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# I.O.S.

## R. R. S. DISCOVERY CRUISE 84

15 June - 28 July 1977

# GEOPHYSICAL AND GEOLOGICAL STUDIES OF THE CHARLIE GIBBS FRACTURE ZONE THE REYKJANES RIDGE AND KING'S TROUGH

I.O.S. CRUISE REPORT No. 60
1977

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Institute of Oceanographic Sciences,
Brook Road,
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SCIENTIFIC PERSONNEL

| | | | |
|---|---|---|---|
| A. S. Laughton | Principal Scientist | I. O. S. Wormley | Legs 1 & 2 |
| D. G. Roberts | Geophysics | " | Leg 1 |
| R. C. Searle | " | " | Legs 1 & 2 |
| R. B. Kidd | " | " | Legs 1 & 2 |
| P. M. Hunter | " | " | Legs 1 & 2 |
| P. R. Miles | " | " | Leg 2 |
| M. R. Saunders | " | " | Legs 1 & 2 |
| W. S. Blyth | " | " | Leg 1 |
| M. L. Somers | GLORIA | " | Legs 1 & 2 |
| J. Revie | " | " | Legs 1 & 2 |
| B. J. Barrow | " | " | Legs 1 & 2 |
| S. V. Bicknell | " | " | Legs 1 & 2 |
| A. R. Stubbs | Side-scan sonar | " | Leg 1 |
| D. G. Bishop | SRP | " | Legs 1 & 2 |
| B. S. McCartney | Acoustic navigation | " | Leg 2 |
| R. Edge | Mechanical Engineering | " | Legs 1 & 2 |
| A. W. Gray | Workshop | " | Legs 1 & 2 |
| A. F. Madgwick | Photographer | " | Leg 2 |
| M. G. Beney | Gravimeter | I. O. S. Barry | Legs 1 & 2 |
| T. Colvin | Computer | " | Legs 1 & 2 |
| D. Lewis | Computer | " | Legs 1 & 2 |
| M. Tharp | Visitor | Lamont-Doherty Geological Observatory U. S. A. | Leg 1 |
| J. Egloff | Visitor | U. S. N. O. R. D. A. | Leg 1 |

## SHIP'S OFFICERS

| | |
|---|---|
| M. A. Harding | Master |
| S. D. Mayl | Chief Officer (Leg 1) |
| P. J. MacDermott | Chief Officer (Leg 2) |
| J. S. Jones | 2nd Officer (Leg 1) |
| T. Gray | 2nd Officer (Leg 2) |
| M. S. Putman | 3rd Officer |
| J. J. MacLeod | Radio Officer |
| R. L. Cornford | Purser Catering Officer |
| J. A. Lennox | Chief Engineer Officer |
| P. J. Byrne | 2nd Engineer Officer (Leg 1) |
| P. Stone | 2nd Engineer Officer (Leg 2) |
| N. Wilson Deroze | Extra 2nd Engineer Officer (Leg 2) |
| R. J. Perriam | 3rd Engineer Officer (Leg 1) |
| B. J. Entwistle | 4th Engineer Officer (Leg 1) |
| P. March | 4th Engineer Officer (Leg 2) |
| R. G. Whitton | 5th Engineer Officer (Leg 1) |
| J. Landry | 5th Engineer Officer (Legs 1 & 2) |
| P. G. Barker | Electrical Engineer Officer (Leg 1) |
| B. Winchester | Electrical Engineer Officer (Leg 2) |

## DATES

| | | | |
|---|---|---|---|
| Leg 1 | Leave Barry | 15th June 1977 | Day 166 |
| | Arrive Reykjavik, Iceland | 5th July 1977 | Day 186 |
| Leg 2 | Leave Reykjavik, | 8th July 1977 | Day 189 |
| | Arrive Lisbon, Portugal | 28th July 1977 | Day 209 |

## SUMMARY OF CRUISE INTENTIONS

The cruise was devoted to two main objectives ( (1) and (2) ) following along projects started in previous years, and to several subsidiary objectives:-

### (1) The study of tectonic processes in mid-ocean ridges and associated fracture zones

Cruises in 1973 (FAMOUS area at 37°N), and 1975 (Kurchatov Fracture Zone at 42°N and the Canadian 45°N area) used GLORIA Mk I as a prime tool to study the accretion zone and the tectonic fabric of a slow spreading ridge typified by a median valley, small offset fracture zones and nearly orthogonal spreading. This cruise used the new two-sided GLORIA Mk II, in conjunction with the new medium range 36kHz side-scan sonar and other geophysical techniques, to study

(a) the oblique spreading Reykjanes Ridge,

(b) the transition between the elevated axial zone of the Reykjanes Ridge north of about 60°N and the rifted median valley zone of the Reykjanes Ridge south of about 59°N,

(c) the intersections of the orthogonal spreading of the Mid-Atlantic Ridge with the large offset Charlie-Gibbs Fracture Zone.

### (2) The evolution of King's Trough

Geophysical and geological data have been collected on many cruises since 1958 on King's Trough but a clear understanding of its origin has not yet emerged. On this cruise, the morphology of the whole feature was studied by side-scan sonar and other techniques and dredge and core samples obtained on a typical section of the faulted flanks.

### (3) Sediment transport mechanism in Rockall Trough

On passage to the Mid-Atlantic Ridge, a reconnaisance survey was planned to evaluate the performance of GLORIA Mk II in studying the low relief sediment structures on the Feni Ridge in Rockall Trough, believed to have been formed by south-going deep ocean currents.

### (4) Collection of passage sonar and other geophysical data

(5) First full operational use of GLORIA Mk II

(6) First full operational use of the hull mounted retractable sonar pod (36kHz side-scan sonar and narrow beam echo-sounding modes).

(7) Acoustic navigation

A new system of acoustic navigation for the ship and for near bottom equipment with reference to bottom beacons was tried.

## NARRATIVE

### Leg 1

R. R. S. Discovery sailed from Barry at 0900 and proceeded in fine calm weather west to the SW tip of Ireland and NW to the edge of the continental shelf north of Porcupine Bank (Figure 1). GLORIA was successfully launched at 1420/167 and sonographs were obtained from 2000/168 onwards as we crossed the shelfbreak and slope. The sonar pod was deployed and the 3. 5kHz fish launched by 2000/167. At 1200/168 the magnetometer was streamed and at 1720/168 seismic profiling started.

Three days were spent in Rockall Trough looking at sediment bedforms on the Feni Ridge before proceeding to the first survey area (area A) at the intersection of the mid-Atlantic Ridge axis and the Charlie-Gibbs Fracture Zone. The passage was made north of the East Thulean Ridge, associated with magnetic anomaly 24, and then along the sediment-filled southern trough of the eastern part of the Fracture Zone arriving at area A at 0600/173.

The survey at area A was only partly completed when news came of Professor B. C. Heezen's untimely death, and it was necessary to break off the survey to take Marie Tharp, his assistant and colleague, to Iceland to fly back to the U. S. A. All the overside gear was recovered in calm weather by 2200/174 and a fast passage made to Reykjavik anchoring in the harbour at 0830/177.

After landing Marie Tharp, we sailed at 1300 and set course down the axis of the Reykjanes

Ridge. In the time available before our scheduled visit to Reykjavik for leave and some changes in personnel, it was not possible to return to area A and so the original programme was altered to work first at area C on the Reykjanes Ridge. GLORIA and the other geophysical survey equipment was deployed by 0950/178, 200 miles SW of Icleland. The survey speed was increased for this and subsequent work from 7 to 8 kts with no deterioration of signal to noise. Oblique sections of the Ridge were made until 2200/180, the weather deteriorating to a force 8 gale on the night of 179-180. Another gale gave rough seas on days 182, and 183, subsiding on day 184 but with warnings of worse weather again on day 185. So after the completion of eleven short sections across the ridge crest and a profile up the ridge crest at 15 km range (20 sec pulse repetition period), GLORIA and the other gear was recovered by 2300/184. Seismic profiling had had to be terminated at 1800/182 on account of compressor failure in rough sea conditions. Discovery arrived at Reykjavik at the end of Leg 1 at 0930/186 and berthed alongside the central quay in the old harbour.

## Reykjavik

During the stay in Reykjavik, a party of four flew to Myvatn in the north of Iceland to examine rifting, akin to that being studied on the Reykjanes Ridge, which has been active since 1975. (See separate report).

## Leg 2

For Leg 2 there were several changes in scientific staff. The revised plan was to sail south to the Gardar Ridge, southwest to area B at the westerly intersection of the Charlie -Gibbs Fracture Zone (CGFZ) with the median valley, complete survey work in area A and then proceed to King's Trough (Figure 1).

We sailed at 0930/189 due south. At 61°N, 24°30'W at 0900/190, 1000 gallons of surface sea-water were collected for the Standard Sea Water Service at I. O. S.

By 1000/191 we arrived on the Gardar Ridge, after a calm passage and through a lot of fog, and deployed GLORIA, 3.5kHz fish, sonar pod, magnetometer and seismic reflection gear to make a reconnaissance run over the sediment bedforms related to the bifurcation of the ridge. A disposable sonobuoy station (9555) was made at 1732/191. An additional drogue that had been added to the GLORIA fish proved to be unstable and at 1915 we started recovering GLORIA. Entanglement of the drogue with the magnetometer and hydrophone array during recovery led to some cable damage on all three pieces of gear and all had to be recovered. It was not possible to wait around for repairs so the Gardar Ridge survey was abandoned and we proceeded to area B.

At 1530/192 all the survey gear was again deployed and we began the approach to the crest of the ridge north of the CGFZ. The area B survey was curtailed, by shortage of time from that originally planned, to three oblique crossings over the junction area before we made broad zig-zags along the active section of the CGFZ to area A. Two profiles were made in area A along the ridge between the north and south valleys, primarily to examine the continuity of the valleys and to obtain magnetic sections before leaving the area at 0500/196.

The passage to King's Trough (area D) took us along the western crestal mountains of the Mid-Atlantic Ridge viewing one side across the median valley and the other down the west flank, and later diverging from the axis.

The King's Trough survey started at 0900/198 on the extreme NW end and tracks were planned to examine all the interesting features. Disposable sonobuoy stations (9556, 9557, 9558) were shot in selected sedimented areas. The survey work was completed at 1930/201 on Antialtair seamount when all the gear (except for the sonar pod) was recovered. The sonar pod had jammed but was successfully retracted at 1200/202.

The second phase of the King's Trough work was devoted almost entirely to dredging and coring. Two bottom acoustic beacons were laid (after testing on the hydrographic wire) on the flat floor of the trough just south of the northern scarp in order to navigate both the ship and the dredge. A velocimeter station (9559) was made to 2000m. Although the ship navigation system was extremely effective, the remote interrogation for the dredge navigation proved to be impossible to use.

After a minisurvey of the scarp which was also used to calibrate the acoustic navigation, a series of eight dredge stations (9650-9566, 9572) and five gravity cores (9567-9571) were made on the scarp and on the crest of the north ridge, all of which yielded significant collections of bottom samples. Preliminary sedimentological and micropaleontological studies of the latter were completed on board ship.

By 1530/206 both acoustic beacons were recovered and a short passage made to Antialtair Seamount on the south flank of King's Trough where two gravity cores (9573, 9574) were taken near the top.

At 2000/206 we departed for Lisbon, with magnetometer echo sounding and gravity observations only, the track being designed to obtain a gravity profile across the Azores-Biscay Rise northeast of Peake Deep. Discovery berthed in Lisbon at 0900/209. On day 210, a gravity connection was made between Discovery and the local gravity base station at the Instituto Geografico e Cadastral.

Throughout the cruise the weather was very kind and only at the end of Leg 1 did we have significant rough weather which slowed the ship down. No other time was lost due to bad weather. The loss of working time due to the unscheduled visit to Reykjavik was about three days although the rearrangement of the programme enabled all the projects planned to be carried out. The only major equipment problems were concerned with the hydraulic power unit for the new twin barrel hydrophone and airgun capstan which was out of action for most of the cruise. The gear was operated from the centre line capstan. The compressors gave their usual continuous problems but seismic profiling was curtailed only once because of these. The 3.5kHz profiling system was disappointing in its performance due to high noise level in the receiver. By contrast the hull mounted 36kHz sonar proved to be extremely valuable in depths up to 1500m and was used both in the side-scan mode and as a narrow beam echosounder. GLORIA Mk II gave excellent results and the ability to look both sides gave double the coverage of Mk I. Launching and recovery proved to be very quick and easy, taking about 15-30 minutes in contrast to 3-6 hours for Mk I, and without the need for any work over the side or in the sea.

The scientific work was greatly assisted by the continuous collaboration and forbearance

of the Master, Officers and crew of Discovery to whom all the scientists are grateful.

## PROJECT REPORTS

### (1) Feni Ridge and the South Rockall Trough

The principal objective of the GLORIA traverses in the Rockall Trough (also made with airgun, 3.5kHz profiler and magnetometer) was to examine the spatial variation in morphology of the longitudinal sedimentary features which are developed on the flanks of the Feni Ridge, itself a thick accumulation of sediments or sediment drift that is built up against Rockall Plateau. The outward traverse to the Feni Ridge was planned to examine the slope north of Porcupine Bank and a large sedimentary slump that intersects the Feni Ridge.

Iceberg plough marks were observed on the outer edge of the Porcupine Bank but the floor of the Rockall Trough was in contrast relatively featureless. The traverse crossed the southeastern edge of the slump previously identified by a "deep-tow" study by Woods Hole Oceanographic Institute. At the edge of the slump, the layered sediments of the trough were truncated against the edge of a moat-like feature which was filled with acoustically transparent sediments. In contrast, the top of the slump was characterised by numerous hyperbolic echoes without coherent sub-bottom echoes. The GLORIA sonographs suggested a radial texture to the slump surface. The southwestern edge of the slump was crossed as the ship began a southwesterly traverse to the east of the Feni Ridge crest. At the edge of the slump, the hyperbolic echoes abruptly gave way to the uniform sub-bottom echoes which characterise the Feni Ridge sediments. Prominent sediment waves with a relief of 10 to 30 meters observed on the 3.5kHz seismic profile could be followed to extreme range (30 km) on the GLORIA sonographs. The waves are apparently linear over tens of kilometres and diverge from the trend of the Feni Ridge crest. Close to the crest semi-circular sediment waves were observed. At 53 °N where the Feni Ridge changes trend from southwest to west, the sonographs showed that the flanking sediment waves parallelled this change in trend. Analysis of the variations in thicknesses beneath sediment waves suggest that these waves are migrating toward the ridge crest.

GLORIA Mk II with the new facility of examining the seafloor on either side of the ship's track has shown that low angle relief of the order of 10 metres can be identified and followed to extreme range. In conjunction with the 3. 5kHz seismic profiler, GLORIA Mk II can provide a useful synoptic view of the dynamics of deep ocean sediment transport.

D. G. R. and R. B. K.

(2) Charlie-Gibbs Fracture Zone

The intentions here were to study the junctions of the mid-Atlantic ridge median valley with the fracture zone, to study the nature of the fracture zone median ridge, and to look for a possible short spreading centre in this ridge near 32°W.

The survey was divided between 1½ days on Leg 1 and 2½ days on Leg 2. We obtained almost complete GLORIA coverage of the two junction areas and the whole fracture zone east of 32°W and two oblique crossings between 32° W and the western junction area (Figure 2). We also ran two E-W lines along the median ridge east of 32°W, using the medium-range sonar principally as a narrow beam (fore and aft) echosounder. Magnetics, gravity, 40 cu. in. airgun, 3. 5kHz and PES were also run on all these tracks.

The familiar N-S, mid-Atlantic ridge trend fault scarps were clearly seen; they begin to curve sinistrally within a few kilometres of the transform fault traces. The transform faults are marked by deep (about 4km), narrow (also 4km wide), extremely straight valleys, V-shaped in cross-section, but sometimes partially filled with sediment. There are two major transforms as previously suggested, but we also observed several other, shorter, E-W lineations to the north and south of these major valleys. The median ridge which lies between the two transform faults contains numercus N-S trending targets, similar in spacing to the MAR trend fault scarps. We interpret this as evidence that the median ridge was produced by a short N-S trending spreading centre. However other trends, both NW-SE and NE-SW, are present in the median ridge so the precise nature of the spreading mechanism here is rather complex.

To the east of the active part of the fracture zone we observed NW-SE trending scarps, analogous to the oblique scarps observed at Kurchatov Fracture Zone during cruise 73.

Sedimentation at Charlie-Gibbs Fracture Zone is rather complex and current-produced sediment drifts are common.

R. C. S. and A. S. L.

(3) The Reykjanes Ridge

The accretion and tectonic processes of the central 100 km of the Reykjanes Ridge between 58° and 61 °N were studied by side-scan sonar survey using both the GLORIA Mk II and the hull mounted medium range (2. 5 km) sonar. A series of narrow-beam echo-sounding sections was made across the central 30 km. (Fig. 3).

In contract to the mosaics made of the FAMOUS area (1973) and the 45 °N area (1975), the survey was on a more open plan utilising the double-sided viewing of Mk II. Lines were run in a variety of directions enabling features to be seen from different angles. A final line along the axis was made using the 20 sec pulse repetition period (15 km range) and viewing to starboard only.

Two distinctive zones were found on the basis of the nature and trend of the bottom morphology:-

(1) Along the axis of the ridge (trending 036°) there is a zone of rough topography of constant width (13 km) giving high energy echoes and characterised by many discrete lobate reflectors of the order of 100 m across which are interpreted as lava flow fronts. This zone contains a series of 010° trending ridges several hundred metres high arranged en echelon with a spacing of about 8 km. These ridges, whose sides have moderate slopes, are interpreted as constructional volcanic ridges lying over the current or a recent spreading axis. Since a section, in the spreading direction, across this zone may contain two or sometimes three ridges, the crustal extension must either be shared between them or some ridges must be extinct, the spreading axis having jumped to a new position. The central rough zone is characterised also by faulting parallel to and mostly near the bases of the volcanic ridges.

Near the edge of the central rough zone are inward facing faults trending 030°, more nearly parallel to the Reykjanes Ridge axis. The volcanic ridges apparently either terminate at these faults obliquely or converge asymptotically so that they are sigmoidal in plan. The faults increase in throw from north to south.

(2) Outside the central rough zone, the entire area surveyed was characterised by linear faults with trends varying between 032° and 022°. A comparison of the echoes from two surveying directions and examination of the narrow beam profiles across the faults showed that the great majority were facing inward toward the ridge axis and that individual blocks were tilted outwards. The fault spacing along the flow direction is approximately 3km although several faults in this area are obscured by sediments. Sedimentation is patchy and appears to result from drifting associated with bottom currents parallel to the ridge axis. Little evidence has been found in this preliminary analysis of volcanic ridges (of 010° trend) in the outer zone, suggesting that faulting has destroyed or reduced them. Alternatively, the trend of the accretionary ridges may have changed about 600,000 years ago.

South from 61°N, the axial high, characteristic of the Reykjanes Ridge, reduces steadily in amplitude until by 58°N there is a well defined median valley. The transition depends on the balance of relief resulting from (a) the accretionary volcanic ridges and (b) the faulting adjacent to the rough zone. No significant changes are seen in the height of the ridges from north to south whereas the throw of the faults increases by a factor of three or more. In the north the axial high is a combination of volcanic ridges, outward tilting blocks and small inward facing faults, whereas in the south the cumulative throw of the faults exceeds the effect of tilted blocks and volcanic ridges, producing a median valley in which the ridges are found as echelon features.

A. S. L., D. G. R., and R. C. S.

(4) Field trip to Krafla rifting in northern Iceland

An episode of active rifting in northern Iceland started on 20th December 1975 and is still going on. Since this rifting may have close association with the rifting being studied on the Reykjanes Ridge, a field trip to observe it was organised through Dr. Sigvaldason of the Nordic Volcanological Institute and Dr. Björnsson of the National Energy Authority.

Dr. Laughton, Dr. Searle, Dr. Kidd and Mr. Egloff flew to Myvatn in the evening of day 187 187, spent the night at the Hotel Reynihlid, and were conducted around the area of recent rifting by Hjurte Tryggvason of the National Energy Authority.

Descriptions of the current rifting episode have been published by Björnsson, Selmundsson, Einarsson, Tryggvason and Grönvold (Nature 266, 318-323, 1977) and by Björnsson (Natturufraedingurinn, 46, 177-198, 1976). We were shown new fissures and faults near and across the tephra volcano of Hverfjall, the crater row of Ludentsborgir, new steaming and sulphurous fissures near to and crossing the diatomite factory, new dry fissures north of the Krafla power station which are twice weekly measured by micrometer, new mud volcanoes which had only developed two weeks previously, a sulphurous and steaming volcano and recently extruded lava fields. The Krafla geothermal power station, still under construction, is levelled daily to monitor inflation and deflation of the Krafla Crater floor.

Since December 1975, a total extension across the rift zone of 2 metres has been measured equivalent to 200 years worth of spreading at a mean rate of 1 cm per year. It is over 200 years since a major extension was last observed. A cycle of several months duration has been observed consisting of gradual regional inflation caused by the accumulation beneath the Krafla crater at shallow levels of magma from deep sources, followed by rapid deflation resulting from the widening of the rifts and fissures, and accompanied by a flow of magma along the fault system, seismic activity, volcanic tremors, faulting and thermal activity. The cyclic nature of this rifting episode and the episodicity of active rifting with intervals of several hundred years may have its analogue in the spreading and accretion process on the Reykjanes Ridge. To see these features in the field helped considerably in visualising the possible nature and scale of the features shown by the medium and long range sonar beneath the sea.

A. S. L.

(5) King's Trough

Because of the rearranged programme following the ship's double visit to Reykjavik in

Leg 1, only $3\frac{1}{2}$ days were available for underway surveying at King's Trough. It was therefore decided to abandon the survey of the junction of Peake and Freen Deeps with the Azores-Biscay Rise and concentrate on King's Trough west of 20°W (Fig. 4). Using GLORIA Mk II, 160 cu. in. airgun, gravimeter, magnetometer and PES, we obtained complete GLORIA coverage of the trough between 25°W and $21\frac{1}{2}$°W, examined the seamounts near $43\frac{1}{2}$°N, $23\frac{1}{2}$°W, ran up the ridge to the summit of Antialtair Seamount from the SE (the last part including a medium range side-scan sonar traverse of the top of Antialtair) and obtained one profile normal to the trough at $22\frac{1}{2}$°W and one oblique to it near 21°W.

Preliminary analysis of GLORIA sonographs reveals a complex pattern of fault trends. The dominant trend is 120° (King's Trough trend), but trends of approximately 100° and 155° are also common; there are also a few NE-SW and N-S trending targets. One new feature observed was the almost complete closure of the abyssal plain in King's Trough by a N-S ridge at 21°51'W. The side-scan record over Antialtair revealed a flat top to the seamount comprising numerous outcrops of rock, probably basalt, and small pockets of sediment. A prominent terrace was seen 200m below this. Three sonobuoy stations were run, one in the trough and two on the north flank (Table I).

Following the recovery of the streamed gear we dredged and cored for 5 days, completing 8 dredge and 7 core stations (see Table I, Fig. 5 and later reports). Our prime sampling site was the south-facing scarp at 44°N, 22°W; the GLORIA and airgun data showed this to comprise a number of downstepping fault blocks striking 120° between south-jutting spurs of mid-Atlantic ridge trend. Most of the fault scarps were successfully dredged while navigating acoustically using bottom-laid beacons; the dredge-hauls recovered volcanic and sedimentary breccias; volcanic ashes, basic igneous rocks, chalks, and a variety of limestones, together with numerous erratics (granites, gneisses, schists and quartzites). The volcanic breccias and the chalks were recovered from most depths in the section and it is likely that the downfaulting repeats the sequence. The sedimentary breccias are partly made up of rounded fragments of volcanic material and are probably shallow water deposits. The occurrence in the wholely volcanic breccias of large clasts of vesicular basalt may also suggest deposition in relatively shallow water. Most of the chalks are tentatively dated as Oligocene in age based upon shipboard study of nannofossils. These nannofossil chalks contain aragonite needles which would indicate open marine environments but at depths shallow enough to preclude aragonite dissolution.

Coring around the crest of the ridge recovered white nannofossil chalks, tentatively dated as Late Oligocene (or Earliest Miocene). One contains macrofossils which again suggests relatively shallow environments. The coring also recovered fragments of the same volcanic breccias as in the dredge hauls, and also unconsolidated recent oozes. The last two core stations were on Antialtair Seamount. Station 9573, on the flat summit, recovered only a few chips of weathered basalt and bryozoan debris and resulted in a bent core-barrel. Station 9574 on the terrace 200 m lower, recovered foram nannofossil chalk of possible Middle Miocene age (?).

R. C. S. and R. B. K.

(6) GLORIA Project (Mk II)

Cruise 84 was the first operational cruise of the Mark II equipment. The vehicle was deployed twice on the first leg, the break being due to the necessity of going to Iceland. During the second deployment the ship encountered a two day gale at the end of which it became necessary to shut down the port array. Some of the vehicle data was also missing but not the heading. The damage turned out to be due to mis-alignment of the armouring wires known as "bird-caging". It was thought at this time that the root cause had been surging of the cable during the gale, allowing the residual twist in the armouring to accumulate at the towing point. To avoid this surging a small drogue was fitted to the end of the tailrope for the second leg deployment. However after a few hours it became apparent that the drogue was interfering with the vehicle towing behaviour and the vehicle was recovered sustaining superficial cable damage in the process. The third deployment was successful and the vehicle was recovered only when the cruise programme called for it. There was, however, a certain amount of the same "bird-caging" problem.

The majority of the surveying was carried out at 8 knots (7 knots for the first seven days of operation) with the 40 second pulse repetition period, that is a range of 16 nautical miles (30 km) each side of the track, and targets were frequently detected out to this full range. The 4 second 100 Hz FM pulse was used almost exclusively and both arrays were processed in both AGC and fixed gain channels giving four information channels in all. Transmitted power was 1.5 Kw in each of three sections of each array. For the first seven days of operation the beam steering servo was zeroed at each transmission pulse and during the subsequent reception interval the acoustic beam was stabilised to this direction. Transmission on less than the whole array widens the effective horizontal beamwidth slightly, but has great operational advantages and is essential for the reception mode used latterly, when the beam steering servo was not zeroed but stabilised continuously to a direction perpendicular to the vehicle heading filtered with a high pass characteristic of 10 minutes cut-off period. The final option of steering the full array transmission to this filtered direction as well as the reception is being reserved until full confidence in the equipment is built up. On very rare occasions this wider effective beam showed evidence of hyperbolic patterns from extremely strong isolated targets. Also on one or two occasions when operating over flat high reflectivity bottoms there was clear evidence of surface-bottom reflected paths. There was virtually no evidence of double-bottom reflections. It has to be remembered that although an optical analogy is often used, side-scan sonar is in no sense an optical tool and the inevitable imperfections while confusing the data do not obscure it.

The recording and replay arrangements reflected the interim state of the project between Mk I and Mk II. Due to a shortage of tape-recorder channels all three machines available had to be in use continuously, two recording and one replaying at a speed-up factor of eight. While the arrangements worked it was possible to keep up with the replay, anamorphosis and printing with the usual delay of between 36 and 48 hours. If a replay went wrong it was not always possible to refit it into the schedule. Altogether nearly 300 tapes of four hours duration each were recorded, entailing several hundred passes through the anamorphic camera and over 3000 prints at different scales. At the end of the cruise only one tape had not been replayed, a short section at 10 second pulse period.

The towing characteristics of the vehicle came under severe test during the gale. There is a tendency for the vehicle, when the pitching of the ship snatches the cable, to recover from the induced pitch by way of a yaw. Pitch was found to be the most unsatisfactory ship motion for the vehicle. Occasionally, especially in the King's Trough area, quite large heading variations were encountered which could only be ascribed to current shear.

It might in conclusion be recorded that the Mk II equipment came fully up to the expectation and only changes in detail are contemplated.

M. L. S.

(7) Seismic reflection profiling

4000 miles of track were surveyed at an average speed of 8 kts, using a Géomechanique 2 channel array. Despite the higher than normal surveying speeds, the background noise level remained low, resulting in good quality records which gave all the information required on this cruise. Two EPC recorders were run side by side. One was filtered 5-100Hz and the other was time-varied filtered (TVF). The TVF record is particularly useful because it has high frequency filtering in the first $\frac{1}{2}$ - 1 second of penetration where resolution is important, decreasing to low frequency filtering where the deeper reflectors are expected.

Owing to a fault in the hydraulic pump, the new twin drum capstan was inoperative for most of the cruise and was used only towards the end, after it had been repaired. It proved to be highly successful, giving complete independence in operation of the airguns and hydrophone array. It does, however, require some form of reeving gear to assist in layering the array on the drum, and also an extra roller-guide to keep the tow cable away from the 'A' frame and to improve the direction in which it passes over the stern-roller.

Just over half way through the cruise the GLORIA drogue snarled up the array tow cable and damaged it 80 metres from the array. This was taken off and replaced by the new spare cable.

The compressors were more reliable this cruise, but still required more attention than would normally be expected.

The airguns were still extremely reliable requiring only the usual maintenance of servicing. A problem which will have to be resolved at the end of the next cruise is the excessive corrosion on the aluminium connector which is attached to the two cable connector.

Despite some of the problems, the down-time of the system was minimal and the quality of the data high.

D. G. B.

(8) Disposable sonobuoys

Four successful sonobuoy stations were occupied during leg 2. No sonobuoy failures occurred and apart from the first station good signal-to-noise records were obtained. The sonobuoys were attenuated by 20dB. Irregular sea bed topography was a problem in choosing sites but this did not diminish the quality of the records significantly. Good refracted arrivals were obtained at two stations. The 10 second gun rate improved the event correlation of the data particularly when monitoring on an EPC recorder.

P. R. M.

(9) 3.5 kHz profiler

This cruise was used to test the Edo Western 3.5 kHz system, in deep water beyond the continental shelves, as a tool in distinguishing gross sedimentary structure down to 100 metres subbottom.

Past experience has shown that this system with an unfaired tow cable, produces noisy records due to strumming. For this reason the tow cable was faired prior to this cruise. At a surveying speed of 8 kts the fish towed well with no detectable strumming.

What we had not expected was the high level of ship's noise picked up by the transducer at this operating frequency; the noise was modulated at about 7 Hz and is probably caused by the main diesel enginees or propeller. One other source of interference was the GLORIA transmission pulse, which was reduced considerably by the use of a bandpass filter connected between the receiver and the EPC recorder.

The instrument was at its most useful during the Reykjanes Ridge survey operating at depths between 1000 to 2500 metres. Here gross sedimentary structure could be classified into three main types: draped (pelagic sediments), ponded (gravity-emplaced sediments) and "drifted" (contour current deposits). Such classification provided considerable information on the sedimentary history of this part of the mid-ocean ridge system and it would be useful to have the facility to use the instrument in deeper regions.

Generally, however, low level signals coupled with the high ambient noise made the system virtually inoperative in deep water. The only answer to this problem seems to be a receiving transducer towed behind the ship, well away from the ship's noise, since all measurements of transmitter power into the transducer suggest adequate insonification.

D. G. B. and R. B. K.

(10) Medium range sidescan sonar and telesounder instrumentation

In general the side-scan sonar equipment worked well, double-sided operation being used on all occasions when the depth allowed. In deeper water the Port side was used at certain times as a narrow beam echo-sounder, the pulse length and gain being reduced to give a 'just marking' trace. This was an attempt to produce a more precise profile. The refraction and noise were about the same as for the previous cruise (no. 83).

The telesounder was not used for any survey work. The opportunity was taken to determine the source of some persistent interference on the record (which had also been observed on radios on the long-wave band). This was found to emanate from the ship's compass system and suppressor capacitors across each phase provided a cure. It was noted that although the distribution cables are screened the latter are not connected to the ship.

A. R. S.

(11) Gravimeter

Gravity data were recorded throughout the cruise using an Askania GSS3 Gravity Meter (Serial No. 52) mounted on a stabilised platform of S. G. Brown (Watford) construction. The analogue value from the gravity electronics was digitised by means of a Hewlett Packard digital voltmeter and the parallel BCD output was initiated and sampled once a second by the 1800 computing system. The three least significant digits were converted to an analogue signal and recorded on a chart recorder giving a chart span of approximately 100 mgals.

Every two minutes the computer averaged and logged the recorded one-second values, and during course updates it calculated an Eotvos and latitude correction. The corrections were applied to the next measured gravity value to take account of the two minute delay due to the internal filtering of the gravity electronics, and the resulting Free Air Anomaly was stored in CDAT. There was also provision for off-line smoothing and recomputing of Eotvos correction and Free Air Anomaly.

Installation of the cabling was achieved in South Shields during the refit prior to Cruise 83 together with the testing of the sampling and programming facilities. Installation of the gravity meter took place in Barry prior to the cruise.

Interference from radio transmissions on the ship produced positive bumps in the data logged by the computer and an undiscovered source produced negative spikes with a maximum occurrence of six a day. Both forms of interference were edited from the data on a daily basis.

The major problem of the cruise involved the Eotvos correction. This was calculated from the course and speed-made-good. Between two satellite fixes the course and speed-made-good were dependent on the current velocity and direction as calculated using these two fixes. On either side of the time for a satellite fix the current velocity and direction differ whilst between them it remains constant. The effect was to produce an Eotvos correction with steps. Applying this correction to a relatively smooth value of uncorrected gravity produced a Free Air Anomaly with steps. It was necessary to use the gravity data to assess the quality of the satellite fixes, and by rejecting up to forty per cent of the daily satellite fixes a reasonably smooth value for Free Air Anomaly could be obtained. An eight minute filter was applied to the final value. This problem could be overcome if more sophisticated navigation software were available to make a "best fit" of track to fixes, rather than forcing the track to pass through every fix.

Down time for the gravity system amounted to three hours, most of which was lost due to overheating of the digital voltmeter.

Some problems occurred during the first few days of the cruise due to dropouts of the bit 8 of the next to least significant digit at the computer/gravimeter interface. Most of the effects were edited out, affected data being given status 1. Other data were given status 2 during this initial period. The fault was rectified on 172/1500, and subsequent gravity data was logged at status 3, except for obvious errors and spikes.

The ship tied up opposite the gravity base station at Reykjavik J at the end of leg 1, and a tie was made with station Lisbon A at the end of leg 2. The differences (ship-base) were -0.4 mgal and +0.6 mgal respectively. Crossover errors between Day 174 (Leg 1) and 209 (Leg 2) averaged 3 mgals.

M. G. B. and R. C. S.

(12) Magnetometer

Operation of the Varian V-75 Proton magnetometer was continuous throughout the cruise except during the dredge and core stations of Leg 2. The system operated well with a marked decrease in the number of data spikes produced from external interference. Damage to the fish cable from contact with the hydrophone and GLORIA cables during Leg 2 was repaired and gave no trouble. Owing to these repairs, the amount of service left in the cable of fish A may be limited, the outer covering having been damaged in two places. The poor operation of the pens on the analogue chart recorder was rectified during the cruise.

P. R. M.

(13) Acoustic navigation

Because of the need to deploy GLORIA and recover it once only in order not to jeopardise Cruise 85, it was not possible to test any of the bottom transponder beacons (B. T. B. s) or the remote interrogator package (R. I.) until just before their deployment. Two B. T. B. s were tested to 4,000 m on the 6mm conducting cable of the forward electric winch, which was also used to 2000 m with the third B. T. B. and the sound velocimeter for station 9559.

Two bottom transponders were then laid about 10 km apart in King's Trough, 4 km SE of the north scarp where dredge stations were planned. Each B. T. B. had a 200 lb length of chain for anchor, 200m of light line to the B. T. B., and a further 100 m of line to two glass buoyancy spheres in plastic protectors. Each B. T. B. was fitted with a double pyro-release. The interrogator 'fish' was towed from the aft boom on the Port side.

The B. T. B. s worked satisfactorily, ranges being generally limited by topographic shadowing before the refraction limit of 32 km. The network was surveyed in for initial operational use by making three baseline crossings during S. R. P. traverses of the North scarp. Subsequently all the good satellite fixes obtained whilst acoustic ranges were taken were used in the programme COKAT to determine the best (least mean square error) estimate of the B. T. B. positions (Table II). The ranges of the ship from each beacon were plotted manually, with a beam compass to a scale of 1:50,000, generally at 10 minute intervals, to navigate the ship during eight dredge stations. The beacon depths 4357 m and 4353 m were taken to be 200 m less than the corrected echo-sounding depths at the lay positions. The sound velocity used during the operational phase, 1506.5 m/s, was taken from Matthews tables, but the harmonic mean sound speed from the sound velocity profile, which showed an unusual maximum at 900m, was 1510.5 m/s and this was used for final working up of the data. At the end of the dredge stations the B. T. B. s were acoustically released and then recovered. Rise time to the surface was approximately 45 minutes, compared with a fall time at deployment of 42 minutes. After 4 days use the batteries had more than 80% capacity remaining on recovery.

The remote interrogator in its protective sledge was tested four times in the main warp after an initial deployment on the dredge had been unsuccessful. It operated as a reply transponder after some adjustments to gain and thresholds, but the remote interrogation channel proved difficult to set up. Either the channel was too sensitive and triggered on noise, possible rattling shackles, or too insensitive in which case the remote interrogation channel would not work deeper than 1,000m. Problems were also experienced with component failures, particularly the driver stage transistors and the output transformer. Time ran out before all these could be resolved, but in any case the noisy environment on the wire offers little prospect of success when the acoustic link needs a listening device near the dredge. It will be worth considering an alternative approach in which the sea unit contains a precision 5.1kHz source pulsing on a timed cycle to allow the dredge position to be determined relative to the B. T. B. s whilst allowing the ship to do the same. Dredge depth will need to be determined separately, by a pressure transducer for example, if only 2 B. T. B. s are used.

The principle development of the B. T. B. is one of engineering for simpler, quicker use, possibly expendable, possibly able to be deployed from the ship when underway and towing S. R. P. gear, GLORIA and the magnetometer.

B. S. M.

(14) Shipborne computing and data logging

The computer system was used during Cruise 84 to log meteorological, bathymetric, magnetic, navigational and, for the first time, gravimetric data. It was also used to provide accurate navigation and produce a variety of track charts and data annotated tracks.

The navigation was achieved by combining the satellite fixes obtained from a Magnavox Satellite Navigation System on the bridge with the DR (calculated from the E. M. log and gyro) produced by the I. B. M. 1800.

Each midnight the previous day's navigation was examined and corrected by editing out poor quality satellite fixes. During most of the cruise this was done in conjunction with the gravimeter data. As the correction applied to the gravity data was dependent on speed and heading apparent changes in these parameters assisted in determining the quality of satellite fixes.

Once all the data had been checked and edited as necessary, track charts and annotated track charts with bathymetry, magnetic anomaly and free air gravity anomaly were produced daily at a scale of 1:1,000,000. Where required these charts were also made at a scale of 1:250,000 and 1:50,000.

Profiles along the ship's track of bathymetric and magnetic data were produced for specific surveys during the cruise. Listings of bathymetric and gravimetric data were printed daily. The course and speed-made-good, magnetic and bathymetric data was plotted against the distance run for each day.

The computer functioned well for the majority of the cruise, only a short period of data being lost due to equipment failure. The logging of gravity functioned satisfactorily after some early component failures in the interface circuit.

Some improvements to the software were suggested. Satellite fixes of a low elevation and poor quality were often accepted and used by the computer when they had been rejected by the HP 2100 system. Some refinement was requested to alter this so that only good quality fixes were passed to the computer. Also, it was felt that some means of plotting the current vectors calculated by the computer would have been very helpful in assessing satellite fixes and the behaviour of the navigation system as a whole.

T. C. and D. L.

(15) Meteorological observations

Meteorlogical observations were logged automatically by the computer and manual checks were made each day at 12. 00 from the following instruments:

(1) Bridge screen thermometers (port and starboard)
(2) Bridge barometer
(3) M. O. sea temperature (R. A. S. T. U. S. )
(4) M. O. anemometer (relative wind)
(5) Ship's speed and course

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

On analysis, the comparison series showed a good correlation, indicating that the readings obtained from all the instruments were of good quality.

Data were obtained throughout both legs of the cruise. All the scientific instruments functioned well, requiring only general servicing.

M. R. S.

(16) Dredging

All dredging operations were carried out on the scarps on the north side of King's Trough (in depths between 1850 and 4550 metres), in order to sample a section of the faulted crust. The intention was to navigate both the dredge and the ship acoustically with reference to the two beacons laid on the sediment plain in King's Trough. However, owing to the failure of the remote interrogator unit which was to have been used 200 m above the dredge chain, only the ship was acoustically navigated. The rig consisted, therefore, of the main warp, a 6 ton swivel, a tilt switch pinger housed in a robust in-line sledge, a 5 ton weak link, 10m of 15 ton studded cable, a 2 ton weak link, a chain bag dredge (IOS design) and a throttling band connecting the dredge bag to the chain side of the 2 ton weak link. The shear pins in the dredge frame were increased in size to 3/8" bolts to avoid low stress shearing. The dredge was further modified by the addition of four one inch square aluminium sampling boxes in the corners of the dredge frame. These proved very valuable in collecting some sediment and small pebbles which would have been filtered out by the dredge bag. The chain bag was lined with a nylon net of about 1 inch mesh.

The dredging operation was helped enormously by the 10 minute fixes from the acoustic beacons giving true positions relative to the bottom and enabling the reactions to changes in ship's head and speed to be monitored. The tilt switch (operating at 10° from the horizontal) gave good indications of the dredge being on the bottom, although more power is necessary to give consistent bottom echoes. Another great improvement in technique was the recording of the direct and filtered (greater than 2 Hz) dynamometer output in the plotting office. The filtered output showed when the dredge was sampling the bottom even in the presence of ship heave and wire thrum, and avoided the need to feel or sit on the wire.

Apart from the first dredge station when the pinger failed and acoustic navigation was not available, all stations collected rocks many of which were broken off cliffs. In one haul, a full bag of in situ and large erratic rocks was recovered (see Table I). A. S. L.

(17) Coring

The 3 foot, narrow diameter core barrels from MSES specifically provided for rock coring are not suitable for fitting with core catchers and we felt that recovery of both unconsolidated and consolidated sediments from depths greater than 1000 meters would only be successful using equipment fitted with both catcher and liner. Thus the MSES $2\frac{1}{2}$" diameter corer was rigged for gravity-type coring and both 12 foot and 9 foot barrels were used during the programme at King's Trough. A 124lb trigger weight with a double-stropped rope was assembled together with a free fall wire of approximately 20 m, giving a free fall of about 8 m.

The coring sites were accurately located as a result of detailed pre-site surveying. No pinger was used since triggering and pull-out were easily seen on the dynamometer. (The dynamometer output was recorded on an HP 2100B chart recorder with 10 ton f. s. d. and 0. 5 inch per minute paper speed). Pull-out force varied from 0 to about 2 tons and was generally correlated with the length of core recovered. Table I shows the results of the seven coring stations, five at the crest of the northern ridge of King's Trough upslope from the dredge stations and two on the summit of Antialtair Seamount on the south side of the trough. All but two stations, D9569 and D9573, were successful in terms of our objectives: that is, the recovery of consolidated sedimentary or volcanic rock.

The core cutters used were not really suitable for rock coring operations since they were too soft; specially tempered metal will be required in future. When the 12 foot barrel was in use core cutters were lost. This appeared to be due to insufficient matching of the cutter groove with its retaining grub screws. The 12 foot barrel was reduced to half its two-section length after its lower end became flattened at Station D9568 but flattening occurred again at D9570. Eventually at Station D9573 the whole barrel length was bent and fractured so that at the last station a 9 foot barrel was used.

At the stations where most corer damage was sustained there was little or no recovery. Here we suspect we may have encountered either outcropping basalt or large erratics. A surface scattering of small erratic pebbles however does not seem capable of preventing penetration since such a surface was penetrated successfully at Station D9567.

R. B. K.

(18) Water samples for the Standard Sea Water Service

One hundred 10 gallon samples of surface water were obtained for the Standard Sea Water Service at I. O. S. The samples were collected, through the ship's seawater pump system after several hours of flushing, in plastic containers which were rinsed before filling. The samples were collected between positions 60° 49'N, 24°21'W, and 60°36'N, 24°27'W between 0900 and 1039 on day 190. They were stowed in the forward hold and in the magazine to reduce possible evaporation.

M. R. S.

(19) Passage data

Every opportunity was taken to obtain data on passage with echo-sounder, magnetometer, gravimeter, 3.5kHz profiler, seismic reflection profiler, medium range sonar and GLORIA. The periods during which equipment was deployed (or used) is shown in Table III. Echo-sounding, gravity and magnetics could be run at full cruising speed whereas 3.5kHz profiler, SRP, medium range sonar and GLORIA were limited initially to 7 kts, but from day 178 to 8 kts.

A. S. L.

(20) Navigation

Satellite navigation was used throughout the cruise as the prime navaid, the course corrected track between fixes being calculated by the computer from the fore-and-aft and athwartships logs combined with the ship's head from the gyro. Current vectors were calculated. The Magnavox 702A receiver and the HP2100 computer were used throughout and all fixes regardless of whether they were rated as "CRIT. OK" or not were transferred to the 1800 and evaluated on the basis of a maximum current vector of 2 knots. Many low or or high pass satellite fixes had to be rejected manually in subsequent editing and new tracks prepared. A modification in the software is necessary to use the HP2100 assessment of the fix quality in deciding whether it should be used by the 1800 or not.

Although Loran C coverage in the Reykjanes Ridge region is good, a defect in the power supply of the unit prevented us from using it.

During operations in King's Trough the acoustic navigation system described in Section 12 was used.

A. S. L.

(21) Filming of geological and geophysical activities

During Leg 2 of the cruise sequences were shot for the proposed film "The Earth Beneath the Sea". The deck activities were filmed from as many positions as possible to show the deployment and recovery of the instruments and equipment to best advantage. This is becoming difficult because of the increased amount of fixed deck equipment and the number of people on the deck during these operations. The laboratory sequences including activities in the plotting room and scientific discussions were shot, in most cases, during the normal routine of the ship. Only a few shots had to be set up for the camera. In all about 3,600 feet of film was used. The footage which is not edited into the film will go into the Institute's film archives. Spot effect, general atmosphere sounds, and discussions were recorded 'wild' for subsequent use in the film. Still photography was used to systematically record all the dredge and core samples.

A. F. M.

TABLE I - STATION LIST, DISCOVERY CRUISE 84

| Station No. | Type | Equipment Used | Date | Time (Z)/Day No. From | To | Lat. N Long. W | to Lat. N Long. W | Seafloor Depth Range (m) Max. | Min. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 9555 | Seismic | D. S. B. | 10 July | 1732/191 | 1836/191 | 56°24.8'<br>27°17.7' | 56°18.8'<br>27°29.4' | 2701 | 2631 | Successful.<br>Poor signal to noise ratio. |
| 9556 | Seismic | D. S. B. | 18 July | 0401/199 | 0532/199 | 44°02.4'<br>22°29.6' | 43°56.1'<br>22°15.6' | 4539 | 4500 | Successful. |
| 9557 | Seismic | D. S. B. | 18 July | 1301/199 | 1420/199 | 44°15.9'<br>22°02.3' | 43°26.1'<br>22°05.4' | 3608 | 3119 | Successful.<br>Poor definition of reflecting horizons. |
| 9558 | Seismic | D. S. B. | 19-20 July | 2243/200 | 0004/201 | 43°30.5'<br>20°57.6' | 44°33.3'<br>22°59.1' | 3915 | 3379 | Successful.<br>Poor basement topography.<br>First arrival refractions. |
| 9559 | V. and B. T. B. test | V<br>B. T. B. (no. 3) | 21 July | 0504/202 | 0736/202 | 43°49.8'<br>22°07.8' | -<br>- | - | - | To 2000m in King's Trough. |
| 9560 | Dredge | Dredge<br>B. T. B. s | 21-22 July | 1032/203* | 1110/203 | 43°50.67'+<br>21°56.72' | 43°49.69'<br>21°56.88' | 4485 | 4530 | Dredge bag empty. In corner boxes: three chips of basalt and one of metamorphic rock. |
| 9561 | Dredge | Dredge<br>B. T. B. s | 22 July | 1804/203* | 1951/203 | 43°50.18'+<br>21°52.85' | 43°49.18'<br>21°50.15' | 3791 | 3635 | Good haul: More than 120 separate rock samples recovered. Pins sheared on dredge arms. White ooze in corner boxes. One small live squid. In-situ rock assemblage includes: volcanic breccias and ashes, sedimentary breccias and chalks. |

| Station No. | Type | Equipment Used | Date | Time (Z)/Day No. From | To | Lat. N Long. W | to Lat. N Long. W | Seafloor Depth Range (m) Max. | Min. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 9562 | Dredge | Dredge B. T. B. s | 23 July | 0108/204* | 0204/204 | 43°54.75'† 21°56.47' | 43°53.90' 21°55.22' | 3350 | 3187 | Small haul: 35 assorted rocks. Dredge arm pins sheared again. Foram chalk in one corner box. In-situ rock assemblage includes white (Oligocene?) chalks, basalts and volcanic breccias. |
| 9563 | Dredge | Dredge B. T. B. s | 23 July | 0543/204* | 0702/204 | 43°53.66'† 21°57.57' | 43°52.75' 21°56.38' | 4117 | 3611 | Small haul: 32 rocks but mostly large in-situ boulders. White chalk and tan foram ooze in corner boxes. Rock assemblage mainly freshly broken volcanic breccias or white chalks. |
| 9564 | Dredge | Dredge B. T. B. s | 23 July | 1218/204* | 1335/204 | 43°59.09'† 21°54.08' | 44°00.11' 21°52.34' | 2645 | 2446 | Dredge bag absolutely full. Largest boulders are glacial erratics. Ooze with pteropods in corner boxes. Live debris of echinoids, brittlestars and encrusting organisms in bag. In-situ rock assemblage includes basic igneous rocks, white (Oligocene?) chalks, volcanic breccias and ashes. Much still unsorted. |
| 9565 | Dredge | Dredge B. T. B. s | 23-24 July | 2046/204* | 2309/204 | 43°52.90'† 21°57.85' | 43°51.57' 21°56.41' | 4182 | 3880 | Small haul: 9 rocks. Bag throttled, 2 ton weak link gone. Foram ooze in corner boxes. One live sea pen. In-situ rock assemblage is volcanic ashes and breccias and limestones. |
| 9566 | Dredge | Dredge | 24 July | 0755/205* | 0810/205 | 44°02.64'† 21°48.68' | 44°02.92' 21°48.56' | 1859 | 1856 | Small haul: 13 rocks thickly $M_n$-encrusted. Dredge frame lost but bag throttled. All rocks in-situ sedimentary breccia with volcanic clasts. |

| Station No. | Type | Equipment Used | Date | Time (Z)/Day No. From | To | Lat. N Long. W | to Lat. N Long. W | Seafloor Depth Range (m) Max. | Min. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 9567 | Core | 12' Gravity corer | 24 July | 1020/205 | 1228/205 | 44°02.12'** 21°48.79' | - - | 1823†† | | Core length recovered: 74.5cm. Cutter and catcher lost. Upper 5cm is $M_n$-encrusted rubble of glacial erratics. Overlies foram ooze. Lowermost 40 cms is white nanno chalk. Base is Late Oligocene or Earliest Miocene (?). |
| 9568 | Core | 12' Gravity corer | 24 July | 1432/205 | 1604/205 | 44°01.06'** 21°47.45' | - - | 1751†† | | About 6 cm of white nanno chalk with macrofossils jammed in core catcher. Cutter lost and lower end of barrel flattened. Chalk age is Late Oligocene or Earliest Miocene (?). |
| 9569 | Core | 6' Gravity corer | 24 July | 1706/205 | 1832/205 | 44°00.51'** 21°46.07' | - - | 1766†† | | Core catcher contains coral and bryozoan debris. Cutter fractured and bent. No core. |
| 9570 | Core | 6' Gravity corer | 24 July | 1948/205 | 2126/205 | 44°02.26' 21°46.18' | - - | 2042†† | | Pieces of volcanic breccia jammed in core catcher overlain by white foram ooze. Core cutter fractured and bent. Lower end of barrel flattened. No core. |
| 9571 | Core | 6' Gravity corer | 24 July | 2224/205 | 0008/206 | 44°02.80'** 21°47.03' | - - | 2009†† | | Core length recovered 129cm. Upper 16cm grey foram ooze. At 95cm, change from grey ooze or chalk to yellowish sediment, which in the core catcher is altered volcanic ash. |

| Station No. | Type | Equipment Used | Date | Time (Z)/Day No. From | To | Lat. N Long. W | to Lat. N Long. W | Seafloor Depth Range (m) Max. | Min. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 9572 | Dredge | Dredge<br>B. T. B. s | 25 July | 0935/206* | 1037/206 | 43°53.93'†<br>22°07.22' | 43°54.04'<br>22°06.58' | 4544 | 4531 | Small haul: 6 rocks. Nylon-mesh lined bag throttled. Nothing in corner boxes. Live soft-bodied holothurians, some bivalve shells and small pebbles of limestone, pumice and basalt contained in lump of soft ooze. Larger rocks are all (Oligocene?) volcanic breccia. |
| 9573 | Core | 6' Gravity corer | 25 July | 1755/206 | 1804/206 | 43°34.3'**<br>22°23.4' | -<br>- | 973†† | | Only recovery is a few chips of weathered basalt crust with bryozoan debris. Barrel bent and fractured at lower end. Cutter lost. No core. |
| 9574 | Core | 9' Gravity corer | 25 July | 1906/206 | 1957/206 | 43°33.5'**<br>22°23.9' | -<br>- | 1141†† | | Core length recovered: 38 cm. All light grey foram nanno chalk. Base is Middle Miocene (?). N. B. 2 meter penetration, from smear on outer barrel. |

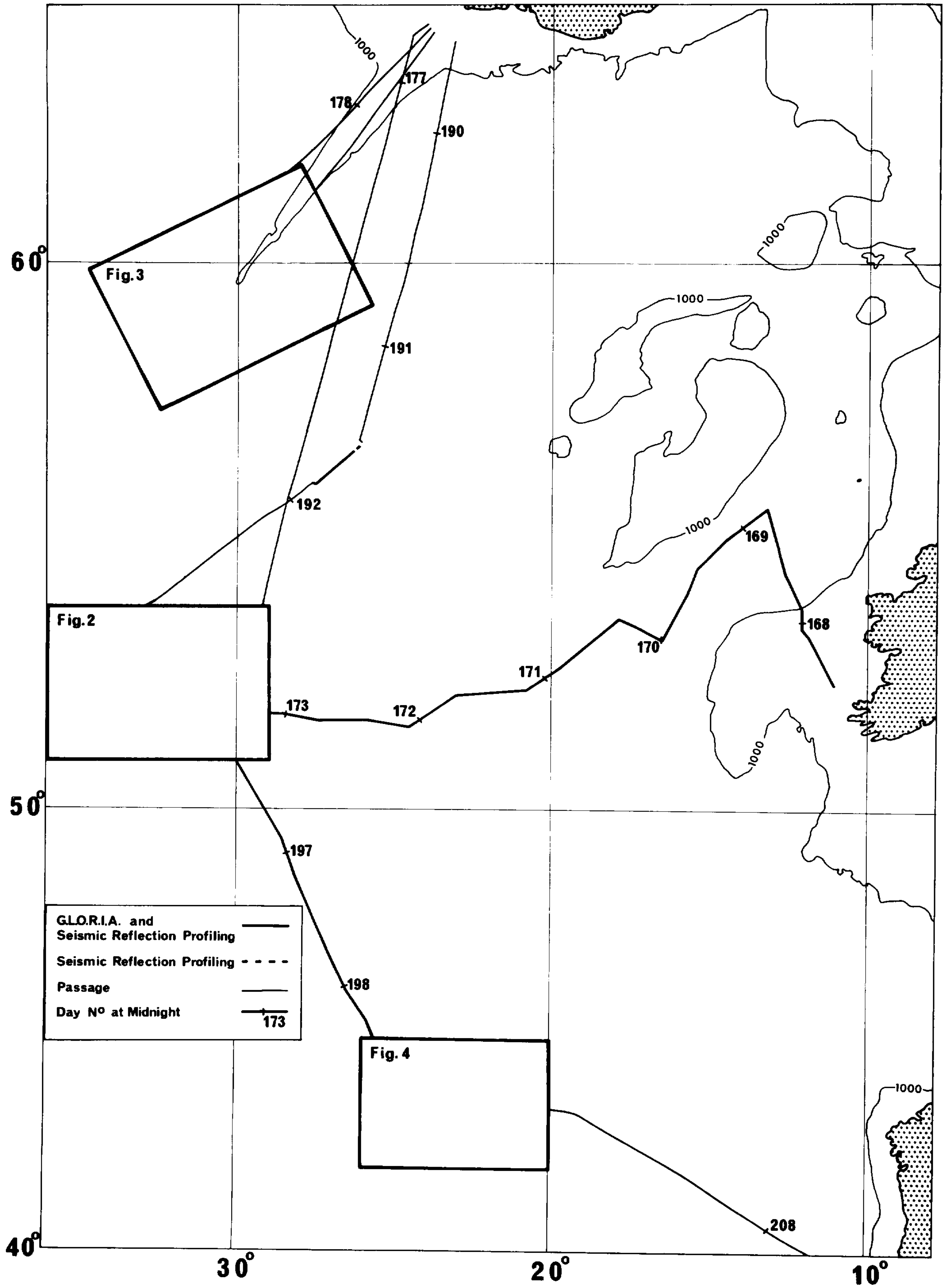
D. S. B. = Disposable sonobuoy
V = Velocimeter
B. T. B. = Bottom Transponder Beacon
* = Times are for dredge on bottom
† = Ship positions when dredge on bottom
** = Ship position when corer triggered
†† = Depth under ship when corer triggered

TABLE II Acoustic Beacon Positions

| | | |
|---|---|---|
| BEACON A | Lat. | 43°52.635'N |
| | Long. | 22°03.316'W |
| BEACON B | Lat. | 43°47.383'N |
| | Long. | 21°59.994'W |

TABLE III Periods during which underway equipment was deployed or used.

| Equipment | From | To | Days | Total Days |
|---|---|---|---|---|
| Echosounding fish | 0900/167 | 1203/176 | 9.1 | |
| | 0810/178 | 1923/184 | 6.5 | |
| | 1630/190 | 2032/208 | 18.2 | 33.8 |
| Gravity | 0900/166 | 0930/186 | 20.0 | |
| | 0930/189 | 0900/209 | 20.0 | 40.0 |
| Magnetometer | 1200/168 | 1145/176 | 8.0 | |
| | 0952/178 | 1842/184 | 6.4 | |
| | 1140/191 | 1940/201 | 10.3 | |
| | 2006/206 | 2012/208 | 2.0 | 26.7 |
| 3.5 kHz Profiler | 2003/167 | 2059/174 | 7.0 | |
| | 0845/178 | 1902/184 | 6.4 | |
| | 1028/191 | 2100/191 | 0.4 | |
| | 1547/192 | 0926/202 | 9.8 | 23.6 |
| S. R. P. | 1724/168 | 2130/174 | 6.2 | |
| | 0910/178 | 1748/182 | 4.3 | |
| | 1638/192 | 2038/201 | 9.8 | |
| | 1536/202 | 2140/202 | 0.3 | 20.6 |
| Sonar pod | 1930/167 | 2202/174 | 7.1 | |
| | 0730/178 | 2302/184 | 6.7 | |
| | 1038/191 | 2100/191 | 0.4 | |
| | 1614/192 | 1208/202 | 9.8 | |
| | 1513/202 | 2150/202 | .3 | |
| | 1656/206 | 1941/206 | .1 | 24.4 |
| GLORIA | 1422/167 | 2158/174 | 7.3 | |
| | 0810/178 | 1834/184 | 6.4 | |
| | 1020/191 | 2000/191 | .3 | |
| | 1538/192 | 2106/201 | 9.2 | 23.2 |



1000
178
177
190
60°
Fig. 3
1000
1000
191
192
1000
169
Fig. 2
168
170
171
173
172
1000
50°
197
G.L.O.R.I.A. and
Seismic Reflection Profiling
Seismic Reflection Profiling
Passage
Day N° at Midnight
173
198
Fig. 4
1000
208
40°
30°
20°
10°


Fig 1

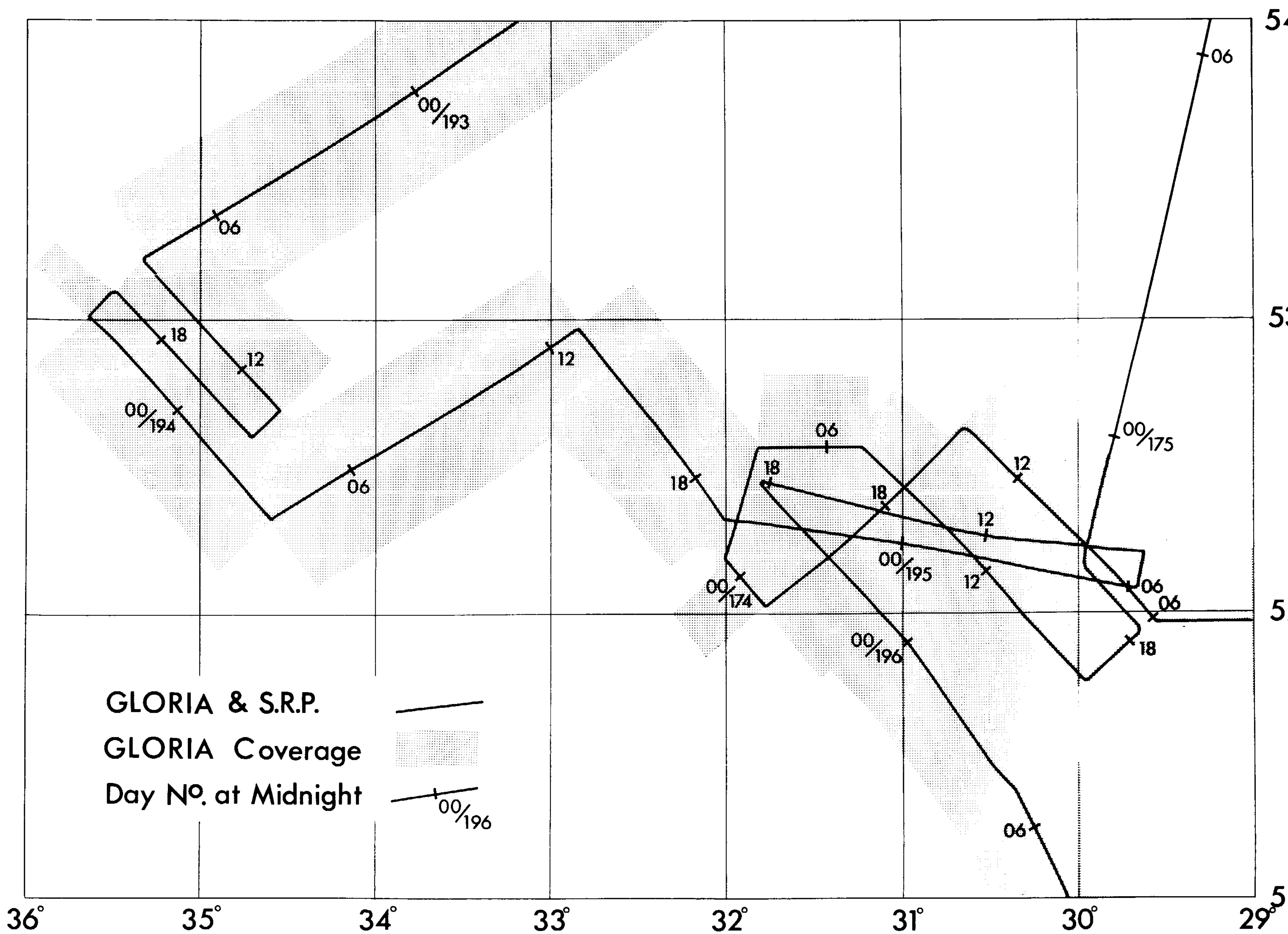

54°
53°
52°
51°
36°
35°
34°
33°
32°
31°
30°
29°
00/193
00/194
00/174
00/175
00/195
00/196
GLORIA & S.R.P.
GLORIA Coverage
Day No. at Midnight

Fig 2

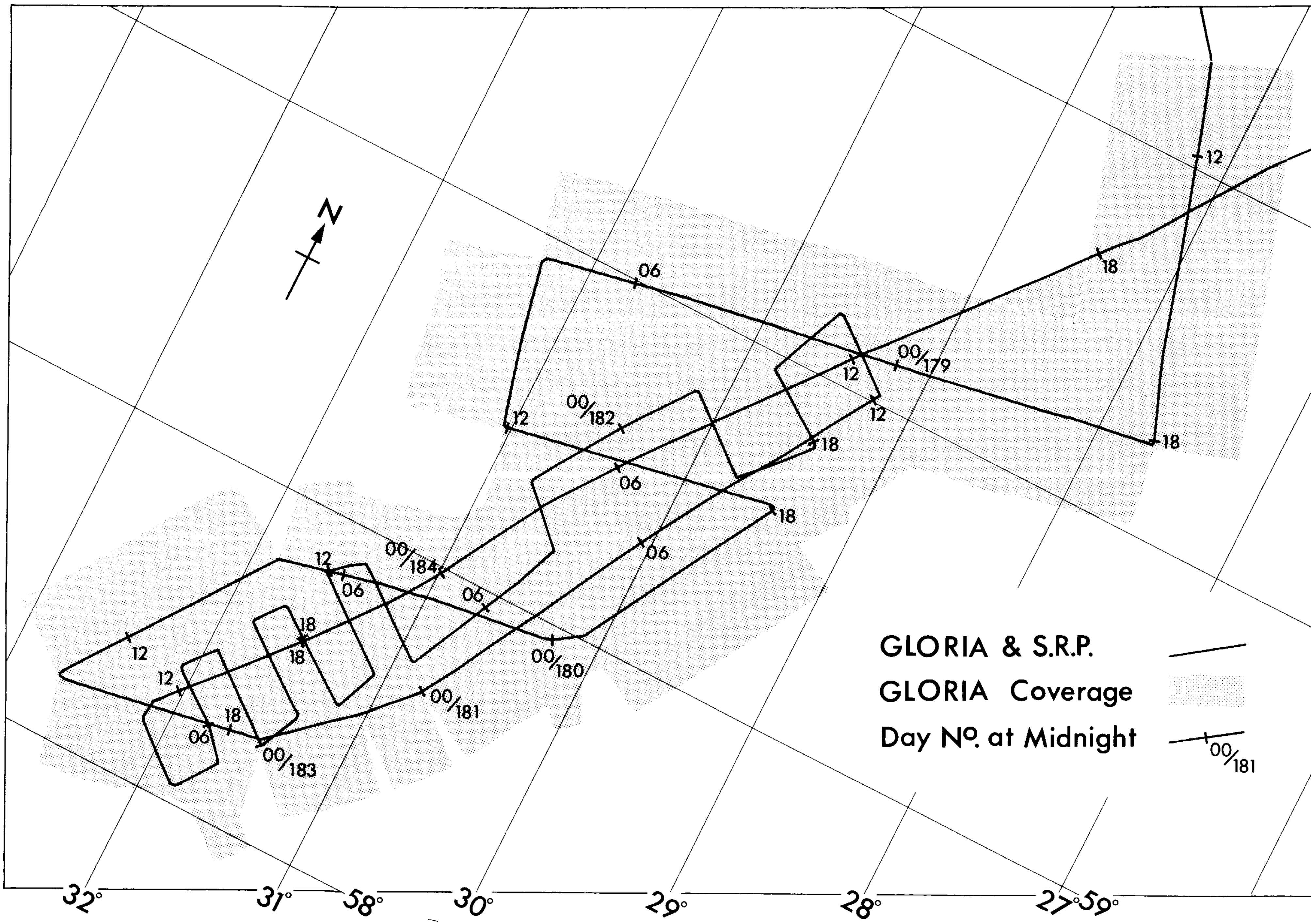

N
61°
60°
58°
59°
32°
31°
30°
29°
28°
27°
GLORIA & S.R.P.
GLORIA Coverage
Day No. at Midnight
00/181
00/179
00/182
00/180
00/184
00/183

Fig 3

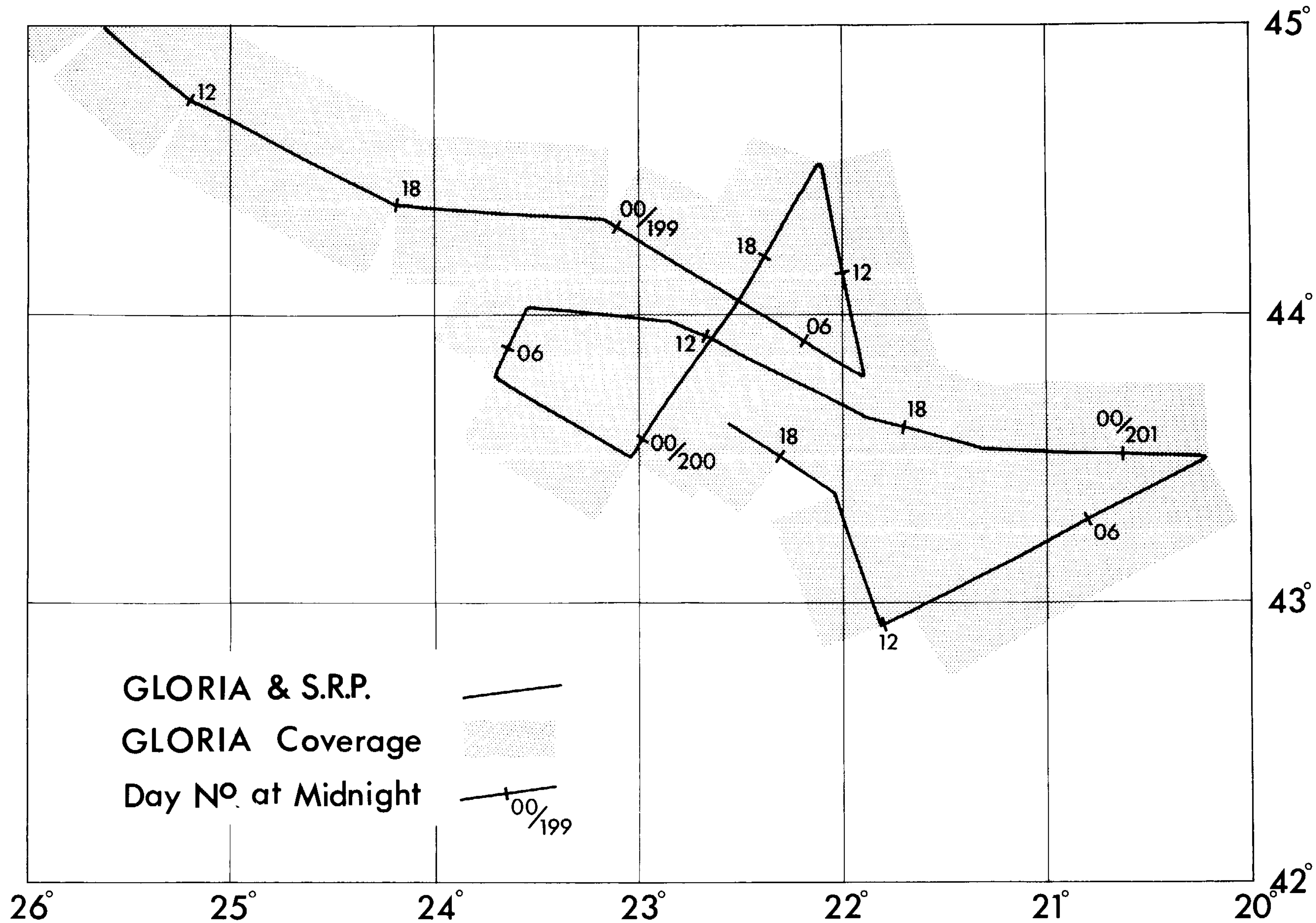

45°
44°
43°
42°
26°
25°
24°
23°
22°
21°
20°
12
18
00/199
18
12
06
12
06
00/200
18
18
00/201
06
12
GLORIA & S.R.P.
GLORIA Coverage
Day No. at Midnight
00/199

Fig 4

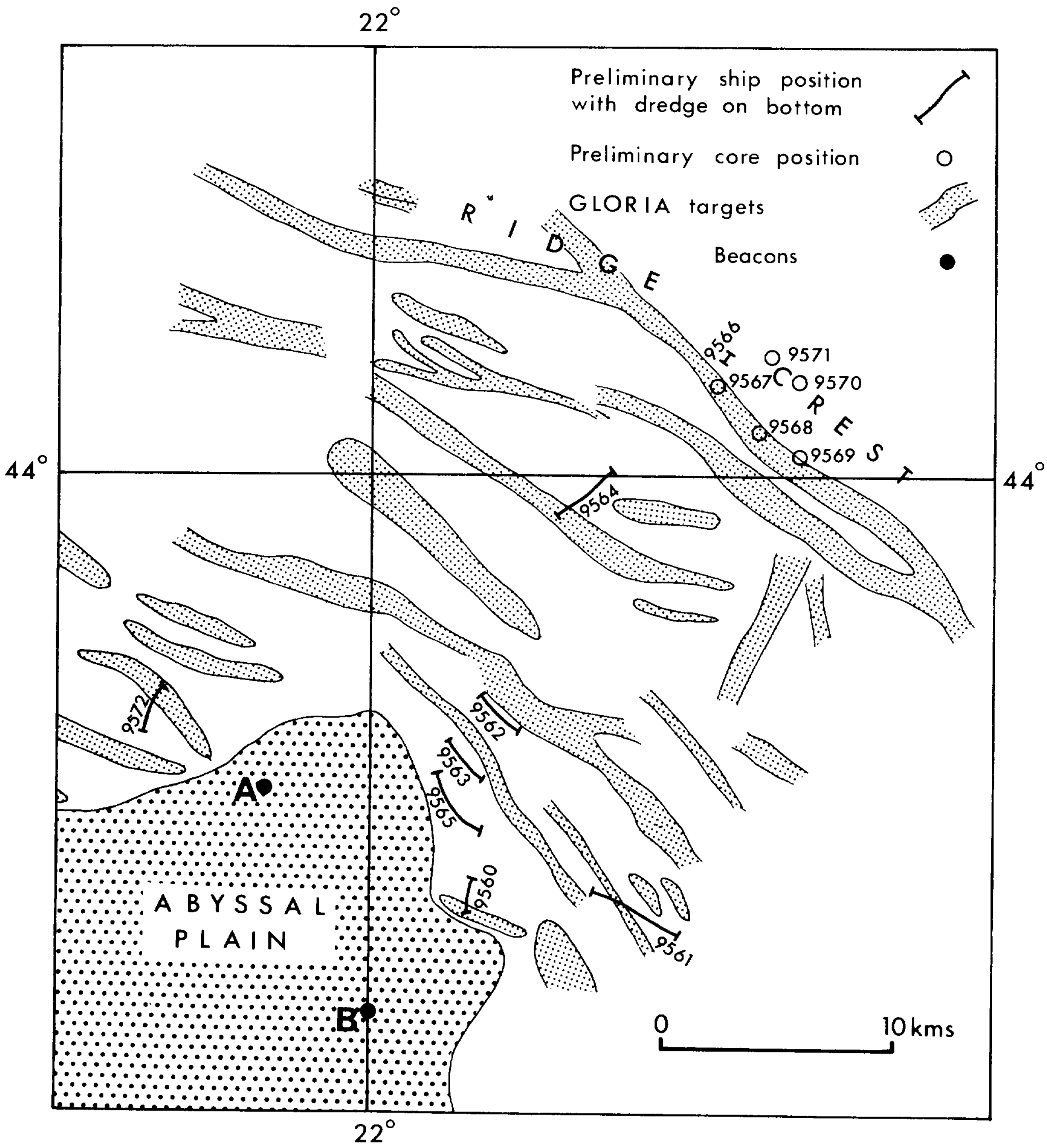

22°
Preliminary ship position with dredge on bottom
Preliminary core position
GLORIA targets
Beacons
RIDGE
CREST
9566
9571
9567
9570
9568
9569
44°
44°
9564
9572
9562
9563
9565
9560
9561
A
B
ABYSSAL PLAIN
0
10 kms
22°

Fig 5

# CRUISE REPORTS

RRS DISCOVERY

| CRUISE NO | | REPORT NO |
|---|---|---|
| 1 | JUN - AUG 1963 | 1* |
| 2 | AUG - DEC 1963 | 2* |
| 3 | DEC 1963 - SEP 1964 | 3* |
| | | NIO CR** |
| 4 | FEB - MAR 1965 | 4 |
| TO | TO | TO |
| 37 | NOV - DEC 1970 | 37 |
| 38 | JAN - APR 1971 | 41 |
| 39 | APR - JUN 1971 | 40 |
| 40 | JUN - JUL 1971 | 48 |
| 41 | AUG - SEP 1971 | 45 |
| 42 | SEP 1971 | 49 |
| 43 | OCT - NOV 1971 | 47 |
| 44 | DEC 1971 | 46 |
| 45 | FEB - APR 1972 | 50 |
| 46 | APR - MAY 1972 | 55 |
| 47 | JUN - JUL 1972 | 52 |
| 48 | JUL - AUG 1972 | 53 |
| 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 | | 35 |
| | SEP - OCT 1975 | |
| 74/2 | | 33 |
| 75 | OCT - NOV 1975 | 43 |
| 77 | JUL - AUG 1976 | 46 |
| 78 | SEP - OCT 1976 | 52 |
| 79 | OCT - NOV 1976 | 54 |
| 86 | SEP 1977 | 57 |

* 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

| CRUISE DATES | REPORT NO |
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| APR 1975 | IOS CR 23 |
| MAY 1975 | IOS CR 32 |
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| JUL 1975 | IOS CR 31 |
| JUL - AUG 1975 | IOS CR 36 |
| AUG - SEP 1975 | IOS CR 41 |
| AUG - SEP 1975 | IOS CR 44 |
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| APR - JUN 1976 | IOS CR 50 |
| MAY 1976 | IOS CR 53 |
| **RRS "JOHN MURRAY"** | |
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| SEP 1973 | IOS CR 7 |
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| AUG - OCT 1975 | IOS CR 42 |
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| 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 |
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| MAR - MAY 1975 | IOS CR 24 |
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