R.R.S. SHACKLETON
CRUISES 3/75 AND 4/75

27 MARCH (086) – 7 MAY (127), 1975

# GEOPHYSICAL STUDIES OF THE GULF OF ADEN. GULF OF OMAN AND OWEN BASIN (NORTH WEST INDIAN OCEAN).

CRUISE REPORT NO. 24

1975

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Geophysical studies of the Gulf of Aden,
Gulf of Oman and Owen Basin (North West Indian Ocean).

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## SUMMARY OF CRUISE

| | | | |
|---|---|---|---|
| Cruise 3/75 | Departed Djibouti, TFAI | March 27 | Day 086 |
| | Arrived Dubai, UAE | April 15 | Day 105 |
| Cruise 4/75 | Departed Dubai, UAE | April 18 | Day 108 |
| | Arrived Bombay, India | May 7 | Day 127 |

The two cruises consisted of a magnetic survey of the western Gulf of Aden, a seismic refraction experiment on the crest of the East Sheba Ridge, and refraction and reflection profiling over the northern Gulf of Oman, the Murray Ridge and the region between the Owen Fracture Zone and the Oman continental margin (Owen Ridge and Basin). Bathymetry, magnetics and gravity were measured almost continuously when underway; seismic reflection profiling was carried out along about 55% of the track. Station work consisted of coring and velocimeter dips.

## CRUISE OBJECTIVES

Cruise 3/75 was divided between the Universities of Cambridge and Newcastle and the Institute of Oceanographic Sciences (Wormley) as follows,

### (i) Magnetic survey, western Gulf of Aden

Four days at the beginning of the cruise were reserved for completing a magnetic survey begun by the University of Newcastle during Shackleton Cruise 2/75. The object of the survey was to obtain profiles along the spreading direction in order to look for the two-stage spreading history already postulated for the Red Sea (GIRDLER and STYLES, 1974).

### (ii) Seismic refraction experiment, East Sheba Ridge

Following work done on the Mid-Atlantic Ridge (WHITMARSH, 1975 ) this experiment was designed to see whether a shallow zone of low-velocity material also underlay the median valley of the Sheba Ridge, using I.O.S. pop-up bottom seismic recorders (PUBS).

### (iii) Subduction zone off the Makran coast, Gulf of Oman

First motion studies of earthquakes near the Makran coast (McKENZIE, in preparation), and other evidence, suggest that an incipient subduction zone should exist offshore. Participants from the University of Cambridge wished to obtain seismic reflection and gravity profiles over the continental margin in the search for a zone of compression. Two long seismic refraction lines were also planned.

### (iv) Reflection profiles across the Murray Ridge

Since the work of BARKER (1966) little more has been done to investigate the Murray Ridge. Two reflection and gravity profiles were planned across the ridge to shed further light on its origin.

### (v) Passage track over Owen Basin

A long passage track, from the East Sheba Ridge to the Murray Ridge, down the axis of the Owen Basin, was planned as a preliminary investigation for the following cruise.

Cruise 4/75 was planned to be devoted almost entirely to studies of the Owen Basin and its margins.

(vi) Geophysical study of the Owen Basin

The main objective was to establish the nature and origin of the crust beneath the Owen Basin and to gain some insight into the age of the crust, since it is possible that its history goes back to the break-up of Gondwanaland. It was also planned to relate the deeper reflectors seen beneath the basin to those uplifted on the Owen Ridge which have already been sampled in holes drilled by D.V. Glomar Challenger. The chain of seamounts along the Owen Basin/Sheba Ridge boundary were also to be studied.

(vii) Organic geochemistry of recent sediments

Three cores were planned at different depths on the continental margin off Masirah Bay to expand the current studies of upwelling regions being undertaken at I.O.S. (Wormley).

(viii) Other geological sampling

Dredging of the escarpment at the south end of the Owen Ridge and coring across a leveed channel on the Indus Cone were subsidiary objectives of Cruise 4/75.

(ix) On-line digital processing of seismic profiles

It was planned to develop at sea simple algorithms for an on-line signal processing system designed to enhance the penetration of seismic reflection profiles.

## NARRATIVE

### Cruise 3/75

R.R.S. Shackleton was due to leave Djibouti on March 24 (083), however one of the three A.C. generators on board had had a catastrophic breakdown two days beforehand and was still undergoing major repairs. Also on March 24 a second generator stopped working followed by the third generator on March 26 (085). The ship finally left Djibouti three days late at 1015 (-4) March 27 (086).

Once the echo-sounder fish was deployed normal watchkeeping was begun and we headed at full speed along the first of Newcastle's 030° trending magnetic profiles (Figs. 1 and 3). At the end of the first profile we stopped to calibrate the depth sensor on the 2-section array. Following unsuccessful attempts to get the ship's programme altered, to recoup some of the time lost in Djibouti, the planned profiles were broken off at 1545 the following day. We headed east to begin a final magnetic profile at longitude 45°39'E, this time seismic profiling as well at about 6.5 knots, to complete the survey.

The short seismic and magnetic profile was completed at 1800 March 29 (088). To save time the profiling equipment was then brought inboard, before we began to steam at full speed down the Gulf of Aden.

The area of the refraction experiment on the East Sheba Ridge was reached at 0300 April 1 (091) and a short bathymetric survey of the median valley was begun before deploying three PUBS. The sound source for this station (1285) was a 1000 $ins^3$ airgun (Table 1). No trouble was experienced in relocating the PUBS all of which were inboard by 1525 the following day. After the PUBS work the three Cambridge sonobuoys were launched for three Aquaflex test shots.

The profiling system was redeployed at 2300 April 2 (092) at the beginning of a long passage leg to the Murray Ridge. Almost immediately the airgun began to fire intermittently. The problem was traced to a faulty trigger cable and a provisional arrangement, which prevented the trigger cable from coming under tension, was then devised. This worked reasonably well and was used for all subsequent profiling.

The long passage profile over the Owen Basin ended at 1850 April 5 (095) when we altered course to make two crossings of the Murray Ridge. The second crossing was finished at 1427 April 7 (097). After a velocimeter station (1286) three Cambridge sonobuoys were laid for a seismic refraction line (1287). During the buoy deployment one of the sonobuoy hydrophone cables became snagged around the head of the electromagnetic log and the head was pulled off. Aquaflex shots were fired along a westerly course out to a range of 105 kms and a reflection profile was obtained on the return track. When the last sonobuoy had been recovered at 1613 April 8 (098) a series of zig-zag profiles up to and away from the Pakistani and Iranian coasts was begun using the seismic profiling system.

The profiling was ended at 2120 April 10 (100). A short bathymetric survey was carried out before three Cambridge sonobuoys were launched for the second long seismic refraction line (1288). Aquaflex was fired along an easterly course and airgun profiling carried out on the return track. Three disposable sonobuoys were also launched during the station.

The last sonobuoy was recovered at 2105 April 11 (101) when the zig-zag profiles were recommenced. Two disposable sonobuoys were launched on April 12 (102). The same evening radio contact was made with an Omani research ship which wished to put an observer on board. We slowed down for the Omani vessel to catch us up and at dawn the next day the observer came aboard by small boat.

Seismic profiling continued until 0500 April 14 (104) when the airgun and array were retrieved and a course was set at full speed for the Straits of Hormuz. The echo-sounder fish and magnetometer were also brought inboard at 1310. The Port Rashid (Dubai) pilot came aboard at 1000 the following day.

## Cruise 4/75

The Port Rashid pilot came aboard at 0935(-4) April 18 (108) and R.R.S. Shackleton left Dubai Harbour shortly afterwards. Normal watch-keeping was begun at dawn the next day when the echo-sounder fish and magnetometer were streamed. Seismic profiling was not begun until 2155 April 19 (109) and a disposable sonobuoy was launched an hour and a half later. Seismic profiling continued along a number of roughly 110° to 135° trending profiles across the northern part of the Owen Basin and across the Murray and Owen Ridges (Figs. 2 and 3). A second disposable sonobuoy was launched at 0845 April 21 (111) but, like the previous one, signals from it were quickly lost.

The electromagnetic log, now with a new head fitted, was operational again at 2230 April 22 (112). A disposable sonobuoy, launched at 0826 April 24 (114), was used in an attempt to recalibrate the log by using water-waves to accurately determine range.

At 0700 April 26 (116) we altered course to run up the continental slope off Masirah Bay. The towed equipment was recovered shortly afterwards in preparation for coring. Three cores were obtained for organic geochemical studies at the top, about half way down and the bottom of the slope (1289, 1290 and 1291) (Table 2).

The electromagnetic log was then recalibrated relative to a free-floating dan buoy and a velocimeter station (1292) was occupied. Next an experiment to measure airgun waveforms by means of a "deep" towed hydrophone was attempted. Shortly after the hydrophone was lowered overboard the STD cable parted in the winch room and the hydrophone fell to the sea-bed thus prematurely ending the experiment.

Two PUBS were then deployed for a seismic refraction line (1293) at the base of, and parallel to, the continental slope. Aquaflex shots were fired on the outward track and Geophex shots, followed by the 1000 ins$^3$ airgun, on the return track. The last PUBS was recovered by 2325 April 27 (117).

Next a magnetometer survey was begun of an area about 100 kms square to search for sea-floor spreading lineations. During main engine repairs on April 29 (119) a core (1294) was obtained. The survey was restarted at 1600 and finally ended at 1900 on the following day.

Immediately two PUBS were launched for another seismic refraction profile (1295). As before Aquaflex was fired followed by Geophex and the 1000 ins$^3$ airgun. A disposable sonobuoy was also deployed. Following overheating of the compressors, and the resulting fire alarm at 1040, airgunning was abandoned and both PUBS had been brought inboard by 1821 May 1 (121). Seismic profiling with one compressor, the other having been damaged by overheating, was restarted at 2000.

The following day, as a result of large quantities of sea water entering the engine room, an inspection was carried out which revealed a 2 in. diameter hole in the ship's hull directly beneath a bilge suction pipe. For safety reasons the ship was therefore instructed to make directly for Bombay. The magnetometer and profiling equipment were brought inboard at 1236 May 2 (122) and a course set to the east. After a temporary but effective repair had been made to the hull seismic and magnetic profiling were restarted at 1630 and the last disposable sonobuoy was launched at 1800.

On May 3 (123) three attempts were made to core across a leveed channel on the Indus Cone but, due to a corer fault, only one core was brought on deck. Profiling restarted at 2310.

On the afternoon of May 4 (124) the ship passed through a "red tide". The following day the remaining explosive was dumped overboard and seismic profiling finally ended at 1900($-4\frac{1}{2}$).

After the magnetometer was finally brought inboard at 1600(-5) May 6 (126) all remaining detonators were fired off. Echo-sounding ceased at 1940 but a gravimeter watch was maintained till morning.

R.R.S. Shackleton entered Bombay Harbour at 1030($-5\frac{1}{2}$) on May 7 (127) and lay at anchor until the following day when she came alongside New Ferry Wharf.

PROJECT REPORTS

## (1) Navigational Aids

The Magnavox Satellite Navigator and Hewlett Packard computer performed satisfactorily throughout both cruises. The only problem was the occasional corruption of the stored computer program which caused satellite passes to be ignored and spoiled ancillary software facilities. This problem was overcome by reloading the program.

On the first cruise it was rarely necessary to reload the program (MAPS U-73303) because the other facilities, such as "recompute", were not used a great deal. The most common reason for the corruption of the computer program on this leg was starting the calculation of alerts during a satellite pass.

On the second cruise, with the increased use of the other computer facilities, the number of program corruptions also increased. This normally occurred when recomputing a satellite fix. In fact, as regards the recompute mode, the different copies of the same program tapes tended to respond to "recompute" differently at different times. Some would allow "recompute" one day and not the next; others would not allow "recompute" at all. However, in all cases if an error was made during an operator's reply to the computer's questions during recomputation, the computer would reject the whole program. The errors in the different copies were probably due to the rather tattered condition that most of them were in.

During Cruise 4, when a set of satellite alerts was regularly taken to the bridge, there were less poor fixes caused by the ship changing course or speed during a satellite pass.

Overall the fixes given by the satellite navigator were very good even for a satellite having a high or low angle of elevation. The operation of the whole system, considering the high temperature and humidity, was excellent.

S.A.

The Redifon Omega receiver was switched on throughout both cruises but, due to propagation and station problems, it is unlikely that useful navigational information will be obtained from the chart records. During our work in the Arabian Sea the new Station E in Réunion, due to open in January, 1975, was not operational. Consequently, only two sets of lines of position (LOPs) were available and these intersected at a low angle. These LOPs were also severely affected by the dawn effect each day leading to lane jumps at this time. It is hoped that the Omega chart records can be used to improve the propagation corrections for the Arabian Sea by making comparisons with satellite fixes. However this task will be made more difficult by the rather small scale of the chart record.

R.B.W.

The Colnbrook two-component electromagnetic log gave a mixed performance during Cruises 3 and 4. Occasional periods of erratic speed readings were noticed which were difficult to explain and to simulate. At low speeds (less than 1 knot) the distance run integrators appeared to stick on at least one occasion.

The most serious difficulty, however, occurred towards the end of Cruise 3 when the sensing head was damaged after it had been fouled by a sonobuoy hydrophone cable. It was found later that the head had been knocked off and only the stainless steel flange and electrical pin connectors remained. Salt water had also leaked into the stem and had partially saturated the electrical cable.

A new head was received in Dubai and was fitted onto the stem but tests conducted before the log was refitted revealed that the insulation resistance, which the handbook claims should be at least 1000 M$\Omega$, was very low, sometimes around 10M$\Omega$. Attempts to 'dry out' the wiring were only partially successful because of the high humidity. However, when the insulation resistance was as high as was possible the log was refitted and lowered beneath the ship.

It immediately flooded with sea water and water was leaking out of the top of the electrical cable at the top of the head. A fresh program of repair was instigated, the result of which was successful.

The log was completely dismantled and the stem brought up from the winchroom, where it is fitted, into the gravimeter room. It was hoped that the air-conditioner there would make work more pleasant and also reduce the humidity sufficiently to allow the electrical resistance between conductors to rise. The electrical cable was removed and the decision made to renew it. The original cable had twelve cores individually screened. This in itself caused problems when it was connected to the head because some of the conductors are paired together before being soldered onto the pins on the head. Since the paired conductors do not lie beside each other in the multicore cable and have to be soldered onto pins which are mounted at the bottom of the well in the head flange, it can be appreciated that the task is not easy.

The new cable, which was made up on board, consisted of seven individually screened wires and one single core unscreened wire. These wires were put in 10 mm dia. plastic sleeving. The inside of the stem was flushed out with 'Inhibisol' to remove the remaining traces of sea water and the cable passed through it. The flange joint connecting the head to the bottom of the stem was fitted with new 'O' rings and the mating surfaces cleaned up.

The electrical connections were made so that there were no twisted wires, each soldered joint was sleeved, and all the connections were potted in silicon rubber compound. The wiring was checked out with a 'Megger' at various states of the proceedings and whilst the newly formed cable was open circuit, the head itself was only reading 400 M$\Omega$. In spite of meticulous cleaning, including the removal of the top layer of potting compound around the pins in the head, it was not possible to improve on the insulation resistance.

After the stem was sealed up, it was removed from its air-conditioned environment and moved back down to the winchroom where it was reinstalled in the log.

Calibration, by means of the internal test signal, is easy to perform but only of practical use when it is known what the signal is supposed to represent. Tests were made using a floating dan buoy and a value for the fore/aft test signal of $9.20 \pm 0.05$ knots was established. Drift tests were also conducted in an attempt to derive the athwartship component and although they produced a value it has not yet been tied into the instrument.

M.B.

## (2) Bathymetry

Echo-sounding was carried out continuously from off Djibouti to the top of the continental slope off Bombay, except for the time spent in the Arabian (Persian) Gulf. Either an I.O.S. Mark III Mufax and towed fish were used or a Kelvin Hughes MS 38 with hull transducer. Fish No. IV, which had been air-freighted to Djibouti, was used practically the whole time and performed normally once a loose connector inside the fish had been correctly fitted. The Mk III fish already on board was not in a serviceable state.

On several occasions we were able to compare the Mk III and MS 38 displays side by side, usually using the Mk III fish to transmit. It was the widely accepted view of those on board that in fact the MS 38 display was superior in its ability to give both a strong bottom echo and a strong trace from a pinger or acoustic transponder. This suggests that the Mk III on Shackleton is not working correctly, however the particular MS 38 on board is recognised to have an unusually good performance.

Depths were read visually from the echo-sounder records and, after careful checking, were punched onto paper tape for later incorporation at Barry with other parameters logged by the data logger. The logger recorded depths on a 'real time' basis for only the first three days of Cruise 3. Matthews area was logged throughout.

R.B.W.

(3) Magnetic Field

The earth's total magnetic field was measured every six seconds for most of the cruise by a Varian Type 4937 proton precession magnetometer. Values were displayed on a 0-99 or 0-999 analogue chart recorder and logged by the data logger.

The particular chart recorder and towed fish we used functioned for almost six weeks without a single breakdown. The fish sustained minor shark bite damage. The chart record occasionally contained noise spikes of unknown origin which could not be correlated with the ship's own radio transmissions.

R.B.W.

(4) Gravity Field

A LaCoste-Romberg marine gravimeter was used from Djibouti to Bombay to continuously measure gravity. Cross-coupling and total corrections, spring tension and gravity were displayed on a chart recorder and gravity was logged by the data logger. Spring tension and gravity were also output every five minutes on a digital printer.

The generally low sea-states during both cruises probably meant that good quality data were obtained and this is confirmed by preliminary estimates of cross-over differences. The LaCoste meter was tied into land base stations at Djibouti, Dubai and Bombay by means of a Worden Educator land gravimeter. The LaCoste meter had drifted at a mean rate of +0.048 mgal/day between Djibouti and Bombay. The gravity data will be finally corrected for drift and the Eötvös correction when the data logger tapes are processed at Barry.

R.B.W.

## (5) Seismic Reflection Profiling

The profiling system was composed of equipment supplied by I.O.S. (Barry), I.O.S. (Wormley) and Cambridge University. In spite of its diverse origins the system performed reasonably reliably and provided generally high quality records with penetrations of up to 4½ seconds. About 5900 km of profiling were accomplished mostly at speeds of 6.8 to 7.0 knots.

Two Reavell compressors running in parallel pressurised up to 70 $ft^3$ (1980 litres) of air per minute to 2000 p.s.i. (141 $kg.cm^{-2}$) for a set of 160 to 1000 $ins^3$ (2.6 to 16.3 litres) Bolt airguns which were fired at rates between 10 and 60 seconds. The large diameter Géomechanique array comprised two active sections with additional neutral, spring, depth and tail sections terminated by a tail rope and a 105 kg buoyancy float. It was towed about 160 m astern. On Cruise 3 the shipboard displays were an EPC recorder (intensity modulated) and a Cambridge jet pen (variable area mode); on Cruise 4 two EPC recorders were used. Unfiltered signals from each active section were recorded on one or two instrumention tape recorders. Pre-display processing included analogue filtering, time variable gain and direct summing of the signals from the two active sections (from Day 099). On Cruise 4 digital processing was also used (see section (6)). The low sea states and the excellent design of the array caused array noise of only 3 mV peak to peak at the array output in the laboratory.

For the first 150 km long profile of Cruise 3 a 160 $ins^3$ chamber and a gun rate of 14 seconds, being the optimum for CDP stacking, were used. When profiling was resumed at a 12 second rate all the trigger cables on board were found to be liable to go open circuit at the bridle plate connector when under tension. For practical handling reasons the airguns were towed with the hose and trigger cable separate from the towing cable. Consequently the drag of the loop of cables astern of the gun pulled on the connectors to the bridle plate. It is probably due to the effect of these drag forces on Cruise 3, and on earlier cruises, that the faults developed. Once the fault had been located the trigger cable was clamped to the hose so that all tension was taken off the trigger connector; this system worked satisfactorily until Bombay.

370 km later the aft air compressor burst a pipe and a temporary repair had to be made due to the lack of any spare pipe on board.

After a near continuous run of 1110 km profiling ceased for the first sonobuoy refraction line. Here a 100 km profile was obtained with a 300 $ins^3$ chamber firing every 20 seconds at 2000 p.s.i. in an attempt to reach acoustic basement beneath very thick sediments. After another 670 km profile (160 $ins^3$ chamber firing every 12 seconds at 2000 p.s.i.) a 300 $ins^3$ chamber firing every 20 seconds was used again at the second sonobuoy line. Finally a 720 km zig-zag run up the Gulf of Oman with a 160 $ins^3$ chamber firing every 12 seconds at 2000 p.s.i. completed profiling on Cruise 3.

The first 555 km of profiling on Cruise 4 was carried out using a 300 $ins^3$ chamber firing every 15 seconds at 1800 p.s.i. The larger chamber was used primarily to obtain penetration of the thicker sediments in the Gulf of Oman but also to obtain some data suitable for CDP stacking. A maximum of about $4\frac{1}{2}$ seconds penetration was achieved. As these sedimentary layers thinned out the 300 $ins^3$ chamber was changed to a 160 $ins^3$ chamber a further 1420 km of profiling carried out, firing every 10 seconds at 2000 p.s.i.

The 1000 $ins^3$ chamber was used as a sound source for part of the two PUBS refraction lines (Stations 1293 and 1295) and during the last line one of the Reavell compressors overheated and had to be shut down permanently for safety reasons, spares for the damaged pipe being unavailable.

Profiling recommenced with only one compressor using a 160 $ins^3$ chamber firing at a 15 seconds interval and 1500 p.s.i. There was a brief $3\frac{1}{2}$ hour break in the run whilst a hole in the ship's hull was repaired, and a further nine hours of coring, otherwise an uninterrupted 1110 km of profiling with a maximum penetration of $4\frac{1}{2}$ seconds was achieved.

Overall the system was reliable except for two minor problems with the compressors and the loss of record caused by the ship's radio transmissions.

D.G.B., D.W.W.

## (6) Digital Signal Processing

For the first time during an I.O.S. cruise, on-line, signal processing was performed upon data obtained from the Seismic Reflection Profiling (SRP) system. The signal processing unit is built around a Nova central processor and comprises,

(a) a two channel 12 bit analogue to digital converter,

(b) a two channel 10 bit digital to analogue converter,

(c) a digital input/output unit,

(d) provision for external interrupts,

(e) an interface unit to interface the SRP system to the processor and to generate manual interrupts when required,

(f) a dual cassette unit to store and read core image versions of developed programs,

(g) a Silent 700 typewriter.

Data were output from the processor to an EPC recorder whose sweep was also controlled by the processor.

A total of 201 hours of data was processed using a running average algorithm which subsequently improved the signal to noise ratio. The running average was performed over only four traces due to restrictions imposed by the Nova core storage capacity. A modified version of the above algorithm was also developed to allow averaging of disposable sonobuoy data after first compensating for move-out, but was not used on-line.

J.J.L.

## (7) Seismic Refraction Profiles (PUBS)

The Pop Up Bottom Seismic Recorders (PUBS) were deployed for three seismic refraction lines. One line was completed during Cruise 3 and the remaining two during Cruise 4. A total of seven PUBS deployments were carried out over the three refraction lines and all PUBS were safely recovered.

The data recovered from the first refraction line were generally good except for a section of data which was lost due to a faulty battery in one of the tape recorders.

Data obtained from the second refraction line were contaminated by ground loop noise within the PUBS, as a result of modifications made after the first line, however it is hoped that a good portion of the data can be improved by suitable processing. Only one tape recorder worked satisfactorily during the third refraction line; three recorders were affected by wow and flutter of the tape speed during recording which in turn results in large amounts of noise when the FM signals are replayed. The problem was caused by an unknown incompatibility between the brand of magnetic tape used and the tape recorders. Since the noise generated on replay is due to wow and flutter present during the recording it should be possible to compensate for this and, therefore, to recover the data.

Geophex, Aquaflex and the 1000 $ins^3$ airgun were used as sound sources for the PUBS. Aquaflex, which we used for the first time, was used at intermediate ranges between series of airgun and Geophex shots. Initial experience with firing 100 m lengths of Aquaflex every two minutes was very disappointing with 17 'detonator only' and five misfires out of 52 shots. However, possibly because of an improved operator technique (the flex was pulled more firmly down into the detonator holder) the second Aquaflex line was much more successful with only one misfire and four 'detonator only' out of 48 shots. Geophex was fired in the normal way with shots between 25 and 300 lbs. The 1000 $ins^3$ airgun was fired at 2000 p.s.i. at 60 second intervals.

PUBS relocation and recovery proceeded normally. The MS 38 echo-sounder was of great assistance in picking up the PUBS transponder, having a better signal/noise ratio than the Mk III Mufax. One remarkable recovery was effected on a very calm night using the radar to find the PUBS at the surface when neither flashing light nor the radio beacon were operative.

J.J.L., R.B.W.

## (8) Seismic Refraction Profiles (Sonobuoys)

Two 100 km long east-west refraction lines were shot; the western ends of the lines were at 23°41'N, 61°01'E and 24°20'N, 61°01'E. Three Cambridge Bradley buoys were laid at one end of each line, spaced at 1 km intervals. On the first line only one buoy worked satisfactorily, the other two failing because of hydrophone troubles. One hydrophone had an intermittent open circuit in the power lead to the preamplifier, the other was flooded by water leaking in through a cut in the rubber cable insulation sustained during launching. Having rebuilt one hydrophone and repaired and waterproofed the spare, two buoys worked well on the second line. Failure of the third buoy was again due to an old and probably leaky hydrophone cable. The radio telemetry and tape-recording electronics worked well in all buoys, with the radio being picked up out to about 83 kms.

Aquaflex was fired into the buoys at three minute intervals, while steaming at 6 knots. On the first line, twenty-five 200 ft lengths were fired, followed by one hundred and twenty 100 m lengths of 200 grain explosive. Out of these there were 35 misfires or 'detonator only' and 12 shots fired either earlier or later than the clock pulse. On the second line there was twenty-four 200 ft and one hundred and forty 100 m charges, with 41 misfires and five not on time. A disturbing failure was that three times the firing cable had to be hauled in to free unexploded charges which had become stuck in sliding down the firing cable.

It was felt unwise to stream the array whilst firing Aquaflex, so each return profile was made using a 300 $ins^3$ airgun as close as possible to the outward path.

Two disposable sonobuoys were deployed on the first line and three on the second line in order to reverse the lines and to obtain an estimate of the variation in shallow structure along the profiles. Refracted arrivals were obtained up to 30 kms away using Ultra type SB6E4 sonobuoys reduced in sensitivity by 20 dB.

Relocation of the buoys was markedly easier at night when their flashing lights were seen from the bridge some 9 kms away (compared with 1 km during the day). Despite calm seas they drifted up to 14 kms in the 24 hours we were away from them.

R.S.W.

## (9) Disposable Sonobuoys

Twelve Ultra Electronics type SB6E4 disposable sonobuoys were used during both cruises either as a means of reversing part of the Cambridge refraction lines or to obtain single unreversed profiles. 160 and 300 $ins^3$ airguns were used as sound sources. The signals were received by a Lafayette communications receiver with crystal controlled tuning.

Two or three buoys ceased operating only a few minutes after being launched. Once this was attributed to the hydrophone cable getting snagged and broken by the towed array steps were taken to avoid this recurring. Later launches did not experience the problem.

R.B.W.

## (10) Data Logger

The data logger operated almost continuously during Cruises 3 and 4, with a break of four days in Dubai. On the first three days of Cruise 3 the following data were logged,

(a) two-component electromagnetic log (fore/aft, port/starboard),
(b) total magnetic field,
(c) gravity,
(d) Matthews area,
(e) time (G.M.T.),
(f) ship's head,
(g) depth.

For the rest of Cruise 3 and all of Cruise 4 the day number was logged instead of depth.

There were many periods during the two cruises when the data logger was not logging all the parameters shown above. For example, the magnetometer was not towed when Aquaflex or Geophex shots were being fired. Also there was a period just before and just after the port stop at Dubai when the EM log was not working.

On the first cruise there was only one major hold-up, lasting one hour, when the control unit for the tape decks malfunctioned. The cause was not found and may have been due to a loose circuit board. The problem did not recur.

The most annoying fault, which appeared only once or twice on Cruise 3, was a stoppage of the data logger for no apparent reason. Neither the tapes nor the clock would increment. The logger was easily started up again but, nevertheless, it became a very annoying fault on the second cruise. The cause of the fault was not sought by detailed tests, since that would have meant losing more logging time, and also the very nature of the fault would have made it difficult to find. Therefore the logger was restarted each time. The fault may have been caused by mains transients; it certainly did not correlate with radio transmissions from the ship.

Another problem on both cruises was the vulnerability of the push button switches on the tape decks to accidental operation. Certainly on the second cruise this caused a tape to start to run forward without recording data. A similar fault, which may also have been caused by accidental operation of the switches, occurred on the second cruise when a tape rewound itself. The exact amount of lost logging time was not determined but it was less than three hours.

The period of logging was from Day 086 to Day 114 (Cruise 3) and from Day 118 to Day 127 (Cruise 4). On the second cruise the logger stopped ten times, eight of which account for five hours of lost logging time.

In spite of the fault mentioned above, the logger worked very well, notwithstanding the adverse climatic conditions.

S.A.

## (11) Coring

A four foot long wide barrelled Calvert gravity corer was used. Three cores were successfully taken on the continental slope off Masirah Bay for the program concerned with sedimentation in upwelling areas. A fourth core for general regional studies was obtained in the Owen Basin. In three attempts at coring across a leveed channel on the Indus Cone only one core was obtained; two cores were lost due to a sticking piston valve.

R.B.W.

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## SCIENTIFIC PERSONNEL

| Cruise 3 | Cruise 4 | |
|---|---|---|
| R.B. Whitmarsh[1] | R.B. Whitmarsh[1] | Principal Scientist |
| S. Audley[2] | S. Audley[2] | Data Logger |
| M. Beney[2] | M. Beney[2] | M.S.E.S. equipment |
| R.E. Kirk[1] | R.E. Kirk[1] | PUBS |
| J.J. Langford[1] | J.J. Langford[1] | PUBS, digital signal processing |
| A. Claydon[3] | S. Smith[2] | Airguns |
| S. Jones[2] | P. Hillary[2] | Data Logger |
| K.D. Klitgord[3] | R.L. Chase[5] | Geophysics |
| D.P. McKenzie[3] | P.M. Hunter[1] | Geophysics |
| R.S. White[3] | | Sonobuoys |
| D.W. Wright[3] | D.G. Bishop[1] | SRP |
| I. Elboushi[4] | | Observer (April 13 - 15 only) |
| | C. Spong[1] | Cartography |

### Affiliations

[1]I.O.S. (Wormley)

[2]I.O.S. (Barry)

[3]Department of Geodesy and Geophysics, Cambridge

[4]Department of Petroleum and Minerals, Muscat

[5]Department of Geological Sciences, University of British Columbia, Canada

SHIP'S OFFICERS

| Cruise 3 | Cruise 4 | |
|---|---|---|
| G.H. Selby-Smith | G.H. Selby-Smith | Master |
| P. Warne | K. Avery | Chief Officer |
| T. Gray | S. Sykes | Second Officer |
| J. Evans | P. Booker | Third Officer |
| A. Coombes | D. Lintern | Chief Engineer |
| T. Rees | T. Rees | Second Engineer |
| C. Phillips | G.M. Batten | Third Engineer |
| B. Entwhistle | B. Entwhistle | Fourth Engineer |
| P. Sharpe | P. Sharpe | Electrical Officer |
| S. James | A. Landry | Radio Officer |
| R. Cridland | R. Cridland | Catering Officer |

TABLE 1

CRUISE 3 - STATION LIST

| Station No. | Type | Time(GMT)/day no. Start | End | Lat. N | Long. E | Depths CM | CF | Comments |
|---|---|---|---|---|---|---|---|---|
| 1285 | PUBS | 0812/091 | 1125/092 | 14°58.8'<br>14°34.8' | 55°45.6'<br>55°43.9' | 2517-<br>3255 | 1376-<br>1780 | 3 PUBS used. Aquaflex, Geophex and 1000 $ins^3$ airgun. |
| 1286 | V | 1106/097 | 1231/097 | 23°18.4' | 64°16.0' | 3345 | 1829 | To 2400 metres wire out. |
| 1287 | S | 1248/097 | 1213/098 | 23°41.5<br>23°34.5' | 61°01'<br>62°03' | 3345 | 1829 | 3 buoys used. Aquaflex and 300 $ins^3$ airgun. |
| 1288 | S | 1922/100 | 1705/101 | 24°20.0'<br>24°17.5' | 61°00'<br>61°59' | 1898-<br>2458 | 1038-<br>1344 | 3 buoys used. Aquaflex and 300 $ins^3$ airgun. |

TABLE 2

CRUISE 4 - STATION LIST

| Station No. | Type | Time(GMT)/day no. Start | End | Lat. N | Long.E | Depths CM | CF | Comments |
|---|---|---|---|---|---|---|---|---|
| 1289 | C | 0530/116 | 0615/116 | 19°17.6' | 58°22.6' | 823 | 450 | Core obtained. |
| 1290 | C | 0738/116 | 0905/116 | 19°13.8' | 58°34.6' | 2292 | 1253 | Core obtained. |
| 1291 | C | 0955/116 | 1144/116 | 19°10.3' | 58°40.0' | 3172 | 1735 | Core obtained. |
| 1292 | V | 1526/116 | 1647/116 | 19°11.4' | 58°41.3' | 3176 | 1737 | To 2200 metres wire out. |
| 1293 | PUBS | 2046/116 | 1925/117 | 19°06.1'<br>19°36.2' | 58°33.4'<br>59°02.6' | 2911-<br>3202 | 1592-<br>1751 | 2 PUBS used. Aquaflex, Geophex and 1000 $ins^3$ airgun. |
| 1294 | C | 0507/119 | 0705/119 | 19°02.2' | 59°12.4' | 3383 | 1850 | Core obtained. |
| 1295 | PUBS | 1250/120 | 1421/121 | 18°51.5'<br>18°12.8' | 59°42.2'<br>59°25.2' | 3555-<br>3544 | 1944-<br>1938 | 2 PUBS used. Aquaflex, Geophex and 1000 $ins^3$ airgun. |
| 1296 | C | 1120/123 | 1500/123 | 18°16.8' | 61°56.7' | 3699 | 2023 | Core obtained at second attempt. |
| 1297 | C | 1640/123 | 1750/123 | 18°17' | 61°54.7' | 3703 | 2025 | Core lost. |

PUBS = Seismic refraction with pop-up buoys
S = Seismic refraction with sonobuoys
V = Velocimeter
C = Coring

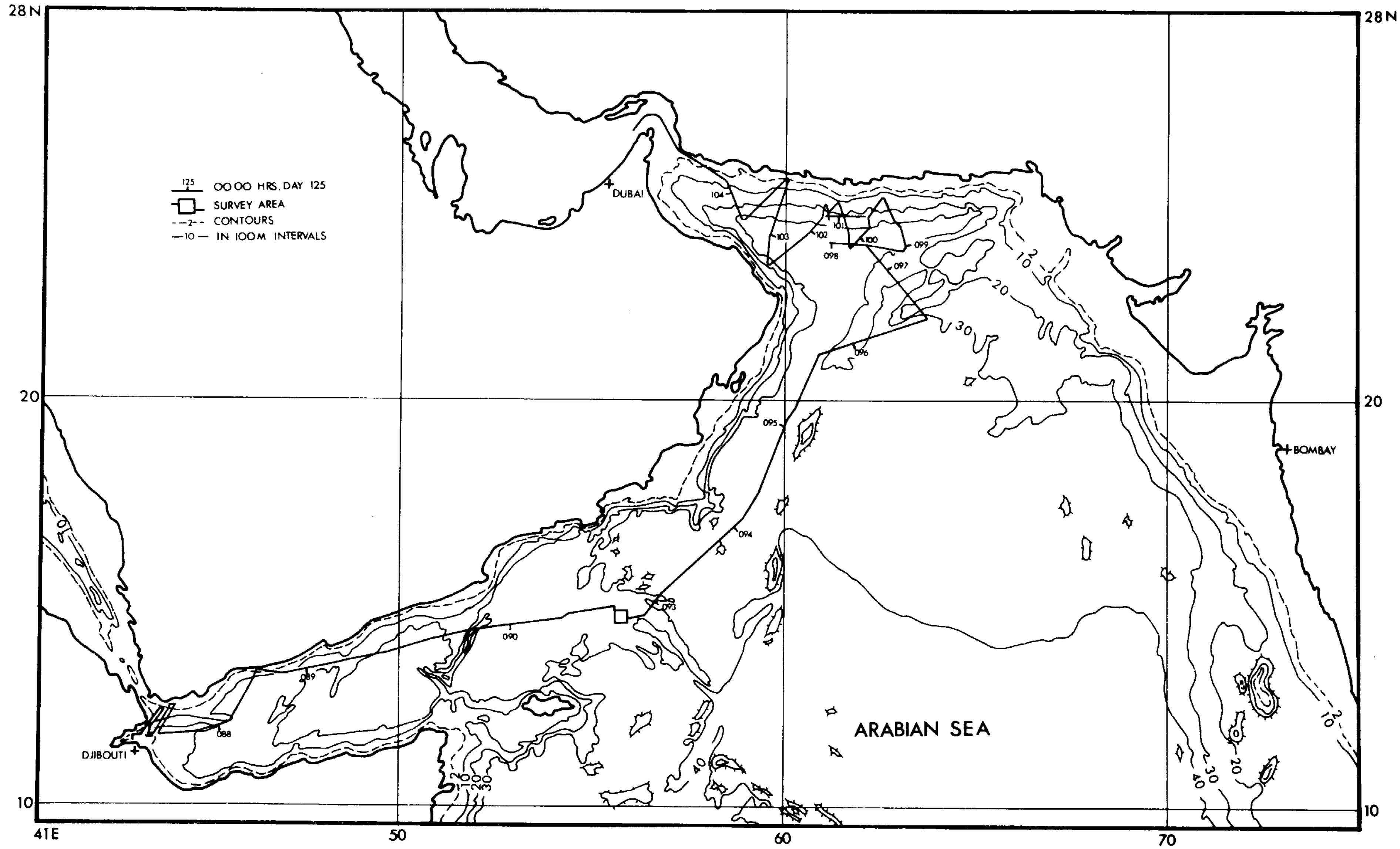


Fig. 1 Track for Cruise 3/75 in the North Arabian Sea.

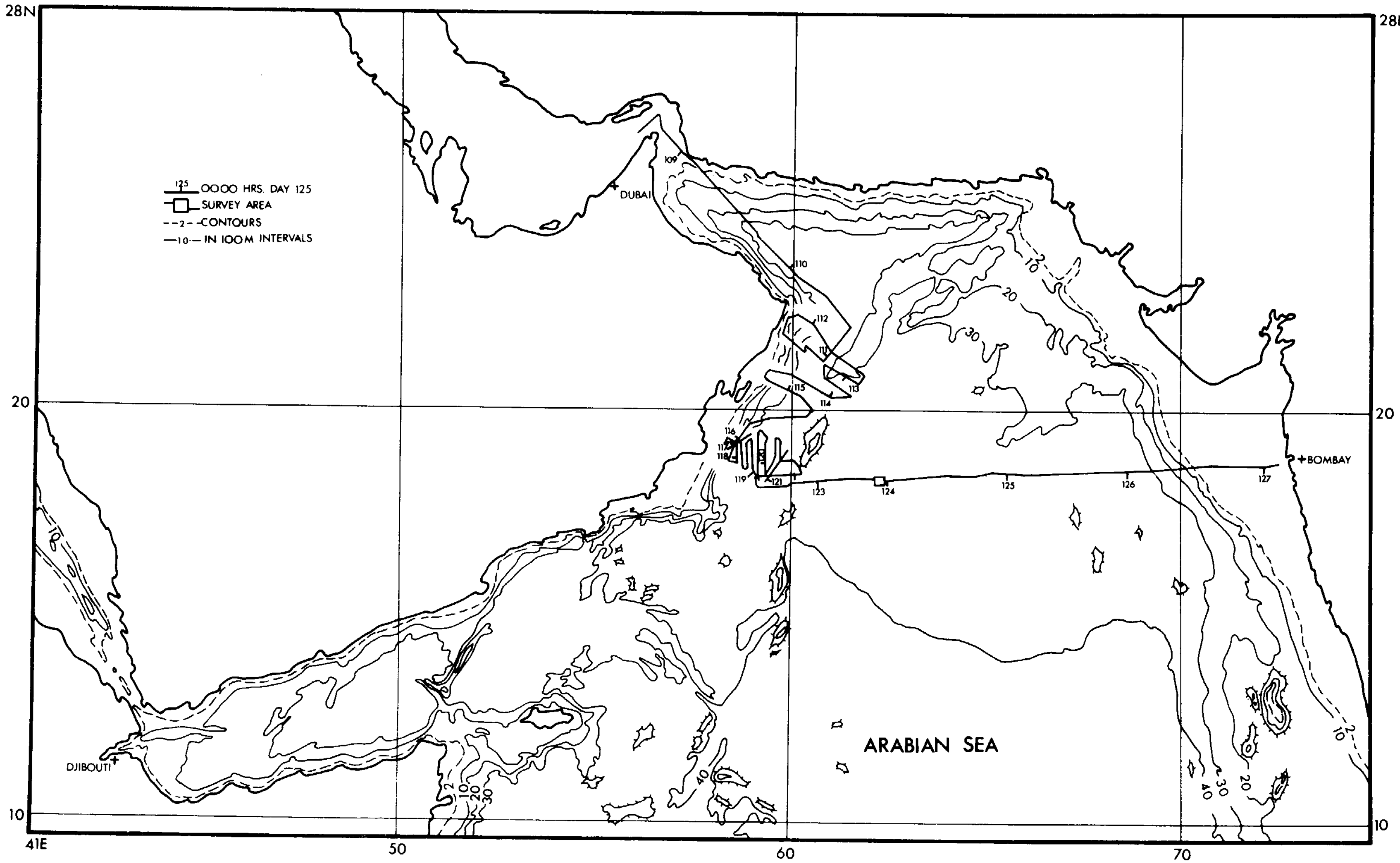


Fig. 2 Track for Cruise 4/75 in the North Arabian Sea.

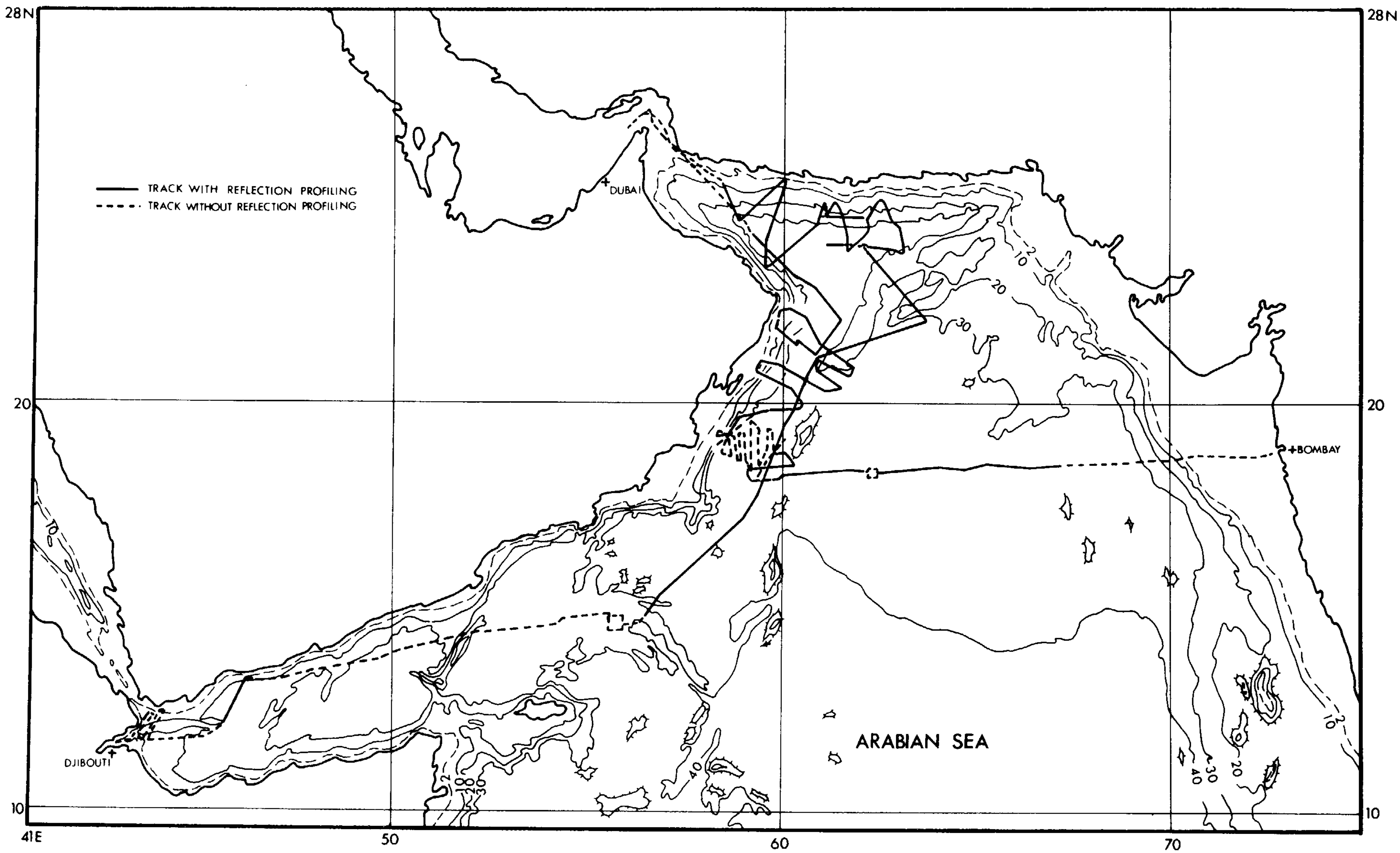


Fig. 3 Tracks with and without seismic reflection profiling for Cruises 3/75 and 4/75.
An echo-sounder, magnetometer and gravimeter were operational along practically all tracks.