R.R.S. "JOHN MURRAY" CRUISE 3/69

8th to 22nd April, 1969

Geophysical investigations in the Firth of Clyde and adjacent areas

Preliminary Cruise Report

Department of Geology,
University of Glasgow,
GLASGOW, W.2.

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(Department of Geology, University of Glasgow)

The primary aim of Cruise 3/69 was to make a seismic-refraction survey of two sedimentary troughs, one lying north-west, and one south-east of Arran. The general structure of the area had been determined previously by sea-bottom gravity-meter and magnetic surveys and it was hoped the refraction results would assist in identifying the geological formations present. It was planned to use time surplus to this programme for seismic profiling and magnetics in areas of special geological interest within the Firth; and (as an insurance against failure of the refraction programme) some reconnaissance lines to the west of Kintyre were planned, but did not have to be run.

To make as much use of the ship as possible, two other projects were organised and carried out, by non-Glasgow scientists. Staff from S.M.B.A. (Mr. Brown and Dr. Brude) used the otherwise unproductive passage time to and from the Firth of Clyde to test undulating recorder equipment, on tow,. Mr. Eden (I.G.S., Edinburgh) joined the ship to assist Mr. Harrison (Liverpool University) in tests of a solid-rock-corer designed and built in the Department of Geology, Liverpool University (Dr. Flynn). Some dredging was done in association with these tests.

PROGRESS AND RESULTS

The seismic-refraction survey consisted of 4 lines, of total length 37 miles (see accompanying map). Lines 1 (north) and 1 (south) were positioned along the axis of the sedimentary trough lying N.E. of Arran (in such a way as to avoid shots near the submarine telephone cables); and Line 2 was placed normal to these lines, across the middle of the trough. Line 3 lay along the axis of the trough lying between S.W. Arran and the Mull of Kintyre.

Each line was about 10 miles long, to be shot both ways at intervals of 4000 ft. into a set of four sono-buoys placed 1000 ft. apart, at one end of the line being surveyed. Despite initial difficulties with weather, with the firing system, and the eventual failure of two hydrophones, the main programme east of Arran (Lines 1 N, 1 S and 2) was completed satisfactorily; but Line 3, off Campbeltown had to be abandoned with only five shots fired. Arrangements had been made to shoot this area during the first Saturday and Sunday of the programme (to avoid the mid-week fishing fleet) but bad weather and the other initial difficulties hindered progress; and arrangements and agreements with interested parties, ruled out a second try. In any event it was thought scientifically more profitable to give full attention to the Eastern trough. Details of progress and results are given later (Methods and Equipment: Seismic refraction). A preliminary estimate of the velocities was made on board ship, and processing of the records to improve quality has been carried out. Interpretation can only be started after further study of station locations, and this is now in progress.

In the time extra to the main refraction programme, 430 miles of seismic profiles and magnetic traverses were made across structures of special interest. Continuous information on rock-head and the dips in the immediately underlying solid rocks was obtained; and indications of faulting were found, some consistent with structures already inferred from previous gravity and magnetic surveys.

Acknowledgements: I would like to express my appreciation of the willing co-operation given by the crew of the John Murray, the efficiency of the officers, and the cordial atmosphere found on board. These, with the invaluable assistance of the R.V.U. technician, Mr. Winfield, were important in achieving a flow of results after some initial operational difficulties, and doing so in a way that made the visiting Glasgow scientists enjoy the cruise. I would also like to thank Capt. Turner (Clyde Port Authority), Cdr. Bradbury (Clyde Submarine Base), and the Resident Naval Officer (Greenock) for their co-operation in the organising and planning of the survey. The use of the NATO pier at Fairlie and the facilities for loading explosives were

of great help, and the superintendent of the establishment, Mr. Coleman, assisted us in all possible ways.

Scientific personnel:			On board
Dr. A. C. McLean	(U. of Glasgow)	Sen. Scient.	8 - 20 April
Mr. J. Hall	(")		8 - 20
Mr. R. Cumberland	(")		8 - 20
Mr. M. J. Winfield	(R.V.U.)		8 - 22
Mr. R. Whittington	(U. College, Aberystwyth)		8 - 14
Mr. E. Harrison	(U. of Liverpool)		10 - 14
Mr. R. Eden	(I.G.S., Edinburgh)		10 - 14
Dr. R. Bruce	(S.M.B.A.)		8 - 10; 20 - 22
Mr. W. Brown	(")		8 - 10; 20 - 22
Mr. J. Hayres	(I.C.I. Nobel Div.)		16 (only)

METHODS AND EQUIPMENT

Position Fixing: All seismic refraction stations were pre-determined, and were located by simultaneous Decca (Chain 3B/MP) and radar fixes. While seismic profiling was being carried out, fixes with Decca and radar were taken at 15 minute intervals. The enclosed waters of the Firth of Clyde provide adequate satisfactory reference points for radar fixes, but the high ground of the adjacent coasts, particularly around northern Arran, produces relatively large fixed errors in the Decca grid. Fixed errors of 1/3 lane (equivalent to about 300 metres) exist in the confined waters of Kilbrannan Sound and the Sounds of Bute and the worst discrepancies between corrected Decca and radar are of the same order. An analysis of the errors is being made so that the geometry of the refraction stations may be determined as precisely as possible.

Minor faults developed in both Decca and radar, and were attended to in Fairlie, though complete repairs to the radar were postponed till the ship reached Barry.

Depth recording: The ship's Kelvin Hughes MS 38 Precision Depth Recorder was used for determining depths along the seismic refraction lines and the seismic profiles. Record quality was good, and in some areas showed a second sub-bottom reflection, apparently from rock-head.

Several minor instrumental faults interfered with

recording for short periods and were attended to, but the PDR requires a thorough check at Barry.

Seismic refraction: The system consisted of four outboard detecting stations. At each station was placed a hydrophone suspended on 200 ft. of partially neutrally-buoyant cable, fixed below a sono-buoy (mfd. by Bradley) which transmitted the hydrophone signal to the ship. On board the John Murray the output of the receivers and demodulators was fed through a T.I.800CE seismic amplifier system and recorded on paper and tape. The filtering and playback facilities of the seismic instrument were used to improve record quality, since model time-distance graphs had suggested the possibility of gaining useful information from second arrivals.

The hydrophones were made in the Department of Geology, University of Glasgow, and consisted of PZT ceramics cast in Araldite and connected to matching amplifiers driven by Mallory batteries. The hydrophones worked adequately until near the end of the survey when the seals failed on two of them and the survey had to be completed with three, then two, buoy stations.

The cables were made neutrally buoyant over the last 80 ft. by the addition of corks at 5 ft. intervals. This attempt to reduce the mechanical coupling between buoy and hydrophone was not as good as required. In the poor weather of the first few days, the records were poor, due partly to this noise, and, even in ideal weather, there remained a fair amount of noise on the records.

Each buoy, made from a polythene beer barrel with balance pole attached below and aerial atop, transmitted the seismic signal to the ship via a frequency in the 27 MHz band. Two aerials were mounted as high as possible on the ship, fore and aft. The forward one gave the best reception and this was adequate for the transmitting distances involved (up to 12 miles). However, radio signal strengths received varied so much from buoy to buoy that it was not possible to adjust the gain to record all four channels simultaneously, and three was the maximum attained satisfactorily.

The frequency characteristics of the system possess a pass-band of about 7-200 Hz. Initially a high cut at 160Hz was used to reduce high frequency noise. This wide band was used to attempt to include both the first arrivals and the higher frequency water break, but the latter was not coming through satisfactorily and a high cut of 72Hz was used later.

Marine Seismex from I.C.I. was used as the explosive source. 16 lb. cans were fired at distances of up to 2 miles from the buoys, 33 lb. at distances of 2-4 miles and 50 lb. beyond this. The shots were fired electrically using a sea-return system. Charges were suspended by strings from plastic bags. The length of string dictates the depth at which the charge is fired; initially this was 10 ft. but later the length of string was increased

to 17 ft. to avoid unnecessary loss of energy into the air. The two detonator wires were connected one to the explosive can, to act as an earth, the second to a metal ring around the shot-firing cable, which was 600 ft. long and terminated in a brass hook. As the ship came on station the can was launched and, as the ship proceeded forward, drifted down the cable. Its arrival at the hook was indicated by a deflection on an ohmmeter connected across the 800V blaster. The shot was fired immediately by remote control from the tape recorder.

This firing system did not work satisfactorily for the first five days. On the first occasion that the shot-firing cable was run out, it snarled up in the turbulence aft of the ship and a 50 ft. section had to be removed. The first end-piece on the cable blew off after a few shots and the next charge down the cable drifted off, to be sunk later from the ship's boat. Both the first two end-pieces used were T-shaped and retained the metal rings, strings and attached bags from previous shots. After several shots the end of the cable became so tangled with these remnants that a further charge had difficulty reaching the hook and could not be detonated. On the last occasion the T-end-pieces were used, the ship's boat had to be launched to cut free a charge which did not fire, by severing the firing cable some 50 ft. short of the end and attaching weights before sinking. After this, an open-ended hook was used and more thorough attachments of detonator wires made (on advice from I.C.I.). The firing system worked perfectly thereafter with no misfires in about 90 shots on 16-18 April.

Each line was about 10 miles long and intended to be shot both ways at intervals of 4000 ft. into buoys 1000 ft. apart at one end of the line. All lines had to be shot in daylight to keep a visual look-out when firing and in order to recover the buoys before dusk.

The launching of all four buoys eventually took between 15 and 45 minutes and was carried out from the stern gantry. Shots were then fired as the ship retreated from the buoys along the survey line. The interval between shots averaged 5-6 minutes, much faster than expected. The buoys were then recovered, a procedure aided by the attachment of red flags to the buoys' aerial. Sighting was never difficult since the buoys could be seen at distances up to three miles on a fine day and a little less on less calm ones. Since the buoys were free-floating they drifted appreciably, up to three miles on one occasion, though one mile was more normal. Knowledge of wind and current directions made the drift easily predictable and no time was lost in long searches for the buoys. Time spent on recovery was comparable with that for launching.

On the first five days, the detonation depth was so shallow and the level of sea noise so high that the signal-to-noise ratio was often less than one, and the consequent record quality poor. On the last three days (16-18 April) the weather was ideal and this, together

with the lengthening of strings to 17 ft., resulted in a satisfactory signal-to-noise ratio of appreciably more than one, for all but the most distant 50 lb. shots and the record quality was very good, though there were still indications of mechanical coupling of buoy to hydrophone from sporadic kicks on the records.

By the 16th April all the major operating problems were sorted out expeditiously and the seismic programme (except for line 3 off Campbeltown) was completed even though the number of data points on each line was reduced by 50% due to the failure of the two hydrophones. The progress achieved on 18 April, the last day of shooting, was the most impressive -- 36 shots fired and three traverses made, including the moving of buoys to new locations for each line and despite delays arising from submarines exercising near one line.

The R.V.U.'s Sound Velocity was used to measure the water velocity twice in the early part of the survey, but failed on 16 April and did not give proper readings thereafter.

Seismic profiling: The ship's seismic profiling system (E. G. & G. sparker, type 254 seismic recorder, and type 264 6-element hydrophone array) was used on all occasions when its use did not interfere with the seismic refraction programme. Traverses were laid out, so far as possible, to cross structures of particular interest, such as major faults already known from gravity and magnetics, and also along the refraction lines. Of necessity, many lines converge on the Cumbraes, as the ship's tracks led back on several occasions to Fairlie for reasons such as loading explosives. 430 miles of profiling were done, at an average cruising speed of about 5 knots, and during most of the survey with 1000 joule sparker pulses, a firing rate of 1 second, and a printing sweep of 0.5 second. Water depths range from 15 to 100 fathoms. Usable events were consistently obtained to 1/10th second after the sea-bottom reflection (corresponding to depths of about 100 metres); and locally, for example across the Arran trough, penetration was to 1/5th second (200 m.). The records appear to define rock-head over the whole area, even where, as in the troughs, superficial deposits are a few hundred feet thick; and commonly show dips in the underlying sedimentary rocks, and indications of faulting. The minor instrumental troubles that arose (such as perforating of the records because of a badly adjusted recorder blade) were corrected.

Magnetic measurements: The ship's Varian proton magnetometer was operated on all occasions that seismic profiling was being done, with the aim not only of adding detail to the complex pattern of anomalies in the Firth, but to assist in correlating the sparker results with the existing magnetic maps. Since the area contains numerous strong magnetic anomalies the 1000 F.S.D. setting was used. The instrument was completely reliable and no difficulties were encountered with it.

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Department of Geology,
University of Glasgow.

APPENDIX

Summary of log:

8th April: Sailed from Barry at 14.00 hr. S.M.B.A. staff tested undulatory recorder in shallow water.

9th April: En route for Firth of Clyde, via Irish Sea. Undulatory recorder on town, being tested in deep water. Tested sparker, magnetometer and P.D.R.

10th April: Berthed at Fairlie at 08.45 hr. and loaded 3200 lb Seismex with boosters and detonators. S.M.B.A. staff went ashore with gear; Messrs. Eden and Harrison came aboard with solid-rock-corer. Left Fairlie at 12.00 hr. to shoot Seismic Refr. Line 2, with sono-buoys at western end. End of shooting cable damaged after 5th shot, trouble with Shot 6. Recovered all buoys by 20.30. Ship cruised to shallow water locality (a pinnacle) S. of Arran to test solid-rock-corer, with Messrs. Eden and Harrison working over-night. One sample recovered by dredge.

11th April: Returned to Refr. Line 2, and put out buoys at western end. Commenced firing at 10.29 hr, and ended with 8th shot at 12.04hr on last station. Recovered all buoys by 13.58 hr. Weather deteriorating with strong south-westerly winds. Abandoned refraction work for day and put out sparker and magnetometer en route to Kilbrannan Sound (Profile Line 1). Rapid fall of barometer, with severe gale, Force 9, forecast. Retrieved equipment at 20.00 hr. Messrs. Eden and Harrison worked over-night, attempting solid-rock-corer in Kilbrannan Sound, but ship eventually had to shelter in Campbeltown Loch.

12th April: Mr. Eden put ashore at Campbeltown at 10.00 hr. Continuing high winds. Decided to make sparker and magnetometer runs (Profile Line 2) in Kilbrannan Sound in lee of Kintyre coast. At 14.00 hr. forecast of continuing gales. 17.30 took gear aboard. Berthed at Campbeltown at 18.20 hr.

13th April: Sailing delayed till all crew aboard. Left Campbeltown 13.00 hr. to shoot Seismic Refraction Line 3. All buoys on stations, N.W. end of line, by 14.44 hr. Commenced shooting at 14.35 hr. and ceased at 16.01 hr. after trouble with shooting system and 6th shot misfired. Recovered all buoys by 19.55 hr. Put out sparker and magnetometer (Profile Line 3) at 20.15 hr, traversing back to Fairlie.

14th April: 5.45 hr. retrieved sparker and magnetometer. Mr. Harrison tested solid-rock-corer in Largs Channel on dyke outcrops. 7.30 hr. berthed at Fairlie. Messrs. Harrison and Whittington went ashore with corer. Decca technicians came aboard to attend to faults in Decca and radar. Contacted I.C.I. Nobel Division about difficulties with shooting system. Weather poor for shooting; continued high winds (6) heavy swell and poor visibility with drizzle. Left Fairlie at 12.30 hr. to traverse with sparker and magnetometer (Profile Line 4); returned at 19.00 hr.

15th April: 9.00 hr. to 13.00 hr Decca technicians came aboard to complete repairs to radar (bad sea clutter); Mr. Hayres, I.C.I. visited ship and arranged to come out on the following day to advise on shooting procedure. Shooting system checked, and T-bar on end replaced by hook. Left Fairlie 13.00 hr. to traverse with sparker and magnetometer (Profile Line 5).

16th April: 7.45 hr. ended run (Profile Line 5) and retrieved gear. 8.20 hr. berthed Fairlie and Mr. Hayres came aboard. Left Fairlie 9.00 hr. to shoot Seismic Refr. Line 1 (north). Weather much improved. All buoys on station at north end of line by 11.21 hr. Fired 12 shots by 13.17hr. Arrivals weak for longer distances, so re-shot line with charges deeper in water (using longer ropes). No difficulties of any sort with any of 24 shots. Recovered buoys. Put out sparker and magnetometer, traversing (Profile Line 6) en route to Fairlie. Arrived Fairlie 19.30 hr. Mr. Hayres went ashore.

17th April: Left Fairlie 7.00 hr. Bright clear day with no wind. Proceeded to Refr.Line 1 (north), and put out buoys at S. end by 8.18 hr. Fired 14 shots, then turned south to shoot Line 1 (south), with buoys at northern end. Fired 11 shots. Recovered buoys at 14.11 hr. Commenced sparker/magnetometer Profile Line 7, as explosive magazines were nearly empty. Arrived Fairlie 19.05 hr and loaded 1000 lb Seismex.

18th April: Left Fairlie 7.00 hr. Little wind, hazy but steadily clearing. Put out buoys at Southern end of Line 1 (south) by 8.26 hr. Fired 12 shots. Recovered buoys at 10.51 hr and put out again at S, end of Line 1 (north). Re-shot this line, with 14 shots. Recovered buoys at 14.34 hr. and put out again at east end of Line 2. Fired 10 shots; all explosives used. Recovered buoys at 18.38 hr. and terminated refraction programme. Put out sparker and magnetometer at 19.45 hr and started traversing on Profile Line 8.

19th April: Good weather continued. Continued Profile Line 8 until 18.36 hr. Berthed Fairlie at 19.15 hr.

Dr. Bruce and Mr. Brown, S.M.B.A., came aboard with gear.

20th April: All equipment belonging to University of Glasgow unloaded, and Messrs. McLean, Hall and Cumberland went ashore. Ship sailed for Barry at 10.00 hr. Profile Line 9, across Firth of Clyde en route. Undulatory recorder tested.

22nd April: Ship arrived Barry 6.18 hr.