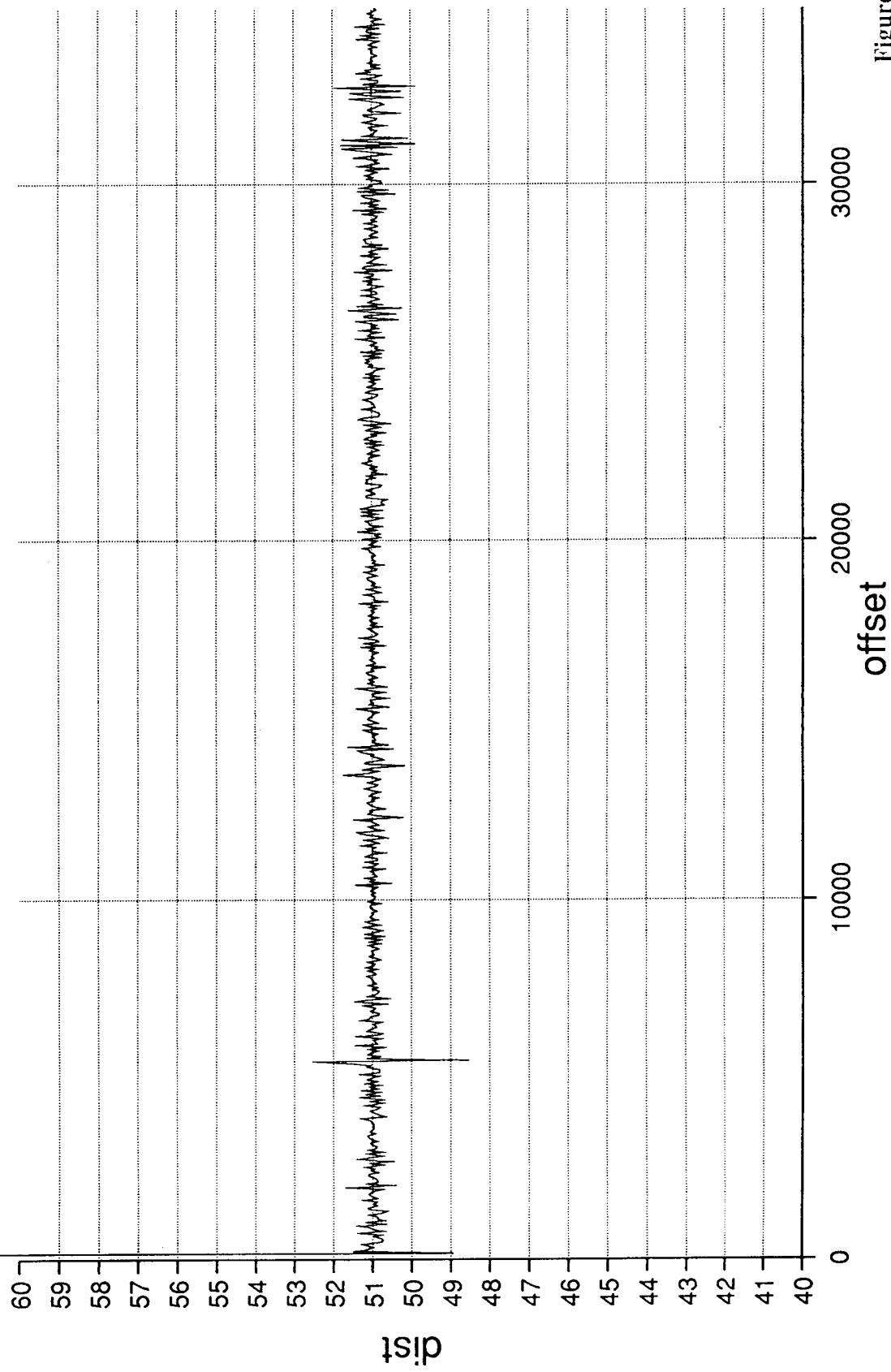


Figure 10

line 211 sp error

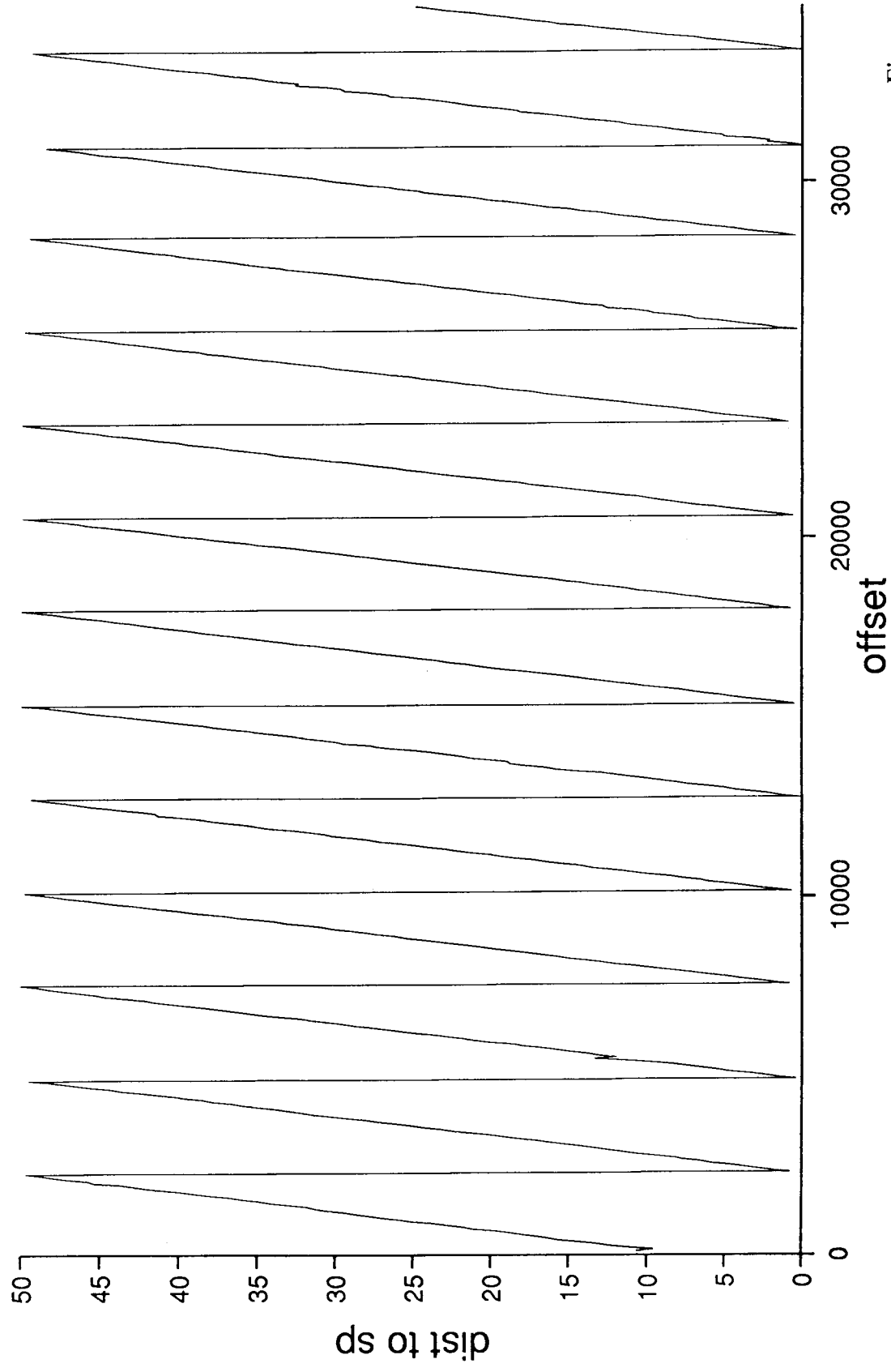


Figure 11

lines 215 sp dist

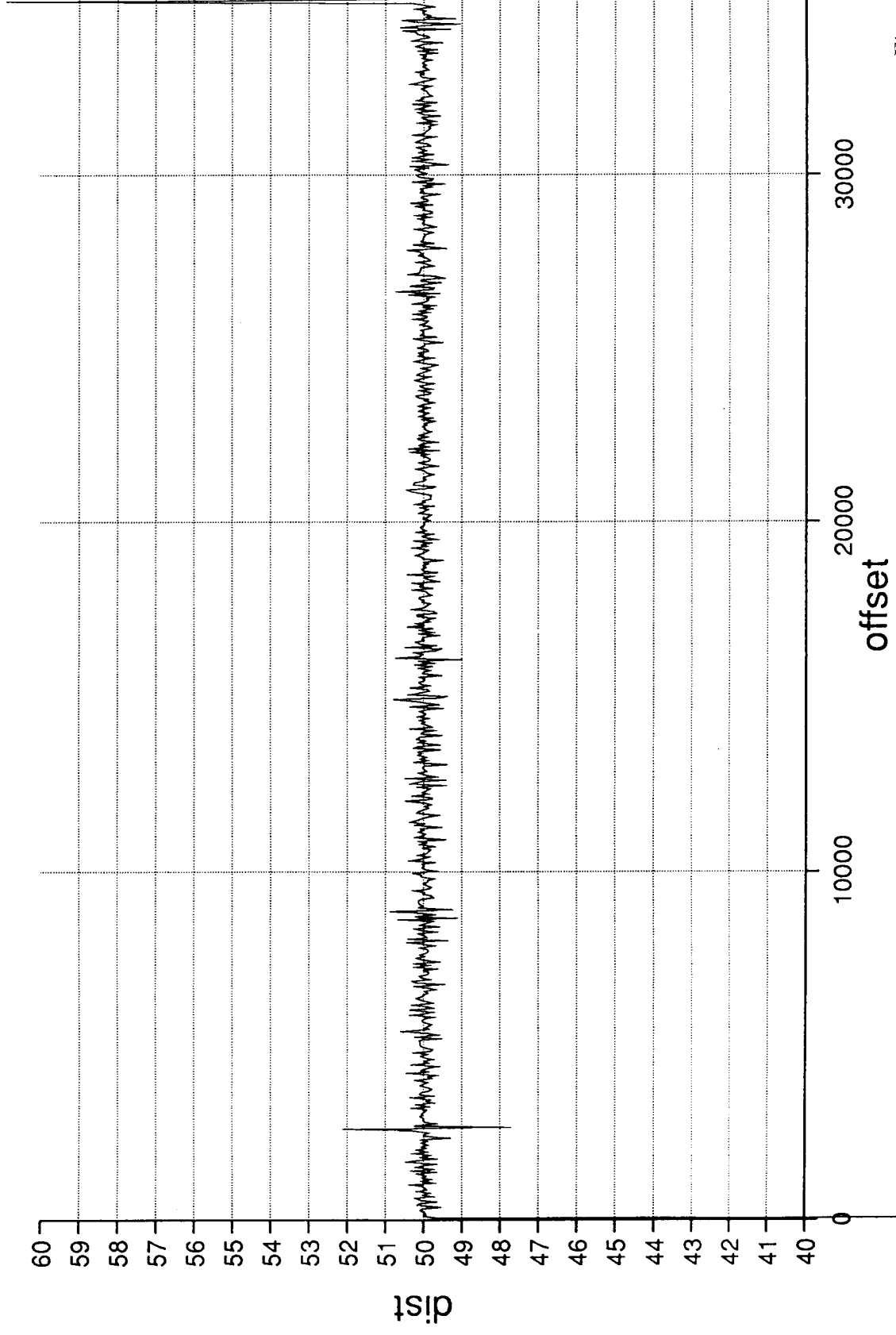


Figure 12

line 215 sp error

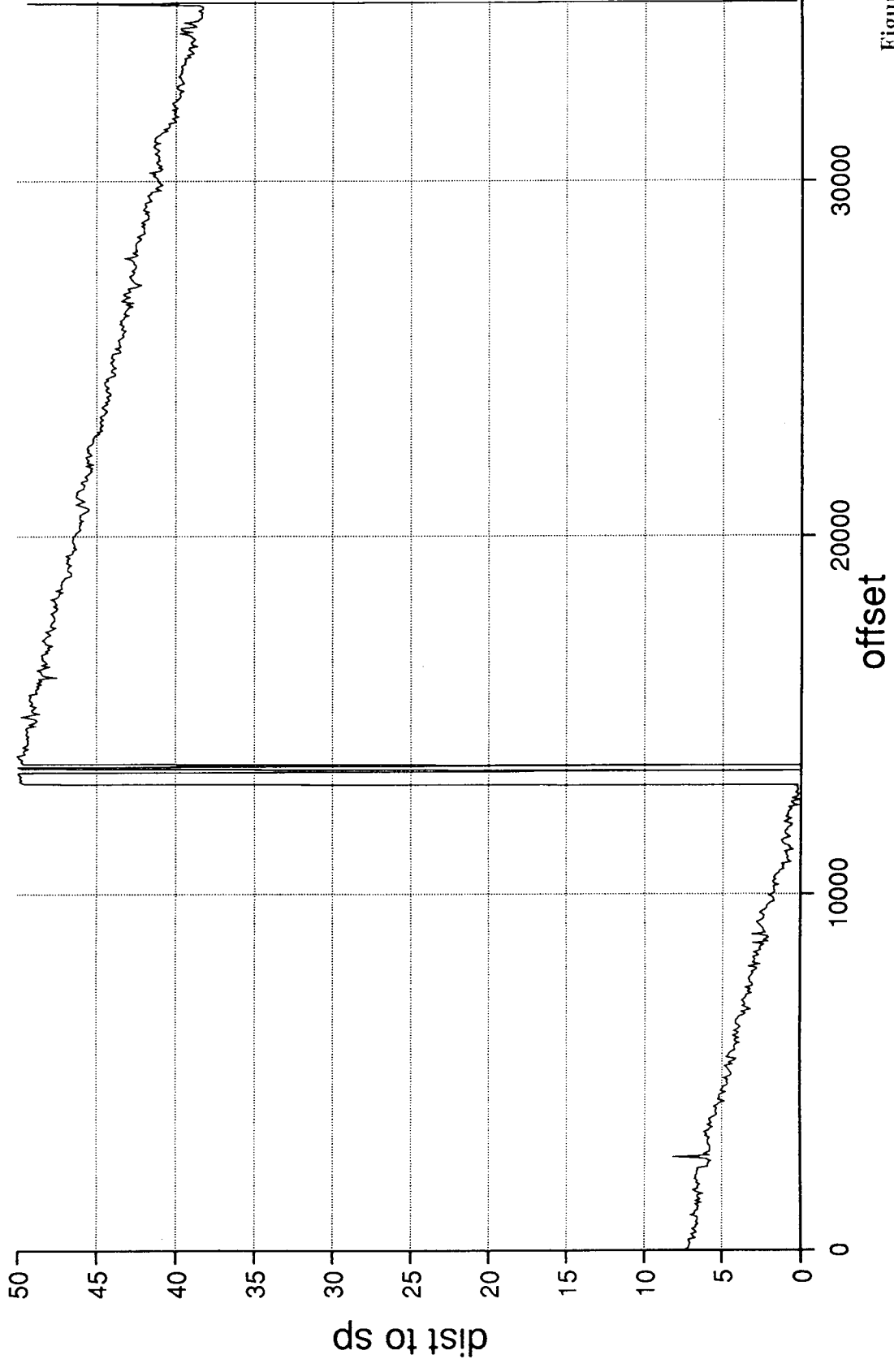


Figure 13

line 301 sp dist

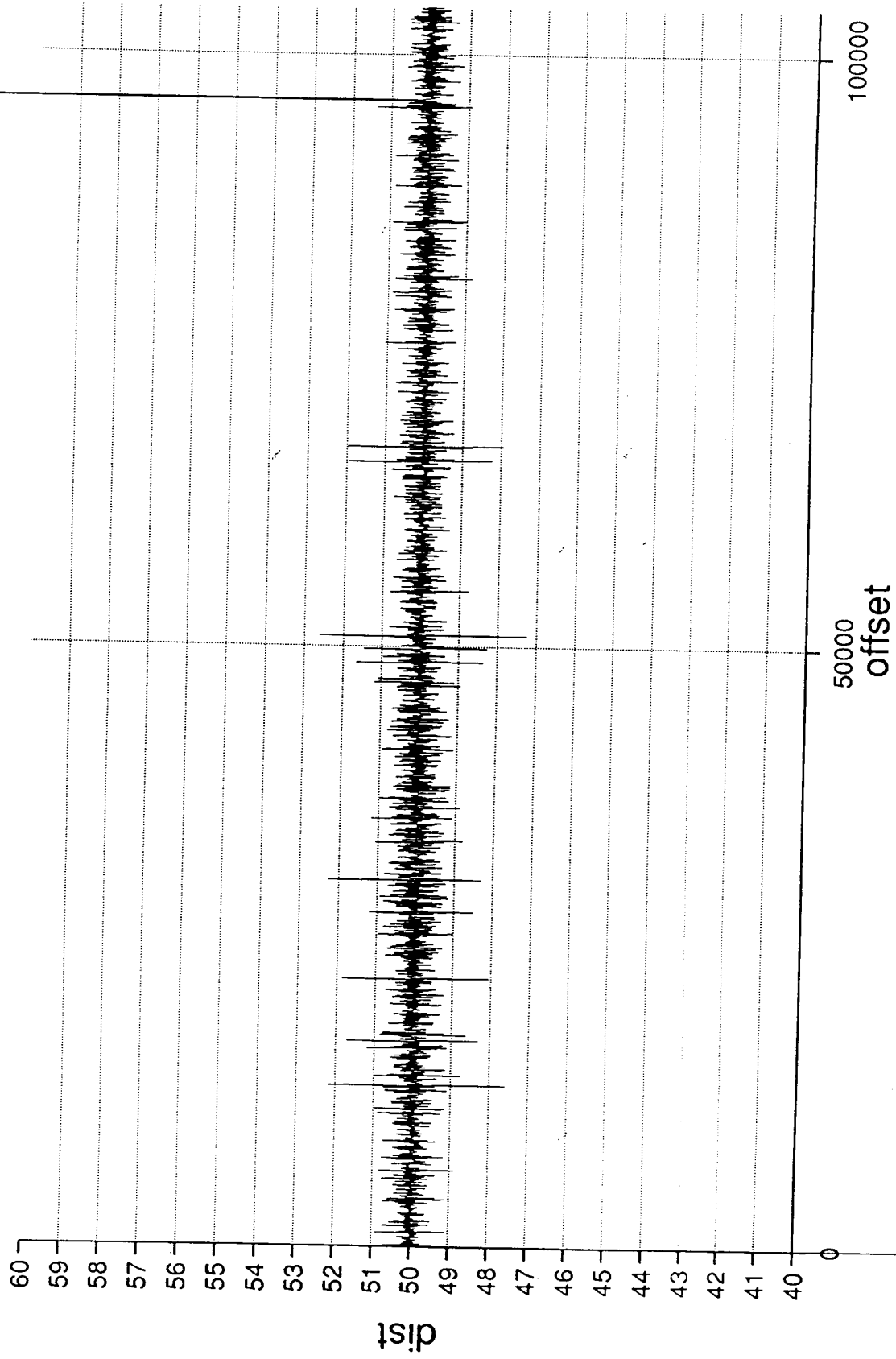


Figure 14

line 301 sp error

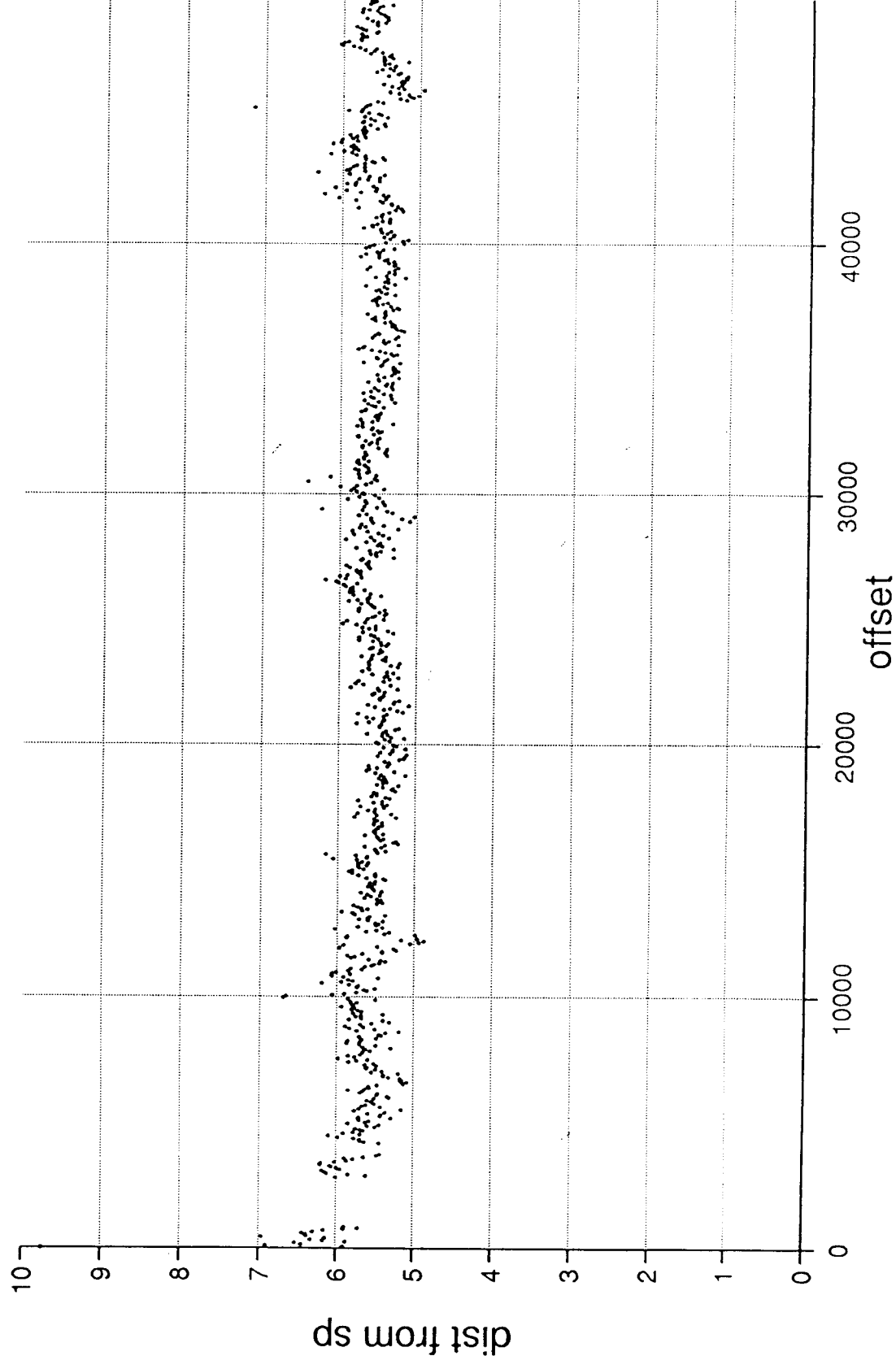


Figure 15

line 303 sp dist

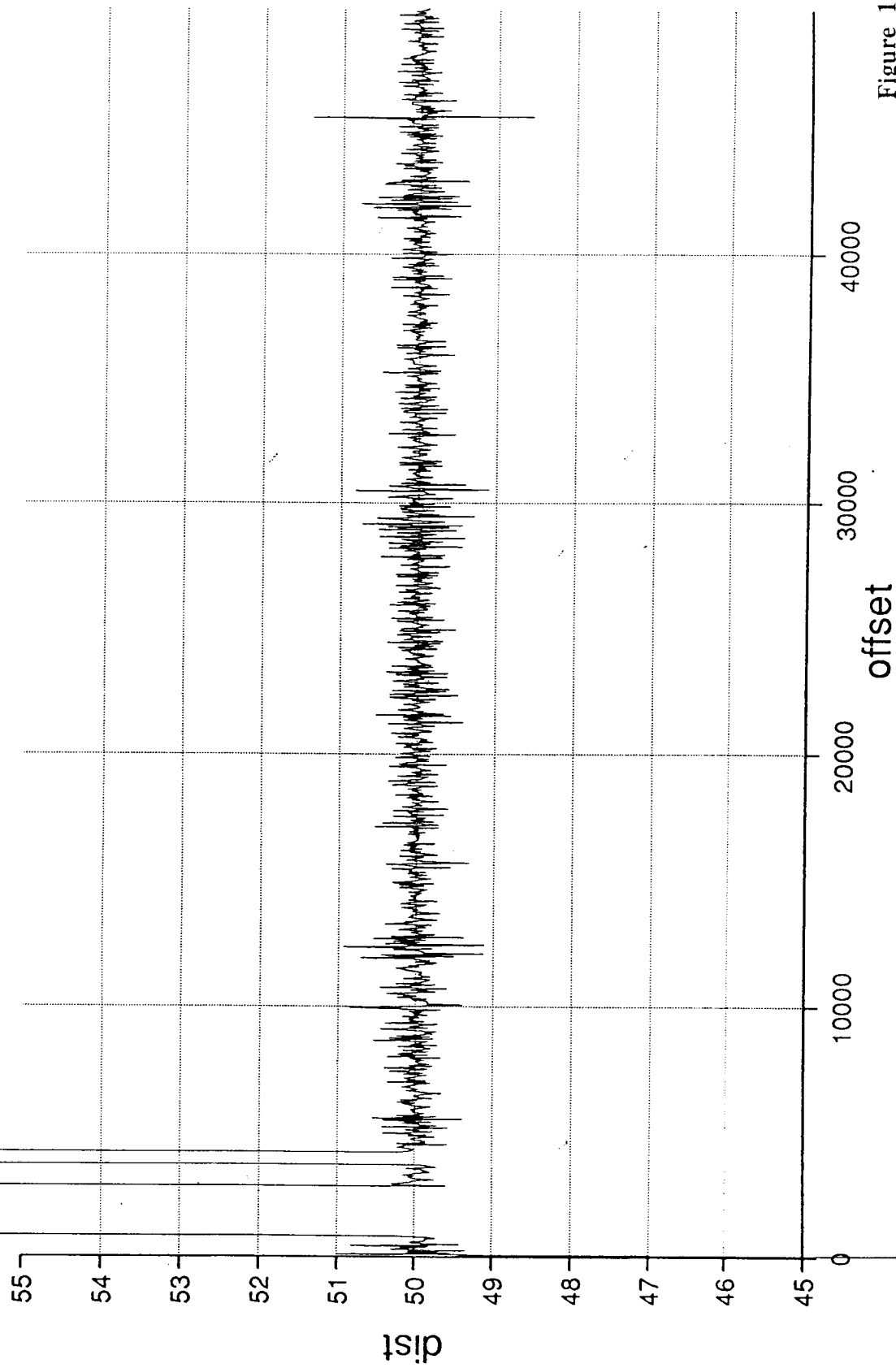


Figure 16

line 301 sp error

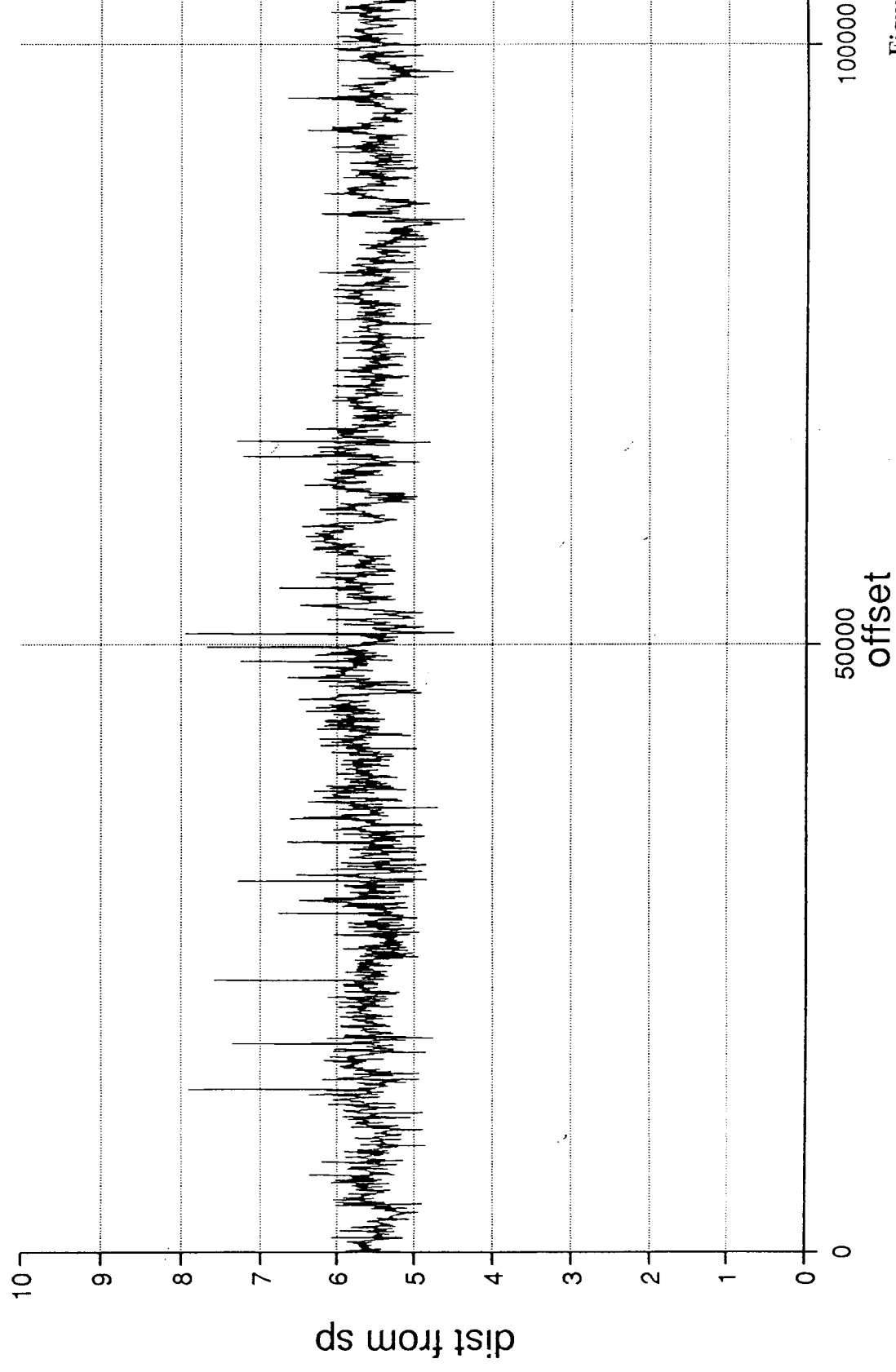


Figure 17

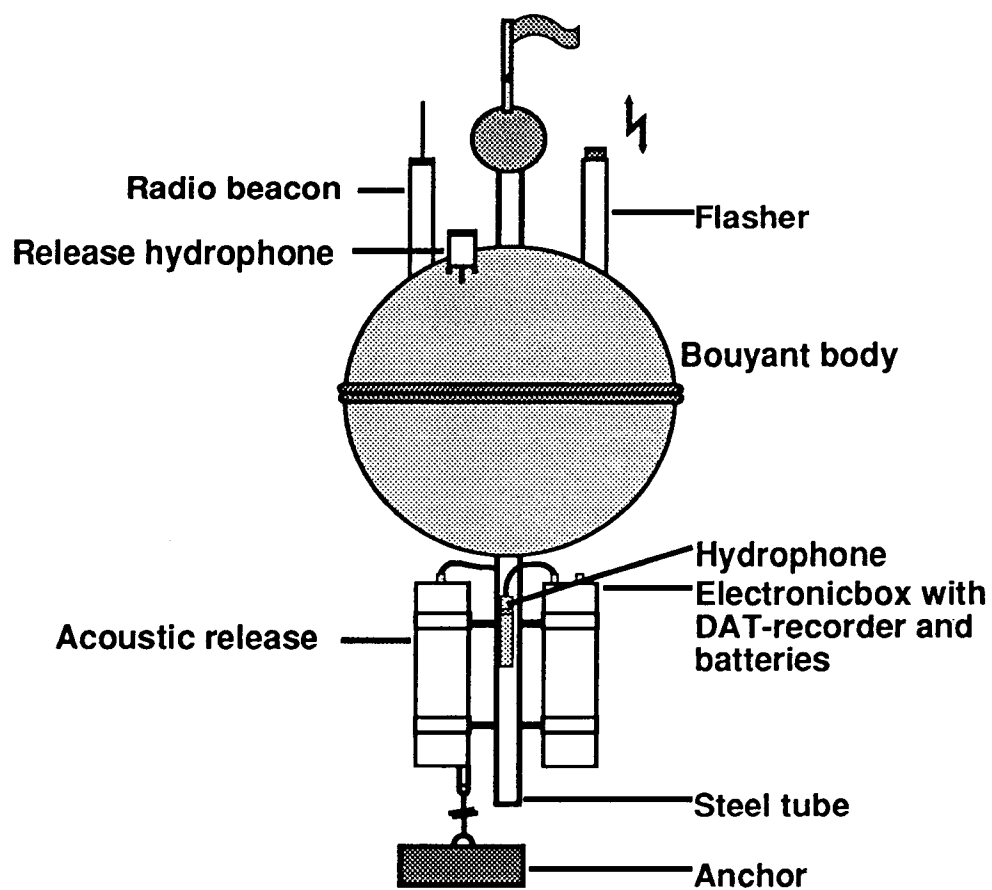


Fig.18: Composition of the GEOMAR OBH - System

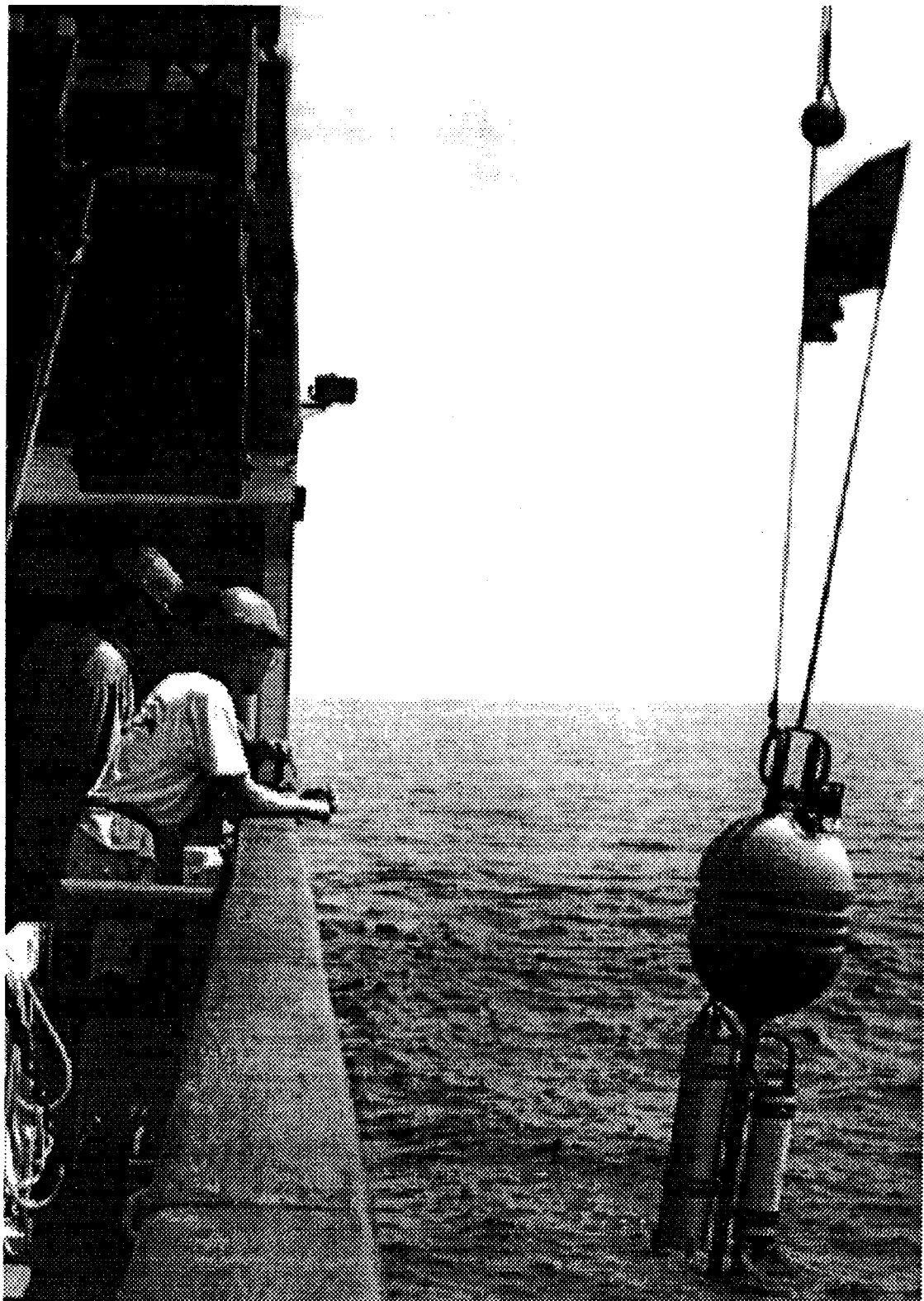


Figure 19: GEOMAR OBH during recovery at sea

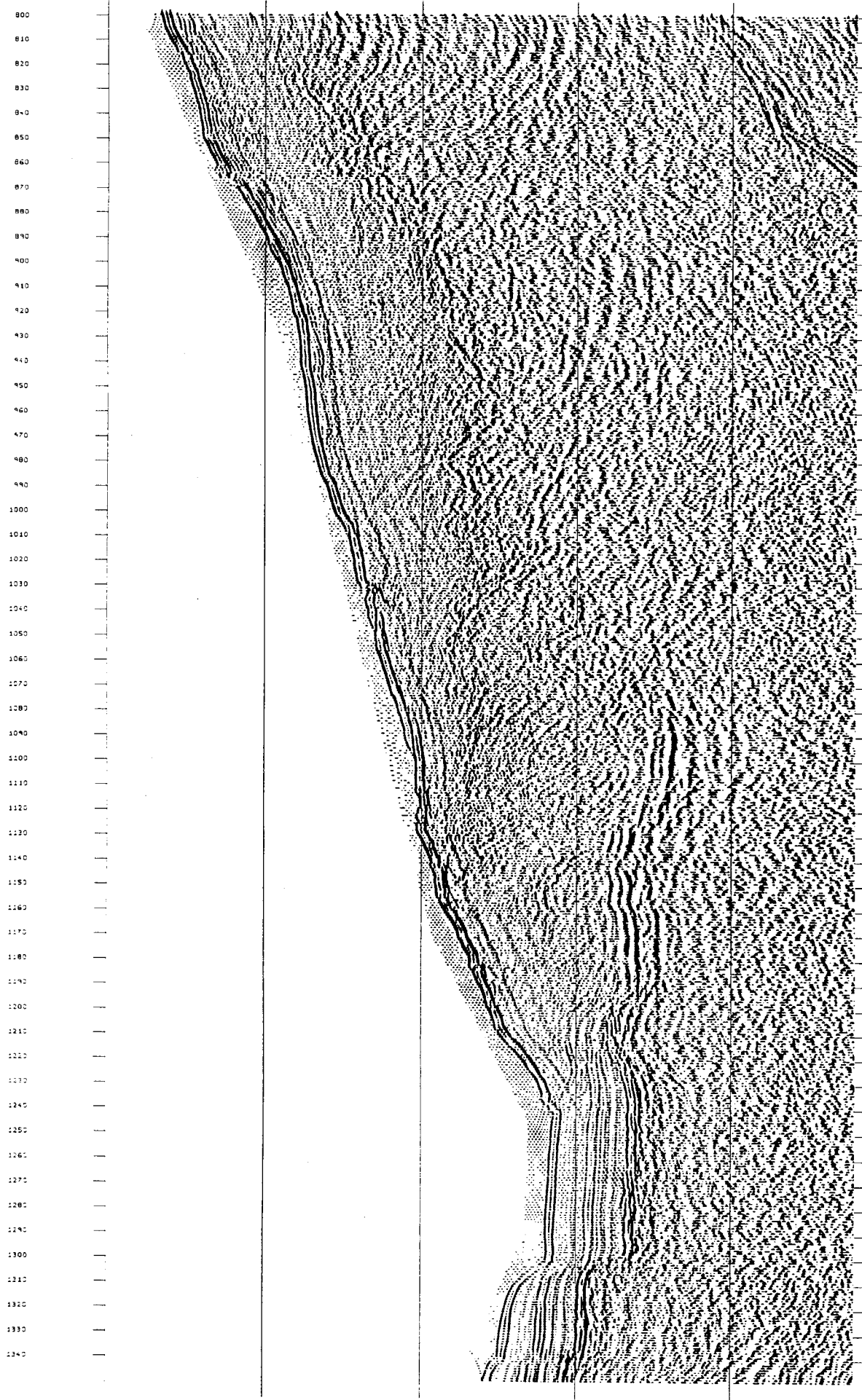


Figure 20

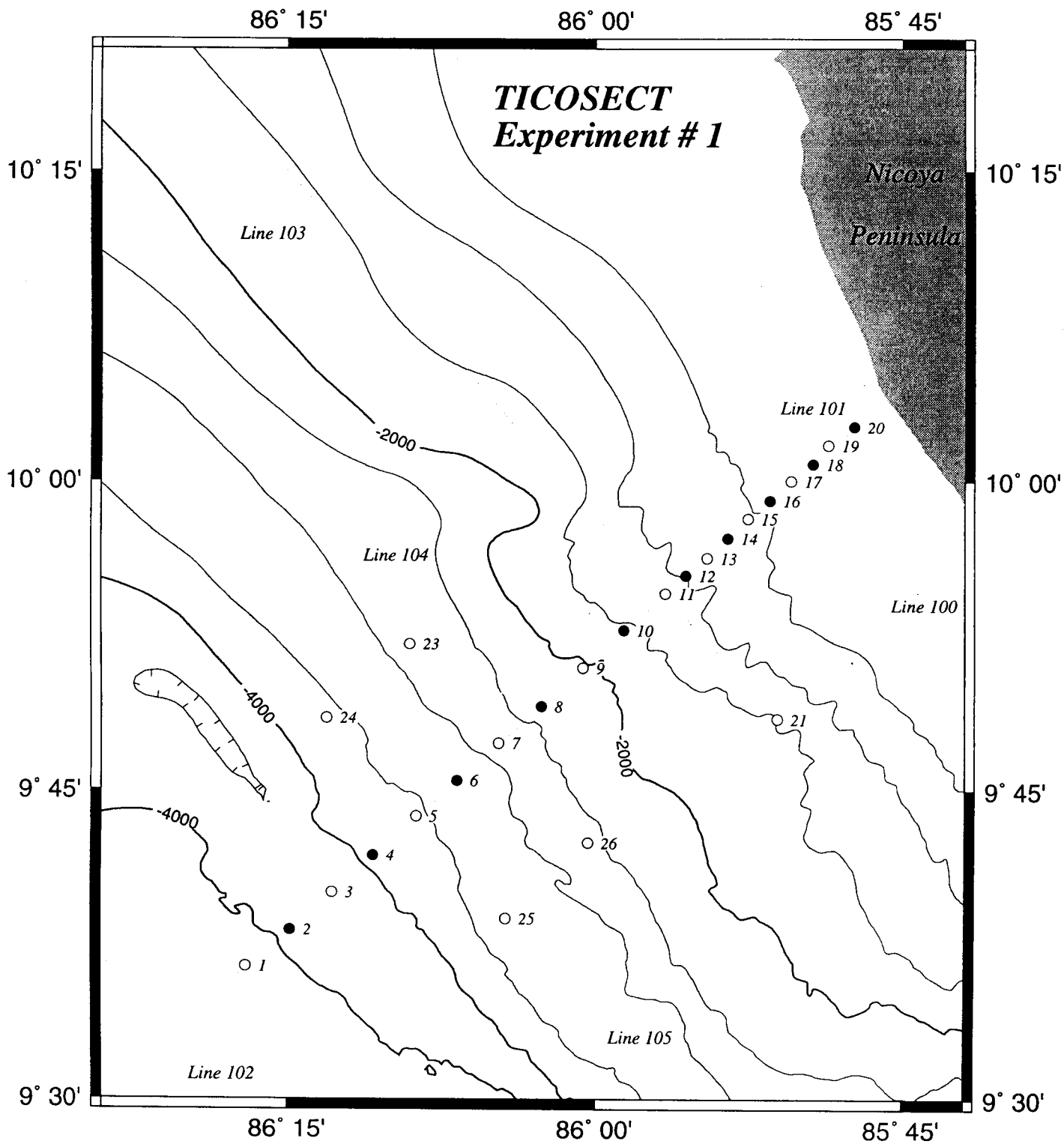
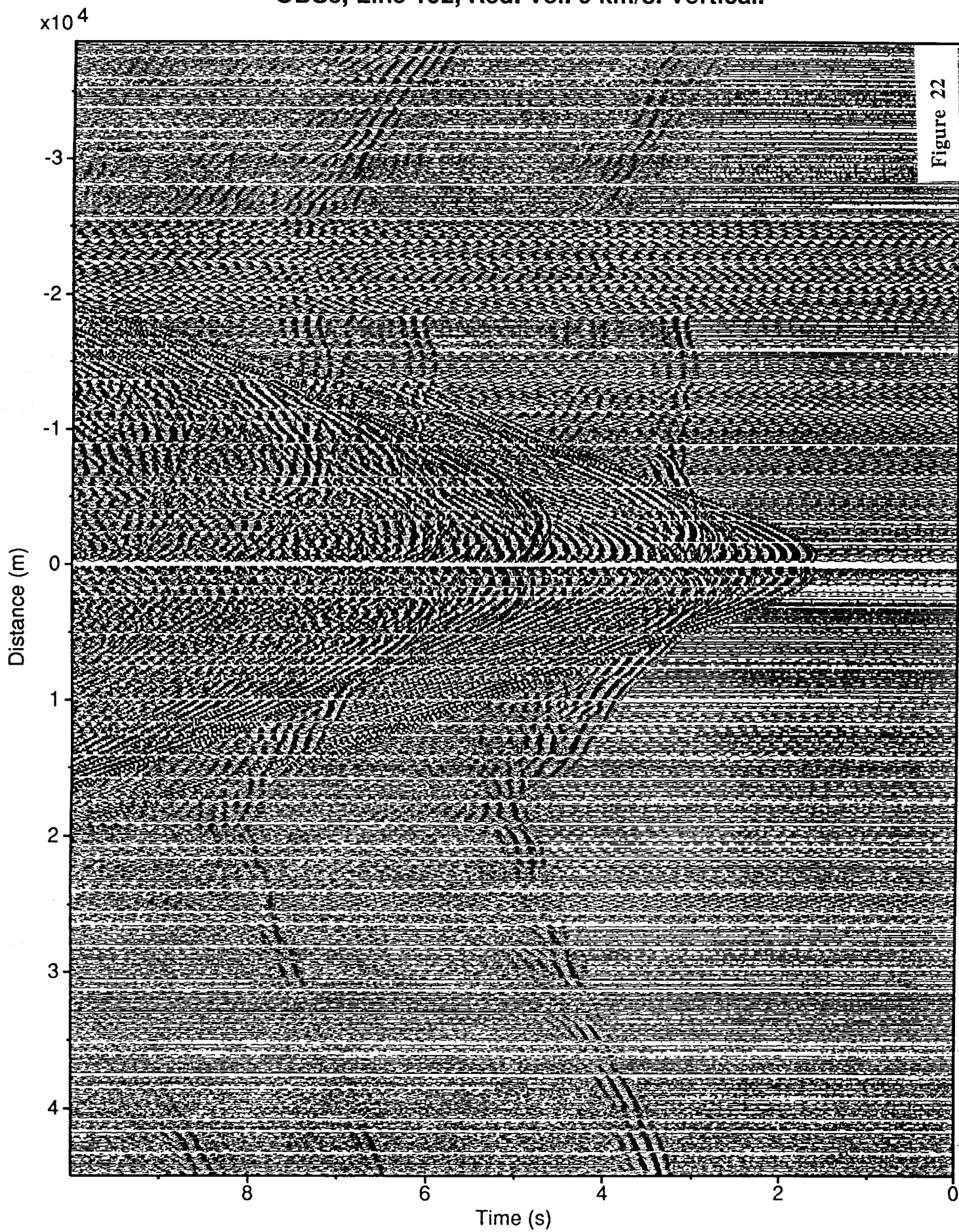


Figure 21

OBS8, Line 102, Red. Vel. 6 km/s. Vertical.



OBS14, Line 102, Trenchward. Red. Vel. 6 km/s. Vertical.

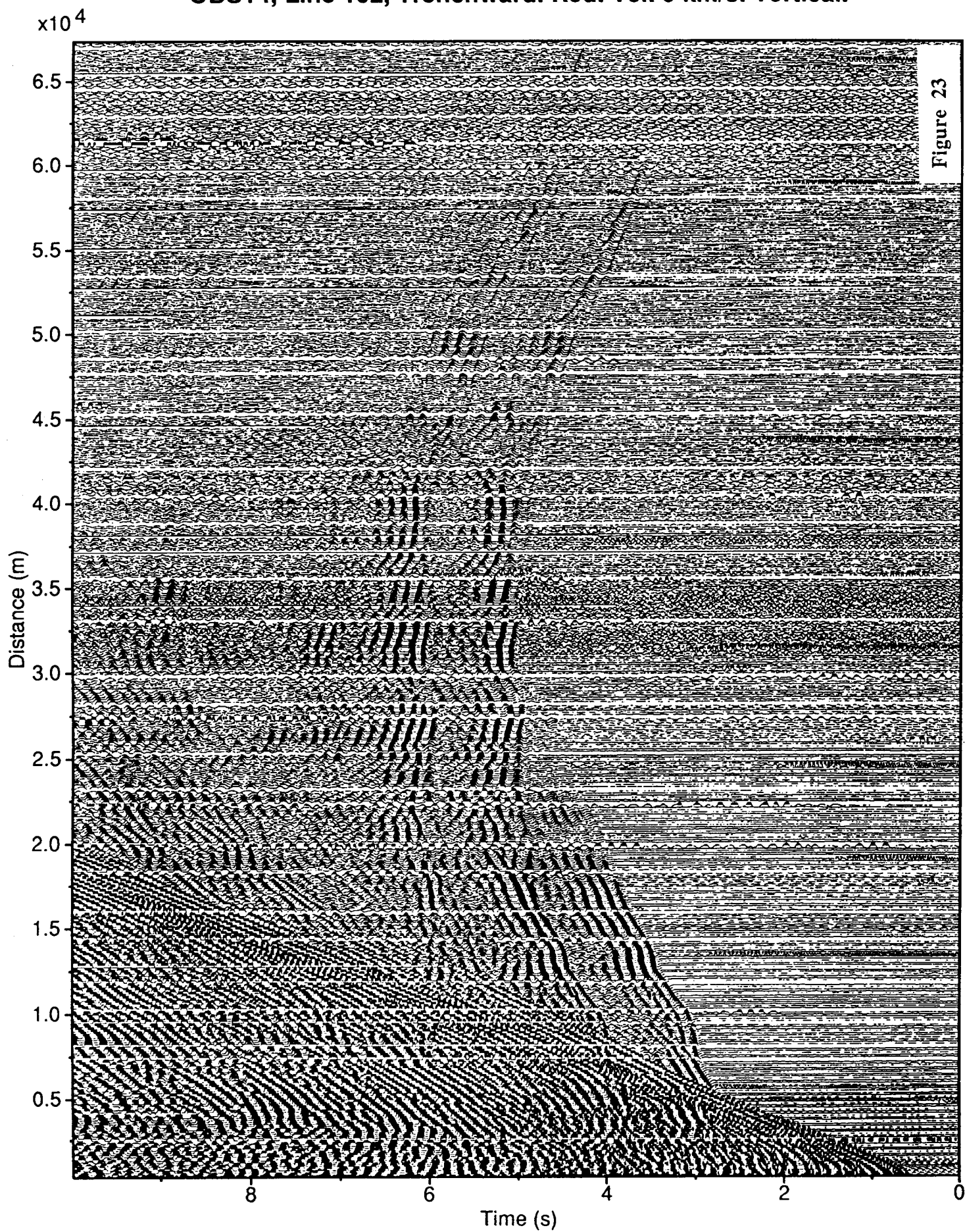
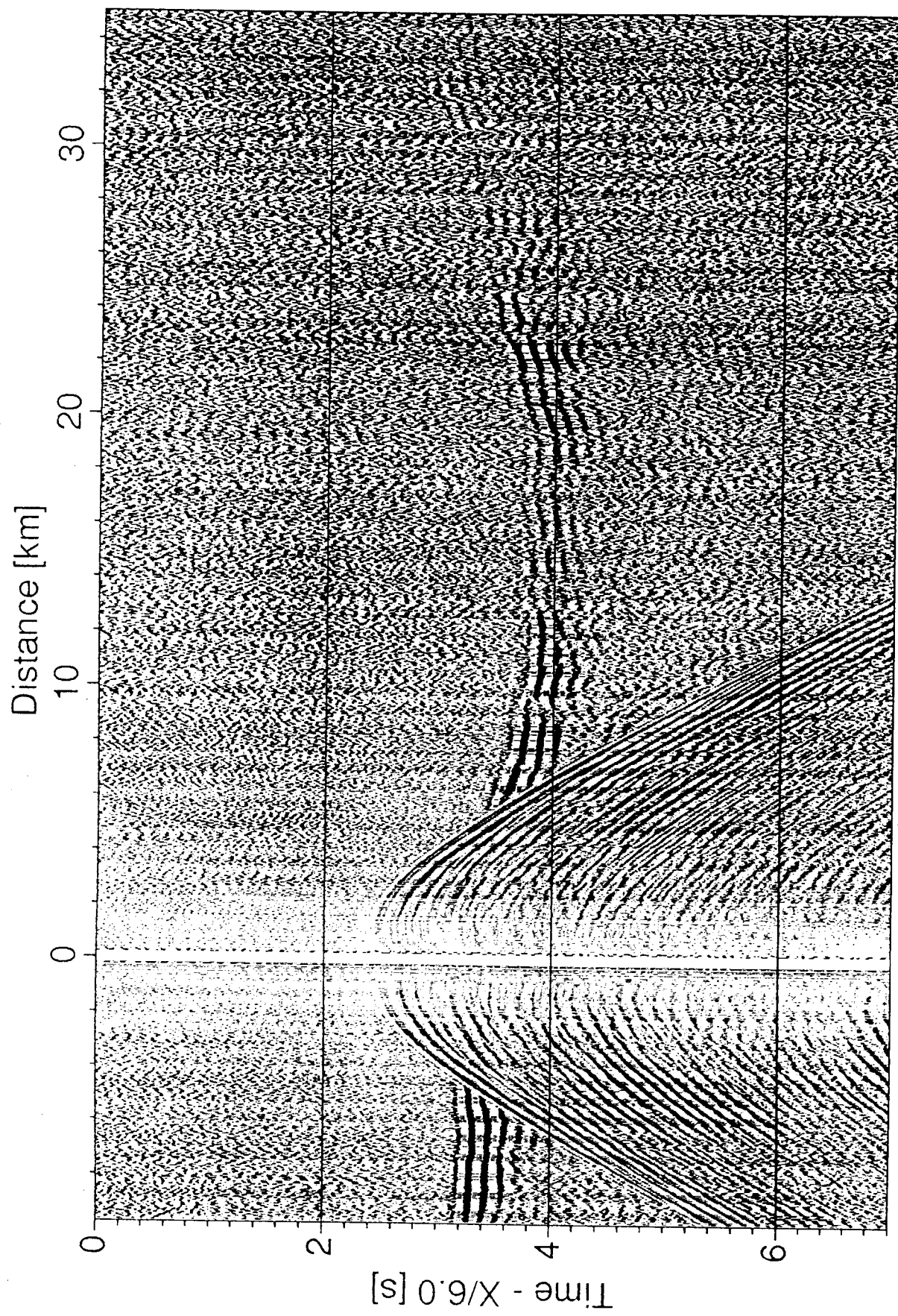


Figure 24 a. TICOSECT Experiment 1, GEOMAR OBH 1, LINE 101

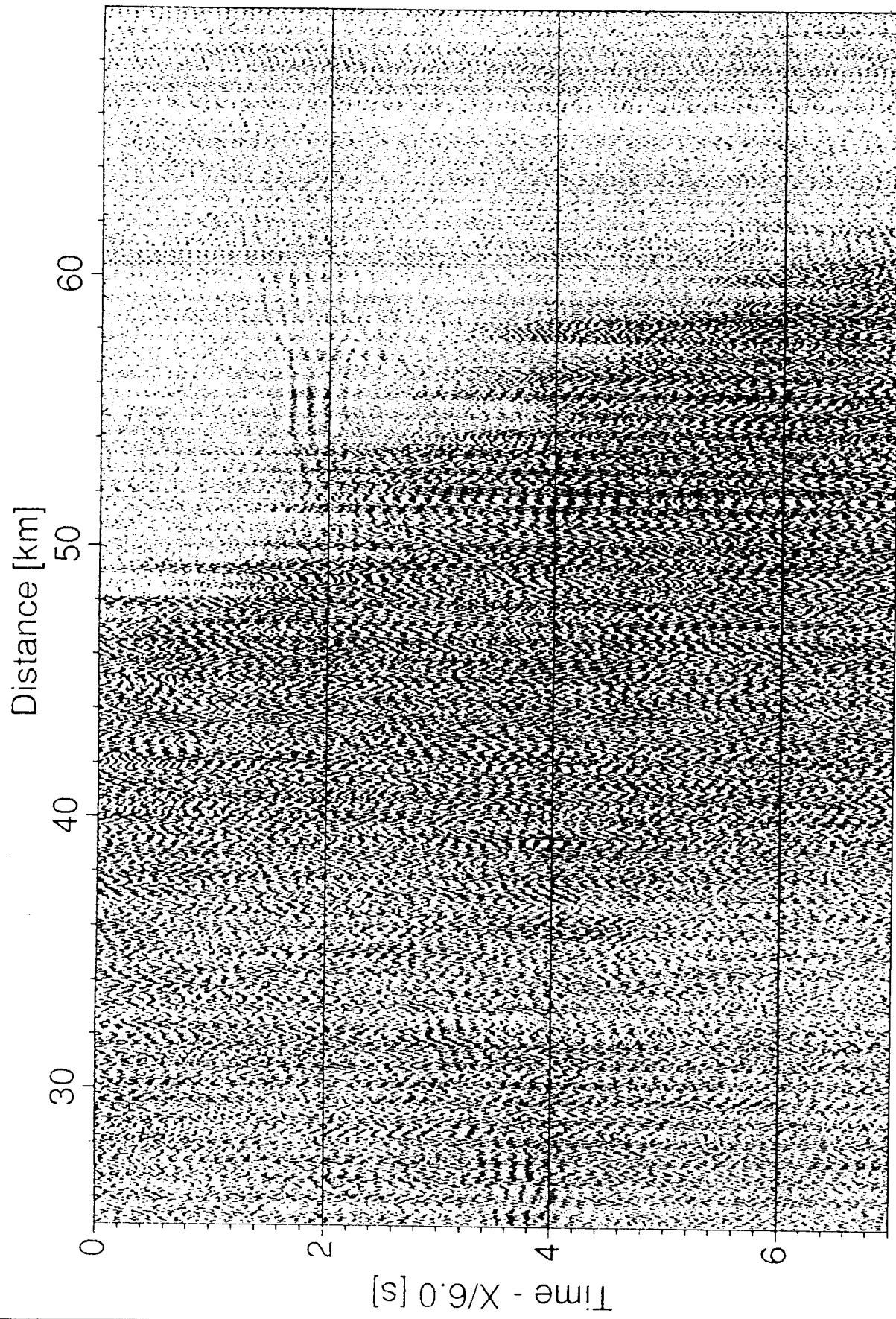


SW

OBH: 01 Line: 101 - 5 / 16 Hz

NE

Figure 24 b. TICOSECT Experiment 1, GEOMAR OBH 1, LINE 101



SW

OBH: 01 Line: 101 - 5 / 16 Hz

NE

Figure 25 a. TICOSECT Experiment 1, GEOMAR OBH 1, LINE 102

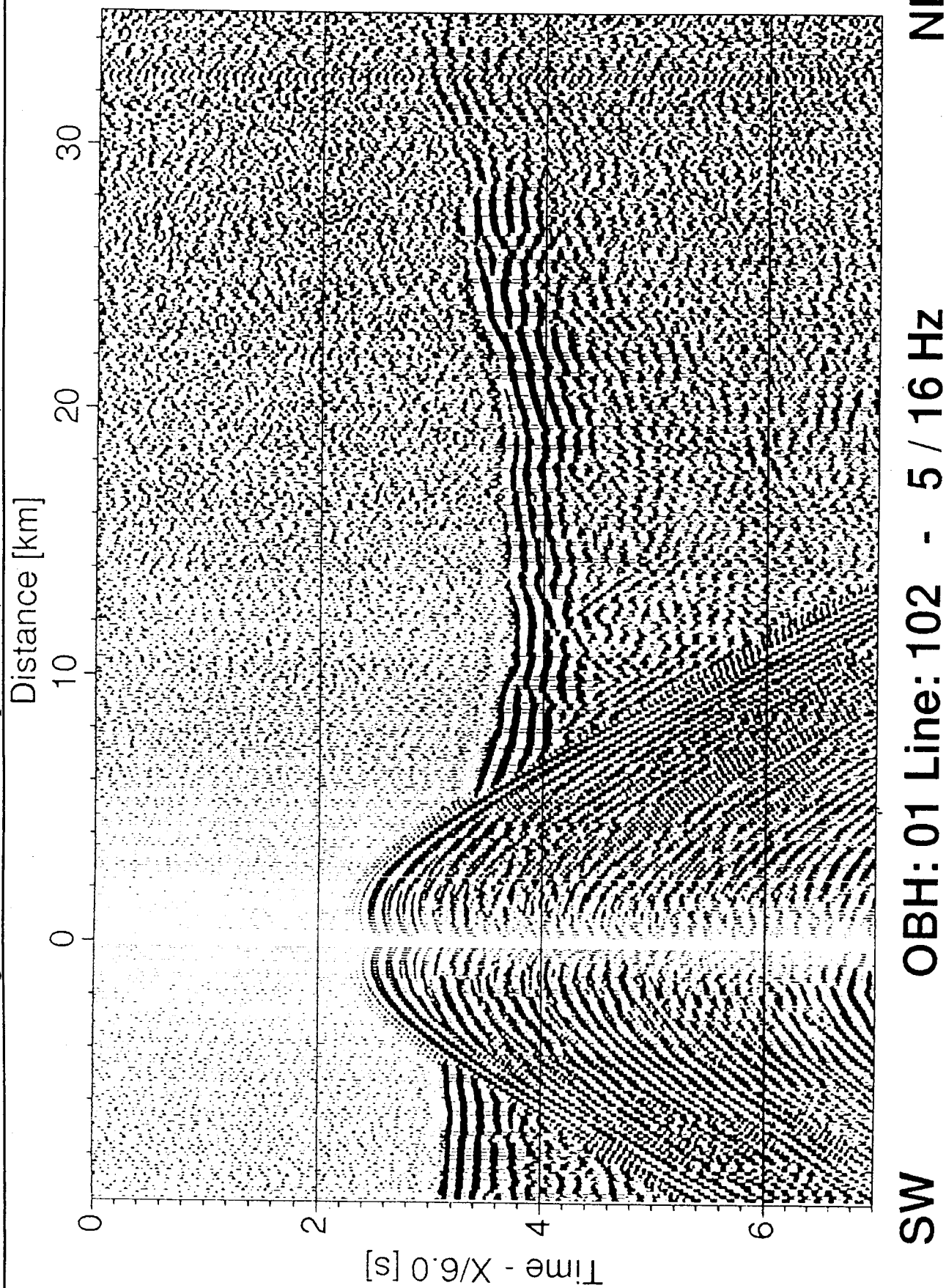
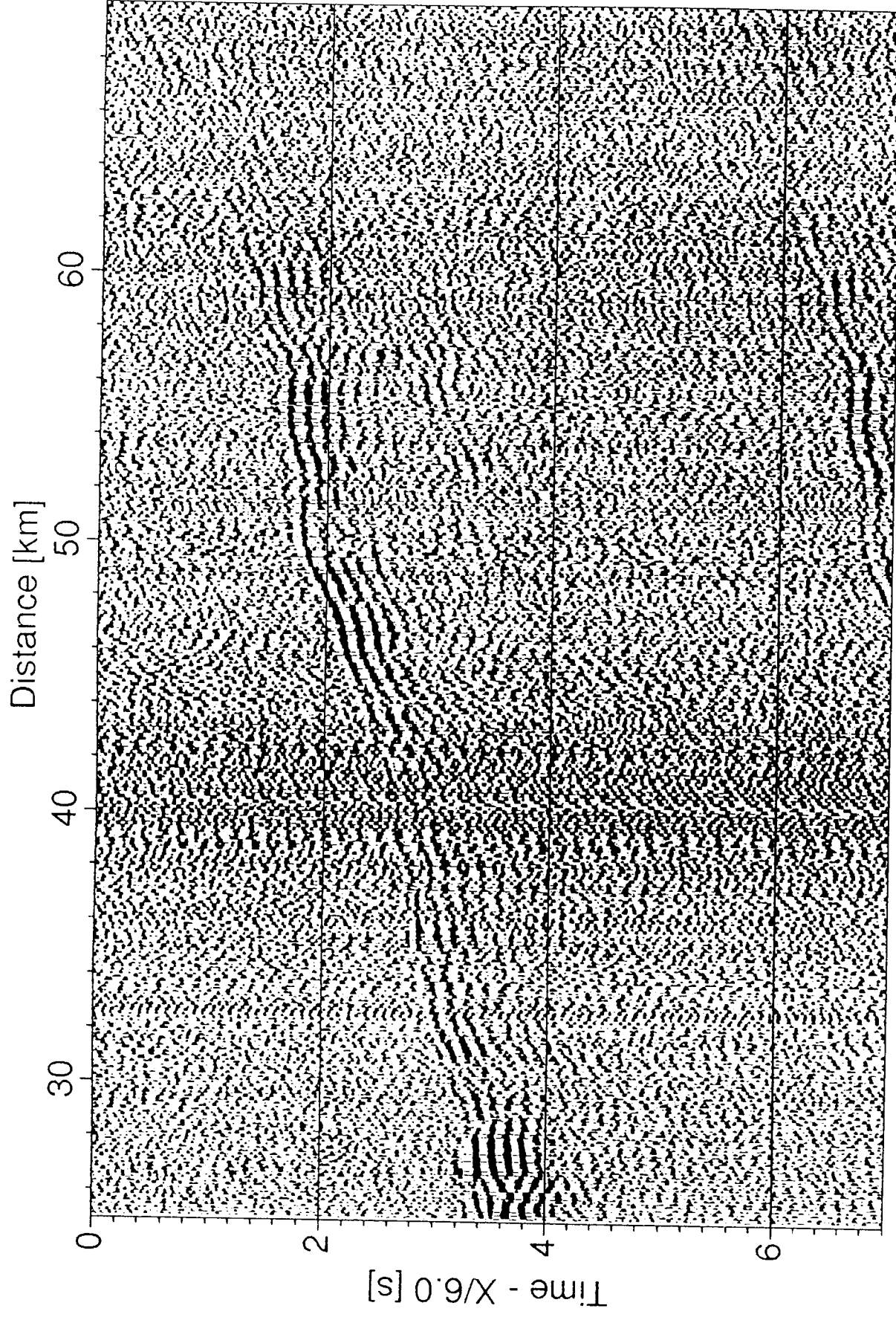


Figure 25 b. TICOSECT Experiment 1, GEOMAR OBH 1, LINE 102

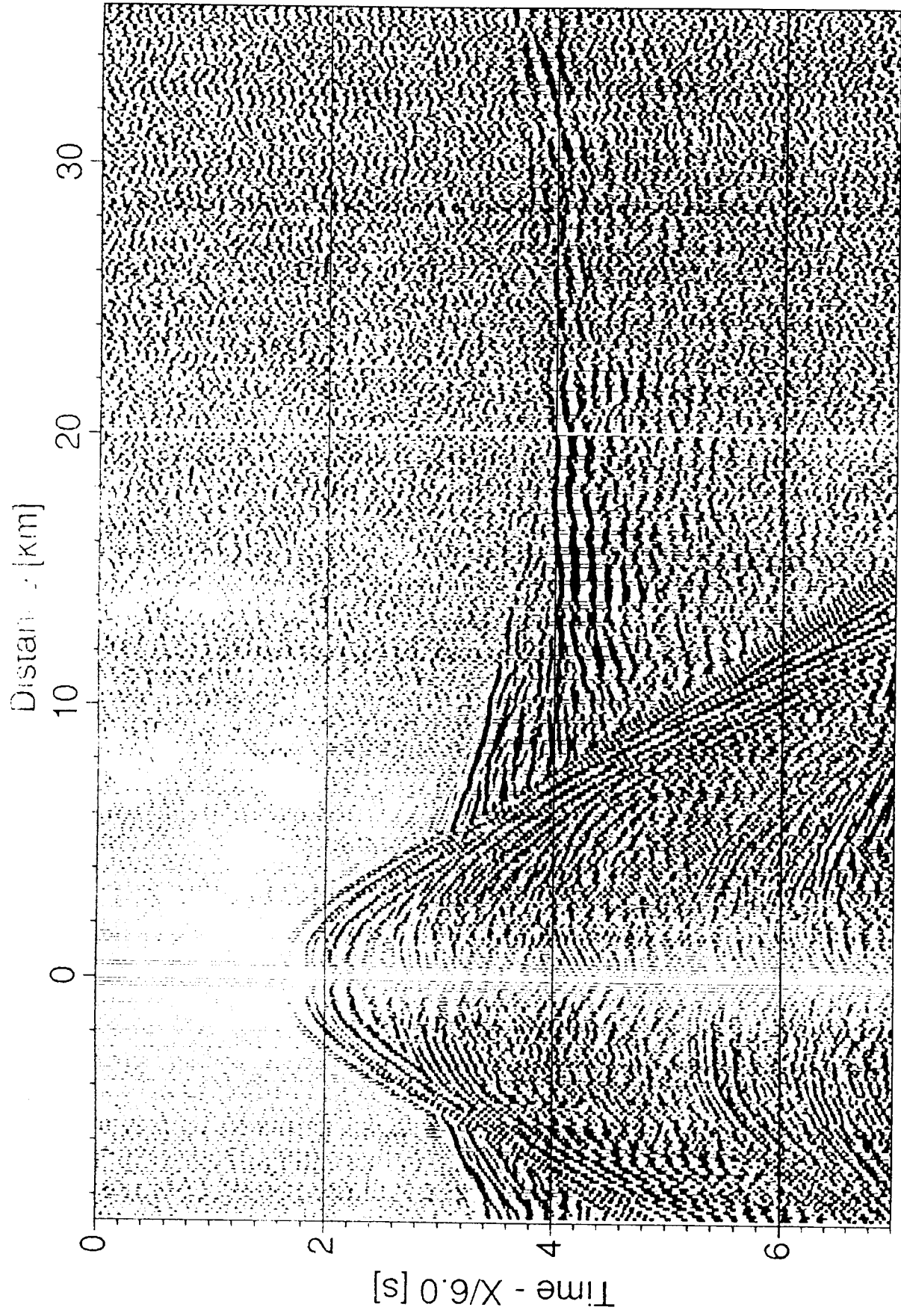


SW

OBH: 01 Line: 102 - 5 / 16 Hz

NE

Figure 26 TICOSECT Experiment 1, GEOMAR OBH 23, LINE 104



NW

OBH: 23 Line: 104 - 5 / 15 Hz

SE

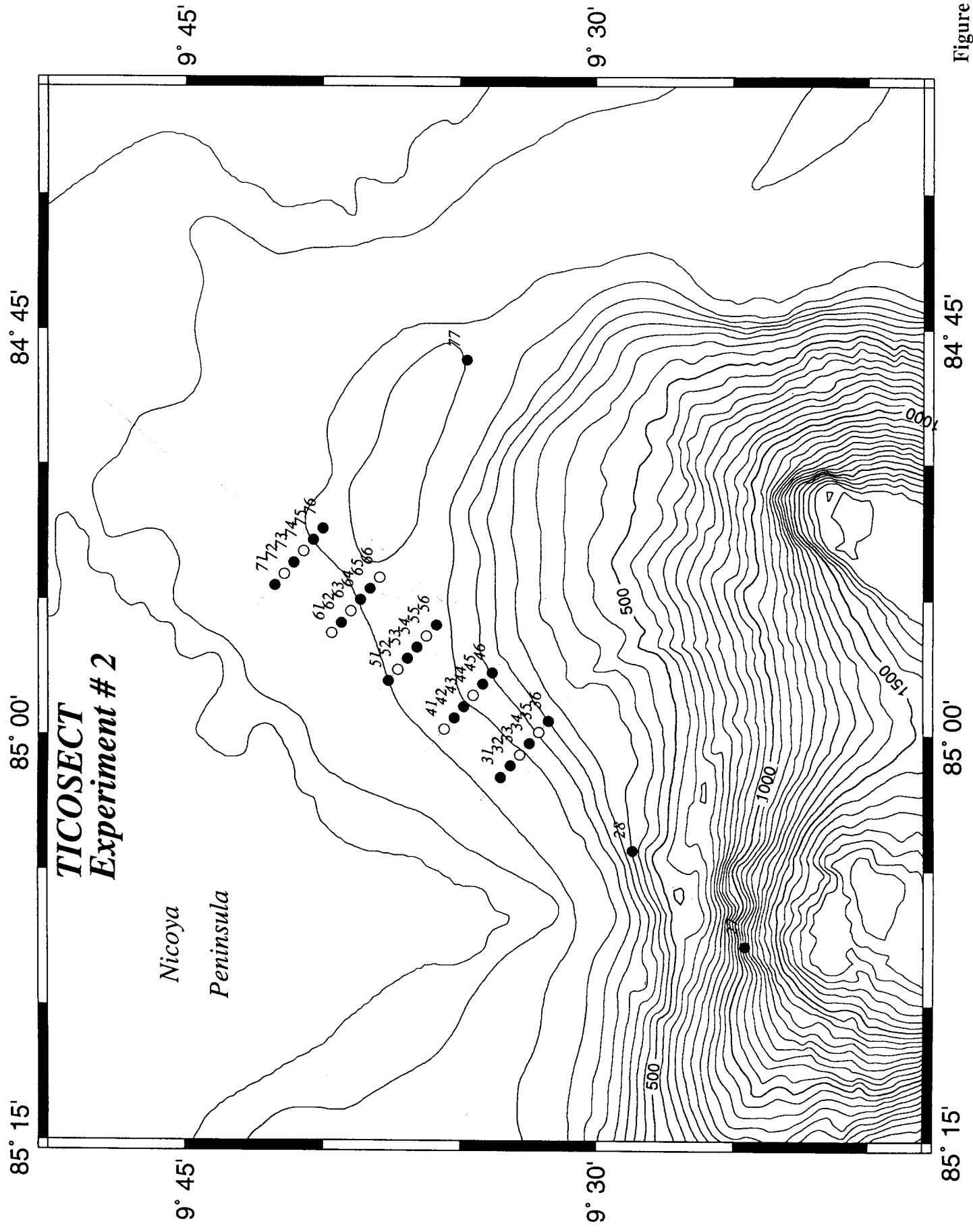


Figure 27

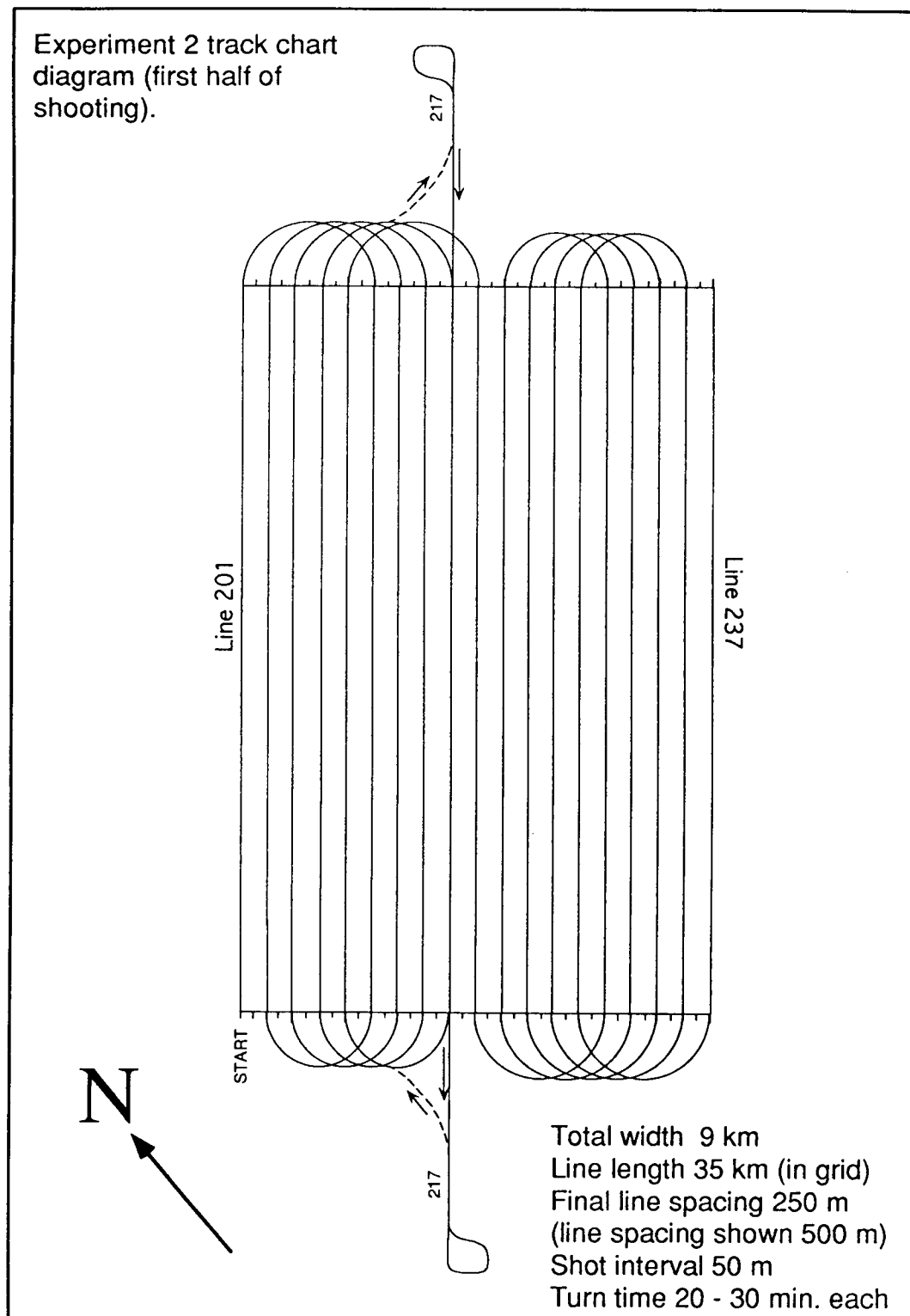
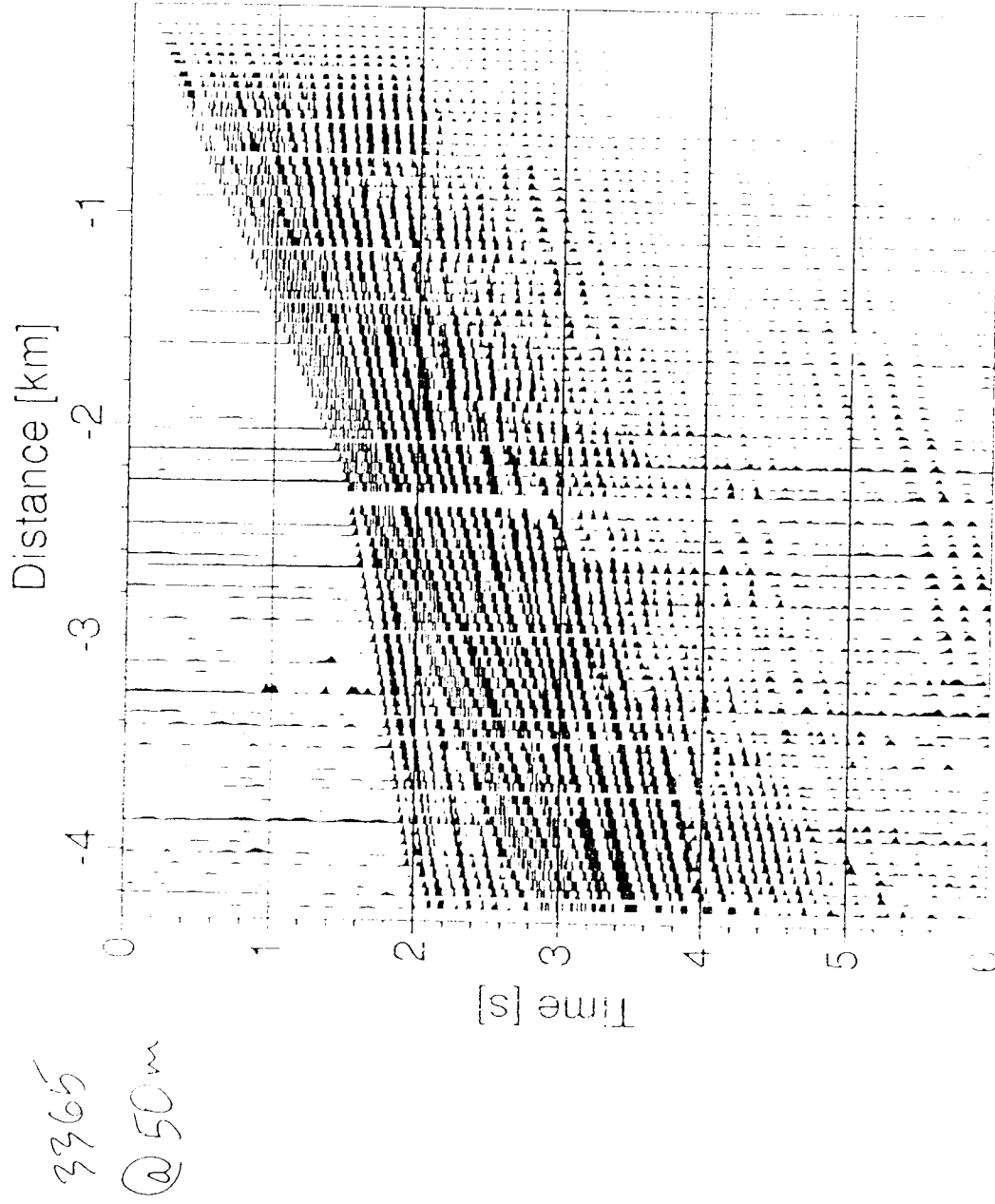


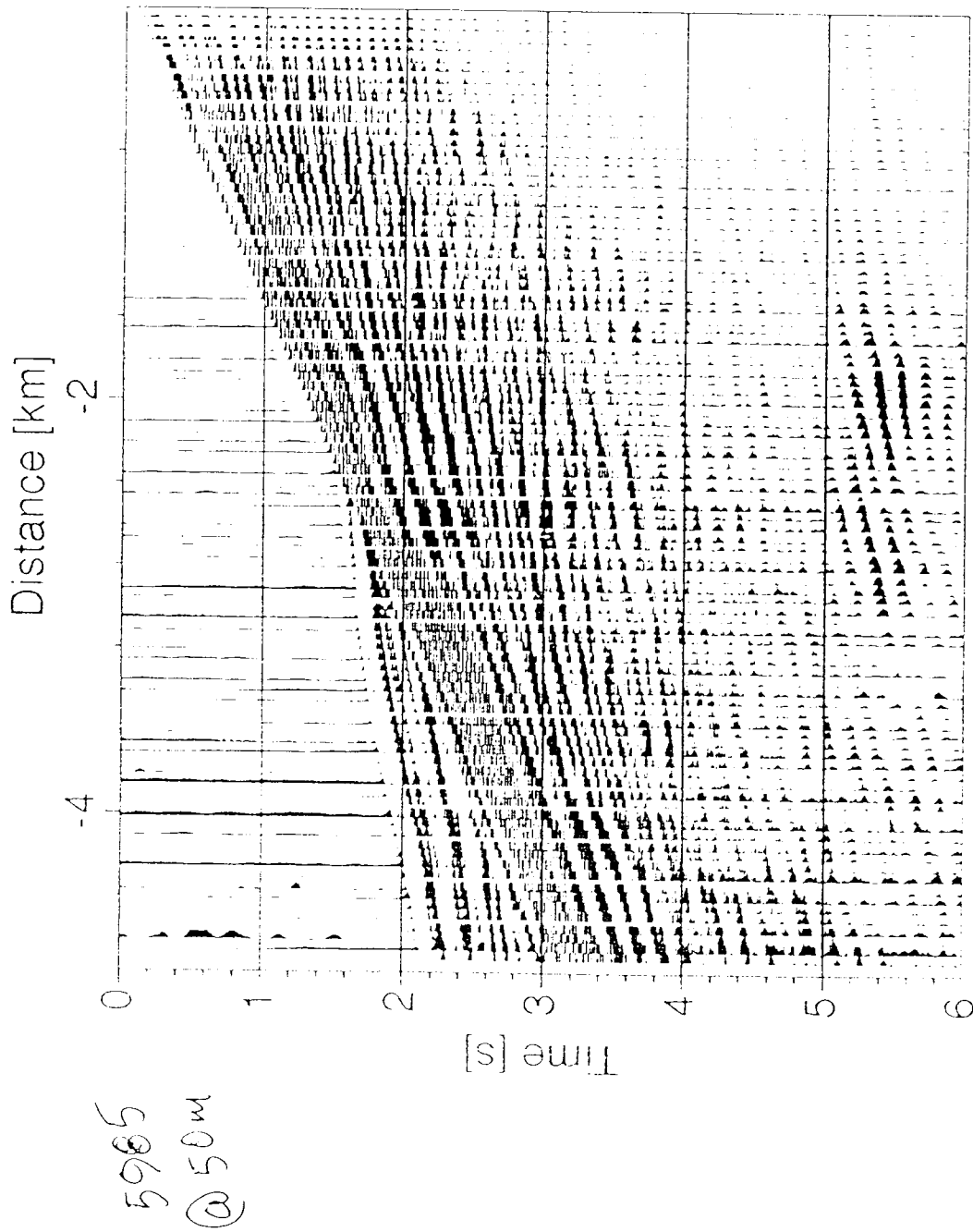
Figure 28. Shiptrack diagram for first half of 3D shooting during Experiment 2. The turn diameter alternated between 2.0 and 2.5 km to advance across the grid at 500 m line spacing. The second half of shooting advanced from right to left in the same manner resulting in final line spacing of 250 m. Length is not to scale for grid lines or line 217.

Figure 29 a. Airgun array test records for TICOSECT Experiment 2



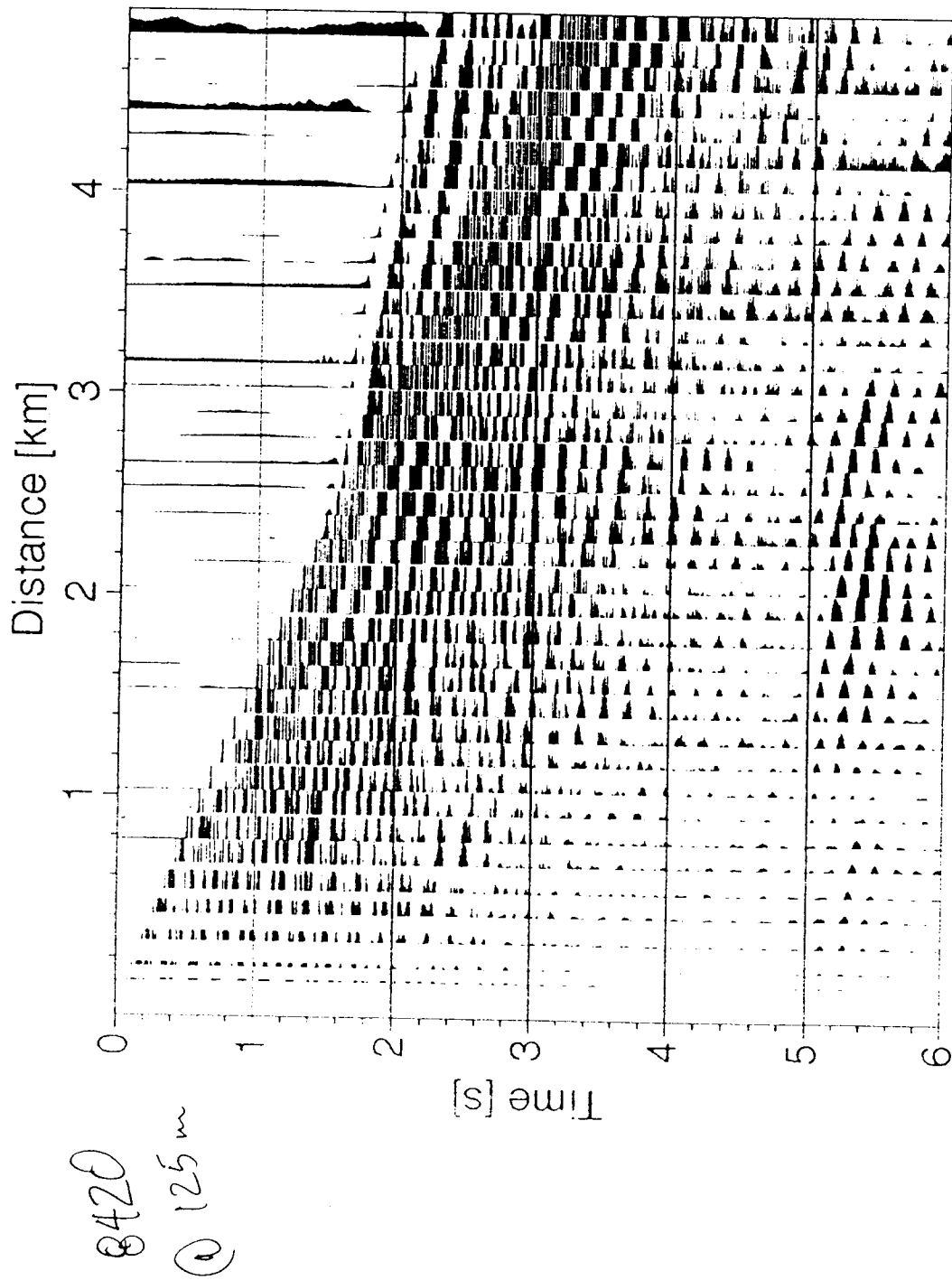
St:900k1 P:903 Filt:2,4-18,25 Hz rpow: 1.0 Sc:80//1

Figure 29 b. Airgun array test records for TICOSECT Experiment 2



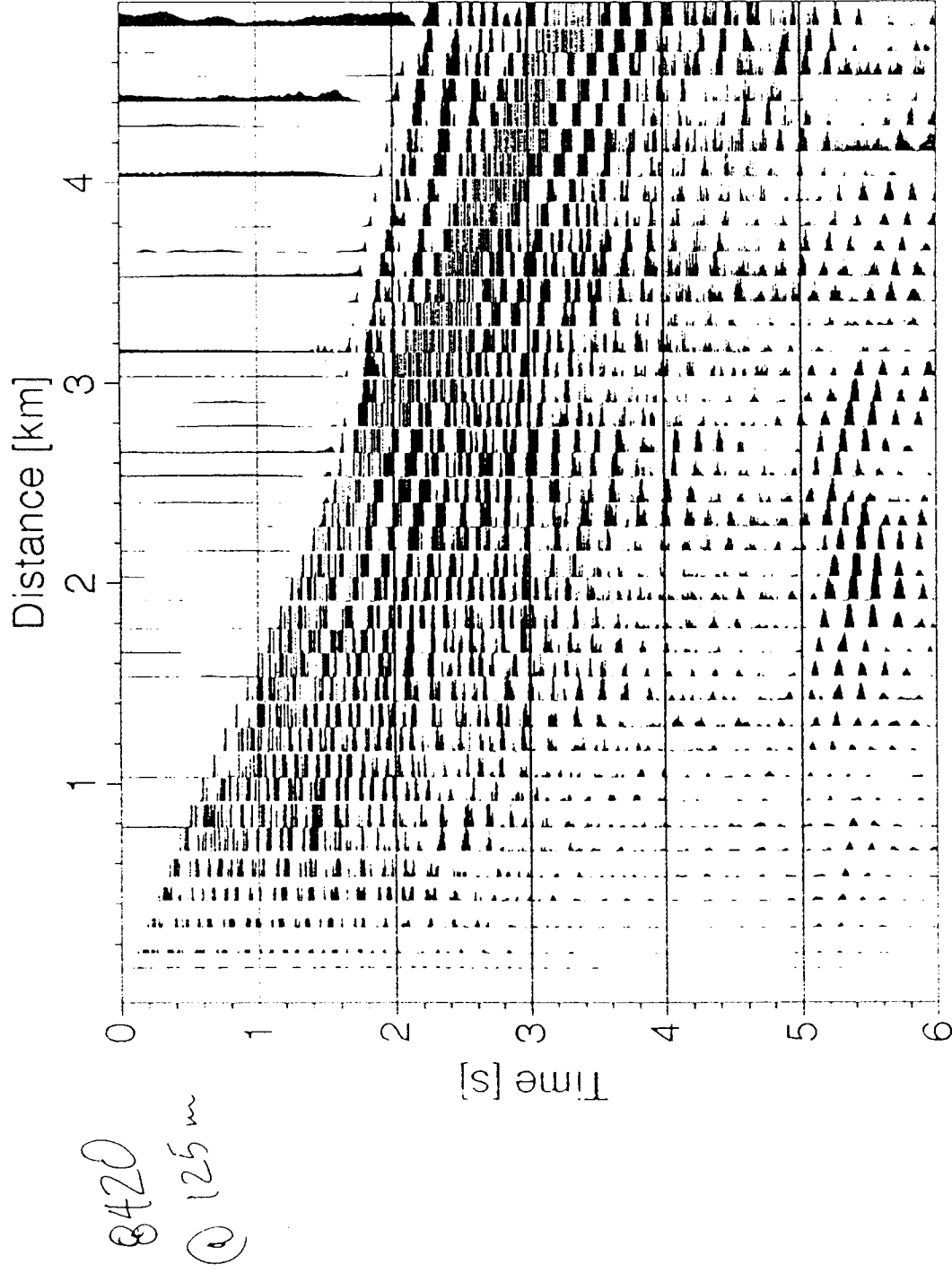
St:900k1 P:901 Filt:2,4-18,25 Hz rpow: 1.0 Sc:80//1

Figure 29 d. Airgun array test records for TICOSECT Experiment 2



St:900k1 P:904 Filt:2,4-18,25 Hz rpow: 1.0 Sc:80//1

Figure 29 e. Airgun array test records for TICOSECT Experiment 2



St:900k1 P:904 Filt:2,4-18,25 Hz rpow: 1.0 Sc:80//1

OBS 32, Line 213, Hydrophone, Red. Vel. 8 km/s.

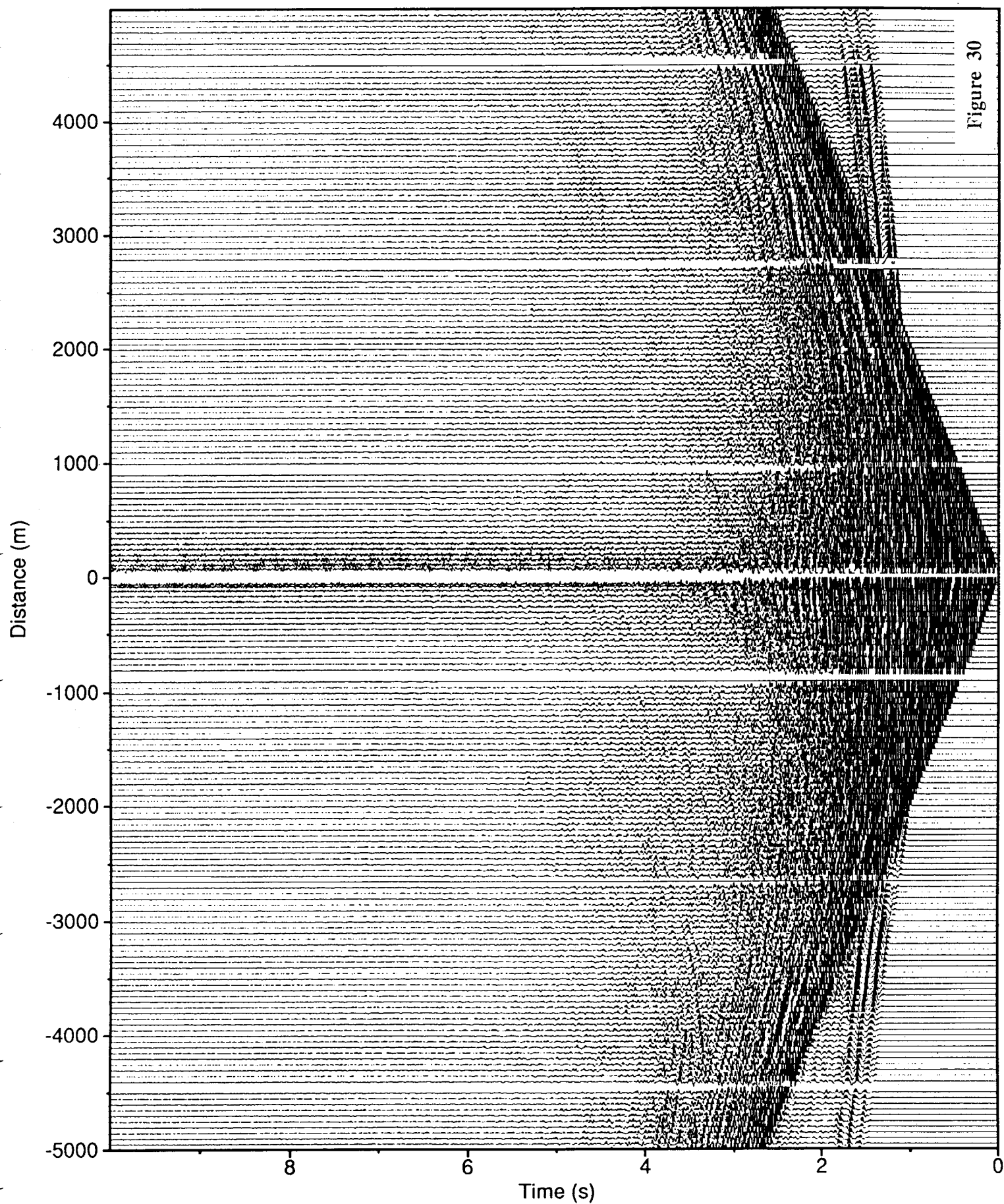


Figure 31

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95944.7
96044.7
96144.7
96244.7
96344.7
96444.7
96544.7
96644.7
96744.7
96844.7
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97344.7
97444.7
97544.7
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98144.7
98244.7
98344.7
98444.7
98544.7
98644.7
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99044.7
99144.7
99244.7
99344.7
99444.7
99544.7
99644.7
99744.7
99844.7
99944.7
100044.7

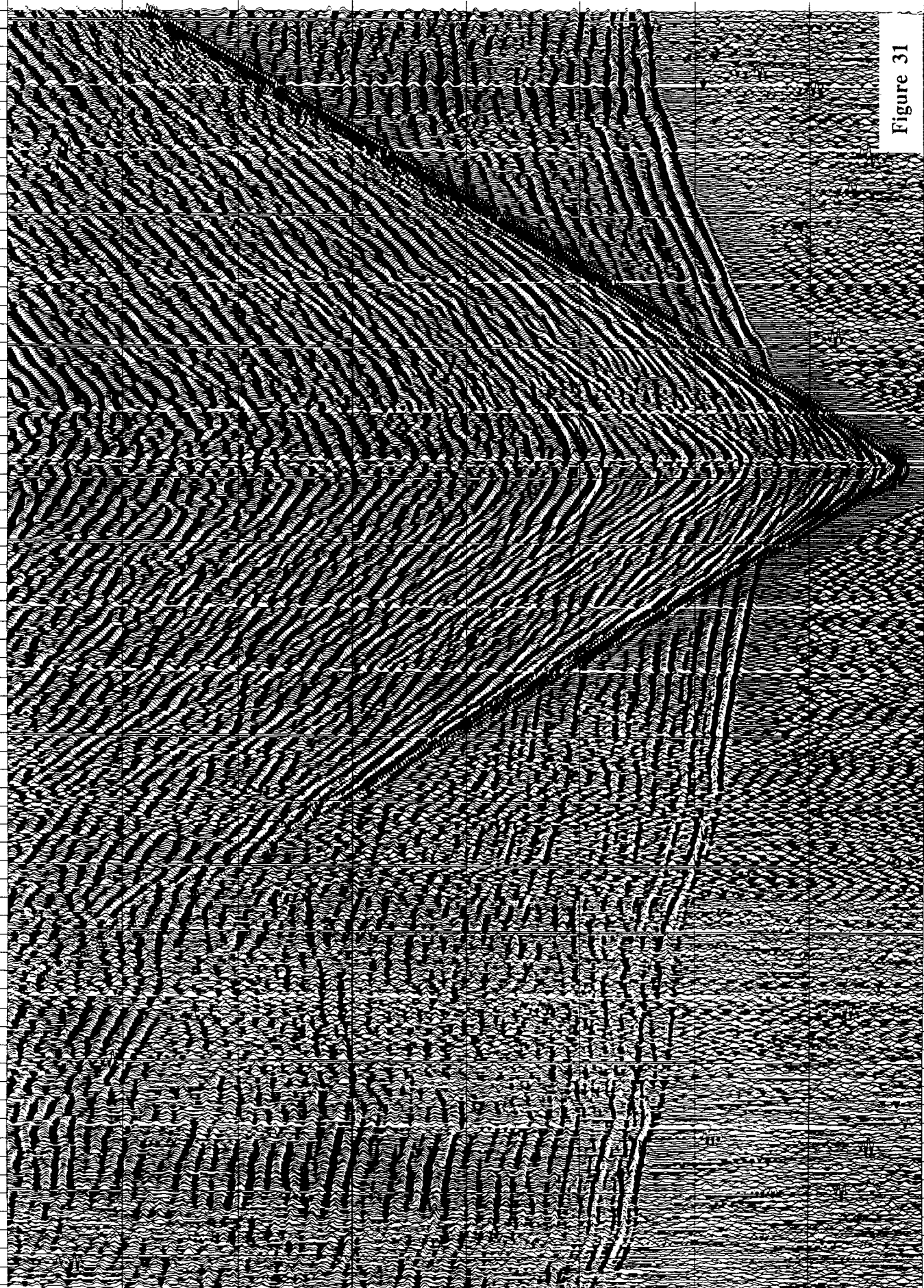
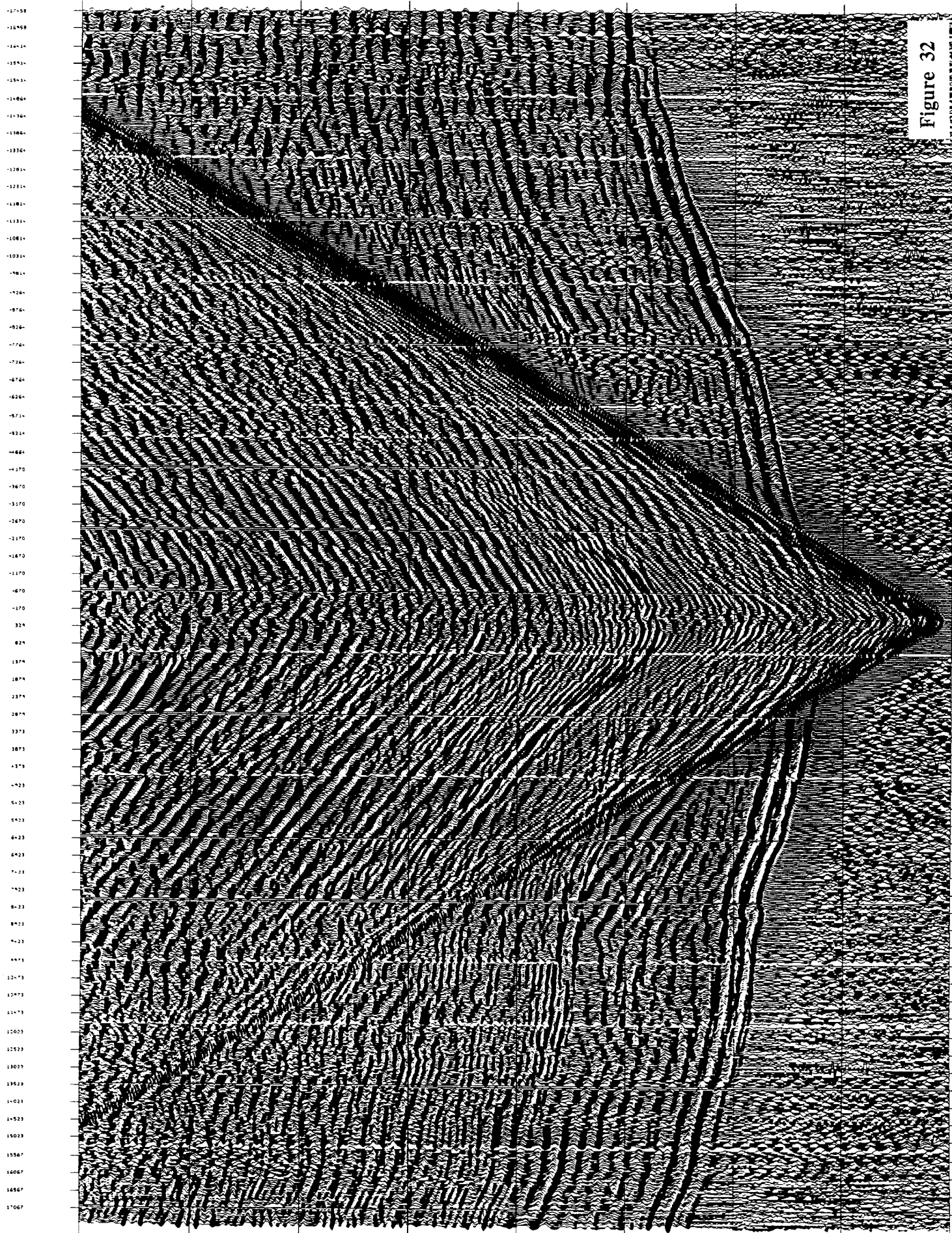


Figure 32



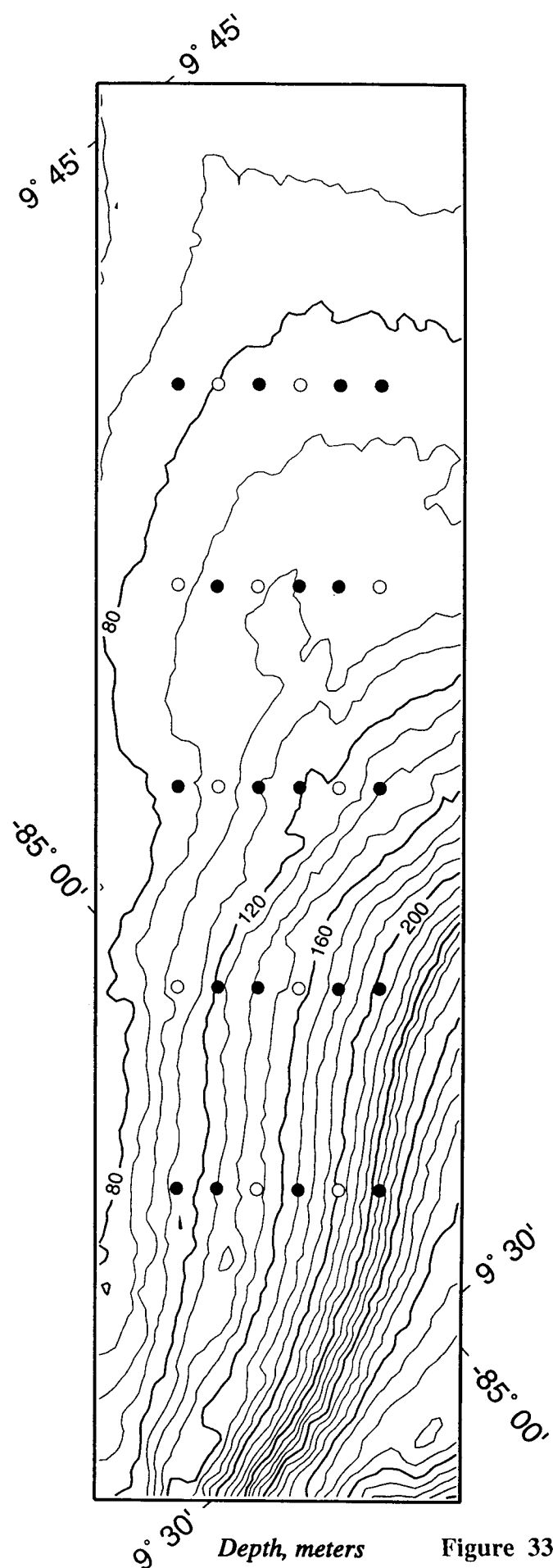
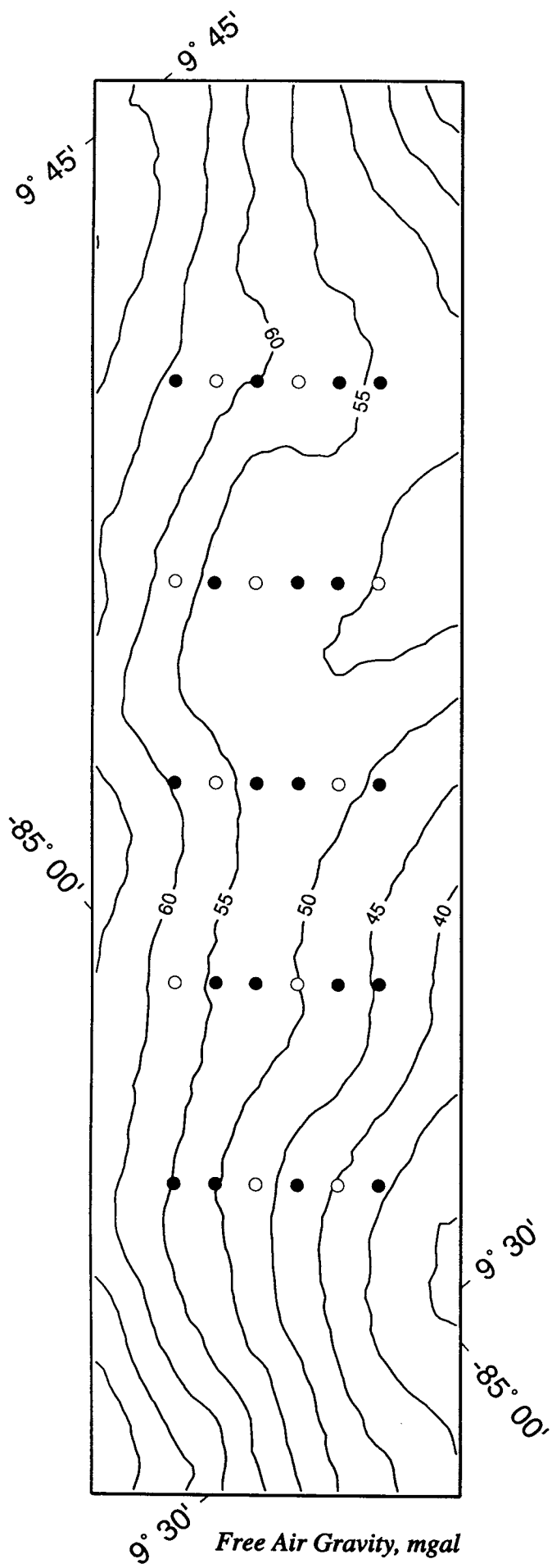


Figure 33

Expendable Bathythermographs

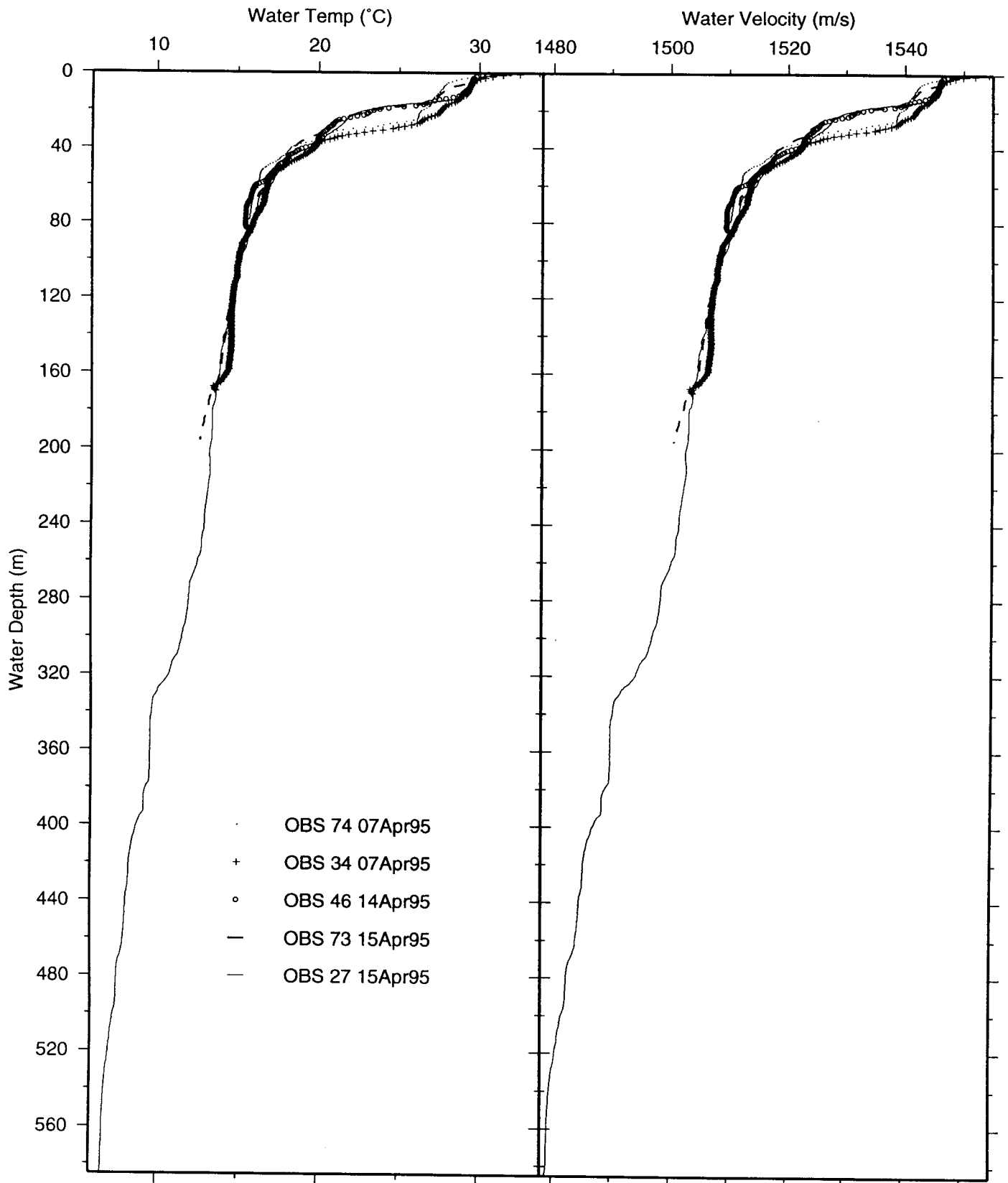


Figure 34

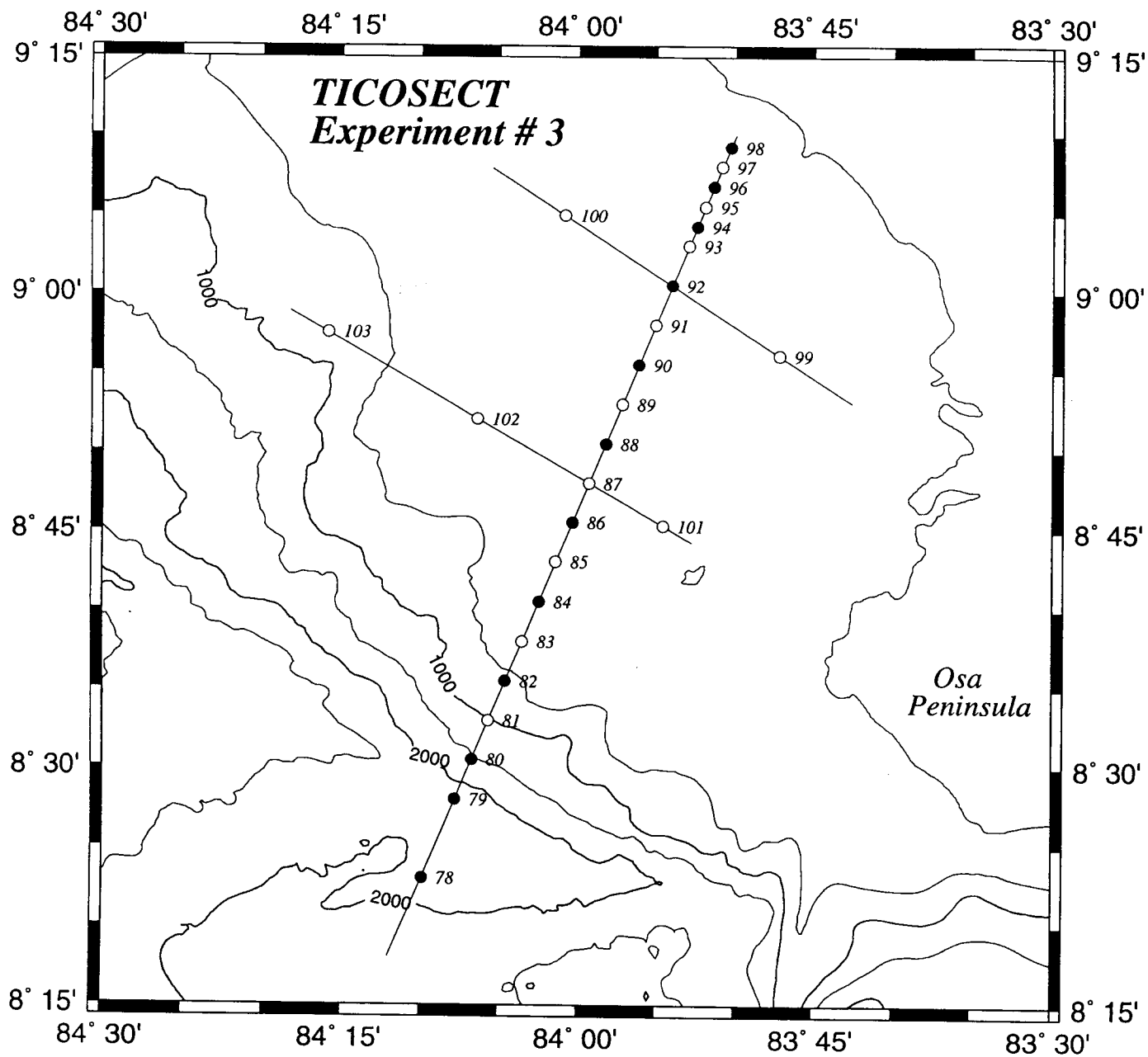
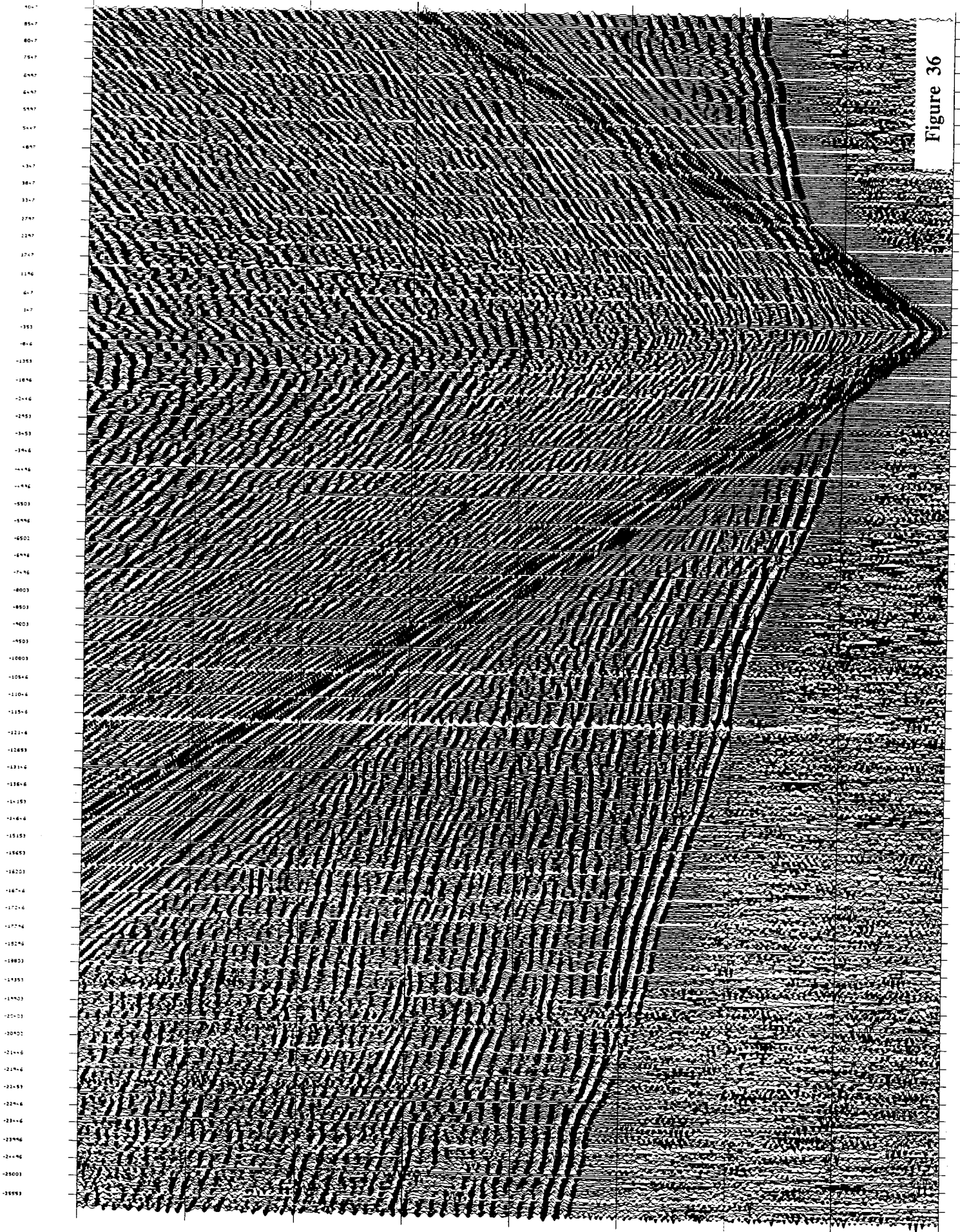


Figure 35

Figure 36



XII. Appendix

UTIG OBS Deployment, Recovery and Data Summary

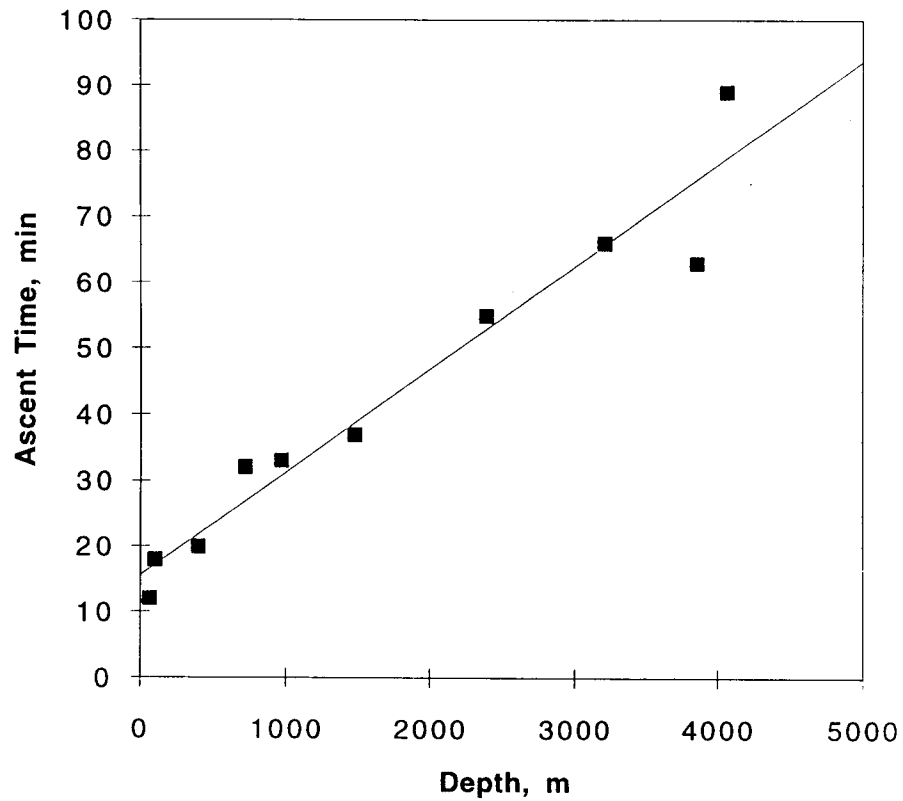
Station	Chassis S/N	Sphere S/N	Active Channels	Deployment			Recovery			Acquired Data	
				Time	Location	Depth m	Time	Location	Depth m	Period	Mb
2	92-1	29034	1-4	3/29/12:30:31	9°38.24'N, 86°14.91'W	4068	4/2/20:29	9°38.56'N, 86°15.21'W	4063	3/30/17:58-3/30/18:04; 3/30/18:58-3/30/19:04; 3/30/19:58-3/30/20:04; 3/30/20:58-3/31/20:35; 4/1/19:00-4/2/10:38	203
4	92-2	44568	1-4	3/29/13:24:50	9°41.85'N, 86°10.82'W	3850	4/2/22:21			3/30/17:58-3/30/18:04; 3/30/18:58-3/30/19:04; 3/30/19:58-3/30/20:04; 3/30/20:58-3/31/20:30; 4/1/19:00-4/2/10:20	203
6	92-3	52239	1-4	3/29/14:16:30	9°45.48'N 86°06.77'W	3218	4/3/00:18	9°45.85'N 86°06.97'W	3215	3/30/17:58-3/30/18:04; 3/30/18:58-3/30/19:04; 3/30/19:58-3/30/20:04; 3/30/20:58-3/31/20:35; 4/1/19:00-4/2/10:24	203
8	92-5	55316	1-4	3/29/15:15:48	9°49.06'N 86°02.65'W	2415	4/3/02:19	9°49.35'N 86°02.85'W	2393	3/30/17:58-3/30/18:04; 3/30/18:58-3/30/19:04; 3/30/19:58-3/30/20:04; 3/30/20:58-3/31/20:34; 4/1/19:00-4/2/10:32	203
10	92-6	55429	1-4	3/29/16:06:39	9°52.77'N 85°58.60'W	1607	4/3/04:17	9°53.16'N 85°58.99'W	1480	3/30/17:58-3/30/18:04; 3/30/18:58-3/30/19:04; 3/30/19:58-3/30/20:04; 3/30/20:58-3/31/20:34; 4/1/19:00-4/2/10:22	203
12	92-7	55454	1-4	3/29/16:44:24	9°55.62'N 85°55.56'W	994	4/1/05:21	9°55.69'N 85°55.77'W	976	3/30/11:00-3/31/20:33	171.5
14	93-4	55467	1-4	3/29/17:20:06	9°57.23'N 85°53.51'W	751	4/1/03:31	9°57.54'N 85°53.92'W	716	3/30/11:00-3/31/20:34	173.5
16	94-6	55473	1-4	3/29/18:02:20	9°59.05'N 85°51.44'W	477	4/1/01:27	9°59.32'N 85°51.54'W	397	3/30/11:00-3/31/20:31	174
18	94-7	55478	1-4	3/29/18:31:35	10°00.83'N 85°49.36'W	99	3/31/23:20	10°00.94'N 85°49.43'W	99	3/30/11:00-3/31/20:35	173.5
20	94-8	55496	1-4	3/29/19:16:23	10°02.65'N 85°47.36'W	62	3/31/21:23	10°02.67'N 85°47.27'W	62	3/30/11:00-3/31/20:30	173

27	92-7	23641	1-3	4/5/00:59:51	9°24.56'N 85°07.81'W	1204	4/15/09:06	9°24.55'N 85°07.75'W	1207	4/5/21:00-4/8/01:04	203
28	92-1	23646	1-3	4/5/01:50:24	9°28.66'N 85°04.28'W	379	4/15/07:50	9°28.64'N 85°04.37'W	379	4/5/21:00-4/8/00:33	203
31	93-4	31615	1 & 2	4/5/02:37:52	9°33.52'N 85°01.54'W	117	4/13/22:19	9°33.59'N 85°01.67'W	112	4/5/21:00-4/13/16:25	500
32	94-9	55458	1 & 4	4/5/02:57:07	9°33.19'N 85°01.13'W	130	4/13/23:15	9°33.13'N 85°01.19'W	130	4/5/21:00-4/13/16:33	500
34	94-10	55472	1 & 4	4/5/03:30:00	9°32.47'N 85°00.33'W	168	4/14/00:21	9°32.50'N 85°00.39'W	170	4/5/21:00-4/13/16:27	500
36	94-11	56962	1 & 4	4/5/04:01:28	9°31.74'N 84°59.48'W	251	4/14/03:10	9°31.60'N 84°59.39'W	268	4/5/21:00-4/13/16:30	500
42	94-15	55478	1 & 4	4/5/05:19:07	9°35.24'N 84°59.35'W	121	4/14/05:14	9°35.15'N 84°59.39'W	126	4/5/21:00-4/13/16:23	500
43	94-14	55496	1 & 4	4/5/05:08:45	9°34.91'N 84°58.94'W	142	4/14/04:26	9°34.64'N 84°59.00'W	146	4/5/21:00-4/13/16:17	500
45	94-13	57113	1 & 4	4/5/04:42:20	9°34.19'N 84°58.10'W	178	4/14/03:40	9°33.67'N 84°58.10'W	201	4/5/21:00-4/13/16:26	500
46	94-12	57112	1 & 4	4/5/04:31:16	9°33.80'N 84°57.72'W	204	4/14/02:22	9°33.72'N 84°57.63'W	211	4/5/21:00-4/13/16:29	500
51	94-16	55473	1 & 4	4/5/06:05:35	9°37.62'N 84°58.00'W	87	4/14/06:22	9°37.18'N 84°58.28'W	87	4/5/21:00-4/13/16:26	500
53	94-17	55467	1 & 4	4/5/06:36:57	9°36.93'N 84°57.15'W	108	4/14/18:07	9°36.82'N 84°57.29'W	106	4/5/21:00-4/13/16:29	500
54	94-18	55454	1 & 4	4/5/06:53:57	9°36.58'N 84°56.74'W	119	4/14/19:16	9°36.57'N 84°56.94'W	116	4/5/21:00-4/13/16:26	500
56	93-8	40329	1 & 4	4/5/07:15:03	9°35.86'N 84°55.91'W	143	4/14/20:16	9°35.96'N 84°56.17'W	130	4/5/21:00-4/13/16:36	500
62	93-15	29034	1 & 4	4/5/08:50:00	9°39.35'N 84°55.83'W	94	4/14/23:18	9°39.56'N 84°55.85'W	92	4/5/21:00-4/13/16:45	500
64	93-12	40377	1 & 4	4/5/08:17:12	9°38.62'N 84°54.98'W	95	4/14/22:14	9°38.88'N 84°55.09'W	99	4/5/21:00-4/13/16:30	500
65	93-10	40365	1 & 4	4/5/08:05:20	9°38.29'N 84°54.57'W	94	4/14/21:19	9°38.40'N 84°54.68'W	93	4/5/21:00-4/13/16:31	500
71	94-4	44568	1 & 4	4/5/09:53:32	9°41.74'N 84°54.46'W	75	4/15/00:27	9°41.95'N 84°54.49'W	74	4/5/21:00-4/13/16:26	500
73	94-8	52239	1 & 4	4/5/10:45:12	9°41.09'N 84°53.63'W	83	4/15/01:13	9°41.18'N 84°53.64'W	84	4/5/21:00-4/13/16:29	500
75	94-7	55316	1 & 4	4/5/12:41:55	9°40.36'N 84°52.80'W	86	4/15/02:12	9°40.29'N 84°52.82'W	87	4/5/21:00-4/13/16:28	500

76	94-6	55429	1 & 4	4/5/12:56:30	9°40.01'N 84°52.38'W	85	4/15/03:24	9°39.92'N 84°52.43'W	88	4/5/21:00-4/13/16:28	500
77	92-3	44398	1-3	4/5/14:00:40	9°34.72'N 84°46.16'W	102	4/15/04:42	9°34.50'N 84°46.34'W	108	4/11/13:00-4/13/17:	
78	93-4	52239	1-4	4/16/17:31:30	8°23.01'N 84°09.87'W	2074					
79	92-5	55458	1-4	4/16/18:17:05	8°28.00'N 84°07.76'W	2216					
80	92-6	55472	1-4	4/16/18:40:20	8°30.50'N 84°06.68'W	1504					
82	92-2	44568	1-4	4/16/19:18:52	8°35.48'N 84°04.59'W	523					
84	94-9	56962	1-4	4/16/20:04:39	8°40.51'N 84°02.48'W	140					
86	94-10	57112	1-4	4/16/20:58:59	8°45.52'N 84°00.38'W	97					
88	94-11	57113	1-4	4/16/21:47:19	8°50.52'N 83°58.23'W	73					
90	94-12	55496	1-4	4/16/22:33:56	8°55.51'N 83°56.14'W	59					
92	94-13	55478	1-4	4/16/23:23:14	9°00.50'N 83°54.00'W	95					
94	94-14	55473	1-4	4/17/00:01:27	9°04.30'N 83°53.42'W	89					
96	94-15	55467	1-4	4/17/00:29:06	9°06.77'N 83°51.35'W	73					
98	94-16	55454	1-4	4/17/00:56:58	9°09.27'N 83°50.30'W	52					

OBS Ascent estimate from TICOSECT Experiment 1

Station	Depth	Ascent Time		
2	4063	89		
4	3850	63		
6	3215	66		
8	2393	55		
10	1480	37		
12	976	33		
14	716	32		
16	397	20		
18	99	18		
20	62	12		
	0.01561675	15.5595519		
Speed -->	64.0 m/min	15.6 min	<-- Burn time	
	0	15.5595519		
	5000	93.6432806		



Experiment 1 Schedule

Activity	Allocated, hrs.	From	To	Completed	Remarks
Transit from Balboa to OBH release test site	24	3/27/ 07:00	3/28/ 07:00		
Test GEOMAR OBH release	8	3/28/ 07:00	3/28/ 15:00		
Transit from release test site to S1	24	3/28/ 15:00	3/29/ 15:00		
Array 1					
Deploy OBS/H's at S1-20 (20 stations)	15	3/29/ 15:00	3/30/ 06:00		
Transit from S20 to S21	1.5	3/30/ 06:00	3/30/ 07:30		
Deploy OBH at S21	0.5	3/30/ 07:30	3/30/ 08:00		
Transit from S21 to S22	1.5	3/30/ 08:00	3/30/ 09:30		
Deploy OBH at S22	0.5	3/30/ 09:30	3/30/ 10:00		
Transit from S22 to 103 BOL	0.75	3/30/ 10:00	3/30/ 10:45		
Deploy airgun array	1	3/30/ 10:45	3/30/ 11:45		
Recording at S12-20		3/30/ 11:00	3/31/ 20:30		
Shoot strike line 103, NW—>SE	7.5	3/30/ 11:45	3/30/ 19:15		
Recording at S2-10		3/30/ 17:58	3/30/ 18:04		
Land shot #1		3/30/ 18:00			
Recording at S2-10		3/30/ 18:58	3/30/ 19:04		
Land shot #2		3/30/ 19:00			
Transit from 103 EOL to 101 BOL	2.25	3/30/ 19:15	3/30/ 21:30		
Recording at S2-10		3/30/ 19:58	3/30/ 20:04		
Land shot #3		3/30/ 20:00			
Recording at S2-10		3/30/ 20:58	3/31/ 20:30		
Land shot #4		3/30/ 21:00			
Shoot dip line 101 NE—>SW	11	3/30/ 21:30	3/31/ 08:30		
Turn around ship	0.5	3/31/ 08:30	3/31/ 09:00		
Shoot dip line 102 SW—>NE	11	3/31/ 09:00	3/31/ 20:00		
Retrieve airgun array	1	3/31/ 20:00	3/31/ 21:00		
Recover OBS/H's at S20-12 (9 stations)	9	3/31/ 21:00	4/1/ 06:00		
Transit from S12 to S21	1	4/1/ 06:00	4/1/ 07:00		
Recover OBH's at S21,11,22 (3 stations)	3	4/1/ 07:00	4/1/ 10:00		
Transit from S22 to S23	1.5	4/1/ 10:00	4/1/ 11:30		
Deploy vertical streamer at S23	1.5	4/1/ 11:30	4/1/ 13:00		
Transit from S23 to S24	0.5	4/1/ 13:00	4/1/ 13:30		
Deploy OBH at S24	1	4/1/ 13:30	4/1/ 14:30		
Transit from S24 to S25	1.25	4/1/ 14:30	4/1/ 15:45		
Deploy OBH's at S25, 26	1.5	4/1/ 15:45	4/1/ 17:15		
Transit from S26 to 104 BOL	0.75	4/1/ 17:15	4/1/ 18:00		
Deploy airgun array	1	4/1/ 18:00	4/1/ 19:00		
Recording at S2-10		4/1/ 19:00	4/2/ 11:00		
Shoot strike line 104 SE—>NW	7	4/1/ 19:00	4/2/ 02:00		
Transit from 104 EOL to 105 BOL	1.75	4/2/ 02:00	4/2/ 03:45		
Shoot strike line 105 NW—>SE	7	4/2/ 03:45	4/2/ 10:45		
Retrieve airgun array	1	4/2/ 10:45	4/2/ 11:45		
Transit from 105 EOL to S25	0.75	4/2/ 11:45	4/2/ 12:30		
Recover OBH's at S25,26,23,24	5	4/2/ 12:30	4/2/ 17:30		
Transit from S24 to S1	1.5	4/2/ 17:30	4/2/ 19:00		
Recover OBS/H's at S1-10 (10 stations)	10	4/2/ 19:00	4/3/ 05:00		
End of Array 1 Activity			4/3/ 05:00		

TICOSECT Array 2 UTIG OBS/H Recovery Schedule

Station	Deployment Location	Release Time	Water Depth, m	Expected Surfacing*	Beacon Channel
31	9°33.524'N, 85°01.544'W	4/13/21:47	117	4/13/22:03	C
32	9°33.192'N, 85°01.134'W	4/13/22:47	130	4/13/23:04	D
34	9°32.466'N, 85°00.334'W	4/13/23:46	168	4/14/00:03	A
36	9°31.741'N, 84°59.485'W	4/14/00:45	251	4/14/01:04	B
46	9°33.797'N, 84°57.716'W	4/14/01:46	204	4/14/02:04	C
45	9°34.186'N, 84°58.099'W	4/14/02:46	178	4/14/03:03	D
43	9°34.911'N, 84°58.940'W	4/14/03:47	142	4/14/04:04	A
42	9°35.238'N, 84°59.350'W	4/14/04:47	121	4/14/05:04	B
51	9°37.624'N, 84°58.000'W	4/14/05:48	87	4/14/06:04	C
53	9°36.928'N, 84°57.152'W	4/14/17:47	108	4/14/18:03	D
54	9°36.585'N, 84°56.745'W	4/14/18:47	119	4/14/19:03	A
56	9°35.858'N, 84°55.914'W	4/14/19:47	143	4/14/20:04	B
65	9°38.291'N, 84°54.569'W	4/14/20:48	94	4/14/21:04	C
64	9°38.618'N, 84°54.976'W	4/14/21:48	95	4/14/22:04	D
62	9°39.350'N, 84°55.833'W	4/14/22:48	94	4/14/23:04	A
71	9°41.745'N, 84°54.460'W	4/14/23:48	75	4/15/00:04	B
73	9°41.094'N, 84°53.632'W	4/15/00:48	83	4/15/01:04	C
75	9°40.362'N, 84°52.803'W	4/15/01:48	86	4/15/02:04	D
76	9°40.009'N, 84°52.378'W	4/15/02:48	85	4/15/03:04	A
77	9°34.721'N, 84°46.157'W	4/15/04:18	102	4/15/04:34	B
28	9°28.663'N, 85°04.280'W	4/15/07:12	379	4/15/07:33	B
27	9°24.556'N, 85°07.812'W	4/15/08:20	1204	4/15/08:55	A

*The times are in local (UTC - 6 hours). The actual surfacing time may vary because of the variations in wire burn time and ascent speed, which are estimated to be 15 minutes and 60 m/min, respectively.

Submersible Transmitter Beacon Frequency

Channel	A	B	C	D
Frequency, MHz	154.585	159.480	160.725	160.785

Recovery Comparison Experiment 2

Station	Latitude, N		Longitude, W		Δ lat.	Δ long.	Δ , nm	Release	Depth	Surface
31	9	33.524	85	1.544				4/13/21:47	117	4/13/22:03
32	9	33.192	85	1.134	-0.332	-0.410	0.5	4/13/22:47	130	4/13/23:04
34	9	32.466	85	0.334	-0.726	-0.800	1.1	4/13/23:46	168	4/14/00:03
36	9	31.741	84	59.485	-0.725	-0.849	1.1	4/14/00:45	251	4/14/01:04
46	9	33.797	84	57.716	2.056	-1.769	2.7	4/14/01:46	204	4/14/02:04
45	9	34.186	84	58.099	0.389	0.383	0.5	4/14/02:46	178	4/14/03:03
43	9	34.911	84	58.940	0.725	0.841	1.1	4/14/03:47	142	4/14/04:04
42	9	35.238	84	59.350	0.327	0.410	0.5	4/14/04:47	121	4/14/05:04
51	9	37.624	84	58.000	2.386	-1.350	2.7	4/14/05:48	87	4/14/06:04
53	9	36.928	84	57.152	-0.696	-0.848	1.1	4/14/17:47	108	4/14/18:03
54	9	36.585	84	56.745	-0.343	-0.407	0.5	4/14/18:47	119	4/14/19:03
56	9	35.858	84	55.914	-0.727	-0.831	1.1	4/14/19:47	143	4/14/20:04
65	9	38.291	84	54.569	2.433	-1.345	2.8	4/14/20:48	94	4/14/21:04
64	9	38.618	84	54.976	0.327	0.407	0.5	4/14/21:48	95	4/14/22:04
62	9	39.350	84	55.833	0.732	0.857	1.1	4/14/22:48	94	4/14/23:04
71	9	41.745	84	54.460	2.395	-1.373	2.8	4/14/23:48	75	4/15/00:04
73	9	41.094	84	53.632	-0.651	-0.828	1.0	4/15/00:48	83	4/15/01:04
75	9	40.362	84	52.803	-0.732	-0.829	1.1	4/15/01:48	86	4/15/02:04
76	9	40.009	84	52.378	-0.353	-0.425	0.5	4/15/02:48	85	4/15/03:04
77	9	34.721	84	46.157	-5.288	-6.221	8.1	4/15/04:18	102	4/15/04:34
28	9	28.663	85	4.280	-6.058	18.123	18.9	4/15/07:12	379	4/15/07:33
27	9	24.556	85	7.812	-4.107	3.532	5.4	4/15/08:20	1204	4/15/08:55

Schedule for End of Experiment 2 through Experiment 3

Activity	Allocated, hrs.	From	To
Recover S31-S51 (9 stations) and refurbish instruments	9	4/13/ 22:00	4/14/ 07:00
Continue and complete refurbishing of above	3	4/14/ 07:00	4/14/ 10:00
Rest	8	4/14/ 10:00	4/14/ 18:00
Tom B. transfers data from 3 500MB disk drives	11	4/14/ 07:00	4/14/ 18:00
Recover S53-S27 (13 stations)	16	4/14/ 18:00	4/15/ 10:00
Start clocks, S78-S98 (12 stations), between recoveries	16	4/14/ 18:00	4/15/ 10:00
Rest	8	4/15/ 10:00	4/15/ 18:00
Close up spheres, 12 OBS's	15	4/15/ 18:00	4/16/ 09:00
Monitor test recording	0.4	4/16/ 09:00	4/16/ 09:24
Mount beacons and hydrophones, 12 OBS's	4	4/16/ 09:00	4/16/ 13:00
Rest	5	4/16/ 13:00	4/16/ 18:00
Deploy GEOMAR OBH's S100-S81 (11 stations)	12	4/16/ 06:00	4/16/ 18:00
Deploy UTIG OBS's S78-S98 (12 stations)	9	4/16/ 18:00	4/17/ 03:00
Transit from S98 to 303 BOL	2	4/17/ 03:00	4/17/ 05:00
Deploy airgun array	1	4/17/ 05:00	4/17/ 06:00
Shoot line 303	6.75	4/17/ 06:00	4/17/ 12:45
OBS recording	7.5	4/17/ 05:45	4/17/ 13:15
Transit from 303 EOL to 301 BOL	4.75	4/17/ 12:45	4/17/ 17:30
Shoot line 301	14.25	4/17/ 17:30	4/18/ 07:45
Turn around	1	4/18/ 07:45	4/18/ 08:45
Shoot line 302	14.25	4/18/ 08:45	4/18/ 23:00
OBS recording	30.5	4/17/ 17:00	4/18/ 23:30
Retrieve airgun array	1	4/18/ 23:00	4/19/ 00:00
Recover UTIG OBS's S98,96,94,92,90,88 (6 stations)	6	4/19/ 00:00	4/19/ 06:00
Recover GEOMAR OBH'S S89,91,99,93,95,97,100 (7 stations)	7	4/19/ 06:00	4/19/ 13:00
Transit from S100 to S103	2	4/19/ 13:00	4/19/ 15:00
Deploy OBH's, S103,102,101 (3 stations)	3.5	4/19/ 15:00	4/19/ 18:30
Transit from S101 to S86	0.5	4/19/ 18:30	4/19/ 19:00
Recover OBS's & OBH's, S86-S78 (9 stations)	9	4/19/ 19:00	4/20/ 04:00
End of UTIG OBS recovery operation			4/20/ 04:00
Transit from S78 to line 304 BOL	2	4/20/ 04:00	4/20/ 06:00
Deploy airgun array	1	4/20/ 06:00	4/20/ 07:00
Shoot line 304	7.5	4/20/ 07:00	4/20/ 14:30
Retrieve airgun array	1	4/20/ 14:30	4/20/ 15:30
Recover OBH's, S101,87,102,103	4	4/20/ 15:30	4/20/ 19:30
End of GEOMAR OBH recovery operation			4/20/ 19:30

Required OBS Services in Preparation for Array 3

Now

- Replace burnt diode on 92-2
- Mount 200 Mb disk drives on 92-2, 92-5 and 92-6
- Check out 92-2, 92-5 and 92-6
- Prepare 9 sets of CPU and drive battery packs (4 from line 1 plus 5 new sets)

During and immediately following recovery of S1-S51

Refurbishing of 93-4, 94-9, 94-10, 94-11, 94-12, 94-13, 94-14, 94-15, and 94-16 (9 chassis), including:

- Remove 500 Mb disk drive
- Have Tom B. copy the data off the first three disk drives
- Mount 200 Mb disk drive on each of first 6 units
- Remove battery monitor
- Reinstall op-amps and filters on all channels
- Replace CPU and drive battery packs
- Check out each chassis for battery voltages and operation
- Replace hydrophone preamp batteries on spheres 55496, 55478 and 55473 (from stations 43, 42 and 51)

During and immediately following recovery of S53-S27

- Mount 500 Mb disk drives on 94-14, 94-15 and 94-16
- Replace hydrophone preamp batteries on spheres 55467 and 55454 (from stations 53 and 54)
- Start clock on all 12 units

Experiment 3 Detailed Schedule

		Chassis	Cik.St.Int	BUT Set	BUT Start	T Rcd.Int.	Sphere	Strobes	Beacons	Depl.Int.	Data Acq. 1	Data Acq. 2	Wire Burn	Asc.Spd.	Recv.Int.	BU Delay
			1:00			0:03				0:30	7.5 hrs.	30.5 hrs.	15 min	60 m/min	1:00	5 min
Station			Clock Start	BUT Set	BUT Start	Test Record	Sphere	Strobes	Beacons	Deployment	DA Start	DA Stop	Release	Depth	Surface	BU Rel.
78	93-4		4/14 18:30	119	4/15 03:46	4/16 09:00	52239	12	A	4/16 18:00	4/17 05:45	4/18 23:30	4/20 02:11	2050	4/20 03:00	4/20 02:16
79	92-5		4/14 19:30	118	4/15 03:42	4/16 09:03	55458	6	B	4/16 18:30	4/17 05:45	4/18 23:30	4/20 01:07	2300	4/20 02:00	4/20 01:12
80	92-6		4/14 20:30	117	4/15 03:52	4/16 09:06	55472	6	C	4/16 19:00	4/17 05:45	4/18 23:30	4/20 00:17	1700	4/20 01:00	4/20 00:22
82	92-2		4/14 21:30	115	4/15 04:10	4/16 09:09	44568	12	D	4/16 19:30	4/17 05:45	4/18 23:30	4/19 22:35	600	4/19 23:00	4/19 22:40
84	94-9		4/14 22:30	113	4/15 04:17	4/16 09:12	56962	6	A	4/16 20:00	4/17 05:45	4/18 23:30	4/19 20:42	170	4/19 21:00	4/19 20:47
86	94-10		4/14 23:30	111	4/15 04:18	4/16 09:15	57112	6	B	4/16 20:30	4/17 05:45	4/18 23:30	4/19 18:43	120	4/19 19:00	4/19 18:48
88	94-11		4/15 00:30	97	4/15 04:18	4/16 09:18	57113	6	C	4/16 21:00	4/17 05:45	4/18 23:30	4/19 04:43	100	4/19 05:00	4/19 04:48
90	94-12		4/15 01:30	96	4/15 04:18	4/16 09:21	55496	6	D	4/16 21:30	4/17 05:45	4/18 23:30	4/19 03:43	120	4/19 04:00	4/19 03:48
92	94-13		4/15 02:30	95	4/15 04:18	4/16 09:24	55478	6	A	4/16 22:00	4/17 05:45	4/18 23:30	4/19 02:43	120	4/19 03:00	4/19 02:48
94	94-14		4/15 03:30	94	4/15 04:18	4/16 09:27	55473	6	B	4/16 22:30	4/17 05:45	4/18 23:30	4/19 01:43	110	4/19 02:00	4/19 01:48
96	94-15		4/15 04:30	93	4/15 04:19	4/16 09:30	55467	6	C	4/16 23:00	4/17 05:45	4/18 23:30	4/19 00:44	90	4/19 01:00	4/19 00:49
98	94-16		4/15 05:30	92	4/15 04:19	4/16 09:33	55454	6	D	4/16 23:30	4/17 05:45	4/18 23:30	4/18 23:44	70	4/19 00:00	4/18 23:49
										Data Acq. 1	4/17 05:45	4/17 13:15				
										Data Acq. 2	4/17 17:00	4/18 23:30				