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THE DEEP STRUCTURE OF THE NORTHERN AZORES BISCAY RISE AND DETAILED SEISMIC STUDIES OF CRUSTAL AGEING EAST OF THE MID-ATLANTIC RIDGE

26 MAY (146) – 5 JULY (186) 1978

R.R.S. DISCOVERY
CRUISE 93

CRUISE REPORT No. 71
1978

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Institute of Oceanographic Sciences,
Brook Road, Wormley, Godalming,
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CONTENTS

SUMMARY OF CRUISE

Leg 1	Departed Lisbon, Portugal	26th May	Day 146
	Arrived Ponta Delgada, Azores	13th June	Day 164
Leg 2	Departed Ponta Delgada, Azores	16th June	Day 167
	Arrived Barry, U. K.	5th July	Day 186

The cruise comprised seismic refraction, seismic reflection and gravity studies of the northern Azores-Biscay Rise followed by a seismic refraction study of ageing of the oceanic crust between 45° and 46°N and 22° and 28°W. Ocean bottom seismographs were used for all the refraction work which amounted to nineteen profiles. Some coring and dredging was also carried out. Routine underway geophysical measurements were made almost continuously. The ship's track is shown in Figs. 1 to 6. Details of station work are given in Table I.

CRUISE OBJECTIVES

The main objectives of this cruise were two-fold. The first objective was a study of the deep crust and upper mantle structure associated with the Azores-Biscay Rise using seismic refraction and gravity profiles. Three refraction lines were planned to be shot on the crest and flanks parallel to the ridge axis while three gravity and seismic reflection profiles were to be obtained across the ridge. This work represented an extension of an already completed, and similarly executed, study of Kings Trough, in order to establish the relationship (if any) of Kings Trough to the anomalous Azores-Biscay Rise.

The second objective was a detailed study of crustal ageing along a flowline. The band between 45° and 46°N east of the Mid-Atlantic Ridge was chosen for study, particularly crust between 0 and 40 m. y. old where the greatest ageing changes are believed to occur. The study was planned to consist of unreversed NS and reversed EW refraction profiles shot with a 1000 ins^3 airgun and explosions out to 50 kms range. An ancillary experiment was designed to seek for any azimuthal anisotropy in the upper part of young oceanic crust which is liable to be caused by cracks and fissures known to be preferentially oriented parallel to the Mid-Atlantic Ridge axis.

Subsidiary objectives of the cruise were to gain experience with a wide variety of sediment corers and to dredge, in particular for serpentine rocks. It was also planned to fire a half-ton shot to assess the long-range capabilities of the new PUBS.

NARRATIVE

Leg 1

In spite of the delayed unloading of equipment sent overland by lorry from the U. K., Discovery sailed approximately on time from Lisbon at 1145/146. The echo-sounder fish was deployed at 1315, although scientific watchkeeping was not begun until 0800/148. Data logging by the IBM 1800 began at 2130/146.

The next day leak tests of the PUBS spheres were performed on the 6mm electrical wire down to 100m, and then to 4000m with concurrent testing of the acoustic releases and transponders. The two spheres tested to 4000m leaked, fortunately without damaging the

electronics. Deep testing of the spheres recommenced next day and was successfully completed at 0213/149, when the magnetometer was streamed and we continued on our way to the first work area on the Azores-Biscay Rise. Later the same day the array and a 40 ins^3 airgun were deployed for profiling up to the first refraction profile (9802).

Towed gear was retrieved early on Day 150 and the first refraction line, a single unreversed profile shot from NE to SW along the crest of the Rise, was begun at 0505. A 1000 ins^3 airgun firing every 2 minutes was used as a sound source out to 25kms and 17 Geophex shots were fired at greater ranges. We also attempted to obtain a reflection profile out to 25kms using the 40 ins^3 airgun, but the towing cable was damaged during deployment and needed lengthy repairs. The station ended at 0203/151. Some time was then spent profiling across the Azores-Biscay Rise to the NW and back at the end of which the first refraction line was reversed by shooting from SW to NE (9803) using the 1000 ins^3 airgun and Geophex shots. This ended at 0807/153 and was followed by a final pressure test of a leaky sphere, two core stations (9804, 9806) and a velocimeter dip (9805). We then began reflection profiling to the next refraction line which lay on the south-east flank of the Rise. This line (9807) was shot as a reversed line with two PUBS at the southwest end and one to the northeast. Again 1000 and 40 ins^3 guns were used as well as Geophex shots. Towards the end of the station it appeared that main bearings in compressor no. 1 needed replacing and this major repair job was begun at once. The station ended at 1231/155 after which we steamed into deeper water for a core station (9808) which included the unsuccessful deployment of a free-fall corer.

At 1840/155 we began reflection profiling to the northwest flank of the Azores-Biscay Rise for the final refraction line across the feature (9809). Two PUBS were laid at the north-east end of the line and one to the southwest. The line was shot with a 1000 ins^3 airgun and Geophex shots and finished at 0106/158. Towards the end of this station the compressor that had been repaired was run up under no load. It was brought into service during the final stages of the station while the ship was profiling back to the southwestern PUBS. Station 9809 was followed by a core station (9810) during which another unsuccessful attempt was made to core with a free-fall corer.

At 0639/158 we set course for the area of the first major experiment designed to investigate

crustal ageing and deployed the 160 ins^3 airgun, array and magnetometer. This area was reached at 0715/159. Three PUBS were laid during the experiment (9811) during which the 1000 and 40 ins^3 airguns were used within 25 kms of each PUBS and Geophex shots were fired, in seven sessions, at greater ranges out to 50 kms. On Day 160 we were unable to release PUBS 1 acoustically and in view of a wait of several hours before the back-up release clock was due to operate a core station (9812) was occupied. A free-fall corer was deployed which this time brought back a core to the surface. In spite of waiting 50 minutes after the PUBS should have surfaced no trace of it was found either visually or by radio and reluctantly it was abandoned and the experiment continued. An hour was lost on Day 161 due to engine trouble. The station was finally completed at 1035/162.

The ship now headed south towards the Azores. En route three core stations (9813-9815) were occupied at different latitudes in the vicinity of Crumb Seamount between 2135/162 and 1800/163. At the first station the piston corer, modified on board from a standard gravity corer, was lost due to the top end of the piston coming unscrewed from the main warp. At neither of the remaining stations (9814, 9815) did we succeed in obtaining a core nor in retrieving a free-fall corer (9815). At 1800/163 the ship finally set course for Ponta Delgada.

In the afternoon of Day 164 preparations were made to fire a half ton shot for the benefit of stations recording on the island of Sao Miguel. The handling and launching arrangements for the shot proceeded smoothly but in spite of it being doubly fused it did not fire. The charge was suspended from a self-deflating surface float marked with an orange flag. A detailed search of the area revealed no trace of the float which was therefore presumed to have sunk. At 1620 the PES fish was retrieved.

The ship tied up at Ponta Delgada the same day at 2400 hours.

Leg 2

The ship sailed from Ponta Delgada at 1120/167. Immediately there were problems with the IBM 1800 and a series of faults prevented regular data logging until 1430/169. Meanwhile we steamed northwards to the Mid-Atlantic Ridge at 45°N which was to be the main area of operation for the rest of the cruise. Seismic profiling was carried out along the

latter part of this track, beginning at 1741/168. The 45°N area was reached at 2058/169 when a second major seismic refraction experiment to study crustal ageing was begun (9816). As before the experiment involved 3 PUBS, a 40 ins^3 and a 1000 ins^3 airgun, the array and Geophex shots. A new departure however was the experimental use of two 1000 ins^3 airguns fired at 2 minute intervals as a sound source for the PUBS out to a range of 30 kms. Station 9816 was completed at 1356/172.

The ship then set off towards Kettle Mountain on the crest of the Ridge which was due to be the site of intensive dredging. Due to fresh headwinds, which slowed us down to 9 knots, it was decided to reflection profile as well and this was begun at 2220/172. The profiling was extended throughout the night on reaching Kettle Mountain in order to survey a large sediment pond southwest of it which was to be the site of a further seismic experiment. The survey was finished at dawn and by 0740/173 the ship was in position to lay a radar transponder buoy (D/B I) for the dredging and seismic refraction operations. Unfortunately the transponder did not function to an adequate range for it to be useful either for the dredging or the seismic work. Therefore the mooring had to be cut and the transponder relaid close to the east flank of Kettle Mountain. Dan buoy II was finally laid at 1511/173.

The first dredge station (9817) up the east flank of Kettle Mountain began at 1603. Three further dredges followed (9818, 9819, 9820). Rocks were obtained at the first two stations, mud only at the third and the whole dredge and chain were lost at the fourth which ended at 1108/174.

At this point a seismic experiment (9821) was begun to look for crack-controlled anisotropy in the uppermost oceanic crust. Three PUBS were laid in the sediment pond already surveyed beginning at 1402/174. Two 1000 ins^3 airguns were used as a sound source while the ship steamed along a set of polygonal tracks centred in turn on the different PUBS. The station lasted until 1547/175.

We then returned to the east flank of Kettle Mountain and one last dredge station (9822), which successfully sampled the ridge crest of the seamount, was carried out before dan buoy II was recovered at 2315.

Next the ship steamed to the starting point of the third and last major seismic experiment

to study crustal ageing a short distance to the east. This station (9823) was begun at 0109/176 and as before relied on a 1000 ins^3 airgun and Geophex shots as sound sources together with a 40 ins^3 airgun and array for profiling. The station was completed by 1453/178.

At this point we began a seismic reflection profile to the east in order to re-occupy the refraction line where a PUBS had been lost during the first leg. This proceeded without difficulty, beyond a change of guns early on Day 179, and was ended at 1339/179. The re-shot line (9824) was begun at 1413 with a single PUBS laid and two 1000 ins^3 airguns as sound source out to 50 kms with two 100 lbs Geophex shots at maximum range. The PUBS was back on board at 0401/180.

A short period of steaming followed to the next dredge site at 46°N, 20°W. On arrival, after a short survey, we began to lay a radar transponder buoy (dan buoy III). This was completed by 1840. Shortly afterwards the first dredge station (9825) was begun. Dredging was hampered by the difficult combination of a NNW scarp and NW winds. Luckily the wind was light so that dredging could proceed with the wind forward of the beam. A good haul of rocks was back on deck by 0208/181. The second dredge (9826) was less successful and was seriously hampered by the wind veering from SW to NW during the station. The last dredge (9827) succeeded in obtaining a few rocks and finished at 1545/181. Dan buoy III was lifted on board at 1810 and we then set off to occupy a final seismic refraction line.

This station (9828) was begun at 2210/181 and consisted of a single unreversed line, with a PUBS at the north end, shot with two 1000 ins^3 airguns out to 50 kms followed by a 150lb and a 200lb Geophex shot. During the return to the PUBS the remaining 22 cases of Geophex were dumped overboard since all the detonators had been used up. The PUBS was recovered at 1331/182 whereupon the ship set course for Barry. Seismic reflection profiling was immediately begun along this track and continued, as long as possible consistent with out planned ETA at Barry, up to 2400/183.

In the afternoon of Day 183 four hours were spent towing a hydrophone on the end of the faired batfish cable in order to measure the far-field waveform of an airgun. This was

done at different gun pressures and ship speeds.

Scientific watchkeeping ended at 1630/184 as the shelf edge was reached and the magnetometer was retrieved and the echo-sounder switched off. Data logging by the IBM 1800 ended at 2200. The ship docked at Barry at 0900/186.

PROJECT AND EQUIPMENT REPORTS

Navigation

The prime navigational aid throughout the cruise was the Transit Satellite system with dead reckoning between fixes provided by the two-component electromagnetic log and gyro. No recalibration of the e. m. log was attempted since it was known that this had been done over a measured mile on the previous cruise. At one stage we suspected the athwartships log had a systematic bias but an analysis of computed current vectors, relative to ship's head, obtained over a few days did not support this idea. One unusual aspect of the satellite fixes was the frequency of "bunching". The histogram in Fig. 7 illustrates how about a quarter of all satellite passes were within 15 minutes of another satellite pass. This explains why a greater proportion of fixes than is usual were not locked on to or were in error due to another satellite being in view at about the same time. Apparently this situation is only temporary and is caused by the present near synchroneity of orbits of three of the Transit Satellites.

On two occasions during shot firing the Magnavox satellite receiver became faulty. It is probable that the larger shots (300 lbs) that were being used on these occasions had disturbed the receiver printed circuit boards in their sockets into a position where bad edge connections were being made, since removing the boards and replacing them in their sockets restored the receiver to a working condition.

Radar transponders mounted on moored dan buoys were used for relative navigation during dredge stations (Table II). Adequate signals from the transponders were obtained out to about 7 miles range.

RBW

Precision Echo-Sounder

The echo-sounder fish and Mufax were continuously used during the cruise not only for echo-

sounding but also for acoustic tracking of pingers on wires and transponders on the PUBS. Only occasional problems were had with Mufax FN3 mainly due to lack of cleaning and lubrication of moving parts. At these times the spare Mufax, FN8, was pressed into service but did not always give as good a record. The same fish, No. 2, was towed throughout the cruise and gave no trouble whatsoever.

RBW

Gravimeter

A Lacoste and Romberg gravimeter (serial no. S40) was used throughout the cruise to measure gravity and to supply the necessary digital information for gravity to be logged by the IBM 1800 data logging system. The gravimeter had been installed on the ship at South Shields in January for this cruise and for the two previous cruises, 90 and 91. The meter was powered on in Lisbon on Day 143 and a tie-in made with a gravity base station. Tie-ins were also made at Ponta Delgada and Barry. The tie-ins indicated that there had been a negligible drift rate during the cruise.

During the cruise there were no major problems. However, on three occasions the platform went off level for not apparent reason. There were few times when the ship crossed its previous track and hence there was a lack of cross-overs with which to monitor the performance of the instrument. Those which did occur suggest that the cross-over differences were less than 2 mgals.

MGB

Magnetometer

The Varian V75 magnetometer was operated on all passage tracks of the cruise. At the beginning of Leg 1 the repotted fish, A, was streamed to test whether the noise reported during cruise 91 had disappeared. The noise was still present, and gave negative spikes of the order of 20 gammas. The second fish, B, was deployed during the remainder of the cruise and operated well. The magnetometer console and chart recorder functioned well at all times.

PRM

IBM 1800 Computer System

The 1800 computer was used to provide data logging facilities, navigation and plots of data. Satellite fixes were obtained from the Magnavox satellite navigation system on the bridge

and were fed on-line to the 1800 system. Both systems behaved well for the majority of the time.

At the start of the second leg, apparent software errors started to occur fairly frequently and eventually a persistent analogue input error made the system inoperable. A thorough diagnostic check of the analogue input circuitry and disc drives failed to reveal any hardware faults and about 18 hours of data were lost whilst the checks were being made (midday, Day 167 to early morning, Day 168). The system was made to operate again by specially selecting the system disc. The system was kept going in this way for the next three days when frequent errors started to occur again. It was decided to stop the system at the next dredge station (Day 173) to enable a disc-head alignment check to be made. After the heads had been aligned, the system was restarted and no further problems occurred for the remainder of the cruise.

DJ, DL

Quantitative underway geophysical observations

The echo-sounder was run at an assumed sounding velocity of 1500 m. s. $^{-1}$. Depths were corrected by the IBM 1800 computer according to Matthews' tables appropriate to this velocity.

Magnetic anomalies were calculated relative to the International Geomagnetic Reference Field 1975.

Gravity anomalies were calculated with respect to the 1967 International Gravity Formula and the International Gravity Standardisation Net 1971.

RBW

PUBS and seismic refraction profiles

This cruise was the first time the new Mk II PUBS had been used routinely. It was originally intended to deploy the PUBS about 40 times, a far higher number than normal for a cruise. In addition to the normal explosive sound source, two 1000 ins^3 airguns were used in an attempt to increase the range of effective airgun coverage from the previous typical range of 15 to 20 kms.

At the start of the cruise all the PUBS were wire tested, primarily to check the acoustic release electronics. The release electronics proved satisfactory at this point, but all the spheres suffered water leakage at depths of 3000 m. Several attempts had to be made to reseat O-ring seals before all the spheres were made watertight.

During the first leg, a total of 14 lays was achieved but one PUBS was lost. This PUBS could not be located or released acoustically and as it did not return to the surface under command of its back-up release clock, it was assumed that the pressure vessel had leaked. It became apparent during the early lays that the PUBS recording system was very reliable and that it was unnecessary to lay two PUBS (one as a back-up) at each site; this had previously been normal practice. The acoustic transponders failed a number of times due to faulty crystal oscillators. These failures made relocation difficult and gave no indication at the surface that the PUBS had released. When the transponders worked, relocation and recovery became routine. The radio beacon was particularly useful when the transponder had failed because it was the only indication, apart from visual sighting, that the PUBS had surfaced.

During the second leg, 11 lays were completed without loss. Problems were again encountered with the release electronics. During station 9812 two PUBS could not be relocated or released acoustically and were finally released by the PUBS back-up clock. On recovery it was discovered that the battery supplies had been exhausted. It was found that the release electronics consumed more power in the silent than in the operate mode, thus reducing the endurance of the release electronics from 1000 to 120 hrs of operation.

A high speed (x 4) replay facility was completed at sea which allowed PUBS data to be replayed after each lay to determine the performance of the instrument prior to the next lay. The replay facility included a trigger unit necessary for the display of the airgun record sections on the jet pen recorder.

The Mk II PUBS has proved to be a reliable instrument with a very high data recovery rate. It should, in future, be possible to deploy the PUBS at an even faster turn around than was achieved during cruise 93. The primary limitation of the instrument is its size and weight which limits the number of instruments which can be handled in the ship's laboratories.

Preliminary data indicates that the sensitivity of the Mk II has been improved over the Mk I; for example, useful data is observable from two 1000 ins^3 airguns out to 40 kms compared with 20 kms from a single gun for the Mk I PUBS.

Only the most preliminary examination of data from the three geophones has been carried out so far. However this revealed that the vertical geophones are capable of providing useful data whereas the horizontal geophones have a tendency to exhibit a ringing trace once they have been excited by a strong signal. On one, possibly several, occasions a gimbal jammed and the horizontal geophones on it gave useless signals because they had been tilted too far from horizontal.

JJL, RBW

Half Ton Shot

A half ton charge was launched on Day 164 just before the ship entered Ponta Delgada. The shot was fired for the benefit of land stations set up on the island of Sao Miguel. The charge was suspended from a self-deflating surface float and was double fused with detonators and 10 feet of slow burning fuse to each detonator. Although the handling and launching of the charge went smoothly enough unfortunately it did not fire for reasons which can only be speculated about. RBW

Seismic reflection profiling

During Discovery Cruise 87 an experiment was carried out to determine whether it was possible to run a 40 ins^3 and a 1000 ins^3 airgun together, and at what firing rates. The experiment was successful and the new technique was used on most of the refraction lines during Cruise 93. The 1000 ins^3 gun firing at 2 minute intervals replaced explosives up to 25 km, and the 40 ins^3 firing at 12 sec intervals gave a reflection profile along the same track, thus providing necessary information about the variation of sediment thicknesses.

Owing to two major setbacks with the hydrophone array the first two refraction lines did not include a recording of the 1000 ins^3 gun and a 40 ins^3 gun reflection profile.

The first setback was caused by the leading spring section leaking oil. Investigation revealed that an aluminium collar on the connector had almost corroded away. A temp-

orary repair was effected and the section refilled.

The second setback involved the cable jamming between a retaining bracket on the bottom cheek of the hydrophone drum and the reeving gear column. This resulted in the 36 cores of the cable breaking and the outer sheath stripped. Again, a temporary repair was carried out. Both repairs lasted for the remainder of the cruise.

No. 1 compressor developed low oil pressure in the second week and had to be completely stripped. Main bearings, big ends, a small end and piston on the second stage were all replaced. Shortly after the same compressor overheated due to bits of the water pump impeller in the third stage cooler.

For the remainder of the first leg the SRP equipment worked well, and all refraction and reflection lines were carried out successfully.

At the start of leg 2 the leading spring section was topped up with oil on its way out for the first run. For the second run two 1000 ins^3 guns were deployed and fired together at a 2 minute rate. The compressors coped well at a maximum pressure just over 1600 psi, and continued to give no trouble for the remainder of the leg.

For reflection/refraction lines the 40 ins^3 and 1000 ins^3 guns were usually fired as before except that the firing circuit was modified to inhibit firing of the smaller gun one shot prior to the big gun to help reduce reverberation on the refraction record.

Apart from one gun failure towards the end of the leg there were no problems, though the repeated deployment and recovery of the guns has done some damage to the towing bundles. The hydrophone chute, however, seems not to have caused any chafing of the cable, though admittedly the weather was good throughout the leg.

DGB, CF

Far field airgun waveform measurements

An experiment was performed to measure the outgoing pulse from the airgun sound source. A ceramic transducer with an integral pre-amplifier was contained inside a towed fish

fitted to the faired Batfish cable. The fish was towed at a depth of approximately 120m beneath the airgun for a period of 2 hours while a normal seismic reflection profile (SRP) was in progress. The data from the towed fish and SRP array were recorded for future use in seismic signal processing. JJL

Coring

The aims of sediment coring were:

(a) to gain experience in the handling and deployment of presently available MSES and IOS coring equipment;
(b) to assess their suitability for use in any expansion of sediment sampling requirements, and
(c) to determine any necessary modifications that might be undertaken.

The equipments to be used were:-

(1) the LeHigh Hydroplastic Gravity Corer
(2) the Calvert Wide Diameter Gravity Corer
(3) the MSES Piston/Gravity Corer
(4) a number of Moore Pop-Up Corers.

The LeHigh corer is a gravity corer which uses high impact plastic piping as its barrel. This is removable and is replaced when full so no inner liner is required. The corer relies heavily on the operation of a neoprene stop valve to retain the sediment, since the core catcher which has a spring-loaded jaws mechanism is not operated until the core has returned to near the surface. Two modifications were made prior to use: a light spring was fitted to the valve spindle and it was well greased; also a 14m long catcher release line was clamped to the main warp thus allowing the catcher to be operated from deck level when the corer was still 5 to 10 metres below the sea surface.

During three coring attempts one core was obtained (9806). At the other two stations, too large a freefall near the bottom resulted in coiling of the corer in the warp, once causing a complete tangle and the other possibly causing the check valve not to operate. The catcher failed to close over the successful core due to barrel slippage but the valve still

retained the sediment. The tops of the barrels should be grooved and their fixing modified to prevent this movement. With proper freefall and no barrel slippage this corer could prove very useful. It is supplied with 4ft barrels at present and is said to be capable of 8ft and 12ft lengths. Experience on this cruise suggests that the corer requires modification to the catcher so that a triggered release closes it over the bottom of the barrel as the latter emerges from the bottom. The corer would probably also require a greater capacity on the weightstand for operations below 3000 m especially if longer barrels are tried.

The Calvert gravity corer is of similar barrel diameter to the LeHigh but is of stainless steel and uses a plastic liner. A 2 m long barrel was used with a conventional finger-type catcher to which a plastic skirt had been added. During four attempts with this corer one sediment core was recovered (9812). At all but one of the sites barrel smears suggested good penetration and indeed sediment was seen to be lost on breaking the sea surface. The problem appears to be with the top check valve: at the first site it was stuck fully open and a full barrel of sediment had obviously slipped past the catcher turning it inside out. Prior to the second site the valve unit was completely taken apart, the valve replaced and tested underwater - this was the only successful site. At the remaining sites catcher samples only were retained. Possibly modification of this valve is required making its compartment longer and more open and using either a neoprene or a flap-type valve.

The MSES Gravity Corer was supplied without its piston conversion unit. A piston was fashioned aboard ship from a brass cylinder using O-rings and a circular shackling point. The corer was rigged on a trigger arm with a weight designed to allow a 26ft freefall. After triggering the corer was lost. The shackling point on the piston was screw-threaded into its top and this had obviously unscrewed during the haul-in.

The Moore Pop-Up Corers have a disposable steel barrel/cutter and top housing unit together with a recoverable unit comprising a liner attached to two glass spheres which are designed to release on impact, thus drawing the plastic liner with its recovery held in by the catcher back to the surface. Four corers were deployed resulting in one good core recovered (9812). Trip times were calculated from descent and ascent velocities given in the UMEL brochure. The core that was recovered had a trip line roughly three times that

calculated from these manufacturer's figures. Despite the lack of good visibility for spotting at the first two sites, one suspects that the ship was just leaving the area when the buoys were due to appear. Good spotting conditions prevailed at the last site and it is believed that, after first prefiring at about 20 m depth, this core when redeployed did not release its spheres after impact at the bottom. The corers definitely require better recovery techniques for use in the North Atlantic and some suggestions are: a radio beacon, as used in sonobuoys and in PUBS, operating from one of the spheres; a brighter flashing light unit in the other sphere (again as used in PUBS); and a dayglo flag (the latter was fitted and found useful for spotting on this cruise). The technique provides rather good cores over the upper 1.5 m of sediment and is most useful if the corers are deployed in profiles. If recovery could be improved it might then be worth building a stern shute for assembly and deployment in profiles.

RBK

Dredging

The aim of the dredging was to obtain rocks from the oceanic crust and preferably to pick up rocks from sites in a favourable position to have basic and ultramafic outcrops.

Two sites were chosen for dredging:-

1. Kettle Mountain lies at 45°30'N on the Mid-Atlantic Ridge and rises with steep sides suitable for dredging to give a relatively shallow water depth over the peak of 900m. Kettle Mountain has the advantage of being covered by a detailed bathymetric survey carried out by the Canadian Bedford Institute of Oceanography (BIO) and it lies in an area which has been successfully dredged for basic ocean crust in the past.

2. In contrast the second area lies much further from the ridge, although still close to 45°N, and in much deeper water, and forms a scarp rising out of a sediment pond SW of the Porcupine Abyssal Plain. The feature was chosen as it appeared to run in an E-W direction suggesting the possibility of a transform fault where Layer 3 material might be present. This particular scarp was well documented by several ship tracks which crossed it at this point. SRP records showed possible basement overlain by sediment and both exposed in the scarp.

Each dredge station was navigated by radar by taking bearings and ranges every ten minutes on a dan buoy with a radar transponder. This was anchored to the bottom and laid in a sediment hollow to try to prevent drifting. The position of the buoy was fixed by less frequent satellite fixes. The dredge itself consists of a frame with a chain bag attached and two inner bags, one of chicken mesh and one of nylon netting. Four small sediment traps are attached to the dredge frame and chain is attached to the bag to give it weight. The dredge has two weak links in the wire attaching it to the ship. The 2.7 ton weak link allows the dredge bag to be throttled by a wire loop and if the 5 ton weak link is snapped the whole dredge is lost. The distance which the dredge is off the bottom is recorded by a tilt switch pinger attached 10 m above the dredge and joined to the dredge by a wire and a chain. The distance which the dredge is behind the ship is determined by the number of metres of wire paid out and by the angle of the wire as it leaves the ship. The collecting of rocks when the dredge is on the bottom is indicated by the tension on the wire at the ship which is measured by a dynamometer. Bites, or sudden increases in tension, represent the dredge picking up material or getting stuck on the bottom. The dredging carried out at these dredge sites was done by power dredging which involves steaming into the wind at 0.5-1.0 kts. If the dredge becomes stuck on the bottom it may be released by letting the ship fall back with the wind. On Kettle Mountain the choice of dredge path was determined by the wind direction as the mountain is surrounded by suitable sites to dredge. The second site had a linear trend and fortunately the wind direction was tolerable for two out of three of the dredges. Due to the wind the third unsuccessful dredge could not be guided up slope but only sideways across it as the wind direction had changed.

The dredging at both sites was very successful. There were some problems with the equipment, for example the pingers were faulty and did not always continue to transmit throughout the station. One dredge became caught on the bottom and was lost while four were throttled when the 2.7 ton weak link broke; these were the largest of the hauls. Five dredges were successful in obtaining rocks of which two were very large.

Dredging at Kettle Mountain produced an abundant variety of erratics some of which had very well marked ice scratches. The rock types included granites, schists and gneisses as well as shales, sandstones and limestones. There was a considerable number of basalt erratics and some larger and less rounded samples may well have come from the

vicinity of Kettle Mountain. Amongst the erratics small conical shells of one species were very abundant. Erratics were obtained from all depths but the coral was obtained only from the shallowest dredge which was also the largest at this site. The reef from which it came may have been the structure on which a dredge was lost. Dredging operations revealed that the Canadian BIO bathymetry was very accurate but needed to be displaced a little to the south.

Dredging at the second site was very successful and it seems likely that the rocks dredged here were of local origin. An initial survey showed that the east/west feature had in fact a NW/SE trend and did not rise as high as at first had been suspected but the survey revealed a vertical cliff of over 400 m. Two dredges brought up rocks. The first probably missed the steep part of the cliff and collected from the more gentle upper slopes. The dredge was full of samples set in a cream coloured mud matrix and the samples range from 0.5 cm - 0.5 m in diameter. There were three types of rock in approximately equal proportions. One third were green serpentines with abundant bastite crystals some of which were deformed to give well developed augen structures. A third were basalt some of which were jagged and probably from the local area. The last third were erratics and some poorly rounded clayey mudstones which may be local but it is unlikely that the slates are of local origin. The second successful dredge only contained one piece of serpentine which was attached to the chain link on the outside of the dredge and a few small erratic pebbles. It is very likely that the dredge sampled from the steep part of the cliff thus suggesting that the serpentines are actually exposed in the cliffs at this site. One large sample was almost entirely composed of manganese coating and contained angular pieces of serpentine which suggests a type of scree slope breccia.

In conclusion the dredging was very successful and in the short time available a good collection of rocks was made from both dredge sites.

HP

SCIENTIFIC PERSONNEL

R. B. Whitmarsh	Principal Scientist	I. O. S., Wormley	Legs 1, 2
D. G. Bishop	SRP	" "	Leg 1
R. N. Bonner	Airguns, compressors	" "	Legs 1, 2
W. Davey	PUBS	" "	Legs 1, 2
C. G. Flewellen	SRP	" "	Leg 2
A. W. Gray	Airguns, compressors	" "	Leg 1
D. Grohmann	PUBS	" "	Legs 1, 2
P. M. Hunter	Geophysics	" "	Legs 1, 2
R. B. Kidd	Coring	" "	Leg 1
R. E. Kirk	PUBS	" "	Legs 1, 2
B. G. Knowles	Airguns, compressors	" "	Leg 2
J. J. Langford	PUBS	" "	Legs 1, 2
P. R. Miles	Geophysics	" "	Legs 1, 2
I. T. Porter	Geophysics	" Blacknest	Leg 2
R. G. Rothwell	Geophysics	" Wormley	Leg 2
N. Scarle	Geophysics	" "	Legs 1, 2
R. C. Searle	Geophysics	" "	Leg 1
M. G. Beney	Computer, gravimeter	" Barry/RVS	Legs 1, 2
D. A. Jones	Computer	" "	Legs 1, 2
D. Lewis	Computer	" "	Legs 1, 2
H. Prichard	Dredging	Dept. Geology, Univ. of Newcastle	Legs 1, 2
I. Moita	Observer	Hydrographic Inst., Lisbon	Leg 1

SHIP'S OFFICERS

J. Moran	Master	Legs 1, 2
D. Noden	First Officer	Legs 1, 2
R. Coutts	Second Officer	Legs 1, 2
G. Harries	Third Officer	Legs 1, 2
A. Coombes	Chief Engineer	Legs 1, 2
T. Rees	Second Engineer	Leg 1
N. De Roza	Second Engineer	Leg 2
J. Richardson	Third Engineer	Legs 1, 2
P. March	Fourth Engineer	Legs 1, 2
R. Thomas	Fifth Engineer	Legs 1, 2
P. Sharpe	Chief Electrician	Legs 1, 2
W. Mullen	Radio Officer	Legs 1, 2
R. Overton	Catering Officer	Leg 1
R. Cridland	Catering Officer	Leg 2

TABLE I STATION LIST

Station No.	Station Type	Latitude °N	Longitude °W	Time (G. M. T.) Start	Time (G. M. T.) End	Water deptn (metres)	Comments
9802	PUBS	43°56' 43°17'	17°15' 18°11'	0505/150	0203/151	2960- 3725	2 PUBS used. 1000in^3 airgun firing at 2 min intervals. 17 Geophex shots.
9803	PUBS	43°31' 44°10'	17°57' 16°49'	0630/152	0807/153	3045- 3850	2 PUBS used. 1000in^3 airgun firing at 2 min intervals. 19 Geophex shots.
9804	C	43°30.6'	17°55.5'	1205/153	1437/153	3527	Le High hydroplastic corer. No sediment.
9805	V	43°32'	17°55'	1448/153	1625/153	-	2000m wire out.
9806	C	43°32.5'	17°53.3'	1625/153	1855/153	3594	Le High hydroplastic corer. Core length 62cm. Moore pop-up corer.
9807	PUBS	43°23' 42°48'	16°17' 17°08'	0418/154	1231/155	4070- 4790	3 PUBS used. 1000in^3 airgun firing at 2 min intervals plus 40in^3 gun. 31 Geophex shots.
9808	C	43°24.7'	16°01.6'	1410/155	1840/155	5232	Le High hydroplastic corer. Sediment smear 60cm up outside and 40cm up inside of barrel. Small amount on upper side of catcher.
9809	PUBS	44°43' 43°58'	18°11' 18°38'	1425/156	0106/158	4335- 4922	3 PUBS used. 1000in^3 airgun firing at 2 and 2½ min intervals. 35 Geophex shots.
9810	C	43°59.8'	18°32.4'	0110/158	0639/158	4767	Calvert gravity corer. Sediment smear 2m up outside of barrel and to weight stand inside. Moore pop-up corer.
9811	PUBS	45°13' 45°40' 45°13' 45°40'	22°23' 22°13' 23°47' 23°32'	0715/159	1035/162	2940- 3964	3 PUBS used. Lost PUBS 1. 1000in^3 airgun firing at 2 min intervals, plus 40in^3 airgun. 92 Geophex shots.

TABLE 1 (contd.)

Station No.	Station Type	Latitude °N	Longitude °W	Time (G. M. T.) Start	Time (G. M. T.) End	Water depth (metres)	Comments
9812	C	45°14.4'	22°25.8'	0830/160	1400/160	3898	Calvert gravity corer. Core length 134cm. Moore pop-up corer - core length 90cm.
9813	C	43°36.2'	24°24.6'	2135/162	0003/163	3346	MSES piston corer. Corer lost.
9814	C	42°45.4'	24°49.8'	0733/163	1013/163	3546	Calvert gravity corer. Small amount of sediment in catcher.
9815	C	42°14.4'	24°26.8'	1345/163	1800/163	3935	Calvert gravity corer. 10cm sediment above core catcher.
9816	PUBS	45°22' 45°22' 45°48' 45°48'	25°40' 24°26' 24°17' 25°33'	2058/169	1356/172	2590- 3419	3 PUBS used. 2 x 1000in^3 gun or 1000in^3 plus 40in^3 airguns deployed, firing at 2 min intervals. 98 Geophex shots.
9817	D	45°29.8' 45°31.0'	27°16.7' 27°17.6'	1600/173	2205/173	2500- 1600	Erratics and basalts.
9818	D	45°32.3' 45°33.8'	27°15.7' 27°18.0'	2250/173	0312/174	2545- 1100	Erratics and basalt.
9819	D	45°33.6' 45°33.7'	27°17.3' 27°18.7'	0554/174	0742/174	1585- 1243	Empty.
9820	D	45°32.6' 45°32.1'	27°17.5' 27°30.4'	0830/174	1105/174	- -	Dredge lost.
9821	PUBS	45°20' 45°33' 45°20' 45°33'	27°24' 27°24' 27°41' 27°41'	1402/174	1547/175	1300- 3000	3 PUBS used. Anisotropy expt. 2 x 1000in^3 airguns, firing at 2 min intervals.
9822	D	45°33.3' 45°32.8'	27°16.5' 27°18.3'	1748/173	2130/174	2151- 1250	Coral fauna, erratics.

TABLE 1 (contd.)

Station No.	Station Type	Latitude °N	Longitude °W	Time (G. M. T.) Start	Time (G. M. T.) End	Water depth (metres)	Comments
9823	PUBS	45°19' 45°50' 45°50' 45°19'	26°18' 26°05' 27°24' 27°34'	0109/176	1453/178	2985- 1380	3 PUBS used. 1000in^3 plus 40in^3 air-gun, 93 Geophex shots.
9824	PUBS	45°13' 45°47'	22°24' 22°10'	1413/179	0401/180	3506- 4026	1 PUBS used. 2 x 1000in^3 airguns firing at 2 min intervals. 2 Geophex shots.
9825	D	45°55.7' 46°00.1'	19°57.5' 19°57.3'	1942/180	0200/181	4800- 4125	Mud, serpentine basalt, limestone, shale, erratics.
9826	D	45°58.7' 45°54.7'	19°59.0' 19°50.7'	0430/181	1042/181	-	Empty.
9827	D	45°57.0' 45°58.2'	19°57.0' 19°56.4'	1200/181	1742/181	4800- 4200	Serpentine and pebble erratics.
9828	PUBS	45°46' 45°16'	19°16' 19°29'	2210/181	1331/182	4669- 4225	1 PUBS used. 2 x 1000in^3 airguns firing at 2 min intervals. 2 Geophex shots.

TABLE II

Dan buoy positions

Dan buoy	Time laid	Time recovered	Latitude	Longitude
I	0837/173	1220/173	45°30.3'N	27°26.5'W
II	1422/173	2315/175	45°31.35'N	27°15.4'W
III	1840/180	1810/181	46°0.9'N	19°55.9'W

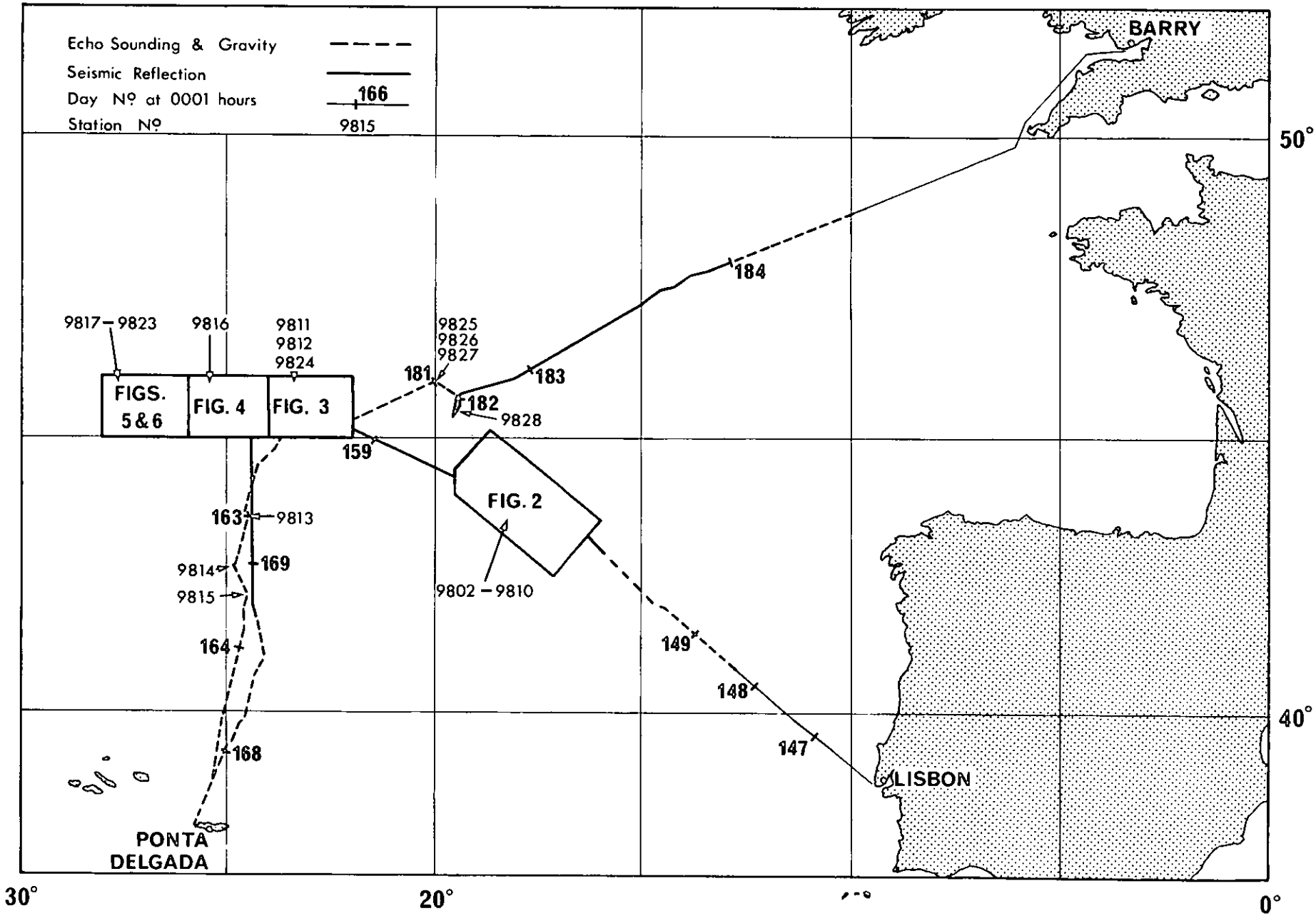

FIGURE 1 General track chart

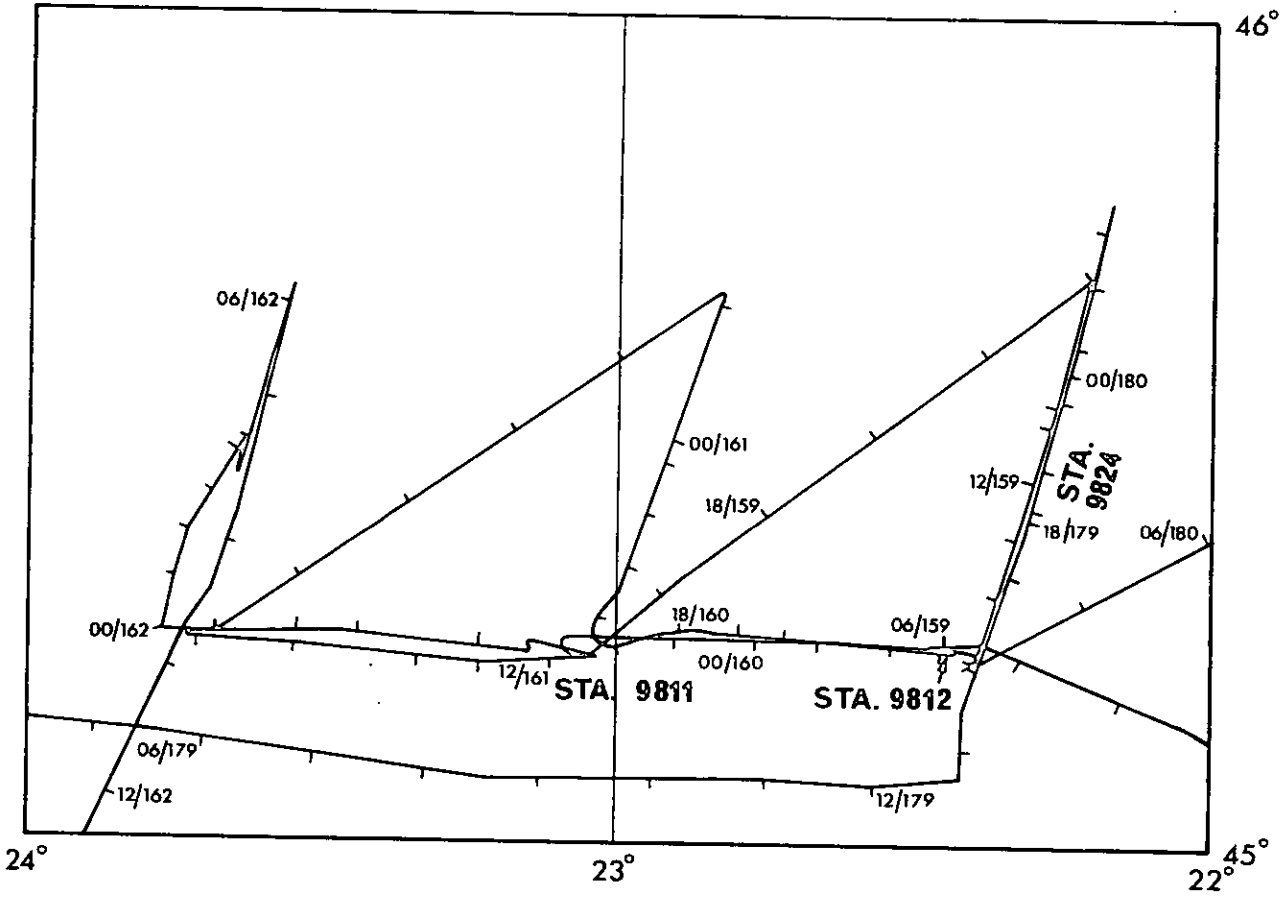

FIGURE 3 Details of track 22 °W to 24 °W

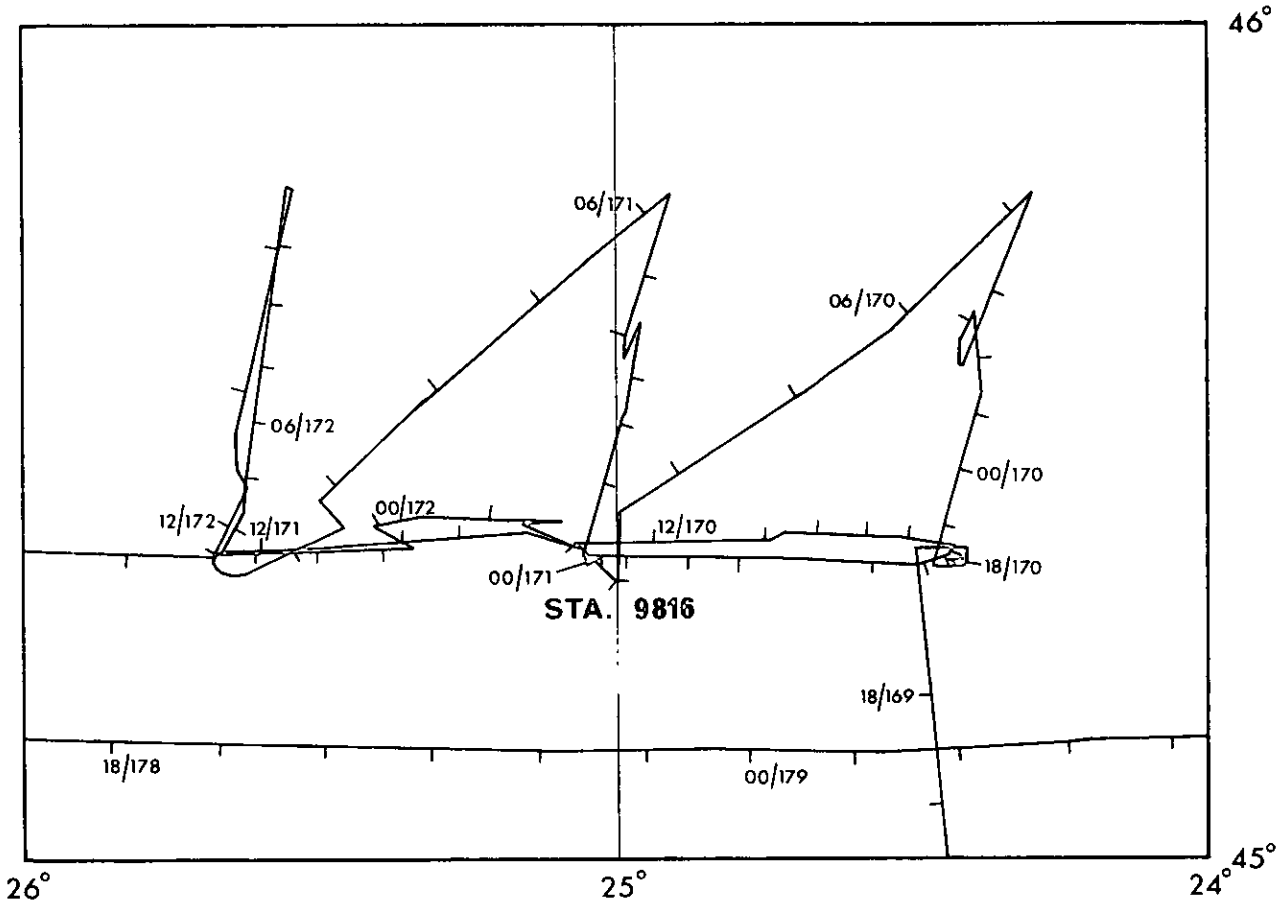

FIGURE 4 Details of track 24°W to 26°W

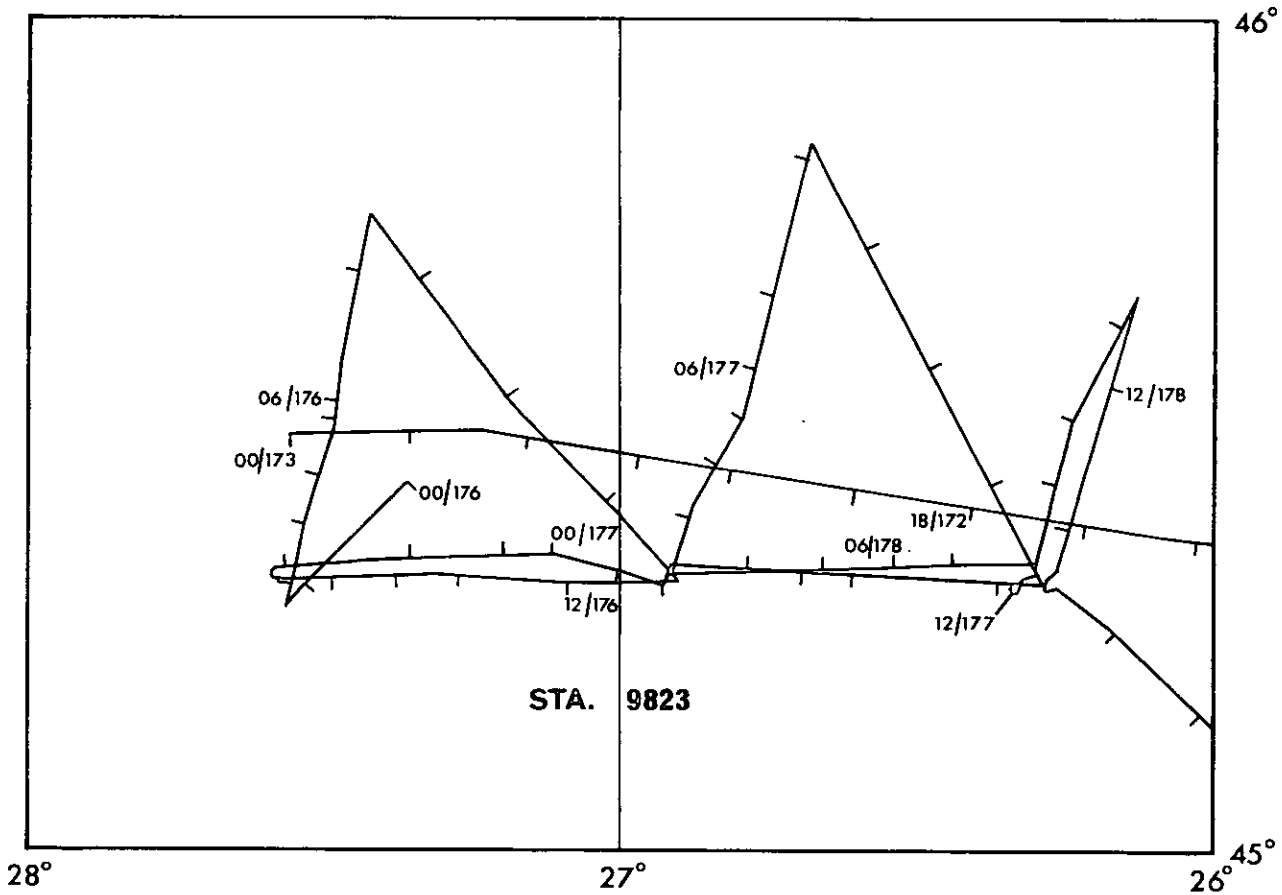

FIGURE 5 Details of track 26°W to 28°W

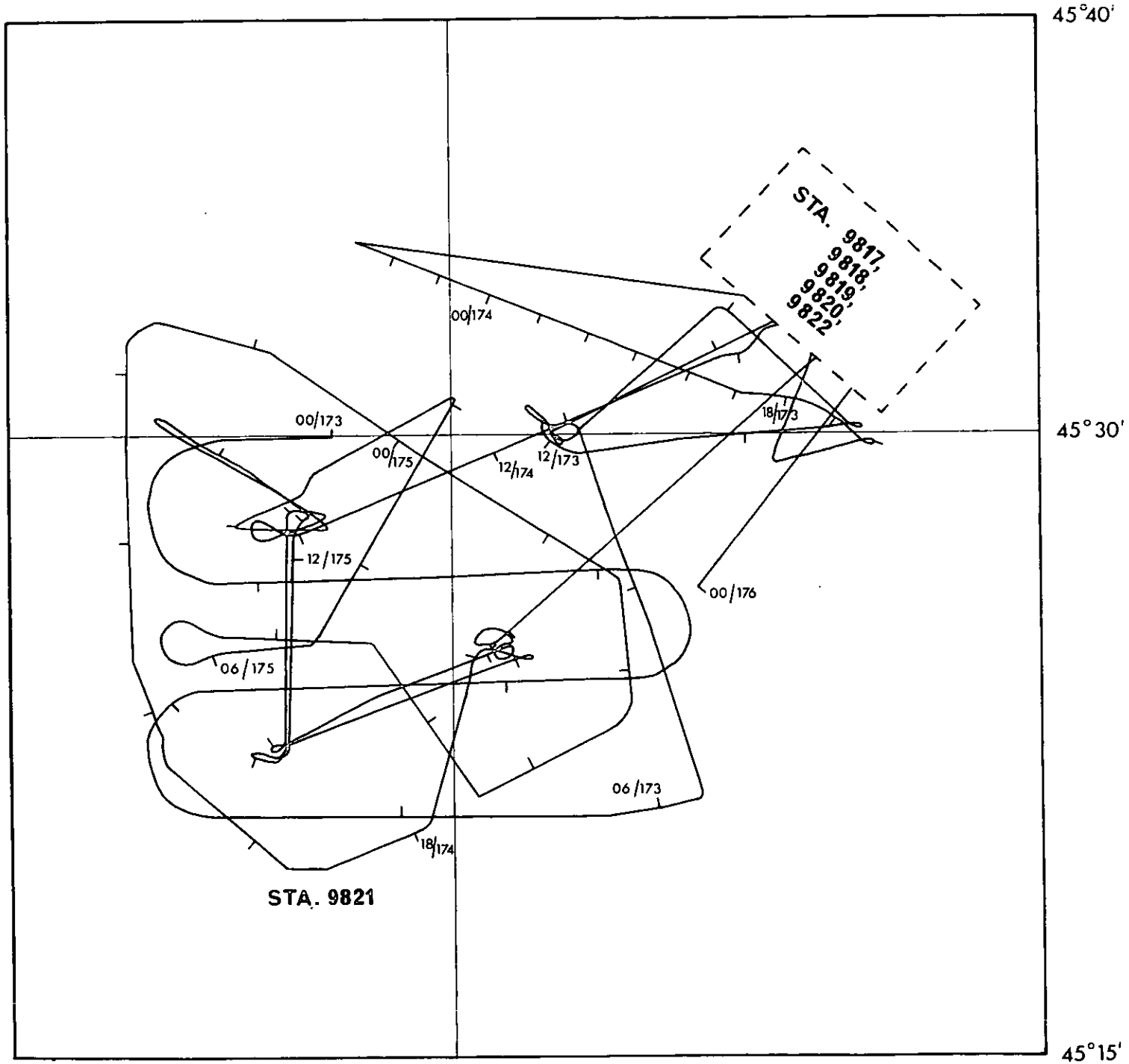

FIGURE 6 Details of track 27°W to 28°W

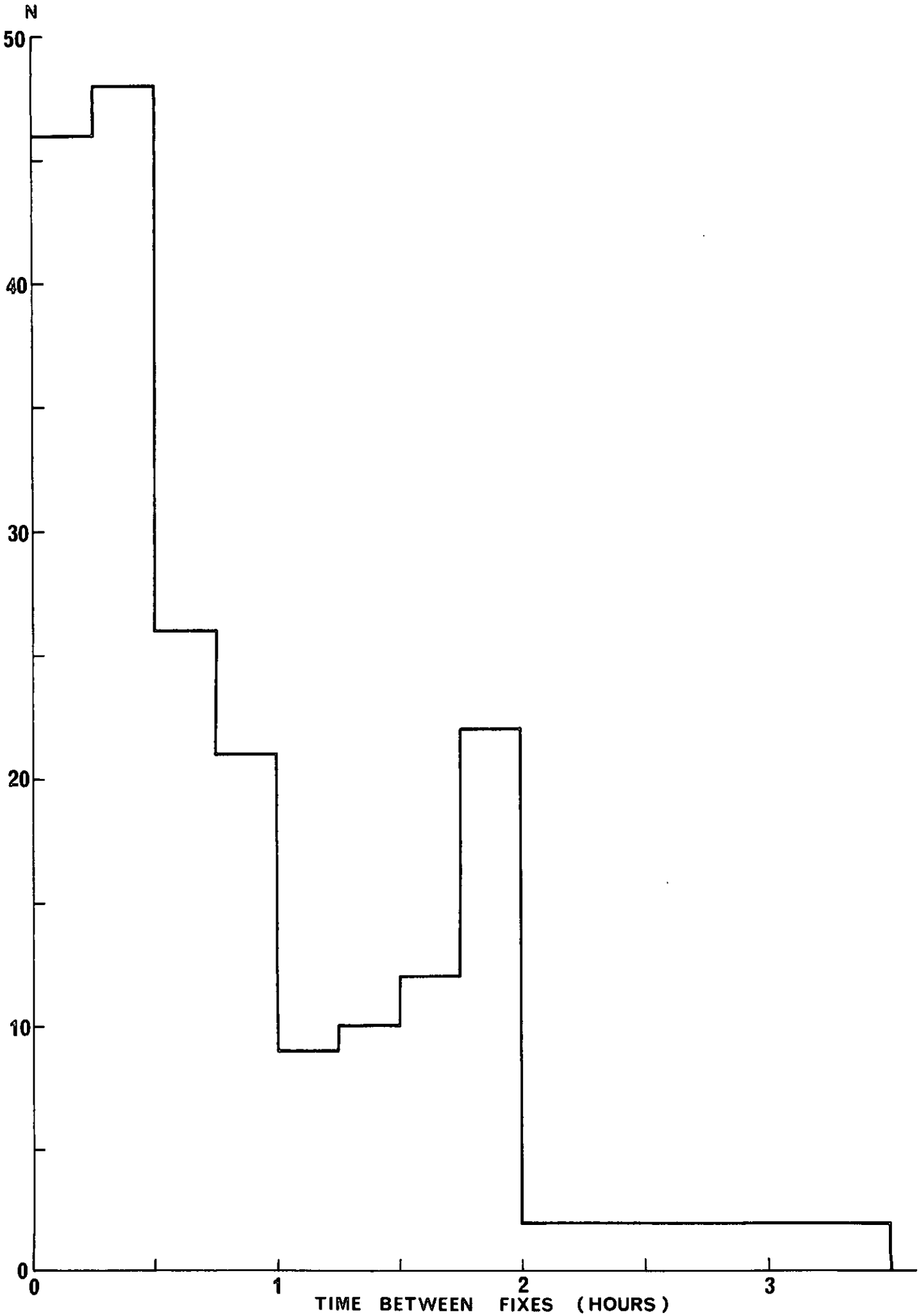

FIGURE 7 Histogram of intervals between satellite passes

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CRUISE NO		REPORT NO
1	JUL - AUG 1963	1*
2	AUG - DEC 1963	2*
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46	APR - MAY 1972	55
47	JUN - JUL 1972	52
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49	AUG - OCT 1972	57
50	OCT 1972	56
51	NOV - DEC 1972	54
52	FEB - MAR 1973	59
53	APR - JUN 1973	58
		IOS CR***
54	JUN - AUG 1973	2
55	SEP - OCT 1973	5
56	OCT - NOV 1973	4
57	NOV - DEC 1973	6
58	DEC 1973	4
59	FEB 1974	14
60	FEB - MAR 1974	8
61	MAR - MAY 1974	10
62	MAY - JUN 1974	11
63	JUN - JUL 1974	12
64	JUL - AUG 1974	13
65	AUG 1974	17
66	AUG - SEP 1974	20
68	NOV - DEC 1974	16
69	JAN - MAR 1975	51
73	JUL - AUG 1975	34
74/1+3	SEP - OCT 1975	35
74/2		33
75	OCT - NOV 1975	43
77	JUL - AUG 1976	46
78	SEP - OCT 1976	52
79	OCT - NOV 1976	54
82	MAR - MAY 1977	59
83	MAY - JUN 1977	61
84	JUN - JUL 1977	60
86	SEP 1977	57
87	OCT 1977	58
88	OCT - NOV 1977	65
90	JAN - MAR 1978	68

* REPORTS 1 TO 3 WERE PUBLISHED AND DISTRIBUTED BY THE ROYAL SOCIETY FOLLOWING THE INTERNATIONAL INDIAN OCEAN EXPEDITION

** NIO CR: NATIONAL INSTITUTE OF OCEANOGRAPHY, CRUISE REPORT

*** IOS CR: INSTITUTE OF OCEANOGRAPHIC SCIENCES, CRUISE REPORT

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CRUISE DATES	REPORT NO
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AUG - SEP 1974	IOS CR 22
MAR - APR 1976	IOS CR 47
RV "EDWARD FORBES"	
OCT 1974	IOS CR 15 X
JAN - FEB 1975	IOS CR 19
APR 1975	IOS CR 23
MAY 1975	IOS CR 32
MAY - JUN 1975	IOS CR 28
JUL 1975	IOS CR 31
JUL - AUG 1975	IOS CR 36
AUG - SEP 1975	IOS CR 41
AUG - SEP 1975	IOS CR 44
FEB - APR 1976	IOS CR 48
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RRS "JOHN MURRAY"	
APR - MAY 1972	NIO CR 51
SEP 1973	IOS CR 7
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APR 1975	IOS CR 39
OCT - NOV 1975	IOS CR 40
AUG - OCT 1975	IOS CR 42
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MC "MARCEL MAYARD"	
FEB - APR 1971	NIO CR 44
MV "DISCOVERER"	
AUG - SEP 1972	NIO CR 60
RV "DARDIA"	
MAY - JUN 1975	IOS CR 30
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MV "SURVEYOR"	
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