Department of Geological Sciences

University of Durham

Hebridean Margin Seismic Project

Report on RRS Challenger Cruise 11/75
in the North East Atlantic.

23 July – 19 August 1975

Contents

1. Scientific objectives

The project was designed as a sea-to-land seismic refraction experiment, using closely spaced shots and receiving stations, across the continental margin west of the Hebrides. The primary objective was the investigation of the transition from oceanic to continental crust in a particularly favourable region where shelf sediments are thin. Secondary objectives included the investigation of the deep structure of the Wyville-Thompson Ridge, and the development of methods for examining the deep structure of margins.

Preliminary results of the North Atlantic Seismic Project (NASP) of 1972 influenced the planning of this project. Work in 1972 showed that shots of 600 lbs of Geophex explosive on the Faeroe Block and in the Faeroe-Shetland Channel are readily detectable in northern Scotland and in the Shetland Isles, although there is a decrease in amplitude for shots just beyond the margin. It was also shown at the boundary between the Iceland-Faeroe Ridge and the Faeroe Block, converted waves which travel as P* or P_n beneath the ridge, and as P_g through the continental crust of the Faeroe Block were detected with some confidence. Also, it was concluded that probably the best way to investigate the transition is to use the time term method with stations offset at Moho distance along the strike from the transition.

Two main lines of closely spaced shots across the margin were planned: one east-west across the central section of the Rockall Trough onto Rockall Bank, passing close and to the north of St. Kilda, the other north-west - south-east from the northernmost part of Rockall Trough across the margin to Lewis. A third line passes approximately north-south from St. Kilda, along the continental shelf to Malin Head. The size of explosive charges for the shelf sections of all lines would be 300 lbs, and for sections seaward of the shelf, 1500 lbs.

A survey based on these shot firing lines would permit, in conjunction with suitably placed receiving stations, investigation of crustal structure across the Caledonian belt and north foreland of Scotland, the crustal structure beneath the Rockall Trough, and the intervening

continental margin and possible converted phases arising from it.

Shot firing was planned to take place in two phases, firstly from HMS Herald, for shots in the shallower water, and secondly from RRS Challenger in the deeper waters off the shelf. In the event, one ship, the Challenger, was used for all shots, as HMS Herald was not available.

A total of twenty-two land receiving stations were planned for sites extending across northern Scotland, the Western Isles, St. Kilda and Northern Ireland. It was planned to use an additional vessel, on charter, to act as a marine receiving station at the oceanic ends of the two main lines of shots. M.V. Charterer was chartered for this purpose, and to act in support of Challenger by carrying additional explosives.

2. Personnel

Throughout the cruise, the scientific and shot firing personnel were as follows:

Senior Scientist	G. Wylie
	D. Asbery
Firing Officer	Lt. Cdr. C.C. Moore, O.B.E.
	C. Kemp
	J. Linklater
	D. Baty
	I. Thomas

3. Scientific Equipment

The following equipment was carried on the vessel during the cruise:-

i) Satellite, Decca and Loran C navigation systems
ii) precision depth recorder
iii) magnetometer
iv) shot timing equipment, plus 100% spares
v) explosives and associated equipment, plus 200% spares for the towing and firing system
vi) coring equipment.

The magnetometer and the equipment for coring was intended for alternative work in the event of weather conditions prohibiting shot firing. The firing and timing systems are discussed in the appendix.

4. Installation and preparation of equipment

All scientific equipment for both vessels, and the shot firing equipment (except for explosives) was transported by road from Durham to Barry on the 19th and 20th July. Seismic receiving and recording equipment for M.V. Charterer, alongside at No.1 Dock, Barry, was left at the Research Vessel Base, and the shot firing and timing equipment taken on by road to Milford Haven, where the RRS Challenger lay, early in the morning of the 21st July. The shot firing party had travelled to Milford Haven on the 20th July; the loading of shot firing and timing equipment was completed on the morning of the 21st. All navigational and depth recording systems were already fitted and operational, with the exception of the satellite navigation system, which was undergoing repair.

The shot firing equipment, comprising ropes, buoys, firing cable, and prepared detonator adaptors, was sorted and stowed in the after hold and small laboratories which communicated directly with the after deck. Most of the preparation work on the shot firing system had been completed well before the cruise date.

The shot timing equipment was installed in the scientific control room, abaft the bridge, overlooking the after deck where shot preparation, arming and deployment would be carried out by the firing party. This arrangement proved to be highly effective in operation, because of the visual communication between the after deck and the scientific control room, the close proximity of the control room and the bridge, and the strategic siting of intercom units permitting immediate contact between all three areas. Installation of the timing equipment required the siting of a geophone close to the hull, and associated cable to connect to the control room. The site chosen was under the lower deck, the geophone being lashed upright close to a bulkhead, in contact with plating above fuel tanks. Most of the shot timing

equipment had been prepared and tested at Durham, all that was required after siting the geophone was the addition of variable attenuation for the geophone and digital clock outputs to the ultra violet recorder used as a visual monitor.

Installation of shot firing and shot timing equipment was completed on the 22nd July; the scientific and shot firing party formally joined the ship in the afternoon. The following morning, 23rd July, Challenger moved to berth at the Royal Naval Armament Depot jetty, Newton Noyes, to load depth charges, primers and detonators for use as explosive seismic sources. Of the total quantity of 180 depth charges, Challenger loaded 72, the remaining 108 were later loaded onto M.V. Charterer, which had sailed from Barry the previous evening to rendezvous at RNAD. All primers and detonators were loaded onto Challenger, together with a small quantity of plastic explosive for use as fish scaring charges in fishing areas before firing the much larger quantities of explosive used as seismic sources.

During the day, trials of the satellite navigation system indicated that it was working correctly; after loading explosives, Challenger anchored off, whilst Charterer went alongside the jetty. During this period, the masters and senior scientists of both vessels met on Charterer to agree a radio contact routine for working purposes whilst shot firing.

5. Narrative Leg 1

At 1513 GMT Wednesday 23rd July 1975, Challenger was under way from Milford Haven; VHF contact with Charterer later confirmed her departure from RNAD Newton Noyes.

In the morning of Thursday 24th July, radio contact with Charterer was attempted, according to the agreed schedule. After several unsuccessful attempts, contact was made by calling up on 2182 kHz. and subsequently using 3201 kHz for communication. The initial difficulty on higher frequencies was thought to be due to an ineffective aerial, which may have been disturbed whilst the satellite navigation system was being repaired.

The shot timing clock was started and tied into Rugby MSF time signals, on 60 kHz, using a Golay LF receiver, at the 1626 hrs. GMT minute marker.

Some difficulty was experienced in triggering the clock, thought to be due to a low signal strength at the Golay receiver because of variation in reception due to movements of the ship.

By 2100 hrs GMT, Challenger was proceeding north along the Sound of Islay, en route for the Sound of Mull and a quiet passage to the first working area near the Rosemary Bank. This course was followed because of poor weather conditions in the area. Challenger came out of the Sound of Mull at 0300 hrs GMT on 25th July, and the decision was taken to proceed up the Minches inside the shelter of the Outer Hebrides. After receiving the 1030 and 1130 hrs BST weather analysis and forecast it was decided to proceed to the first station in the schedule (L11 at 59^{o} 54'N 9^{o} 36'W); at 1750 GMT, Challenger rounded the Butt of Lewis, heading out into the Atlantic. At 1011 hrs GMT on Saturday, 26th July, the vessel was hove to, on station L11, preparing depth charges for firing. The shot firing and timing systems were checked and found to be functioning satisfactorily. The PDR in the laboratory was malfunctioning, so that depth soundings were taken with the bridge sounder.

A radio warning was broadcast on 4139.5 kHz, prior to the shot, and the first shot was fired, at L11, at 1235 hrs GMT. (for corrected shot times refer to appendix). A radio report of a successful shot was broadcast; at 1248 hrs GMT, the tow was being recovered. The arrival of the receiving vessel, MV Charterer, was estimated to be 0400z the next day, Sunday 27th July. Challenger steamed west, to return to L11 to rendezvous with Charterer.

At 0715 z, 27th July, radio contact between Challenger and Charterer was made, on 2246 kHz, followed by contact on the bridge VHF radio. Charterer advised her e.t.a. at L11 to be 1030 z, and her expected readiness to receive seismic data as 1500 z. In view

of this delay, Challenger moved to station L10 to fire the next shot before noon. After firing the shot, Challenger would then return to L11 and, using her satellite navigation system, control Charterer into position on L11 to lay a marker buoy for maintaining station.

A shot firing forecast for the day was issued by telex at approximately 0800 A ; Charterer was informed and requested to transmit shot warnings on 4139.5 kHz as Challenger's R/T transmitter was proving to be ineffective in the 4 kHz frequency range.

At 0827 z the first charge for shot L10 was deployed, and the shot was fired successfully at 1010 z. The charge tow was recovered and stowed at 1114 z· at 1255 z rendezvous was arranged with Charterer to pass across to her a dhan buoy, as the buoy and cable for marking L11 had been lost. The buoy was launched over the side at 1340 z, at 1406 Challenger was returning to L10 to await Charterer relaying the marker, and to control her into position, using Challenger's satellite navigation system, in conjunction with radar.

By 1700 z, Challenger was maintaining position on station L9; at 1807 z Charterer advised that they would be ready to receive seismic data via static hydrophones at approximately 1830 z. Firing was accordingly held until Charterer advised readiness and shot L9 was successfully fired at 1821 z; Charterer reported receiving the water wave arrival. Recovery of the tow commenced, and Challenger was requested to return to L11 to make a navigational fix on the position of the marker buoy. During recovery of the tow, it was discovered that one charge had not exploded (in the opinion of the firing officer due to a defective primer); this was subsequently cut free and sunk at position $59^{o}41.1'N$, 9^{o} 17.3'W.

Weather conditions had been deteriorating steadily during the day, with shot L9 being fired in what was probably the limiting state in view of the degree to which the firing party and deck crew had been worked up. Through the night the weather worsened, and the decision was made to return to the North Minch, and proceed with shot firing on lines G and H within the Minches, until the weather

conditions permitted a return to open water. No shots were fired during Monday 28th July.

Sheltered water in the Minch was reached in the evening of Monday 28th July, and at 0830 A on the morning of Tuesday 29th July, shot firing forecasts for 29th and 30th July were issued by telex to Durham and copied to Barry and Malin. At 0800 z a fisheries representative was taken on board at Ullapool to observe shot firing along line G in the North Minch. Station G6 was omitted because of difficulty in manoeuvring on the station, close to rocks, in the fresh wind. Some engine trouble was experienced as Challenger left Loch Broom, but after a short delay, the vessel proceeded west to take up position on station G6. Charterer informed that she was proceeding to Stornoway to land one member of the scientific personnel, and that she would be ready to receive from shots on line H the next day.

Fish scaring charges were fired just before the main charge on all shots in the Minches on lines G and H. Shot G7 was fired at 1009 z, 29th July and shot G8, G9, G10 and G11, were fired at intervals through the day, concluding with shot G12 at 1821 z. The fisheries representative was landed by boat at Stornoway in the evening.

By 0704 z 30th July, Challenger was in position at station G13, making ready to fire the next shot. The proximity of two vessels forced a delay in the firing of shot G13 until 0805 z, when the charge was successfully detonated. Shot G14 was fired at 0942 z, completing the Minch section of line G. At 1135 z Challenger was approaching station H16 and Charterer was advised of the expected time of firing. The shot was fired at 1206 z .

Shooting along line H in the Minch continued throughout the day, terminating at shot H9, by Loch Torridon, at 2205 z. The shot firing procedure was modified during this period to hold firing until Charterer reported that her seismic receiving and recording equipment was operating.

After firing shot H9 and recovering the tow, Challenger headed for Stornoway to transfer depth charges to Charterer before entering harbour for fuel and water.

In the morning of 31st July, Challenger and Charterer rendezvoused in Branahuie Bay off the Eye Peninsula, Isle of Lewis, to clear charges from Challenger before she entered Stornoway. Durham personnel operating seismic receiving stations on Lewis met the ship in Stornoway, and reported that no radio broadcast from either ship had been received, and that information sent by telex to Durham was slow in coming through to Stornoway. Consequently, it was decided to copy telexes to a telex receiver in Stornoway . A radio transmission and reception test schedule was arranged between Challenger, Charterer and the shore stations, to take place as Challenger departed from the Minch. As transmission on 4139.5 kHz from Challenger was ineffective, it was arranged that Challenger would transmit in future on 2246 kHz, and that simultaneously, Charterer would transmit on 4139.5 kHz.

6. Narrative, leg 2

Challenger departed from Stornoway at 1700 z on Thursday 31st July to rendezvous with Charterer and reload depth charges for the next leg of the cruise. Wind and sea conditions precluded the two ships manoeuvring alongside, and both anchored in the shelter of Broad Bay overnight. Conditions had improved the following morning, and by 1200 A, charges had been transferred. Both ships proceeded north up the North Minch, toward the Butt of Lewis, Charterer to head for station K14 and Challenger to head for Cape Wrath, to fire shot I3, the greater cruising speed of Challenger permitting her to divert. Radio test transmissions were made according to the schedule made in Stornoway. Shot I3 was fired at 1905 z, at the north of Loch Eriboll, and as soon as the tow was recovered, Challenger set course for the western end of line K.

During passage across from the Butt of Lewis to Line K, the weather conditions remained poor and their forecast doubtful.

Charterer was slowed markedly by the conditions, her estimated time of arrival at K14, westernmost station on Line K, postponed. To make use of the delay in time enforced by weather delaying Charterer's progress and preventing Challenger shooting on Line K until conditions improved, Challenger made for St. Kilda, to fire shot J1 at the northern end of Line J in the lee of the islands and, if possible, to continue shooting line J in a north-to-south direction, until sea conditions to the west improved. Challenger anchored in Village Bay, St. Kilda overnight Saturday 2nd August. Contact was made with the St. Kilda garrison and with the Durham personnel operating seismic receiving stations on the island.

The receiving station on the island was operating satisfactorily, and before cruise personnel returned to Challenger from St. Kilda, the probable shot firing programme was outlined, and the Officer Commanding the St. Kilda detachment agreed to maintain a listening watch twice daily to receive updated information from Challenger's radio broadcasts.

Challenger left Village Bay early in the morning of Sunday, 3rd August, and at 0700 z was on station at J1. The shot was fired successfully at 0739 z, and recovery of the tow was completed at 0855 z. Course was then set for station K14 at the western end of line K.

The ship came onto position K14 at 0757 z, 4th August, and charges were prepared for firing. Radio and radar silence was cleared at 0948 z, and contact was established with Charterer, which was standing by to take up position on K14 after the shot.

Immediately after the shot warning had been radioed to Charterer, HMS Tiger communicated with Challenger, and ordered firing to be delayed. Challenger was also instructed to move west out of the area, as quickly as possible; these instructions were complied with, although speed was reduced because of the array of primed and armed charges streamed astern ship on the tow. At 1057 z Tiger gave clearance to fire, and to minimise the risk of misfire through straining the electrical firing cable frapped to the tow, Challenger did not

return to her original position. The shot was fired successfully at 1105 z. The towing and firing cables were recovered and Challenger made for K14 to control Charterer into position to lay a marker buoy for holding station as the receiving ship.

Subsequently, Challenger moved to station K12, arriving on position at 1607 and prepared to fire the next shot. Firing was attempted, but the charges failed to fire; a further attempt was made, but with no success. Recovery of the tow commenced under radio and radar silence at 1748 z, and each unexploded depth charge was cut away and sunk on position 58° 03.3' N, 11° 54.5'W, the last charge being sunk at 2120 z. Some difficulty was experienced in sinking the last charge, as the tow fouled the screw during recovery. Alternate ahead and astern motion of the screw cut free the tow and the buoyed charge drifted off. The tow was recovered, and in the failing light, Challenger returned to the drifting charge. The inflatable boat was deployed, crewed by the third officer, second engineer and senior scientist. Recovery of the buoy was attempted, but considered too dangerous because of the tangle of ropes underneath. Finally the buoy was slashed and the charge sunk in 1820 m. of water. After recovering the inflatable boat, Challenger returned to position K14 overnight, to lay a replacement buoy for Charterer, which was having difficulty maintaining position on K14, due to unreliable performance of her Loran C system.

At 0840, Tuesday 5th August, Challenger laid another dhan buoy for Charterer, and the two vessels compared navigational data between Charterer's Loran C and Challenger's Loran C and satellite navigation system. Charterer's Loran C system appeared to give a 3-7 mile northerly error. Challenger then made for station K12, and the shot was successfully fired at 1336 z, using a replacement firing cable. The next shot, K11, was fired at 1810 z, 5th August. K13 was omitted because of time lost in the delay enforced by HMS Tiger, and the problems of maintaining Charterer's position. After consultation between the senior scientists on both vessels, it was decided to omit K10 and shoot alternate shots on the line. Challenger accordingly proceeded to station K9 overnight, to be ready to fire in the early morning.

Shots K9 and K7 were fired on 6th August at 0906 z and 1446 z; each shot was fired as soon as Charterer radioed that her seismic receiving and recording equipment was ready. The sea state was rising as K9 and K7 were fired, and precluded further shot firing. Logistic requirements arising from the necessity for Challenger to return to Stornoway for fuel and water and supplies over the weekend of the 9th and 10th of August meant that Challenger would need to be under way for Stornoway at some time on Thursday. Charterer's slower speed in the prevailing weather and sea conditions, limited her stay at position K14 to Thursday 7th August also. In the event, shot firing was impossible on Thursday 7th, and shot firing plans were changed,abandoning work on Line K until the final leg of the cruise, instead to fire shots on Line G, proceeding toward Lewis, en route for Stornoway, on Friday 8th August. The proposed changes were communicated to Durham via radio telephone, for notification to all land receiving stations.

Challenger then made for the shelter of St. Kilda, and cruised in the lee of the island overnight, 7th August.

At 0600 z Challenger anchored in Village Bay, and two members of the scientific party went ashore to check the Durham receiving stations were operating and to inform the Durham personnel of the change in schedule. It was confirmed that St. Kilda had been receiving radio transmissions from Challenger. Time and conditions prevented Charterer from taking up position at station G28 to receive shots from the western section of line G across the shelf; the St. Kilda station offered the only facilities for reversing the western shelf section of line G.

At 0745 z the anchor was raised and Challenger headed to station G21 and the shot was fired at 1014 z. To keep shot firing on the forecasted schedule, alternate shots were fired as Challenger proceeded east, and shots G19, G17 and G15 were completed, the last shot being fired at 1622 z. Challenger then headed north for the Butt of Lewis, en route for Stornoway, to rendezvous with Charterer

for the transfer of depth charges.

The two vessels came alongside, in Stornoway Bay, within Arnish Point, to transfer charges to Charterer. Both vessels then moved to Stornoway Harbour and went alongside, remaining moored until the evening of Monday 11th August. During the weekend, Challenger took on fuel, water and supplies in Stornoway; the rope fouling the screw and rudder, remaining from the incident on 4th August was removed. Captain Maw took leave, and the Chief Officer, P. McDermott took over command as Captain. Durham personnel operating receiving stations on Lewis met the vessel in Stornoway, and contact was made by telephone with Durham personnel on the mainland of Scotland operating stations there. As a result of discussion with receiving station personnel, arrangements were made to copy telexes giving shot forecasts to Ullapool in addition to Stornoway as previously arranged. Radio transmissions of shot forecasts and reports were not being received by the land stations. The radio test transmissions made by Challenger and Charterer as the ships departed from Stornoway after their last call on the 31st July, had not been received.

Consultation with Professor M.H.P. Bott produced a schedule for the remaining leg of the cruise, placing priority on the completion of line K and the western shelf section of Line G, with the possible addition of further shots on line L, before line J was completed as the last work as Challenger returned south at the end of the cruise.

7. Narrative Leg 3

Challenger and Charterer cleared the quay at Stornoway on the evening of Monday 11th August at 1700 z; Charterer leaving for Lowestoft at the end of her cruise, and Challenger for station G16 on the western shelf. In calm but very foggy conditions, station G16 was not reached until some 3 hours behind schedule, and the shot at G16 was fired at 1021 z. Alternate shots on line G were fired

to complete the omissions made at the end of leg two: shots G18, G20 and G22 were fired during the day, terminating with shot G23 at 1844 z. By 1849 z the fog was too dense, with the onset of dusk, to permit further firing. As the sea state was, however, ideal for shooting, Challenger proceeded slowly through the night to station K1. Shot K1 was successfully fired at 0906 z on the 13th August, and to obtain at least continuity on line K, shots K3 and K5 were fired on the 13th August, in case the weather deteriorated as the forecasts seemed to indicate, and the central section of K was forced to be omitted. The good sea conditions continued to hold, however, and shots K6, K4 and K2 were fired on the 14th August, thus completing line K except for shots K13, K10 and K8.

Completion of the shelf section of line G was commenced with shot G28 at 0731 z, 15th August, and all intervening shots from these to the previous firings successfully made, finishing with G24 at 1345 z on the 15th August.

The schedule for the return of unused depth charges to RNAD Newton Noyes, Dyfed, prevented a return to line L, further north, to continue firing on that line. To meet the schedule, and have time in hand for contingencies, Challenger would need to be at station J8 by noon on the 17th August.

As station J2 would not be reached in time to fire on the 15th, Challenger anchored overnight at St Kilda. Repairs were made to the seismic receiving stations on St. Kilda and the schedule for the rest of line J outlined to Durham personnel on St. Kilda.

Challenger departed from St. Kilda on 16th August and took up position on station J2 at 0711 z, the shot being fired at 0747 z. Shots J3, J4, and J5 were fired successfully, the last at 1606 z. Challenger delayed firing J7 and J8 until the following day, as requested by MOD(N), and omitted J6, as waiting until the following day to fire J6 would have prevented the vessel clearing J8 by noon on the 17th August.

Shots J7 and J8 were fired on Sunday 17th August, at 0741 and 1030 z respectively, and at 1158 z on the 17th; survey work ceased after the recovery of the tow.

Challenger came alongside at RNAD Newton Noyes at 0800 z on the 19th August according to schedule, and arrived in Barry later the same day, terminating the cruise.

8. Equipment performance

Performance of the ship's navigational equipment, and of the winching and trawling equipment used to handle the charge tow was very satisfactory, causing no difficulties. (However, suggested improvements to the lifting arrangements astern are given in the summary at the end of this report).

Shot firing and timing equipment operated without trouble throughout the cruise, with the exception of the misfire of 5 charges at the first attempt to fire K12. This was probably due to the strain imposed by towing the charges on instructions from HMS Tiger. The only other misfire which occurred, on shot L9 may have been due to a faulty primer charge, or to the depth charge not being armed properly. It is most unlikely that the detonator was faulty, as this would have affected the integrity of the whole firing system.

With regard to performance of the ship itself, this was generally excellent, although some difficulties, which could have been disastrous, were encountered whilst manoeuvring to maintain station with explosives deployed astern, due to random and spontaneous surging of the ship's main engine. (This effect was very noticeable whilst moored alongside at Milford Haven before the start of the cruise).

The bridge radio telephone transmitter (not the VHF system) proved to be ineffective on frequencies much beyond the 2 M.Hz band. This was thought to be due to disturbance of the aerial during repairs to the satellite navigation system in Milford Haven at the start of the cruise.

This restriction on the choice of frequencies for transmission from the bridge R/T meant that shot forecasts and warnings to land receiving stations could not be broadcast on the circulated frequency, 4139.5 kHz. The transmitter was effective in the 2 MHz band, and where proper equipment was used ashore, the land stations did regularly receive transmissions.

9. Summary

Eighty shot firing stations were planned for the Hebridean Margin Seismic Project, comprising 55 single charge shots on the continental shelf, and 25 five-charge shots beyond the shelf. Of these 80 stations, ~~52~~ 38 were occupied and successfully fired, ~~28~~ on the shelf, and 14 in deeper water.

The cruise duration was 28 days, of which time 15½ days were used operationally in firing shots, and the balance used for logistic reasons; lost time directly attributable to poor weather amounted to three days.

The shot firing and timing systems proved to be very effective and reliable in operation, but deployment of the charges could be greatly improved by the provision of a quickly attachable/detachable I section beam across the stern 'A' frame at the lower height. The pendulum effect of slung charges would be considerably reduced by this. Provision, also, of an opening section to deck level in the stern would reduce the height to which charges had to be lifted. The addition of a smooth guide (with an opening top clamp) would reduce chafing and snatching of the tow and firing cable.

The communication of forecasts of shot firing operations to shore parties was improved as the cruise progressed, particularly by the copying of telexes to additional centres.

Two ship working was retarded by the slower speed of Charterer and her difficulties in fixing and maintaining position, and the difficulty she experienced in laying dhan buoys.

However, despite the difficulties, the cruise was generally successful: good results are being obtained from the recordings of the land receiving stations, with the shots at greatest distance across the margin generating useful records.

10. Acknowledgements

Thanks are due to the masters, officers and crew of the RRS Challenger for their consistent efficiency and cooperation during the voyage, and to the staff of the Research Vessel Unit for cruise organisation and support. The firing team, under the direction of Cdr. C.C. Moore willingly and capably worked effectively for long periods whilst shot firing was in progress. We are grateful for the assistance given by the St. Kilda Detachment from the Royal Artillery Range, Benbecula, in monitoring shot forecasts and warnings from Challenger for Durham personnel on St. Kilda. Messrs. Caledonian MacBrayne, Ullapool, and the Hebridean Free Press, Stornoway, very kindly permitted telexes from the ship to be copied to their offices for the field parties in the area; these arrangements were made through the good offices of Duncan McIver, Shipping Agent, Stornoway.

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Appendix

i) Table of shot positions and times

ii) Tables of shot depths and water depths

iii) Map of shot positions

iv) Shot deployment and firing system

v) Shot timing system

University of Durham
Department of Geological Sciences

Hebridean Margin Seismic Project 1975
RRS Challenger Cruise 11/75
Shot positions and times

Line	Shot No.	Position				Date	Time (GMT)		Size (lbs Minol)
		°	' N	°	' W			secs.	
North Minch N	G7	58	00.1	5	30.55	29-7-75	1008	59.20	300
	G8	"	"	"	34.9	"	1148	43.52	"
	G9	"	00.0	"	40.2	"	1308	21.83	"
	G10	"	00.2	5	43.9	"	1436	14.63	"
	G11	57	59.6	6	03.8	"	1706	19.96	"
	G12	"	59.5	"	10.3	"	1821	22.46	"
	G13	"	59.8	"	15.6	30-7-75	0805	46.96	"
	G14	58	00.0	"	21.2	"	0942	55.52	"
West Shelf	G15	57	58.0	7	12.6	8-8-75	1622	05.00	300
	G16	58	00.2	"	22.3	12-8-75	1021	14.04	"
	G17	57	59.2	"	34.0	8-8-75	1419	25.42	"
	G18	58	00.2	"	40.8	12-8-75	1233	54.78	"
	G19	57	59.1	"	53.0	8-8-75	1226	10.60	"
	G20	58	00.2	8	01.8	12-8-75	1441	08.02	"
	G21	57	59.8	"	14.1	8-8-75	1014	53.81	"
	G22	58	00.0	"	25.0	12-8-75	1705	40.99	"
	G23	57	59.8	"	36.5	"	1844	19.73	"
	G24	58	00.0	"	50.3	15-8-75	1345	52.43	"
	G25	57	59.9	9	00.0	"	1227	36.95	"
	G26	58	00.0	"	10.4	"	1028	24.04	"
	G27	"	00.0	"	20.8	"	0905	31.91	"
	G28	57	59.0	"	26.8	"	0731	33.42	"
North Minch S	H9	57	36.1	5	53.5	30-7-75	2205	45.76	"
	H10	"	38.3	"	58.2	"	2039	48.51	"
	H11	"	40.6	6	04.1	"	1911	32.66	"
	H12	"	43.3	"	09.0	"	1740	51.81	"
	H13	"	46.1	"	14.8	"	1608	45.21	"
	H14	"	48.6	"	20.6	"	1446	57.53	"
	H15	"	52.7	"	27.1	"	1313	45.34	"
	H16	"	54.2	"	30.1	"	1206	27.09	"

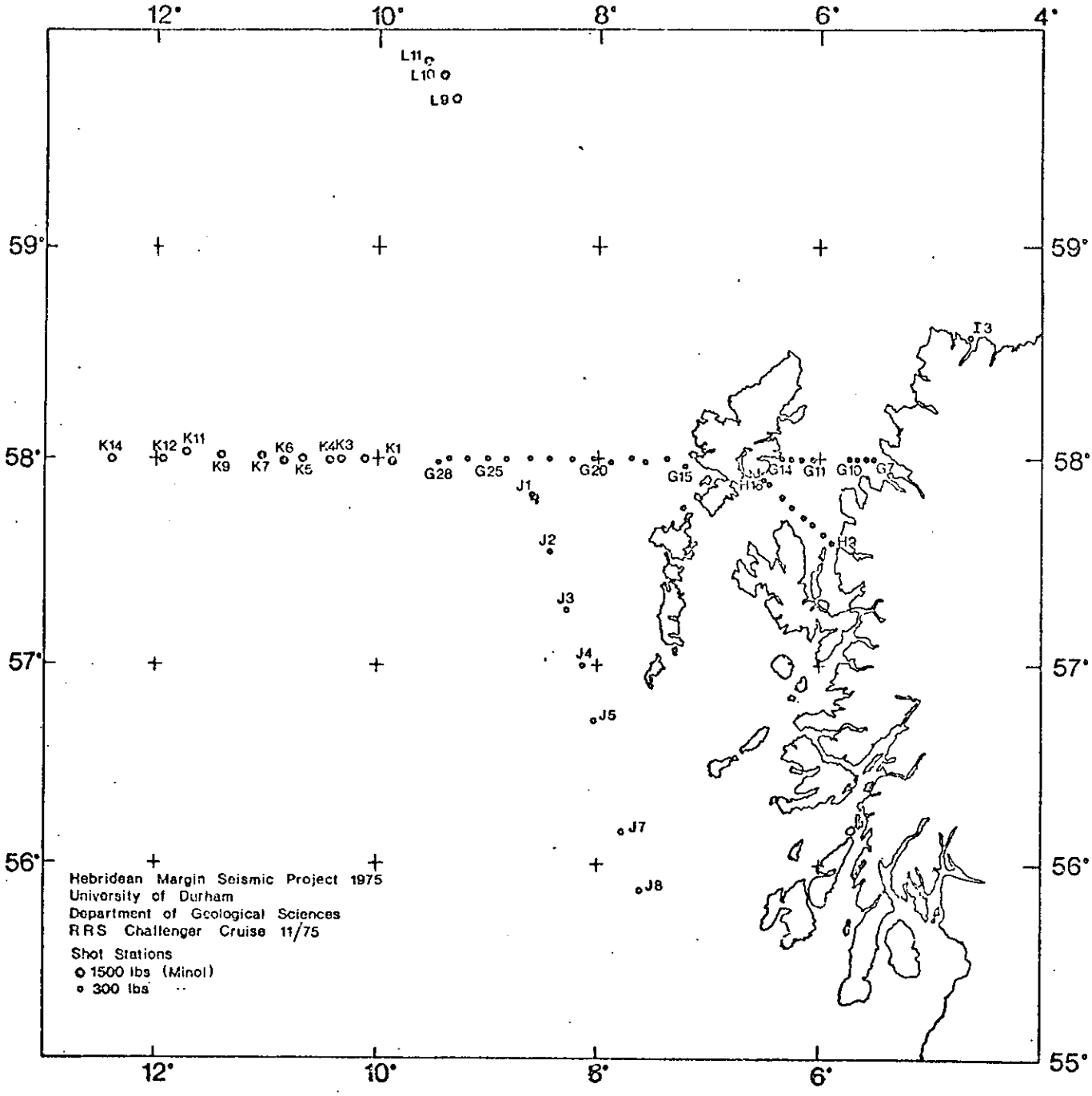
Contd.

Line	Shot No.	Position				Date	Time (GMT)		Size (lbs Minol)
		°	' N	°	' W			secs.	
Cape Wrath	I3	58	34.0	4	37.9	1-8-75	1905	35.01	300
Hebridean	J1	57	50.1	8	35.8	3-8-75	0739	17.77	300
Sea	J2	"	33.0	"	26.0	16-8-75	0747	44.55	"
	J3	"	16.1	"	16.8	"	1033	40.40	"
	J4	56	59.8	"	08.3	"	1319	38.06	"
	J5	"	43.0	"	01.7	"	1606	27.28	"
	J7	"	9.5	7	46.0	17-8-75	0741	49.34	"
	J8	55	52.0	7	37.0	"	1030	32.38	"
Rockall	K1	57	58.95	9	52.83	13-8-75	0906	15.17	1500
Trough	K2	"	59.7	10	05.7	14-8-75	1734	54.14	"
	K3	"	59.6	"	18.7	13-8-75	1330	39.05	"
	K4	"	59.5	"	25.7	14-8-75	1309	54.85	"
	K5	58	00.4	"	39.7	13-8-75	1736	41.83	"
	K6	57	59.3	"	50.2	14-8-75	0821	28.00	"
	K7	58	00.8	11	02.4	6-8-75	1446	39.42	"
	K9	"	00.9	"	24.8	6-8-75	0906	42.43	"
	K11	"	02.8	"	43.9	5-8-75	1810	54.25	"
	K12	"	00.1	"	57.0	"	1336	21.18	"
	K14	57	59.7	12	23.8	4-8-75	1104	56.75	"
Rosemary	L11	59	52.5	9	32.2	26-7-75	1235	30.74	1500
Bank	L10	"	48.2	"	25.1	27-7-75	1010	24.07	"
	L9	"	41.4	"	17.4	"	1820	08.86	1200

Shot depths and water depths

Line	Shot No.	Shot depth	Water depth
		Metres	
North Minch	G7	45	45
	G8	91	102
	G9	91	100
	G10	91	110
	G11	30	48
	G12	45	63
	G13	91	118
	G14	91	151
West Shelf	G15	30	40
	G16	91	97
	G17	76	94
	G18	90	98
	G19	45	70
	G20	91	96
	G21	91	143
	G22	91	140
	G23	91	153
	G24	91	164
	G25	91	172
	G26	91	218
	G27	91	275
	G28	91	364
North Minch S	H9	91	124
	H10	55	55
	H11	91	149
	H12	91	120
	H13	55	74
	H14	60	75
	H15	73	73
	H16	91	136
Cape Wrath	I3	55	55
Hebridean Sea	J1	45	60
	J2	91	174
	J3	91	138
	J4	91	134
	J5	91	120
	J7	76	90
	J8	91	132

Line	Shot No.	Shot depth	Water depth
		Metres	
Rockall Trough	K1	91	1824
	K2	91	1950
	K3	91	2052
	K4	91	2070
	K5	91	2088
	K6	91	2076
	K7	91	2016
	K9	91	1968
	K11	91	1872
	K12	91	1710
	K14	91	1704
Rosemary Bank	L11	91	1365
	L10	91	1416
	L9	91	1464


12°
10°
8°
6°
4°
59°
58°
57°
56°
55°
L11
L10
L9
I3
K14
K12
K11
K9
K7
K6
K5
K4
K3
K1
G28
G25
J1
G20
G15
H16
G14
G11
G10
G7
J2
H3
J3
J4
J5
J7
J8
Hebridean Margin Seismic Project 1975
University of Durham
Department of Geological Sciences
RRS Challenger Cruise 11/75
Shot Stations
1500 lbs (Minol)
300 lbs

Shot deployment and firing system

The explosives used as seismic sources were depth charges fired electrically using a dynamo-exploder (Beethoven) on the ship. Each charge comprised 300 lbs. of Minol explosive, and single charges were used on the shelf shot and five charges fired simultaneously were used for the deep water shots. Each charge was suspended from beneath a large inflatable dhan buoy, at a depth of 300 feet unless the water depth was less. In lesser depths, the attempt was made to suspend the charge as close to the bottom as possible. In some cases, charges were in contact with the sea bed, and this posed the risk of the firing cable fouling and through strain, causing a misfire. In fact, no misfires occurred in shallow water. Charges were deployed astern of the ship on a warp of buoyant rope. The electrical firing cable was frapped to the towing warp and the rope suspending each charge, by self adhesive plastic tape, at frequent intervals, allowing 30% extra cable length over the rope lengths to prevent straining of the firing cable. All firing cable joints were waterproofed with natural rubber strips, bound and cemented with rubber solution. The integrity of the firing cable circuit was tested before and after each shot was fired, using a megger. Where multiple charges were used, the firing circuit connected each detonator in series, to ensure that the required current for detonation was passed through each, and to ensure that the firing current required was kept as low as possible. All detonators were tested before use by using a megger with a current limiting resistor in series. The firing cable used for the harness fitted to the surface tow rope and charge suspension rope was of two types, lightweight practically neutrally buoyant for the surface run, and a heavyweight, sinking type for the vertical section from the surface to the charge. Both the suspension rope and vertical firing cable were terminated in disposable "blow off end" sections severed by the explosion. The remnants were removed from the unaffected main lengths on recovery of the system after each shot, and replaced by new sections.

The physical dimensions, and materials used in the shot firing system are summarised below.

Single shot system

Ropes:

Main towing warp: 3" circumference three-strand staple spun polypropylene white rope. Length 1250 feet to buoy.

Shot suspension rope: 2" circ. polypropylene rope similar to the above. 300 ft. long.

Multiple systems:

Material as for single system, with additional droppers, and 40 m. links between shot suspension buoys/droppers on surface. Length 1750 ft. to nearest buoy.

Manufacturer: Bridon Fibres & Plastics

Supplier : Sea-Dog Life Saving (Scotland) Ltd.,
4 Constitution Place,
Edinburgh,
EH6 7DL.

Shot Suspension Buoys

Bridport Gundry A6 buoys

fluorescent red, 750 lbs buoyancy

Supplier: Tyne Twine & Cordage,
17 Union Quay,
North Shields.

Firing Cable : Lengths equal to ropes + 30%

Surface section : Twin Fig. 8 to N.C.B. Pl15

7/0.40 mm white
(equivalent)

Supplier : B.I.C.C. Ltd.,
Queensway,
Team Valley Trading Estate,
Gateshead,
NE11 OPL.

Vertical section from buoy to charge: AP 6145-99-521-8342 to DG Ships 212 Table 4 2 x 1.0 sq. mm. (32/0.2 mm) twin core turned copper EPR insulated, cores laid up and CSP filled and sheathed black.

Supplier : Sterling Cable Company Ltd.,
Bath Road,
Aldermaston,
Reading RG7 5QD,
Woolhampton 3221

Jointing materials

Firing cable

For waterproof joints in the firing cable thin rubber tape, supplied by the Royal Naval Armaments Depot, Newton Noyes on request, with the depth charges, was used in conjunction with rubber solution.

Rubber solution : L13 specn. CS2880

Supplier : Airborne Industries Ltd.,
Leigh-on-Sea,
Essex SS9 4EF,
Southend-on-Sea 525265

Self adhesive tape

Used for frapping firing cable to ropes, and to bind over cable joints after waterproofing. Red p.v.c. 1" wide.

Manufacturer : Rotunda Ltd., Manchester

Supplier : G. Tennant,
208 Longfield Road,
Darlington.

Explosives

Main charges	Description	RN Ref.
	Depth charge Mk7 filled Minol	SR62002711
	Primer DC Mk7 No.2	SR622018
	Placer Primer	SR62502211
	Detonator Electric No.79	SR637081
	Adaptor Detonator DC3	SR638014

Fish scaring charges

.8 oz. PE4 charges

No.80 detonators

Safety fuse for no.80 detonators

Supplied by Ministry of Defence,
DGST (N),
Block E,
Ensleigh,
Bath.

0225 6933 x4861

Shot timing system

The shot timing system was based on recording the direct water wave arrival at a geophone mounted close to the hull, inside the ship, referred to the time code output from a digital clock. The time of arrival was corrected for clock drift and for the distance and depth of the charge from the ship.

The digital clock was originally tied into Greenwich Mean Time by using the Rugby MSF time signal transmitted on 60 kHz using a Golay pre-tuned receiver. Clock drift was checked daily be comparing to G.M.T. time pips transmitted on BBC Radio 2, 200 kHz. An ultra violet recorder, utilizing mirror galvanometers, was used to compare the two time signals.

Magnetic tape recordings were made of the clock output (an a.m. signal) and geophone output simultaneously using a high quality stereo cassette recorder. The level of the signals from the clock and geophone were adjusted for the recording level by the gain control of the recorder. The clock and geophone signals were also recorded simultaneously on paper using the ultra violet recorder, the input levels were set using potentiometers. To enable the time shot instant to be determined to within 10 milliseconds, the paper speed of the u.v. recorder was adjusted to make the 20 millisecond timing marks of the recorder sufficiently legible to permit reading to half a division. (This level of accuracy is consistent with the accuracy with which correction for shot distance and depth can be made).

All signals to the cassette and u.v. recorders were controlled by a switched control box carrying the potentiometers in circuit. Care was taken with electrically screening input leads, and the box itself. Each shot timing recorded was preceded by a microphone announcement giving the shot number and approximate time of the shot. Both the recording on tape and on the u.v. recorder were long enough (just over one minute) to contain the coded time output from the clock and the water wave arrival. (This technique was possible because the moment of firing was under the control of the shot timing party).

The timing system incorporated a self contained power supply, by using replaceable dry cells for the clock, changed at regular intervals to avoid running down, and by using rechargeable nickel-cadmium cells for the cassette recorder, in parallel with the mains power pack/battery charger made by the manufacturer of the recorder. The u.v. recorder was mains powered, but in the event of a supply failure, the magnetic tape record could have been played back later, into the u.v. recorder. (The shot firing system was also fully independent, being energised by a hand driven generator firing box).

The digital clock, once started at the beginning of the cruise, was left running continuously; the cassette and u.v. recorders were run only at the time of firing, for just over one minute, to ensure that the time code output for each minute was recorded before the shot was fired.

Details of the equipment used for the timing system are as follows:

Hull geophone

A geophone of a few hundred ohms resistance, with a natural frequency of 20-30 Hz was used.

Digital Clock

The clock and time code generator was a thermally compensated crystal oscillator (5 MHz) to generate a modified I.R.I.G.-C. time code and a short code for slow speed visual recorders. The stability of the crystal is better than 1 part in 10^6. A time code recorder with digital display is built in to provide a check of coded time. The clock has automatic facilities for synchronization with a radio time standard, as well as manual facilities. Constructed in Durham, the clock was battery powered.

Cassette Recorder

A Uher mode CR 210 stereo cassette recorder was used to record the clock output and geophone reception of the water wave arrival

from the shot. A rechargeable nickel-cadmium cell pack made by Uher was used in conjunction with a Uher power pack/cell charger, thus providing protection against temporary power failures in the ship's supply, had these occurred Agfa C90 low noise cassettes were used for recording. Voice announcements were recorded using the integral microphone and automatic gain control of the recorder prior to each shot recording. (Care had to be taken to switch out both the microphone and the a.g.c. after use.)

Ultra-violet recorder

The instrument used was a Southern Instrument type M1300 recorder, fitted with a range of 5 galvanometers; SM1 types M, N and P, providing slightly different responses, were used . The clock output was connected across two galvanometers making traces on either side of the paper, and the geophone was connected to a galvanometer making a central trace. (This arrangement facilitates reading the shot instant). The best type of galvanometer for each channel was found by experiment. The levels of the signals fed to each galvanometer were adjusted by potentiometers. Several paper speeds were available on the recorder, and several rates of timing marks at regular intervals. The best combination with regard to economy of paper and legibility and accuracy of timing was found by selection before shot firing began. The paper type used was Kodak Linograph Direct Print paper, Type 1895,/6m/16.2 cm x 45m, 25.4mm I.D. core, emulsion In.

A schematic diagram of the shot timing system is given below.

Shot Timing System - Schematic