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I.O.S.

FARNELLA CRUISE 4/81

28th NOVEMBER – 19th DECEMBER 1981

TIDE-GAUGE DEPLOYMENTS AND GLORIA STUDIES OF MID-ATLANTIC RIDGE FRACTURE ZONES BETWEEN THE AZORES AND NORTHERN SOUTH AMERICA

CRUISE REPORT NO 123

1982

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Tide-gauge deployments and Gloria studies of Mid-Atlantic Ridge fracture zones between the Azores and northern South America

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Institute of Oceanographic Sciences,
Brook Road,
Wormley,
Nr. Godalming,
Surrey

ACKNOWLEDGEMENT

It is a great and genuine pleasure to thank the skipper and crew of M.T. Farnella for their willing, cheerful and competent assistance.

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ITINERARY

Departed Ponta Delgada	1115 GMT	28th November 1981
Arrived Belem	2200 GMT	19th December 1981

Note: It had been planned to end the cruise at Paramaribo, Suriname. However, information received during Cruise 3 suggested that the facilities at Paramaribo were unsuitable and it was decided to use Belem instead. One day was added to the planned length of the cruise to allow for the additional passage involved.

SCIENTIFIC PERSONNEL

D. Bishop	IOS (W)	SRP
P. Foden	IOS (B)	Tide gauges
B. Hughes	IOS (B)	Tide gauges
P. Hunter	IOS (W)	Geophysics
C. Jacobs	IOS (W)	Geophysics
R. Lloyd	RVS	Computers
S. McGiveron	IOS (W)	Geophysics
R. Phipps	IOS (W)	Workshop
C. Paulson	RVS	Gravimeter
T. Probert	RVS	Computers
R. Searle	IOS (W)	Geophysics (Principal Scientist)
M. Somers	IOS (W)	Gloria
R. Spencer	IOS (B)	Tide gauges
R. Walker	IOS (W)	Gloria

CREW - M.T. FARNELLA

Master	E. Thundercliff
1st Mate	P. Taylor
2nd Mate	W. Wilson
Chief Engineer	K. Rudd
2nd Engineer	B. Carrick
3rd Engineer	P. Orr
4th Engineer	H. Templeman
Radio Officer	E. Constantine
1st Cook	P. Mitchell
2nd Cook	B. Morfitt
Steward	R. Brockwell
Bosun	M. Scarpatti
Seaman	J. Laird
Seaman	H. Berry
Seaman	C. Kenny

OBJECTIVES

The cruise was entirely funded from the science vote and was shared between the Wormley Marine Geophysics Group and the Bidston Tide Gauge Group. The objectives were as follows:-

(1) To lay tide gauges at seven locations along the Mid-Atlantic Ridge between the Azores and South America;

(2) To run Gloria and other geophysical equipment between the tide-gauge deployments, with the following objectives:

(a) To determine the separation direction of the North American and African plates at several points along the Mid-Atlantic Ridge by mapping the precise locations and directions of several large-offset transform faults (e.g. at Oceanographer, Kane and Fifteen Twenty fracture zones);

(b) To measure the ratio of inward to outward facing fault scarps near the Mid-Atlantic Ridge axis;

(c) To investigate the extension of Fifteen Twenty fracture zone and the possible North America/South America plate boundary west of the Mid-Atlantic Ridge;

(d) To study how fracture zone morphology is affected by spreading direction changes.

(e) To obtain some Gloria runs over Vema fracture zone.

It was recognised that time would probably not allow all of these objectives to be achieved; in particular (d) and (e) had relatively low priority and in the event were not achieved. All the other objectives were fulfilled.

NARRATIVE - All times GMT, with Julian Day number

The ship sailed from Ponta Delgada at 1115 on day 332. Course was set for the first tide-gauge position at 34^{o}N, 35^{o}W and the PES fish, Gloria and magnetometer were deployed by 1430 that day, after which we proceeded at 10 knots. Moderate

head winds and seas were met on passage, requiring increased engine revolutions to maintain speed.

On nearing the first tide-gauge position, at 334/1430, Gloria was switched off for tests, and at 1635 Gloria and the magnetometer were recovered. The tide-gauge station began with an operation to tension the 4-mm wire that was to be used for wire-testing the equipment. After a few minutes the traversing gear on the winch seized. It was removed and the rest of this and subsequent operations were carried out with a rough traversing by hand. The wire tensioning was completed by 2130 and then four sensor packages were lowered together to 3200m. The test was successfully completed and a search for a suitable sea-bottom at 2800m was begun. No depth as shallow as that could be found within a reasonable distance, and the first tide gauge (position A6) was eventually laid at 335/0340 in 3066m.

Difficulty with the navigation was experienced at this and most subsequent stations, inasmuch as the PDP11/34 computed DR positions which differed considerably from the positions of concurrent satellite fixes. This appears to have been a result of the variable pitch propellor, which was feathered but not stopped, pushing water past the head of the e/m log even when the ship was relatively fixed with respect to the mass of the water. A computed track was eventually obtained by relaxing the constraints on acceptance of fixes by the computer, but the positions during such periods must remain somewhat suspect.

At 335/0500 Gloria, the magnetometer, single channel hydrophone and 80 cubic inch airgun with wave-shape kit were deployed, and we set a course of 002° toward the eastern end of Oceanographer transform fault (35°N, 35°W). We ran along the fault from 335/1152 to 336/0036, then turned south to begin a "mini-survey" of the Mid-Atlantic Ridge (MAR) crest just north of Hayes Fracture Zone, near 34.5°N, 37.5°W.

During the mid-cruise stop at Ponta Delgada, the final positions of the Glomar Challenger leg 82 IPOD drill-sites had been communicated to us. The highest priority sites for post-drilling Gloria surveys were numbers 559 to 561, situated along a sea-floor spreading flowline west of the MAR between Oceanographer and Hayes fracture zones. Since we would be making surveys around those sites at magnetic anomalies 5D and 13, it was decided to complete a small traverse of mini-surveys by including the above mentioned one at the ridge crest. This was planned to comprise three tracks parallel to the MAR axis, 30 miles long and 10 miles apart, which it was hoped would provide information on the ratio of inward- to

outward-facing fault scarps near the MAR axis. The other two mini surveys around the IPOD sites would provide some control on the variation of this property with age.

The first mini-survey was begun during the night of 335-336, but the wind had been getting up and was blowing force 8 from the south by morning with the ship barely making 5 knots at times. We therefore altered course to 290° to ease strain on the Gloria cable. By noon the wind was moderating and we were able to turn south once more. The mini-survey was eventually completed early on 337, and we continued south to Hayes Fracture Zone (33.5°N), westwards along the Hayes transform fault, and north again to the IPOD sites 560/561 area which was reached late on day 337.

The second mini-survey (three 30-mile ENE lines) around IPOD sites 560 and 561 was completed in the morning of day 338; we then turned west toward IPOD site 559, near 35°N, 41°W.

During the night of 337-/338 there were difficulties with the navigation, with very large and unexpected drifts being computed by the Magnavox satnav system. Eventually, towards the end of day 338, it was discovered that the sign of the thwartship's log input to the Magnavox had somehow become reversed. This was corrected, and no more trouble was experienced.

Throughout the period 337-339 we suffered heavy weather, with easterly winds up to force 9 and a heavy sea and swell. This frequently slowed our progress, so it was decided to reduce the survey of IPOD site 559, planned as four 30 mile lines, to two lines. After completing this we continued south to the next tide-gauge position (A7, 34°N, 41°W), arriving there and recovering the streamed gear by 339/0953.

We then began a small PES survey to seek a suitable site for the tide gauge. Eventually, at 1248, it was laid on a 3400m terrace on the side of an abyssal hill. Gloria and the magnetometer were redeployed at 1425 and we proceeded south toward Atlantis Fracture Zone, passing 5 miles east of IPOD site 562 near 33°08'N.

The Crater tube (light source) in the Gloria Muirhead photographic recorder was replaced during the deployment of tide-gauge A7, and this resulted in a spectacular improvement in the quality of the subsequent replayed Gloria images.

We turned west to run along the north side of the Atlantis transform fault ($30^{\circ}N$) at 340/1403. During the earlier fracture zone surveys (Oceanographer and Hayes) we had experienced difficulties in observing all the expected transform features with Gloria, because the ship was not always optimally positioned with respect to them. In an attempt to overcome this difficulty, at the Atlantis transform we turned and ran back parallel to, but south of, the transform, thus eventually insonifying it from both sides. This allowed us to keep the transform in range much more easily during the second (eastward) run, and provided much additional information. The same technique was employed again at Kane Fracture Zone ($24^{\circ}N$).

At the end of the eastward leg south of Atlantis Fracture Zone (341/0016), we recovered the geophysical gear for another wire test of the remaining tide gauge sensors, which would take advantage of the 5200m deep at the intersection of the fracture zone with the MAR axis. In the event, the ship drifted slightly out of the centre of the deep and the wire test was terminated at 4200m.

At 0820 the magnetometer was redeployed and course set for the next tide-gauge position (G1: $26.5^{\circ}N$, $44^{\circ}W$) at 12 knots. Gloria was retained inboard to allow tests to be carried out on the vehicle compass during the day.

We arrived at G1 at 342/0427; the tide-gauge was quickly laid in 3600m and by 0826 Gloria and the magnetometer were deployed and course set, at 10 knots, for the western end of the Kane transform fault. The survey of that feature took from 343/0505 to 344/0148; we then ran south again to tide-gauge position G2 ($19^{\circ}N$, $47.5^{\circ}W$).

This tide-gauge was laid at 345/0824 in 3470m. Immediately afterwards the PES fish was recovered for examination as it had been producing noisy records for some time. No serious damage was apparent, but some fairing clips were broken. Those nearest the fish were replaced and because no other spares were available the other broken ones were taped up. The fish was redeployed and subsequently worked perfectly.

Gloria and the magnetometer were redeployed at 345/1051. We then ran SE for a day before turning west along the Fifteen Twenty transform at 346/1530. Near midnight, we passed the MAR median valley at the western end of the transform and continued on the same course, following the fossil part of the fracture zone,

past the position of a supposed change of direction near 47°40'W, until 347/0831. We then turned NW for a brief examination of Royal Trough (an enigmatic 6000m E-W deep) near 16°N, 49°W, before running south, across the Fifteen Twenty Fracture Zone and Researcher Ridge, to tide-gauge station G3.

This station had been planned to be at 14°N, 49°W, in a depth of about 3500m. However, the bathymetric charts available suggested that the nearest sea-floor of that depth was some 40 miles to the NNE, on the southern flank of Researcher Ridge. We consequently recovered the geophysical gear and hove to there at 347/2204. The tide-gauge was eventually laid at 348/0204, in 3527m, after a rather long wait for a good satellite fix.

The magnetometer, but not Gloria, was deployed at 0350, to enable us to make more speed over the last part of the leg, and thus allow time for a short Gloria run over the outer part of the Amazon Cone, in preparation for the next leg which was to be devoted to working there.

We reached tide-gauge station G4 near 10°N, 50.5°W at 349/0918, and recovered the magnetometer for the last time. The tide-gauge was quickly deployed and by 1200 we were again under way to the last tide-gauge station with just the PES deployed. The last tide-gauge was laid at 0543 on day 350, the echo-sounder being switched off immediately afterwards. Course was then set for a point over the Amazon Cone, but outside 200-mile limits, with the intention of conducting the short Gloria run there. However, a combination of moderate southeasterly wind and a 2-knot westerly current reduced our speed over the ground to less than 8 knots. Since that would not allow sufficient time to reach Belem on schedule, it was decided to abandon the last Gloria run, and at 350/1305 course was set for the Salinopolis pilot station. The PES fish was recovered at 350/1412, and the e/m log was retracted at 352/1600, just off Salinopolis. The ship anchored off Belem that night, and tied up at the dock about 2200 on day 353.

PROJECT AND EQUIPMENT REPORTS

Fracture Zones

Gloria coverage of the active (transform fault) sections of all five major fracture zones (Oceanographer, Hayes, Atlantis, Kane and Fifteen Twenty) between

the Azores and 10°N was obtained. At two (Atlantis and Kane) we obtained complete, overlapping coverage from two opposing directions of insonification, and at one (Fifteen Twenty) the coverage was extended at one end beyond the active section to a crustal age of about 12 My.

At each fracture zone, a 'transform domain' some 2-4 km wide could be recognised. Each such domain was characterised by one or more, often anastomosing, sharp, narrow reflectors, inferred to be strike-slip fault traces. These inferred faults were generally not continuous throughout the active section of the fracture zone, and did not everywhere exhibit exactly the same strike. However, the observations should enable the spreading direction to be inferred with a precision of better than 1° at each fracture zone.

Other features often observed within the transform domain are long, narrow, sharp-crested ridges, which may be indicative of volcanism or diapirism within the domains. Some slightly oblique structures which may represent Riedel shears and/or compressional ridges were also observed.

Outside the transform domain, in the fracture zone walls, there were generally few strong reflectors parallel to the fracture zone axis.

RCS

Mid-Atlantic Ridge Faulting

One small, detailed survey was conducted near the MAR axis at 34.5°N, to examine the relative abundances of inward and outward facing fault scarps. This survey forms part of a small 'geotraverse' along a single flow line, which also comprises the surveys at IPOD sites 559 to 561. In addition, Gloria data collected on passage between tide-gauge positions A7 and G1-G3 provide much valuable new information on this question.

The tectonic and volcanic fabric revealed by Gloria at the MAR mini-survey is relatively complex, and does not appear to be typical of simpler parts of the MAR. There are closely-spaced small-offset fracture zones, and possibly some large volcanic massifs. The typical lineated fault-block morphology found at other parts of the MAR does not appear to be so well developed here. In addition, an early interpretation is complicated by the fact that, for technical

reasons, it was not possible to replay all of the Gloria tapes from the mini-survey. However, in spite of these complications, it appears that there is a predominance of inward-facing scarps in this region. Away from the ridge crest, in the areas of the IPOD surveys, there is some evidence of outward-facing scarps. However, this will need careful analysis before any definitive conclusions on the nature of the faulting can be drawn.

The MAR crest south of Hayes Fracture Zone seems to be tectonically simpler than that to the north. Here, and particularly in the region just north of Kane Fracture Zone (24^{o}-26^{o}N), it is quite clear that in the crestal region of the MAR the tectonic fabric is completely dominated by inward-facing faults, and outward facing ones are extremely rare.

RCS

IPOD post-drilling surveys

Gloria data were obtained over IPOD sites 559 to 562 inclusive. A single pass parallel to the magnetic anomaly lineation, with a westward-looking beam, was obtained at site 562. At all the other sites two passes parallel to the magnetic lineation direction were made, providing overlapping westward- and eastward-looking coverage in strips about 10 miles wide (the maximum effective sonar range) and 20 to 30 miles long. Seismic reflection, gravity and magnetic field measurements were made throughout.

These observations allow the volcanic and tectonic setting of each drill site to be determined, and should aid the understanding of regional changes in volcanic and tectonic style. It is hoped to be able to relate such changes to the variations in basalt chemistry seen in the drill samples.

RCS

TIDE GAUGE DEPLOYMENTS

General

The tide gauge capsules deployed consist of a tubular aluminium frame

approximately 1.3m diameter by 1.4m high attached to a disposable steel ballast weight. The data logger, together with its associated battery supply, is lowered in a central 6" I/D aluminium tube. The sensors are mounted externally to the logger housing in separate pressure cases with Marsh Marine connectors. The assembly free falls to the sea bed and is recovered using the IOS acoustic release system to separate the ballast weight. There are two separate acoustic units, each capable of operating the release mechanism. Buoyancy is provided using Corning glass spheres attached to the main frame. A flashing light is fitted to aid recovery.

All the seven capsules deployed had two pressure sensors and one temperature sensor. The type of pressure sensor used was a strain gauge and a Digiquartz oscillator at each station apart from G4 which, because of its depth, 4900m, had two strain gauge sensors. The data logger was a Sea Data system sampling 16 times per hour. In addition to the main logging system, four of the capsules had an Aanderaa type tide gauge also fitted on the frame. Two of these were a standard commercial type with Digiquartz sensors sampling pressure and temperature alternately each quarter-hour, the other two being IOS modified with strain gauge sensors sampling four times each hour.

There were no problems in handling or deploying the gauges on the Farnella. Final assembly was carried out on the foredeck and the forward boom was used to lower the capsule to the sea surface, it being released on the starboard bow. The final assembly might prove to be difficult in bad weather.

Tide-Gauge Acoustic Release System

It was intended to wire test each release unit prior to deployment. RVS provided a winch bolted on the foredeck and this was spooled with 5000m of 4-mm wire. Unfortunately, the traverse mechanism was in poor condition and seized immediately it was used, although it had been well greased and lubricated. This fractured the main drive bearing and hence the traverse system had to be removed and the wire spooled by hand using a scaffold bar as a lever and a running shackle and pulley arrangement. Another disadvantage was that the pay-out and haul rate was at best 0.4m per sec. As a consequence, the wire was only deployed three times: first to tension the wire; second to 3000m with four acoustic units; third to 4200m with four acoustic units. Thus, each gauge

was deployed with one wire-tested set of acoustics and an untested back-up unit of known capability. All the acoustic units worked well with no problems.

With the ship 'laid to' the wire angle was not more than 30^{o} during a four-hour station, sea state 3-4. The propeller was 3% astern at 132 r.p.m. and the signal/noise was acceptable under these conditions with 4200m of wire payed out.

During each deployment the capsule was clearly seen to reach the sea-bed; however, at stations G3, 4 and 5 the ship's main engine was stopped to improve the listening conditions, as the surface current had moved the ship about 1½ miles from the lay position.

R. Spencer

GLORIA

The GLORIA vehicle was launched and recovered five times on this leg and recorded for 315 hours (40 tapes) overall. Except for the Oceanographer F.Z. survey when the seismics were also deployed and the speed was eight knots, the standard towing speed was 10 knots. It was necessary to open the vehicle junction box once for attention to the compass and this caused the loss of one day's recording on passage between tide gauge stations. Apart from this, the vehicle and sonar circuits behaved impeccably. There were a few troubles with the analogue recording and replay but very little data was lost.

The main feature of the records was the extreme variation in target strength encountered with some enormous echoes on the fracture zone. This meant that the dynamic range at the output of the digital correlators was as much as the analogue tapes could handle and the so-called fixed gain channel was difficult to replay without overloading the highlights or losing the weaker features. The so-called fixed gain channel actually has a soft limitation characteristic so some of the excess dynamic range was removed, but it is clear that it needs different adjustment as between passive margin areas and mid-ocean ridges. The difficulties were compounded somewhat by problems with the Müirhead K300 photographic replay machine.

All data on the cruise was also recorded digitally on 800 BPI 9-track magnetic tape using the GLORIA CAMAC system. The system suffered only one spurious

shutdown and it was quickly restarted. Five tapes of 2400 feet were recorded bringing the total in Farnella to 13. Selected tapes were also duplicated at 1600 BPI for replay on the NERC Image Processing System at Swindon. Unfortunately, it was not possible to make passage at 12 knots and with the South Equatorial current set against the ship the detour had to be abandoned for lack of time.

The services of the crew were employed as much as possible in launching and recovering the vehicle, with extremely satisfactory results.

MLS

SRP

Three days out from the Azores, the SRP system was deployed at 0500/335 and then towed at eight knots for 100 hours, covering 800 nm of track. The two-channel array was used in conjunction with an 80 cubic inch air gun plus wave shape kit. All the equipment worked well. The DC compressor, however, over-heated just before the end of the run for no apparent reason. Several gallons of water were needed to top up the radiator which had blown its relief valve. After the compressor had cooled down it was run to see if the H.P. air was getting into the cooling system. There was no evidence that it was. Since no further SRP was carried out, a proper test could not be run.

D.G.B.

Computing

All the routine processing on this leg proved to be reasonably trouble-free. The G2 system is capable of processing minilogger output quickly and the only parameters that have required manual insertion have been gravity and depth. The new software for the minilogger worked after a fashion, but with an unacceptably high level of corrupted navigation data. Two days after leaving Ponta Delgada, the system disks were changed to one of the earlier issues as it was felt that manual insertion of one variable (gravity) was preferable to the random and detailed editing of four variables.

On day 338, it was noticed that the MX1107 satellite navigator had its port/

starboard signs transposed - a drift to port would be registered as a starboard value and vice-versa. After checking the appropriate input connections, it was found that a thumbwheel switch, performing the function of selecting various options in the MX1107, had been set to an incorrect value. Resetting this switch gave the correct values of port/starboard drift.

Other hardware problems that were encountered included a worn bearing on the cooling motor of the hard copy unit, a slipped belt on an RL01 disk drive, and a loose guide rod on the Calcomp 1039 drum plotter. All these problems were overcome with no extended down-time on the machines.

One of us (RBL) rewrote the program VDU to randomise the plotting origin, in order to minimise damage to the phosphor on the display screen, already in a poor condition from previous cruises. The Geophysical listing program IGLIST was modified to allow velocities south and west (i.e. negative values) of greater than 9.99 knots. A new subroutine was added to the plotting suite ZMAPC to give minute marks around Mercator charts. To complement the compass rose plotting routine, developed on leg 3 by D. Jones, degree annotations were added at any desired increments (TCEP). "Distance run" was added to the final listing of cruise data.

On three occasions, starting on day 347, the minilogger presented errors associated with output to magnetic tape. These errors occurred at the end of tide-gauge stations. The logger was restarted successfully twice, but on the third occasion the opportunity was taken to test the minilogger tape drives under CATY, since there was no scientific work in progress. Both decks indicated errors on read and write operations (i.e. DMA transfers) so that DMA unit was exchanged, although the error system appeared to be working satisfactorily. The problem correlated closely with the restart of the main engines, but the actual cause remains open to speculation.

Navigation corrections for the tide-gauge stations proved to be somewhat difficult on account of anomalous EM log reading being generated by the "feathered" propellor. This ship uses a variable pitch system for propulsion so that the propellor is turning even if the ship is not being driven.

Auto-diagnostics were run on the SE8800 tape drives, chiefly to check drive 1 which has, apparently, had difficulty in reading the minilogger tapes for some time. Both drives successfully passed all the diagnostics; the rest of

the processing system passed all the XXDP+ diagnostics run immediately after the SE8800 tests.

At the end of the cruise, the computer systems were fully cleaned and prepared for the quiescent period over Christmas.

RBL

TCEP

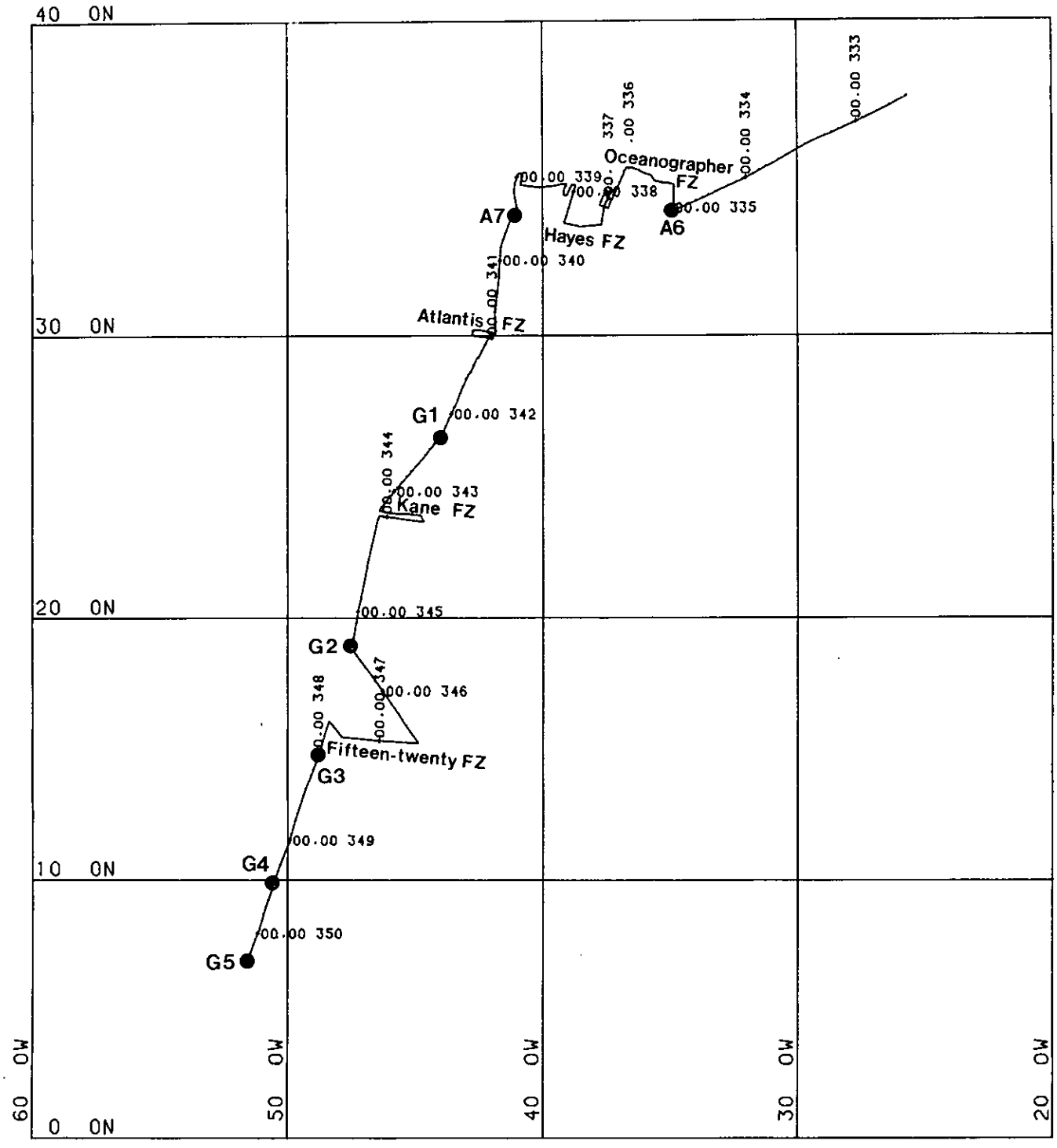
CJP

TABLE 1 - TIMES OF UNDERWAY GEOPHYSICAL OBSERVATIONS

Equipment	On	Off	Comments
Gloria	332/1450	334/1430	
	335/0610	339/0915	
	339/1509	341/0015	Recovered to check compass
	342/0828	345/0731	
	345/1129	347/2203	
PES	332/1354	334/1648	
	335/0500	339/1242	
	339/1424	341/0142	
	341/0818	342/0542	
	342/0754	345/0718	
	345/1048	347/2224	
	348/0342	349/0842	
	349/1200	350/0542	
Magnetometer	332/1434	334/1634	Reduced to IGRF 1975.0
	335/0556	339/0914	
	339/1446	341/0014	
	341/0824	342/0540	
	342/0828	345/0728	
	345/1114	347/2204	
	348/0358	349/0918	
Gravimeter	Ponta Delgada	Belem	Run continuously. Reduced to IGSN 71.
SRP	335/0552	339/0914	80 cu. in. gun and WSK
Computer logging	332/1220	350/0906	

TABLE 2 - TIDE GAUGE DEPLOYMENTS

POSITION GAUGE	GAUGE REF.	DEPTH	LATITUDE	LONGITUDE	INSTRUMENTS	TIME RELEASED
A6	1	3066m	33°59.6'N	34°53.0'W	MK IV TG & Aanderaa	335/0340
A7	2	3372m	33°55.6'N	41°12.0'W	MK IV TG & Aanderaa	339/1248
G1	3	3600m	26°34.9'N	43°57.6'W	MK IV TG	342/0622
G2	4	3470	19°00.3'N	47°30.5'W	MK IV TG & Aanderaa	345/0824
G3	5	3527	14°42.3'N	48°50.3'W	MK IV TG	348/0204
G4	7	4850	9°59.2'N	50°31.3'W	MK IV TG & Aanderaa	349/1008
G5	6	3764	6°59.7'N	51°32.5'W	MK IV TG	350/0543



G|G MERCATOR PROJECTION

SCALE 1 TO 16773412. (NATURAL SCALE AT LAT. 33)

INTERNATIONAL SPHEROID