I.O.S.



R.R.S. DISCOVERY
CRUISE 91

5 - 28 MARCH 1978

# Geophysical Studies of the Azores Triple Junction and the Azores-Biscay Rise

I.O.S. CRUISE REPORT NO. 69

1978

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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ITINERARY

| | | |
|---|---|---|
| Departed Brest | 1978 March 5th, | Day 64 |
| Arrived Southampton | 1978 March 28th, | Day 87 |

SCIENTIFIC PERSONNEL

| | | |
|---|---|---|
| R.C. Searle | Principal Scientist | I.O.S. (Wormley) |
| P.M. Hunter | Geophysics | " " |
| M.R. Saunders | " | " " |
| R.G. Rothwell | " | " " |
| N. Scarle | " | " " |
| J. Revie | GLORIA | " " |
| S.K. Willis | " | " " |
| C.G. Flewellen | Seismic Reflection Profiling | " " |
| R.H. Edge | Mechanical Engineering | " " |
| G. Lodge | " " | " " |
| R.D. Peters | Workshop | " " |
| J. Krawczyk | " | " " |
| D. Jones | Computer | I.O.S. (Barry) |
| P. Hartland | " | " " |
| P. Armitage | Gravimeter | " " |

SHIP'S OFFICERS AND P.O.s

| | |
|---|---|
| P. McDermott | Master |
| S. Mayl | Chief Officer |
| S. Sykes | 2nd Officer |
| J. Seymour | 3rd Officer |
| A. Coombes | Chief Engineer |
| N. Wilson Deroze | 2nd Engineer |
| J. Richards | 3rd Engineer |
| B. Entwhistle | 4th Engineer |
| M. Thomas | 5th Engineer |
| A. Davies | 5th Engineer |
| W. Mullen | Radio Officer |
| P. Sharpe | Electrical Engineer |
| R. Morris | Purser Catering Officer |
| D. Burt | Netman |
| T. Leonard | Bosun |
| D. Knox | Bosun's Mate |
| L. Cromwell | Carpenter |

## CRUISE OBJECTIVES

### 1. The Azores Triple Junction

The Azores region is anomalously shallow and is associated with a local concentration of volcanic activity. Such areas are known geologically as hot spots. It was also thought that a spreading centre (part of the boundary between the Eurasian and African plates) runs through the eastern Azores from the Gloria Fault to the Mid Atlantic Ridge, where it joins the Mid Atlantic Ridge spreading axis at a triple junction. It was planned to examine the nature of the Azores spreading centre, to map its junction with the Mid Atlantic Ridge, and to examine the effect of the adjacent Azores hot spot on the structure of the Mid Atlantic Ridge crest.

### 2. The Azores-Biscay Rise

A linear rise runs south-west from near $45^{o}$N, $15^{o}$W, to about $41^{o}$N, $21^{o}$W, and is known as the Azores-Biscay Rise. Little geophysical work had been done on it in the past, and its nature and origin were uncertain. It was planned to obtain reconnaissance coverage of the north-eastern part (NE of Peake and Freen Deeps), and to make a detailed survey of the rest, in particular to determine its south-western extent.

## NARRATIVE

In Brest, the hull-mounted asdic was unshipped for return to U.K., and a new head was fitted to the port E/M log.

Discovery sailed from Brest at 1206 on March 5th (064). This was a day earlier than planned, the extra time being intended to complete a survey line over the continental margin begun on Cruise 90, but abandoned because of poor weather.

The echo-sounder fish, GLORIA, seismic profiling array, 150 cu. in. airgun, and magnetometer were streamed between 1800 and 1930 on day 64, and scientific watches were begun at 2000. A fault developed in the computer interface of the starboard E/M log, and after trying for some time to rectify it, it was decided to proceed on the uncalibrated port log.

On 065/0936 we turned onto a course of $302^{o}$ for the continental margin profile. At 2150 we turned SW toward the Azores-Biscay Rise.

A disposable sonobuoy was launched at 066/1221 to calibrate the log, and the log orientation and calibration constants were adjusted the following day. While the log calibration run was in progress, some outstanding repairs to GLORIA earth connections were made, considerably improving subsequent records.

From mid-day on 067 we ran down the east flank of the Azores-Biscay Rise. However, few features which could be specifically associated with the rise were seen until we turned across it on day 068, when GLORIA showed that the seamounts on the crest of the rise appear to be volcanic, not tectonic structures.

The next five days were spent on a box survey of the south-western end of the Azores-Biscay Rise. On the first day (069) we were without seismic profiling for about seven hours while both compressors were serviced and repaired. During this survey the wind varied from SW to NW between force 4 and force 7. Wherever possible steaming into the sea was avoided, as this was thought to provide the most damaging conditions for the GLORIA cable. However, the penultimate line of the survey on day 72 was steamed into a moderate-to-heavy north-westerly swell. This reduced ship speed to 6½ knots and caused considerable pitching, but in spite of some increased vehicle yaw, GLORIA stood up to this very well.

At 0840 on day 73 we turned SW towards the Azores, and rounded São Miguel island at noon on day 74. At 074/1600 the 150 cu. in. airgun was replaced by the 40 cu. in. We steamed WNW roughly up the line of the Azores spreading centre until reaching the Mid Atlantic Ridge axis; we then altered course, at 075/2100, to begin a three-day survey of the Mid Atlantic Ridge and its connexion with the Azores spreading centre.

Both compressors were switched off for 70 minutes on day 77 to have their heat exchangers cleaned.

Just after 0900 on day 77 the Sperry gyro malfunctioned briefly. The following day (78) there was a more serious failure, and the Sperry gyro was out of action from 0735 until 1100. On both occasions gyro input to the computer was lost, and hand-steering had to be employed, leading to serious yawing (up to $\pm 12^{\circ}$) of the GLORIA vehicle. This occurred even though the standby Arma-Brown gyro was

functioning, because the latter had been disconnected from the auto-pilot and computer room repeaters.

The Azores survey was completed on day 79 with a run south of Fayal and Pico and then north across the Terceira Rift, and SE along the north flank of the Azores Plateau.

Throughout the Azores surveys the weather was excellent, with mainly force 3-4 winds and a light swell.

At 082/0700 we arrived at a position near 43°N 19°W, ready to begin a further GLORIA and SRP run over the north-eastern end of the Azores-Biscay Rise en route to Southampton. During the passage from the Azores we crossed the area studied in detail on cruise 68.

At 0815 on day 82 Discovery's engines stopped due to an empty fuel header tank, which had gone unnoticed because of a faulty alarm system. The ship broached to in heavy seas. The magnetometer was recovered immediately without damage, and the hydrophone array and airgun were recovered about an hour later when power was restored. When the ship had stopped, the GLORIA cable was running vertically down. Subsequently GLORIA was towed at low speed on auxiliary power for about an hour before speed could be increased. It is thought the GLORIA cable may have been damaged during this slow towing, although no damage was immediately apparent. By 1120 permission was received from the Master to recommence scientific operations, the seismic reflection gear and magnetometer were streamed, and we proceeded with the survey.

However, at 1633 the same day one of the GLORIA cable cores went open circuit, and it was decided to attempt recovery of the vehicle in spite of the presence of a heavy swell. After recovering the SRP gear and magnetometer, GLORIA recovery began at 1809, and was safely completed by 1840, without incident. The other gear was streamed again, and two NW-SE lines were steamed across the northern Azores-Biscay Rise in the time remaining.

At 0843 on day 84 the airgun and hydrophone array were recovered for the last time, and we set course for Southampton at 10 knots, all previous work having been carried out at a nominal 8.5 knots.

The continental shelf was crossed at 86/0100 and the PES fish and magnetometer were recovered at 86/0900. The ship docked at Southampton at 87/0800.

R.C.S.

PROJECT REPORTS

1. Azores Triple Junction

Five and threequarter days were spent surveying in the Azores region, using GLORIA, SRP, PES, magnetometer and gravimeter. Of these, about three days were spent over the Mid Atlantic Ridge.

The passage between the islands on days 74 and 75 showed en echelon swarms of faults trending 330° between the islands. Several volcanic centres in the islands are sited on extensions of these lines, which resemble the fault swarms seen in the neovolcanic zone of Iceland. It is believed that these swarms indicate the position of the Azores spreading centre. The westernmost swarm terminates in an E-W basin at 39°30'N, which appears to be a fracture zone connecting with the Mid Atlantic Ridge.

The Mid Atlantic Ridge survey showed a median valley as far south as 39°35'N. South of that there is a dextral offset of 15 km (at the 39°30'N fracture zone). The axial zone was traced as far south as 38°30'N, where the median valley may be reappearing. In between, the crestal region is either fairly level regionally, though locally block faulted, or there is a topographic high. The latter often did not coincide with the axis of the highly reflective zone seen on GLORIA which is believed to represent the youngest sea floor.

A number of roughly E-W lineations were seen between the eastern Azores and the Mid Atlantic Ridge, but none of them appears to be continuous between the Azores spreading centre and the Ridge axis. The familiar 010° faults of Mid Atlantic Ridge trend could be traced from the ridge axis to about 29°W, east of which Azores trends take over.

In addition to the 330° fault swarms, some strong 295° trends were seen, notably along the line of São Jorge island. These may represent an older style of Azores tectonism.

R.C.S.

## 2. Azores-Biscay Rise

On the outward passage the track was designed to study the eastern margin of the northern part of the rise ($45^{o}$N-$42^{o}$N). Rather surprisingly, the only structures seen were scarps of Mid Atlantic Ridge trend. Two seismic reflexion profiles made at the end of the cruise indicated that this northern part of the rise is characterised by a broad basement high, which is uniformly covered by sediment. Unfortunately GLORIA had to be recovered before the highest points on the northern part of the rise were reached on the return track.

On the south-western part of the rise ($41^{o}$N-$42^{o}$N) five days were spent on a box survey. Here the GLORIA records showed two basic trends, ENE and NNW, each characterised by linear, but apparently unfaulted, volcanic ridges. Several large seamounts previously mapped are located at intersections of these two trends. Some WNW trends were also seen. Few Mid Atlantic Ridge trends were seen on the rise, though they are common immediately to its east. Again this appears to be the result of a smoother basement structure over the rise, and perhaps also a slightly thicker sediment cover there. No sign of a rise structure was seen south of $40^{o}30'$N.

R.C.S.

## 3. Underway geophysical measurements

A summary of all underway observations is given in Table I. The precision echo-sounder, gravimeter and magnetometer were run continuously throughout the cruise except for the beginning and end when the ship was on the continental shelf. Soundings were logged on the computer every 6 minutes, or every 2 minutes over rough terrain. Gravity and magnetics were logged every 2 minutes.

GLORIA was in use continuously for almost 18 days, usually with a 40s pulse repetition rate (maximum range 30 km), but using a 20s rate (15 km range) for one run on the continental margin and one along the Mid Atlantic Ridge axis. Seismic reflection profiling was carried out continuously from the beginning of the cruise until day 84.

All underway operations were carried out at a nominal speed of 8.5 knots. The average speed made good was 8.3 knots. Separate reports on the equipment performance are given below.

R.C.S.

## 4. Navigation and data processing

The prime navaid throughout the cruise was the Magnavox/Hewlett Packard 2100 satellite navigator. This supplied fixes to the IBM 1800 which used them to update its own dead reckoning based on E/M log and gyro input. The new E/M log was initially calibrated using a disposable sonobuoy, but the calibration constants were revised twice following analysis of the course update vectors obtained during the Azores-Biscay Rise and Azores Triple Junction box surveys.

A few gaps in the navigation were created by faults in the E/M log interface and by the power failures to the Sperry Gyro. Pseudo fixes were inserted either side of the breaks to correct the navigation.

The computer was in use practically 24 hours a day. After the first fix of the day, the previous day's navigation was corrected by comparing the profiles of gyro in use, course made good and speed made good. If a noticeable jump occurred in either the c.m.g. or s.m.g. at the time of a satellite fix, that fix was rejected and the course, Eotvos correction, and free air anomaly were recalculated.

Once the navigation was satisfactory, track charts at 1:500,000 and 1:1M were produced, and listings of the depth entries given to the echo-sounder watchkeeper for checking. As soon as the depth, free-air anomaly and magnetic anomaly spikes were edited, profiles of magnetic anomaly and free-air anomaly were produced for each line to the same horizontal scale as the seismic reflection profile prints (see below). Annotated charts of free air anomaly, magnetic anomaly and depth were then plotted and listings of the geophysical data were printed. If there was any spare time, the meteorological data was edited. Finally, A4 sized plots of the track, and profiles of the course-made-good, speed-made-good, depth and magnetic anomaly were produced for inclusion in the cruise data report.

Each day the seismic reflection profiles were photographed by Polaroid camera, and the prints mounted alongside plots of the free-air anomaly and magnetic anomaly at the same scale.

GLORIA processing was carried out on a routine basis in daily batches from 2000 to 2000 hours. 8-hour tapes were replayed through

the Muirhead recorder as soon as they were completed. Anamorphic ratios were calculated each morning as soon as the previous day's navigation had been edited, and the records were then anamorphised and printed by the same evening.

D.J. and R.C.S.

EQUIPMENT REPORTS

1. GLORIA

The Gloria vehicle was launched in very good weather conditions about six hours after sailing from Brest. During the next 18 days, 3481 miles were steamed, before the vehicle was recovered about 24 hours prematurely because one core of the cable had gone open circuit and the unknown mechanical condition of the cable was causing concern.

The recovery was performed in fairly rough sea conditions. Although the wind speed was only 15 kts, there was a 25 foot swell running, but in spite of this the vehicle was recovered quite smoothly with no damage.

The equipment used was the same as in Cruise 90, but the power amplifier battery pack had been re-instated to 93 cells, providing the full line voltage of 35V. As before 4 channels of sonar information were recorded on each tape which had a duration of 8½ hours, allowing $\frac{1}{4}$ hour overlaps on three tapes a day. The AGC and fixed gain port and starboard sonar signals were then replayed on to the modified Muirhead K300 picture receiver and the resulting prints rephotographed on the slit camera with the appropriate anamorphic ratio. The resulting 35 mm negatives were printed to scales of 1:500,000 and 1:1,000,000.

The 4 sec, 100 Hz bandwidth pulse was transmitted at a 40 sec pulse repetition period for most of the time but for two lines, in the Southwest Approaches at the beginning and over the Mid Atlantic Ridge near the Azores, a 2 sec pulse with 50 Hz bandwidth was transmitted at 20 sec pulse repetition period. The pulses were transmitted on three array sections each side except for the triple junction area where two sections each side proved adequate. At all times all six sections each side were used for reception, and the receive beam was

stabilised with respect to the smoothed vehicle heading. About three hours of survey time were lost for system checks and maintenance, and one tape has not been replayed because of a recording fault, but it may be possible to recover this data later.

Vehicle yaw and ship yaw were continuously recorded on a two channel recorder and although it is not expected that this data will be extensively analysed it is a good check on towing stability and the record is available to check any "yaw-like" phenomena.

During the morning of the day that the cable fault occurred, the ship completely lost way for two periods of about 10 minutes, due to engine failure. After the second occasion there was a period of about 30 minutes steaming down wind at 50 rpm on one engine. During this time the vehicle behaviour could not be monitored because there was no a/c power. The speed down wind was probably no more than 3 kts and considerable cable snatching was observed. While the ship was stopped, the cable was more-or-less vertical over the stern. It is thought likely that this unhappy period spelt the end of this long lived cable which had been in use for about 41 days of not always perfect towing weather, with three launches and two recoveries. Although the open circuit core did not occur for a further seven hours, the main damage to the armouring was probably caused by cable snatching while travelling at very low speeds.

J.R.

## 2. Seismic reflection profiling

Seismic reflection profiling was carried out almost continuously for almost 19 days, with a loss of only about 8 hours recording time. Considerable general maintenance was carried out on the Williams and James compressors throughout the cruise, and only on one occasion (day 69) was more than an hour lost because of compressor failure. The airguns performed well, with no serious loss of data due to gun failure. The 40 cubic inch chamber was used for work around the Azores and Mid Atlantic Ridge, and the 150 cubic inch was used for the rest of the cruise. We used the IOS Géoméchanique hydrophone array, recording the two 50 m active sections independently. The only problem was an oil leak from the leading neutral section on day 82, when it was found that the forward joint was loose.

Two disposable sonobuoys were launched for a calibration of the E/M log. The first failed to deploy its hydrophone, but the other worked well.

R.C.S.

3. Echosounder

The echosounder was run continuously from 64/2006 to 86/0904 and gave no trouble. The additional weight recently added to the fish seems to have eliminated any tow-induced vibration. There was negligible wear on the pintles.

R.H.E.

4. Magnetometer

The spare magnetometer sensor was reported to have failed during the previous cruise. The fault was located in a damaged inboard plug on the outboard cable, and the plug was replaced. It will be necessary to stream this magnetometer to determine whether there are any other faults, but this was not done during this cruise because of the lack of suitable stands for the sensor and cable, making handling difficult.

The other fish and cable were towed throughout the cruise. A high frequency, 10 gamma amplitude noise was observed, but was effectively removed by the 2 minute computer filtering. The outboard cable in use is quite worn, and should be thoroughly checked and probably replaced.

P.A. & R.C.S.

5. Gravitymeter

No faults were evident on the gravitymeter for the duration of the cruise. However the meter was switched off for a period of about 2 hours due to a total loss of ship's power on day 82. It was noticed when the power was restored that the meter had cooled down below its working temperature during this period.

It was found that during rough weather the computed free air anomaly was very noisy. The noise was present in the Eotvos correction, but not the observed gravity, and is believed to have been introduced as a result of E/M log misalignment which had not been correctly calibrated out. To reduce the noise in the free air anomaly

the Eotvos correction was averaged over a 16 min window before being used to compute the free-air anomaly. This smoothing of gravity data was only applied when necessary.

During the cruise there were 19 crossover points, and these were used to evaluate the gravitymeter's performance. The worst crossover error in the free air anomaly was 3.3 mgal, with an average error of 1.3 mgal and a standard deviation of 1.1 mgal.

P.A.

6. Navigation instruments

(a) E.M. Log

The port log sensor head was replaced in Brest at the start of the cruise. It was found that the starboard sensor head had been connected to the port electronics unit and that the starboard electronics unit was not functioning correctly.

The port sensor head was reconnected to the port electronics unit, and this unit connected to the computer. This log was then calibrated on the basis of disposable sonobuoy station 9751, and the calibration was subsequently revised slightly to minimise course update vectors experienced on steaming reciprocal courses.

The starboard electronics unit was removed and examined. The athwartships component output was found to drift. This was thought to be caused by contact noise in the calibration switch, so the switch was wired to give operate mode only. The log was tested again and is now working correctly. It will be necessary to replace the calibration switch preferably with one that is more rugged in construction and has silver contacts.

While at sea the port log electronics overheated which caused the output to read zero knots. A fan was temporarily installed to ensure sufficient air circulation, and the problem did not recur. It is recommended that the ventilation of the unit be improved.

Another fault was the power supply's tendency to "latch up" when there was a failure of the ship's main supply. When power was restored the log output read 18 knots, and it was found that the 12 volt negative supply rail had changed to 12 volts positive and latched onto this new value until the mains supply was again

interrupted.

It would be an advantage to have one central calibration control for all the digital repeaters, rather than separate calibrations on each repeater.

P.A.

(b) Gyros

The Sperry gyro failed twice, on days 77 and 78. When the Bridge switched over to the stand-by gyro (Arma-Brown) the latter was found to be unconnected to the autopilot and computer repeaters so that for a while we had to rely on hand steering (which degraded the GLORIA records) and were without ship's head information to input to the computer navigation system.

R.C.S.

(c) Satellite navigator

The Magnavox satellite receiver and Hewlett Packard 2100 computer supplied satellite fixes as the prime navaid throughout the cruise. In general the system was trouble free. However, it was noticed that some of the fixes accepted by the IBM 1800 computer had been rejected by the Hewlett Packard. At the moment, the 1800 expects 2 fixes if the elevation is over $20^{o}$ and one fix otherwise. The 'goodness' of the fix is determined by its elevation (if it is less than $6^{o}$ or greater than $80^{o}$ the fix is rejected), or the number of iterations (if more than 6 the fix is rejected). The final choice between two fixes at the same time rests on the RMS value (the greater RMS fix is rejected). It may be a good idea to include a test of the doppler counts in the best fix decision.

D.J.

7. Meteorological instruments

Throughout the cruise, daily manual observations were made at 1200 from the following instruments:-

(1) Bridge Screen Thermometers (Port and Starboard),

(2) Bridge Barometer,

(3) M.O. Anemometer (relative wind).

These readings and the corresponding data produced by the IBM 1800 computer were recorded in a meteorological log to provide a running

comparison.

On analysis, the comparison shows a good correlation, indicating that the readings obtained were of good quality and that all instruments functioned well, requiring only general servicing.

N.J.S.

TABLE 1 UNDERWAY GEOPHYSICAL MEASUREMENTS

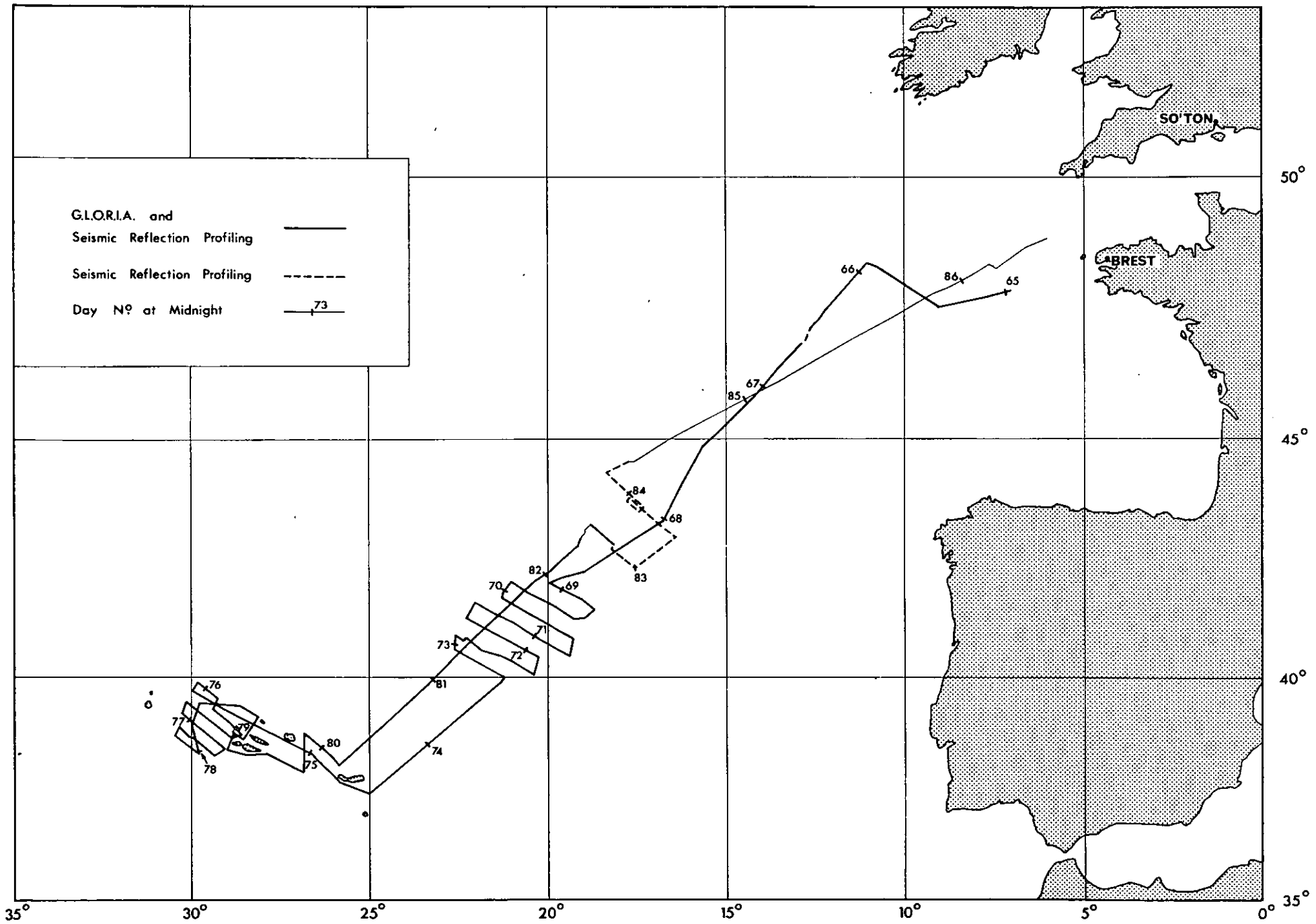
| Instrument | From | To | Total hours | Approximate miles | Comments |
|---|---|---|---|---|---|
| PES | 64/2006 | 82/0818 | 420.2 | | Not logged on computer until 65/0336. |
| | 82/1000 | 86/0904 | 95.1 | | |
| | | | 515.3 | 4277* | |
| Magnetometer | 65/0926 | 82/0818 | 406.9 | | |
| | 82/1202 | 82/1738 | 5.6 | | |
| | 82/1950 | 86/0904 | 85.2 | | |
| | | | 497.7 | 4131* | |
| SRP | 64/2028 | 69/0918 | 108.8 | | 150 cu.in. gun. |
| | 69/1605 | 74/1600 | 119.9 | | " " " " |
| | 74/1616 | 79/2100 | 124.7 | | 40 cu.in. gun. |
| | 79/2122 | 82/0820 | 59.0 | | 150 cu.in. gun. |
| | 82/1502 | 82/1720 | 2.3 | | " " " " |
| | 82/2006 | 84/0842 | 36.6 | | " " " " |
| | | | 451.3 | 3746* | |
| Gravimeter | 65/0810 | 82/0814 | 408.1 | | |
| | 82/1612 | 86/1520 | 95.1 | | Gravimeter run into Southampton. Computer logging stopped at 86/1520. |
| | | | 503.2 | 4177* | |
| GLORIA | 64/2037 | 65/2150 | 25.2 | | 15 km range. |
| | 65/2209 | 66/1200 | 13.8 | | 30 km range. |
| | 66/1500 | 78/0415 | 277.2 | | " " " |
| | 78/0430 | 78/0746 | 3.3 | | 15 km range. |
| | 78/0807 | 82/0820 | 96.2 | | 30 km range. |
| | 82/1255 | 82/1718 | 4.4 | | " " " |
| | | | 420.1 | 3481+ | |

*Assuming 8.3 knots. +Bridge log.

TABLE 2 STATIONS

| Station | Type | Start Time | End Time | Start Position | End Position | Comments |
|---|---|---|---|---|---|---|
| 9750 | Disposable sonobuoy | 66/1150 | 66/1204 | 47°08.8'N 12°39.6'W | 47°07.3'N 12°40.6'W | Hydrophone failed to deploy. |
| 9751 | Disposable sonobuoy | 66/1221 | 66/1401 | 47°05.4'N 12°41.9'W | 46°57.1'N 12°48.7'W | For e/m log calibration. |

# DISCOVERY CRUISE 91 MARCH 1978



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| 3 | DEC 1963 - SEP 1964 | 3* |
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| 40 | JUN - JUL 1971 | 48 |
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* 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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| 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 |
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| **RRS "JOHN MURRAY"** | |
| APR - MAY 1972 | NIO CR 51 |
| SEP 1973 | IOS CR 7 |
| MAY - APR 1974 | IOS CR 9 |
| OCT - NOV & DEC 1974 | IOS CR 21 |
| APR - MAY 1975 | IOS CR 25 |
| APR 1975 | IOS CR 39 |
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