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Wormley, Godalming, Surrey.

R. R. S. "DISCOVERY" CRUISE 29 REPORT

August-October 1969

"GLORIA" IN THE AZORES AND GEOPHYSICS ON AND AROUND ROCKALL PLATEAU

N. I. O. CRUISE REPORT No. 29
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DATES

Leg 1	Leave Southampton	2nd August	Day 214
	Arrive Falmouth	3rd August	215
	Leave Falmouth	3rd August	215
	Arrive Barry, S. Wales	18th August	230
Leg 2	Leave Barry, S. Wales	22nd August	234
	Arrive Londonderry, N. Ireland	11th September	254
Leg 2a	Leave Londonderry, N. Ireland	13th September	256
	Arrive Greenock, Scotland	15th September	258
Leg 3	Leave Greenock, Scotland (via Fairlie, Scotland)	18th September	261
	Emergency visit to Londonderry, N. Ireland	22nd September	265
	Arrive Barry, S. Wales	6th October	279

SCIENTIFIC PERSONNEL

		Affiliation	Leg 1	Leg 2	Leg 2a	Leg 3
A. S. Laughton	Principal Scientist.	N. I. O.	X	X	X	X
R. B. Whitmarsh	PUBS	N. I. O.	X	X		X
C. A. Hunter	PUBS	N. I. O.		X	X	
M. T. Jones	PUBS, data logging.	N. I. O.	X	X		
D. Grohmann	PUBS	N. I. O.		X		X
J. J. Langford	PUBS	N. I. O.			X	X
D. G. Roberts	BM, magnetics, SRP	N. I. O.	X	X		X
D. G. Bishop	SRP	N. I. O.		X		
H. M. C. Fielding	SRP	N. I. O.		X		
E. P. Collins	Cameras, etc.	N. I. O.		X		X
R. Graves		N. I. O.	X			
J. S. M. Rusby	GLORIA	N. I. O.	X			
M. L. Somers	GLORIA	N. I. O.	X			
N. D. Smith	GLORIA	N. I. O.	X			
R. Dobson	GLORIA	N. I. O.	X			
R. H. Edge	GLORIA	N. I. O.	X			
V. A. Lawford	GLORIA	N. I. O.	X			
S. K. Willis	GLORIA	N. I. O.	X			
K. Tipping	GLORIA	N. I. O.	X			
M. Fasham	Comp. & data logging.	N. I. O.	X	X	X	
J. R. Berry	Comp. & data logging.	N. I. O.	X	X		
J. Sherwood	Comp. & data logging.	N. I. O.			X	X
R. Howarth (Miss)	Comp. & data logging.	N. I. O.			X	X
D. H. Matthews	Seis. Refrn. & SRP	Camb.	X	X	X	X
R. A. Scrutton	Seis. Refrn.	Camb.		X	X	X
A. M. Merzer	SRP	Camb.		X		
A. M. Ziolkowski	SRP	Camb.		X		X
G. A. Day	Gravimeter.	Camb.	X	X	X	
A. P. Stacey	Gravimeter.	Camb.	X		X	X
C. A. Williams (Miss)	Data logging.	Camb.				X
T. Vertue		Camb.		X		X
M. Bacon		Camb.	X			
B. King	Gravimeter	R. V. U.		X	X	
R. Taylor	Gravimeter	R. V. U.			X	X
P. Probert	Gravimeter	H. D.			X	
F. J. Davey	Gravimeter	Birmgm.			X	
D. Phillips	Gravimeter	L. & R.			X	
P. N. Chroston		U. E. A.				X
			19	18	15	16

(cf. overleaf for key to acronyms and initials)

PUBS	Pop Up Bottom Seismic Recorder
SRP	Seismic Reflection Profiling
GLORIA	Geological Long Range Inclined Asdic
N. I. O.	National Institute of Oceanography, Wormley, Godalming, Surrey.
Camb.	Dept. of Geodesy and Geophysics, Madingley Rise, Madingley Road, Cambridge.
R. V. U.	Research Vessel Unit, N. E. R. C., No. 1 Dock, Barry, Glamorgan.
H. D.	Hydrographic Department, Ministry of Defence (Navy), Taunton, Somerset.
Birmgm.	Dept. of Geology, The University of Birmingham, P. O. Box 363, Birmingham, 15.
L. & R.	LaCoste and Romberg Inc., Austin, Texas, U. S. A.
U. E. A.	School of Environmental Sciences, University of East Anglia, Wilberforce Road, Norwich.

SHIPS OFFICERS (LEG 2)

G. L. Howe	Master
C. O. Smith	Chief Officer
J. T. Walker	Second Officer
D. J. Williams	Third Officer
A. P. Ross-Murray	Radio Officer
R. D. Johnston	Chief Engineer Officer
H. J. H. Powell	Second Engineer Officer
R. J. Perriam	Third Engineer Officer
G. I. Coupe	T/A Fourth Engineer Officer
J. O. Watkins	Fifth Engineer Officer
H. McCallum	Junior Engineer Officer
D. I. A. Borthwick	Chief Electrical Officer
R. P. Miles	Second Electrical Officer

SUMMARY OF CRUISE INTENTIONS

(1) Trials of the Geological Long Range Inclined Asdic (GLORIA) in deep ocean conditions, (Leg 1) en route to, and in and around King's Trough, NE of the Azores (43°N, 20°W). The aim is to examine the known features of Peake and Freen Deeps and to carry out reconnaissance work for future studies in King's Trough in 1970, using other geological and geophysical techniques.

The project will depend on the results of GLORIA on cruises 27 and 28, and on the ability to handle the towed body in open ocean conditions. Because of these uncertainties a back up project of geophysics is planned in the area. In the event of bad weather, good weather will be sought.

(2) Geophysical studies in King's Trough, as a back up for GLORIA. The aim is to obtain two geotraverses across the feature using seismic refraction, bathymetric, gravity and magnetic methods. 5 tons of explosive will be available for seismic refraction using PUBS and surface sonobuoys. Some effort will be made in mapping magnetic anomalies.

(3) Data logging and computing facilities. This will be the first geophysical cruise with on-line data logging.

(4) Anisotropy experiment (Leg 2). Seismic refraction studies will be made on the flanks of the mid-ocean ridge at 59°30'N, 24°W to determine anisotropic properties in the upper mantle, using PUBS.

(5) Moho reflection experiment (Leg 2). Vertical and wide angle reflection measurements in the area of the anisotropy experiment using small charges and hydrophone array.

(6) Seismic refraction studies of the crustal structure of Rockall Plateau and Rockall Trough (legs 2 & 4). Three long seismic lines will be shot, fully reversed.

(A) Along Rockall Bank (150 miles NE-SW)

(B) Along Hatton-Rockall Trough (100 miles NE-SW)

(C) Along Rockall Trough (100 miles NE-SW)

(7) Seismic reflection profiles across Rockall Plateau and Trough (Legs 2 & 3). Four sections will be made:-

(a) from Bloody Foreland in NW Ireland, across the whole of Rockall Plateau to the position of the anisotropy experiment (59°30'N, 24°W).

(b) from Rockall Bank to Hatton Bank in north.

(c) from Rockall Bank to Hatton Bank in south.

(d) from SW Rockall Bank to Porcupine Bank.

(8) Gravity and magnetic profiles across Rockall Plateau and Trough (Legs 2 & 3). Gravity and magnetic fields will be measured on all passage work, especially on seismic reflection profiles. But principal gravity project is to obtain a good profile from Bloody Foreland to 59°30'N, 24°W.

(9) Underwater photography (Legs 2 & 3). Trials will be made of a new towed buoyant mini-camera for profile photography.

(10) Gravimeter calibration and cross coupling experiments (Leg 2a). Trials will be carried out on the US/UK Gravity Range No. 2 (55°53'N, 7°21'W) to test new N. E. R. C. LaCoste and Romberg gravimeter in comparison with Cambridge Graf-Askania meter. Tests of cross-coupling effects will be made if the weather is suitably bad.

NARRATIVE

Leg 1. Southampton to Barry: August 2nd-18th: Day 214-230.

The entire emphasis on Leg 1 was to test GLORIA. All equipment for this project had been installed and used during the previous two cruises (27 and 28) in the Mediterranean and successful launchings were made and records taken. However it was realised that the handling of the 32 foot long towed body was severely limited by sea and swell, and that extremely good weather would be needed before launching. Furthermore reliable forecasting was needed of deteriorating weather to give time for recovery. In the event of any failure in the GLORIA programme, a fully planned back-up programme of geophysics and geology was available and to this end we loaded 5 tons Geophex at Falmouth on August 3rd (215) en route for the open ocean.

Our aim was to work with GLORIA in the King's Trough area (42°N 21°W) where we had, on previous expeditions, made sea floor surveys. However on nearing this area on August 5th (217), the worsening weather due to Hurricane "Anna" made it abundantly clear that there was no prospect of launching GLORIA. The only likely area of calm weather to be found was in the centre of the Azores high which at that time lay over the Azores, and we steamed directly to the lee of Santa Maria Is. where we arrived at midday on August 7th (219).

In a steadily decreasing wind and in virtually calm sheltered water, the GLORIA fish was launched at 1600. We steamed SW from Santa Maria at 6 kts viewing into the continental slope to starboard and during the following two days made E-W traverses north and south of the narrow ridge south-west of Santa Maria.

After a period of trials and adjustment, a new survey was started p. m. on August 10th (222) of an area of abyssal hills some tens of miles further south. The survey was designed to investigate the method of examining an area where no topographic trends were known. Unfortunately this was terminated after 24 hours owing to fatigue failure of the towing bridles and so the GLORIA fish was recovered p. m. August 11th (223) after remaining in the water for four days. During this period the wind had not risen above force 4 and the waves were never more than 2 feet.

On all passages, continuous bathymetric, magnetic and gravimeter measurements were made. The passage back to Barry (S. Wales) was interrupted by various trials of sonobuoys and PUBS. The main trawl warp was discarded and replaced by a new one from the forward hold. It was subsequently tensioned by streaming in mid water.

On August 13th (225) a small zig-zag survey was made over a reported sounding of 1192 fm. No sounding less than 1965 fm. was found in the vicinity.

"Discovery" entered Barry Docks on August 18th (230) and all GLORIA equipment was removed and the GLORIA scientific team left.

Leg 2. Barry to Londonderry: August 22nd-September 11th: Day 234-254.

In preparation for a big programme of seismic refraction shooting, 11 tons of explosive (10 tons Marine Seismex, 1 ton Geophex) were loaded in Barry and stored in the A/S trunk. A new LaCoste and Romberg Sea gravimeter bought by N. E. R. C. was installed by one of the firm's representatives. On the afternoon of August 22nd, we sailed westwards around SW Wales and up through the Irish Sea in strong NW winds. No magnetic measurements were taken since the area is already well mapped.

On the morning of August 24th (236) we arrived at US/UK Gravity range No. 2 north of Ireland where two N-S gravimeter calibration runs were made. No cross-coupling measurements were possible because of the calm sea state, so we proceeded directly to Bloody Foreland (NW Ireland) to start the long geophysical traverse across Rockall Plateau with magnetometer and gravimeter. Seismic reflection profiling was not planned at this stage because of the desire to proceed quickly to the first seismic refraction station. The profile was broken in Rockall Trough by a gale after which test lowerings were made of PUBS equipment.

By afternoon on August 26th (238) we were at the southern end of seismic line A on Rockall Bank. In order to penetrate to an expected continental depth of Moho, a line 150 miles long was planned along Rockall Bank to be fired in four parts as a fully reversed profile with split profiles at either end. Logistics of the recording buoys required a short range (-10 to 40 miles) and a long range (40 to 150 miles) section to be made from each end as separate stations. A danbuoy (D/B 1), one PUBS and two sonobuoys were laid and a split seismic refraction line (Station 7016) was shot in force 5-6 westerly winds, 10 miles to the SW and 45 miles to the NE of the buoys. All gear was recovered by midday August 27th (239).

Seismic reflection profiling at 6 kts started from the south end of Rockall Bank and crossed to the south end of Hatton Bank along 140 miles. Both N. I. O. and Cambridge recording systems were operated using a single air gun and a Flexotir Géomécanique hydrophone array. The records showed clear evidence of a sediment basin.

"Discovery" arrived at the area for the anisotropy experiment at 59°N 24°W on August 29th (241) but had to remain hove-to in a force 9 gale for 24 hours. Between August 30th (242) and September 4th (247) we remained in this area on the eastern flanks of the Reykjanes Ridge concerned principally with two experiments. Two danbuoys were laid (D/B 2 and 3) with radar transponders for precise navigation. Stations 7018, 7020, 7021, 7022 were concerned with the experiment to measure anisotropy of the velocity in the upper mantle, during which $8\frac{1}{2}$ tons of explosive were fired. One PUBS was lost. The second experiment was concerned with seeking reflections from the Moho using an explosive seismic reflection technique with the Flexotir array (Station 7019). During this period the weather varied between wind force 4 and force 7 and was predominantly cold, overcast and foggy.

At midday on September 4th (247) all gear was recovered and we started back southwards along the principal geophysical traverse across Rockall Plateau with continuous bathymetric, gravity, magnetic and seismic reflection profiling at 6 kts. On September 7th (250) the traverse was stopped on Rockall Bank after 340 miles in

order to go to the northern end of the long seismic refraction profile (A) on Rockall Bank.

A split seismic profile at the northern end of line A was fired on September 7/8th (250/251) with bottom and surface receivers (Station 7023). Shots were fired 10 miles to the NE and 33 miles to the southwest before bad weather terminated the line.

After some trials on the towed camera, the main geophysical traverse was reoccupied in the centre of Rockall Bank late on September 8th (251) and continued south easterly across Rockall Trough and onto the Continental Shelf off Bloody Foreland in NW Ireland. The section of 205 miles finished p. m. on September 10th (253).

A short seismic station (7025) was shot primarily for testing a sonobuoy and another towed camera trial was carried out before steaming to Londonderry where we arrived a. m. on September 11th (254).

Leg 2a. Londonderry to Greenock: September 13th-15th: Day 256-258.

In Londonderry many of the scientists went on leave before rejoining the ship at Greenock, and their places were taken by a group of gravity experts to take part in the gravity trials of Leg 2a.

Although it was originally hoped that there would be three gravimeters available for calibration over the gravity range, illness at Askania prevented the new Askania prototype from being made available. In addition to the old Cambridge Askania, the new N. E. R. C. LaCoste and Romberg gravimeter had been installed at Barry. However it did not perform satisfactorily on Leg 2 and instead of starting Leg 2a as planned on September 11th (254) instrumental failures on the gravimeter prevented us from sailing until September 13th (256) leaving only 24 hours on the gravity range. A series of east-west courses were steered across the range at different speeds. Unfortunately the extremely calm conditions once again prevented any calibration of the cross-coupling computer.

In addition to the gravimeter trials, some experiments were carried out on the technique of laying a ground line attached to instruments on the bottom in shallow water and recovering by grappling. It was necessary to test this technique in an area of rocky bottom where fishermen were unlikely to recover equipment accidentally. Twice we laid 1000m of wire with weights and floats in 40m, but failed to recover it and finally parted the main warp by fouling the bottom with the grapnels, losing 200m of wire.

"Discovery" berthed alongside in Greenock a. m. on September 15th (258).

Leg 3. Greenock to Barry: September 28th-October 6th: Day 261-279.

We sailed from Greenock to NATO Boom Defence Base at Fairlie where we loaded 10 tons of Marine Seismex. Our departure from Fairlie was delayed by injury to Dick Burt the netman who had to be landed.

From the Clyde we steamed directly through a gale to the south end of seismic refraction line A, in order to fire the long range section of the line from the south. A danbuoy, PUBS and three sonobuoys were laid and shots up to 900lb were fired between 40 and 140 miles to the NE. All

equipment was recovered in a gale in the afternoon on September 21st (264).

The recurrent illness of one of the crew required us to land him as soon as possible and so the programme was interrupted to steam back to Londonderry where he was put ashore late on September 22nd (265). We immediately sailed again to the north end of line A to complete the seismic work. However once again it was blowing a gale and from a. m. September 24th (267) to p. m. September 25th (268) we made reconnaissance survey runs across the northeast cliffs of Rockall Bank and out to George Bligh Bank. A successful towed camera profile (Station 7028) was made across the northern cliff of Rockall.

The weather forecast was not propitious for seismic refraction work and so in the afternoon on September 25th (268) we started a seismic reflection profile NW across the Hatton-Rockall Basin in gale conditions. At midnight on September 26th/27th (269-270) after a run of 120 miles, the line was stopped since the forecast showed the possibility of some fine weather between depressions to allow completion of the seismic refraction work.

During the morning of September 27th (270) a danbuoy (D/B 6), two PUBS and three sonobuoys were laid at the north end of line A in a gentle breeze. Very soon however the wind increased and by 2300, shooting (up to 900lb) was abandoned at 77 miles from the buoys in a force 9 gale and with a rapidly falling barometer. By 0600 on September 28th (271) the centre of the depression had passed and the barometer climbed extremely rapidly, the wind shifted from SW force 10 to NW force 12 gusting at times over 90 knots (the full scale reading of the anemometer). During the course of the day the wind slowly decreased and we were able to make our way back to where we had left the sonobuoys. All three sonobuoys were found by sound ranging and were picked up without damage and both PUBS were recovered. However there was no sign of the danbuoy with its radar transponder and after a box search of 20 hours ending a. m. September 30th (273) it was abandoned as lost. In all probability the hurricane force winds had snapped the top pole with the transponder and passive reflector.

At midnight September 30th/October 1st (273-274) a danbuoy (D/B 7), a PUBS and two sonobuoys were laid at the northern end of refraction line C in the Rockall Trough in light airs (Station 7031). Shots were fired to a range of 100 miles. All equipment was recovered once more in a gale.

With the intention of reversing the line if the weather moderated, we steamed towards the south end, but it was clear that refraction seismics were not possible and so the remaining few days of the cruise were devoted to a seismic reflection profile across the Rockall Trough further south from the vicinity of the south end of line A to Porcupine Bank made between a. m. October 3rd (276) and a. m. October 4th (277).

The SRP was interrupted for an experiment using PUBS to determine the output pulse shape of explosive charges in connection with the attempt to obtain reflections from the Moho.

The passage home was around SW Ireland and "Discovery" berthed in Barry Docks p. m. on October 6th (279). On October 7th (280) 5 tons of Marine Seismex were landed. During Legs 2 and 3, 19 tons of explosive were fired and 2 tons were dumped as old stock.

Of the planned projects for Legs 2, 2a and 3, the anisotropy and Moho

reflection experiments were carried out, and the seismic reflection gravity and magnetic profiles were all made and a limited amount of underwater photography was done. Less than half the seismic refraction work was done because of the persistent bad weather (see Fig. 4). Line A was partially reversed, Line B was not attempted at all and Line C was only half completed. The gravity trials were limited by equipment failure and by lack of rough seas on the range.

The results of the projects are reported on more fully in the following sections.

PROJECT REPORTS

(1) GLORIA Trials

The GLORIA vehicle was lowered into the water in a gentle breeze in the lee of Santa Maria Is., Azores, on August 7th (219) and remained out for four days. The initial run to the SW crossed the continental slope into deep water, and after some electrical problems a traverse was made along the south side of a narrow ridge known from the bathymetric charts to run about E-W. The ridge was viewed from the south and the maximum horizontal range of 12 miles was obtained with a picture of echoes from the base of the slope as the ship converged slowly towards it. The ridge was held continually in view for about 70 miles at a mean range of 8 miles. Towards the end of the 110 mile run, it was found to be discontinuous. The ridge was then viewed from the north on the return track and it was found to be possible to piece the records together to make a composite picture. A traverse across the centre of the ridge gave bathymetric data with which to evaluate the GLORIA echoes. During the GLORIA run, the noise level in the vehicle was found to be high due, as was subsequently discovered, to some detached fairing slapping the vehicle.

After some experimental trials with towing arrangements and with signal processing, a new survey was started to the south in an area of abyssal hills. The pattern of these was not known and so a box survey was designed to give optimum overlapping coverage of GLORIA records from both north and south and to provide bathymetric control along the centre of the previous traverse. However navigational control on the survey by Loran A was inadequate, and the survey was prematurely finished by fatigue failures in the towing bridles.

The weather was extremely calm for the entire four days and recovery went very smoothly in spite of some davit troubles.

J. S. M. R.

(2) Experiment to determine upper mantle anisotropy

The seismic experiment to determine upper mantle anisotropy had been planned using three pop-up bottom seismic recorders (PUBS): however, due to the loss of one of the PUBS this experiment was conducted using just one bottom receiver at a time. Three stations were occupied in the region of 59°N 23°30'W and a total of 119 shots were fired and recorded. During two of these stations 150lb charges were fired around the circumference of a circle, with a PUBS at the centre, of radius about 40 kms at which range Moho arrivals could be seen as first arrivals. 63 good Moho arrivals, uniformly spaced in azimuth, have been identified and are being analysed for anisotropy using the modified time-term method developed by Raitt and others.

R. B. W.

(3) Pop-up bottom seismic recorders (PUBS)

The PUBS were used on Legs 2 and 3 of the cruise around 59°N23°30'W and around 56°N 16°30'W (Rockall Plateau area), during 10 separate stations involving 11 drops of the equipment. One PUBS was lost due to a sea bed failure of the acoustic receiver of the ballast release system and jammed

magnetic tape spoiled two drops; the remaining 8 drops were completely successful.

Four stations were carried out south of Iceland with the aim of studying seismic anisotropy of the upper mantle in this area, of which three were successful. Five stations were done in conjunction with surface sonoradio buoys of the Department of Geodesy and Geophysics, Cambridge as part of their study of the deep crustal structure of the Rockall Plateau and Trough. During one of these stations two PUBS were successfully used together on the sea bed for the first time.

The last experiment was unusual in that a PUBS was used, while it descended to the sea bed, to record the direct sound from a number of buoyed charges. This experiment was done to aid a study of reflections from the Mohorovicic discontinuity at near vertical incidence, which is being conducted at Cambridge. While at sea several improvements in the signal to noise ratio of the records was achieved.

A Koden KS-500 direction finder proved useful up to ranges of 1 mile after improvements had been made to the radio beacons in the PUBS. Occasional misleading bearings may have been due to reflections from the ship's superstructure. On average it was found that $1\frac{1}{4}$ hours were required for relocating and releasing each PUBS and $\frac{3}{4}$ hour was taken up by searching for it on the sea surface. This length of time was partly due to the rough sea conditions. It was found that the PUBS could be handled in extremely rough conditions though not without some damage to the framework around the sphere while recovering.

R. B. W.

(4) Moho reflection experiment

The purpose of the experiment was to obtain vertical reflections from the Moho. It was divided into two main parts - (1) a reversed refraction line to give the basic structure of the area and (2) four explosion reflection profiles to be compared with the refraction line.

The experiment was conducted between the Rockall Plateau and the Reykjanes Ridge in the same area as the anisotropy experiment, which therefore provided the refraction data.

Of the four reflection profiles, Nos. 1 and 3 were along the refraction line but 8 miles apart, No. 2 bisected No. 1 perpendicularly, and No. 4 was the same as No. 3 except that heavier charges were used ($12\frac{1}{2}$lb Geophex instead of 5lb). The Flexotir towed hydrophone array was used as a receiver. The charges were exploded at constant depth, using string and floating balloons, so as to obtain the same pulse at every explosion. The experiment was conducted at $1\frac{1}{2}$ knots.

Air-gun profiles were obtained along the tracks of all the explosion profiles and also along a track crossing profile No. 3. These gave shallow structure and should show any side reflector which might be mistaken for a Moho reflection in the explosion profiles.

Gravity and magnetic measurements were obtained simultaneously with the air-gun profiles.

To obtain a record of the downward-travelling explosion pulse, a PUBS was allowed to fall freely to the sea-bottom and, as it was going down, explosions were let off above it.

The data from the explosion profiles will be processed in the laboratory.

A. M. M.

(5) Seismic refraction

Despite the adverse weather conditions five single ship refraction lines were carried out on the cruise, two on Leg 2 and three on Leg 3 : four of them constituted a reversed profile on Rockall Bank and the fifth an unreversed profile in Rockall Trough. The receivers used were the Cambridge internally recording sonobuoys and the PUBS of N. I. O. while the charges were made up of Marine Seismex or Geophex. A sixth refraction line, station 7025, was shot near Bloody Foreland to test a newly made up buoy.

Trouble was experienced with the crystal-controlled shipborne clock of the sonobuoy system which jumped out of synchronisation on four of the stations, but fortunately not to the detriment of the refraction results. Jamming of the magnetic recording tapes occurred in the PUBS on two of the stations thereby losing some arrivals.

Station summary:

7016 - Split profile at the southern end of Rockall Bank, -10' to +45'. Two sonobuoys and one PUBS were laid, and 29 shots fired totalling 1,840lb of explosive.

7023 - Split profile at the northern end of Rockall Bank, -10' to 32'. Three sonobuoys and one PUBS laid, and 26 shots were fired totalling 1,400lb of explosive.

7025 - Unreversed profile off Bloody Foreland, 10' long, one sonobuoy laid for testing. Ten shots were fired totalling 97½lb of explosive. The test was successful.

7027 - Unreversed profile, SW to NE along Rockall Bank, 40'-150' long. Three sonobuoys and one PUBS were laid and 15 shots launched, 11 of 300lb of which three were misfires, and 4 of 900lb of which one was a misfire. In total, 6,900lb of explosive were used.

7030 - Unreversed profile, NE to SW along Rockall Bank in order to reverse 7027 but the worsening weather curtailed the line at 81'. Three sonobuoys and two PUBS were laid and 11 shots were launched, 9 of 300lb of which 2 were partial misfires and 2 of 900lb one of which was lost. 4,500lb of explosive was used.

7031 - Unreversed profile, NE to SW along Rockall Trough, shot out 100'. Two sonobuoys and one PUBS were laid and 16 shots were fired totalling 3,275lb of explosive.

All stations except 7031 gave reasonable results. In the case of 7031 it is thought that the large thickness of sediments in Rockall Trough absorbed

the sound so that beyond 20' signal strength was below the noise level.

This was the first "Discovery" cruise on which charges made up to 900lb had been used. Eighteen 50lb cans of Marine Seismex were stacked in a wooden coffin to make up a 900lb charge and floats were attached to control the sinking rate of the charge so that it exploded at 200 feet on a 2 minute fuse. The most unreliable factors here were the buoyancy of individual cans of Seismex (their weight in water varied between 2lb and 11 lb) and the condition of the containers, making it necessary to check each can before use.

R. A. S.

(6) Seismic reflection profiles

The seismic reflection profiling programme was primarily oriented toward obtaining data along traverses of the Rockall Plateau and Trough, and in particular along a geotraverse, crossing the seismic refraction lines, from the flanks of the Reykjanes Ridge to Bloody Foreland, NW Ireland. These sections provided data on the sedimentary geology of the Plateau and the Trough, and aided the interpretation of the seismic refraction and gravity data.

Two independent sets of profiling equipment built to different designs at N. I. O. and Cambridge were avilable for Leg 2. Only the Cambridge equipment was available for Leg 3.

The N. I. O. equipment consisted of a free running air gun of 30 cu. in. of Lamont design, a 200 ft. array of 100 elements of N. I. O. design and a triggered 18" Mufax recorder with time delays on display and time varied gain. The vertical exaggeration of the records was approximately 14-1 and filter settings of 30-300 Hz were used.

The Cambridge equipment used a nearly identical sound source firing at 3000 p. s. i., a Flexotir-Géomechanique hydrophone array of two 100m long active sections each with 50 elements and two 9" Mufax recorders with time delays. The vertical exaggeration of the records was about 2:1 and filter settings of 3-100 Hz and 40-180 Hz were used. The gun and array depths were matched at 14m (quarter wavelength at a bubble pulse frequency of 36 Hz) in order to maximise the signal, using the sea surface reflection both for the outgoing and the returning waves.

Initially one gun and both hydrophones were used, but the higher signal to noise ratio of the Flexotir-Géomechanique hydrophone lead to the abandonment of the N. I. O. hydrophone and the signals were split between both recording systems. The Flexotir hydrophone behaved reasonably well throughout in spite of some electrical and mechanical failures. However launching and recovering by hand was an arduous job requiring all available hands, especially in rough seas. The guns behaved erratically with failure in the connectors, 0-rings and in the output valves of the compressor. A maximum continuous run of 24 hours without recovery was achieved however. All the received signals were recorded on tape.

A total of 880 miles of seismic profile was obtained comprising the geotraverse, two other sections across the Hatton-Rockall Basin and one other section across Rockall Trough. The details are listed after the station list and are shown on the track chart. An account of some preliminary results is published by:-

Roberts D. G., Bishop D. G., Laughton A. S., Ziolkowski A. M., Scrutton R. A. and Matthews D. H. (1970) New Sedimentary Basin on Rockall Plateau. Nature

(London), 225, 170-172.

D. G. R.
A. M. Z.

(7) Gravity measurements

The Cambridge Graf-Askania sea-gravimeter GSS2-11 was operational throughout the cruise except when seismic refraction was being carried out, when the meter was clamped and hoisted from the gyro-stabilised platform.

Between Legs 1 and 2, in Barry, the gravimeter was accidently allowed to overheat so that the recordings taken on Leg 2 have to be treated with suspicion. Those recordings taken on Leg 2a are also dubious, but on Leg 3 the meter appeared to be functioning properly again. Approximately 5,500 miles of gravity readings were collected.

The cross-coupling computer was not operating properly until the middle of Leg 2, but from then on continuous recording was maintained. However, subsequent examination of the calibrations of the computer show that the calibration factor is in doubt so here too readings must be treated with suspicion.

Trouble was experienced with one of the servo-amplifiers of the gyro-stabilized table. It operated intermittently because of overheating.

On Leg 2, 22 hours were spent on the US/UK Gravity Range north of Ireland. Data was collected for a comparison of the Graf-Askania meter with the LaCoste Romberg and during the trials digital logging of the gravimeter and horizontal accelerometer outputs was achieved despite faults in the digital voltmeters and the interface to the computer. The latter was a step towards the digital filtering and reduction of gravity data to be carried out on the shipborne computer.

R. A. S.

(8) N. E. R. C. gravity meter acceptance trials

During Legs 2, 2a and 3, acceptance trials were conducted on a new LaCoste and Romberg S40 gravity meter on behalf of the Research Vessel Unit of N. E. R. C. at Barry. The meter was delivered to the R. V. U. in July and after a period of operation in the laboratory, was installed in R. R. S. "Discovery" on August 18th (230). The installation was supervised by a LaCoste and Romberg representative, the meter being in the gravimeter room and the control and recording console in the plotting office. The makers representative was not very happy with the 120 ft. run of cable between the console in the plotting room and the meter in the gravimeter room. The longest recommended by the makers is 40 ft. The meter was tested and apart from very slight "pick up" worked satisfactorily. The platform was not as still as desirable and this was attributed to the excessive length of cable.

During the cruise it was noticed that the meter was very sensitive to yaw, changes in the ships heading of $1\frac{1}{2}$ - 2° having the effect of varying the gravity record by 3 or 4 mgal. Changing the period of the platform from 4 to 6 minutes had no effect and different valves of R. C. filtering in

the computer also had no effect. Whilst the ship was returning to Greenock in quiet water she was made to yaw about 5° each way every 30 secs. using the weather control on the auto pilot. This confirmed our previous observations as the record gave a sinusoidal line about 7 mgal P. P. and 30 sec. period in phase with the ships motion.

The one run made over the gravity range on August 24th (236) gave a reasonable correlation with the Askania meter but no firm conclusions could be drawn due to the shortness of the trial and also that the Askania had been overheated giving it an unknown tare. Further analysis of the entire results of the cruise may give a better indication.

R. F. pickup was a problem on "Discovery" as during transmission periods it was possible to read the morse on the heater lights and the computer oscillated violently making the record unuseable.

The failures to the meter in this cruise necessitated a LaCoste and Romberg technician joining the ship in Londonderry and spending a considerable time working on the meter delaying the sailing time from Londonderry and shortening the time on the gravity range on Leg 2a from 3 days to 1 day. The total time lost at sea amounted to about 5 days and was caused by the failure of two multipliers and two 10 turn potentiometers in the computing circuit. Also during this cruise the potentiometer controlling the recorder pen caused some trouble but this cured itself and was possibly just some dirt on the winding. Two diodes in the overload protection circuits of the torque motor amplifiers also burnt out. This was partially responsible for the lack of stiffness in the platform but did not prevent operation of the meter.

In general the meter did not perform too well on this cruise. This can be attributed to various reasons:-

(1) Faulty components.

(2) Too long a connecting cable.

(3) Running on 50 Hz supply.

When "Discovery" returned to Barry the meter was removed for further trials on another ship.

B. K.

(9) Magnetic measurements

Total field magnetic measurements were made during the greater part of the cruise using a Varian proton magnetometer. In addition to recording on an analogue record, the data were fed on line to the computer, combined with the navigational data and the IGRF removed to give magnetic anomalies. These were listed and stored on disc for subsequent profile drawing in the laboratory.

(10) Navigation

Throughout the cruise satellite fixes were taken using a Magnavox 702 satellite receiver, the computations being made on line (for the first time) by the shipboard IBM 1800 computer. The software for these computations was

new and some difficulties were experienced in acquiring the right level of acceptance or rejection, and in entering the correct velocity values for the ship's motion during transit resulting in a number of inaccurate fixes. On an average 4 to 5 acceptable satellite fixes were obtained per day.

On Leg 1 reliable Loran A fixes were obtained from the Azores-Madeira-Cape St. Vincent chain as far north as 44°N 14°W in daylight, but none were available during darkness even in the vicinity of the Azores.

On Legs 2 and 3, Loran C fixes were obtained from a Decca Loran C/A ADL-21 receiver north of about 51°N, using SL3 and SL7 chains. Some difficulty was experienced setting up the receiver for automatic tracking and in identifying the third cycle in rather low signal conditions. Undetected jumps of 10 microseconds were liable to give misleading fixes.

Dead reckoning sensors (ship's head, fore and aft speed through the water, athwartships speed through the water) were recorded on an analogue recorder as well as by the computer. The N. I. O. 2-component electromagnetic log was used for the first time from a new permanent position on the starboard side of the cofferdam. Later a second unit will be placed symmetrically on the port side and means taken of the two units. The calibration factors used were those determined on a previous cruise when mounted on the Asdic plate.

The integration of navigation with the data logging system is described in section (11).

A. S. L.

(11) Data logging system and computer

This cruise was the first on which full geophysical data logging was attempted. During the course of the cruise, the system was slowly built up piece by piece so that by the last leg, a working system was in operation.

Data inputs:-

(a) Dead reckoning sensors (ship's head from gyro, two component electromagnetic log, time).

(b) Navigational fixes from satellite (automatically). Loran A and C, and Decca fixes were computed from raw data off line but stored on disc and used in navigation programmes.

(c) Geophysical sensors (total magnetic field on line, gravimeter beam deflection and cross-coupling on line, depths from PES by manual entry).

The listed outputs were as follows:-

(a) Automatically every 30 minutes blocks of 2 minute interval data were listed:-

Day No., time, speed through water (combining both components), course through water, total magnetic field, gravimeter beam deflection, cross-coupling, total gravity field. These parameters were averaged over a period of 30 or 60 seconds.

(b) Satellite fixes as they were obtained.

(c) On demand every 200 minutes, processed navigational and geophysical data were listed in the following way:-

(i) all fixes (from any source) were listed for acceptance or rejection.

(ii) the closure error between dead reckoning and fixes was attributed to surface currents which were listed (and rejected if they exceeded a set value).

(iii) processed data (in which geophysical and navigational data were combined) were then listed for 4 minute intervals as follows:-

Day No., time (GMT), latitude, longitude, course made good (over ground), speed made good (over ground), distance travelled along track from first entry of block, Matthews area (manually entered), depth in corrected fathoms and metres, magnetic anomaly (after removal of IGRF), gravity anomaly (after Eotvos correction and removal of International Gravity Formula).

All the data was stored on disc for subsequent use. At this stage no plotter was available for track or profile drawing although this has subsequently been installed. Careful comparisons of listed output were made with the conventional log books and analogue records to pick up errors in data entry and programmes. Many calibration factors were provisional and the listed outputs were regarded as provisional only. The entire system is currently undergoing analysis in the laboratory.

The computer was used also in a time sharing capacity for off line computations relating to seismic record interpretations, gravity and magnetic computations, and the preparation of expanded navigational lattices for Loran C.

The computer was closed down for all seismic explosions of 100lb or greater for fear of damage to disc storage unit (cf. paragraph (ii)).

A complete account of the data logging system and computer will be published elsewhere.

M. F.

(12) Vibration measurements on IBM 1800 computer systems during seismic experiments.

Vibration measurements were made on the cruise in order to assess the the probability of damage to the Disc Storage Unit of the ship's computer by transmission of shock waves through the hull during seismic trials. Exploratory tests on a previous cruise had proved that components in both longitudinal and lateral planes, in the region of the computer, were of a very low order and measurements on this cruise were therefore confined to the vertical axis only.

An Electro Mechanism Limited type MEM variable reluctance accelerometer was employed as a sensor and outputs were recorded via a B 450 galvanometer, on a six inch U/V recorder running at 5.1 mm per second. Time base markings on the records were gained from PUBS crystal clock circuits.

Records were obtained during seismic stations 7027, 7030 and 7031. Results

gained on station 7030 were with the accelerometer mounted on the deck head adjacent to an attachment point of the Disc Storage Unit, while in the other two cases the pickup was attached to the outer casing of the unit itself. The results indicate the presence of two distinct frequencies of vibration occurring on the D. S. U. these being 11 and 68 Hz corresponding to the natural frequency of the flexible mountings and local ship's structure respectively.

Shocks recorded in shallow water appeared to be more severe and this is born out by recordings obtained.

The total duration of disturbance varied slightly in each case but in general fall within the limits of 1. 2 to 1. 5 seconds.

A summary of data obtained is given in the following table; deflections quoted being the maximum in each instance.

E. P. C.

Station	Shot No	Charge Size	Depth U/C	Vibration Level	Remarks
7027	12	300 lb	121 fms	± 0.0001"at 68 Hz superimposed on ± 0.035" at 11 Hz	Pick up mounted on top of Disc Storage Unit
"	14	900 lb	132 fms	± 0.0001" at 68 Hz superimposed on ± 0.045" at 11 Hz	As above
7030	5	300 lb	109 fms	± 0.00025" at 68 Hz	Pick up mounted on deck-head
"	11	900 lb	100+ fms	± 0.00028" at 68 Hz	As above
7031	4	25 lb	1374 fms	± 0.00002" at 68 Hz superimposed on ± 0.002" at 11 Hz	Pick up mounted on top of Disc Storage Unit
"	13	300 lb	1500 fms	± 0.00006" at 68 Hz superimposed on ± 0.026" at 11 Hz	As above
"	17	900 lb	1500 fms	± 0.00005" at 68 Hz superimposed on ± 0.025" at 11 Hz	As above. Charge suspect

(13) Underwater photography

A new technique of obtaining profiles of underwater photographs was successfully tried. A new minicamera developed at N. I. O., capable of taking up to 2000 frames at 15 second intervals on 16 mm film, was made buoyant using syntactic foam and a polypropylene towed body. The syntactic foam, "Vicast", was moulded into discs by Vickers, and was tested to 3500m depth and gave a buoyancy of 15. 5lb per cubic foot in fresh water.

The camera was tethered down to a heavy chain towed on the main trawl warp so that the camera floated about six feet above the bottom and looked forward.

At a towing speed of 1. 0 kts., the horizontal separation of separate photographs was about 7 metres. A nearly continuous photographic section of the bottom was therefore obtained.

Of three such camera stations, two gave successful photographic sections, the last station covering a range of two miles in water depths between 700 and 150 m across the northern cliff of Rockall Bank.

A. S. L.

LIST OF DANBUOY POSITIONS

D/B	Laid	Recovered	Lat. N	Long W	Fixed by	Remarks
1	1404/238	0945/239	55°54. 1'	16°20. 5'	Loran C	Passive reflector
2	1643/242	0345/246	59°07. 7'	23°20. 1'	Loran C	Radar transponder
3	0749/246	1352/247	59°21. 5'	23°22. 3'	Loran C	Radar transponder
4	1446/250	0745/251	57°54. 3'	13°34. 4'	Loran C	Radar transponder
5	1235/263	2140/264	55°52. 5'	15°20. 0'	Loran C	Radar transponder
6	1022/270	Lost	57°56. 0'	13°40. 0'	Loran C	Radar transponder
7	2335/273	2345/274	56°33. 8'	11°22. 1'	Loran C	Passive reflector
8	1050/276	1443/276	55°18'	15°36'	Loran C	Passive reflector

KEY TO STATION LIST

AG	Air gun	N. I. O. Rec.	N. I. O. Recording System
BMC	Buoyant Mini Camera	PUBS	Pop Up Bottom Seismic Recorder
Camb. Rec.	Cambridge Recording System	SB	Sonobuoy
CR	Corrected Fathoms (by Matthews Tables)	S. Refr.	Seismic Refraction
CM	Corrected Metres (by Matthews Tables)	S. Refr. (A)	Seismic Refraction (Anisotropy)
D/B	Danbuoy	SRP	Seismic Reflection Profile
DSRP	Deep Seismic Reflection Profile	TC	Towed Camera
FA	Flexotir Hydrophone Array	UCF	Uncorrected Fathoms (at 800 fm/sec)
		V	Velocimeter

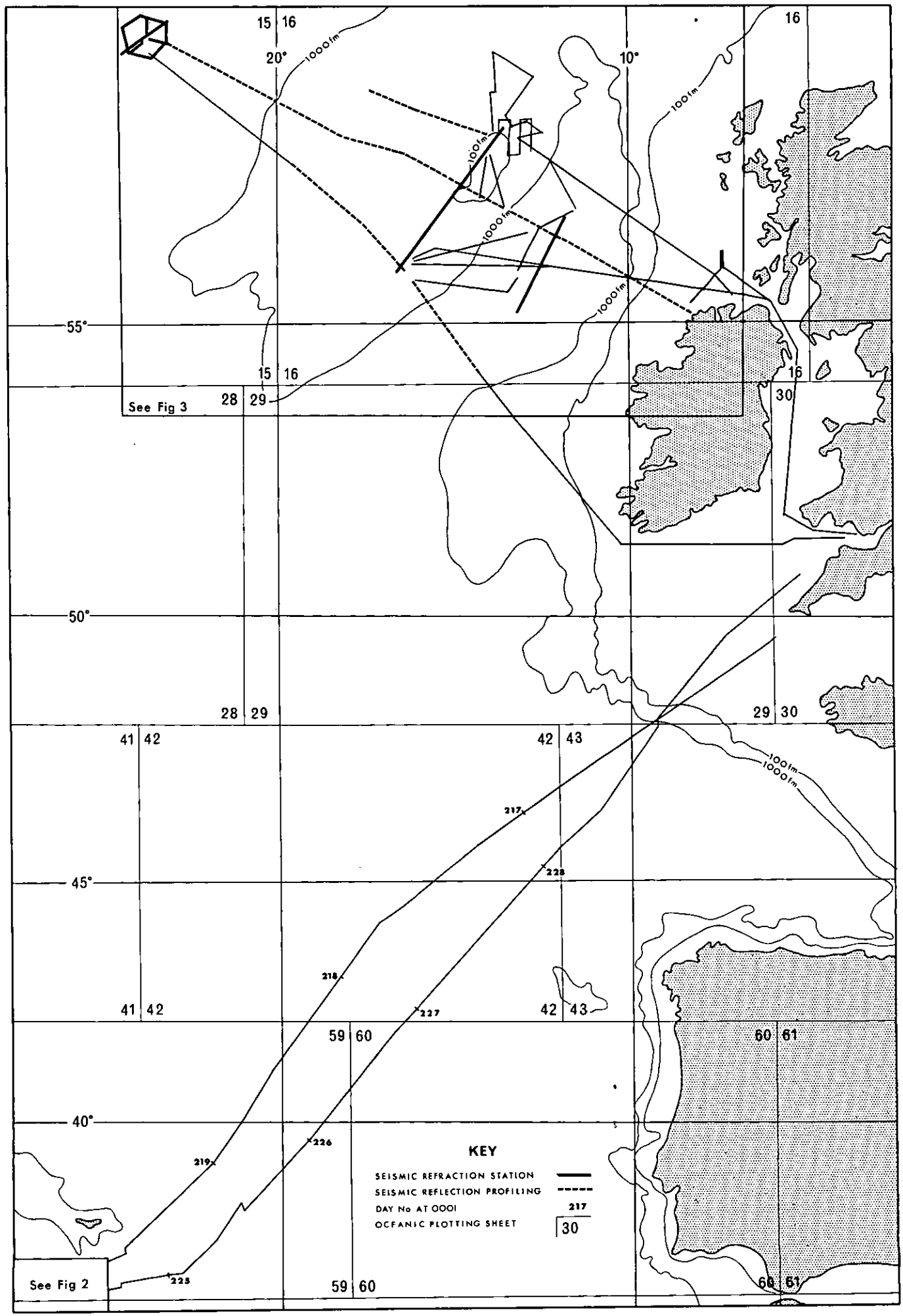
CRUISE 29 - STATION LIST

Stn. No.	Type	Equipment used	Date	Time (z)/Day No. From	Time (z)/Day No. To	Lat. N Lat. N to Long. W Long. W	D/B used	Depth Range UCF	Depth Range CF	Depth Range CM	Comments
7016	S. Refr.	SB(2) PUBS	26/27 Aug	1404/238	0945/239	55°43.5' 56°27.1' 16°38.0' 15°41.0'	1	194-192	200-198	366-362	South end Line A (Rockall Bank); 45 miles.
7017	V	V	29 Aug	2051/241	2200/241	58°59.2' - 23°58.7' -	-	1404-1410	1427-1433	2610-2621	To 2000 m.
7018	S. Refr.	PUBS	30 Aug - 1 Sept	1832/242	0152/244	59°04.4' 59°41.6' 24°12.0' 22°52.1'	2	1358-1360	1380-1382	2523-2527	PUBS lost.
7019	D.S.R.P.	FA	1/2 Sept	0858/244	0016/245	59°12.6' 59°05.5' 23°51.2' 24°07.5'	2	1322-1360	1344-1382	2457-2527	5 and 12½ lb charges
7020	S. Refr.	PUBS	2 Sept	0052/245	1402/245	59°06.6' 59°38.7' 24°03.8' 22°45.2'	2 2	1346-1365	1367-1387	2501-2536	55 miles across anisotropy hexagon.
7021	S. Refr. (A)	PUBS	3 Sept	0918/246	2235/245	59°20.9' hexagon 23°29.2' centre	3	1286-1371	1306-1393	2388-2548	23 miles radius hexagon.
7022	S. Refr. (A)	PUBS	3/4 Sept	2336/246	1314/246	59°20.6' hexagon 23°28.0' centre	3	1286-1404	1306-1427	2388-2610	23 miles radius hexagon.
7023	S. Refr.	SB(3) PUBS	7 Sept	1518/250	0712/251	58°03.7' 57°29.2' 13°25.8' 14°05.5'	4	83-100	85-103	155-105	North end Line A; 32 miles.
7024	T.C.	BMC	8 Sept	1900/251	2026/251	56°57' 56°55' 14°24' 14°29'	-	92-94	95-97	173-177	First trial, too high from bottom.
7025	S. Refr.	SB(1)	10 Sept	1640/253	1914/253	55°18.2' 55°09.5' 8°37.6' 8°45.6'	-	45-47	46-48	86-88	Continental Shelf NW Ireland; 10 miles.

Stn. No.	Type	Equipment used	Date	Time (z)/Day No.		Lat. N Lat. N to Long. W Long. W	D/B used	Depth Range			Comments
				From	To			UCF	CF	CM	
7026	T. C.	BMC	10 Sept	1927/253	2100/253	55°20.3' 55°22.0' 8°36.3' 8°30.0'	-	46-46	47-47	88-88	Successful trial
7027	S. Refr.	SB(3) PUBS	20/21 Sept	1235/263	2140/264	55°50.6' 57°47.2' 15°28.6' 13°41.0'	5	194-209	200-215	366-394	South end Lin A; 40-150 miles.
7028	T. C.	BMC	24 Sept	1100/267	1316/267	57°57.7' 57°55.5' 13°01.5' 13°04.6'	-	484-138	495-142	905-260	Across NE cliff Rockall Bank.
7029	V	V	24 Sept	1500/267	1717/267	57°53' - 13°10' -	-	126-118	130-122	238-223	To 220 m.
7030	S. Refr.	SB(3) PUBS(2)	27/30 Sept	1022-270	0800/273	57°58.2' 56°42.5' 13°31.0' 15°22.6'	6	100-838	103-855	102-1533	North end Line A; 25-81 miles; D/B lost in hurricane.
7031	S. Refr.	SB(2) PUBS	30 Sept - 1 Oct	2335/273	2345/274	56°36.8' 55°06.6' 11°24.0' 13°00.0'	7	1344-1360	1375-1360	2514-2544	North end Line C (Rockall Trough); 100 miles.
7032	V	V	2 Oct	1112/275	1210/275	55°31.5' - 13°03' -	-	1478	1512	2764	To 2000 m.
7033	Spec. expt.	PUBS	3 Oct	1050/276	1443/276	55°16' - 15°36'	8	1130	1156	2113	To measure sound pulses from explosions by PUBS in midwater (for Stn. 7019)

SEISMIC REFLECTION PROFILES

	Equipment used	Date	Time (z)/Day No.	Lat. N Lat. N to	Depth Range			Comments
			From To	Long. W Long. W	UCF	CF	CM	
SRP	AG FA N. I. O. Rec. Camb. Rec.	27/28 Aug	1100/239 - 1654/240	55°56.5' 57°34.0' 16°23.3' 19°45.0'	187-531	193-543	353-994	South section Hatton Rockall Basin
SRP	AG FA N. I. O. Rec. Camb. Rec.	2 Sept	1635/245 - 0250/246	59°12.6' 59°05.5' 23°51.2' 24°07.5'	1362-1410	1382-1433	2527-2621	Profile over Deep SRP.
SRP	AG FA N.I.O. Rec. Camb. Rec.	4/7 Sept	1430/247 - 0700/250	59°21.0' 56°47.0' 23°19.4' 13°43.5'	1305-139	1325-143	2423-262	Reykjanes Ridge - Hatton - Rockall
SRP	AG FA N. I. O. Rec. Camb. Rec.	8/10 Sept	2137/251 - 1630/253	56°55.0' 55°18.1' 14°25.5' 08°06.5'	90-45	93-46	170-84	Rockall Trough section.
SRP	AG FA Camb. Rec.	25/26 Sept	1605/268 - 2300/269	57°54.5' 58°39.5' 14°04.0' 17°31.5'	114-514	117-525	214-960	North Section Hatton Rockall Basin.
SRP	AG FA Camb. Rec.	3 Oct	0433/276 - 1010/276	55°33' 55°18' 15°49' 15°37'	300-1000	306-1021	560-1867	South section Rockall Trough.
SRP	AG FA Camb. Rec.	3/4 Oct	1529/276 - 0700/277	55°19' 54°13' 15°35' 14°24'	920-1560	939-1596	1718-2918	South section Rockall Trough (cont).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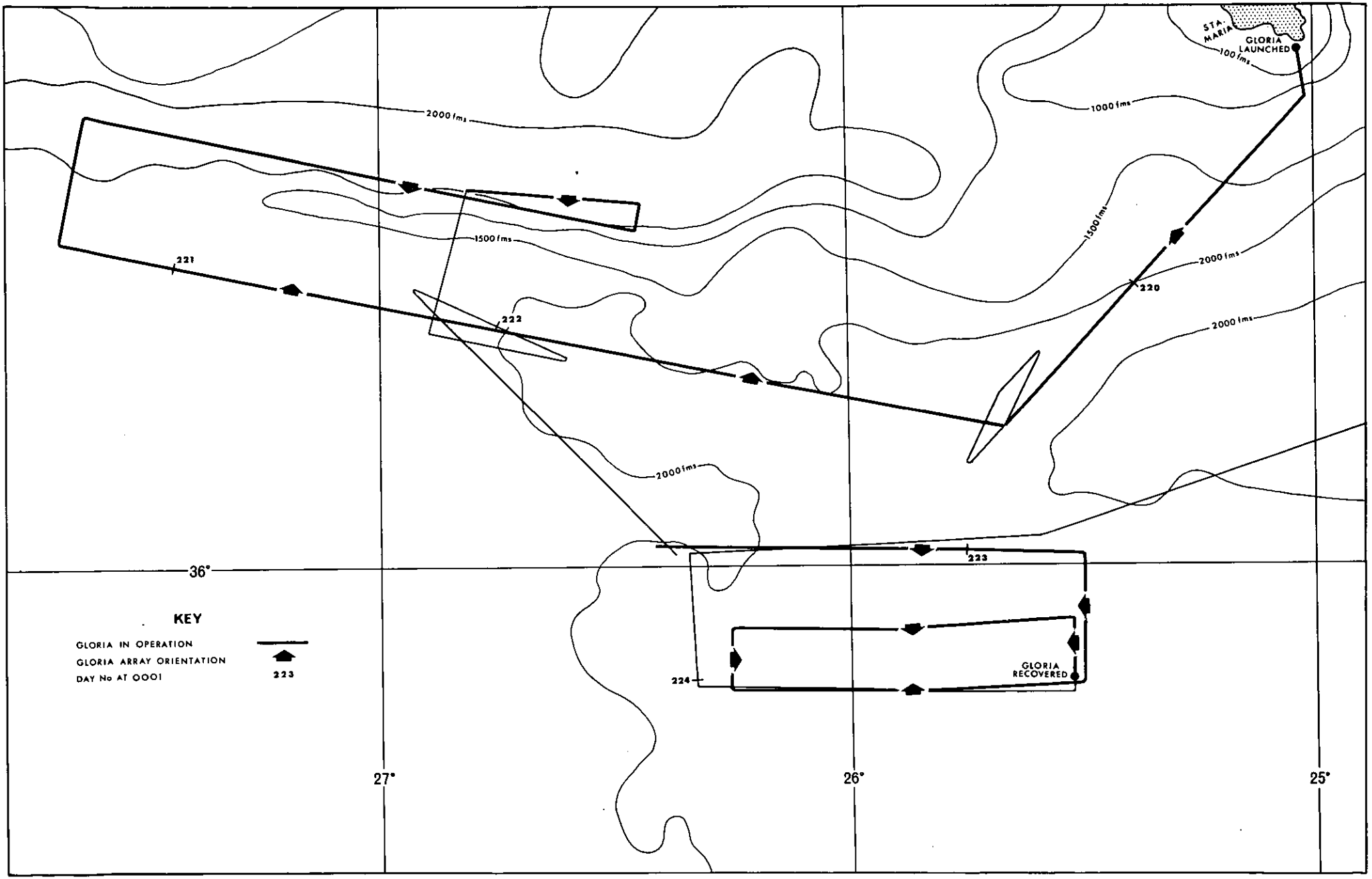
20°
1000fm
10°
100fm
16
55°
See Fig 3
28 29
30
50°
41 42
42 43
45°
217
228
218
227
59 60
60 61
40°
219
226
KEY
SEISMIC REFRACTION STATION
SEISMIC REFLECTION PROFILING
DAY No AT 0001
217
OCEANIC PLOTTING SHEET
30
See Fig 2
225

Fig 1


STA. MARIA
GLORIA LAUNCHED
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1000 fms
2000 fms
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1500 fms
2000 fms
2000 fms
2000 fms
221
222
220
223
224
GLORIA RECOVERED
36°
27°
26°
25°
KEY
GLORIA IN OPERATION
GLORIA ARRAY ORIENTATION
DAY No AT 0001
223

Fig 2

DISCOVERY CRUISE 29

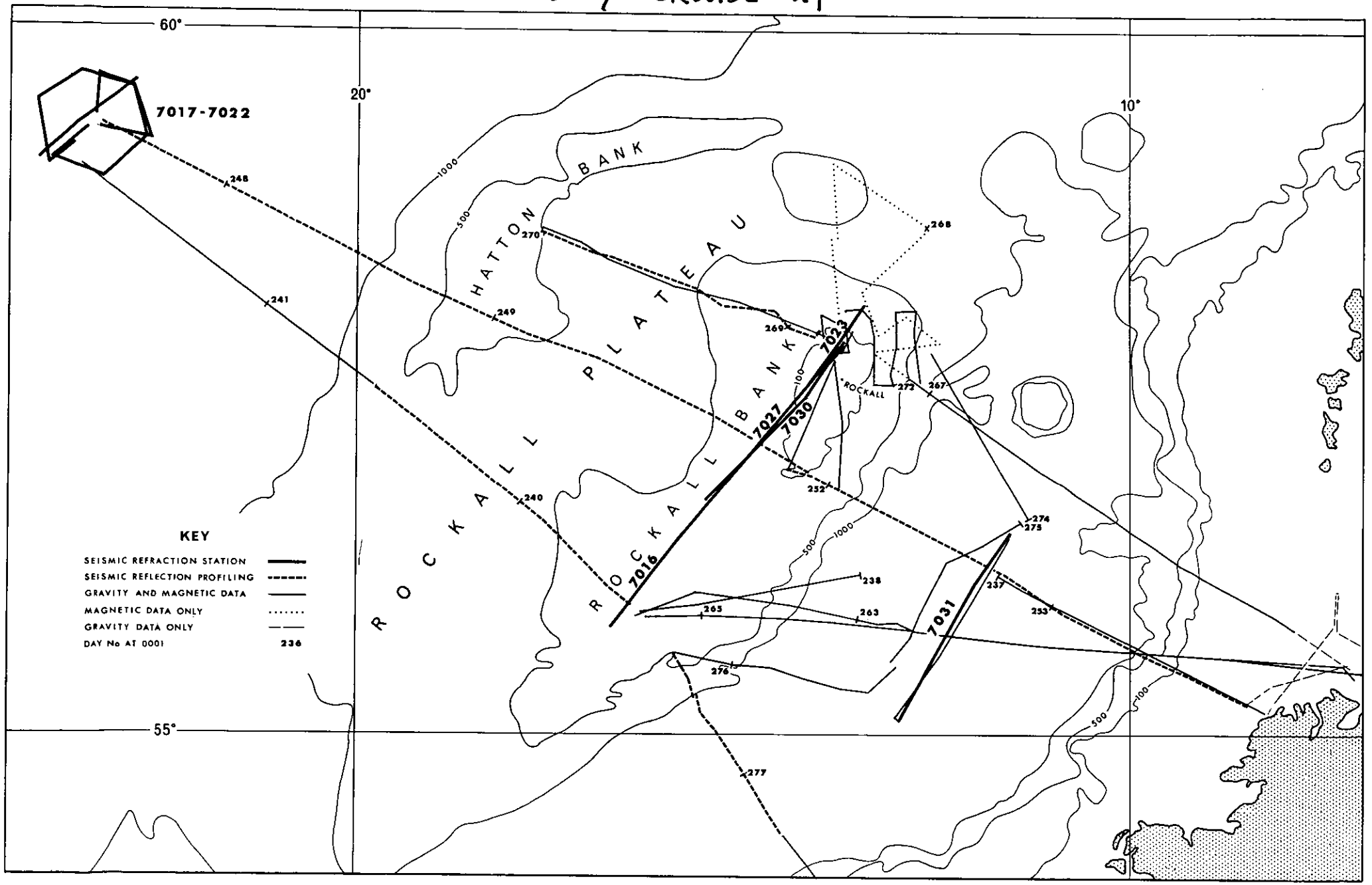
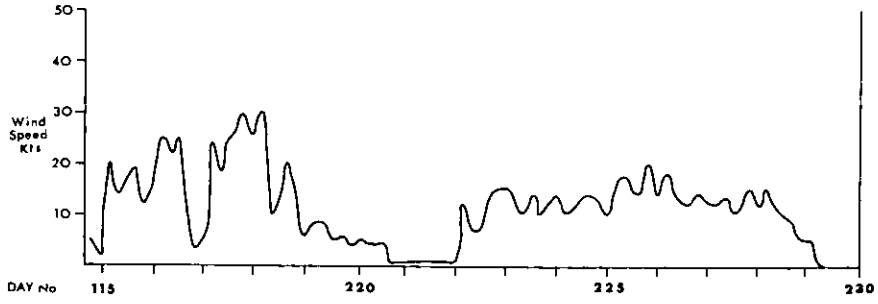
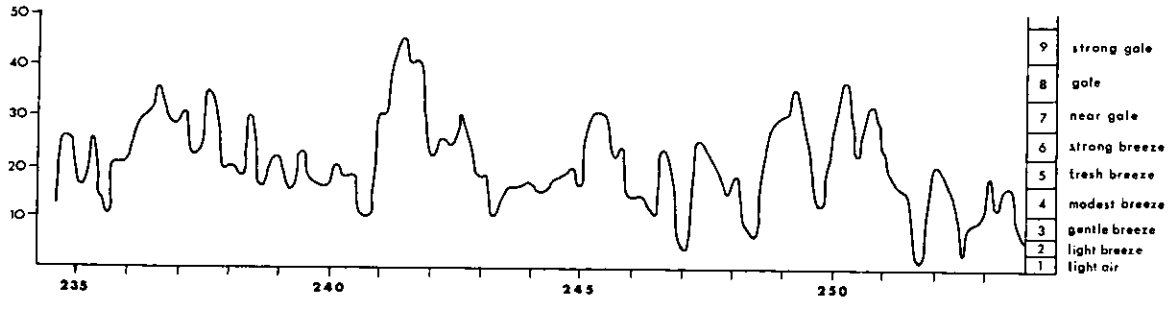


Fig 3



LEG 1



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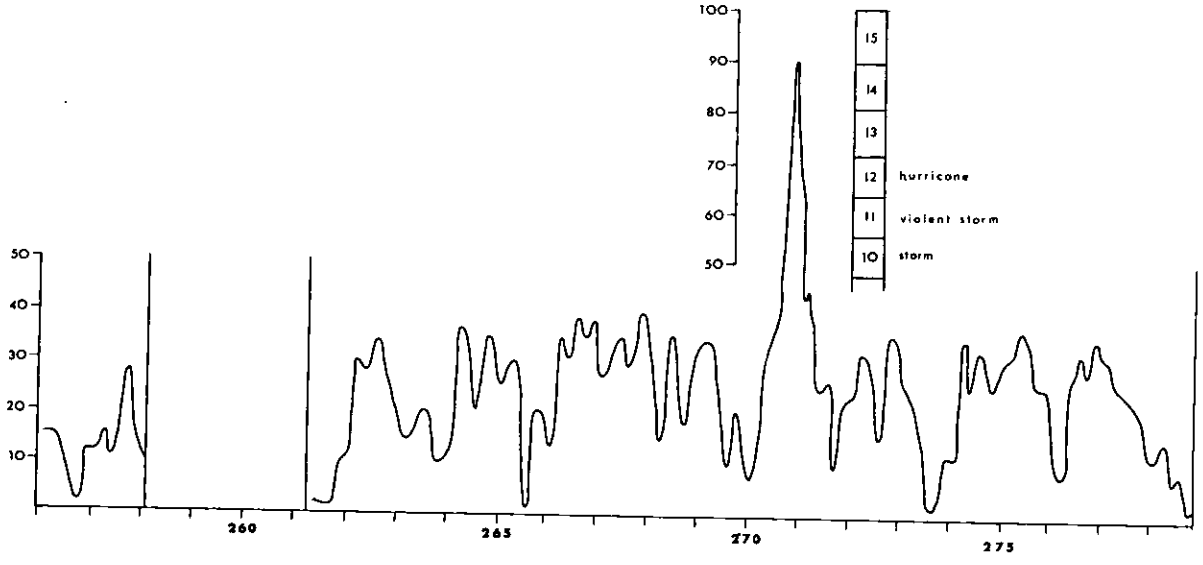

LEG 2A

LEG 3

Fig 4

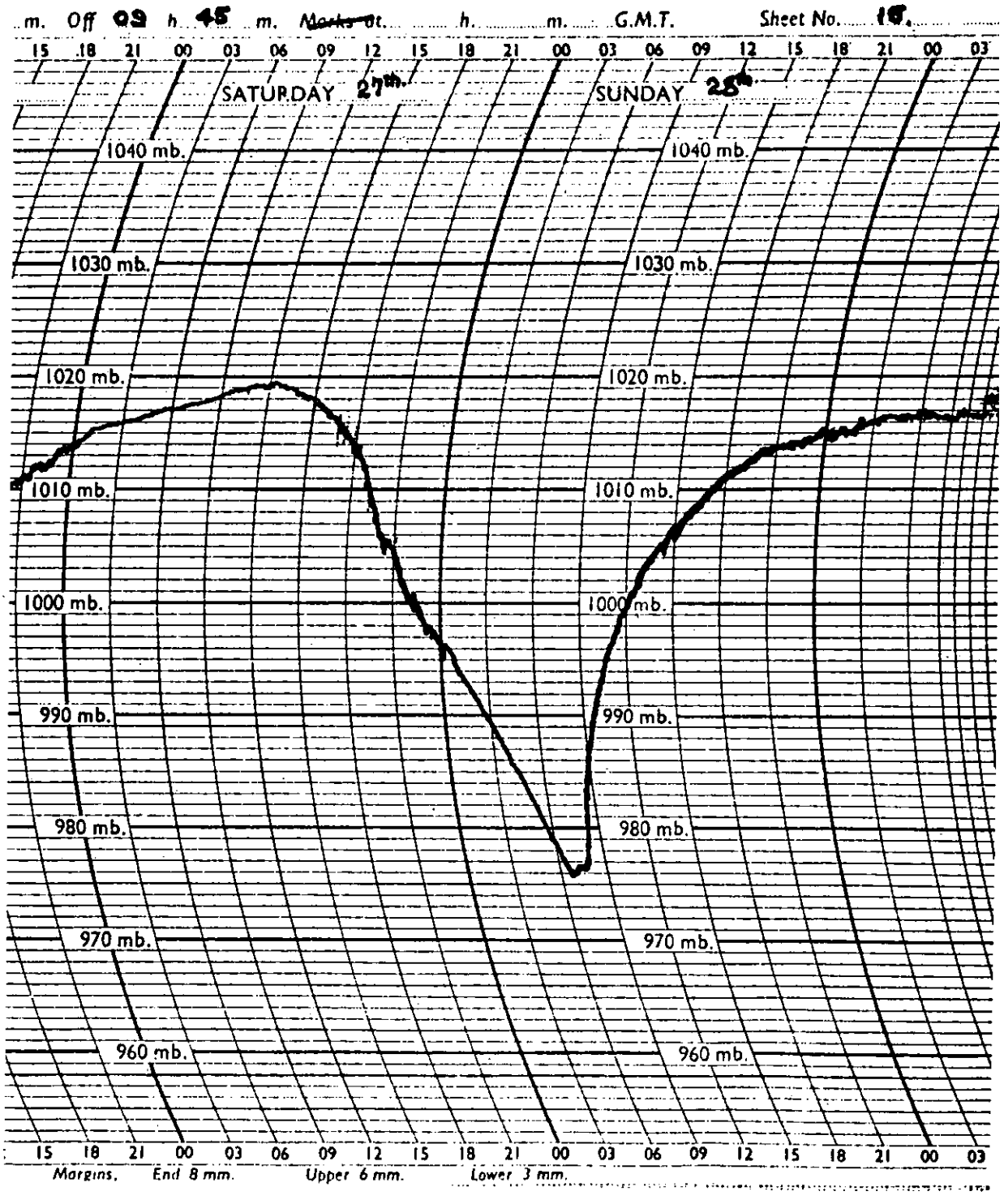

Fig. 5. Barograph record of severe depression on 28th September (271)