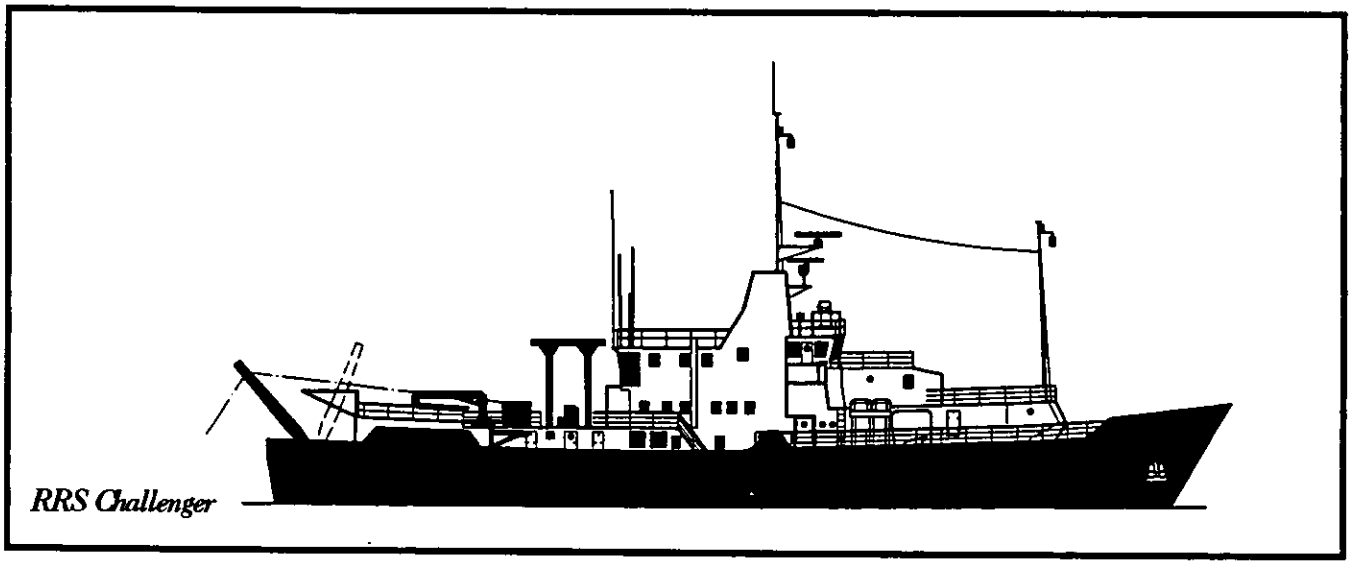
UNIVERSITY OF CAMBRIDGE

CRUISE REPORT

BULLARD LABORATORIES
DEPARTMENT OF EARTH SCIENCES



RRS Challenger

RRS CHALLENGER 113A

FAEROES - ICELAND RIDGE EXPERIMENT

T.A.Minshull

CRUISE REPORT

RRS CHALLENGER 113A/94

Faeroes-Iceland Ridge Experiment

29th July - 12th August 1994

Ardrossan - Mallaig

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SUMMARY

The objective of this cruise was to study the crustal structure of the Faeroes-Iceland Ridge, the trail of the Iceland plume on the Eurasian plate as the North Atlantic opened. The cruise was part of a larger experiment involving a commercial seismic vessel, the GECO Echo, under contract to the British Institutions Profiling Syndicate (BIRPS), and a large number of workers manning land seismometers across Iceland and in the Faeroes. There were also some explosive charges detonated in Iceland. The role of the Challenger was to deploy ocean bottom seismometers (OBSs) along a 450 km line to be shot by the GECO vessel from offshore of Vestmanna in the Faeroes to Reydarfjordur in eastern Iceland, and to shoot 55 explosive charges along this line.

CREW LIST

Tim Minshull (PSO)	Cambridge
Tim Owen	Cambridge
Peter Carter	Cambridge
Miao Fang	Cambridge
Mark Muller	Cambridge
John Smallwood	Cambridge
Peter Morgan	Cambridge
Fernando Neves	Cambridge
Morten Mortensen	Faeroes Coastguard
Kevin Smith	RVS
Tony Cumming	RVS
Robin Plumley	Master
Phil Gauld	Chief Officer
Phil Oldfield	2nd Officer
Matthew Crofts	3rd Officer
Ian Bennett	Chief Engineer
Jim Crosbie	2nd Engineer
Ian Slater	3rd Engineer
Mick Drayton	CPO (Deck)
Peter Bennett	Seaman
Martin Wyness	Seaman
Steve Jones	Seaman
Tim Edwards	Seaman
Arthur Olds	Seaman
Alan Bridge	PO (M)
Jill Edwards	SCM
JJ Swenson	Chef
Mick Stephen	Steward
Andy Duncan	Steward

CRUISE REPORT OF PROCEEDINGS

SHIP ..... RRS CHALLENGER ..... CRUISE No: .113A/94.....

CRUISE DATES (Port to Port Incl) ..29 July-12 August 1994.....

It is requested that the following aspects of the Cruise may be covered in this report of proceedings for delivery to Superintendent Research Vessel Services, immediately upon the ship's return to port.

a) Main objectives of the cruise.
b) Geographical area with Lat/Long.
c) Sea and weather conditions encountered.
d) Conduct of cruise, degree of success and problems encountered.
e) Equipment performance.
f) Ship performance.
g) Any recommendations.
h) Signature and date.

Brief comments are preferred but, if necessary, continue on a separate sheet.

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a) **Main Objectives**: To carry out ocean bottom seismometer (OBS) refraction work using airgun and explosive shots, in support of the 1994 BIRPS program on the Faeroes-Iceland Ridge. The overall aim of the experiment was to establish the structure of crust generated directly above a mantle plume from the continental margin right out to the mid-ocean ridge.

b) **Geographical Area**: North Atlantic, 62°-65°N, 7°-14°W.

c) **Sea and Weather Conditions**: Generally calm with short periods when the wind increased to 20 knts, with a few metres of swell.

d) **Conduct of Cruise**: The cruise was generally successful, with no explosive misfires, and all 12 OBSs recovered. Some data were lost due to OBS malfunctions.

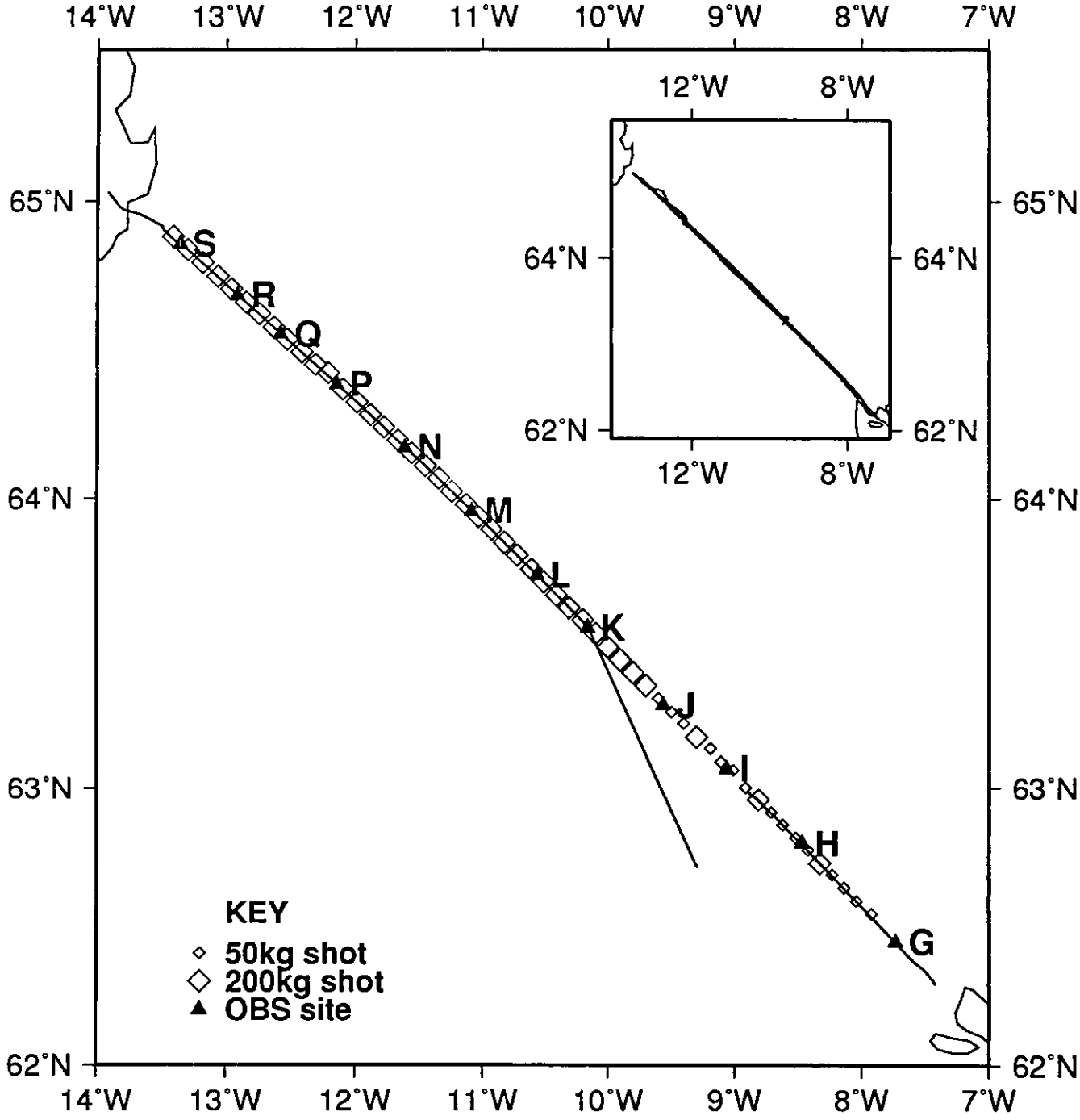
e) **Equipment Performance**: The shotfiring equipment and the Oceano release system worked well. The Chernikeof log was not properly calibrated. There were also a few problems with winches. One Dahn buoy split and sunk.

f) **Ship Performance**: The ship performed very well, and the officers handled well our precise navigational requirements.

g) **Recommendations**
i) The Chernikeof log should be calibrated.
ii) Dahn buoys should be carefully checked before use.
iii) Anchor weights should be weighed and labelled prior to loading on the ship.

h) **Other Comments**: It will be very sad if the excellent service which RVS provides is dispersed and lost within the Southampton Centre.

T. A. Minshull



Ships' tracks: Solid line marks shooting track of GECO Echo.
Insert shows Challenger track during cruise.

CRUISE NARRATIVE

Friday 29th July

The Cambridge party arrived at Ardrossan docks at 1100 local (GMT + 1 hour), to find the lorry already being unloaded. This was complete at 1215, and we began setting up the laboratory. At 1930 we moved berth to pick up the explosives. These arrived at 2030 and were loaded into the explosives container by 2140. The 350 25-kg boxes were lifted onto the deck by a shoreside crane and then carried by hand into the container. The ship then sailed from Ardrossan at 2205.

Saturday 30th July

We continued our passage towards the Faeroes, passing through the Hebrides. A simple wire aerial was rigged up for our radio receiver, and clock checks were started. It was soon established that the RVS clock was running very fast (by about 2 s per day). We also established that the Chernikeef EM log was reading low. The "fine adjustment" knob seemed to have no effect, but adjustments elsewhere seemed to fix the problem. Miao Fang's navigation/EM log logging system was set up on a PC in the Plot. Minidobs construction continued. Ship's time switched to GMT overnight.

Sunday 31st July

Passage to the Faeroes continued. Alarm tables for the first instruments to be deployed were prepared, based on the latest estimate of start time of the GECO Echo on the line. Kevin Smith and Tony Cumming made up the booster charges for the explosives.

Monday 1st August

We arrived at the first OBS site (OBS 6) just after midnight, in 132 m of water close to the Faeroes. For the first deployment, all OBSs were set to record in continuous mode, starting at our best estimate of the start time of firing by the GECO ship, since this was expected to be quite early. One of the winches jammed during deployment, which was completed with a single winch. Due to the foggy weather, which restricted our speed, we abandoned a planned second deployment during the night and instead headed for the Faeroes, where we were due to pick up the Faeroese fisheries observer, Capn Morten Mortensen. We arrived at Vestmanna at 0800 in thick fog and rain. The lifeboat was sent to pick up Capn Mortensen, who was aboard by 0900. We then proceeded down the line for further deployments. During deployment of OBS 16, the wire parted on the winch as it attempted to lift the float frame. This was due to an increase in tension when a rope knot became caught in a block. Three more OBSs, including a Minidobs, were deployed by midnight, all were followed to the bottom with the dunking transducer, except for OBS 16, which was lost at 200 m slant range, possibly because the transducer was streaming out almost horizontally as the ship drifted in the wind. Preparation of the explosive charges continued.

Tuesday 2nd August

OBS deployments continued. Two Icelandic trawlers and a Faeroese longliner were working near the OBS12 site. Capn Mortensen called them up and they agreed to keep 0.5 nm away from the position. The second winch was now working, but we decided to continue deployments with just one winch, since these were proceeding smoothly and the use of two winches

would have occupied both crew as drivers. As we approached Iceland, the weather improved significantly. The final deployment was of a moored Minidobs. The water was too deep (140-160 m) at the original site, and deeper than suggested by the Admiralty chart, and the seabed was rather rough. The site was moved 14 km landward, to an area of flat seabed in about 100 m of water. The bottom wire was laid out to the NE of the instrument, and the instrument may have been dragged about 200 m along the bottom during the deployment. The mooring was completed at 1610, and we then headed back down the line towards the Faeroes at full speed (10 knots). Meanwhile, Tim Owen and Miao Fang began putting together the fourth Minidobs.

Wednesday 3rd August

We arrived back at the first OBS position at 1245. A number of Faeroese fishing vessels were working in the area. Capn Mortensen communicated with them, and they agreed to keep clear of our OBS positions. The fourth Minidobs was now ready, and was deployed on a mooring. OBS6 was recovered and appeared to show clear arrivals from the GECO vessel at approximately 140 km range. The Chernikeef log was adjusted by Tony Cumming, and now read approximately correctly compared to the Simrad log on the Bridge. We proceeded along the line recovering OBS's and redeploying each at the next site, omitting the Minidobs since these were expected to have adequate capacity for the whole experiment. OBS alarm tables included a continuous recording component and also windows for all the expected possible explosive shot times on land and at sea, since we knew by this time that we would be unlikely to have time for a third OBS deployment. In general, since there was around two hours steaming between sites, we were able to refurbish the instruments in time for the next site; in some cases, due to the necessity of designing rather complex alarm tables starting as near as possible to the deployment time, there was some delay at a site while instrument preparation was completed.

Thursday 4th August

Recovery of seven OBSs and redeployment of six was completed by 1430. OBS14 had overwritten its clock after about 250 blocks (i.e near the start of recording), and OBS17 did not record on one tape due to a faulty power lead to the Walkman. There was not time to repair this, so OBS17 was redeployed with an alarm table which minimised use of this Walkman. Some water was found in OBS18, but it seemed to have recorded in full. Since the eighth instrument still had a few hours of recording time left, we then moved into position for the first shot-firing run, at the Iceland end of the line. Nine 200 kg shots were fired at 7 km intervals from 1700 to 2100, with no misfires, and in general the operation went very smoothly. Unfortunately, the signal from the shot hydrophone was rather poor, and the seabed reflection was not clearly observed for three of the shots.

Friday 5th August

OBS19 was recovered and replaced with OBS12 in the early morning. The instrument sphere of OBS19 was found to contain about 300 ml of water, one Walkman was wet, and the clock had been overwritten. The wet Walkman was replaced with the spare, and the OBS redeployed at a new site halfway between OBS 12 and the moored Minidobs near Iceland. A shotfiring schedule for the day was designed to avoid the time of GECO shooting in Reydarfjordur, expected to be around 1200-1500. Seven 200 kg shots were fired from 0800-1100, and another eleven from 1500-2000. In between the

two shotfiring runs, the shot hydrophone was brought in for repair, since it was still giving a rather poor signal, with only a very weak direct and reflected arrival visible on the Jet-Pen record. It was found to be full of water, so Tim Owen cut it off and replaced it with a Minidobs hydrophone. An amplifier was also installed in the lab between the hydrophone and the various recording devices. During the afternoon shotfiring run, the hydrophone signal was much clearer, with direct, reflected, and various multiples and bubble pulses all visible.

Saturday 6th August

Overnight, we returned at full speed to the Faeroes end of the line. We completed two further shotfiring sessions at 0900-1300 and 1500-1700, using all the 50 kg charges and some 200 kg. The shot at 1531 had to be fired a few hundred metres off the line because a fishing buoy was spotted very close to the line. The fishing vessel was also close by and was contacted by Capn Mortensen, but there was no need to abort the shot.

Sunday 7th August

Overnight we drifted in the vicinity of the line. The wind speed rose to around 20 knts, with 2-3 m of swell, and it was cold and wet. The final 10 shots were fired 0800-1230. The ship found it harder to maintain speed in the swell, and one shot was fired a few hundred meters off the line because it was necessary to adjust the ship's heading closer to downwind. On subsequent shots, we diverted west of the line between shots in order to steam downwind across the desired shotpoint. After the final shot, the remaining fuse, detonators and primer were packaged up and deployed at 1252.

We then began OBS recoveries. OBS13 was banged on the ship's hull during recovery, causing slight damage to the endcap. It had recorded very little data because the clock was overwritten about one hour after the start of recording. The first Minidobs (22) came up very slowly; its slant range first decreased, but then began to increase as the ship drifted, and was never less than the water depth. After about 15 minutes, we returned to the original position and the instrument was spotted at the surface. Ranging was not then possible as the transducer was out of the water. The Minidobs display was dead on recovery. The clock was still running, but the CPU had died at about 0850 this morning. OBS18 was still recording on recovery, as expected.

Monday 8th August

OBS recoveries continued after an overnight break, during which we steamed to the Iceland end of the line. OBS19 was still recording on recovery. The moored Minidobs (21) was recovered in a 15 knt wind. The ship's bow-thruster could not really compete against this, but the recovery went smoothly. The Minidobs was still recording on recovery, but the data looked very poor; possibly there is an A-D problem. About 2 hours was spent locating OBS17, which was 1.6 km from where it had been dropped. There was no damage to suggest it had been dragged; one possibility is that it had walked along the seabed in the strong tidal current. The clock was overwritten at 0829 on the 5th, so most of the explosive shots were missed.

Tuesday 9th August

OBS recoveries continued. Minidobs 20 also came up very slowly; this instrument had very poor data (an A-D problem again?), and the CPU had

stopped at 1900 on the 5th. OBS16 was found about 1.2 km north of where it was left. This was in an area with many trawlers, so it may have been dragged, but again there was no sign of damage. We arrived at the final site (Minidobs 23) at 1330, but there was no sign of the Dahn buoy marking the mooring. We searched the area, and approached a small fishing vessel, which had not seen it. We then paid out the "Gifford grapple" to trawl for the instrument bottom wire. The first attempt recovered an old fisherman's bottom line, but the second attempt recovered the Minidobs; clearly the bottom line had been grappled very close to the instrument. The mooring was reeled in from the instrument end, and recovery completed at 1710. The Dahn buoy had split and was full of water, and the flashing light was also waterlogged. We then headed for Vestmanna to drop off Capn Mortensen, arriving at about 2000 and departing 2100.

Wednesday 10th August

The explosives container was packed with Cambridge and RVS equipment, with the urgently needed RVS equipment at the front. This proved to be a very tight fit, and one cage used for Benthos sphere storage had to be left aboard. Packing was complete by 1500.

Thursday 11th August

We arrived at Mallaig at about 1100, nearly a day ahead of schedule.

UNDERWAY DATA

Navigation data were taken from a Trimble GPS unit located on the Bridge. Data were logged at 20-30 s intervals on a PC in the Plot using a program written by Miao Fang. Speed through the water from the Chernikeef log was also logged, at approximately 15 s intervals. This log was not properly calibrated: at the start of the cruise, it was reading about 2.2 knts low at 10 knts, compared to the Simrad EM log on the Bridge. Before explosives shotfiring, the calibration was adjusted; during shotfiring it appeared to read about 0.5 knts high at 9 knts. For a few minutes around the shot times, Decca MK53 GPS navigation and Simrad EM log speeds were logged by hand at 30 s intervals by an observer on the Bridge. Water depths were monitored with a Simrad EA500 echosounder running on the hull transducer; use of the fish was not necessary since we were never in very deep water. The echosounder was not logged, but a paper record was kept and readings noted at OBS deployment positions and at "charge away" positions. The echosounder was set up with an assumed sound velocity of 1500 m/s.

XBTs

XBT	Time	Latitude	Longitude	Comment
1				Failed
2				Test probe
3		64 52.3'N	13 21.4'W	Depth 101 m
4		64 16.6'N	11 53.2'W	Broke at 106 m
5		64 15.9'N	11 51.8'W	Depth 391 m
6		62 56.5'N	8 46.2'W	Depth 453 m
7		62 26.3'N	7 44.3'W	Depth 126 m

TIMING

The main external timebase for the FIRE experiment was GPS time. However, a time signal was not available from the Trimble GPS unit. Therefore the Radio Moscow RWM coded time signal was used as our external timebase; this was monitored against GPS time by Bob White in Iceland, and was found to be 13 ms fast relative to GPS. In addition we had the RVS ship's clock and the Cambridge "Lucky 7" scientific clock. The three clocks were calibrated against each other several times a day throughout the cruise using a four-channel jet-pen. The ship's clock was drifting rapidly at the start of the cruise, but appeared to be reasonably stable after adjustment. Reception from Moscow was variable, but generally good. "Lucky 7" lost about 5 seconds on August 4th.

EXPLOSIVES SHOTFIRING

Explosives shotfiring followed procedures developed on cruises CD67/92 and CD81/93 (see the relevant cruise reports for diagrams of explosive arrangement). Shotfiring was extremely successful, and Kevin Smith and Tony Cumming are to be congratulated on their careful preparations. By preparing and packaging each shot identically, very consistent burn times were achieved, and there were no misfires during the entire experiment, except possibly for one of the scare charges. All shots went off within 20 s of the desired time, except for one for which the countdown was given one minute early.

The following were purchased from Nobel Explosives Co. Ltd (an ICI subsidiary):

350 x 25 kg cases of Powergel E700
125 x 275g Pentalite Primers
500 m of Cordtex detonating cord
200 x No. 8 strength detonators
500 m of Yellow Clover safety fuse

Each case of Powergel consisted of a strong cardboard box containing five 5 kg bags of explosive. The Powergel primers were stored aboard Challenger in the RVS wood-lined explosives container on the afterdeck, and the fuses and detonators, which were prepared at Barry in advance of the cruise, were stored in a locker. Each box was prepared by cutting off each corner about 5-10 cm from the corner, and inserting two house bricks inside the box. We used fifteen 50 kg shots and forty 200 kg shots. Since there were not quite enough bricks, some of the 200 kg shots had 15 rather than 16 bricks. This appeared to make a significant different to the fuse burn time, presumably due to differing sink rates.

The 50 kg shots consisted of two boxes banded together, with a primer charge attached to the central explosives bag in the lower box. The 200 kg shots consisted of eight boxes, in two layers of four, banded to a wooden pallet, which was weighted with a concrete paving slab. The primer charge was attached to the central explosives bag in one of the lower boxes. In both cases, the primer charge was attached to detonating cord wrapped around the main charge, which was in turn attached to two detonators and two safety fuses of equal length. Fuse lengths were designed to give flight times of 100 s for 200 kg charges and 85 s for 50 kg charges, for optimum charge depths according to D. H. Matthews' "Child's Guide". Initially, long fuses were used, and these were then gradually shortened to reach optimum length, which turned out to be about 2.4 m for the 50 kg shots, 3.2 m for 200 kg charges with 15 bricks, and 3.5 m for 200 kg charges with 16 bricks.

Prior to each firing run, two "scare charges" were fired at five minute intervals; these consisted of a primer charge with detonator and 0.75 m fuse.

Flight times were recorded by three independent observers. The shot hydrophone was towed astern of the ship, and a hull geophone mounted on the stern close to the water line. Shot instants were recorded on the Cambridge SAQ and on a Store 4DS with two clocks as follows:

Channel 1: Hydrophone (FM on Store 4)
Channel 2: Hull Geophone (FM on Store 4)
Channel 3: Coded 1 kHz signal from RVS clock (DR on Store 4)
Channel 4: Square wave from "Lucky 7" clock (FM on Store 4)

A paper record was also recorded using the Cambridge 8-channel Jet-pen. The SAQ recorded 60 s records at 4 ms sample interval, and was powered up about 20 s before the expected shot instant. The Store 4 was run at 3.75 in/s and was started up about five minutes before each shot. One shot-firing run then fitted easily on a tape. The Jet-Pen was run at 50 mm/s from the "charge away" time, and the speed increased to 500 mm/s about 20-25 s before the expected shot time. This generally gave very good records, and no shots were missed.

DIMENSIONS

Distance of shot hydrophone from stern	=	84 m
Distance of GPS aerial from stern	=	30 m

OCEAN BOTTOM SEISMOMETERS

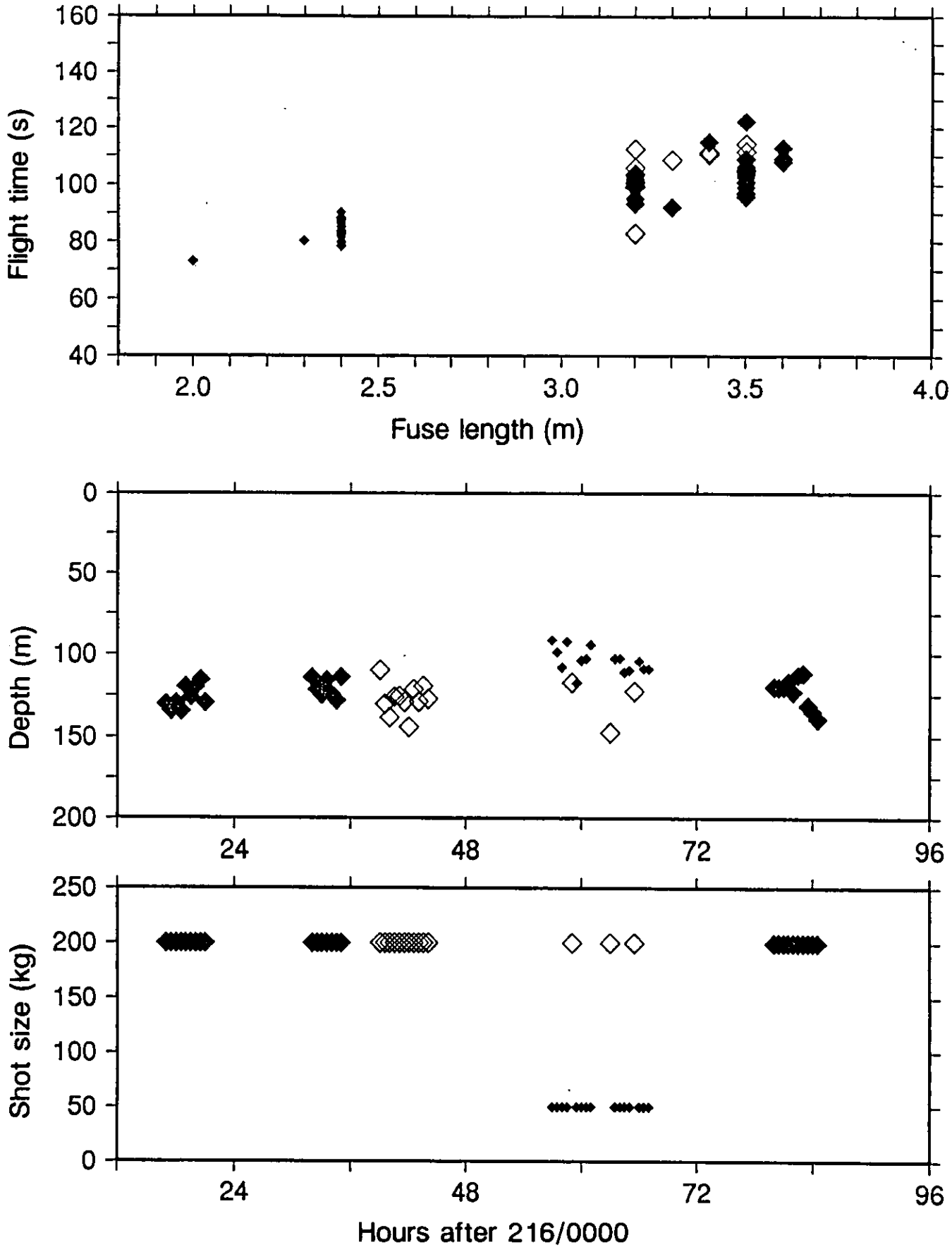
The OBS deployment schedule was complicated by the fact that eight of the instruments had a maximum continuous recording time of 40-45 hours, while the GECO vessel was expected to take 3-4 days to complete the line, and its start date was unknown. In addition, three of the four new Minidobs, which had a much longer recording time, were still under construction as we departed for the cruise. The Echo in fact arrived early at the beginning of the line, which meant that we were unable to complete all our deployments before airgun firing began. However, the Faeroes end of the line was well instrumented at the start of airgun firing, and ultimately we were able to deploy twelve OBSs, including all four Minidobs. Gaps in recording were minimised by "leapfrogging" instruments along the line, so that all sites were almost continuously occupied. It was not possible for us to service all the instruments within 40-45 hours, but we were able to record a large proportion of the Echo's shots on most of the instruments.

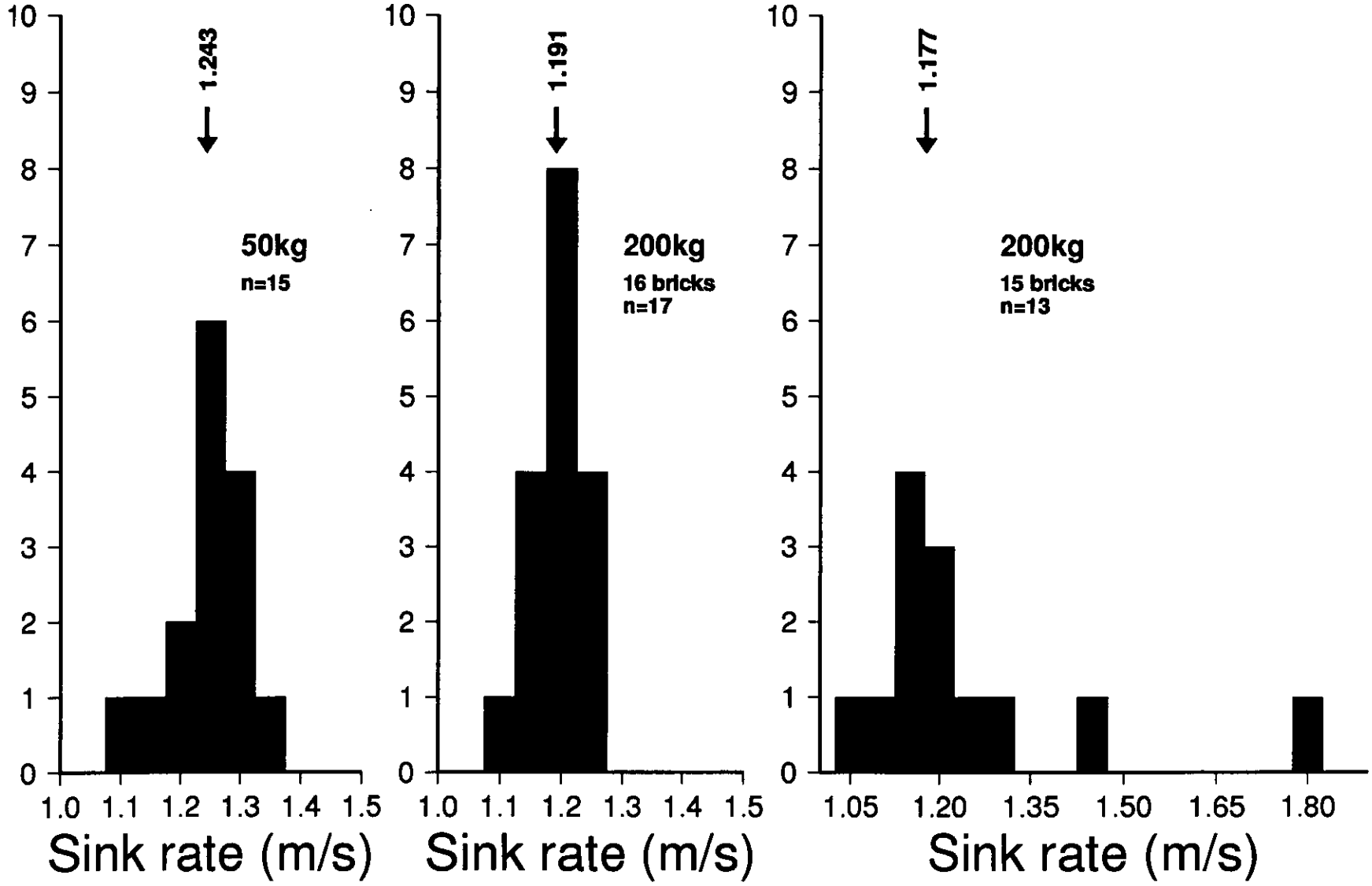
OBSs on releases were deployed from the starboard A-frame. Originally we planned to use two separate winches, as on many previous cruises. However, during the first deployment, one of the winches jammed and could not be used. The first OBS was deployed with one winch by tying off between lifts. This went so smoothly that we decided to continue the same procedure even when the winch was repaired. During recovery, it was found that knots in the instrument ropes could easily become jammed in the winch block; this problem was overcome by putting a half hitch in the rope and lifting from this rather than from the end. Two moorings (with Minidobs) were used in 100-120 m of water at the ends of the line. These consisted of a buoy with radar reflector and pellet floats, a 200 m mooring line of 6 mm wire, and a 1000 m bottom line of 8 mm wire, in two 500 m sections. Moorings were deployed from the stern A-frame.

FIRE Challenger 113A/94			Explosive shots																					
				CHARGE AWAY, SHIP'S POSITION					Uncorr		CHARGE FIRED, SHIPS POSITION				Detonation	SHOT TIME (MOSC)		FROM	Sink rate	CORRECTED POS				
Shot #	Size (kg)	Fuse (m)	Bricks	Day/time	Lat (°N)	(min N)	Lon (°W)	(min W)	Depth (m)	Flight (s)	Lat (°N)	(min N)	Lon (°W)	(min W)	depth (m)	Hr:min	sec.msec		m/s	Lat (°N)	(min N)	Lon (°W)	(min W)
3	200	3.6	16	216/16:58:47	64	35.13	12	37.71	175	108.0	64	35.29	12	38.33	130.3	17:00	35.655	1R	1.21	64	35.12	12	37.68
4	200	3.6	16	216/17:29:45	64	37.86	12	44.75	210	112.8	64	38.04	12	45.15	134.2	17:31	17.019	3P		64	37.85	12	44.72
5	200	3.6	16	216/17:58:15	64	40.18	12	50.85	205	109.1	64	40.35	12	51.39	129.8	18:00	02.918	2P		64	40.17	12	50.82
6	200	3.6	16	216/18:29:16	64	42.75	12	57.62	151	112.9	64	42.92	12	58.11	134.4	18:31	07.800	2P		64	42.74	12	57.59
7	200	3.5	16	216/18:59:16	64	45.29	13	4.01	179	100.6	64	45.49	13	4.47	119.7	19:00	57.366	2P		64	45.28	13	3.98
8	200	3.5	16	216/19:29:25	64	47.95	13	10.98	180	102.8	64	48.20	13	11.44	126.4	19:31	06.677	1R	1.23	64	47.94	13	10.96
9	200	3.5	16	216/19:59:25	64	50.50	13	17.83	124	101.0	64	50.68	13	18.25	120.2[2]	20:01	04.532	3P		64	50.49	13	17.80
10	200	3.5	16	216/20:29:28	64	53.07	13	24.67	91	97.0	64	53.26	13	25.13	89.9[3]	20:31	03.386	3Q		64	53.06	13	24.64
11	200	3.5	16	216/20:59:26	64	55.34	13	30.78	147	108.7	64	55.53	13	34.35	129.4	21:01	14.445	3P		64	55.34	13	30.74
14	200	3.5	16	217/07:59:28	64	32.72	12	31.62	190	95.8	64	32.55	12	31.25	114.0	8:01	02.664	3P		64	32.73	12	31.65
15	200	3.5	16	217/08:29:25	64	30.05	12	24.80	217	104.5	64	29.86	12	24.38	121.4	8:31	08.975	1R	1.16	64	30.06	12	24.83
16	200	3.5	16	217/08:59:25	64	27.55	12	18.59	240	103.7	64	27.40	12	18.05	124.7	9:01	07.822	1R	1.20	64	27.56	12	18.62
17	200	3.5	16	217/09:29:25	64	25.85	12	12.78	347	97.2	64	24.75	12	12.37	115.7	9:31	01.796	3P		64	25.87	12	12.79
18	200	3.5	16	217/09:59:26	64	22.50	12	5.87	440	109.0	64	22.30	12	5.39	124.4	10:01	14.486	1R	1.14	64	22.51	12	5.90
19	200	3.5	16	217/10:29:25	64	19.84	11	59.16	424	105.3	64	19.68	11	58.56	128.1	10:31	09.736	3R	1.21	64	19.85	11	59.19
20	200	3.5	16	217/10:59:27	64	17.29	11	52.87	388	99.0	64	17.08	11	52.46	113.8	11:01	05.276	1R	1.15	64	17.30	11	52.89
23	200	3.5	15	217/14:59:25	64	14.77	11	46.61	374	105.0	64	14.59	11	46.18	109.8	15:01	08.830	3R	1.05	64	14.78	11	46.64
24	200	3.5	15	217/15:29:25	64	12.09	11	40.07	343	114.3	64	11.91	11	40.61	130.2	15:31	18.817	3R	1.14	64	12.10	11	40.04
25	200	3.5	15	217/15:59:27	64	9.43	11	33.60	337	111.6	64	9.23	11	33.17	138.3	16:01	17.566	3R	1.24	64	9.44	11	33.63
26	200	3.45	15	217/16:29:25	64	6.79	11	27.17	341	110.6	64	6.65	11	27.72	126.0	16:31	15.073	3R	1.14	64	6.80	11	27.14
27	200	3.4	15	217/16:59:25	64	4.19	11	20.84	351	111.2	64	3.99	11	20.41	125.4	17:01	15.658	3R	1.13	64	4.20	11	20.87
28	200	3.3	15	217/17:29:26	64	1.53	11	14.53	358	108.5	64	1.33	11	14.08	129.1	17:31	14.042	1P		64	1.54	11	14.56
29	200	3.2	15	217/17:59:26	63	58.85	11	7.92	420	98.9	63	58.68	11	7.50	144.2	18:01	04.006	2R	1.46	63	58.86	11	7.95
30	200	3.2	15	217/18:29:27	63	56.32	11	1.89	423	99.1	63	56.11	11	1.46	121.4	18:31	04.625	3R	1.22	63	56.33	11	1.91
31	200	3.2	15	217/18:59:25	63	53.73	10	55.54	439	105.8	63	53.62	10	55.24	128.8	19:01	11.477	3R	1.22	63	53.74	10	55.57
32	200	3.2	15	217/19:29:27	63	51.09	10	49.56	434	100.8	63	50.92	10	49.20	119.5	19:31	07.987	3R	1.19	63	51.10	10	49.59
33	200	3.2	15	217/19:59:26	63	48.49	10	43.44	447	99.3	63	48.31	10	43.07	127.1	20:01	04.862	3R	1.28	63	48.50	10	43.46
36	50	2	4	218/08:59:46	62	32.59	7	55.35	222	73.0	62	32.71	7	55.71	91.5	9:00	58.456	1R	1.25	62	32.58	7	55.32
37	50	2.3	4	218/09:29:49	62	35.42	8	2.33	439	80.3	62	35.60	8	2.66	98.8	9:31	07.177	3R	1.23	62	35.41	8	2.31
38	50	2.4	4	218/09:59:46	62	38.31	8	8.33	521	88.1	62	38.52	8	8.60	107.9	10:01	13.356	1R	1.23	62	38.30	8	8.31
39	50	2.4	4	218/10:29:51	62	41.06	8	14.01	526	82.6	62	41.17	8	14.41	92.2	10:31	11.994	3R	1.12	62	41.05	8	13.98
40	200	3.2	15	218/10:59:26	62	43.64	8	19.69	505	103.6	62	43.85	8	20.11	117.2	11:01	09.131	3R	1.13	62	43.63	8	19.67
41	50	2.4	4	218/11:29:46	62	46.43	8	25.45	466	87.3	62	46.63	8	25.75	117.5	11:31	13.663	3R	1.34	62	46.42	8	25.43
42	50	2.4	4	218/11:59:45	62	49.18	8	31.25	505	79.8	62	49.35	8	31.55	103.7	12:01	04.329	3R	1.30	62	49.17	8	31.23
43	50	2.4	4	218/12:29:47	62	51.98	8	37.22	499	82.5	62	52.13	8	36.66	102.6	12:31	08.994	3R	1.24	62	51.97	8	37.25
44	50	2.4	4	218/12:59:46	62	54.64	8	42.76	476	81.6	62	54.78	8	43.16	94.3	13:01	06.072	3R	1.15	62	54.63	8	42.73
47	200	3.2	15	218/14:59:31	62	57.42	8	48.79	454	82.7	62	57.61	8	49.20	147.5	15:01	13.089	3R	1.78	62	57.41	8	48.77
48	50	2.4	4	218/15:29:49	63	0.07	8	54.89	460	86.4	63	0.21	8	54.34	102.5	15:31	14.915	3R	1.19	63	0.06	8	54.92
49	50	2.4	4	218/15:59:46	63	3.86	9	0.72	491	78.4	63	3.04	9	1.12	102.7	16:01	03.416	3R	1.31	63	3.88	9	0.71
50	50	2.4	4	218/16:29:47	63	5.63	9	6.49	526	85.1	63	5.79	9	6.83	111.0	16:31	12.142	3R	1.30	63	5.62	9	6.47
51	50	2.4	4	218/16:59:46	63	8.33	9	11.39	527	83.6	63	8.51	9	11.69	109.7	17:01	09.458	3R	1.31	63	8.32	9	11.37
52	200	3.2	15	218/17:29:28	63	10.86	9	18.14	521	112.4	63	11.03	9	18.58	122.4	17:31	18.247	3R	1.08	63	10.85	9	18.11
53	50	2.4	4	218/17:59:48	63	13.62	9	24.03	513	83.4	63	13.77	9	24.37	104.2	18:01	09.175	3R	1.25	63	13.61	9	24.00
54	50	2.4	4	218/18:29:47	63	16.10	9	29.76	468	90.2	63	16.26	9	30.15	108.7	18:31	15.735	3R	1.20	63	16.09	9	29.73
55	50	2.4	4	218/18:59:49	63	19.01	9	36.12	480	88.3	63	18.12	9	35.46	108.9	19:01	15.996	3R	1.23	63	19.03	9	36.13
58	200	3.2	16	219/07:59:30	63	21.70	9	41.92	504	100.3	63	21.87	9	42.33	119.8	8:01	09.575	3R	1.19	63	21.69	9	41.89
59	200	3.2	16	219/08:29:26	63	24.38	9	48.14	519	103.0	63	24.56	9	48.55	119.9	8:31	08.253	3R	1.16	63	24.37	9	48.11
60	200	3.2	16	219/08:59:28	63	27.01	9	54.05	527	102.0	63	27.19	9	54.42	119.7	9:01	09.071	3R	1.18	63	27.00	9	54.03
61	200	3.2	16	219/09:29:26	63	29.64	10	0.01	530	93.3	63	29.83	10	0.34	116.6	9:30	58.626	3R	1.25	63	29.63	9	59.99

62	200	3.2	16	219/09:59:26	63	32.42	10	5.96	532	99.7	63	32.65	10	6.32	122.7	10:01	04.613	3R	1.23	63	32.41	10	5.94
63	200	3.2	16	219/10:29:28	63	35.15	10	12.03	531	95.0	63	35.33	10	12.39	112.8	10:31	01.906	3R	1.18	63	35.14	10	12.01
64	200	3.3	16	219/10:59:29	63	37.69	10	18.50	520	92.1	63	37.85	10	18.80	111.3	11:00	59.949	3R	1.20	63	37.88	10	18.48
65	200	3.5	16	219/11:29:26	63	40.28	10	24.56	510	106.2	63	40.52	10	24.81	131.1	11:31	11.454	3R	1.23	63	40.27	10	24.54
66	200	3.5	16	219/11:59:27	63	42.94	10	30.73	505	122.2	63	43.22	10	31.14	134.8	12:01	28.650	3R	1.11	63	42.94	10	30.71
67	200	3.4	16	219/12:29:28	63	45.59	10	36.70	497	114.9	63	45.80	10	37.11	139.2	12:31	22.183	3R	1.21	63	45.58	10	36.68
NOTES:																							
² Calculated shot depth close to observed sea bed depth - shot may be on sea bed																							
¹ Shot on sea bed																							
Column	CORRECTED POS																						
Actual shot position - Corrected for 30m offset for stern from GPS aerial																							
Column	SHOT INST FROM																						
1=hydrophone																							
2=geophone																							
3=both, averaged																							
R=Reflection+Direct wave																							
P=Preset (Average) sink rate used, since no reflection observed																							
Q=Sink rate unknown, shot on bottom																							
ie 1P/2P least well determined																							
3R most well determined																							

12


Flight time (s)
160
140
120
100
80
60
40
2.0
2.5
3.0
3.5
4.0
Fuse length (m)
Depth (m)
0
50
100
150
200
24
48
72
96
Shot size (kg)
250
200
150
100
50
0
24
48
72
96
Hours after 216/0000
KEY
50kg, 4 bricks
200kg, 15 bricks
200kg, 16 bricks



Explosive Sink Rates

OBS POSITIONS

OBS	Site	Deployment			Recovery			Dist	Azimuth	Depth	Sink	Rise
		Lat N	Lon W	Time	Lat N	Lon W	Time	(km)	(dep-rec)	(m)	(m/s)	(m/s)
06 D	G1	62 26.53	07 43.82	213/0034	62 26.44	07 44.14	215/1319	0.62	254	132	1.22	>1.32 &
16 S	H1	62 48.00	08 28.11	213/1517	62 47.49	08 27.43	215/1819	1.58	127	464	0.77	? 20 mins floating
14 D	I1	63 04.20	09 03.66	213/1805	63 04.06	09 03.70	215/2215	0.27	196	506	1.20	>0.21 &
20 M	J1	63 17.57	09 33.63	213/2032	63 17.24	09 33.88	221/0302	0.77	217	470	1.01	? 30 mins floating
17 S	K1	63 33.65	10 09.54	213/2329	63 33.63	10 09.50	216/0311	0.08	117	529	0.64	1.20
13 D	L1	63 44.37	10 33.72	214/0143	63 44.40	10 33.36	216/0545	0.67	085	500	1.16	1.55
18 S	M1	63 57.54	11 05.06	214/0419	63 57.15	11 05.07	216/0935	0.72	181	427	0.65	1.23
22 M	N1	64 10.60	11 36.64	214/0647	64 10.70	11 36.07	219/1816	1.07	080	341	1.02	>0.32 &
12 D	P1	64 23.50	12 08.57	214/0912	64 23.56	12 08.23$	216/1427	0.64	080	451	1.29	1.57!
19 S	Q1	64 33.78	12 34.65	214/1142	64 33.64	12 34.57	217/0128	0.30	150	180	0.81	>1.20&
21 M	S1	64 51.69	13 21.26	214/1526			220/0930			103	moored	
23 M	G2	62 26.46	07 43.92	215/1352			221/1620			125	moored, buoy sank	
06 D	H2	62 47.90	08 28.45	215/1847	62 48.49	08 28.39	221/1022	1.10	006	469	1.27	2.04!
16 S	I2	63 03.94	09.03.50	215/2136	63 04.80	09 03.50	221/0715	1.60#	000	505	0.55	1.40
14 D	K2	63 33.61	10 09.63	216/0328	63 33.61	10 08.91	221/0008	1.34	090	527	1.16	1.39
17 S	L2	63 44.35	10 33.75	216/0627	63 43.99	10 35.03	220/2150	2.47#	254	530	0.72	1.32
13 D	M2	63 57.37	11 05.02	216/0908	63 57.02	11 05.19	219/1521	0.72	206	426	1.19	1.87
18 S	P2	64 23.56	12 08.85	216/1359	64 23.77	12 07.77	219/2102	2.04	079	448	0.74	1.48!
12 D	Q2	64 33.80	12 34.81	217/0122	64 33.69	12 34.65	220/1225	0.36	125	176	1.20	2.09!
19 S	R1	64 41.55	12 54.55	217/0400	64 41.54	12 54.60	220/0617	0.10	259	195	0.77	1.39

Notes

M miniDOBS
D DOBS
S SOBS
$ GPS problems, position from Chernikeef log
# difficulties locating on recovery
& estimated minimum rise rate from depth, release & observation times
! uncertain rise rate, obs more than about 30 degrees away from vertical from ship to sea floor
? unknown rise rate due to long period before observation on surface

CLOCK DRIFTS AND OFFSETS

Master Clocks relative to Moscow

Clock		Initial offset (ms)	Error (ms)	Drift rate (ms/day)	Error (ms/day)
Lucky 7	1	-27.9	0.6	-0.133	0.021
	2	-4944.1	0.9	-0.127	0.009
RVS		+ 455.6	1.1	-0.373	0.002

Lucky 7 jumped on day 216 between 0714 and 0927. Taking the jump at 216/0820, there was a retardation of 4915.6 ms.

DOBS - MOSCOW

				Pre-deployment		Deployment 1		Recovery		Deployment 2		Recovery	
Inst	Time	Offset	Error	Drift	Error	Drift	Error	Drift	Error	Drift	Error	Drift	Error
		ms	ms	ms/hr		ms/hr		ms/hr		ms/hr		ms/hr	
06	212/1029	181.35	3.7	-18.37	0.31	-3.30	0.02	-16.20	0.19	5.98	0.02	-18.70	0.02
06*	if 1 sec error									- 1.39	0.02		
12	212/2216	- 12.26	2.3	- 2.20	-0.0	-0.70	0.05	- 2.24	0.02	1.22	0.02	- 2.27	0.01
13	212/1029	183.69	0.8	1.36	0.03	0.71	0.23	3.27	0.31	Clock	reset		
14	212/1029	185.40	1.0	0.86	0.04	Clock	reset						
14	216/0252	- 78.34	0.5					0.87	0.04	0.48	0.01	0.88	0.01
16	212/1029	184.74	1.1	- 0.10	0.06	-0.17	0.05	- 0.60	1.80	-0.49	0.01	- 0.67	0.01
17	212/1029	188.86	0.9	- 0.25	0.03	-0.25	0.01	0.87	0.03	Clock	reset		
18	212/1029	184.28	0.7	- 1.57	0.02	-1.24	0.01	- 1.49	0.19	-1.19	0.02	- 1.58	0.01
19	212/1029	180.17	0.7	- 1.51	0.03	Clock	reset						
19	212/0231	-1229.8	0.5					- 1.59	0.03	-1.69	0.02	- 1.67	0.01

Notes

1. Deployment and recovery times are given on the previous page.
2. Drift rate errors should be taken as minimum uncertainties.

OBS RECORDING WINDOWS

DOBS instr	Site	% recorded	Continuous recording Start	Min	Max	Explosives windows Start	End	Number
Deployment 1								
06	G1	100	213/18 00	215/07 11	215/14 42			
16	H1	100	214/01 00	215/14 11	215/21 42			
14	I1	25	214/01 00	215/14 11	215/21 42			
17	K1	75	214/01 00	215/14 11	215/21 42			
13	L1	100	214/02 00	215/15 11	215/22 42			
18	M1	100	214/04 00	215/17 11	216/00 42			
12	P1	100	214/09 00	215/22 11	216/05 42			
19	Q1	15	214/12 00	215/23 51	216/07 06	216/11 59	216/23 59	25
Deployment 2								
06	H2	100	215/17 00	216/22 56	217/05 01	217/07 59	217/20 59	93
						218/07 59	218/20 59	
						219/07 59	219/20 59	
						220/06 29	220/11 59	
16	I2	100	215/21 00	217/01 58	217/07 51	217/07 59	217/22 59	105
						218/07 59	218/22 59	
						219/07 59	219/22 59	
						220/06 29	220/11 59	
						218/07 59	218/23 59	
						219/07 59	219/23 59	
						220/06 29	220/11 59	
17	L2	80	216/06 00	217/04 51	217/09 33	217/07 59	217/23 59	111
						218/07 59	218/23 59	
						219/07 59	219/23 59	
						220/06 29	220/11 59	
13	M2	5	216/09 00	217/09 48	217/14 54	217/09 59	217/23 59	111
						218/07 59	218/23 59	
						219/07 59	219/23 59	
						220/06 29	220/11 59	
18	P2	100	216/14 00	217/16 31	217/21 54	217/14 30	217/23 59	98
						218/07 59	218/23 59	
						219/07 59	219/23 59	
						220/06 29	220/11 59	
12	Q2	100	217/01 00	218/00 19	218/05 01	218/07 59	218/23 59	78
						219/07 59	219/23 59	
						220/06 29	220/11 59	
19	R1	100	217/03 00	218/02 19	218/07 01	218/07 59	218/23 59	78
						219/07 59	219/23 59	
						220/06 29	220/11 59	

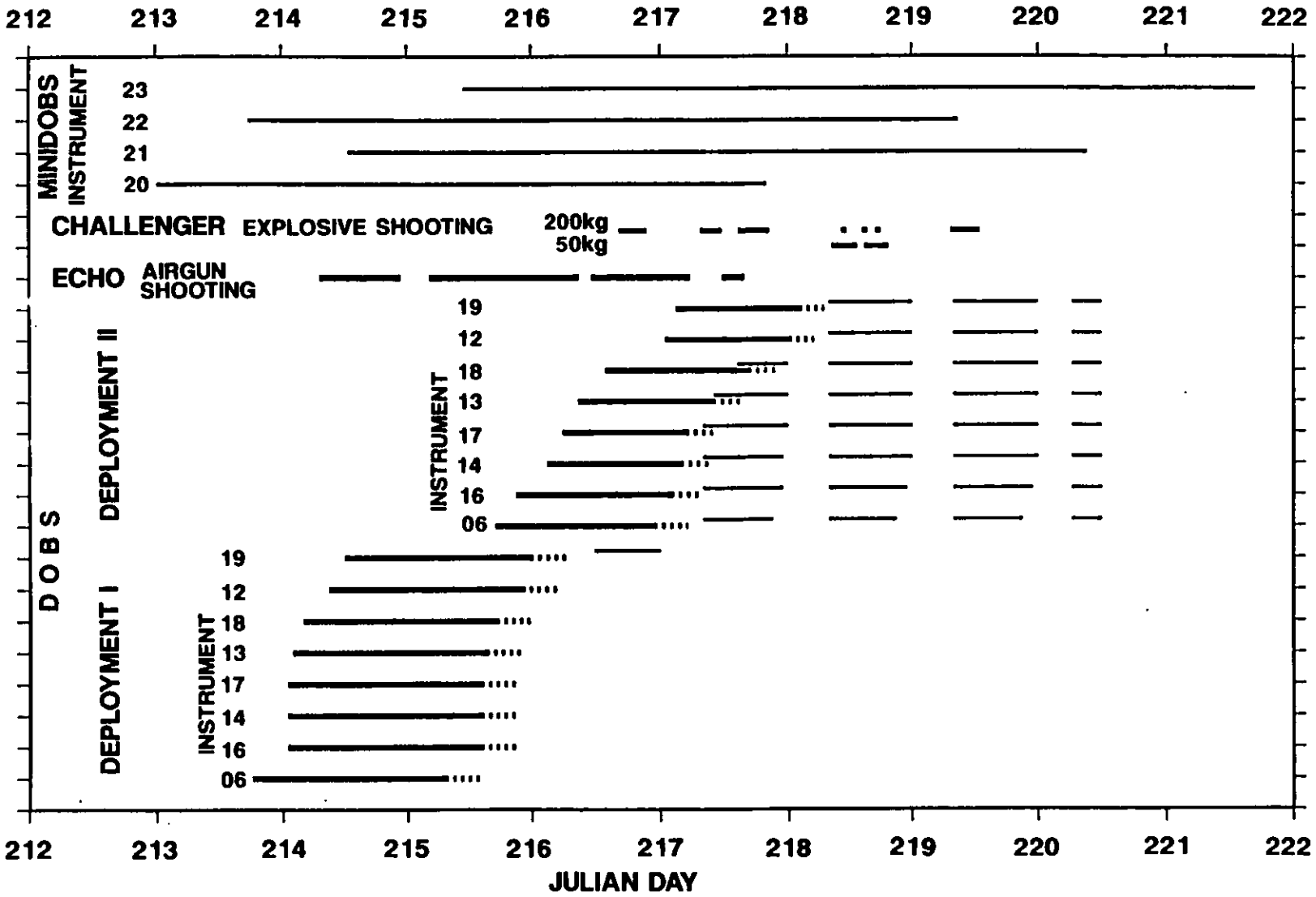
Notes 1. All explosive windows were at least 3 blocks long.

2. Explosives windows every half hour between times shown, except when continuous recording may just finish before a shot. In these cases (OBS13 at 217/0959 to 217/1429, OBS18 at 217/1430-217/2129) there were 4 alarm entries at: 1 min before, 30 secs before, on and 30 secs after the half hour mark.

miniDOBS

Instr	Site	% recorded	Recording Start	End	Deploy	Recovery
20	J1	49	213/00 18	217/19 53	213/20 15	221/02 25
22	N1	93	213/17 44	219/08 49	214/06 40	219/17 30
21	S1	100	214/15 26	220/09 15	214/15 26	220/09 15
23	G2	100	215/10 54	221/16 44	215/13 52	223/16 20

miniDOBS and DOBS '% recorded' figures may include unrecoverable or poor data.



KEY

MINIDOBS ——— Recording Time

DOBS ———···· Min/Max Continuous Recording Windows

——— Explosives Recording Windows

SHOTS ——— Time of Shot

TABLE OF JULIAN DAY NUMBERS

Fri	29th	July	210	Fri	5th	August	217
Sat	30th	July	211	Sat	6th	August	218
Sun	31st	July	212	Sun	7th	August	219
Mon	1st	August	213	Mon	8th	August	220
Tues	2nd	August	214	Tues	9th	August	221
Wed	3rd	August	215	Wed	10th	August	222
Thur	4th	August	216	Thur	11th	August	223