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Regional Geophysical Survey of Northern North Sea on m.v. Sperus. 28 June-5 September 1977

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INTRODUCTION

This report is an account of regional geophysical investigations carried out during 1977 by the Marine Geophysics Unit of the Institute of Geological Sciences. The programme was a continuation of the IGS geological and geophysical mapping of the UK Continental Shelf.

It was planned to survey in four areas with the following priority:-

1. 1:250 000 Cormorant Sheet (61°-62°N, 0°-2°E).

2. West of Shetland in 1:250 000 Shetland Sheet (60°-61°N, 2°W-0°).

3. Additional data was required to complete interpretation of 1:250 000 Sutherland Sheet (58°-59°N, 6°-4°W).

4. 1:250 000 Halibut Bank Sheet (60°-61°N, 0°-2°E).

Areas, 1, 2 and 4 would be surveyed along a regular grid of lines - N-S at 13km spacing and E-W at 8km spacing. Areas 1 and 2 had top priority because these areas are programmed for sampling by Continental Shelf Unit North (CSU N) in 1978. After completion of areas 1 and 2, depending on time remaining, a decision would be made on whether or not to attempt survey of area 3. As there are no plans for MGU to go back into area 4 before the CSU N 1979 sampling season, it was important to obtain good coverage in this area, even if it precluded additional work in the Sutherland area.

Three small additional survey jobs had been requested:-

(a) A 250km sparker survey to clarify outcrop of base Upper Cretaceous in North Sea Quadrant 42 off the Yorkshire coast.

(b) A 300km regional survey extension east off Shetland between 60^{0}N and $60^{0}20'$N.

(c) A 300km gravity, magnetic and airgun survey to investigate a possible Tertiary igneous centre west of the Cormorant Sheet.

It was proposed that the survey in Quadrant 42 should be undertaken at the start of the first leg upon leaving the Tyne after mobilisation of seismic equipment and prior to sailing north to start priority 1. Jobs (b) and (c) would be undertaken if time allowed.

The ship used for this regional survey was m.v. Sperus, owned by Cosag Marine Services Limited. She is 63 metres long with a beam of 11 metres and a draught of 4 metres. She is a former Northern Lights ship and was on charter to IGS for six months. This present report is confined to Project 77/07 and refers to legs 7-11 inclusive of the 1977 MGU survey programme on Sperus. Legs 1-6 and 12-13 were devoted to Project 77/02, a gravity and magnetic survey of the entire UK sector of the North Sea, commenced in 1976 and planned for completion in 1978, (see MGU Report No. 086).

Equipment used during the regional survey comprised of pinger, sparker and airgun systems; a system for conducting both wide angle and vertical incidence reflection profiling using sonobuoys; side scan sonar, gravity meter and magnetometer (see Table 5). The primary navigation system was a Magnavox integrated satellite navigation/doppler sonar. During the vessel maintenance period at South Shields, prior to commencement of leg 7, a containerised air compressor with airgun control system and a containerised sparker system were installed on the port side of the ship's after deck. The sonar winch, cable and fish were also fitted to the after deck. Some minor modifications to the ship's A-frame were necessary. Seismic recording equipment and side scan sonar recorder were installed in the geophysical laboratory which is situated in the forward hold. Pinger, gravity meter, magnetometer, echo-sounder, data logger and navigation equipment was already installed having been used during the previous three months on Project 77/02.

SENIOR SCIENTIST'S REPORT

On departure from South Shields a small sparker survey of 300km was carried out in Quadrant 42 to provide shallow seismic data to assist interpretation by IGS of commercial deep seismic data in the area. Results from this survey were of good quality. It was also intended to use a 40 cubic inch airgun in this area but a failure of the air compressor prevented this. A brief port call at Leith after completion of this sparker survey enabled engineers to repair the compressor. An engineer from the Institute of Oceanographic Sciences, Barry, joined the ship at Leith for the remainder of Leg 7. Whilst at Leith, the opportunity was taken to re-establish a gravity base reading as the reading taken at South Shields at the start of the leg had proved to be in error.

On transit to the northern regional area, good pinger and echo-sounder records were obtained over a target pockmark in the Forties area which had been the object of investigation by IGS earlier in the year.

For surveying in the regional area, sparker, airgun, side scan sonar, pinger, echo-sounder, gravity and magnetic equipment were used concurrently. Good sonar records were only obtained when the fish was towed less than 40m from the seabed. Deep water often prevented this from being achieved. By alternate triggering, airgun and sparker records were obtained simultaneously. During Leg 7 an extension of the survey lines in the priority 1 area westwards was made over an area of a large magnetic anomaly.

Gravity measurements showed a high positive anomaly associated with this feature. This anomaly was investigated further later in the survey. Leg 7 was dogged by equipment problems which limited survey coverage.

At the end of Leg 7 a fault developed in the MX610 doppler sonar. This was exchanged with an MX600, an earlier device used as a back-up spare which is not capable of bottom tracking in water depths much in excess of 200m. Work in Leg 8 was thus confined to the shallower waters of the southern part of Cormorant Sheet and in the Halibut Bank Sheet. Progress was also inhibited by poor weather.

The first two days of Leg 8 were taken up by calibration runs with the MX600 sonar. While this was carried out, gravity, magnetic and pinger data was recorded with the primary navigation aid being Decca Main Chain. During the leg various problems were encountered with the airgun, compressor and hydrophones. On 19 July the Klein sonar was deployed and towed at a depth of 400m. As no suitable record was being obtained an instruction was given to pay out more cable. It was discovered then that all of the cable on the winch had been run out and that the fish had been on the seabed. On recovery the fish proved to be undamaged but the cable was damaged at the winch connection and this could not be repaired on board; therefore, no sonar records were acquired during this leg.

Before the start of Leg 9 the Klein cable drum was lifted ashore at Lerwick so that it could be sent to the manufacturers for repair. During Leg 9, priority was placed on obtaining regional coverage of area 2 to the west of Shetland. This was achieved with additional coverage in St Magnus Bay. On passage to Lerwick from the area, at the end of the leg, three short seismic lines were run in the bay at the east entrance to Yell Sound to augment previous data for the area. The LaCoste and Romberg 9400 logger was non-operational throughout this leg, but this in no way restricted the acquisition of good gravity data.

There were minor problems with the doppler sonar. Most of the problems encountered were with seismic equipment. At one stage neither of the two Geomecanique hydrophones were functioning. The IGS multi-element sparker sources were unreliable and their use was abandoned midway through the leg to be replaced by an EG & G 9-element array. Triggering problems on the airgun were overcome by additional circuitry at the firing box. The compressor was out of action for one night. One hydrophone was lost during the leg due to the cable strain member coming out of the clamping cone at the head of the hydrophone.

During this leg, a number of lines were run close inshore and thanks are due to Captain Donald Carmichael who made himself available at all hours for this purpose.

Weather throughout the leg was moderate to good with poor conditions for 24 hours during which survey was suspended and the ship aided Aith Lifeboat in the rescue of two men in a small boat whose engine had failed.

There was a long period of good weather during Leg 10 which enabled the completion of coverage in area 1 as well as completion of job (a). Midway through the leg the compressor became unuseable due to damage to the second stage cylinder. The pinger transducer ceased to function and no examination of it was possible until the ship drydocked at end of charter in October.

Leg 11 was not very productive due to continuous bad weather throughout the period. At the start of the leg, severe gale 9 conditions delayed departure from Lerwick until Sunday morning, 28 August. Moderate weather allowed two to three hours of survey before worsening conditions forced the abandonment of the survey and shelter was obtained north of Fetlar. This was the pattern for the next week with about two productive days between gales. The Klein winch drum was reinstalled at the beginning of the leg. The sonar worked well apart from some cross-talk between channels. Due to failure of the compressor on the previous leg, no airgun records could be obtained.

Throughout the survey, gravity measurements were made on all lines and these will be incorporated into the compilation of a gravity map of the North Sea (Project 77/02).

TECHNICIAN'S REPORT

Some extensive equipment failures occurred during the first leg of the programme which resulted in loss of survey time and restricted operations. Subsequent legs were less eventful but problems did occur. Each item of equipment will be dealt with separately with notes on their respective performances.

1. Atlas Deso 10 Echo Sounder and Associated Edig

This system functioned well throughout with two exceptions. During Leg 7 the paper advance circuit and motor failed. The circuit was repaired using a substitute device. On Leg 8 the readout of the Edig was on over-range. This was rectified by changing the base frequency from 100KHz to 33KHz.

2. Edo Western Pinger and 10KW Booster

No problems arose with this instrument until midway through Leg 10. The main symptoms of the fault were reduced audible tone from the transducer assembly and no return signal being detected. Investigations carried out on the Booster amplifier and transceiver assembly revealed no faults - both units appearing to be perfectly serviceable. Since the transducer unit seemed the most likely cause of the problem, continuity tests of the cable and transducer were carried out, the cable being parted six feet from the transducer. These checks were inconclusive. After the spell of rough weather at the beginning of Leg 11, the Pinger was switched on for further tests and was found to be operating correctly. However, towards the end of the leg the unit failed as before.

3. Sparker Systems

(a) Power, capacitor and trigger units.

During mobilisation control circuitry in the power and trigger units supplied by IOS, Barry were extensively damaged by having 230v applied instead of 115v. The damaged components - transformer and control board - were replaced. On Leg 7 a 4000v capacitor in the IOS trigger unit short circuited. However, the unit continued to be used by selecting the 500 joule section thus bypassing the faulty component. During Leg 8 two capacitors and a voltage dropper resistor were changed in the trigger units. At the beginning of Leg 9 one of the two trigger units was stripped, cleaned and rebuilt with three capacitors being replaced. Initially there had been heavy internal arcing when the H.V. reset button was pressed. It was thought the prime cause was a greasy dust film which covered most internal components. After the maintenance described above there was no further recurrence of the fault. One of the power units failed to make the contactor K2 on a few occasions. It was thought that relay K1 was the culprit since the fault was rectified on each occasion by cleaning K1 contacts. On Leg 10 both power units gave continuing problems with the high and low voltage trip circuitry failing to detect high voltage. The cause of the problem was thought to be the relay on the detect board but as no spare was available, continuous adjustments were necessary. During Leg 11, the voltage sensing circuit of the power unit was inoperative, causing high voltage to be placed permanently across the capacitors. The resistor that connects the high voltage line to the Schmitt trigger switching circuit had gone open circuit. This resistor was replaced and the unit performed correctly. Later, however, trouble occurred with the small relay in the Schmitt circuit, necessitating constant cleaning of the relay.

(b) Arrays

At the beginning of Leg 7, the cables for both the EG & G 9-element array and the multi-element arrays were extended so that the junction was neither outboard of the vessel nor subject to any mechanical strain. There was no problem associated with the arrays until Leg 10. A new multi-element array was tried out at 1000 joule but was unsuccessful probably due to faulty manufacture. On Leg 11 corrosion of one of the sockets on the 9-element array prevented a candle from fixing properly. The socket was blanked out.

4. Airgun System

(a) Bolt Airgun Model 600B.

On Leg 7 the main air line to the gun had to be replaced because of chaffing against other towed bodies. Subsequently a close watch was kept on all towed equipment to ensure that no touching or ensnarement could occur. During Leg 8 a new gun was fitted and the forty cubic inch chamber attached. The first gun had been triggering eratically. Early in Leg 9 the gun assembly developed a slight leak at the towing bracket hose junction but it did not seriously hamper operations. During a break for bad weather, the gun was stripped and new firing seals, springs and solenoid were installed. The spare unused towing bracket was put into use. The spare gun was rebuilt with new seals and springs and fitted with a thirty cubic inch chamber. The airgun triggering system was modified by the inclusion of additional circuitry in a successful attempt to cure misfiring. During Leg 10, when the gun was used, problems were encountered with the triggering circuits, trigger leads and air hoses. The gun was not used during Leg 11.

(b) Refnell Sat 6H Compressor

At the beginning of Leg 7, this unit failed completely after a few hours operation and a port call to Leith on 8 July was necessary in order to complete its repair. A representative from the manufacturer attended to the repair and found that a safety bursting disc had failed and caused overheating. The reason for its failure was that a previous replacement of inferior and unsuitable material had been used. After this the compressor worked well until Leg 9 when two periods of breakdown occurred. In the first case the output pressure would not rise above 650 psi and the second stage relief valve was venting on each plunger stroke. The two valves from the head and valve assembly of stage three were removed, cleaned thoroughly and reground into their seats. The second breakdown occurred when output pressure rose to over 2500 psi. The drain and diaphragm valves from the bottom of the output separator were removed, drained of all sediment, cleaned and replaced. The compressor worked well until the middle of Leg 10, then venting, particularly of the second stage, became progressively more difficult. Eventually the venting became so difficult, it was decided that a comprehensive maintenance was required. Internal damage to the inside of the column, above the second stage pressure valve, was found and was of such a nature as to be the cause of the poor venting. The second stage pressure valve was removed from the column and inspection revealed a cross thread on the boss which must have taken place either at the time of manufacture or during some other maintenance. During its replacement difficulty was experienced in achieving a good air seal and in ensuing adjustments the thread gave way completely thus rendering the compressor unserviceable until the end of survey, no spares being available.

5. Hydrophones

(a) 30 metre Geomecanique

Soon after the commencement of survey, this item failed and upon inspection, the coupling housing at the hydrophone was found to be flooded, this being caused by insufficient pressure being applied to the sealing gland. Extensive work was required to make the hydrophone operational. In the course of this the actual tow cable was found to be low resistance, 70m of which had to be removed. After completion of the repairs the unit was streamed but after a short period failed again. On recovery, the hydrophone was found to have become entangled in the sparker array with resulting damage to both pre-amplifiers. After this accident the hydrophone was used without pre-amplifiers and performed well. During Leg 9, there was trouble with the battery terminals. On Leg 10 there were no problems with the hydrophone array but the inboard line amplifier and matching transformer gave trouble. Another amplifier stage was fabricated and the fault cleared. The system functioned well until the end of survey.

(b) 20 metre Geomecanique

When the pre-amplifiers of the 30m hydrophone failed, a spare pre-amplifier was successfully fitted to the 20m hydrophone. However, soon after deployment, this hydrophone failed. The symptoms were seen as a degraded signal level. Inspection of the tow cable revealed low resistance to screen and the cable had to be discarded. A replacement cable was obtained but some difficulty was experienced in fitting it. Unfortunately this hydrophone was lost during Leg 9 and on retrieval of the cable the indication was that the cable to hydrophone clamping system had failed.

(c) EG & G 263C

This hydrophone, obtained from IOS Barry as an emergency replacement was completely functional but was unsuitable for the type of operation which was being carried out.

6. Seismic Recording/Playback System

Part of the recording system was made up of two EPC graphic recorders - one 4600 and one 4100. The 4600 recorder had been adapted for use with a magnetic tape recording system and controlled the alternate firing of sparker and airgun. Very occasionally the sparker, airgun firing ratio, which was normally set at 8:1, changed to 16:1 or 12:1 for no apparent reason. A tachometer was replaced on the 4600 at the start of survey. Otherwise the system functioned very well.

7. Klein Sonar System

At the beginning of Leg 7, prior to deployment, the 'signal' wiring in the cable was found to have two conductors open circuit; the fault being located in the shackle assembly. The cable was re-made using a spare shackle assembly which proved satisfactory. Difficulty was experienced in keeping the fish close enough to the seabed, at normal survey speeds of 6/7 knots. Considerable problems can arise from playing out too much cable and a constant watch had to be kept on the system whilst in use. At the beginning of Leg 8, the print band drive and the main helix drive motors on the recorder were replaced. On Leg 8, while the fish was deployed, the lock system on the winch failed resulting in all the cable being played out and it being crimped at the base of the winch drum. Due to the design of the drum and slip ring assembly the cable could not be repaired on board. During port call at Lerwick, 26-29 July, the winch drum and cable were off-loaded for shipment to Edinburgh for repair. The drum and cable were reinstalled, after repair, at the beginning of Leg 11. During this leg, the loop electrode in the recorder was not rotating correctly. Cross-talk between the left and right channels was common but the cause was not discovered. The fail safe lock valve on the winch malfunctioned and the drum tended to slowly pay out the cable if the brake was not applied.

8. Barringer Magnetometer

This instrument functioned with few problems throughout the survey. On Leg 8 the cable connector at the base of the winch was remade. On Leg 11, water entered the outboard plug on the inboard cable. Also on this last leg, it was found that the Decca data logger was corrupting the digital count on the magnetometer during the time it was being displayed. The connection from the data logger to the magnetometer was removed and, for the remainder of the survey, magnetic values were obtained from the pen recorder only.

9. Gravity Systems

(a) LaCoste and Romberg S75 Meter

The meter was operated without difficulty throughout the survey. On Leg 7 the power supply tripped out for some inexplicable reason thus requiring the system to be re-set. During Leg 11, on one occasion after the end of a line and during a normal turn, spring tension began falling rapidly. The beam was clamped and the system held until it settled, which took approximately 30 minutes. Then, the beam was released and slewed back towards its normal position. The system eventually settled and no further difficulty was experienced.

(b) LaCoste and Romberg 9400 Data Logger

This system performed satisfactorily for Legs 7 and 8. At the beginning of Leg 9 the magnetic tape unit failed. The fault appeared to lie in either the WRITE board or the READ amplifier. The tape transport was repaired on Leg 10, but it still appeared not to read-after-write in that the printout was only of the input data. A tape was tested to see if data was being recorded which proved not to be the case. On the last leg, an investigation of the recording circuits showed that no current was being passed to the leads. After cleaning the circuit boards, this current was restored and another tape was tested. The verifier was still not functioning at the end of survey.

10. Decca Data Logger

The recording decks sometimes failed to change over automatically and constant attention was necessary as the end of tape approached so as to assure changeover. The 10500 series tape transport gave intermittent problems with loading and tape drive.

11. Satellite Navigation System

On Leg 7, the doppler sonar MX610 became inoperative, the fault being a degraded signal return from the AFT tracking channel. Investigation indicated that the fault was in the transducer assembly. The MX610 was removed and the spare MX600 was substituted. The defective transducer was returned to the manufacturers. The MX600 was calibrated at the beginning of Leg 8. The disadvantage of the MX600 is the limitation of its operative depth range. At the beginning of Leg 9, a new MX610 was installed and calibrated. After a couple of days the aft channel return signal was fluctuating quite considerably. The fault appeared to lie in the MX610 JUNCTION BOX RX card. The MX610 head was exchanged for the MX600 but the fault reappeared. The interface cable was examined and the AFT CHAN SIG RETURN conductor was found to be disconnected. This was re-soldered and no further trouble was observed on this leg. Prior to the start of Leg 10, the MX610 sonar transducer and main cable plug were fitted, also the 4 tracker cards were re-aligned using information gained from Magnavox. During subsequent operation, the sonar functioned successfully though failing on some occasions to indicate when entering water track. This fault was intermittent in nature and although blanking control and associated tracker cards were changed, the sonar unit continued to give bottom track logic outputs when clearly in water track. Even when the tracking logic indicated water track, the computer system sometimes failed to recognise it. Twice, during Leg 10, the program became corrupted and needed re-entering. Throughout the survey the auto-deck change-over was intermittent in which condition the upper deck seemed to double feed. On the last leg, it failed completely and, for the remainder of the survey, only tape deck 1 was used.

12. Power Supply

(a) Generators

On Legs 7 and 8, the generators operated without failure. There were problems due to a fuel leak and a leaky radiator hose on generator 3. The former was repaired and the latter replaced.

During Leg 9, the fuel gauges on generators 1 and 2 developed faults. On Leg 10 the battery of number 3 generator failed to charge. During Leg 11 the supply to the laboratory from number 1 generator failed for no obvious reason and it is thought that a relay tripped out in the switching unit. The laboratory supply was transferred to number 2 generator, while generator number 1 was used to supply the sparker container. The alternator was replaced in generator number 3.

(b) Uninterruptable Power Supply (UPS)

This system functioned well for the duration of the survey.

SATELLITE NAVIGATION REPORT

The satellite navigation system was powered down immediately before the survey started while modifications to the generator equipment were made. The receiver had been running for about two days before the first line was started. A systematic increase in receiver offset frequency of approximately 1½ counts/billion/day was observed which eventually stabilised within a week. Drifts after 24 hours operation were greater than 3 counts/billion/day, the quoted reliable limit.

When working on job (a) integrated only to doppler sonar, it was necessary to slightly increase the value of TADI from that used during previous higher speed surveys to the north (part of Project 77/02). When working in the north at 6 knots, ØE Decca Main Chain was interfaced as well. The doppler sonar lost bottom lock at approximately 350m and in the extreme north-west and north-east of the survey area 500m water depths were encountered. Operation with Decca worked well with a .KI. filter constant of 0.003, giving average drift rates of 0.5% distance travelled at an average speed of 5½ knots. When a fault developed on the MX610 sonar transducer, an attempt to use Decca Main Chain alone interfaced to the satellite navigation system produced poor results probably due to too long a filter (0.001) being used.

After substitution of the MX610 by the MX600, lines 18-21 were run to calibrate the sonar concurrently with normal surveying logged on Decca Main Chain ØE. Workable values for constants ABIA and TADI were obtained and lines 22-31 inclusive were run normally with satellite fix updating. During line 22, running northwards into water deeper than 200m, the sonar went into water track mode and Decca Main Chain ØE appeared to work well as a dead reckoning system. However, on line 23, running southwards there were many bursts of "sonar range errors" for no apparent reason. Resetting the Decca filters and trying different values of the filter constant .KI. did not help the situation. Bottom tracking, and normal operations were possible in water depths of less than 190m. As the "range error" problem could not be solved, the remainder of Leg 8 was confined to the shallow water of the southern part of area 1 and to area 4. A new program, number HP 30, "Satellite Updates" was written for the Hewlett Packard calculator, to aid identification of any small systematic bias in satellite updating due to possible minor errors in the adopted values of the constants ABIA and TADJ. The evidence of this survey leg has suggested that there is a secular drift of the thermistor output used for water velocity measurement, since the value of TADJ required seemed to drop slowly but systematically from 1.008 to 1.000 between 17 and 24 July. The mean radial update for all auto-update fixes was 67m with an average survey speed of 6 knots.

At the beginning of Leg 9 the replacement MX610 sonar transducer head was installed. Calibration was begun and was, initially, promising. However, unrealistic drops in speed, associated with aft channel doppler counts drifting close to the 150 000Hz transmit frequency, began occurring intermittently. Suspecting a preamplifier fault, the MX610 was replaced by the MX600. Again intermittent drops in speed occurred, though not to the drastic extent experienced with the MX610. Attempts to rectify the fault continued during lines 35-41 when large updates, greater than 300m, occurred periodically. The problem came to a head during line 42 when the positions fixed were so poor that the line had to be replotted using Decca Main Chain 6C. At this stage a broken connection was found in the sonar cable and rectified. Lines 43-73 were run with the integrated system operating normally with the MX600 sonar. However, due to the short length of many of the lines, sonar calibration was not fully refined. During normal operations at 7 knots on lines 43-70, the mean radial update was 75m and the largest radial update was 331m. The ends of lines 35 and 37 were run using a manual speed input derived from a mean of earlier speeds. On these lines, the doppler sonar lost bottom track at around 250m;

continuous "SNR-RANGE-ERR" messages were output and updates of around 600m were experienced. No attempt to introduce Decca dead reckoning was made.

During Leg 9, the availability of satellite updates caused some problems. Satellite 30460 was apparently faulty, particularly in the middle of the leg, causing abnormal frequency solutions. Also, coincidence of orbits, causing lower occurrence of updates and occasional mutual interference, developed towards the end of the leg. An unpredicted "rogue" satellite also appeared occasionally.

Prior to sailing on Leg 10, the MX600 doppler sonar head was replaced by the new MX610 sonar head. This was done to increase the bottom track capability in deeper water which was desirable for surveying in the north of area 1. The first three lines of this leg (lines 74-76) were used to calibrate the sonar against satellite fixes. Regional surveying was conducted along these lines using ØE Decca Main Chain. After a successful initial calibration of the sonar, succeeding lines were run with satellite navigation and doppler sonar integrated with Decca Main Chain, as water depths in excess of 300m were anticipated. The MX610 appeared to lose bottom track in water depths of about 350m; however, this was difficult to determine with confidence. The water track indicators on the CRT and the MX200 interface did not always show that the sonar was water tracking although monitoring the blanking pulse/signal detect waveforms showed this to be the case. This fault did not appear to affect the accuracy of the system. A filter constant of .KI. = 0.003 was used which is equivalent to a time constant of $5\frac{1}{2}$ minutes. The size of update did not seem strongly dependent upon whether the sonar was in bottom lock, with typical dead reckoning drift rates at 7 knots of 0.6% distance travelled. However, occasionally during dusk periods, difficulty was encountered conning the ship along the desired sail line probably due to the long time constant of the velocity filter. Although the Decca pattern noise figures had not increased, variations in the derived correction velocities did. During this leg, there were occasions when the Decca was switched out and doppler sonar alone was used, with an improvement in ease of steering. A shorter time constant of $3\frac{1}{2}$ minutes was tried which also made the system more responsive to course changes. However, this gave slightly increased scatter in the observed drift rates. Satellite 30460 continued to give poor data. Over the whole leg this satellite gave only two acceptable satellite fixes. It was therefore, tuned out in preference to other satellites.

A drift test was performed at anchor in Bressay Sound at the end of Leg 10. This indicated a steady drift of about 70m/hour at an angle of 45^{0} to the long axis of the ship. This figure is greater than the Magnavox specification.

Poor weather persisted throughout Leg 11 which affected the performance of the doppler sonar. In particular, large AC updates tended to occur in rough seas, deeper water (over 200m) and combinations of these conditions. Where sea conditions were moderate, dead reckoning accuracy was up to normal standard with updates of the order of 60m. Satellite 30460 continued to transmit but with invalid message data. Coincidence of orbits between satellites reduced the incidence of useable satellite updates, there were periods of 6 hours or more when no update occurred.

GEOPHYSICS REPORT

1. Gravity

After the base tie was made in South Shields, but before sailing at the start of the survey, some drift was noted on the meter but it appeared to return to approximately its previous value. However, misties of about 6-7 milligals with previous work were found on lines 1-9, so the opportunity was taken to go into Leith on 8 July to make a new base tie. It was found that a tare of 6 mgals had occurred before survey work started. All computations on the first leg have been adjusted using Leith as base. At the end of Leg 7, in bad weather, the table hit the stops and was clamped until the ship tied up at Lerwick. The meter drifted by 1.1 mgal between Leith and Lerwick. Prior to departure from Lerwick for Leg 8, another base check was carried out and this differed by 1.1 mgals from the value obtained soon after docking. At the end of Leg 8, prior to going into Lerwick, the meter again had to be clamped due to gale force conditions. Establishment of a base value indicated that the meter had drifted 0.3 mgal for the period 15-26 July. Meter drift was continued at a similar rate for the remainder of the survey.

The quality of data was of a very high standard throughout the survey. A cross tie analysis for the area north of 60°N shows that the mean mistie is 0.79 mgal averaged over 300 cross ties. This figure can be broken down as follows:-

For 44% of cross ties, the mistie is 0 mgal,
for 36.5% of cross ties, the mistie is 1 mgal,
for 14.25% of cross ties, the mistie is 2 mgal,
for 3.5% of cross ties, the mistie is 3 mgal,
for 1.75% of cross ties, the mistie is 4 mgal or greater.

All data were reduced on board m.v. Sperus with a Hewlett Packard calculator by program HP 29 and Bouguer Anomaly values for each fix were plotted at 1:250 000 scale. Such was the quality of the data that on board contouring at a 5 mgal interval was possible with very little editing of the data; it will be possible eventually to contour at a 2 mgal interval.

The area within 0°-1°W and 61°30'N-62°N is dominated by a large circular gravity high. This rises from a background value of 50 mgal to 115 mgal. There appears to be a NW extension of this feature outside the survey area. The area from 61°N to 62°N between 0° and 2°E has quite a different character. It shows a NNE-SSW trend with a broad high extending down the western side of the area. There is a depression in the central part, the Bouguer Anomaly falling steeply from 80 mgal on the ridge to less than 10 mgal in the depression. On the eastern side the anomaly values rise again but much less steeply. A possible interpretation is that there is a sedimentary basin, with a steep western edge, and thinning gradually eastwards. From the data available between 60°N and 61°N to the south, the basin clearly extends southwards, becoming thicker. An interesting feature is an offset of the gravity ridge on the western edge of the depression. This offset is very steep and is indicative of fault control of the western boundary of the basin. The area from 60°N to 61°N and from the west coast of Shetland to 2°10'W has a dominant NNE-SSW trending high. In the south, to SSE of the high, there is a low which is associated with the northern extension of the Fair Isle Basin.

2. Magnetics

The magnetometer was towed approximately 200m astern. The measured total magnetic field values were plotted for each fix on 1:250 000 scale. Generally misties, at intersections, were acceptable being approximately $\pm$ 30γ although several in excess of 100γ occurred. A plot of mistie versus ship's head revealed no obvious correlation, suggesting that the magnetometer was being towed a sufficient distance astern to be isolated from the ship's field. Several of the misties were in areas of steep magnetic gradient and the misties could be minimised by taking into account the layback of the sensor. The remaining large misties were isolated to a few lines and were possibly surveyed during periods of diurnal magnetic activity.

There is a prominent positive closure with relative amplitude of + 1200γ trending E-W at 61°30'N, 00°30'E with high intensity short wavelength anomalies superimposed on a broad high. This

For the northern area, reference should be made to Table 2 for the power of sparker used on each line. The EG & G 9-element array was used on most lines. The IGS MESS arrays were used on lines 35-50 and 102, fixes 1-20. To the north and east of Shetland, the 9-element array was used in preference to the MESS as it gave much better penetration though not such good resolution. The airgun operated at a pressure of 1750-2000 psi.

In the area west of Shetland, the resolution on the sparker records was average to poor with penetration averaging less than 100 msec below seabed except in areas of Tertiary sediments where penetration reached 200 msec in some instances. The average penetration achieved with the airgun was 100-200 msec below seabed and in places, mainly in the NW of the area where thick Tertiary and Quaternary is present, it reached as much as 350 msec.

North-east of Shetland, north of 61°N, the sparker records were of a high quality. The airgun records were very useful for interpretation in deeper water areas but in shallow water the combination of the seabed and bubble pulse multiples masked much of the data. East of Shetland, between 60°-61°N, the sparker data was of reasonable quality. The airgun records only occasionally enhanced the interpretation of the sparker records.

A reversed wide angle reflection profile was shot over the postulated Tertiary igneous centre along parts of lines 81 and 82. The source was a 40 cubic inch airgun, maintained at 2000 psi and firing at a repetition rate of 6 sec. This experiment was conducted using sonobuoys. The seismic signal was received on an Eddystone receiver and displayed on an EPC graphic recorder. Usable data were received up to a range of 6km. Preliminary results indicate four low velocity horizons producing wide angle reflections, the deepest at 1.5sec two-way time with an interval velocity of 2km/sec. In addition, a vertical incidence airgun profile was recorded on a second EPC to provide dip information. Both sets of data were recorded on magnetic tape for further replay and analysis. Apart from the obvious restriction of not operating additional seismic equipment in the same frequency band as the wide angle reflection source, the use of disposable sono-buoys offered the opportunity of collecting velocity information at the same time as regional geophysical surveying.

GEOLOGY REPORT

1. <u>Area West of Shetland</u> (see fig. 3)

The land geology of the Shetlands consists of a metamorphic basement of Dalradian rocks with a pronounced NNE-SSW trend and overlain in the southern and western parts of the region by sandstones, conglomerates and lavas of Devonian age.

Basement rocks extend offshore in the north-western part of the area and extend from 61^{O}N southwards to 60^{O}30'N, where they are unconformably overlain by strata of presumed Devonian age. They are terminated to the NW against supposed Tertiary sediments by a major NW-SE fault, termed the

West Shetland fault. No apparent structure is visible within the basement which forms irregular outcrops over the majority of the area. The basement is highly magnetic, the highest values occurring adjacent to the West Shetland fault. A north-south trending magnetic ridge is present in the basement due north of the Shetlands which may represent a major intrusive dyke or the continuation northwards of the Walls Boundary fault.

Strata of presumed Devonian age occur in the southern part of the area forming a direct continuation from the mainland westwards to the Isle of Foula. Little structure is visible within this strata apart from occasional fine bedding. Out-crops are often present, but in general the Devonian is covered by a thin layer of superficial sediment and pockets of Quaternary. The Devonian exhibits low even magnetic values throughout the area apart from a central NW-SE trending topographic ridge, which may represent outcropping Devonian lavas similar to those exposed on land.

Permo-Triassic rocks are present in the extreme south of the area where they form a direct continuation of the Fair Isle basin. They form a series of very well bedded strata, unconformably overlying the Devonian, and being terminated to the east against basement rocks by the Walls Boundary fault. Low magnetic values and gentle gradients are associated with this basin.

Strata of presumed Tertiary and Mesozoic age are present in the extreme NW of the area to the NW of the West Shetland fault, occurring as a series of very gently dipping continuous beds over which the magnetic field is undisturbed. This area is the eastern part of the West Shetland basin.

Quaternary strata are present as only isolated pockets throughout the area, rarely exceeding 20m in thickness. These pockets are more frequent in the area of Devonian strata.

A major basin, present in St Magnus Bay and appearing to be fault controlled, is thought to contain thick Quaternary strata. This basin reaches a depth equivalent to 200 msec two-way time (about 2-300m) below seabed and probably also contains Tertiary and Mesozoic sediments. Two major faults are present, namely the West Shetland and the Walls Boundary faults. The West Shetland fault trends NW-SE and occurs in the NW of the area, defining the eastern margin of the Tertiary and Mesozoic strata of the West Shetland basin. The Walls Boundary fault is clearly visible in the south of the area where it defines the eastern margin of the Permo-Triassic Fair Isle basin, and may continue north of the Shetlands where it is represented by a pronounced linear magnetic anomaly. Other minor faulting, as in St Magnus Bay, is present throughout the area, but these faults cannot be traced for any distance on the seismic records.

2. Area 61°-62°N, 0°-2°E

Over most of the southern and western part of the area the water depth is generally constant at around 150m. In the north-east it increases to about 350-380m passing into the Norwegian Channel, the margin of which is marked by a distinct NW-SE trending escarpment. In the NW the water deepens to over 500m on the continental slope.

Seabed topography is generally smooth throughout the area with occasional shallow depressions, some of which may be either pockmarks or iceberg scours. In the west the seabed sometimes becomes rougher over the East Shetland Platform where superficial deposits are thin. On at least two lines a rougher seabed is present in the Norwegian Channel but its origin is not obvious. Pinger records indicate a fill of recent sediments in many of the seabed depressions.

In the south-west of the area a strong reflector probably marks the surface of the East Shetland Platform and this is overlain by thin superficial deposits; in places filling shallow channels. Well marked dipping reflectors underly this horizon, and these are probably Mesozoic or older rocks with locally a thin Tertiary cover.

To the east and north, the surface of the platform dips in a general northerly direction here overlain by a thickening wedge of sediments. Within this sedimentary wedge are numerous reflectors which appear to offlap towards the north and to a lesser extent to the east.

Two reflectors, in particular, can be mapped over a large area and these correlate well at line intersections. A map was produced of the depth and extent of these reflectors. A number of other reflectors could be correlated over restricted areas.

The higher of the two regionally distinct reflectors occurred at about 350-400m below sea level in the central part of the area dipping to around 800m in the extreme north-west on the continental slope. This reflector truncates a series of underlying more steeply dipping events and is clearly a significant horizon. It seems possible to trace this horizon to the north-east in the Norwegian Channel where it is disected by at least one large infilled channel. This horizon may represent an erosion surface, signifying a period of lower sea level which might correspond approximately with the base of the Quaternary. However, it is more probable that it is an intra-Quaternary event produced by a marine transgression during a phase of rising sea level. The fact that significant channels occur beneath the present day Norwegian Channel suggests an association with a considerably lower sea level in the early stages of its formation.

A lower prominent reflector, which is present in the south of the area, dips northwards and disappears beneath the upper horizon near the centre of the area, where it appears as a discrete event. To the south (up dip) it passes into, and probably forms the base of, an extensively channelled unit.

This has the appearance of a Quaternary channelled deposit and strengthens the suggestion that the higher reflector is an intra-Quaternary event.

No obvious correlations were apparent with the gravity and magnetics, as they seem to be reflecting deeper seated anomalies. However, the gravity data will probably assist with defining the margin of the East Shetland Platform after further study.

3. Area 60^{o}-61^{o}N, 1^{o}W-2^{o}E

Water depths in this area range from 70-170m with depths of less than 100m confined to areas close to the Shetlands. The greatest depths are attained in several, well defined, depressions which occur in the central part of the area, east of 0^{o}. Basement rocks, which probably include the Dalradian and Old Red Sandstone such as exposed on Shetland, crop out on the seabed as far east as 0^{o}10'E. Eastwards, the top of these formations dips steeply beneath younger Tertiary(?) and Quaternary sediments. Sediments, probably mostly of Quaternary age overly, and truncate the dipping Tertiary(?) reflectors, and further east dominate the sparker and airgun records. East of 0^{o}40'E the Quaternary includes abundant channelled sequences and in the extreme SE a sequence dominated by abundant small channels overlies a sequence dominated by broad but generally shallow channels. The latter are traceable as far as 60^{o}30'N, north of which they may occur at depths beyond the range of the sparker and airgun records. North of 60^{o}30'N, channelled sequences dip to the north, however the channels are invariably moderate or small in size. The youngest Quaternary sediments have accumulated depressions in the central part of the area and these sediments are best seen on pinger records where they are characterised by a distinctive series of regular reflectors, infilling depressions in a very irregular floor. Pockmarks occur at the seabed directly above the largest of these depressions, and its sedimentary infill at approximately 60°19'N, 0°55'E. Elsewhere, minor troughs and depressions are similarly filled by "recent" sediments, though only as a thin veneer. Similar veneers of "recent" sediments fill the more numerous troughs and depressions where the basement rocks crop out at the seabed adjacent to the Shetlands.

CONCLUSION

In spite of all the problems experienced with some of the equipment and the generally poor weather conditions, nearly 8500 line km were surveyed. Priority areas 1 and 2 with additional work on jobs (a) and (c) were satisfactorily completed. Midway through the project it was decided to abandon the idea of carrying out work in areas 3 and on job (b) and to concentrate on the other areas. It was unfortunate that the spell of very bad weather on Leg 11 meant that survey of priority area 4 remained incomplete. However, sufficient data has been collected to allow a meaningful interpretation of the geology of the area.

TABLE 1

PROJECT 77/07

PERSONNEL

LEG 7

3 July-15 July

A Dobinson	Senior Scientist	Marine Geophysics Unit
N Kenolty		Marine Geophysics Unit
J Chalmers		Marine Geophysics Unit
S Spencer		Marine Geophysics Unit
P Mulholland		Marine Geophysics Unit
P Roberts		Marine Geophysics Unit
A Oliver		Marine Geophysics Unit
R Holmes		Continental Shelf Unit North
D Woodall		Continental Shelf Unit North
J Price		MSES, IOS Barry
P Taylor		MSES, IOS Barry

8-15 July

J Stanwood		MSES, IOS Barry

LEG 8

16 July-28 July

R A Floyd	Senior Scientist	Marine Geophysics Unit
M C Tully		Marine Geophysics Unit
J Donato		Marine Geophysics Unit
D Smythe		Marine Geophysics Unit
P Western		Marine Geophysics Unit
M Davis		Marine Geophysics Unit
A Oliver		Marine Geophysics Unit
D Woodall		Continental Shelf Unit North
J Price		MSES, IOS Barry
A Clark		MSES, IOS Barry

16 July-18 July

A Dobinson		Marine Geophysics Unit
P Roberts		Marine Geophysics Unit
O Petrie		Continental Shelf Unit North

LEG 9

29 July-10 August

A S Mould	Senior Scientist	Marine Geophysics Unit
S E Deegan		Marine Geophysics Unit
J Chalmers		Marine Geophysics Unit
P Towle		Marine Geophysics Unit
S Spencer		Marine Geophysics Unit
J Bulat		Marine Geophysics Unit
A Davies		Marine Geophysics Unit
J Chesher		Continental Shelf Unit North
S Paterson		Continental Shelf Unit North
K Robertson		MSES, IOS Barry
P Walters		MSES, IOS Barry

LEG 10

11 August-25 August

R A Floyd	Senior Scientist	Marine Geophysics Unit
A Rochester		Marine Geophysics Unit
A Dobinson		Marine Geophysics Unit
S Spencer		Marine Geophysics Unit
P Burke		Marine Geophysics Unit
P Roberts		Marine Geophysics Unit
J McDonald		Geomagnetism Unit
C Deegan		Continental Shelf Unit North
M Dean		Continental Shelf Unit North
P Armitage		MSES, IOS Barry
P Walters		MSES, IOS Barry

LEG 11

26 August-5 September

M C Tully	Senior Scientist	Marine Geophysics Unit
D K Smythe		Marine Geophysics Unit
J Bulat		Marine Geophysics Unit
A S Mould		Marine Geophysics Unit
S Spencer		Marine Geophysics Unit
A Milne		Marine Geophysics Unit
C Dewar		Marine Geophysics Unit
A Oliver		Marine Geophysics Unit
N G T Fannin		Continental Shelf Unit North
S Paterson		Continental Shelf Unit North
P Armitage		MSES, IOS Barry

TABLE 2

Line No	No of Fixes	Line Length (km)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9400 Logger
1	63	122	SN + DS	-	✓	-	-	-	-	✓	✓	✓
2	25	41	SN + DS	20-25	✓	1000J	-	-	-	✓	✓	✓
3	32	57	SN + DS	✓	✓	1000J	-	-	-	✓	✓	✓
4	30	55	SN + DS	✓	✓	1000J	-	-	-	✓	✓	✓
5	17	37	SN + DS	✓	✓	1000J	-	-	-	✓	✓	✓
6	30	51	SN + DS	✓	✓	1000J	-	-	-	✓	✓	✓
7	12	23	SN + DS	✓	✓	1000J	-	-	-	✓	✓	✓
8	24	47	SN + DS	✓	✓	1000J	-	-	-	✓	✓	✓
9	75	252	SN + DS	✓	-	-	-	-	-	✓	✓	✓
10	34	107	SN + DS	✓	✓	-	-	-	✓	-	✓	✓
11	157	450	SN + DS	✓	✓	-	-	-	✓	Part	✓	✓
12	67	106	SN + DS + MC ØE	✓	✓	3000J	-	✓	✓	✓	✓	✓
13	58	106	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	✓	✓	✓	✓	✓
14	66	110	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	✓	✓	✓	✓	✓
15	24	50	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓

Line No	No of Fixes	Line Length (km)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9400 Logger
16	94	160	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	Part	✓	✓	✓	✓
17	41	77	SN + MC ØE	✓	✓	3000J	40 ins^3	Part	✓	✓	✓	✓
18	29	62	SN + MC ØE	✓	-	-	-	-	23-29	✓	✓	✓
19	32	61	SN + MC ØE	✓	✓	-	-	-	✓	✓	✓	✓
20	6	10	SN + MC ØE	✓	✓	-	-	-	✓	✓	✓	✓
21	48	103	SN + DS + MC ØE	✓	✓	-	-	-	✓	✓	✓	✓
22	68	131	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	-
23	80	160	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	-
24	91	168	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	-
25	85	172	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓
26	77	176	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓
27	84	164	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓
28	48	94	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓
29	66	119	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓
30	92	174	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓

Line No	No of Fixes	Line Length (KM)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9400 Logger
31	72	115	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	✓
32	29	55	MC ØE	✓	✓	-	-	-	✓	✓	✓	-
33	93	192	MC ØE	✓	✓	-	-	-	✓	✓	✓	-
34	96	157	MC ØE	✓	✓	-	-	-	✓	✓	✓	-
35	61	115	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
36	47	84	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
37	56	91	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
38	26	68	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
39	16	31	SN + DS	✓	✓	1000J	-	-	✓	✓	✓	-
40	18	41.5	SN + DS	✓	✓	1000J	-	-	✓	✓	✓	-
41	13	28	SN + DS	✓	✓	1000J	-	-	✓	✓	✓	-
42	10	21	MC 6C	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
43	30	68	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
44	30	58	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
45	17	37	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-

Line No	No of Fixes	Line Length (km)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9400 Logger
46	26	53	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
47	34	66	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
48	10	17	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
49	9	17	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
50	7	13	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
51	25	45	SN + DS	✓	✓	-	-	-	✓	✓	✓	-
52	23	46	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
53	24	46	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
54	16	34	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
55	11	21	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
56	11	22	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
57	14	28	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
58	11	23	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
59	5	9	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
60	9	16	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-

Line No	No of Fixes	Line Length (km)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9400 Logger
61	18	39	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
62	17	34	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
63	53	115	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
64	26	53	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
65	12	25	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
66	13	27	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
67	29	69	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
68	14	31	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
69	11	21	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
70	17	35	SN + DS	✓	✓	1000J	40 ins^3	-	✓	✓	✓	-
71	15	47	SN + DS	✓	✓	-	-	-	✓	✓	✓	-
72	15	47	SN + DS	✓	✓	-	-	-	✓	✓	✓	-
73	11	30	SN + DS	✓	✓	-	-	-	✓	✓	✓	-
74	76	171	MC ØE	✓	✓	-	-	-	✓	✓	✓	-
75	54	117	MC ØE	✓	✓	6-54 1000J	-	-	✓	✓	✓	-

Line No	No of Fixes	Line Length (km)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9400 Logger
76	58	121	MC ØE	✓	✓	1-21 1000J 22-58 3000J	40 ins^3	-	✓	✓	✓	-
77	34	58	SN + DS	✓	✓	3000J	-	-	✓	✓	✓	-
78	43	76	SN + DS + MC ØE	✓	✓	3000J	-	-	✓	✓	✓	-
79	77	161	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	-
80	81	163	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	-
81	30	40	SN + DS	✓	✓	-	40 ins^3	-	✓	✓	✓	-
							+ WAR					
82	27	37	SN + DS.	✓	✓	-	40 ins^3 + WAR	-	✓	✓	✓	-
83	21	41	SN + DS	✓	✓	-	40 ins^3	-	✓	✓	✓	-
84	84	163	SN + DS + MC ØE	✓	✓	1-30 5000J 31-84 3000J	40 ins^3	-	✓	✓	✓	-
85	55	117	SN + DS + MC ØE	✓	✓	3000J	40 ins^3	-	✓	✓	✓	-
86	64	111	SN + DS + MC ØE	✓	1-56	3000J	40 ins^3 47-64	-	✓	✓	✓	-
87	56	124	SN + DS + MC ØE	✓	-	3000J	40 ins^3	-	✓	✓	✓	-

Line No	No of Fixes	Line Length (km)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9400 Logge:
88	77	120	SN + DS + MC ØE	✓	-	3000J	40 ins^3	-	✓	✓	✓	-
89	55	115	SN + DS + MC ØE	✓	-	3000J	40 ins^3	-	✓	✓	✓	-
90	59	122	SN + DS + MC ØE	✓	-	3000J	40 ins^3	-	✓	✓	✓	-
91	51	122	SN + DS + MC ØE	✓	-	3000J	40 ins^3	-	✓	✓	✓	-
92	55	124	SN + DS + MC ØE	✓	-	3000J	40 ins^3	-	✓	✓	✓	-
93	58	117	SN + DS + MC ØE	✓	-	3000J	-	-	✓	✓	✓	-
94	26	50	SN + DS + MC ØE	✓	-	3000J	-	-	✓	✓	✓	-
95	30	69	SN + DS + MC ØE	✓	-	3000J	-	-	✓	✓	✓	-
96	51	122	SN + DS + MC ØE	✓	-	3000J	-	-	✓	✓	✓	✓
97	27	61	SN + DS + MC ØE	✓	-	3000J	-	-	✓	✓	✓	✓
98	52	128	SN + DS + MC ØE	✓	-	3000J	-	-	✓	✓	✓	-
99	30	67	SN + DS + MC ØE	✓	-	3000J	-	-	✓	✓	✓	✓
100	55	124	SN + DS + MC ØE	✓	-	5000J	-	-	✓	✓	✓	✓
101	14	34	SN + DS + MC ØE	✓	-	1000J	-	1-2	Part	✓	✓	-
102	55	130	SN + DS	✓	✓	1000J	-	-	Part	✓	✓	-

Line No	No of Fixes	Line Length (km)	Primary Nav Aid	EQUIPMENT USED								
				Echo Sounder	Pinger	Sparker	Airgun	Side Scan	Magneto-meter	Data Logger	Gravity-meter	9480 Logger
103	55	130	SN + DS	✓	✓	1000J	-	-	-	✓	✓	-
104	65	163	SN + DS	✓	✓	1000J	-	✓	✓	✓	✓	-
105	70	161	SN + DS	✓	✓	1000J	-	✓	✓	✓	✓	-
106	19	33	SN + DS	✓	1-14	1000J	-	✓	✓	✓	✓	-
107	11	29	SN + DS	✓	-	-	-	-	-	✓	✓	-
108	37	112	SN + DS	✓	-	1000J	-	-	✓	✓	✓	-
109	87	192	SN + DS + MC ØE	✓	-	-	-	-	-	✓	✓	-

Notes

SN = Satellite Navigation
DS = Doppler Sonar
MC ØE = Decca Main Chain ØE Vestandet
MC 6C = Decca Main Chain 6C North Scottish

WAR = Wide Angle Reflection

TABLE 3

LOCATION OF LINES 11, 18-21 AND 109

LINE NO	START CO-ORDINATES		END CO-ORDINATES	
11	56° 07.145'N	00° 36.184'E	60° 09.393'N	00° 36.219'E
18	59° 51.284'N	00° 54.624'W	59° 16.282'N	00° 54.631'W
19	59° 14.533'N	00° 25.843'W	59° 14.781'N	00° 41.106'E
20	59° 14.540'N	00° 39.082'E	59° 12.279'N	00° 42.497'E
21	59° 20.392'N	00° 23.360'E	60° 00.102'N	00° 57.686'W
109	60° 33.434'N	01° 05.559'E	59° 01.510'N	00° 19.611'W

TABLE 4

PORTS OF CALL

DATES	PORT	REASON
28 June-3 July	Tyne Dock, South Shields	Vessel maintenance and mobilisation of seismic equipment. Gravity base check.
8 July	Victoria Quay, Leith	Repair of compressor. Gravity base check.
14-15 July	Holmsgate, Lerwick	Personnel change. Gravity base check.
26-29 July	Victoria Pier, Lerwick	Personnel change. Gravity base check.
10-11 August	Breakwater Pier, Lerwick	Personnel change. Gravity base check.
25-28 August	Victoria Pier, Lerwick	Personnel change. Gravity base check.
5-8 September	King George V Wharf, Dundee	Demobilisation of seismic equipment. Gravity base check.

TABLE 5

Types of Equipment Installed on m.v. Sperus

1. LaCoste and Romberg air-sea gravity meter S75.

1a LaCoste and Romberg 9400 data acquisition system.

2. Barringer magnetometer.

3. Edo Western pinger with hull mounted transducer.

4. Klein side-scan sonar and associated winch.

5. Atlas Deso 10 echo sounder with hull mounted transducer and digital readout unit (Edig 10).

6. Seismic system:-

   (i) Bolt airgun 200B.

   (ii) Refnell Sat 6H compressor.

   (iii) Multi-element spark array (IGS).

   (iv) EG & G 9-element spark array.

   (v) EG & G trigger, power and capacitor units.

   (vi) 30m and 20m Geomecanique hydrophones.

   (vii) EG & G 263C hydrophone.

   (viii) EPC graphic recorders (4100 and 4600).

   (ix) Analogue tape system.

   (x) Ultra sono-buoys.

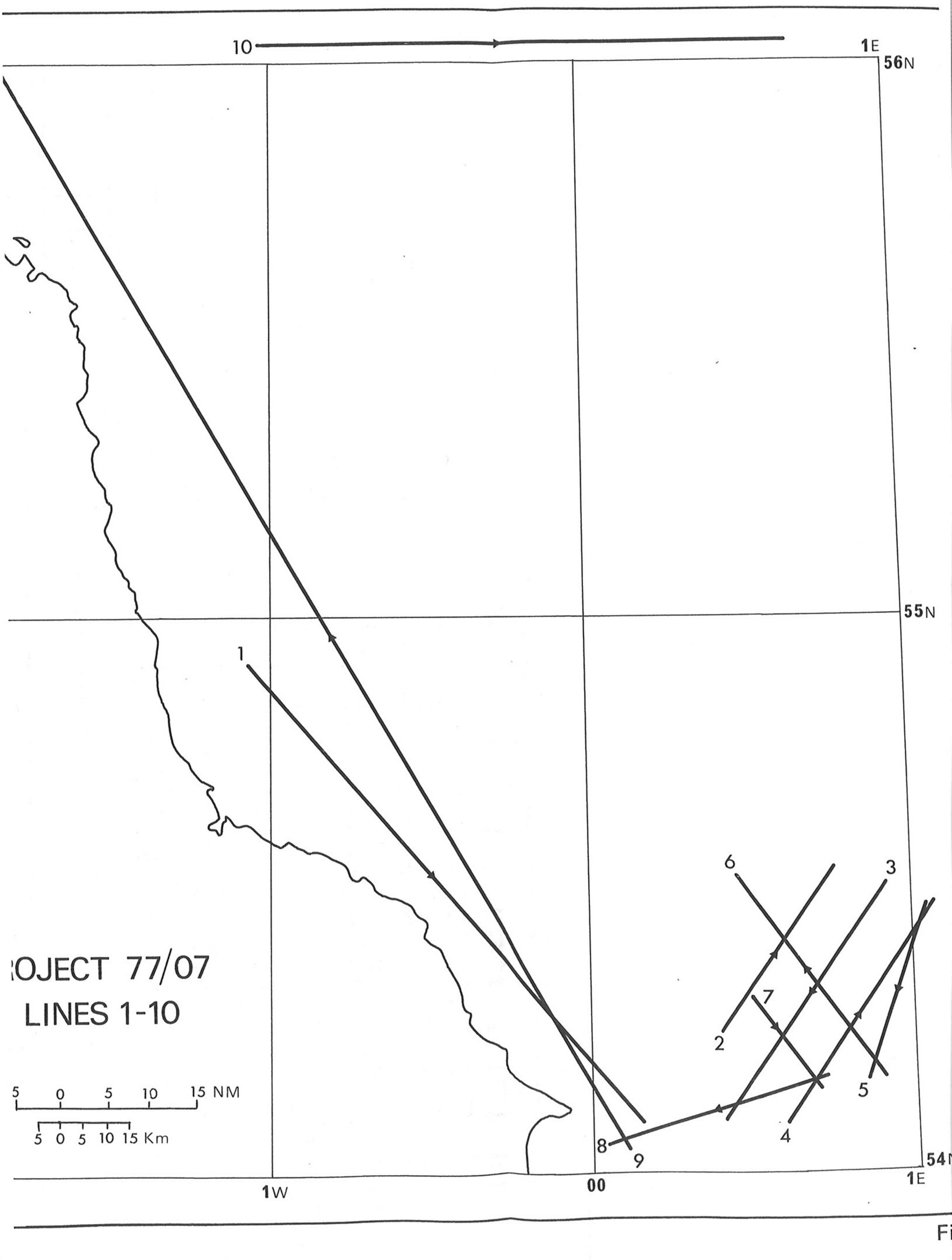
7. Magnavox Satellite Navigation system integrated with MX610 or MX600 doppler sonar.

8. Decca Mk 21 main chain receiver.

9. Decca data logger.

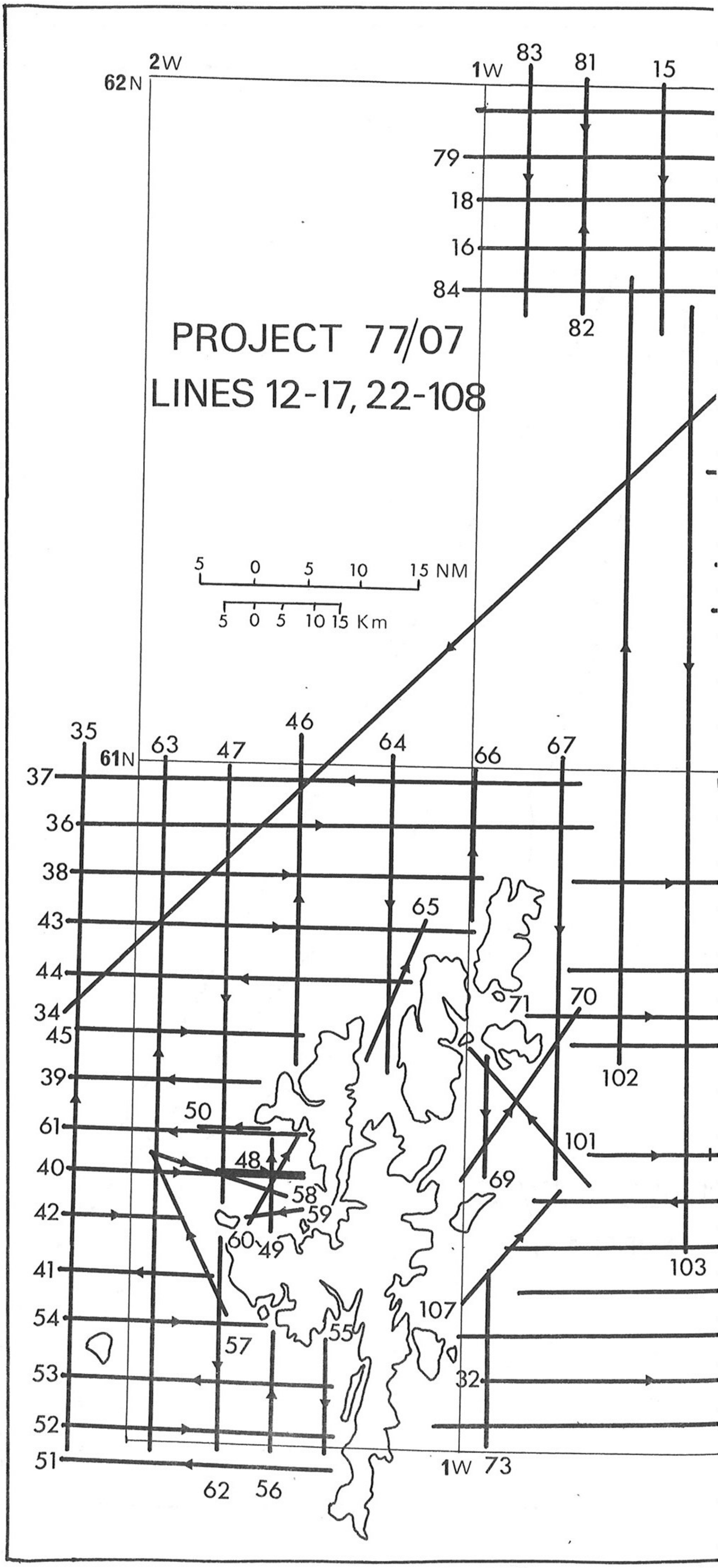
10 Three 60KVA AC generators.

11 Stabilised no break power supply system (UPS).



10
1E
56N
55N
1
6
3
2
7
4
5
8
9
54N
1W
00
1E
ROJECT 77/07
LINES 1-10
5 0 5 10 15 NM
5 0 5 10 15 Km

Fi


PROJECT 77/07
LINES 12-17, 22-108
5 0 5 10 15 NM
5 0 5 10 15 Km
62N
61N
2W
1W
1W
83
81
15
79
18
16
84
82
102
103
35
63
47
46
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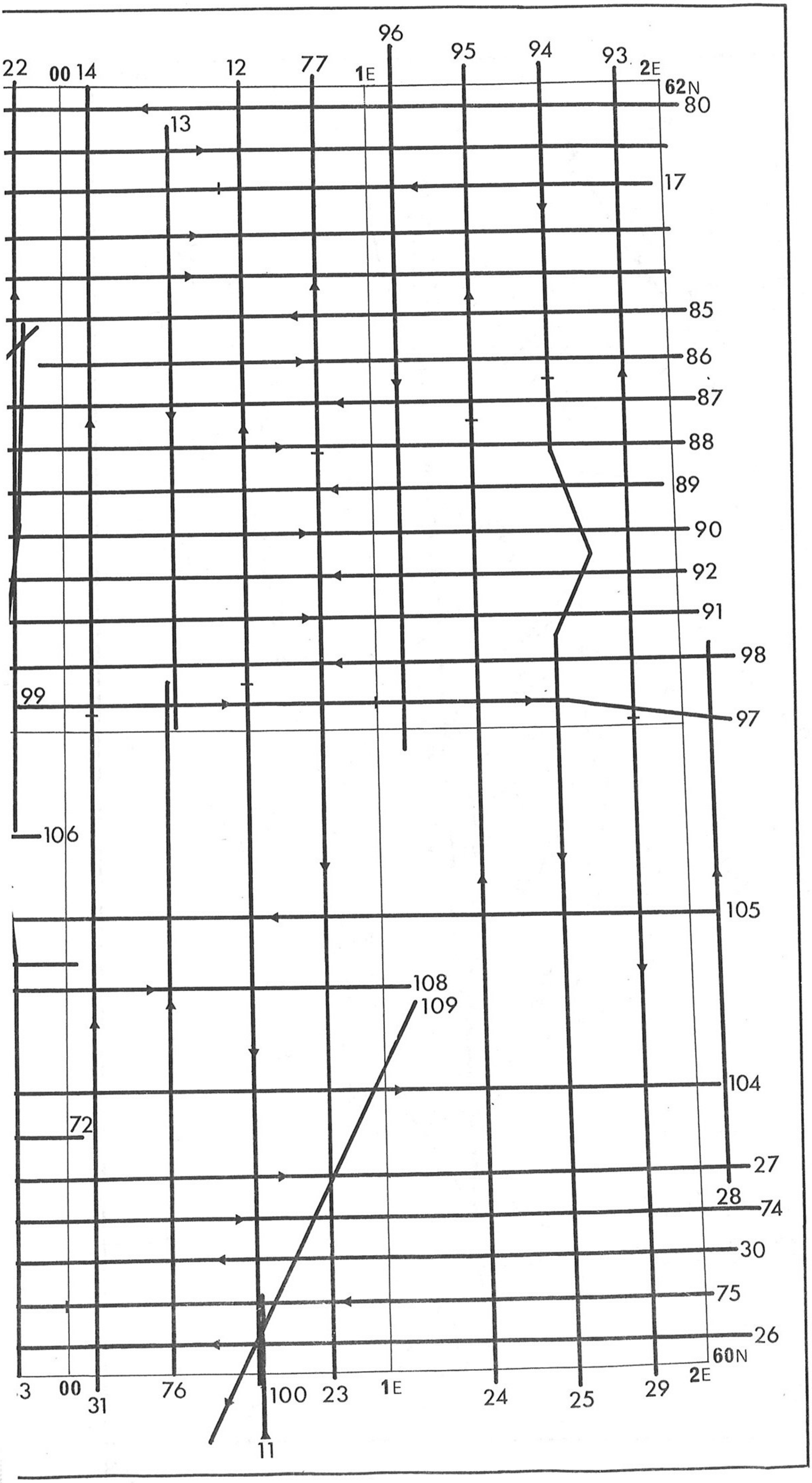
73



96
95
94
93
22
00
14
12
77
1E
2E
62N
80
13
17
85
86
87
88
89
90
92
91
98
99
97
106
105
108
109
104
72
27
28
74
30
75
26
60N
3
00
31
76
100
23
1E
24
25
29
2E
11

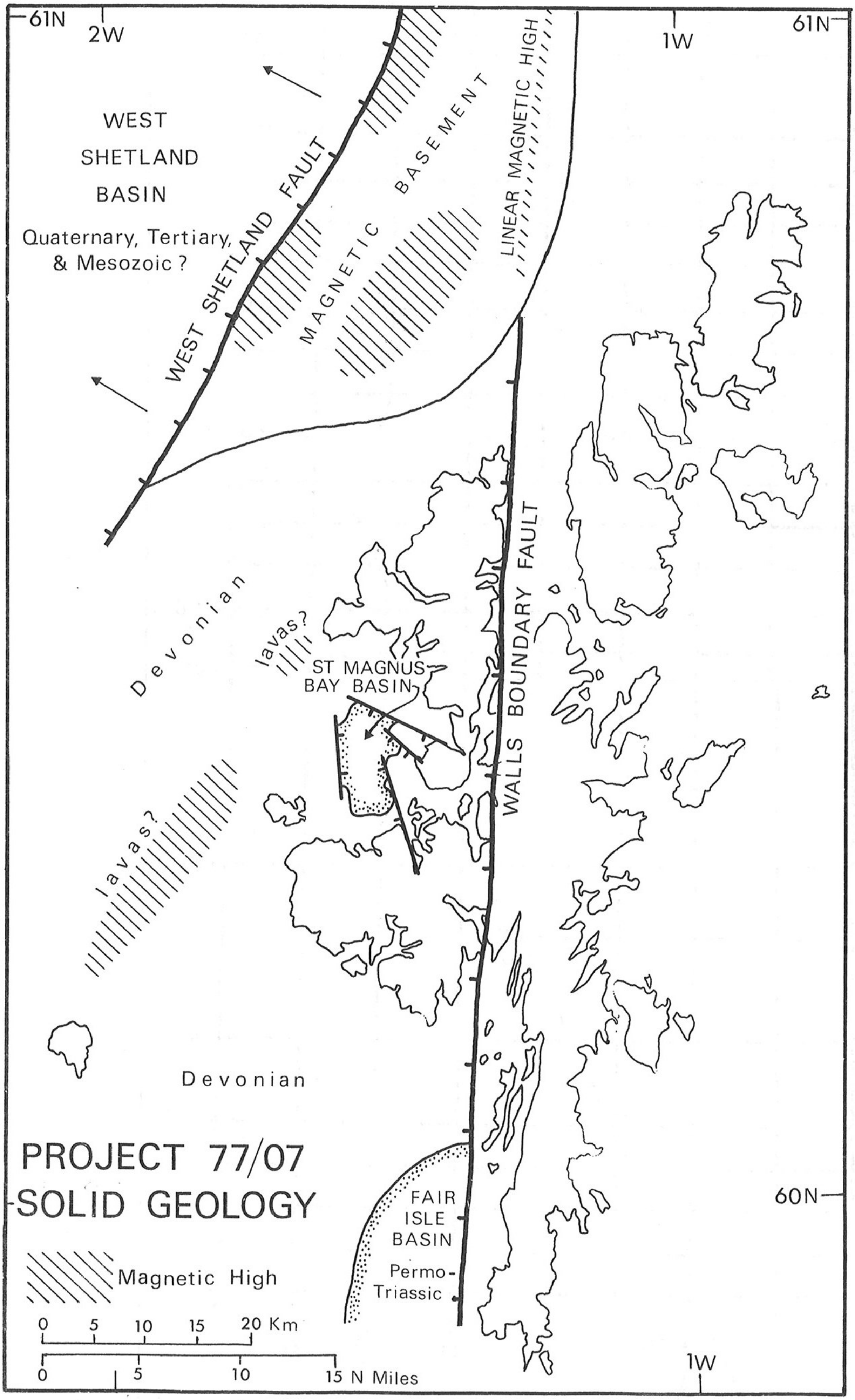

61N
2W
1W
61N
WEST
SHETLAND
BASIN
Quaternary, Tertiary,
& Mesozoic ?
WEST SHETLAND FAULT
MAGNETIC BASEMENT
LINEAR MAGNETIC HIGH
Devonian
lavas?
ST MAGNUS
BAY BASIN
WALLS BOUNDARY FAULT
lavas?
Devonian
PROJECT 77/07
SOLID GEOLOGY
FAIR
ISLE
BASIN
Permo-
Triassic
60N
Magnetic High
0 5 10 15 20 Km
0 5 10 15 N Miles
1W

Fig.3