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DEACON LABORATORY

M.V. EASTELLA

19 JUL (200) – 8 AUG (220) 1989

BOTTOM SHOT EXPERIMENTS WITH OCEAN BOTTOM SEISMOGRAPHS IN THE NORWEGIAN SEA.

CRUISE REPORT NO. 208

1989

Natural Environment Research Council

INSTITUTE OF OCEANOGRAPHIC SCIENCES DEACON LABORATORY

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Bottom shot experiments with

Ocean Bottom Seismographs

in the Norwegian Sea

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ABSTRACT

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CRUISE OBJECTIVES

This cruise was carried out under a contract with the Admiralty Research Establishment, Portland to make and interpret measurements of seismic velocities in the top thousand metres or so below the sea-bed. Six sites were to be visited in the Norwegian Sea along a line from about 62°20'N 15°40'W to 64°15'N 2°20'W (Figure 1). At each site the same sequence of experiments was planned. Bottom shots were to be deployed along a line a few kilometres long and recorded by two digital ocean-bottom seismographs (DOBS). These instruments had previously been modified under an earlier contract in order that they could record digitally the rather high frequency signals generated by such bottom shots. In addition the DOBS were to record shots fired by an array of near-surface airguns. Reflection profiles were also to be obtained to aid the interpretation of the seismic refraction profiles and disposable sonobuoys were to be deployed as opportunities arose.

NARRATIVE

The M.V. *Eastella,* a stern trawler owned and operated by J. Marr, mobilised in its home port of Kingston-upon-Hull on 17 July 1989. The mobilisation was the responsibilty of NERC's Research Vessel Service. A great deal of equipment had to be loaded and installed onto the ship including a stern A-frame and flat-bed, containerised compressors, davits and a seismic streamer winch. In addition a hatch had to be modified and an overhanging davit constructed for lowering the DOBS to the below-deck lab area. The work proceeded steadily over three days and with only minutes to spare to catch high-water we sailed from the Albert Dock at 1852 on 19 July (Day 200) 1989.

Following a short ceremony to scatter the ashes of a former member of the crew at Spurn Head we dropped the Pilot and mourners and at 2118 we turned north into the North Sea en route for Strome Ferry in NW Scotland where explosives were to be loaded. This had not been possible in Hull due to the National Dock Strike affecting that part of the port licensed to load explosives.

The 20 July (201) was spent in preparing equipment for the cruise ahead and in planning logistics. A test of the electrical hoist for raising and lowering the DOBS from the lab area was carried out while hove to. A scientific meeting was held in the evening to explain the cruise objectives to the scientific party. Ship's time changed to GMT during the night.

On 21 July (202) after breakfast we hove to off the north end of the Minches to carry out a trial deployment of the echo-sounder fish. This was useful in revealing a number of problems requiring modification of the usual deployment technique. We also began to realise how difficult it was to heave to in a ship with a variable pitch propeller. The PES fish was towed for several hours at 5 knots as a test. The Oceano acoustic navigation fish was also deployed to gain familiarisation with it. At 1700 it was agreed to increase speed in order to reach Strome Ferry that night and anchor.

The ship was off Kyle of Lochalsh by 0700 22 July (203) the time at which the explosive was to be loaded. However it was difficult to contact the agent for some time. A launch appeared at 1020 eventually with the explosive and the agent on board. We had anchored in the wrong place, Kyle of Lochalsh and not Strome Ferry. The transfer of explosive proceeded smoothly. The launch then took the Captain ashore for a medical appointment. He returned at 1235 and the ship set sail shortly afterwards. The PES fish was deployed at 1515 in a flat calm sea and we resumed passage at 1540. Scientific watchkeepers were introduced to their tasks by means of a short tour and talk in the evening.

On 23 July (204) the ship steamed through thick mist on passage to a test site at which it was planned to deploy a DOBS to record two bottom shots at different ranges. A Fire and Boat drill was held at 1300. During the afternoon three shots were made up for the test site. This revealed several minor problems, principally that the filled charges of Powerprime (in contrast to the empty dummy cartridges with which ICI had supplied us earlier for design purposes) were somewhat wider in diameter than expected. As a result the bundled groups of 7 cartridges did not fit easily in the shot cases. The made up charges of Powerprime, with RDX cord explosive threaded through them, were returned to the magazine. A DOBS was also prepared in the evening for the test the following day.

An early start was made on 24 July (205) at the Test Site NE of Iceland. A DOBS was deployed at 0647 with an extra buoyant hydrophone suspended 40 metres above the DOBS. The shot preparation required a considerable time and the second charge was deployed with little time to spare in order for it to reach the sea-bed before being detonated by its timer clock. The two charges were laid at ranges of 2.5 and 4 kms from the DOBS as part of an experiment to demonstrate the necessity, or otherwise, of having a buoyant hydrophone above the sea-bed to record the direct water-wave. The first shot was not heard on the echo-sounder and the second shot sounded like a click suggesting that only the detonator had fired. At this point it seemed more sensible to recover the DOBS and reconsider the shot firing technique rather than to attempt to fire the third reserve charge. We came to the conclusion that the RDX cord was the weak link in the initiation chain. Either the RDX was not being initiated or else the RDX was not setting off the Powerprime. The DOBS was recovered normally. Inspection of the DOBS recordings however showed unexpected full-scale monotonic signals on both hydrophone channels. More bottom charges were prepared for the first full experiment the following day.

On arrival at Site 4 early next day (Day 206) a bathymetric survey was carried out to find a region of flat sea-bed for the bottom shot experiment. In what was to become standard procedure for the rest of the cruise a set of three Oceano acoustic beacons was deployed next. The beacons were deployed at the corners of a 5 km on-a-side equilateral triangle. On arriving at the third vertex however the other two beacons could not be heard. We found empirically that this was due to the noise of the main engines. The only solution was to lower the towed Oceano fish to a greater depth. About 40 m of extra unfaired cable was paid out although this automatically reduced the speed at which the fish could be towed to about 4 knots. At this point a survey was started to determine the relative positions of the three beacons. The two DOBS were laid by 1408 and then 8 bottom shots were deployed at 450 m spacings along a southwesterly line in foggy and damp conditions (Figure 2). Only three of the shots detonated but one other was heard to fire the detonator only. Subsequently the large gun array was deployed and this was up and firing by 2049.

The guns were fired during the early hours of 26 July (207) until 0136 (Figure 3). A 300 ins^3 gun with wave-shape kit was deployed next in preparation for a seismic reflection profile back to the DOBS. However the gun could only be triggered intermittently. In spite of intensive efforts this could not be resolved and at 0630 the reflection profile had to be abandoned. The DOBS were recovered by late morning in very poor visibility. Attempts to release the first acoustic beacon, which involved the use of a 'dunked' overside hydrophone instead of the fish, also met with problems due to the noise produced by the ship's bow thruster. All three beacons had been recovered by 1541 when course was set for Site 6 with a following SE swell. During the beacon recovery operations the acoustic fish had inadvertently been towed at 6.5 knots for a time and this caused damage to a connector within the fish itself which needed to be replaced. A set of ten bottom shots was prepared during the evening for use the following day. Inspection of the DOBS recordings, although excellent on the geophone channels, revealed the same problem with the hydrophones as seen at the Test Site. A sea earth problem was suspected.

At Site 6 early next morning (Day 208) the connector in the acoustic navigation fish was repaired. By 0925 the fish was in the water and working again. The three beacons were laid and their relative positions determined by about 1500. Two DOBS were then deployed and the airgun array was in the water and firing by 1900 as the ship passed over the DOBS. The guns were fired along a line parallel to the trend of the Kolbeinsey Ridge and brought inboard at 2300 (Figure 4). They were replaced by the reflection profiling equipment (streamer and 300 ins^3 gun with wave-shape kit). A reflection profile was obtained not only along the airgun refraction line but also along the line of bottom shots to be fired next day.

Reflection profiling ceased at 0535 28 July (209). We were in position to begin bottom shot deployments at 0700. Ten charges were laid at 280 m spacings along an ENE line in damp and rainy weather during the morning (Figure 5). A substantially improved success rate was achieved as a result of revised procedures, the last shot firing at 1350. Shot instants were recorded using an overside hydrophone with the ship lying to and the main engines stopped. The two DOBS had been recovered by 1700 and the three beacons by 2010 in thick fog. The hydrophone noise problem was found to have been solved by the elimination of an earth loop. Course was then set for Site 5.

The acoustic fish was deployed on approach to Site 5 at 0825 29 July (210). The familiar process of beacon deployment and relative navigation was completed by early afternoon and was followed by DOBS deployments at 1355 and 1411. Five bottom charges, prepared the previous day, were armed and laid at intervals of 280 m in good conditions along an 043° trending line (Figure 6; the remaining charges were to be laid the following day). All five charges detonated successfully. At 2042 the airgun array was out and firing following a short failure of the ship's power supplies. The guns were fired away from the DOBS along the same direction as the bottom shot line until 0230 when the seismic profiling equipment was deployed instead (Figure 7). This time a 40 ins^3 gun was used to obtain higher resolution records because of problems with the wave-shape kit on the 300 ins^3 gun. Two disposable sonobuoys were also deployed.

The laying of bottom shots resumed next morning at 0800 in rather windy conditions. Five shots had been laid by 1005. Three of these fired on time but the next was 3 minutes late and the last did not fire at all. The two DOBS had been recovered by 1454 and the acoustic beacons and the Oceano fish were on deck by 1810. Course was then set for Site 3. Examination of the DOBS data that evening showed high quality data was still being collected.

A site survey was started at Site 3 at 0600 on 31 July (212). Eventually a sufficient length of flat sea-bed was found for the bottom shot experiment. The ship started to lay acoustic beacons at 0800 and their relative positions had been determined by 1215. By then however a swell had appeared from a depression over Scandinavia and this caused the ship to roll excessively making it too dangerous to retrieve the heavy DOBS from the hold or to deploy them. Work therefore had to be abandoned temporarily. Although the swell eased in the afternoon the requirement to re-program the DOBS recording windows meant that they could not be laid until 1900. Bottom shots were postponed until the following day. Thus the gun array was deployed in the evening and it was up and firing by 2100 as the ship passed over the DOBS on a southerly course parallel to the regional strike (Figure 8). This line was completed by 0143 when the guns were brought on deck and a 40 ins^3 gun and the streamer were deployed instead. A reflection profile was obtained on return to the DOBS position and also along the intended 309° trending line of bottom shots.

Ten bottom shots were laid between 0833 and 1400 on 1 August (213), with a short rest break for the shotfirers halfway through (Figure 9). By 1445 the ship was lying to with engines off and an overside hydrophone deployed. All shots bar one fired. By 1700 the first DOBS was closed and both were back on board by 1842. Beacon recovery proceeded without difficulty and was completed by 2155 with the recovery of the acoustic fish. Course was then set for Site 2.

We arrived in the vicinity of Site 2 at 0700 on 2 August (214). A short bathymetric survey was conducted to find the centre of the median valley of the Aegir Ridge and also to check that the valley was indeed flat along the axis of the valley. At this point however a weather forecast of Gale force 8 later in the day together with a falling barometer and a freshening wind indicated a deterioration in the weather was imminent. Work was temporarily halted. Although the weather was monitored frequently during the day the barometer continued to fall more rapidly in the afternoon as we expected an increase in wind. This did not materialise but the large seas and frequent rain were sufficient to make work on deck, and particularly shotfiring, hazardous. Work was thererfore postponed until the following day.

Early next morning (Day 215) a fresh wind was still blowing but the barometer appeared to have 'bottomed out' and there was an improved weather forecast. As we steamed between the acoustic beacon deployments we noticed from time to time that the transponder signals were being completely lost. Eventually the signals were lost altogether and this, together with the illness of the sole operator of the Oceano equipment aboard ship, put paid to any further attempts to use the acoustic navigation at this site. The fish problem was isolated to the underwater connector in the towed fish but in spite of replacing it the problem was not solved. At this point the only sensible way forward seemed to be to abandon the acoustic navigation and to rely on less precise Loran C for positioning the bottom shots. Therefore in the evening of 3 August we deployed the two DOBS and continued with firing the large airgun array during the night (Figure 10).

During the early hours of 4 August (216) a strong wind got up as the airguns were being recovered and this delayed the onset of the reflection profiling. As a result we returned to the vicinity of the DOBS rather later than anticipated. Preparation of bottom shots then went ahead but was soon threatened by the appearance of a Danish military aircraft which repeatedly 'buzzed' the ship and called us on VHF. As soon as the first charge had been deployed we were able to call back and explain our presence in Faroese (Danish) waters. Eventually all nine charges were laid in fine sunny weather with reasonable success using Loran navigation (Figure 11). All nine shots fired but two were late, presumably because of a problem with their timers. At the end of the shot instant recording our drift track had brought us close to one of the acoustic beacons which was then released before returning to the DOBS. Finally we released the remaining acoustic beacons the last of which was located at the surface in rapidly fading twilight at 2230. The acoustic fish connector had been carefully repaired during the day and a short tow test confirmed it was in good repair.

The ship steamed overnight to Site 1. After a short bathymetric survey the acoustic beacons were laid in turn in a stiff breeze with northwesterly swell. The DOBS were then laid and deployment of the bottom shots began at 1500. The shotfirers worked straight through in difficult swell conditions and all shots had been laid by 1834 (Figure 12). (All of the small amount of remaining explosive was then ditched overboard (a few cases of Powerprime remained because the charge configuration had had to be changed to ensure reliable detonation). The ship was lying to by 2015 to record the bottom shots. All ten detonated on time. Shortly afterwards the airgun array was deployed and by 2300 we were steaming over the DOBS in a northeasterly direction with the guns firing (Figure 13).

About 0100 on 6 August (218) there was a short power failure which temporarily halted the airguns and compressors but work resumed after about ten minutes. Reflection profiling began on the run back to the DOBS at 0430 and was completed at 0815. It remained only to recover the DOBS and the three acoustic beacons to finish the station. The echo-sounder fish was also brought inboard in good conditions and the ship set course for Hull at 1512. Scientific watchkeeping ended at that point.

The ship made good speed in fairly calm, if at times foggy, conditions and docked at Hull at 2055 on 8th August.

R.B.W.

NAVIGATION

A variety of navigation systems was used during the cruise. Equipment installed on the Bridge included an MNS-2000 system (which can receive Decca, Loran C, Transit etc.). This was used with Loran-C as the principal navaid throughout the scientific operations and provided the ship's officers with a visual display of ship's position and waypoints. In addition ARE provided a second Loran-C receiver which was installed in the Main Lab. This had the great advantage of providing watchkeepers with real time ship's track, speed and heading information. The option to enter waypoints on the screen was most useful in planning the disposition of bottom shots and acoustic beacons. A GPS system provided by RVS was also installed and enabled a check on the Loran positions to be made for those times (upto about 12 hours/day) when it was running. Lastly the Oceano acoustic navigation system was used to determine the relative positions where the DOBS and bottom shots were dropped with a precision approaching a few metres.

All four systems had their own advantages. Loran-C provided 24-hour coverage in the work area with a degree of consistency which was very adequate for general navigation and relocating bottom packages. Several times however discrepancies between the two Loran sets of upto 0.4 miles were apparent and occasionally any one set would exhibit a systematic jump or offset with respect to the other of the same magnitude. In these circumstances it was very useful to have the GPS receiver to decide which set was correct. The Oceano acoustic navigation system is described separately.

R.B.W.

ACOUSTIC NAVIGATION

An Oceano Acoustic Navigation System was employed at each site to give precise navigational information about the drop positions of both the DOBS and the shots. This information was presented graphically on the Bridge and in the Main Lab. as well as being logged on disk and plotted in real time.

The system performed well, however some problems were experienced. Three bottom transponders were deployed at each of the six sites. The baselines were between 4 and 5km long. The same transponders were used throughout the cruise (Ser. Nos 919, 921, 923) operating at frequencies of 11.5, 13.5 and 14.5kHz respectively with a common frequency of 9kHz. At each site a relative calibration was carried out, after the deployment of the transponder beacons. This entailed the ship steaming around the work area while a set of ranges was obtained (35-40 groups of ten). These were then processed to provide a relatively calibrated transponder network. Time did not permit, nor was it necessary, to repeat this exercise to perform an absolute calibration of the system.

At the first deployment it was found that the ship's engines generated so much noise that the automatic gain of the Acoustic Module (in the fish) was reduced, thereby limiting the slant range to less than 3km. To overcome this problem the fish had to be deployed with 50m of cable outboard. Apart from the first 18m this cable is not faired and therefore a towing speed restriction of 4 knots was imposed to limit strumming of the cable. This meant however that the fish had to be recovered to allow for either passage between sites or for airgun/SRP work. With 50m of cable out the effective slant range was approximately 7km. Recovering the fish was a long job each time on the manually powered winch. During an early deployment the inboard tow cable connector became trapped in the winch and was damaged. This connector and its mating connector will need to be replaced before the equipment is used again.

The noise of the bow thruster prevented the release transducer/Telecommand Unit from hearing the command-acknowledged signal from the transponders on the sea bed. This signal is also used to confirm that the transponder has carried out the release command. Towards the latter part of the cruise problems with turning the bow thruster on and off meant that these signals could not be heard. The only way of knowing whether a transponder had released was to use the fish/Range Meter. This is not good practice and does not allow safe recovery.

During recovery of the transponders at Site 4 the signal received from the Acoustic Module failed. The fault was caused by water behind the pins in the connector in the fish. The cable was shortened and the connector renewed. After the deployment of the transponders at Site 2 trouble was experienced with the fish again. The relative calibration run was abandoned and the fish recovered. Water in the connector was again found to be the cause. Again the connector was replaced. Problems were still being experienced with the fish when it was deployed again and it was decided to use Loran C for the site rather than lose any more time. A wire in the connector had corroded away. Yet again the cable was reterminated. The fish was redeployed to recover the beacons and worked satisfactorily.

The only logging of acoustic data was carried out by the Hewlett Packard personal computer which is part of the navigation package. The format of the disks (and data) obtained is not readily usable except on this machine so a program was written during the cruise to transfer, via the RS232 port, data suitably converted for storage on an IBM PC. The transferred fix data included time, latitude and longitude information for every cycle (every 10 secs) and the quality of the fix determination.

Other software changes were made to allow for A4 plots. Plots were made of the drop positions for each site including Site 2 where Loran C was used. It should be noted that the uncertainty of positions at Site 2 is much greater than at the other sites where the RMS misfit is less that 5m.

Generally the system performed very well allowing accurate navigation to be carried out. The only lost time was caused by the ingress of water into a connector and the difficulty of recovering the acoustic fish.

The following table gives the Central Meridian for the UTM co-ordinates for each site.

Site	1	2	3	4	5	6
Degrees (west)	-3	-6	-9	-12	-12	-15

Time statistics for the cruise:

	Hours	
Time used for navigation	47.5	(44%)
Time down	12	(10%)
Time deploying/recovering	35	(32%)
Time calibrating	15.5	(14%)

D.G.B.

DIGITAL OCEAN BOTTOM SEISMOGRAPHS (DOBS)

During the autumn of 1988 two Teledyne Geotech PDAS 100 (portable data acquisition systems) were purchased as replacements for the previous DOBS data acquisition systems. These new units enabled recording of geophone and hydrophone data at up to 1000 samples per second per channel, all the data being stored on battery-backed solid-state memory. Low-noise hydrophone pre-amplifiers were interfaced to the new logger and geophones were directly connected to make use of the internal PDAS pre-amplifiers and analogue filtering. Analogue filters for 3 geophones and hydrophones were modified from the standard 200 Hz low pass to 400 Hz low pass by resistor changes to the PDAS analogue signal processor boards. It was planned to record sea bed explosive charges at 1000 samples/sec and air gun refraction lines at 100 samples/sec. However final testing just before the cruise revealed that data corruption occurred on the auxiliary hydrophone channel when this combination of sampling rates was used. Contact was made with Teledyne Geotech in Texas and a software fault was discovered. Rather than attempt a hasty software modification just prior to the cruise, Teledyne supplied and fitted both of our PDAS units with an extra recording channel so that we did not have to use the corrupted auxiliary channel. This work was carried out in Hull just prior to sailing.

An external hydrophone deployed some 40 metres above the DOBS was also added because of fears that, due to refraction of the direct water wave, arrivals from near bottom explosive shots would not be detected by the DOBS-mounted hydrophone. This deployed unit consisted of a 40m cable from the DOBS up to a housing, containing a pressure case with pre-amplifier and an O.A.S. E-4SD hydrophone, the housing and cable being buoyed up by a 10 inch Benthos glass sphere.

Our first instrument deployment was at a test site to check deployment and recovery systems, instrument performance, and explosive shot preparation techniques. Examination of the data retrieved from the DOBS showed a large signal of approximately 80Hz recorded on both hydrophone channels. The source of the noise was puzzling; a local acoustic source was suspected.

At Site 4 both DOBS were deployed and again hydrophone channels were swamped with similar low frequency noise. However a high impedance path between one hydrophone terminal and its case was then discovered which led to a suspicion that a sea-earth loop involving the two hydrophones was causing PDAS, or other, circuitry to become unstable. The explosive charges generated direct water waves which could be detected by the vertical geophone channel. These arrivals were needed to calculate shot instances and hence shot ranges to the DOBS.

At Site 6 one DOBS was deployed with a single hydrophone mounted on the instrument, in its usual configuration, and the other instrument carried only the floating hydrophone unit. Results from this site again showed noise on the floating hydrophone channel but the DOBS in its standard form had recorded perfectly. It was therefore decided, in the light of this result and the successful recording of direct water waves by the DOBS-mounted sensors, to remove the buoyed hydrophone from all future deployments at the next four sites.

A total of thirteen instrument deployments was made during the cruise (Table 1) and the new PDAS data loggers performed flawlessly, no sensors were damaged and the acoustic release systems performed well.

Deployment and recovery of the instruments was at times a little exciting, however only one instrument suffered a slight impact on the side of the ship during deployment. This did no damage to the internal electronics and the instrument subsequently performed perfectly. The final site was a total success, in that all bottom shots and the airgun refraction line were recorded.

Examination of some of the raw unfiltered data aboard ship revealed very interesting results (Figure 14). As data recorders the PDAS units were very impressive, detecting background noise levels 75-80 dB below full signal levels. Post-cruise filtering of the data should produce some very good data sets. This was the first time PDAS data loggers, originally designed for land use, had been deployed in the deep ocean. Future upgrading of the instrument with ruggedised hard disc drives (40 Mbyte capacity) and externally deployed geophone packages is intended.

The DOBS instruments in their new configuration have proved to be robust, reliable, capable of obtaining results of the highest quality. Funding to purchase two more units would give I.O.S. a suite of instruments at the forefront of oceanographic technology.

To enable DOBS experiments to be carried out extremely accurate timing is needed to synchronise remote airgun or explosive shot firing with clocks in the recording instruments. During 1988 a clock unit was built at I.O.S. and two repeater units were also built. The master clock was designed to transmit a time code at 10 Kbaud along co-axial cable to the clock repeaters. These repeaters gave a time display and could also generate variable period pulses used to fire airguns. The master unit had a built in battery back-up supply to maintain crystal oscillator operation during power failures.

Several short interruptions to the ship's supply occurred during the cruise, however the clock system performed without fault. The time output was compared with the M.S.F. Rugby radio time code transmission (60kHz) for much of the cruise and a drift in absolute terms of 2mS/day was recorded. This versatile clock system will be of great use when DOBS are used on non-NERC ships and when RVS clock systems are not available or not working.

R.E.K.

BOTTOM SHOTS

The programme called for 10 bottom charges to be laid at each of 6 sites. Due to accidental breakage of some of the shot cases during loading onto the ship in Hull, it was possible to make up only 59 of the 60 planned charges. The design of the charges was novel, being based upon partly succesful earlier experiments on RRS *Discovery* during 1986 and 1987.

Each shot was planned to consist of the following components:

28 ICI Powerprime 400 gramme primers.

8 ft.of Ensign Bickford "Primacord" Nylon 80 RDX.

1 Jet Research pressure resistant electrical detonator,type D1012.

1 PVC weighted tube with lid to encase the explosives.

1 Electronic firing circuit in pressure housing.

As an initial test of the design and handling systems,two experimental shots were fired on 24 July, with only limited success. It appeared that only the detonators were firing. A number of alterations were made to the packaging of the RDX and Powerprime and a further eight shots were deployed on 25 July, during which four different configurations were experimented with. As a result, a final configuration was chosen and used at the remainder of the sites.

The initial design employed four separately bound packs, each of seven primers, inserted end to end in the PVC tube housing,with the length of Primacord threaded through in a loop from top to bottom to top of the charge. One end of the Primacord was crimped to the detonator and the other end sealed against water ingress. This was done by sealing the end of the RDX cord with Cowgum, inserting it into one of the aluminium caps supplied by Jet Research, double-crimping the cap and finally covering the outside of the joint with a 2 x 2 mastic pad. The detonating cord was a very loose fit in the holes through the primer casings and, in spite of manufacturer's assurances, this is thought to have contributed to the poor rate of success during the early trial shots. It was also thought possible that the end of the cord which was crimped into the detonator could have become wet and desensitised due to the lack of an adequate waterproof seal at this junction.

In the finally adopted design one of the packs of seven primers was replaced by a pack of four, around which the Primacord was taped tightly in a spiral. A length of twine was threaded through the holes in the primers and tied at the top of the assembly to maintain intimate end-to-end contact during deployment. Finally, the free end of the detonating cord was smeared with a quick drying gum (Cowgum) before being crimped into the detonator. The crimped junction was then wiped clean of traces of glue and well sealed externally with a 2 x 2 inch 3M mastic pad.

With this modified assembly the rate of successful detonations increased immediately. The results achieved at the ensuing sites were as follows (see also Table 1).

SITE	DATE	NO. CHARGES DEPLOYED	NO. FIRED	NO. MISFIRES
4	25 July (206)	8	4	4
6	27 July (208)	10	7	3
5	29 July (210)	5	5	0
5	30 July (211)	5	4[1]	1
3	1 August (213)	10	9	1
2	1 August (216)	9	9[2]	0
1	5 August (217)	10	10	0

[1] One shot fired 3 minutes late

[2] Two shots fired 12 minutes late

In most cases of misfire the detonator was heard to have been successfully initiated. The three shots which detonated later than planned did so as a function of incorrect resetting, or incorrect operation, of the electronic timers. The exact cause is not yet established (but see below).

The detonators were fired by a small electronic timer and battery pack inside an aluminium pressure case. Sixty of these units were produced at I.O.S., one for each bottom shot. The oscillator circuits for the timers were set to the correct frequency at a temperature of 2° C. At sea battery packs were constructed and shot timer-to-charge cables were prepared. Once the timetable for an experiment was known, each timer had its delay set to the required integral number of hours delay. The divider chain was then tested to ensure that the correct delay had been set.

Finally, just prior to bottom shot deployment, the timers were reset, using the contact closure output of the I.O.S. ship's clock, at precisely ten minute intervals. The timers were now placed inside the pressure cases and the end caps were fitted. Each timer case was marked to ensure the correct timer was used at the correct point in the shot line.

In total 59 bottom shots and timers were deployed. Only three shots were noted as going off late, one being approximately three minutes late and two more were twelve minutes late. Failure of one timer stage to reset properly could explain the twelve minute errors but the three minute error was thought at the time to be a malfunction of the crystal oscillator circuit due to temperature effects or shock during deployment.

K.G.R., R.E.K.

AIRGUNS AND COMPRESSORS

The RVS containerised 2 x VHP36 compressor unit was run for approximately 10-12 hours at each site. During these periods the compressors ran well within their capabilities (maximum demand was for 1200 ins^3/min at 2000 psi) and were problem free. In fact except for electrical problems in port at the start of the cruise no problems at all were encountered with the unit.

The airguns used during the cruise (an array of 1000 + (2 x 700) ins^3, a 300 and a 40 ins^3 gun) ran virtually problem-free for the duration of each experiment. The only exception was the failure of one 200 ft trigger cable at Site 4 caused by a corroded connector pin. After replacing this cable the gun umbilicals gave no further trouble. The wave-shape kit for the 300 ins^3 gun was used twice but the first time the chosen orifice was not optimal.

K.S.

UNDERWAY GEOPHYSICAL MEASUREMENTS

A Mk.III Precision Echo-Sounder was operated throughout the cruise. It was used not only for echo-sounding but also for transmitting to the DOBS and monitoring the DOBS release sequence. The fish was towed from the port side by an RVS davit. The only problem with this arrangement was the impossibility of slewing the davit while the fish was suspended from the block on the davit by its tow cable; a strop had to be used to take the weight. Speeds of upto 12 knots on passage between sites did not seem to cause any wear of the bushes in the towing arm.

The PES records were probably somewhat noisier than usual because of the very noisy surroundings of the ship. Fortunately no depths greater than 4000 metres were met so that the limit of the system as installed was not quite reached. However it is thought to be unlikely that useful records could be obtained at passage speeds in water depths much greater than 4000 metres. The 'fish depth' was set at 10 metres throughout the cruise equivalent to the depth of the fish when the ship was hove to.

Seismic reflection profiles were obtained at each site (except Site 4) both over the profile shot with the large airgun array as well as over the line of bottom shots. Source sizes (40 or 300 ins^3) were chosen appropiate to the expected sediment thickness. Data was recorded on the RVS Store-4 taperecorder together with a trigger pulse and a time code from the IOSDL Master Clock. The quality of the profiles, which were obtained at the relatively slow speed of 5 knots, were relatively good and did not seem to be excessively affected by ship noise.

During the reflection profiling one or two disposable sonobuoys were deployed to record mainly reflected signals from the airgun source. The relevant information is tabled below.

DISPOSABLE SONOBUOY DEPLOYMENTS

SITE	DAY NO.	TIME	LAUNCH POSITION (Lat.°N,Long.°W)		DEPTH (ucm)	SOURCE (ins^3)	COURSE (degress)
1	218	0502	64° 26.2	1° 58.9	2925	300+WSK	219
2	216	0549	65° 0.7	5° 34.5	3925	40	038
3	213	0305	66° 6.0	8° 19.8	1374	40	360
5	211	0334	67° 43.3	11° 57.1	1872	40	222
5	211	0512	67° 36.8	12° 12.9	1827	40	222
6	209	0048	68° 26.8	15° 25.7	1480	300+WSK	203

WSK = Wave-shape kit

Expendable bathythermographs (XBT's) were deployed from time to time during the cruise and in particular on the approach to each site. The latter data was required to specify a soundspeed/depth model for the correct operation of the acoustic navigation system. Data are held by ARE, Portland from whom requests for copies can be made. Measurements were made down to 1800 metres except at Site 2.

R.B.W.

TABLE 1

SITES OF BOTTOM SHOT EXPERIMENTS[1]

SITE	DAY NO.	DOBS NO.	DEPTH (m)	POSITIONS Lat.(°N)	Long.(°W)	SHOTS[2] L	R	SPACE (m)	GUN[3] (ins^3)
Test	205	55	2116	64° 23.40	7°54.79	2	0	1500	-
4	206-	55	1410	66°52.15	10°19.67	8	3	450	300+
	207	56	1425	66°52.41	10°18.22				WSK[4]
6	208-	55	1440	68°16.09	15°38.44	10	7	280	300+
	209	56	1440	68°16.08	15°39.11				WSK
5	210-	55	1799	67°31.08	12°26.79	10	8	280	40
	211	56	1795	67°31.25	12°26.32				
3	212-	55	1462	66°24.33	8°19.62	10	9	440	40
	213	56	1470	66°24.52	8°20.39				
2	214-	55	3935	65°17.11	4°58.63	9	7	360	40
	216	56	3936	65°16.89	4°59.04				
1	217-	55	2965	64°14.83	2°17.62	10	10	340	300+
	218	56	2968	64°15.06	2°17.25				WSK

1 All lines shot with a gun array of (2 x 700) + 1000 ins^3

2 L = number of shots laid; R = number of shots recorded by DOBS; SPACE = spacing between shots.

3 Size of airgun used for reflection profiling; WSK = wave-shape kit.

4 Reflection profiling abandoned due to gun trigger problem.

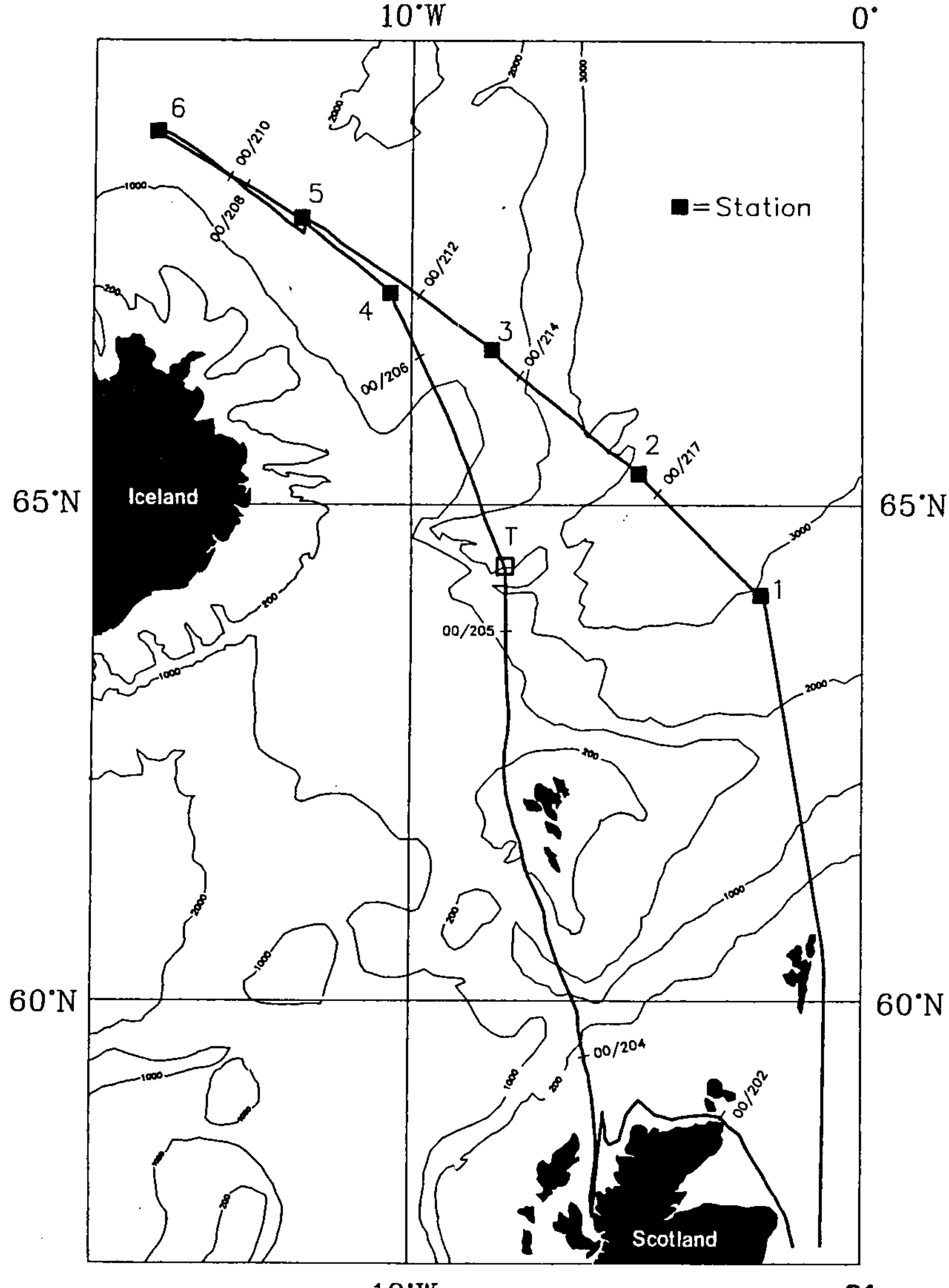

Figure 1.MV *Eastella* 19 Jul (200) - 8 Aug (220) 1989. Track chart.
Bathymetric contours are in metres. Bars on the track denote mid-night (oo hours) at the given Day Number.

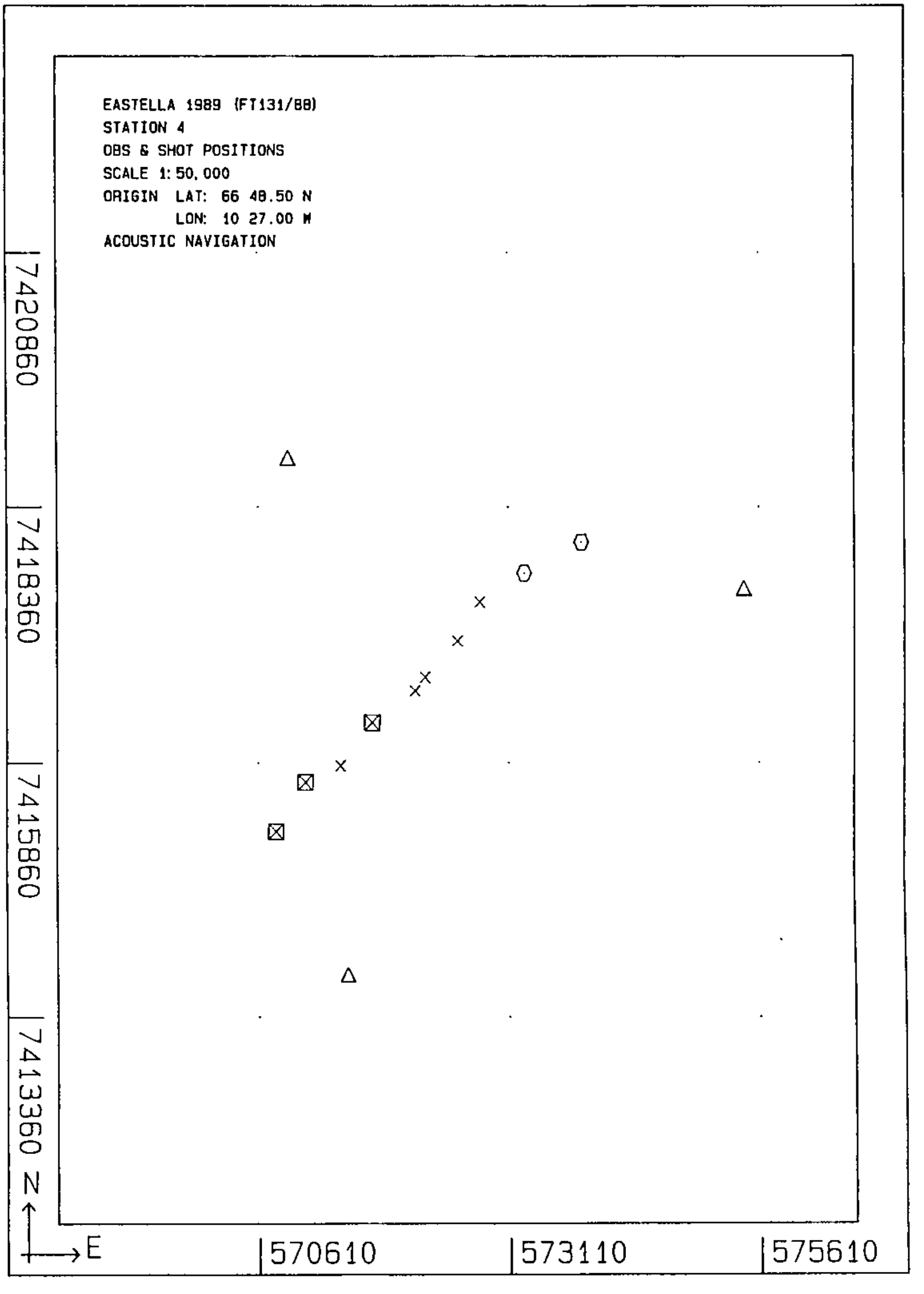

Figure 2. Relative lay positions of DOBS, bottom shots and acoustic beacons at Site 4 (hexagons = DOBS; box + cross = shot fired; cross only = misfire; triangle = acoustic beacon).

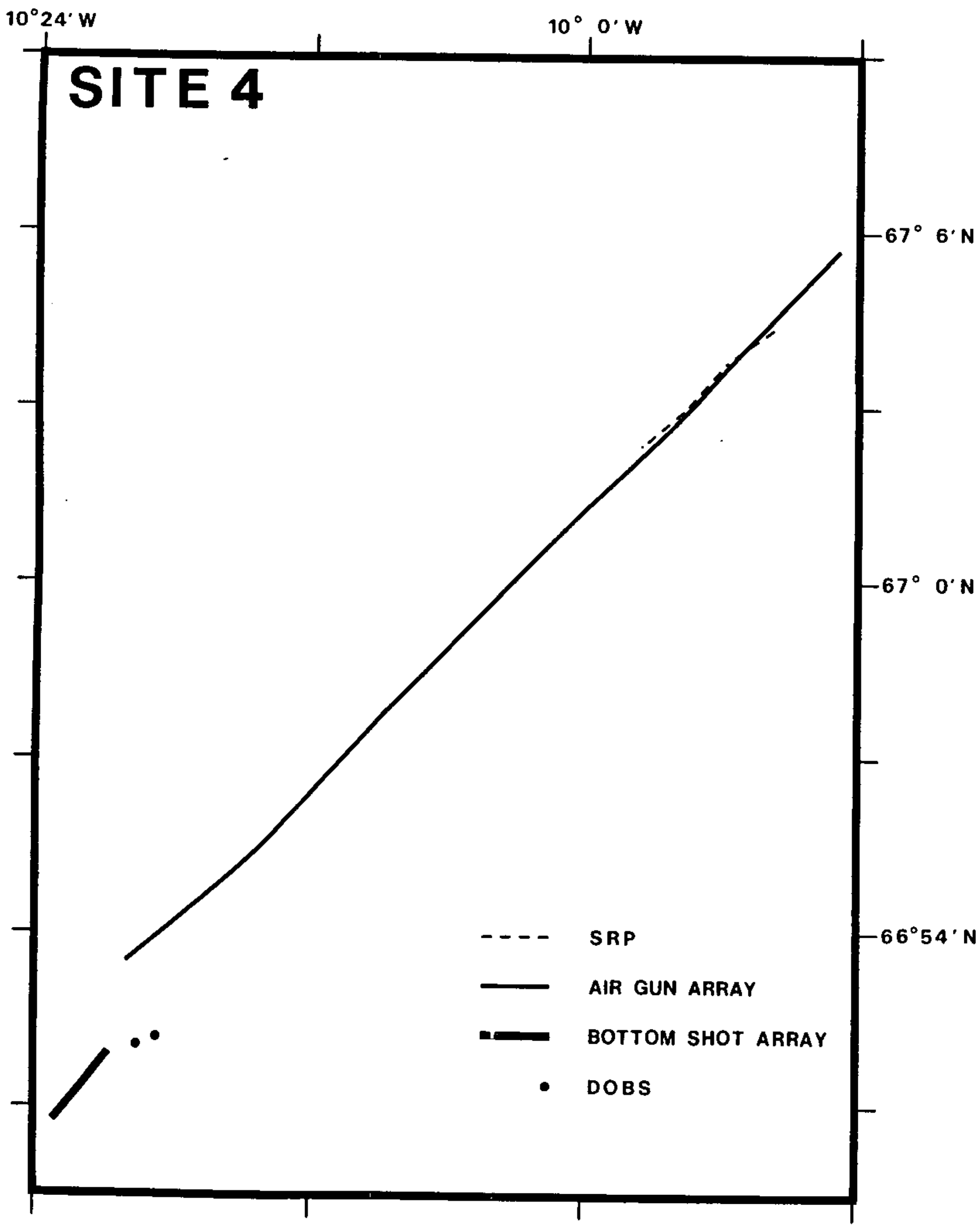

Figure 3.Track chart showing the tracks at Site 4 along which the airgun array and the seismic reflection profiles were fired.

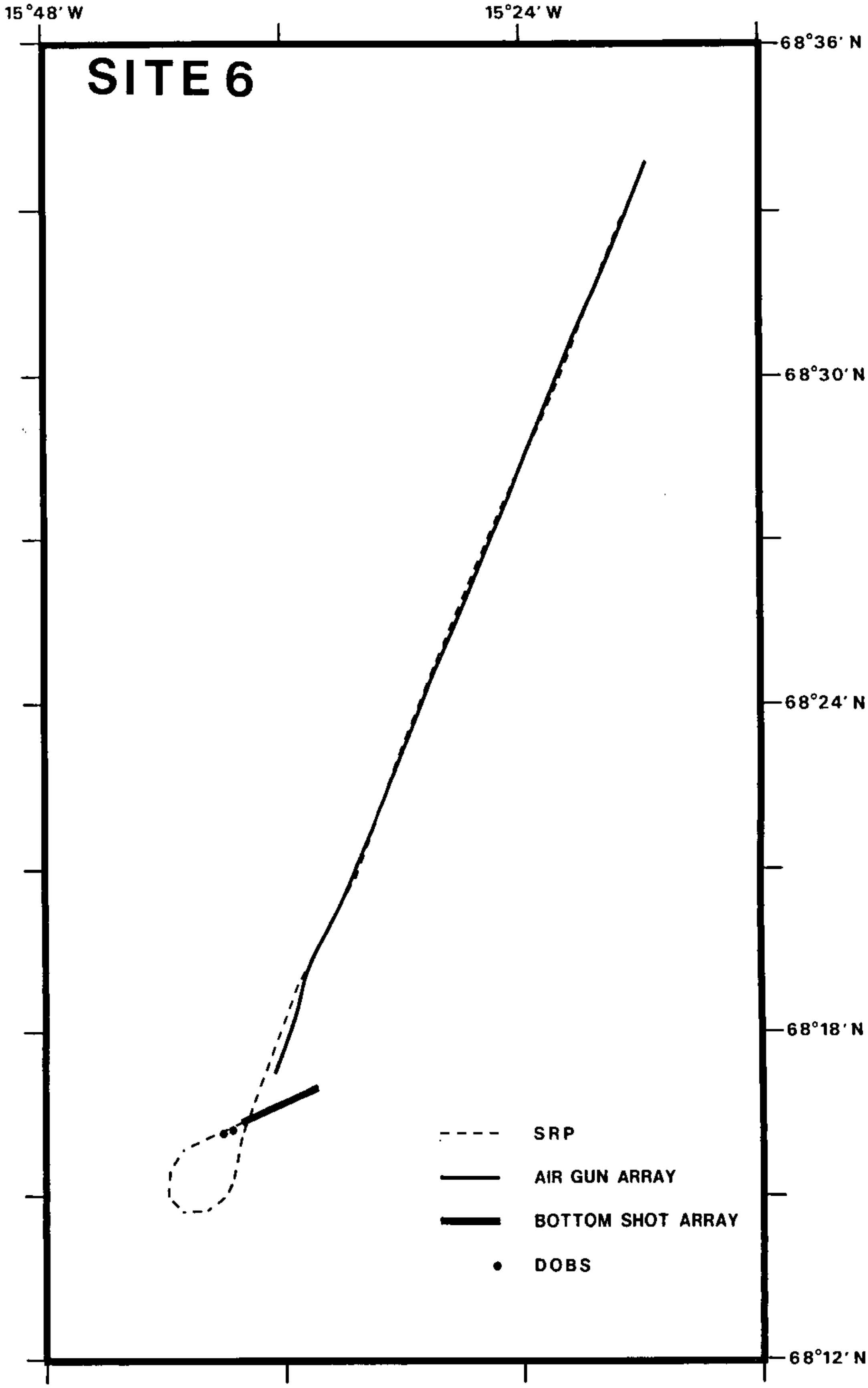

Figure 4 Track chart showing the tracks at Site 6 along which the airgun array and the seismic reflection profiles were fired.

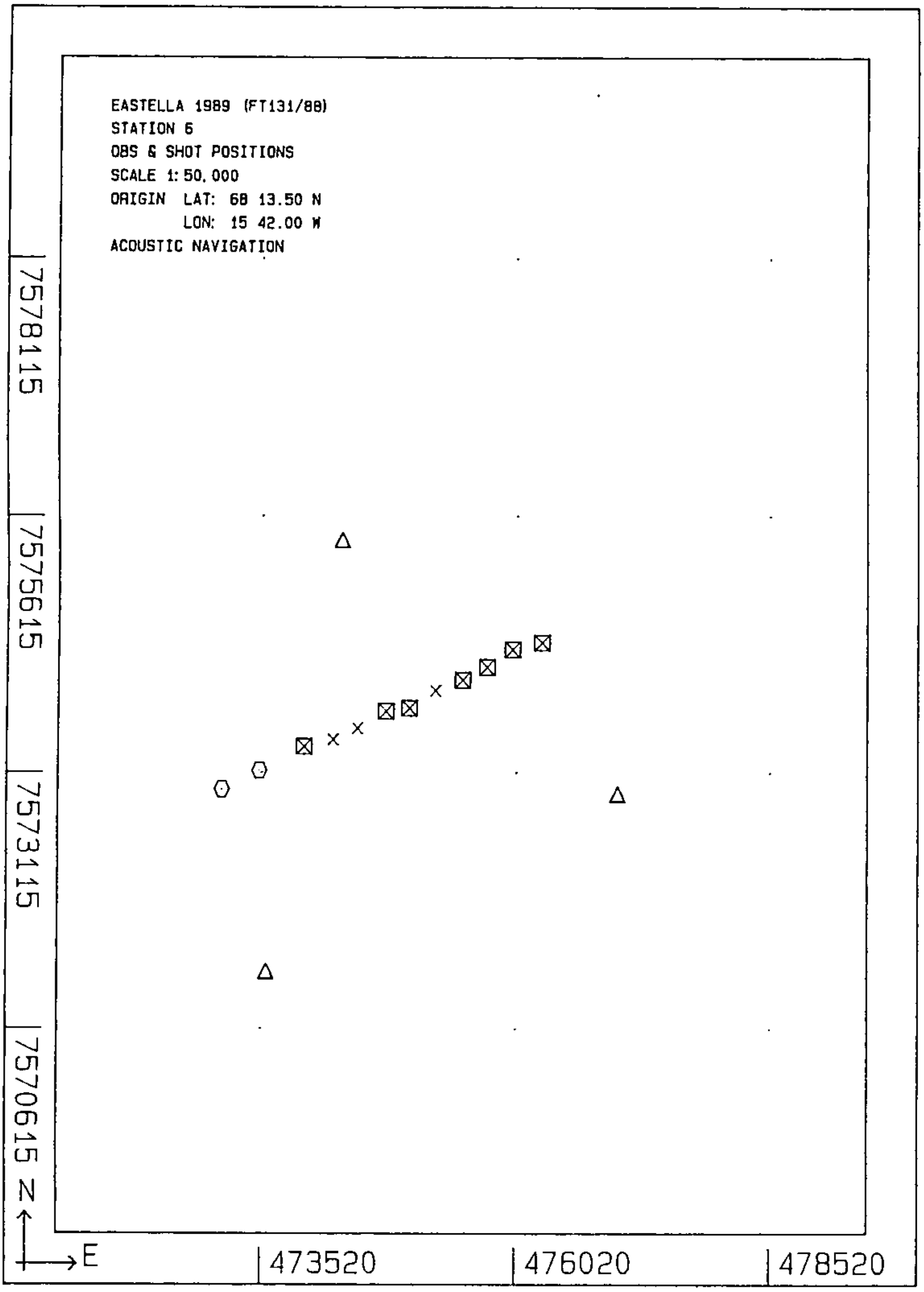

Figure 5. Relative lay positions of DOBS, bottom shots and acoustic beacons at Site 6 (hexagons = DOBS; box + cross = shot fired; cross only = misfire; triangle = acoustic beacon).

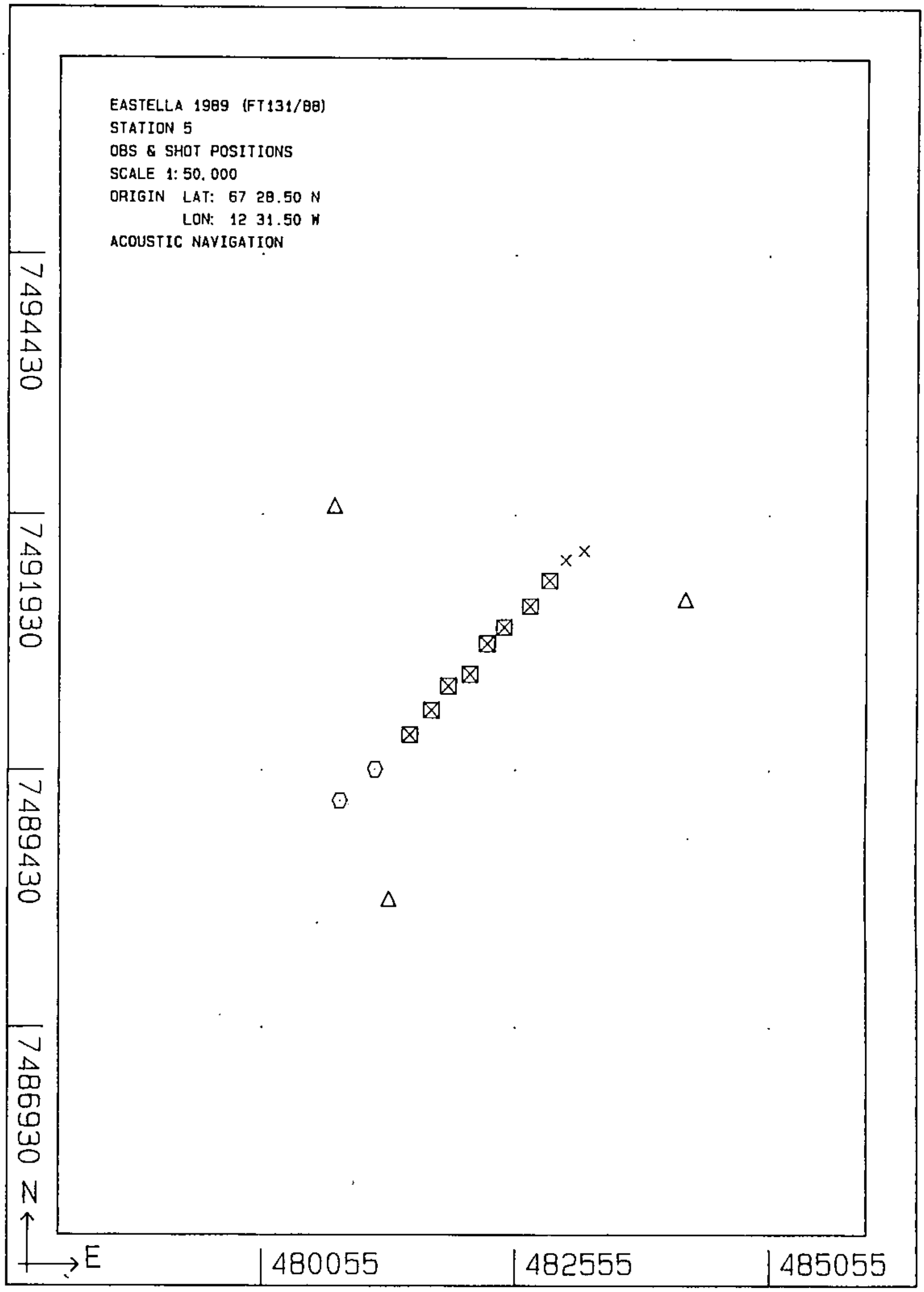

Figure 6.Relative lay positions of DOBS, bottom shots and acoustic beacons at Site 5 (hexagons = DOBS; box + cross = shot fired; cross only = misfire; triangle = acoustic beacon).

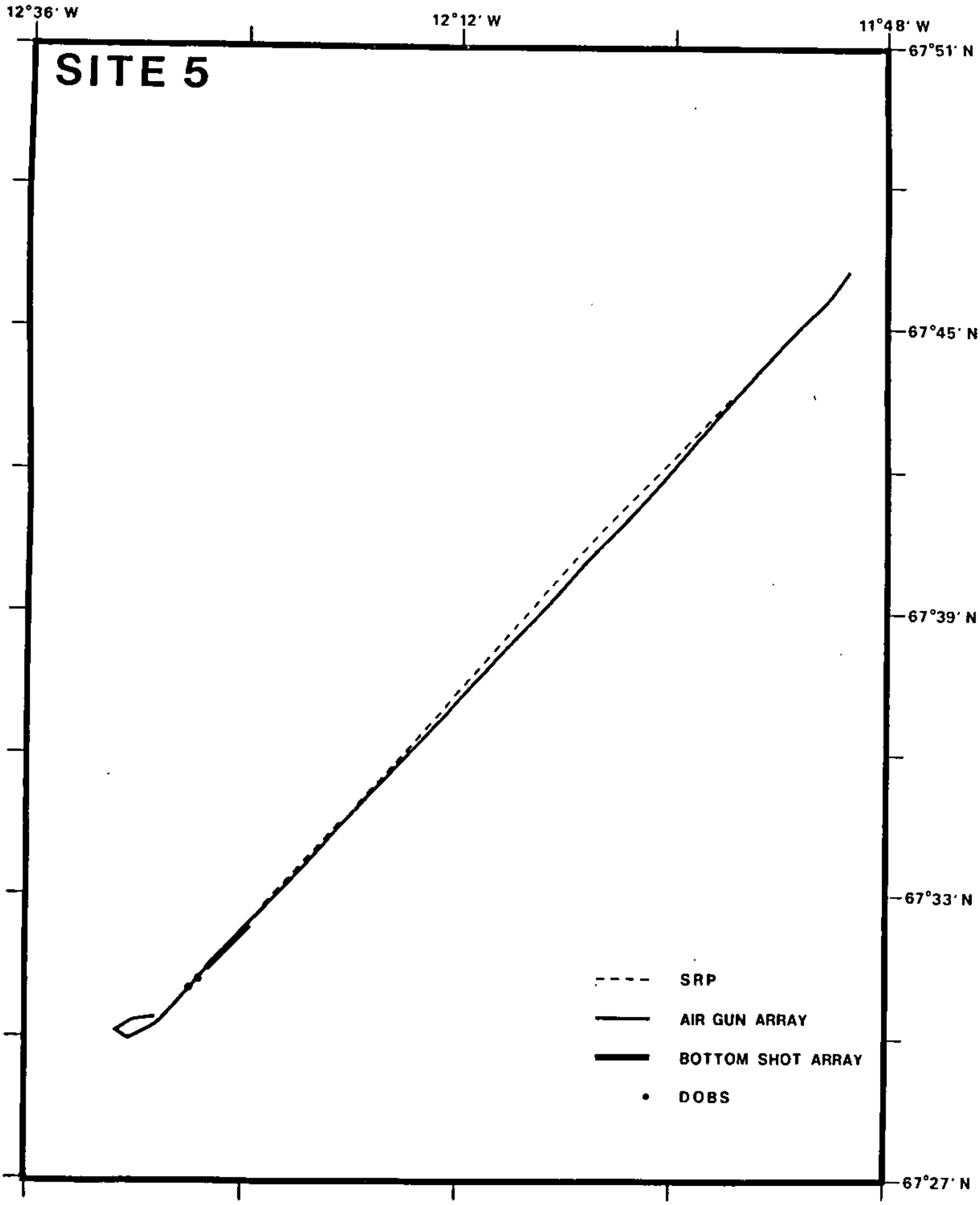

Figure 7.Track chart showing the tracks at Site 5 along which the airgun array and the seismic reflection profiles were fired.

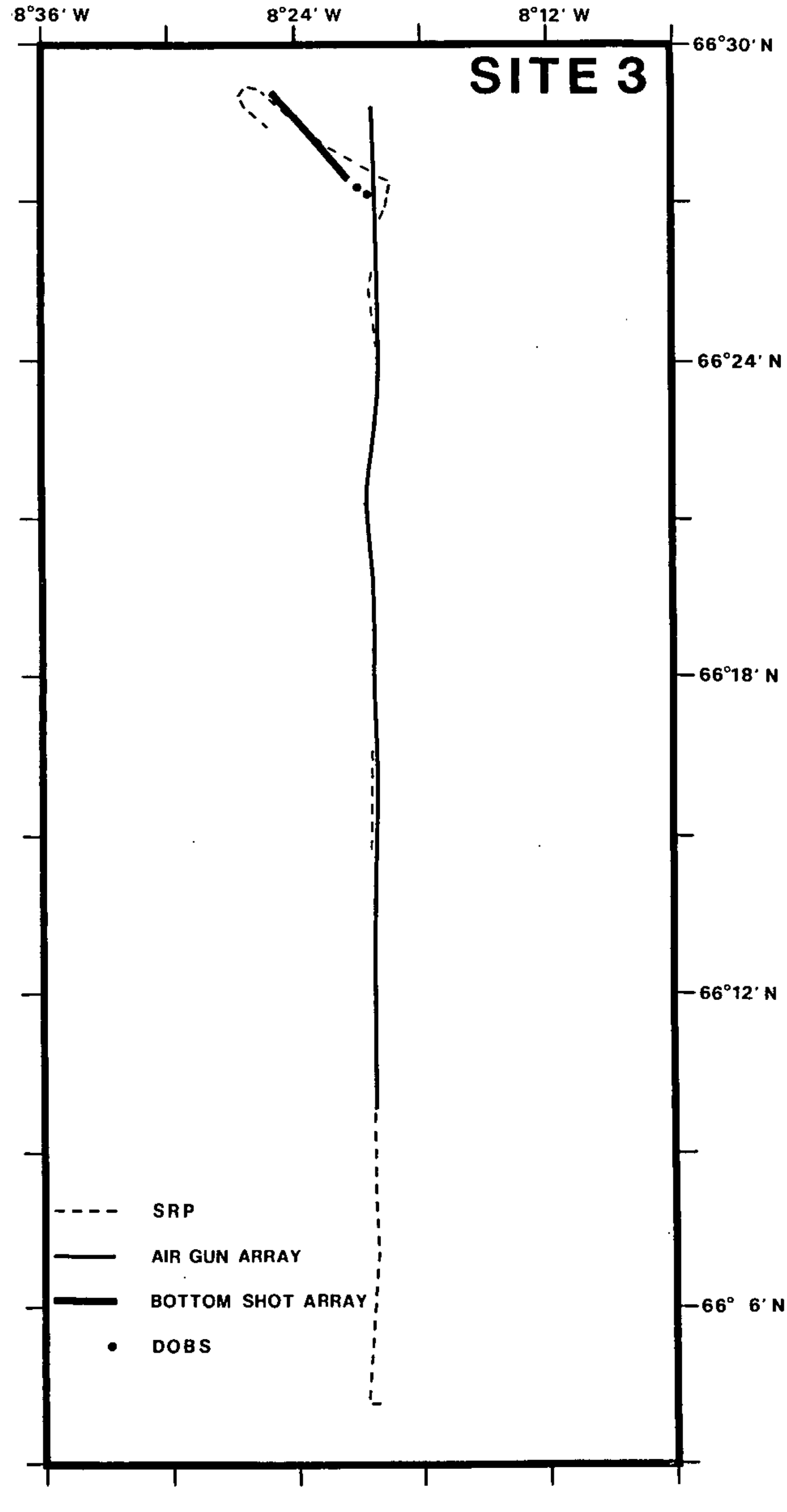

Figure 8.Track chart showing the tracks at Site 3 along which the airgun array and the seismic reflection profiles were fired.

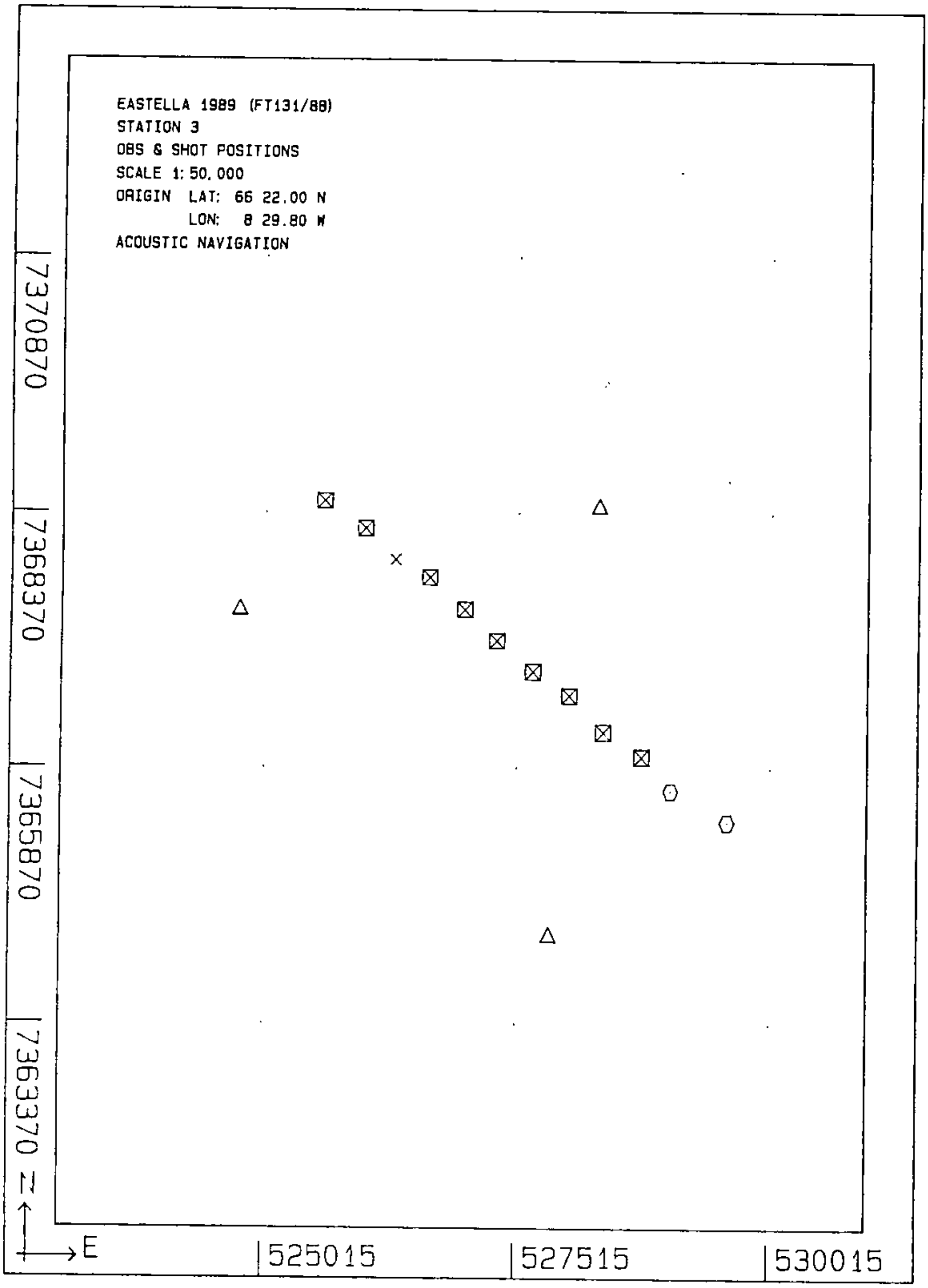

Figure 9.Relative lay positions of DOBS, bottom shots and acoustic beacons at Site 3 (hexagons = DOBS; box + cross = shot fired; cross only = misfire; triangle = acoustic beacon).

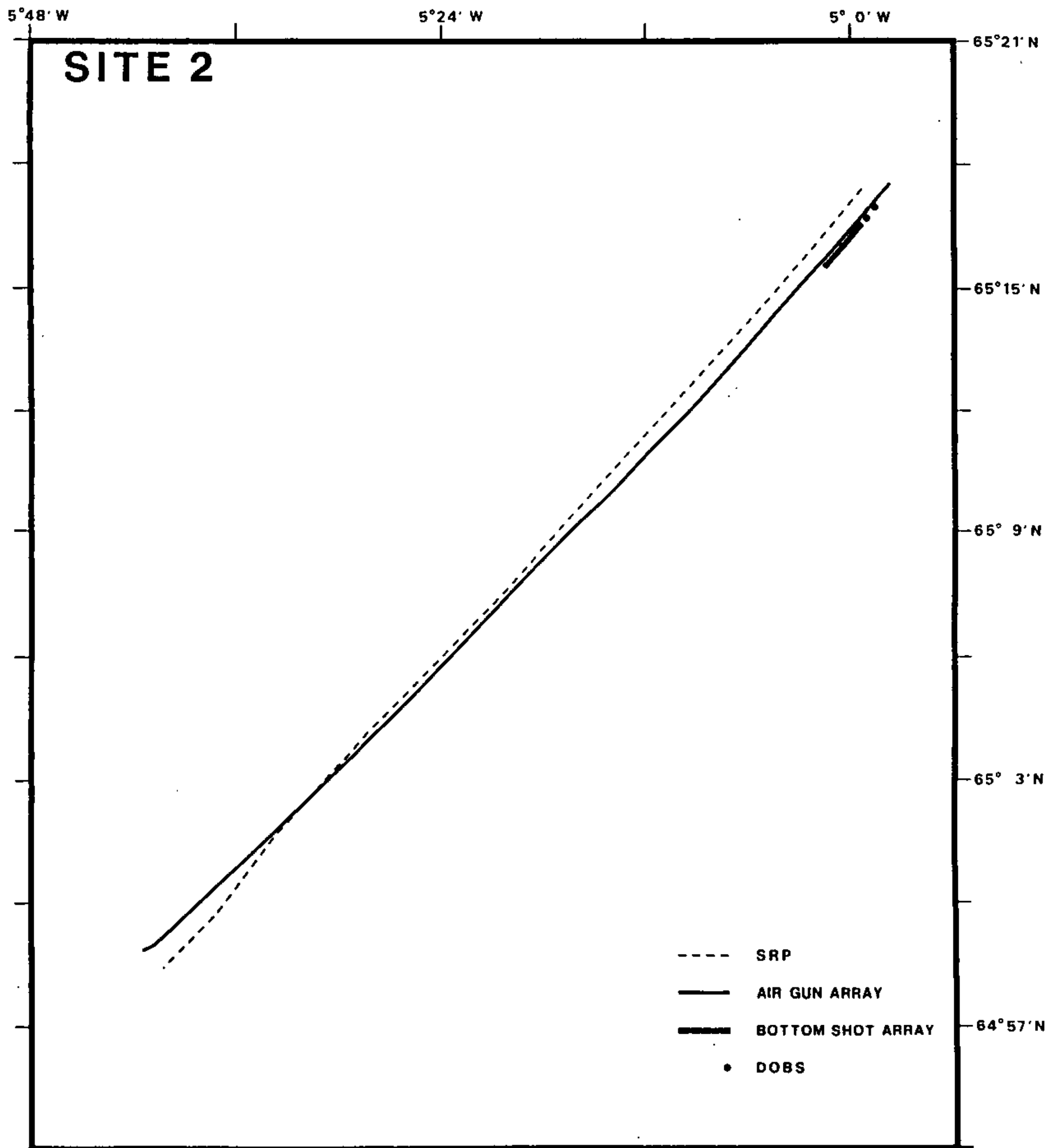

Figure 10.Track chart showing the tracks at Site 2 along which the airgun array and the seismic reflection profiles were fired.

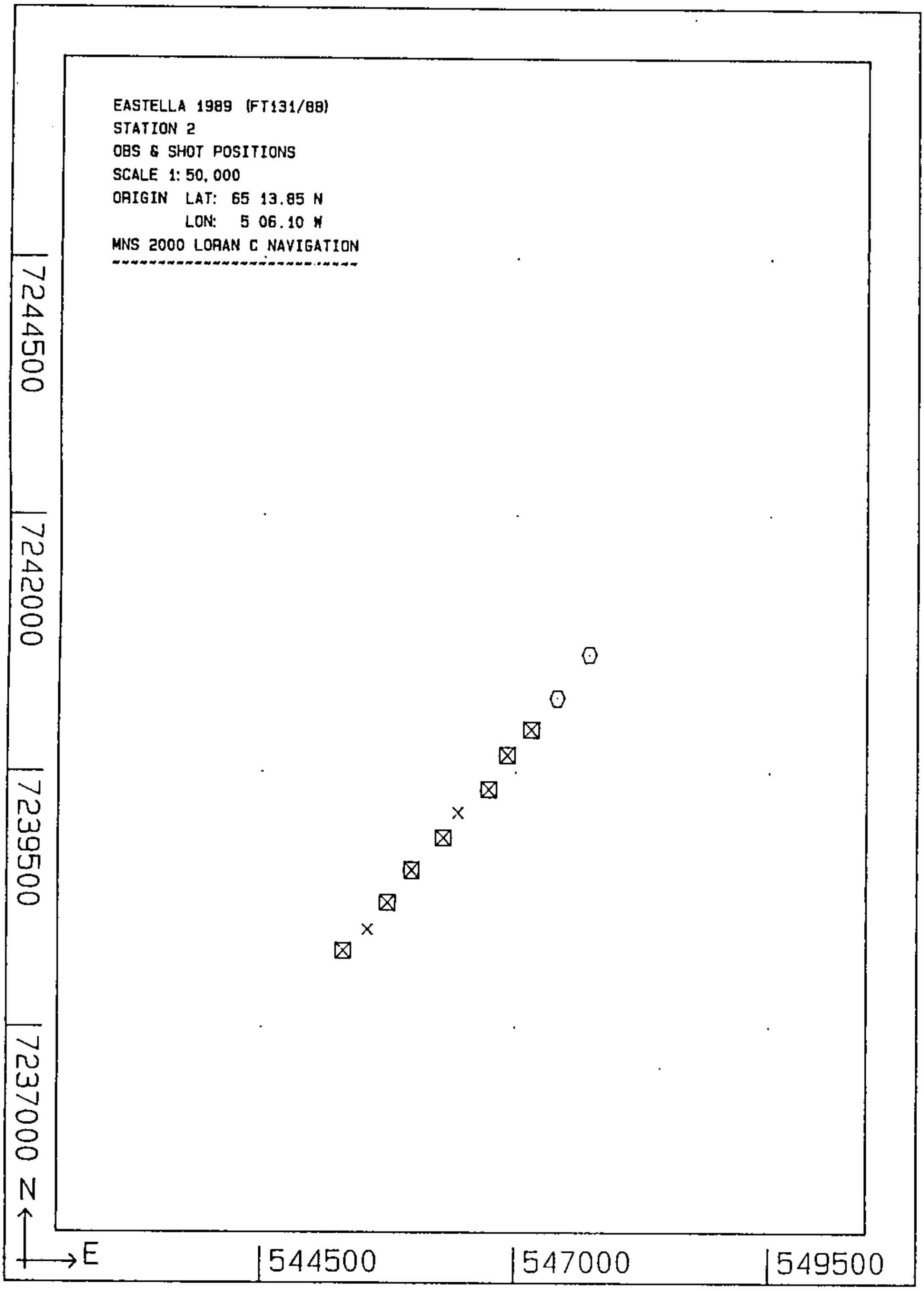

Figure 11.Relative lay positions of DOBS, bottom shots and acoustic beacons at Site 2 (hexagons = DOBS; box + cross = shot fired; cross only = misfire; triangle = acoustic beacon).

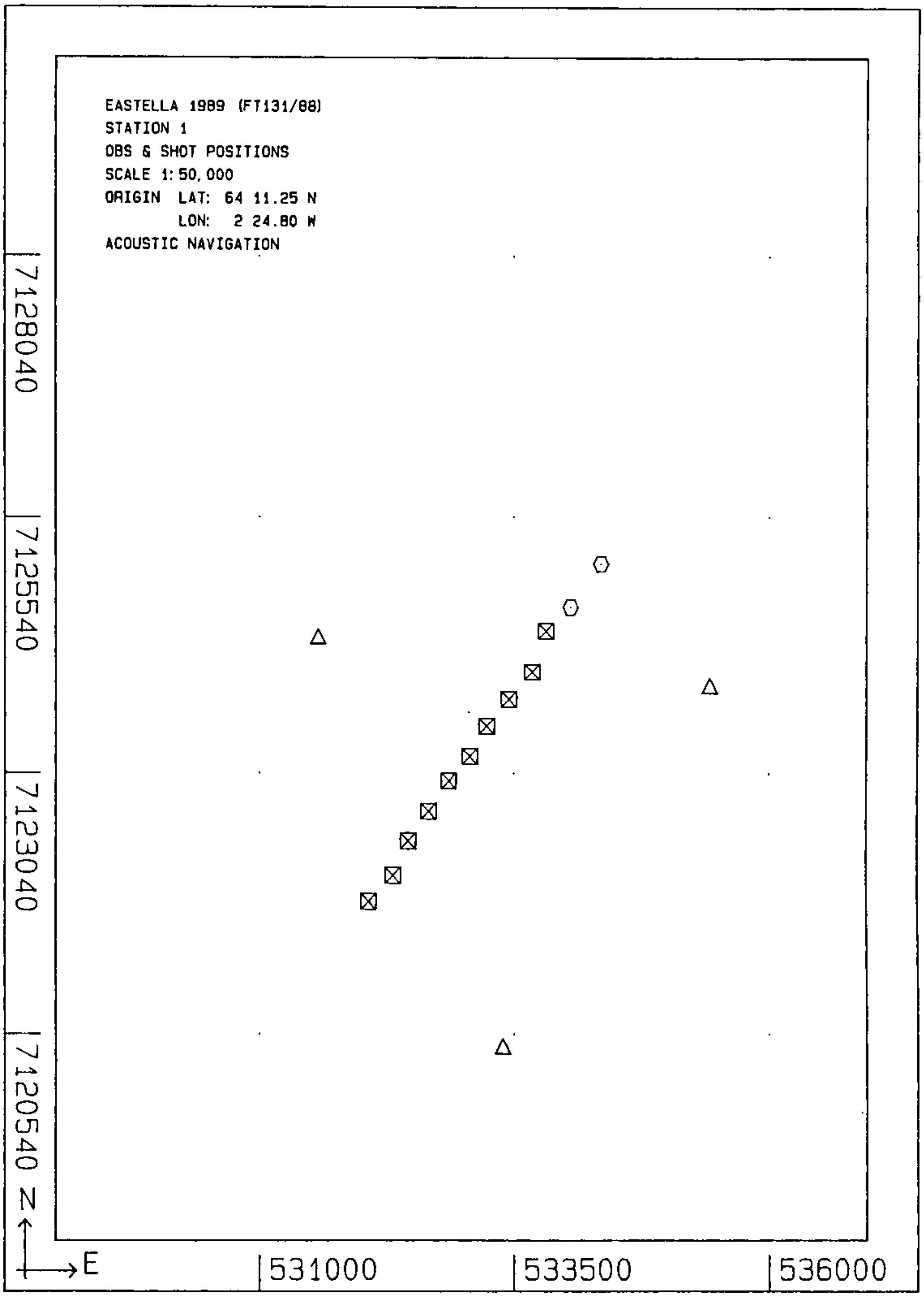

Figure 12. Relative lay positions of DOBS, bottom shots and acoustic beacons at Site 1 (hexagons = DOBS; box + cross = shot fired; cross only = misfire; triangle = acoustic beacon).

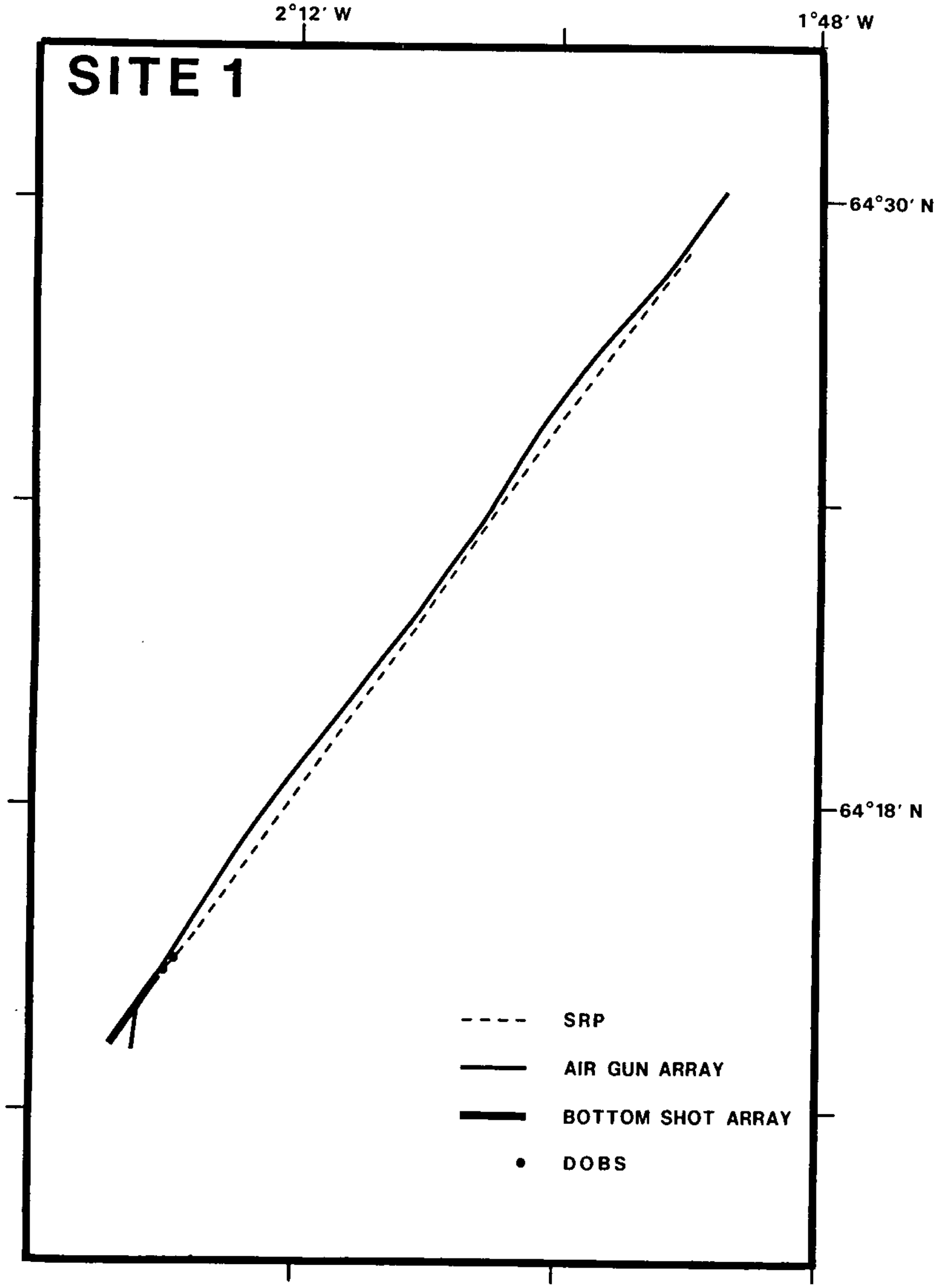

Figure 13.Track chart showing the tracks at Site 1 along which the airgun array and the seismic reflection profiles were fired.

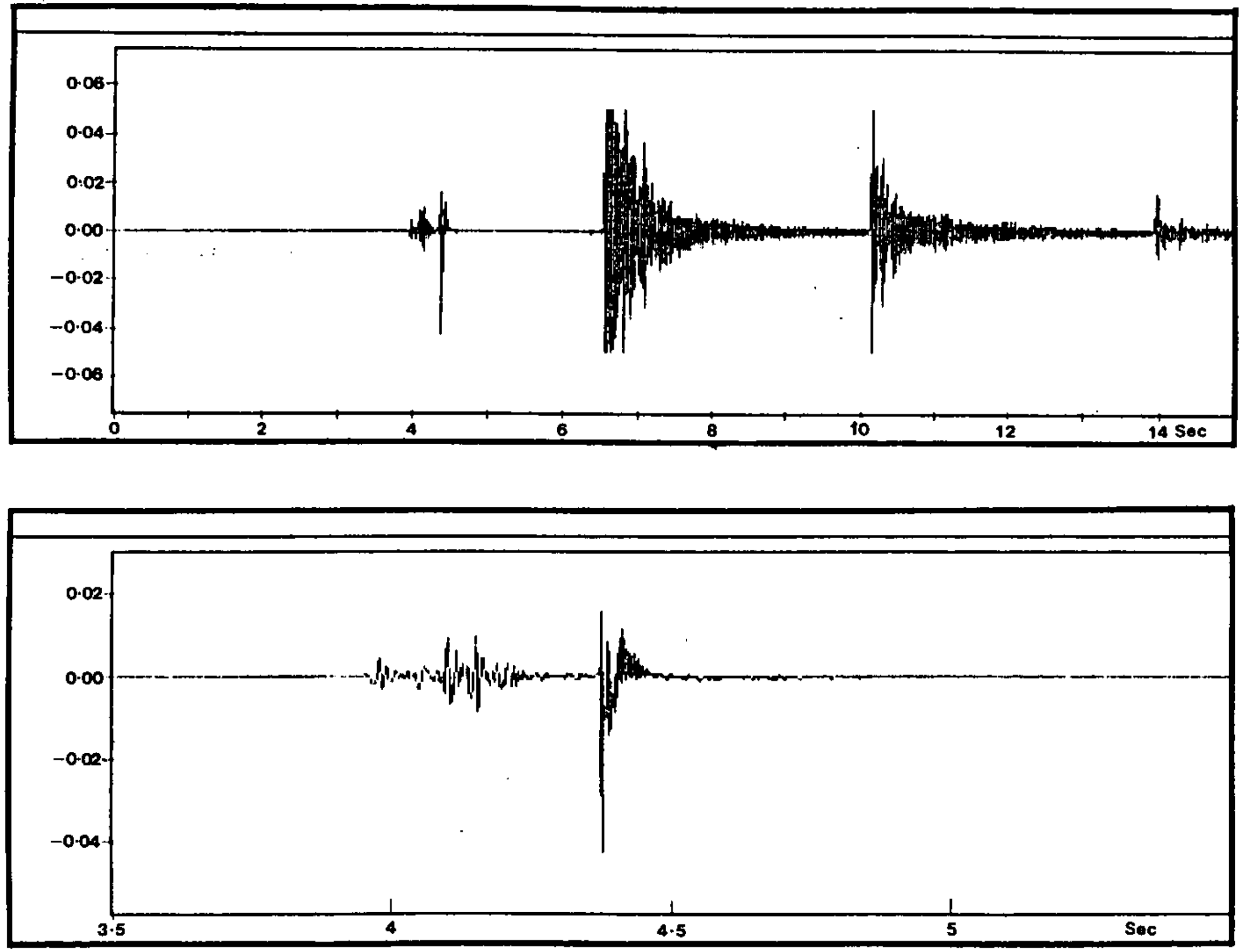

Figure 14. A typical seismogram of a bottom shot recorded by the PDAS system.
Top: a 15 second window showing the direct water-wave and three surface reflected multiples.

Bottom: expanded seismogram showing sedimentary phases followed by the direct water-wave.