CRUISE REPORT

RRS Charles Darwin Cruise 75

6th January - 1st February 1993

Barbados Ridge Accretionary Complex
Seismic Experiment

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Contents

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INTRODUCTORY SUMMARY

The objectives of the cruise were to conduct seismic experiments at four sites in two areas to determine the effect of the accretion of sediment into an accretionary wedge upon the porosity and pore-fluid pressure of the accreted sediments and the sediments thrust beneath the wedge. In each area measurments of P-wave and S-wave velocities from a site on the undisturbed ocean floor in front of the accretionary wedge were to be compared with measurments taken from a site on the toe of the accretionary wedge where the upper layers of sediment are deformed and thickened above undeformed layers of sediment beneath the wedge. In addition it was hoped that changes in the seismic anisotropy of the sediments could be distinguished between the two sites. In one area (A) the thickness of sediments on the ocean floor is small (about 500 m) and predominantly formed of pelagic clays. In the other area (B), the thickness of sediments is greater (1800 m) andthe upper two thirds is formed of distal turbidites of the Orinoco submarine fan. Explosive charges of 20 lb or 90 lb of pentolite were detonated on the sea bed to generate S waves. Shots from airguns at the surface were fired to give dense coverage of the P-wave structure. Grids of seismic reflection profiles were run to define the shapes of layers and show where sediments were deformed.
The cruise took place in the western Atlantic, east of the Lesser Antilles, over the Barbados Ridge accretionary complex in the general area 13°40'- 16°00'N, 57°25'- 59°00'W. The two areas in which the work of the cruise was concentrated were Area A (Sites 1 & 2): 15°20'- 15°40'N, 58°30'- 58°55'W; Area B (Sites 3 & 4): 14°15'- 14°35'N, 57°25'- 57°55'W.

At each of the four sites of the seismic experiment, the typical sequence of operations extending over a period of six days was as follows:

i) Deploy acoustic beacons.
ii) Calibrate acoustic beacon net.
iii) Deploy six digital ocean-bottom seismographs.
iv) Fire explosive bottom-shots, over two days.
v) Shoot airgun array to ocean-bottom seismographs.
vi) Retrieve ocean-bottom seismographs.
vii) Retrieve acoustic beacons.

At each site an L-shaped pattern of digital ocean-bottom seismographs (DOBS) was deployed; one DOBS lay at the end of each arm of the L , and four were deployed along a short diagonal line bisecting the corner of the L. One arm of the L ran perpendicular to the strike of structure in the accretionary wedge and the other lay parallel to the strike. Explosive shots on the sea bed and airgun shots fired at the surface were run down each arm of the L , extending beyond the ends of the arms of the L in the case of the airgun shots. A short line of bottom-shots was run along the diagonal to ensure that anisotropy in the sediments would be detected, if present. Grids of seismic reflection profiles were run across sites 1 and 2 together, and similarly across sites 3 and 4.

Typical weather conditions were 20-knot winds from 080°, with a 5 metre swell and waves of 1 to 1.5 metre height. There were periods when wind speed increased to 30 knots, and one brief period of a day when it decreased to 5 knots. The weather was never sufficiently poor to stop the scientific programme or to cause it to be amended significantly.

The cruise was very largely successful. At each of the four sites all of the six ocean-bottom seismographs recorded the explosive bottom-shots and the airgun shots. The data quality was good, with very low noise, although it was unfortunate to lose three of the external geophine packages during the retrieval of the DOBS at Site 1. Of the 123 bottom shots, 15 failed to detonate, although a further 4 only detonated partly. All of the planned work, including seismic reflection surveys of each site, was completed.

Operations in Area A

DAY	TIME	ACTIVITY
08		On passage to Area A
	0512	Arrive Site 1
	0612	Lay acoustic beacon 1
	0655	
	0719	Velocimeter dip
	1056	Lay beacon 2 Lay beacon 3
	1215	Calibrate network of acoustic beacons
	1845	
	2058	Deploy DOBS A,B,C,D,E,F at Site 1
09	0619	
	1000	Prepare explosives
	1109	Lay explosive shots 1 to 18 at Site 1
	1935	Detonation of shots 1 to 18
	2141	Lay acoustic beacons 4,5,6 at Site 2
10	0215	Calibrate acoustic net at Site 2
	0735	
	1035	Deploy explosive shots 19 to 22
	1145	
	1350	Prepare and deploy airgun array
	1844	
	1900	Shoot air guns into DOBS at Site 1

DAY	TIME	ACTIVITY
11	0100	Recover air guns
	0215	Recover DOBS A-F from Site 1
	2157	
	2314	Deploy 3.5 kHz fish, streamer & airguns
12	0212	Seismic reflection survey of Sites 1 & 2
13	1305	Recover air guns, streamer & 3.5 kHz
	1455	
	1520	Recover acoustic beacons 1 & 3
	1854	
	2050	

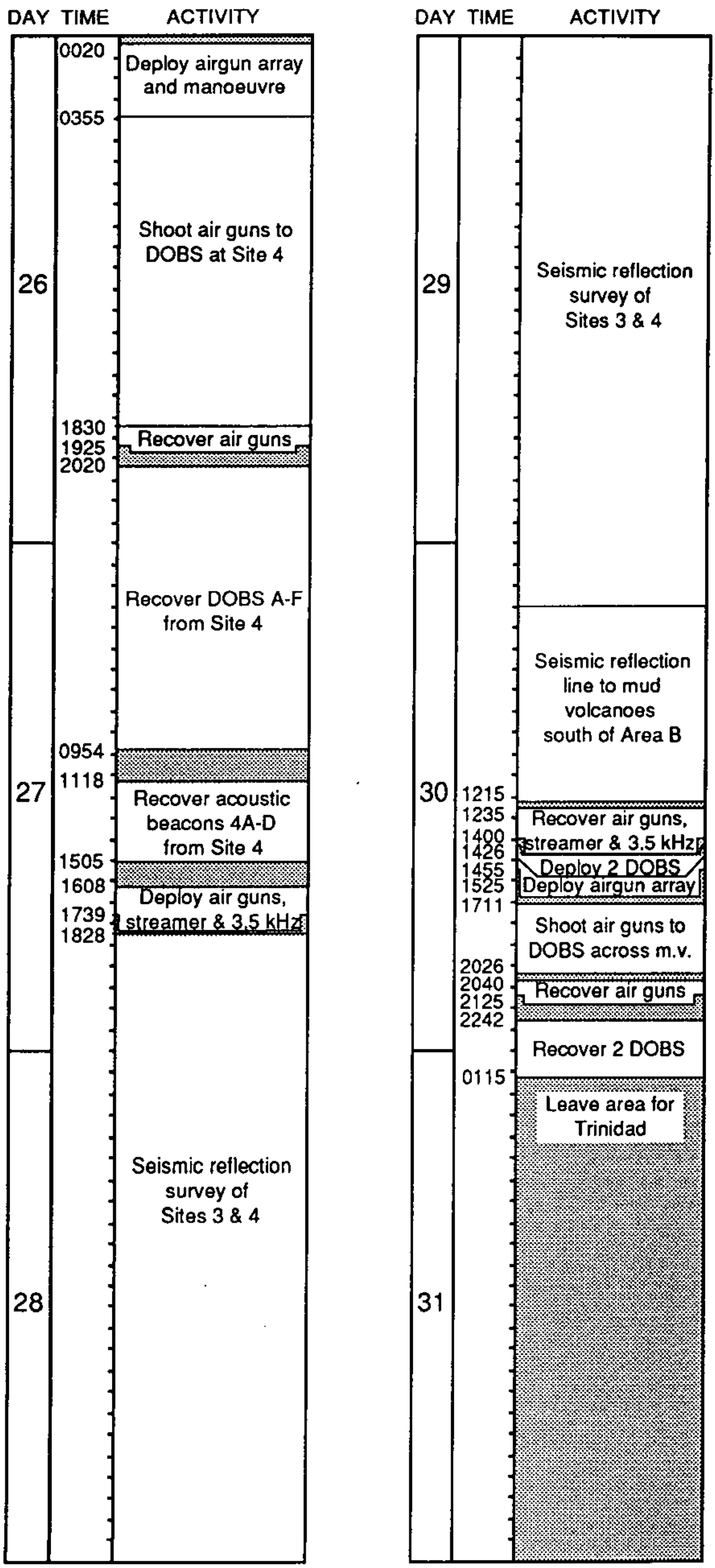
DAY	TIME	ACTIVITY
14		Deploy DOBS A-F at Site 2
	0524	
	1045	Lay explosive shots 1-11 at Site 2
	1453	
	1600	Shots 1-7 fired
	1700	
	1806	Lay explosive shots 12-20 at Site 2
	2053	
	2120	Shots 8-20 fired
15	0020	
	1041	Lay explosive shots 21-26 at Site 2
	1306	
	1330	Shots 21-26 fired
	1420	
	1451	Deploy airgun array and manoeuvre
	1800	Shoot airguns to DOBS at Site 2
16	0300	
	0338	Recover air guns
	0435	
	0526	Recover DOBS A-F from Site 2
	1819	Recover acoustic beacons 2,4,5,6 from Site 2
	2315	

Operations in Area B

DAY	TIME	ACTIVITY
17		Transit to Area B
	0900	Arrive Site 3 Area B
	1001	Lay acoustic beacons 3A, 3B, 3C, 3D
	1422	Begin calibration of acoustic net. Abort because of fault in fish. Also beacon 3B may be faulty.
	2010	Recover and redeploy beacon 3B
	2359	
18	0120	Calibrate acoustic net. Problems with incorrect operation of calibration software by operator and with unknown source of acoustic noise.
	1902	
	1956	Deploy DOBS A-F at Site 3
19	0332	
	1043	Lay explosive shots 1-12 at Site 3
	1542	
	1600	Shots 1-9 fired
	1720	
		Lay explosive shots 13-24 at Site 3
	2146	
	2220	Shots 10-24 fired

DAY	TIME	ACTIVITY
20	0040	
	0200	Lay acoustic beacons 4A & 4B
	0400	
	1106	Lay explosive shots 25-30 at Site 3
	1337	
	1515	Shots 25-30 fired
	1700	
	1816	Lay explosive shots 31-37 at Site 3
	2142	
	2300	Shots 31-37 fired
21	0030	Deploy airgun array and manoeuvre
	0430	Shoot air guns to DOBS at Site 3
	1630	
	1650	Recover air guns
	1740	
	1900	Recover DOBS A-F from Site 3
22	0853	
	0922	Recover acoustic beacons 3B, 3C & 3D. Beacon 3A lost.
	1500	
	1646	Deploy acoustic beacons 4c & 4C
	1817	
	1945	Calibrate acoustic net at Site 4

DAY	TIME	ACTIVITY
23		Calibrate acoustic net at Site 4
	1237	Velocimeter dip
	1649	
	1928	Deploy DOBS A-F at Site 4
24	0249	
	1100	Lay explosive shots 1-11 at Site 4
	1602	Shots 1-9 fired
	1720	
	1745	Lay explosive shots 12-20 at Site 4
	2107	
	2220	Shots 10-20 fired
	2400	
25	1044	Lay explosive shots 21-29 at Site 4
	1512	
	1530	Shots 21-29 fired
	1730	
	1844	Lay explosive shots 30-38 at Site 4
	2140	
	2200	Shots 30-38 fired
	2400	


DAY TIME ACTIVITY
26
0020
Deploy airgun array and manoeuvre
0355
Shoot air guns to DOBS at Site 4
1830
1925
2020
Recover air guns
Recover DOBS A-F from Site 4
27
0954
1118
Recover acoustic beacons 4A-D from Site 4
1505
1608
1739
1828
Deploy air guns, streamer & 3.5 kHz
Seismic reflection survey of Sites 3 & 4
28
DAY TIME ACTIVITY
29
Seismic reflection survey of Sites 3 & 4
Seismic reflection line to mud volcanoes south of Area B
30
1215
1235
1400
1426
1455
1525
1711
Recover air guns, streamer & 3.5 kHz
Deploy 2 DOBS
Deploy airgun array
Shoot air guns to DOBS across m.v.
2026
2040
2125
2242
Recover air guns
Recover 2 DOBS
0115
Leave area for Trinidad
31

DIGITAL OCEAN-BOTTOM SEISMOGRAPHS (DOBS)

R.E. Kirk, C. Peirce, R.B. Whitmarsh

Preparations Ashore

Preparations for this cruise began during the summer of 1992 with the purchase of consumable items required for 26 DOBS deployments and the production of 130 ocean bottom explosive charges. These charges each required an electronic timer housed in an individual pressure case with electrical connector. Thus 130 timers were built and tested at IOSDL, and large quantities of batteries, cable, connectors and pressure cases were purchased.

Two more deployed geophone and arm assemblies (making a total of four to be used on the cruise) were built in the IOSDL workshops. A total of 6 DOBS (2 belonging to Durham University) were stripped to their component parts cleaned, rewired, assembled and pressure tested in readiness for the cruise. Once all preparations were complete, the DOBS, lab equipment and bottom shot hardware were loaded aboard the ship in Barry during December, 1992 for the transit to Trinidad.

The equipment was set up in the lab aboard ship during the two days in Port of Spain at the start of the cruise. Preparations for the first working site deployments and bottom shots began as we left port.

DOBS Deployments

The two tables below give details of the DOBS deployments and the PDAS data logger set-ups for each site. These are followed by brief comments for each site.

TABLE 1

TABLE OF DOBS DEPLOYMENTS

SITE	DOBS	POSN	PDAS	LAY TIME (GMT-4)	LAY POSITION LAT. °N	LONG. °W	DEPTH (uc.m)	NOTES
1	DDOBS1	A	111	1709/008	15 34.14	58 38.50	5005	
	WDOBS1	B	165	2001/008	15 31.75	58 38.50	4928	ext. package did not deploy, not lost
	WDOBS2	C	056	2128/008	15 31.75	58 38.45	4926	ext. package lost
	WDOBS3	D	055	2307/008	15 31.78	58 38.38	4926	ext. package lost
	WDOBS4	E	215	0046/009	15 31.89	58 38.33	4928	ext. package lost
	DDOBS2	F	112	0219/009	15 31.80	58 36.00	4886	
2	DDOBS2	A	112	1650/013	15 33.72	58 44.84	4919	
	WDOBS3	B	055	2220/013	15 31.01	58 44.59	4832	
	WDOBS4	C	215	2220/013	15 30.93	58 44.54	4833	with ext. package
	WDOBS2	D	056	2327/013	15 30.88	58 44.51	4833?	
	WDOBS1	E	165	0023/014	15 30.86	58 44.38	4855	
	DDOBS1	F	111	0124/014	15 30.59	58 47.69	4558	
3	DDOBS1	A	111	1602/018	14 29.82	57 35.00	5419	
	WDOBS1	B	165	1753/018	14 22.78	57 35.26	5337	
	WDOBS4	C	215	1938/018	14 22.95	57 35.09	5337	with ext. package
	WODBS2	D	056	2034/018	14 23.14	57 34.93	5336	
	WDOBS3	E	055	2121/018	14 23.28	57 34.77	5341	
	DDOBS2	F	112	2334/018	14 23.01	57 27.98	5354	
4	DDOBS2	A	112	1542/023	14 28.99	57 46.90	4897	
	WDOBS3	B	055	1758/023	14 22.53	57 49.56	4914	
	WDOBS4	C	215	1927/023	14 22.60	57 49.44	4906	with ext. package

	WDOBS2 D	056	2008/023	14 22.72	57 49.28	4909
	WDOBS1 E	165	2050/023	14 22.78	57 49.15	4890
	DDOBS1 F	111	2249/023	14 21.23	57 42.54	5256
TEST	WDOBS1	165	1054/030	13 48.26	57 39.19	? moored 200m off bottom
SITE	WDOBS2	215	1025/030	13 48.24	57 39.01	4871 with int. + ext. package

TABLE 2

TABLE OF PDAS RECORDING DETAILS

DOBS	PDAS	PRIMARY (sps/secs)	SCNDRY	CH USED Z Y X H	CLOCK CHECK	NOTES
SITE 1						
DDOBS1	111	1000/40	100/10	1 2 3 6	N	stopped at end gun window 1. H gain range problem
WDOBS1	165	1000/40	100/10	1 2 3 4	N	Z spiky. last quarter gun window 4 lost
WDOBS2	056	1000/40	100/10	1 2 3 6	N	last 2 gun windows lost
WDOBS3	055	1000/40	100/10	1 2 3 6	N	H,Y very noisy
WDOBS4	215	1000/40	200/9	1 2 3 4	N	
DDOBS2	112	1000/40	100/10	1 2 3 6	N	half gun window 4 lost
SITE 2						
DDOBS2	112	1000/40	100/15	1 2 3 6	N	all channels good on all DOBS
WDOBS3	055	1000/40	100/15	1 2 3 6	Y	
WDOBS4	215	1000/40	100/15	1 2 3 4	Y	
WDOBS2	056	1000/40	100/15	1 2 3 6	Y	
WDOBS1	165	1000/40	200/9	1 2 3 4	Y	
DDOBS1	111	1000/40	100/15	1 2 3 6	N	
SITE 3						
DDOBS1	111	1000/40	100/15	1 2 3 6	N	all channels good on all DOBS
WDOBS1	165	1000/40	100/15	1 2 3 4	Y	
WDOBS4	215	1000/40	100/15	1 2 3 4	N	
WODBS2	056	1000/40	100/15	1 2 3 6	N	
WDOBS3	055	1000/40	200/9	1 2 3 6	N	
DDOBS2	112	1000/40	100/15	1 2 3 6	N	
SITE 4						
DDOBS2	112	1000/40	100/15	1 2 3 6	N	all channels good on all DOBS
WDOBS3	055	1000/40	100/15	1 2 3 6	Y	
WDOBS4	215	1000/40	100/15	1 2 3 4	Y	
WODBS2	056	1000/40	100/15	1 2 3 6	N	6 H ch. files lost, disk problem
WDOBS1	165	1000/40	200/9	1 2 3 4	Y	
DDOBS1	111	1000/40	100/15	1 2 3 6	N	
TEST SITE						
WDOBS1	165	200/15		1 2	Y	noisy data due to strumming
WDOBS2	215	200/15		1 2 3 ext 4 5 6 int	Y	only 185 files recorded per channel

NOTES:

1. DDOBS = Univ. Durham DOBS, WDOBS = IOSDL Wormley DOBS

2. CLOCK CHECK refers to whether the DOBS clock was still powered up on recovery thereby enabling the clock drift to be checked

Site 1

Six DOBS were deployed, four IOSDL units had external deployable geophone packages and the two Durham instruments used internally mounted geophones. Both triaxial sets of geophones were gimballed. All instruments carried a hydrophone. Poor weather conditions made preparation and launching uncomfortable. Extra time was required on deck to rig the external geophones and other delays meant that these deployments took 15 1/2 hours, much longer than anticipated. Bottom shots and airgun lines were fired to the array of DOBS.

Some time after the deployments it was realised that the external packages had not been properly secured to the line by which they would be pulled up from the sea bed and as a direct result of this three of the four packages were lost on recovery of the instruments. One geophone package failed to deploy from the instrument and was recovered with the DOBS.

Recovery of the DOBS was difficult as acoustic contact was made with only two units, the other four being released by internal timer. All DOBS were easily located on the surface by means of their flashing light and radio beacon. Acoustic problems were attributed to moisture in the slip-rings of the PES winch as all DOBS acoustics functioned perfectly when tested immediately after recovery. The PES fish was subsequently recovered, the transducer connectors cleaned and the slip-rings dried.

All loggers had functioned and recorded data; however a variety of noise problems was evident, associated with the IOSDL DOBS with deployed geophones. The noise was particularly evident on the hydrophone channels. The conventional arrangement of the two Durham instruments produced good data on all channels. Earth loop problems were the suspected source of the spurious signals. It was decided that a different type of encapsulated hydrophone should be used on the next deployment of the one remaining external geophone package.

Site 2

Internally mounted gimballed triaxial geophones were fitted to three IOSDL DOBS as replacements for the lost external packages. The single DOBS with external geophones had a Benthos hydrophone fitted, kindly made available from the Durham spares.

Again all six instruments were deployed and bottom shots and airgun lines were fired. Instrument preparation and deployment time was reduced to 11 1/2 hours. Recovery of all but one instrument was by means of the acoustic command. Acoustic contact was made with the final instrument only some 25 minutes after the back-up timer had released the instrument. Once again this acoustic unit functioned perfectly when tested aboard ship.

All loggers functioned correctly and good data records were acquired by all instruments. The hydrophone loaned from Durham produced good results so this arrangement was kept for the rest of the cruise.

Site 3

Instrument launch, bottom shot deployment and airgun operations were now proceeding efficiently. Despite an intermittent fault on one of the acoustic deck units contact was made with all DOBS prior to release. The first instrument was allowed to release itself by its back-up clock as a test. Loggers and sensors produced good recordings on all instruments.

Site 4

DOBS preparation and deployment was carried out in some 9 1/2 hours, about 2/3 of the time taken at Site 1. Instrument recovery proceeded smoothly as all were released under acoustic command and once again all radio beacons and flashing lights performed faultlessly. All instruments recorded good data on all channels.

Deployments at the Test Site

Two DOBS were deployed at a Test Site at the end of the cruise. One DOBS deployment was designed to measure the far-field waveform of the airgun array and the other to perform a direct comparison of signals recorded concurrently by a set of internal (ungimballed) and external (gimablled) geophones. The first DOBS was moored 200 metres above the sea bed and recorded on 2 hydrophone channels. This DOBS was also unusual in that it was released by a fizz-link instead of the standard pyrolease. Unfortunately no useful data were recorded; a strong ca. 5 Hz strumming noise, possibly of the mooring line, swamped all the signals from the airgun array on both hydrophone channels. The second DOBS recorded only 185 out of the expected 390 files per channel, possibly because the PDAS could not handle the rate of data acquisition and transfer to the hard disk. However the data that was acquired is of excellent quality and will help us to understand better the performance of the external geophones.

PDAS Power Requirements

Some post-deployment checks of the logger clock could not be carried out due to lack of battery capacity (the clocks had stopped on recovery). This was due to the fact that the deployments were slightly longer than originally anticipated and the unpredictable duty cycle of power hungry disc drives made power budgeting difficult. Logger battery supplies (parallel stacks of 15v Lithium cells) were increased from 3 x 8Ah at Site 1 to 4 x 8Ah at Site 2 to 5 x 8Ah at Sites 3 and 4. This left just two battery packs for the final two instrument deployments.

Data Handling, Transfer and Storage

The data recorded on the Teledyne Geotech PDAS-100 dataloggers used inside the DOBSs are stored in 14/2 bit gain-ranged format as binary files using the DOS filing system. Two types of storage medium were used in combination during this cruise: firstly, 3 Mbytes of solid state RAM located internally within each PDAS; secondly external hard disks. The majority of the external hard disks used have a data capacity of 42 Mbytes and operated well with low power consumption. Two 123 Mbyte hard disks were tested for the first time on the two Durham instruments and although they proved to have longer spin up times, they functioned satisfactorily. These larger disk drives also have a slightly higher power consumption resulting in a greater drain on instrument batteries and hence a reduction in possible data collection time.

The data recorded by the DOBSs were transferred to the hard disks of two DOS-based PCs (one IOSDL IBM PS/2 PC, one Durham Dell 386 machine), using a kermit-based system using a parallel interface between the PDAS and the setup computer. This process proved exceedingly time consuming, averaging about 3.5-4 hours to transfer ca. 25 Mbytes of data, and significantly restricted the turn around time possible between successive DOBS deployments. Two copies were made, of the data recorded by each DOBS, one on each of two separate magnetic tapes (DC600A - using QIC-02 format). The speed of this stage of the process was rather restricted by the speed of the IBM PC (model PS/2 50Z) which took more than 6 times as long as the Dell to write and verify each tape! In the light of the increased amount of data collected during recent experiments (more than 0.6 Gbytes compressed during this cruise!) it must be recommended that this machine be upgraded to at least a 386 as soon as possible for future experiments.

Finally, the recorded signals were inspected in the first instance using a basic record-section plotting program written by CP and Tim Le Bas (IOSDL) and DADiSP to look at the airgun traces and longer bottom shot windows, respectively. This process served as a check for the correct functioning of each instrument, to aid in the design of later experiments conducted during this cruise and to verify data quality. This process was carried out using an IOSDL IBM AT. This machine proved to be 'underpowered' to deal with the large volume of data being checked. It took a considerable time to read each tape, degainrange the data, plot and print a selection of traces from each channel's primary and secondary windows. It is also strongly recommended that, if a similar scale DOBS cruise or cruises are planned in future, the IBM AT be upgraded to at least 386.

Experimental Design and PDAS Programming

The PDAS dataloggers are based on PC XT architecture and hence are rather limited in their processing power. The 'idealised' experimental design on this cruise called for relatively long primary windows of 4-channel data, collected at the maximum sampling rate (1000 sps), at relatively frequent repetition rates for the explosive bottom shots and for shorter secondary windows at a lower sampling rate (200 sps), recorded at a higher repetition rate for the airgun shots. These criteria proved to be beyond the technical specifications as outlined in the PDAS operator's manual and hence an in-lab test was conducted before the first experiment to test the ability of the datalogger to collect valid data reliably using these 'ideal experiment' parameters.

This lab test showed that the PDAS cannot really accommodate data collection at these sampling rates, window lengths and repetition rates without the clock reliability being affected, the possibility of data corruption being reported in the status files and with the hard disk data copying not being completed during the 'off times'. The latter factor leads to data corruption and excessive power consumption.

As a result of this test it was felt that the secondary sampling rate should be reduced to 100 sps on all but one of the instruments. Even at this lower rate some 'possible data corruption' was reported during disk copying operations. In general however, the instruments successively completed their programmes and recorded very high quality data.

External Geophone Packages

This was only the second cruise on which the IOSDL external geophone packages had been used. Therefore their use was still somewhat experimental. We encountered a number of problems with the use of the packages. The first problem was the loss of 3 of the 4 packages at Site 1 when, by an oversight, the packages were not connected to the lower end of the rope designed to lift them from the sea bed when the DOBS begins its ascent. The packages were connected to the DOBS only by their electrical connectors which, although just strong enough to lift the packages back to the surface in some cases, were unable to withstand the strong surge forces experienced on recovery and were lost. Fortunately, for an unknown reason, one geophone package did not deploy at the sea bed and this package was retrieved for further use during the cruise.

Inspection of the data later in the cruise revealed that there was a possibility that sometimes the external geophone package had not deployed at the sea bed, even though on retrieval it was found to be detached from the arm. At Sites 1 and 3 the recorded signals on PDAS 215 had features in common with data recorded by the 'suspended', i.e. undeployed, external package of PDAS 165 at Site 1. A careful inspection of the geophone package release mechanism revealed a number of potential sources of malfunction and suggested some simple modifications which were implemented in time for the final deployment at the Test Site at the end of the cruise. At this site the PDAS recorded before and after the deployment of the external package thereby qualitatively confirming our earlier suspicions.

Data Quality

The acquisition of DOBS data during the cruise followed a familiar pattern i.e. once a few initial problems had been sorted out the collection of high quality data became almost routine. Although with the time and resources available at sea it was not possible to inspect all of the thousands of traces recorded (approximately 3000 bottom shot traces and 57000 airgun traces) we did manage to check the quality of data recorded by each sensor immediately after every site, usually based on recordings of the airgun array. It was assumed that if the sensors were working correctly for the airgun recording windows then the bottom shots, which preceeded them, would have been correctly recorded too. Airgun traces were displayed with the IOSDL program TRACES (which also automatically degainranges the files read off the Everex cartridge tape) and bottom shot traces were displayed one at a time using DADiSP after degainranging and converting the binary files to ASCII characters.

At Site 1, the two Durham DOBS (DDOBS) both stopped recording early because their battery packs became exhausted and consequently some airgun shots were not recorded (Table 2). The hydrophone channels of these DOBS also exhibited unusual amplitude reductions on many traces often at the same times after the beginning of the airgun recording windows. Although not serious this problem persisted throughout the cruise. At present we can only speculate on the cause of this problem. The principal problem at this site however was the quality of the data recorded by the Wormley DOBS (WDOBS), all of which were fitted with external geophone packages. On PDAS 055, for example, the hydrophone channel was especially noisy to the extent that all signal was swamped and the geophone channels were more noisy than usual. On the Z-channel of the bottom shot traces the noise consisted of a regular 24 Hz waveform of alternating positive and negative spikes. The same pattern of a very noisy H channel and slightly noisy geophone channels all contaminated by 24 Hz was seen on the other three WDOBS.

Since we had never before experienced this sort of problem with the PDAS system we considered what was new or different about the current DOBS set-up compared with our earlier work. The clue seemed to be the use of a hydrophone with an external geophone package. During the only previous deployment of a geophone package on Darwin Cruise 55, when excellent data had been acquired, we had not used a hydrophone. We also recalled experiencing similar problems in 1989 when trying to use a hydrophone with a pre-amplifier in a pressure case at a distance of a few tens of metres from the DOBS. But if the hydrophone was contributing to the problem then why were the DDOBS H channels providing clean data? The answer seemed to lie in the different hydrophones employed by the DDOBS; they use Benthos hydrophones encapsulated in rubber whereas the OAS hydrophones in the WDOBS have metal cases. The evidence therefore pointed towards a sea-water electrical loop via the metal case of the WDOBS hydrophones. One possible source of the 24 Hz, to be investigated ashore, is the oscillator in the timer used to delay the release of the geophone package after deployment. The adopted solution for Site 2 therefore was to mount a Benthos hydrophone on the WDOBS with the one remaining external geophone package.

At Site 2, we were rewarded with excellent data on all channels of all 6 DOBS including those of PDAS 215 which was in the DOBS with an external geophone package. Even so the airgun geophone traces of PDAS 215 did show a slightly different character to those of the other DOBS; the water-waves were relatively weak and the post-direct-sound arrivals were relatively strong. This is puzzling and will be investigated ashore. It could relate to a problem with the deployment of the external geophone package itself.

Good data were also acquired by all DOBS at Site 3, although remarks similar to those made about Site 2 are applicable to the traces from the external geophone package. There is some evidence that the geophone package may not have deployed at the sea bed. The airgun traces showed that ground waves had been recorded from the rather small (1426 in^3) airgun array out to a range of 22 km.

Lastly, good data were acquired by all DOBS at Site 4, where there is also evidence that the external geophone package deployed successfully.

An important feature of the bottom shot traces played out at sea was the fact that the 90 pound shots, which had been designed for shooting to the relatively long range of 12 km, were powerful enough to generate body wave arrivals of adequate energy. Further we were able to show that the direct water-wave arrival from these shots could be distinguished easily at ranges of 12 km; it had been feared that refraction effects in the water would so reduce the amplitude of this arrival as to make it undetectable.

Increases in noise were occasionally noticed on some airgun traces. This was attributed to the vibrations caused by spinning of the hard disk while data was being written to it. The problem is more severe for the 123 Mbyte disks used on the Durham DOBS; the 42 Mbyte disks in the Wormley DOBS also generate noise which is usually well above the seismic frequency band of interest and can be filtered out when record sections are produced.

EXPLOSIVE SHOTS

K. Smith

The explosive exercise this cruise was quite demanding in both time and labour. The exercise consisted of the construction and deployment of 123 bottom charges of either 20 or 90 lbs in weight (one charge 15 lb weight was deployed).

Charge design and construction

Each charge consisted of a D1012 high-pressure electrical detonator and P2180 Ensign Bickford 80 RDX nylon detonating cord, bought from Jet Research Labs, Aberdeen, and 80L (5 lbs) Trojan Super Prime pentolite boosters purchased from Exchem, Alfreton.

Table 3 shows the dimensions, weights and calculated terminal velocities of the two different charge sizes used on the cruise.

TABLE 3

PRINCIPAL CHARGE PARAMETERS

WEIGHTS (KG)	AIR (KG)	WATER (KG)
20 LB CHARGES (4 X 5 LB)		
Charge tube (143 dia. x 706 L mm) 0.7	0.14	
Explosive	9.1	3.4
Metal weight	5.2	4.5
	15.0	8.0
90 LB CHARGES (18 x 5 LB)		
Charge tube (281 X 950 L mm)	0.7	0.34
Explosive	40.9	15.3
	42.6	15.6

CALCULATED TERMINAL VELOCITIES (M/SEC)

1) clock tube*	2.7
2) 20 lb charge	3.3-3.4
3) 90 lb charge	2.4-2.5

* to prevent the clock tube overtaking the 90 lb charges a 120 mm wide disk was added to the clock tube at the connector end to increase its drag.

All charges deployed had to be built up and placed inside PCV tubes; see drawings IOS/C567 GA4 for details of the 20 lb charges and IOS/C5567 GA3 for the 90 lb charges.

The 20 lb charges were relatively straightforward in their construction, the method being as follows:

(1) A steel billet is placed into the bottom of the PVC tube. This weight causes the package to sink at about 3.3 m s^{-1}.

(2) On top of the weight a felt pad is placed.

(3) A length of RDX80 primercord is cut from the reel. One end is waterproofed with a rubber cap and mastic pad. The other end is sealed with a rubber cap.

(4) Four of the individual blocks of pentolite explosive, each weighting 5 lb, are placed on the table to be made into the main charge, in this cause the explosive used was Superprime booster explosive.

(5) The length of RDX80, starting with the sealed end, is wound around one of the blocks for approximately eight turns in a tight spiral taking care that none of the turns cross over.

(6) A length of cord is then fed through each individual block of explosive using the integral fuse and detonator channels.

(7) The charge with RDX80 wound around is placed third in line of construction, ie last but one in line of construction.

(8) When all four blocks have been threaded the cord is tied. The free tail of RDX is then wound in a loose spiral along the length of the top charge and taped in place, leaving a free tail approximately 8" in length.

(8) The whole package is then fed into the PVC tube taking care not to drag the RDX away from the explosive.

(10) A felt pad is placed on top of the charge, and a PVC cap is placed on top of the pad.

(11) The PVC cap is then held in place by six screws around the circumference of the PVC tube.

(12) A suspension rope with PVC "cotton reel" is secured to the top of the tube.

The charge is then ready for deployment (see diagram).

The 90 lb charges took somewhat longer to construct and used a slightly different method of construction.

(1) A felt pad is placed inside the PVC tube (no weight being needed).

(2) A length of RDX80 primercord is prepared in a similar manner to the 20 lb charges.

(3) With these charges, because of their size, the main explosive charge for the tube is prepared in two parts, each part being constructed of three layers of three blocks.

(4) Each half of the charge is again tied together to hold the charges in place.

(5) The RDX80 is wound around the layer of charges in the top half at the bottom (eight turns) and the free tail spiralled and taped to the top of the charge leaving a free tail protruding.

(6) The felt pad and PVC cap are again secured in place by eight screws around the circumference of the tube.

(7) A suspension rope with two PVC "cotton reels" is then secured to the top of the tube.

(8) During construction of the charge two rope handles were tied into the tube to help with deployment and handling on deck.

The charge was then ready for deployment.

Deployment

All charges were deployed using much the same method, each charge undergoing the same process of having the detonator fitted and electrical timer wire attached.

(1) Each charge was brought to the deployment table.

(2) The RDX80 free tail was cut to length.

(3) The electrical detonator was then crimped to the RDX.

(4) The joint of the RDX and detonator was then watersealed, as much as possible, using mastic pads sealing the edges with rubber solution, initially rubber solution as placed around the det/RDX joint before the mastic pad, but this was discontinued partway through Site 3 and appears to have cut down the number of misfires.

(5) The detonator sealed with the mastic was secured to the support pillar of the PVC cap with tape.

(6) The joints in the electrical wires of the detonator and timer cable were made up and sealed in the same method as the detonator and RDX.

(7) The electrical timer cable had been taken from the winch and through a small sheave block (snatch block) suspended over the stern by the "A" frame and then back to the table, before connection to the detonator.

(8) The wire was then tied to the cotton reel of the suspension rope on the tube.

(9) Before the electrical wire was connected to the detonator care was taken to ensure that when the suspension rope was taut the electrical connection had no strain on it.

(10) On the signal to commence deployment the charge was taken to the stern and lowered by hand into the sea whereupon the winch brake was released and the charge allowed to sink, the electrical wire on the winch drum free-wheeling outboard pulled by the weight of charge.

(11) Once outboard, the charge being 100 m from the ship for the 20 lb charges and 200 m for the 90 lb charges, the wire was released from the winch passed through the block, the timer was then attached and the charge released to free fall to the sea bed.

With the 90 lb charges, because of their physical size, a slightly different method of deployment was used. A ring was suspended alongside the sheave block under the "A" frame. A rope 200 m in length was placed on a reel stand around a cleat, screwed into the deck, through the suspended ring and back to the table, where the rope was tied to the second of the PVC "cotton reels" fitted to the large charges.

On deployment of the 90 lb charges the rope and not the electrical cable took the strain of the weight of the charge whilst being lowered to the surface during sinking and fitting of the electrical timer. On release of the timer the rope was cut outboard of the block.

Results

As previously stated 123 charges were deployed at the four sites as follows:

Date	Site no.	Size of charge	No. off
9/1/93	1	20 lb	18
10/1/93	1	20 lb	4
14/1/93	2	20 lb	20

15/1/93	2	20 lb	6
19/1/93	3	20 lb	24
20/1/93	3	90 lb	13
24/1/93	4	90 lb	4
		20 lb	15
		15 lb	1
25/1/93	4	90 lb	10
		20 lb	8

Misfires were experienced as follows:

Site no.	Size of charge	No. off
1	20 lb	4
2	20 lb	5
3	20 lb	1
	90 lb	2
4	20 lb	3

A total of fifteen misfires. This gives an approximate success rate of 87.8% of the charges laid initiating at a water depth of approximately 5300 metres.

Modifications

During the construction and deployment of the charges a few modifications were made to the basic design and should be incorporated in any future experiment:

(1) As mentioned, the use of rubber solution to seal the joint between the dets and RDX primercord before applying a mastic pad was discontinued at Site 3 as it is possible the rubber solution stopped the mastic bonding to itself.

(2) All the PVC top caps had their support pillars moved from a central position to a point approximately 1"-1$\frac{1}{4}$" in from the inside of the PVC tube. This allowed for a much easier lay of the RDX primercord and positioning of the detonator.

(3) Extra holes of approximately $\frac{3}{4}$ diameter were drilled in the casing of the 90 lb charges. This was to allow water to full the case much quicker at the surface during deployment. Two sets of four holes each 18" apart were drilled towards the base of the tube.

(4) The number of rope handles on the 90 lb tube were reduced from three to two. This made the deployment a lot easier as one person could stand either side of the tube opposite each other.

Conclusion

Altogether a fairly successful explosives experiment, which was a credit to everyone involved, especially to the officers and crew aboard the Charles Darwin whose invaluable assistance made the exercise run so much easier and made it so successful.

SEISMIC REFLECTION PROFILING

Grids of seismic reflection profiles were run at each of the four sites to define the principal seismic boundaries within the sedimentary section to provide a starting model and constraint for the interpretation of the seismic data recorded by the DOBS. Only a few lines, along those of the shots to the DOBS, were run at Site 2, because it is already covered by a 3-D survey carried out by the Institute for Geophysics of the University of Texas at Austin from the R/V Maurice Ewing in June 1992. The reflection profiles were run with a streamer with 8 contiguous 50-m active hydrophone sections, giving 25-m common mid-points. The shot spacing was 50 m, giving four-fold cover.

Airgun Array

An array of seven air guns, of total capacity of 1426 cu. in., was employed for both the reflection profiling and shooting to the DOBS. Using the same seismic source should make comparison of the two data sets simpler. The array was the same as that designed for Cruise 40 of the RRS Charles Darwin, and has a good peak-to-bubble ratio. The guns were deployed on two beams or towed singly behind the ship as follows:

80, 100, 120 cu. in. starboard beam
160, 200 cu. in port beam
300, 466 cu. in. towed singly

The tow depth was 10 m. The centre of the array was 46 m from the stern of the ship. Initial deployment of the air guns took five hours, because of problems and faults discovered during the deployment, but subsequently it took about an hour and half to deploy the array. In general, the guns worked reliably. There were two occasions when guns failed and had to be retrieved.

Seismic Streamer

The seismic streamer was composed of elements of the Geomechanique streamer. Its make-up was as follows:

162-m tow cable from stern of ship
25-m spring section
10-m weighted section
25-m spring section
1-m depth section
5 x 50-m active hydrophone sections
1-m depth section
3 x 50-m active hydrophone sections
1 x 50-m neutral section
1 x 25-m spring section
tail rope

The centre of the first active section was 202 m from the centre of the airgun array. Depth controllers (birds) were attached to the streamer at the two depth sections and were set to a depth of 10 m. Only one of the two depth sensors worked and so it was not possible to check how level the streamer towed. The working depth sensor, at the head of the first of the active sections, showed depths of between 9 m and 12 m.

SAQ1 Digital Seismic Recording System

The system worked moderately well. It is still prone to "hanging up" with consequent loss of data. This occurred four times during the cruise. The eight channels of data were digitised with a 2 ms sample interval and using a 125 Hz anti-alias filter. Record lengths were generally 5 s in Area A and 7 s in Area B, but some data were recorded with a 10 s record length to capture the seabed multiple for subsequent determination of the reflection coefficient of the sea bed. A recording delay of 5 s was used for the records to allow for the great water depth. The data tapes number from 1 to 32.

Data

In Area A, the data suffered from tow noise in the streamer brought about the swell. Even so, all the major reflectors are visible on the monitor records. During reflection profiling in Area B, the swell and wind speed were about half as great as they were in Area A, and the data were far less noisy. The quality of the data is good. Although in this area of much greater sediment thickness (up to 5 time greater than Area A) the deeper reflectors are not always shown clearly on the monitor records, processing and redisplay should make them clearer. Preliminary proccesing of some of the data has demonstrated this already.

ACOUSTIC NAVIGATION

The Oceano acoustic navigation system was required to give an internally consistent method of navigation accurate to a few metres, that would not be subject to the dithering applied to GPS. It provided a real-time system for guiding the ship to the drop positions for the DOBS and explosive shots. Although successful in general, the system suffered badly from the noise generatedby the bow thruster, and so the efficiency of quick and accurate deployment was crucially dependent on the technique of the officer of the watch in bringing the ship on to station. Continuous use of the bowthruster was counter productive, as it was not possible to find the ship's position, unless the bowthruster was not running. Apart from this there were also some technical problems with the system.The cable connections to the transducer fish for the Oceano acoustic navigation system had to be remade, because of breaks in the wiring and leaks, and the towing arrangements were not satisfactory. The fish was towed from the davit for an accommodation ladder on the port side of the after deck. This davit has a very short reach, and the cable was frequently rubbing against the ship's side. A mooring rope and a rope fender were rigged along the ship's side to protect it during the cruise. More seriously, the fish is not very directionally stable, and often dived under the ship's stem, bringing the tow cable close to the ship's propeller. On one occasion the fish appeared astern of the ship to starboard of the ship's centre line. All turns, except the most gentle, had to be made to port to avoid bringing the fish under the stern of the ship. This often made manoeuvring to lay ocean-bottom seismometers and explosives unnecessarily complicated. The fish towed at quite a large angle from the vertical, and the cable commonly strummed and vibrated. The cable should have been faired, but the clip-on fairings brought on the cruise fell off the cable almost immediately after deployment. The sheave in the block on the davit had too small a radius for the thickness of cable used.
An additional problem at site 3 was acoustic interference from an unknown source that triggered the beacons, so that they produced false ranges to the ship. The source of this interference was less active at night, was absent during one lunch hour, and stopped for two or three minutes following the detonation of each bottom shot. No surface ships were within the 30 km acoustic horizon of the system during the period when the interference occurred.
An acoustic beacon (3A) failed to come to the suface at site 3. Its acoustic range indicated that it was lying on the sea bed rather than suspended 200 m above, and so it appears that the beacon's flotation spheres had imploded or broken away. Examination of the seismic recordings of the four shots closest to the beacon (The nearest was 1300 m away.) showed no sign of implosion of a sphere triggered by the explosions.

VELOCIMETER

The velocimeter was used twice to provide the variation of velocity of sound in the water with depth. for both the acoustic navigation system and for ranging between the DOBS and the shots (airgun and explosive) On both occasions all the sound speed measurements were about 10% too low, but not incorrect by a simple scaling factor. The values were checked by making measurements on deck with the velocimeter in buckets of sea water and pure water at different temperatures. The downward and upward runs of the velocimeter on both occasions showed quite different curves of sound speed as a function of depth.

EXPENDABLE BATHYTHERMOGRAPHS (XBT's)

R.B. Whitmarsh

Four T-4 XBT's were successfully deployed to their maximum depth of 450 metres during the cruise, one at each of the four sites (Table 4).

TABLE 4

XBT DEPLOYMENTS

SITE	TIME/DATE (GMT-4)	LATITUDE °N	LONGITUDE °W
1	1521/013	15 33.0	58 38.0
2	1518/014	15 30.8	58 44.6
3	1939/016	14 23.3	57 37.5
4	1317/021	14 24.9	57 45.9

ACOUSTIC LOCATION OF DOBS

N.P. Mountney

Following deployment of the DOBS at each of the four sites a computerised method for calculating their seabed position was employed. Accurate location of the instruments on the seabed enabled the amount and direction of drift, from the drop position to the seabed position, to be quantified. Sonic pulses transmitted regularly from the ship trigger a response signal from the DOBS. These emitted pulses arrive back at the ship with varying time, due to its motion. The intervals between these pulses and the position of the ship with time were used as data for an inversion to locate the instruments. The intervals between the pulses were recorded on a Waverley plotter and transferred to the input file by hand. These intervals were two-way travel times and had to be halved as the software was written for use with pulses emitted directly from the seabed instrument. The GPS data file was stored on a SUN workstation and, once transferred to a PC, could be read by the software via the GPSCON file conversion routine. The software consists of a set of four programs. GPSCON merges the raw GPS data file, a file containing the interval times and a header file into a single output file. Program CONVERT reads this data and converts it into UTM geographic grid co-ordinates. Program READ formats this data ready for input into program INVERT which performs the inversion calculation and predicts the seabed location. If the water depth is known then the only unknowns are the latitude and the longitude. In such a case INVERT performs a two dimensional inversion. If the depth is unknown then a three- dimensional inversion can be used to locate the instrument. A two-dimensional inversion was performed on the data collected during cruise CD75 since the water depth was accurately known from on board sonar instruments. The only other required information is the average water velocity, which was measured using a velocimeter and corrected for velocity change with depth. Once INVERT has predicted a bottom water position then CONVERT can be used again to convert the results from geographic grid co-ordinates to degrees and minutes.

Procedure for transfering GPS data to PC system

open shelltool window

anylist -sYYDDDHHMMSS -eYYDDDHHMMSS -i60 -dprintgps.fmt >
/rvs/pro_data/tmp/sonar/filename <ENTER>

where:
-s is the start time for the GPS data required
-e is the end time for the GPS data required
-i is the time interval for data acquisition (seconds)
-d is the format of the file

It is also possible to specify a data source other than GPS. This is performed by using the -f flag:-

-fbestnav
-fgpsav
-facnav

/rvs/pro_data/tmp/sonar is the path set up specifically for cruise CD75

Once the file has been created it must be transferred from the SUN to the PC. On the PC change to the directory that contains the file (eg. N:) and type the command

UNIX2DOS filename1 filename2

This converts the file from UNIX format to DOS format.

Using a text editor delete the first line of the file which contains the column headings. The file is then ready for input into the GPSCON program.

Other data required by GPSCON is the interval time data of the pulses. These times should be stored in a separate file and are assumed to be two-way travel times. GPSCON will convert the data to one-way travel times. These times can be entered in the format of distances in mm. across the width of the printout, assuming that the width of a full one second interval is known.

The remainder of the technical information for running the software can be found in the MSc thesis by M. Sheath (University of Birmingham, 1992).

Interpretation of Results

TABLE 5 ACOUSTICALLY LOCATED POSITIONS OF DOBS ON SEA BOTTOM

DOBS NO.	DROP POSITION		BOTTOM POSITION		DRIFT	
	LAT.	LON.	LAT.	LON.	BEARING	AMOUNT
S1DC056	15 31.75	-58 38.47	15 31.59	-58 38.34	144°	375m
S1DD055	15 31.78	-58 38.36	15 31.55	-58 38.19	143°	547m
S2DA122	15 33.70	-58 44.83	15 33.53	-58 44.65	137°	455m
S2DB055	15 31.01	-58 44.59	15 31.06	-58 44.58	009°	88m
S2DD056	15 30.87	-58 44.51	15 30.93	-58 44.47	032°	118m
S2DE165	15 30.84	-58 44.39	15 30.86	-58 44.34	295°	100m
S2DF111	15 30.59	-58 47.69	15 30.72	-58 47.79	323°	294m
S3DA111	14 29.80	-57 35.80	14 29.88	-57 34.93	068°	342m
S3DB165	14 23.78	-57 35.26	14 22.85	-57 35.14	054°	250m
S3DD056	14 23.40	-57 34.93	14 23.14	-57 34.84	084°	188m
S3DE055	14 23.28	-57 34.77	14 23.30	-57 34.70	067°	140m
S4DA112	14 28.99	-57 46.90	14 29.12	-57 46.75	049°	370m
S4DB055	14 22.52	-57 49.56	14 22.68	-57 49.44	036°	386m
S4DC215	14 22.60	-57 49.43	14 22.89	-57 49.28	028°	605m
S4DD056	14 22.72	-57 49.28	14 22.86	-57 49.15	042°	330m
S4DE165	14 22.77	-57 49.15	14 22.96	-57 49.04	031°	395m

A clear relationship for drift between the drop position and the bottom position of the DOBS at the four sites is difficult to identify. From the 16 DOBS that were located on the seabed it is clear that drift may occur in any direction and the amount of that drift varies from less than 100m to over 600m. The drifting of DOBS that were deployed relatively close to each other, in terms of both time and space, does show some limited relationship in certain cases. At site 3, the drifting of DOBS B, D and E lies within a 30 degree range and amount of drift varies from 140-250 m. Similarly at site 4, DOBS B,C,D and E all lie within 14 degrees and three of the four appear to have drifted between 330-386 m. While these figures cannot be said to correlate well, they do show an overall trend. This does not enable us to make any deductions concerning the nature of ocean currents within the drop area. Re-adjustment of drop positions in order to anticipate drifting and attain more accurate bottom water positions cannot be easily achieved in the Barbados region.

3.5 KHZ PROFILER

The 3.5 kHz profiler was run when reflection profiling was being undertaken. It was towed from its own davit on the starboard side. of the after deck The data were recorded in analogue form on a Raytheon electrosensitive paper recorder. The 3.5 kHz records were of generally good quality.

10 KHZ PRECISION ECHO-SOUNDER

The 10 kHz precision echo-sounder was used with the towed transducer throughout the operations in Areas A and B and the line across the mud volcanoes south of Area B, except when deploying and retrieving the DOBS. The data were displayed on a chart recorder and digitised and logged directly on the level B system. The PES fish was used to transmit signals to and receive signals rom the DOBS, during their deployment and retrieval. Over the rough sea bed of the accretionary wedge the 10 kHz records give only an indirect measure of the shape of the sea bed, but existing multibeam bathymetry already provide this.

SHIP PERFORMANCE

The ship performed satisfactorily throughout the cruise, with the exception of the poor arrangements for deployment of the transducer fish for the Oceano acoustic navigation system. Also, the constant temperature laboratory, which was used to replay data from the ocean-bottom seismographs, was both noisy and too warm. A better display of navigational information should be provided in the main laboratory. The existing displays of gyro, log and transit satellite receiver should be grouped together, not spread around the lab as at present, and there should be a display of GPS position in degrees, minutes and decimal fractions of a minute. During the cruise, the only way to display GPS data was to list them from the navigation files on a Sun in the computer room, other than on the Level B monitor which gives position in degrees and decimal fractions of a degree and is a rolling screen display with a short residence time for information displayed. What would be suitable would be a remote display of the Racal-Decca CVP 2500 that is on the bridge, so that track and way points can be monitored easily, or a similar display with real-time track plotting.
The cruise posed the ship's officers with some problems in ship handling to ensure that the DOBS and explosive shots were dropped within 50 m of their designated positions and to ensure that the ship was running along the correct portions of the airgun shot lines during the DOBS recording windows. These objectives were not always achieved, as some of the officers found the tasks difficult, especially early in the cruise. They were not daunted by the problems, however, and improved their performance greatly as they developed their techniques for overcoming these problems. In more conventional aspects of ship handling, such as picking up beacons, a high level of professional competence was demonstrated. Over the whole cruise the ship's master, officers and crew were most cooperative and friendly, and in particular, provided invaluable assistance with the preparation and deployment of the explosive charges.

WEATHER
R.J. Campbell

The wind was almost constantly from an easterly direction, with a mean direction of 083°. This is characteristic of the trade winds in this region. The average wind speed was 10 m/s (20 knots). On 22 January it dropped to minimum of 1.5 m/s, and between 8 and 14 January it achieved maxima of over 15 m/s (30 knots), excluding gusts. Wind waves had an average height of 2 m, but of greater importance were the swell waves which had an average height of 7 m (peak to trough). These swell waves were always present and came from a mean direction of 070°. Rain was infrequent and isolated, usually occurring as short moderate-to-heavy bursts (eg. 9 January), with a few light showers (eg. 22 January).

SHIP'S COMPANY

MARINE

R.A. Bourne	Master
C.M. Leather	Chief Officer
R.J. Chamberlain	2nd Officer
R.A. Warner	3rd Officer
J. Blane	Radio Officer
I.G. McGill	Chief Engineer
D.E. Anderson	2nd Engineer
V.E. Lovell	3rd Engineer
P. Martin	3rd Engineer
G.A. Pook	CPO (D)
M.A. Harrison	PO (D)
A. Marren	SG.1A
J.R. Perkins	SG.1A
K.R. Luckhurst	SG.1A
J. Miller	SG.1B
C.J. Elliot	S.C.M
J.B. Edwards	Chef
R.M. Stephen	Steward
R. Bell	Steward
A.P. Lee	Steward
A.M. Bridge	PO M/M

SCIENTIFIC

G.K. Westbrook (Pri. Sci.)	Univ. Birmingham
R.J. Campbell	Univ. Birmingham
D.P. Graham	Univ. Birmingham
P.S. O'Neill	Univ. Birmingham
N.P. Mountney	Univ. Birmingham
C. Peirce	Univ. Durham
R.B. Whitmarsh	IOSDL
R.E. Kirk	IOSDL
M.R. Saunders	IOSDL
D. White	IOSDL
W.K. Smith	RVS
C.H. Woodley	RVS
M.A. Davies	RVS
D. Lewis	RVS
D. Dunster	RVS
C.J. Paulson	RVS
J.L. Jones	RVS

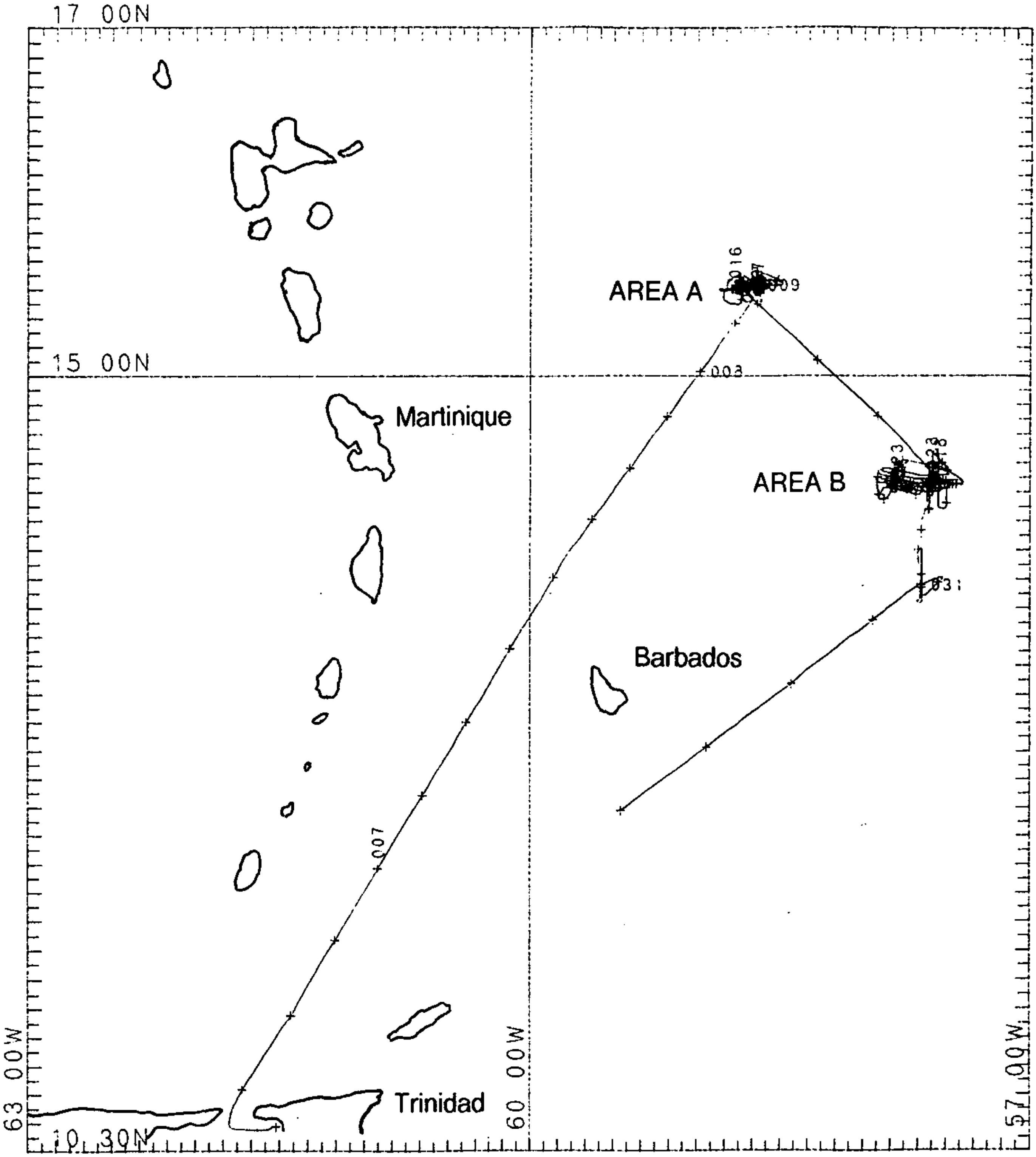


Fig. 1

Track chart for RRS Charles Darwin Cruise 75
Most of the work of the cruise was concentrated in two areas, A and B.
Scale is 1:3,500,000 at 22.5°N

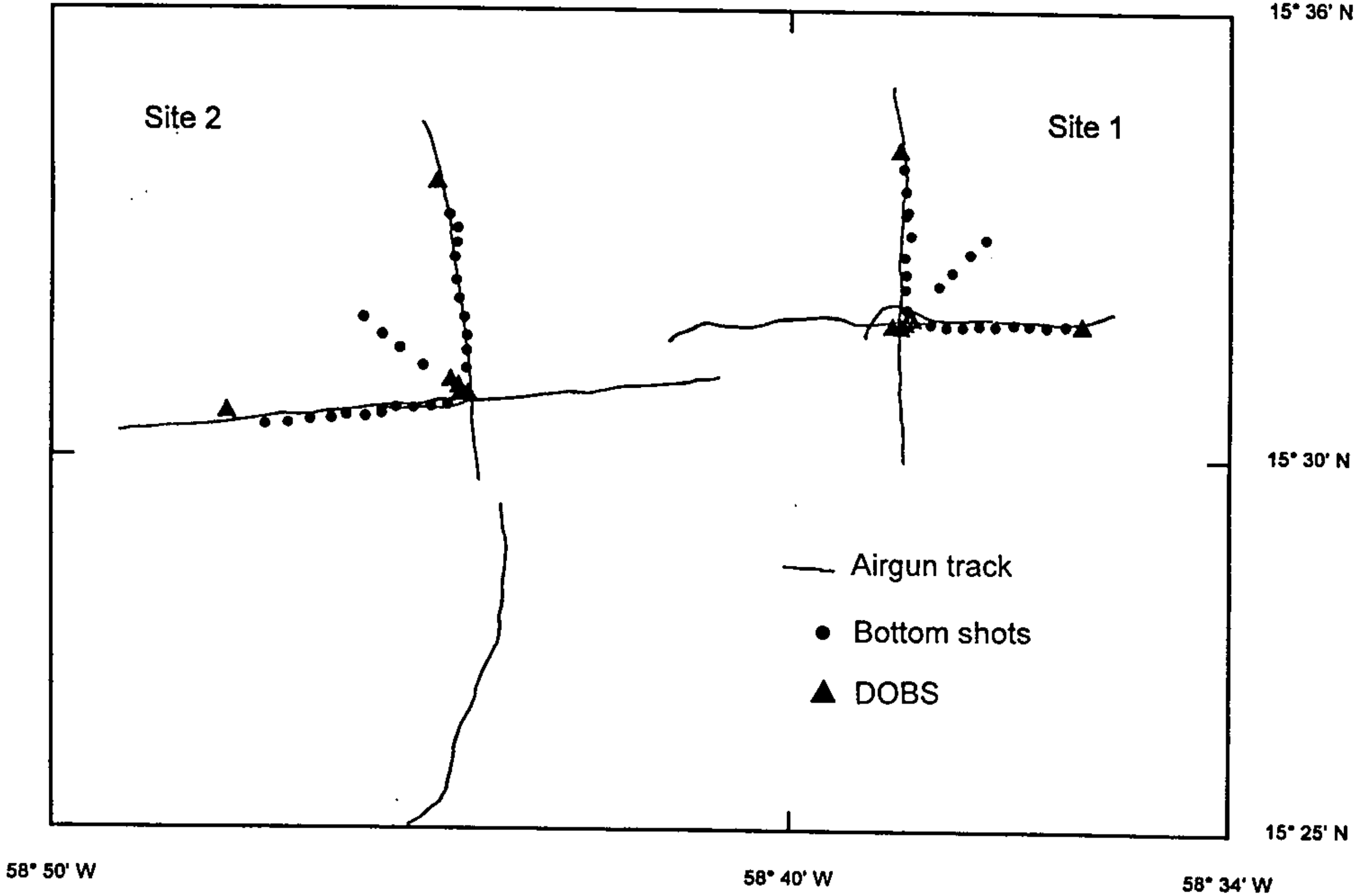


FIG. 2 LOCATION OF DOBS, BOTTOM-SHOTS AND AIRGUN SHOTS IN AREA A

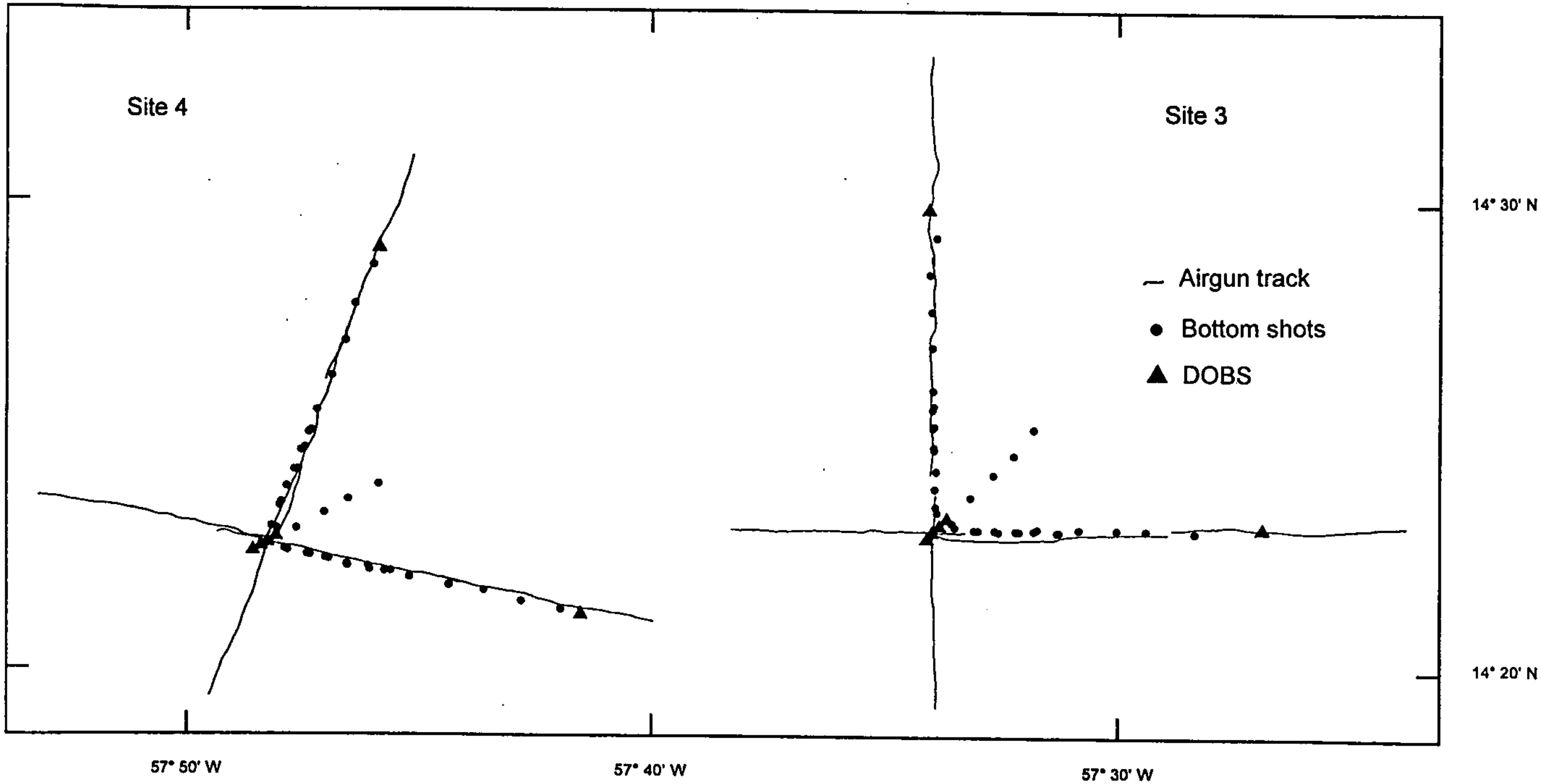


FIG. 3 LOCATION OF DOBS, BOTTOM-SHOTS AND AIRGUN SHOTS IN AREA B

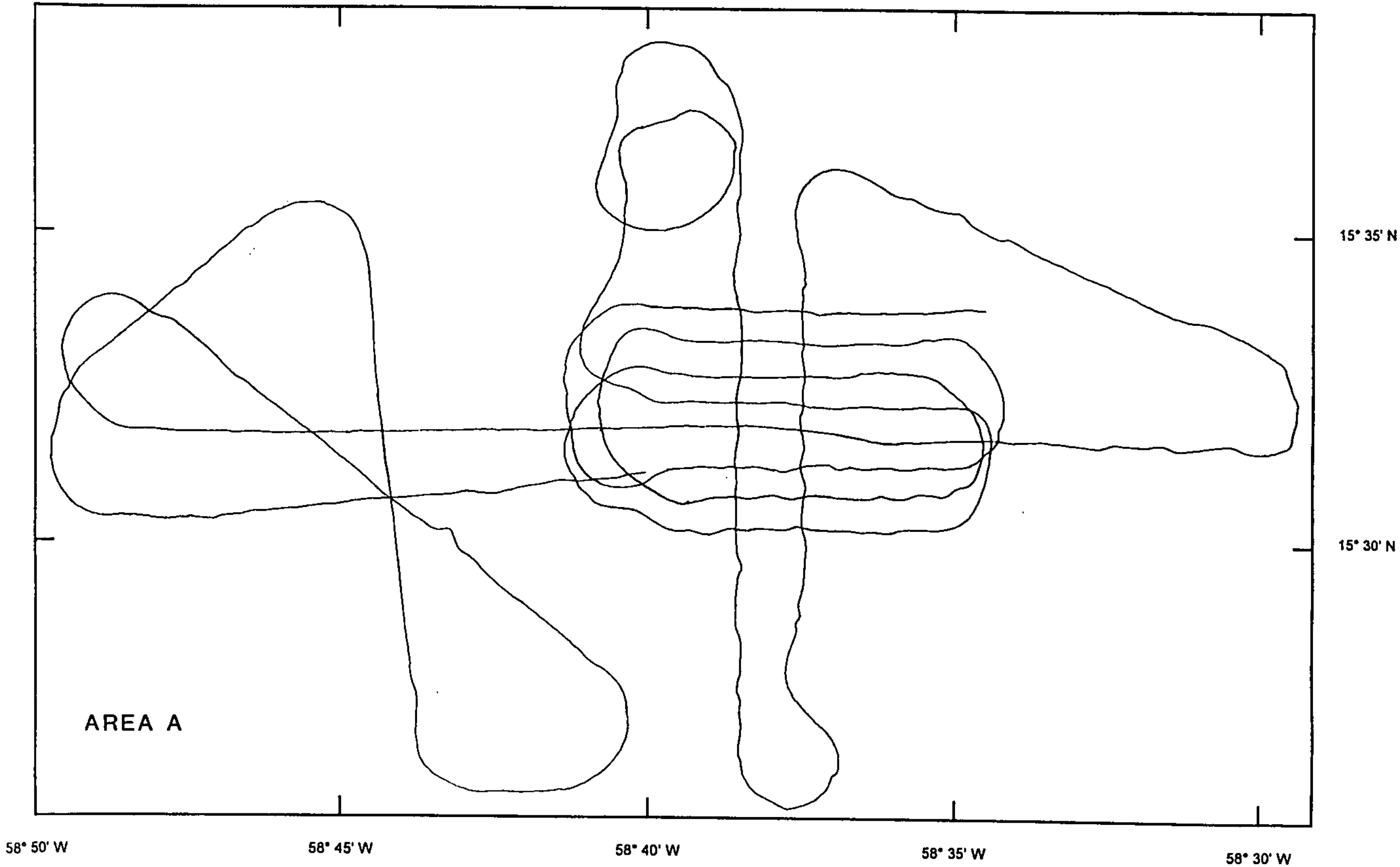


FIG. 4 TRACK CHART FOR REFLECTION PROFILES IN AREA A

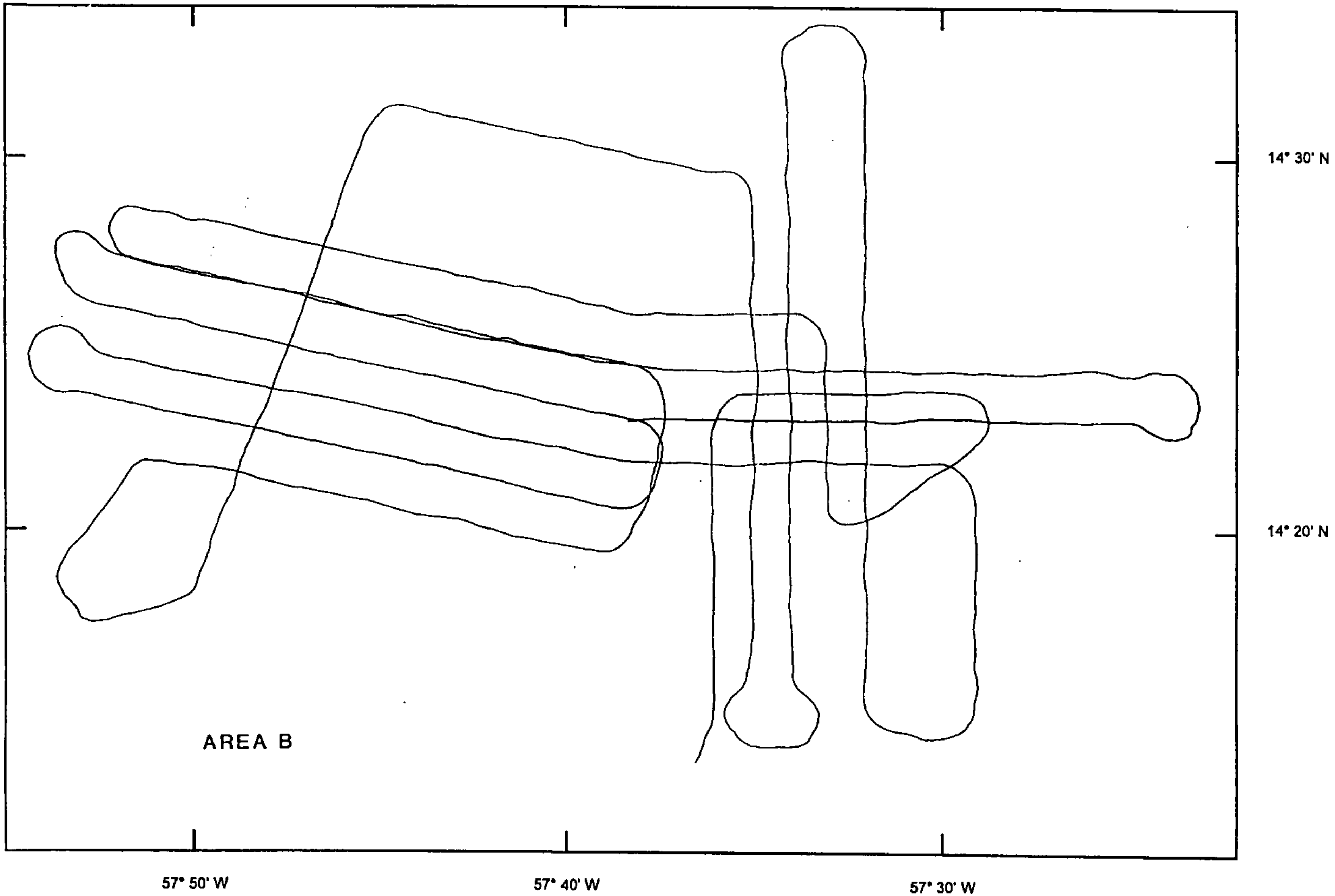
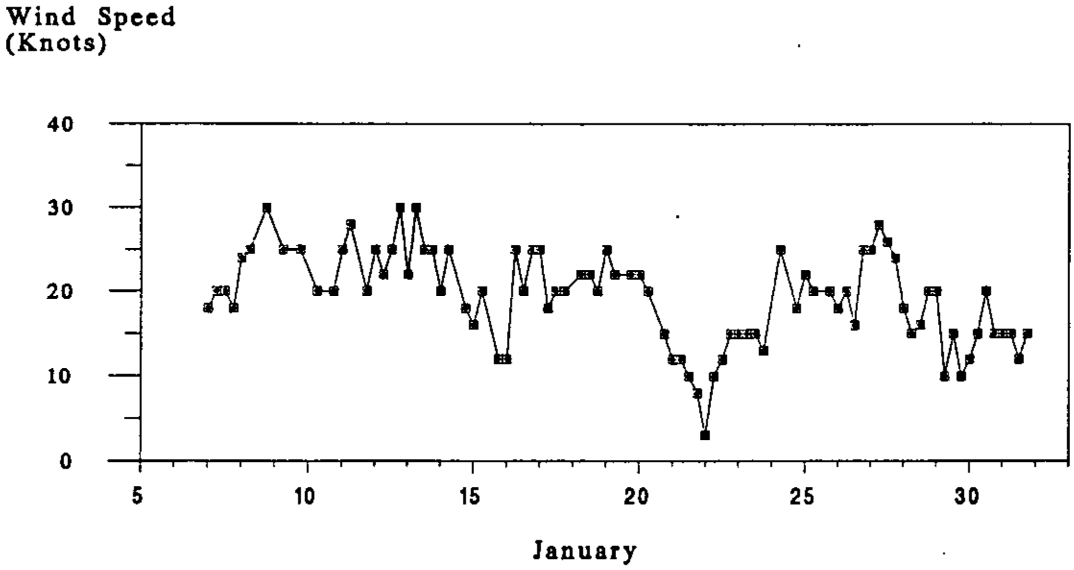
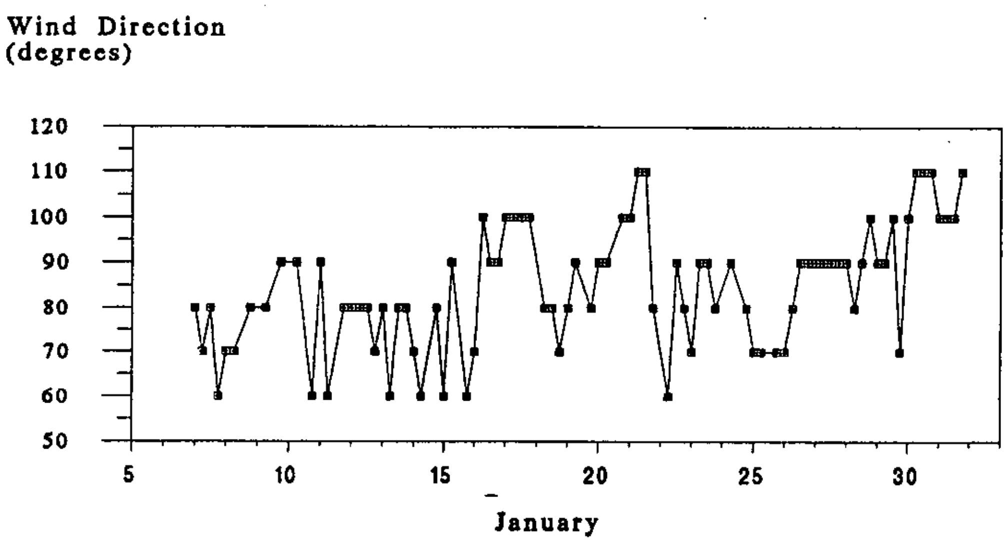


FIG. 5 TRACK CHART FOR REFLECTION PROFILES IN AREA B





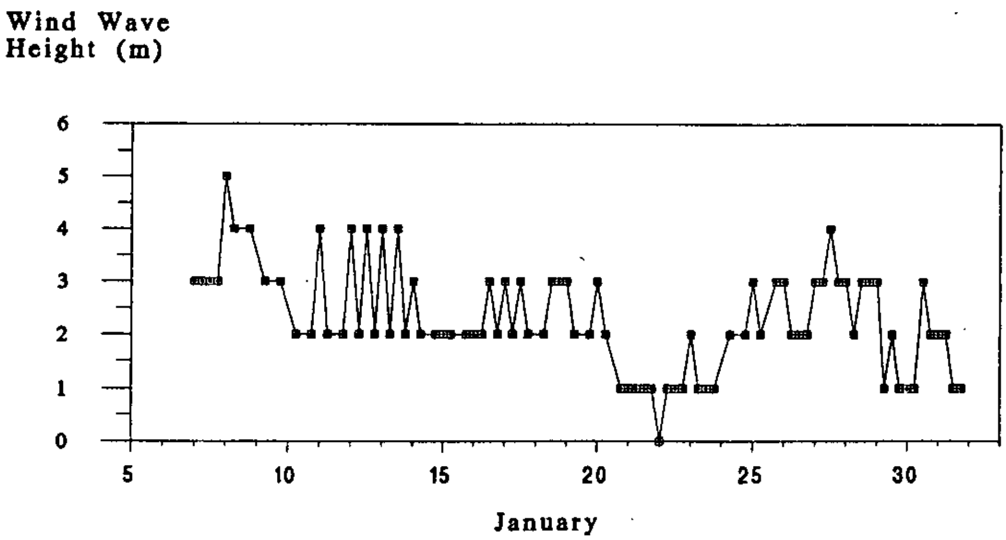
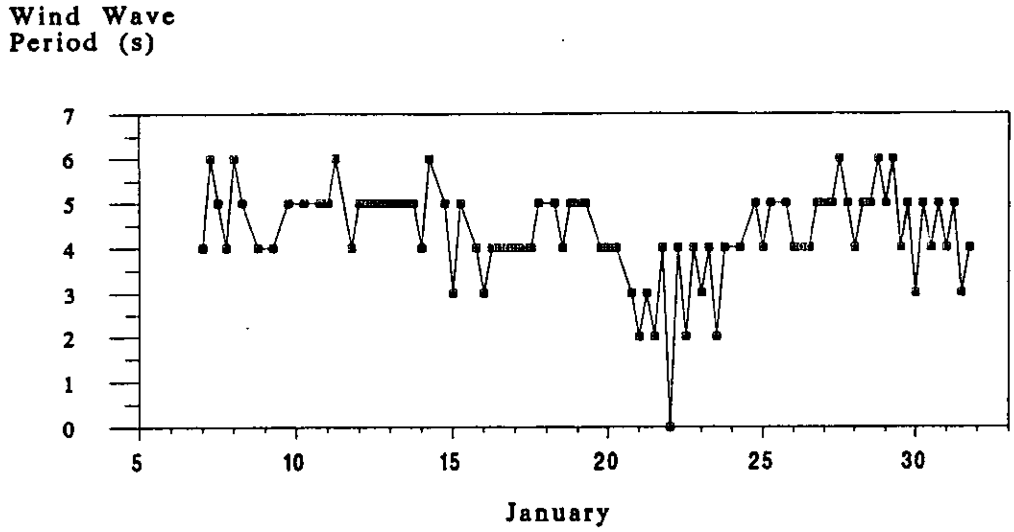
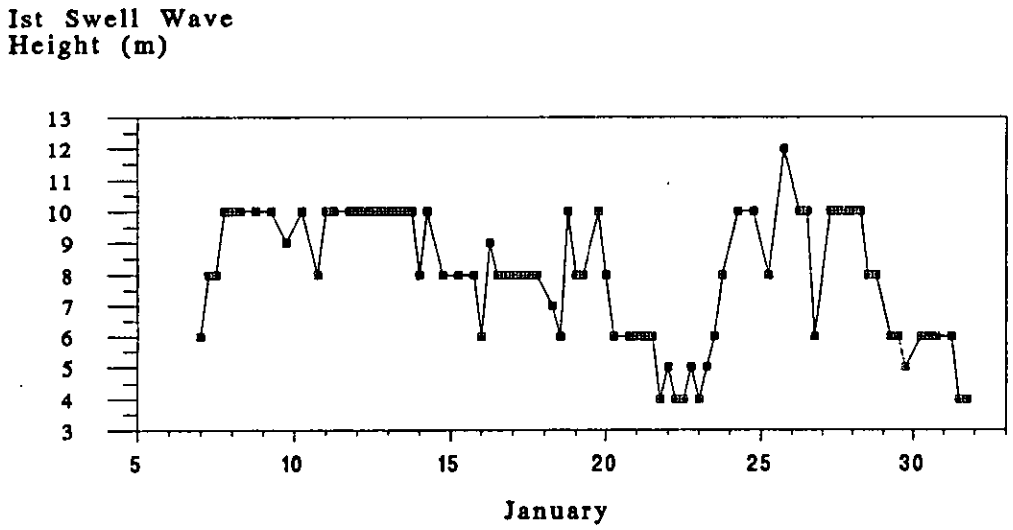
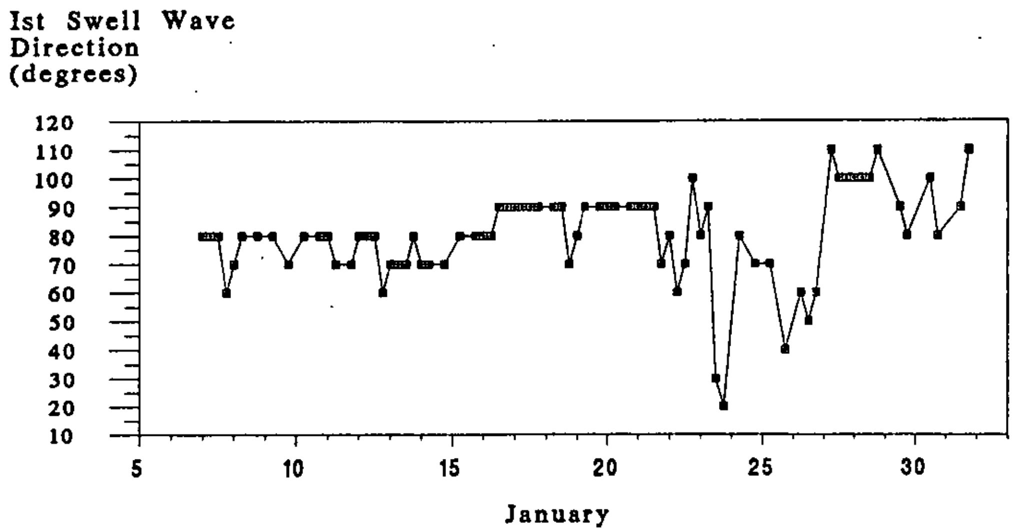


FIG. 6 GRAPHICAL DIGEST OF WEATHER CONDITIONS


Wind Wave
Period (s)
7
6
5
4
3
2
1
0
5
10
15
20
25
30
January


Ist Swell Wave
Height (m)
13
12
11
10
9
8
7
6
5
4
3
5
10
15
20
25
30
January


Ist Swell Wave
Direction
(degrees)
120
110
100
90
80
70
60
50
40
30
20
10
5
10
15
20
25
30
January