I.O.S.

FARNELLA CRUISE 3/81

7th NOVEMBER – 26th NOVEMBER 1981

GLORIA STUDIES OF LOWER CONTINENTAL RISE AND ABYSSAL PLAIN SEDIMENTATION IN THE CANARY BASIN

CRUISE REPORT NO 122

1982

INSTITUTE OF OCEANOGRAPHIC SCIENCES

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey, GU8 5UB.
(0428 - 79 - 4141)

(Director: Dr. A.S. Laughton FRS)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051 - 653 - 8633)

(Assistant Director: Dr. D.E. Cartwright)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823 - 86211)

(Assistant Director: M.J. Tucker)

FARNELLA CRUISE 3/81

7th November - 26th November 1981

Gloria studies of lower continental rise and abyssal plain sedimentation in the Canary Basin

IOS Cruise Report No. 122

1982

DOE Report No. DOE/RW/82.053

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

This work has been commissioned by the Department of the Environment, as part of its radioactive waste management research programme. The results will be used in the formulation of Government policy, but at this stage they do not necessarily represent Government policy.

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.

CONTENTS

ITINERARY

Departed Ponta Delgada 1312 GMT, 7th November 1981

Arrived Ponta Delgada 1030 GMT, 26th November 1981

SCIENTIFIC PERSONNEL

M. Beney	RVS	Computers
J. Campbell	IOS (W)	Gloria
S. Drake	IOS (W)	Geophysics
C. Flewellen	IOS (W)	SRP
A. Gray	IOS (W)	Workshop
P. Hunter	IOS (W)	Geophysics
C. Jacobs	IOS (W)	Geophysics
D. Jones	RVS	Computers
R. Le Suavé	COB, Brest	(Visitor)
S. McGiveron	IOS (W)	Geophysics
C. Price	IOS (W)	Geophysics
J. Revie	IOS (W)	Gloria
R. Searle	IOS (W)	Geophysics (Principal Scientist)
R. Simm	IOS (W)	CASE student

CREW, M.T. FARNELLA

Master	R. Hadgraft
First Mate	P. Taylor
Second Mate	R. Moss
Jnr. Second Mate	F. Gordon
Chief Engineer	K. Rudd
Second Engineer	B. Carrick
Third Engineer	P. Orr
Fourth Engineer	H. Templeman
Radio Officer	E. Constantine
First Cook	P. Mitchell
Second Cook	B. Morfitt
Steward	R. Brockwell
Seaman	J. Laird
Seaman	H. Berry
Seaman	W. Mabbott

CRUISE OBJECTIVES

The cruise was funded by the Department of the Environment, and was given over to studies of sediment distributions and dynamics as part of the oceanic radioactive waste disposal research programme. The major tool to be used was Gloria. An important aspect of this work was that it formed part of a combined study with work to be undertaken on Discovery Cruise 126 in March 1982. Sites for sediment sampling and near-bottom observations during that cruise were to be chosen on the basis of our results, to complement the underway geophysical studies undertaken from Farnella.

The detailed objectives were as follows:-

(1) To complete a detailed Gloria survey of the Great Meteor East (GME) study area, approximately 31°-32°N, 24°-26°W. The intention was to locate all abyssal hills and basement outcrops in the area, and seek evidence of sea-bed sediment transport or erosion.

(2) To map the distribution of different sediment facies (distal and proximal turbidites, debris flows) and structures (channels, fans etc.) on the giant sediment slide mapped by Embley and Jacobi using 3.5 kHz echograms, which runs from the African continental margin to an area immediately to the east of GME.

(3) To carry out a reconnaissance of the south-western corner of the Canary Basin (23°-25°N, 24°-30°W), with the intention of choosing a new distal abyssal plain study area (CV3), in a more distal environment than the present CV1.

(4) If (3) were successful, to carry out a detailed Gloria and seismic survey of CV3.

(5) To provide some Gloria coverage over the CV1 study area.

(6) To investigate possible extensions of the GME study area to the west and southwest.

(7) To examine the distribution of abyssal hills in a region of the Madeira Abyssal Plain near 33°N, 22°W for the IOS Marine Physics Group, which is

conducting studies of the oceanic circulation using an array of current meters moored there.

(8) To determine the position of the western edge of the Madeira Abyssal Plain.

Most of these objectives were achieved. Following the reconnaissance of the SW Canary Basin, we did not feel prepared to define a CV3 study area, so (4) was not carried out. Objective (8) which was to have been attempted mainly on the return north after working CV3, was to a large extent abandoned in favour of a line farther to the east which allowed us to investigate the extent of sea-bed sediment transport adjacent to the most distal areas of the abyssal plain.

NARRATIVE (All times GMT)

In Ponta Delgada the RVS multichannel hydrophone winch was unshipped prior to returning it to the UK. The procedure for emergency shutdown of the main engine in case of AC power failure was also tested in port, with complete success. The ship sailed at 1312 on November 7th (Julian day 311), with all scientific personnel but without the Spanish observer, from whom nothing had been heard. We headed southeast from Ponta Delgada, extended the E/M log and deployed the PES fish, and started watches at 1520.

We then spent half-an-hour testing the 3.5 kHz system with the ship hove-to: first with the engine running and propellor feathered, then with the engine stopped. This test was carried out over a sedimented, 2000m deep basin. Even in the latter condition the performance was minimal: a rather fuzzy bottom echo and a total penetration of about 30m were obtained. With the engine running, the bottom was barely visible. It was concluded that the Edo Western fish, with its single torroidal transducer, has a completely inadequate power output for deep water work.

Following this trial we deployed Gloria and the magnetometer and came up to 10 knots. After rounding Santa Maria at 1930, we set course for the area of the Marine Physics current meter array near 33^{o}N, 22^{o}W.

During the previous cruise the starboard beam of Gloria had appeared anomalously broad. There was a suspicion that this might have been due to a fault in the new digital correlator. This cruise had therefore been started using the old drum

correlator. However, this gave no improvement, so we switched back to the digital correlator at 311/2130.

We crossed onto the Madeira Abyssal Plain at about 1200 on day 312. Gloria showed there are numerous abyssal hills jutting above the plane. We passed over the site of the current meter array at 312/2350, and altered course to ESE toward the Great Meteor East (GME) study area. The IOS single channel hydrophone array and a 20 cu. in. airgun were deployed at 313/0630. Although giving adequate penetration and a good high-freqency component to the signal, this gun produced 5 clear bubble-pulse oscillations, obscuring structures in the upper part of the section. We therefore changed to an 80 cu. in. gun fitted with a wave-shape kit at 313/1642. This was the smallest chamber for which a wave-shape kit was available. The energy and penetration were comparable with those of the 20 cu. in. gun, although the high-frequency content was slightly less. The number of bubble-pulse oscillations was drastically reduced to 2 or 3. It was decided to use this size gun for the rest of the leg. After changing the gun, we increased speed to 8 knots and set a course of 233^{o} to begin a survey of the GME area.

During day 313/a check was made on the Gloria resolver circuits, and it was found that these were not correctly aligned. They were realigned, and recording recommenced at 1730 after a gap of three hours. The record was much improved, although still not completely right.

The DC air compressor failed at 0930 on day 314, because the pressure control valve stuck and finally caused the relief valve to blow. The AC compressor was started without incident.

When the first Gloria records were printed to the size calculated from the anamorphic ratio, they were found to be 4% too short. The same problem had occurred on Discovery Cruise 110, when the trouble had been traced to a mis-calibration of the control for setting the ratio on the anamorphic camera. The control was calibrated by photographing a piece of graph paper at various ratios and comparing the result with the ratio set. Using this calibration produced accurately size prints; it is recommended that a similar calibration be performed at the beginning of each cruise.

The Gloria resolver circuits were again re-aligned between 1615 and 1800 on day 314. This completely cured the beam-broadening problem.

The GME survey continued through days 315 and 316, and at 0114 on 317 we altered course to the southeast to begin a survey of the sediment slide, having by now been advised to go ahead with the planned work in spite of the absence of a Spanish observer. Gloria was soon showing spectacular structure within the slide, and at 317/1132 we altered course to start a small box survey of a part of it. The airgun was brought in for routine maintenance at 1530 and was replaced by the 20 cu. in. without wave-shape kit. At 2000 the box survey ended and the 20 cu. in. gun was replaced by the 80 cu. in. with wave shape kit.

We continued to run up the sediment slide during day 318. During the night the compressor tripped out several times but was restarted without trouble. This problem recurred, with no obvious reason, at intervals throughout the cruise. At 318/1736 the PES broke down, and was out of action for 1½ hours while a pulse power amplifier was replaced.

Around 318/2100 we crossed onto the area of the debris flow part of the sediment slide as mapped by Embley and Jacobi from 3.5 kHz echo-character and cores. We zigzagged across it progressing generally south-east until 319/1724. We then altered course to 225° and at 2135 slowed down to recover the seismic gear. While doing so, one of the hydraulic valves on the Hiab crane jammed and the control lever broke off. The airgun recovery was completed using a ship's windlass and a block. The Hiab was later repaired.

We then continued at 10 knots, crossing an area, northeast of Pap Seamount, of mapped 3.5 kHz hyperbolic echoes (which did not show any different character on Gloria) and then a mapped debris flow northwest of Echo Bank (which did).

At 320/0555 we altered course to 245° at the beginning of a long run across the lower continental rise toward the CV3 reconnaissance area. Throughout most of this run Gloria provided evidence of strong seabed sediment transport, showing broad bands of acoustically distinct material which appears to have been emplaced by down-slope streaming.

We arrived in the CV3 reconnaissance area in the southwestern corner of the Canary Basin early on day 322, and redeployed the seismic gear at 0800. The next two days were spent conducting a reconnaissance of this area. Although two Vema seismic reflection profiles had suggested that no abyssal hills occurred east of about 28°W, we nevertheless found that such hills are common west of 25°50'W at 25°N, and west of 26°40'W near 23°N. Moreover, the whole of this

region displays sediment surface structures probably indicative of sea-bed sediment transport. By 324/0800 it had become apparent that there is no sizeable area west of 26°40'W that would be obviously better than CV1 as a shallow disposal study area.

We therefore concentrated our remaining time in this region on a series of four roughly 50 mile long N-S lines immediately to the west of CV1, and ended with a track running round three sides of the CV1 area itself from 325/1252 to 325/1926. At 325/0500 one of the gravimeter gyros failed. The platform was clamped immediately, the gyro replaced, and the meter re-started at 0747.

After leaving CV1 we turned first SE, then at 362/0032 we altered onto 021° running to the east of CV1. The seismic gear was recovered for the last time at 326/0921, and the rest of the scientific operations were carried out at a nominal 10 knots. At 326/1930 we altered course to due north en route for GME.

On the northward traverse of the abyssal plain we passed out of the area of strong sediment lineaments near 26°10'N, but continued to observe areas of sediment giving clearly different backscattering on Gloria. These differences are thought to be due to facies variations probably reflecting the influence of almost buried abyssal hills on sediment deposition.

At 327/1530, near 30°10'N, we crossed the southern boundary of the northern sediment slide, and at 1750 we altered course to pass WNW through the GME area again, with the intention of examining its westward extension toward Cruiser Seamount. The first sonograph after the turn provided a striking view of the toe of the slide.

Throughout day 327 we had experienced a moderate swell from the NW and winds up to force 5, causing some variation in ship's speed and increased pitching of the Gloria vehicle. At 1300 we dropped to 9 knots to reduce strain on the Gloria cable, but increased to 10 again at 1512 when the swell began to moderate. During the night the swell again increased and we encountered several strong squalls, again giving rise to fears for the Gloria cable. At 0750 on day 328 it was decided to alter course 10° to starboard to ease the situation. Unfortunately this meant that instead of passing through the centre of the basin west of GME we went about 10 miles to the north of its centre. The sonographs showed quite frequent abyssal hills and possible basement outcrops in this area, although they appeared to become less common southwards.

At 328/1434, just east of Cruiser Seamount, we altered course to the NE and began a series of short zigzags to investigate the existence of 'anomalous' NW-SE volcanic alignments which had been suggested to exist here and in GME by our Dutch colleagues. However, our data suggest such structures are not well-developed here. After this, we turned due north at 329/0102.

We slowed to recover Gloria at first light next day, 329/0710. Gloria was recovered easily in a calm sea, and we continued northwards with the magnetometer and PES fish deployed until 1719 the same day, when both were recovered and course set for Ponta Delgada. The ship tied up there at 330/1030.

RCS

PROJECT AND EQUIPMENT REPORTS

Sediment Mass Movement Studies

Research into abyssal sediment transport processes is a critical geological aspect of determining the possibilities for radioactive waste disposal in deep sea areas. Previous work by Embley (1975) and Jacobi (unpublished) on the Moroccan continental margin and abyssal plain has indicated that gravity-induced mass transport processes have been active in the recent geological past. Their 3.5 kHz echo character maps provided the background for the GLORIA survey in this area.

The scientific objective was to use GLORIA in order to detect changes in sediment type and bedform, and map a region in which turbidity currents and possibly debris flow have been active.

Sonographs obtained during the survey confirm that mass transport processes have been operative. A marked increase in the amount of backscattering, and regional contrasts of tone have enabled the turbidite and debris flows to be mapped in a number of places. A striking view of the toe of the turbidite flow has been obtained. The limits of the flow that have been mapped are largely consistent with those mapped on the basis of echo-character.

Tonal contrast throughout the area of sediment mass-movement provides evidence of differences in sediment facies and outlines a number of discrete flow pathways.

Of particular interest are a series of anastomosing channels seen in the middle to lower reaches of the slide. In a number of instances, tributaries can be seen bifurcating at the heads of the channels. 10-15m high steps seen on PES records are clearly seen on the sonographs as linear topographic features, orientated in the direction of flow. Air-gun seismic traces reveal that these structures coincide with basement highs. Subtle changes in echo character on the PES records are also noted across these features. This suggests that there has been an element of topographic control of turbidity current processes.

A traverse across the middle reaches of the sediment slide has revealed a number of linear 4-5 km wide bands orientated in the direction of flow. Broad changes in sediment facies can also be discerned across this area. It is probable that one of these units represents the debris flow mapped by Embley (1975).

PES 10 kHz echo character giving evidence of sediment type and topography has proved to be useful in interpreting the GLORIA sonographs. It is intended to devise a classification of 10 kHz echo character and more closely relate the two sets of data.

The data obtained from this part of the cruise will provide the basis for choosing sites for piston coring and near-bottom geophysical studies of the sediments on RRS Discovery Cruise 126.

RBS

Main Characteristics of Turbidites on the Cape Verde/Madeira Abyssal Plain As Seen on SRP Records

The recent sediments (Pleistocene to the present day) of the Cape Verde-Madeira abyssal plain are largely characterised by lateral transport. The two survey regions (Great Meteor East and the distal part of the Cape Verde abyssal plain) show slightly differing deposition related to the later input.

1. GME. The eastern side displays the termination of input of a proximal turbidite, characterised locally by a marked "toe" of coarse sand. The vertical transition between the proximal and the distal turbidites (the latter having regular bedding, with numerous and continuous reflectors) is marked by a facies

of discontinuous reflectors whose deposition has been closely controlled by the palaeomorphology. The transition between various sub-bottom series, which is clear in the case of the sediment and proximal turbidites, becomes more difficult to identify in distal turbidites.

The lateral change between the various facies is very rapid; this is probably due to the fact that the slope changes acutely around 23°30'W and that the energy of the moving mass (water and sedimentary matter) is rapidly dissipated.

The quasi-horizontal and continuous nature of the distal turbidites and the lack of secondary effects due to piercing basement structures suggest deposition undisturbed by the effects of contour currents or diapirism.

2. Distal sector of the Cape Verde abyssal plain. Three major input sources can be identified. Two of them, noted by Jacobi (Cape Verde Archipelago and the edge of the African margin between 20° and 22°N) probably supply an important part of the material which contributes to the distal part of the abyssal plain; a third mass slide (the upper part of which was noted by Embley - the western edge of the Saharan seamounts) whose western outflow was established by the Jean Charcot cruise (October 1980) also seems to play an important part. The effects of these processes are strongly reflected in the topography of the abyssal plain at distances up to 700 km from the origin:

- evidence of working of the sea-bed (microtopography) (channeling in CV1)
- existence of bathymetric steps of several meters; either the gravity slide encountered a natural obstacle or it lost sufficient energy to stop moving. In this latter case, we are in the presence of a true slide-face.
- hollowing around the base of certain basement features, comparable to sea-moats.

However, three-dimensional geometry of these slides is still difficult to establish precisely because of the relatively low amount of available data.

The regionalisation of various seismic facies (proximal and distal turbidites) is different from that seen in GME. Here, the action of proximal turbidites is dominant and their occurrence so far to the west is surprising. Only small regions to the west of 28°30'W demonstrate the characteristic facies of distal turbidites. This regionalisation is undoubtedly due to the existence of a

continuous slope (from 1.5‰ in the east to 0.5‰ in the west) within the survey zone. Localised flows of later date are superimposed onto earlier apparent slumps and sheet deposits. These are related to instability on the secondary slopes.

All these gravity features may be associated with erosion, especially in the area of proximal turbidites (a hiatus of 450,000 years has been observed at the top of the series in one of the six cores taken in CV1 by an earlier French cruise).

From these various observations, one may conclude that there is no abyssal plain, strictly speaking, in the study zone; the area north of 23° latitude is one of transport-erosion-redeposition (with periods of interbedded pelagic sedimentation). However, the transport-erosion-deposition which appears near 25°W may give way in the west to deposition only, though more data, particularly core samples, would be needed to verify this.

Using data from elsewhere, only a relatively restricted sector (bounded by the Kane F.Z. to the south and by 23° to the north) seems to have undergone true pelagic sedimentation without turbidite activity.

R Le S

GME GLORIA Survey

About four days were spent surveying the GME study area. During this time a complete Gloria coverage of roughly two square degrees was achieved. The survey produced few surprises, but confirmed earlier indications that the area west of 24°W appears to be characterised by distal turbidites, with a few outcropping abyssal hills. Most of these hills were seen to be linear, aligned along 020° and reflecting the faulted block morphology of the oceanic basement. By contrast, one or two of the hills are circular and probably arose as central volcanoes. The survey enabled the sea-floor morphology, especially west of 25°W, to be defined with considerably more precision than hitherto.

RCS

GLORIA

The Gloria vehicle was launched in fairly calm conditions about three hours after leaving Ponta Delgada on day 311. During the following 17½ days it was towed 3250 nm sometimes at 8 kts when seismics were deployed and for the rest of the time at 10 kts. The weather for the most part was very favourable and only once towards the end of the period did the ship's course have to be altered slightly to ease towing conditions and this was when attempting to make 10 kts into a fairly big WNW swell. The vehicle was recovered in the morning of day 329 and again in good weather conditions there were no problems.

The signal processing set up on the ship was such that quick changes could be made between the drum correlators and the new digital correlators. In each case a 4 second 100 Hz F.M. pulse was transmitted every 40 seconds. The drum correlators were used for less than twenty hours but two substitution comparisons were made and in each case the digital correlators produced the better results although neither the analogue tape recorders nor the display system could fully utilise their known better dynamic range. Fifty-three analogue tapes each of eight hours duration were recorded and the "near linear" channels were played back at two levels into the Muirhead K300. In this way it was possible to display the full dynamic range recorded.

It is planned to record the digital data on cartridge recorders but as a stop gap measure the Port and Starboard correlator outputs were recorded on a standard 9-track 800 BPI digital recorder. 496 samples per line were recorded at 12 bit samples so that the whole dynamic range of the digital correlators is stored. It is intended that these tapes should provide the data for some work on image processing.

At the start of the cruise the data was degraded by a fault on the system which resulted in an increase in the horizontal beamwidth. This was traced to a phasing problem in the beam steering resolvers and was cleared on the third day. In all about five hours of recording time were lost due to the resolver fault but this was the only lost time on the cruise.

J.R.

Seismic Reflection Profiling

The IOS two-channel array was towed at a little over eight knots through good seas. A little while into the first run it was decided to double the sampling rate of the logger. With higher filter settings some mains-derived noise was discovered but eliminated when the depth sensors were unplugged.

There were a number of bugs in the logging system:-

(a) Very occasionally missing the end-of-tape sensor. End-of-tape is tested for after writing the last block of each trace, but the tape has still to decelerate through a further 0.2 inches. A delay in the software should have cured this.

(b) Transport not interrupting after writing. This happened a few times during the leg.
Control signals to the transports were terminated at the first transport and this may have caused the problem. The termination board is now at the end of the daisy-chain.

(c) Tape errors. The rate of tape errors increased through the leg. On the previous leg a loose tape guide caused a lot of errors. Although they were not loose during this leg, each has a noticeable flat worn on it. Loosening and rotating the guides should, therefore, improve the error-rate.

An E.P.C. recorder paper drive became erratic due to perished friction 'O' rings. These were renewed.

The air-guns proved to be reliable for the whole leg. The IOS D.C. Revell VHP 36 container compressor was used for the majority of the time with only one major fault, that being the failure of the pilot unloading valve, causing the fourth stage relief valve to blow. Repairs were made and the compressor ran satisfactorily after that.

C.F.

Computing

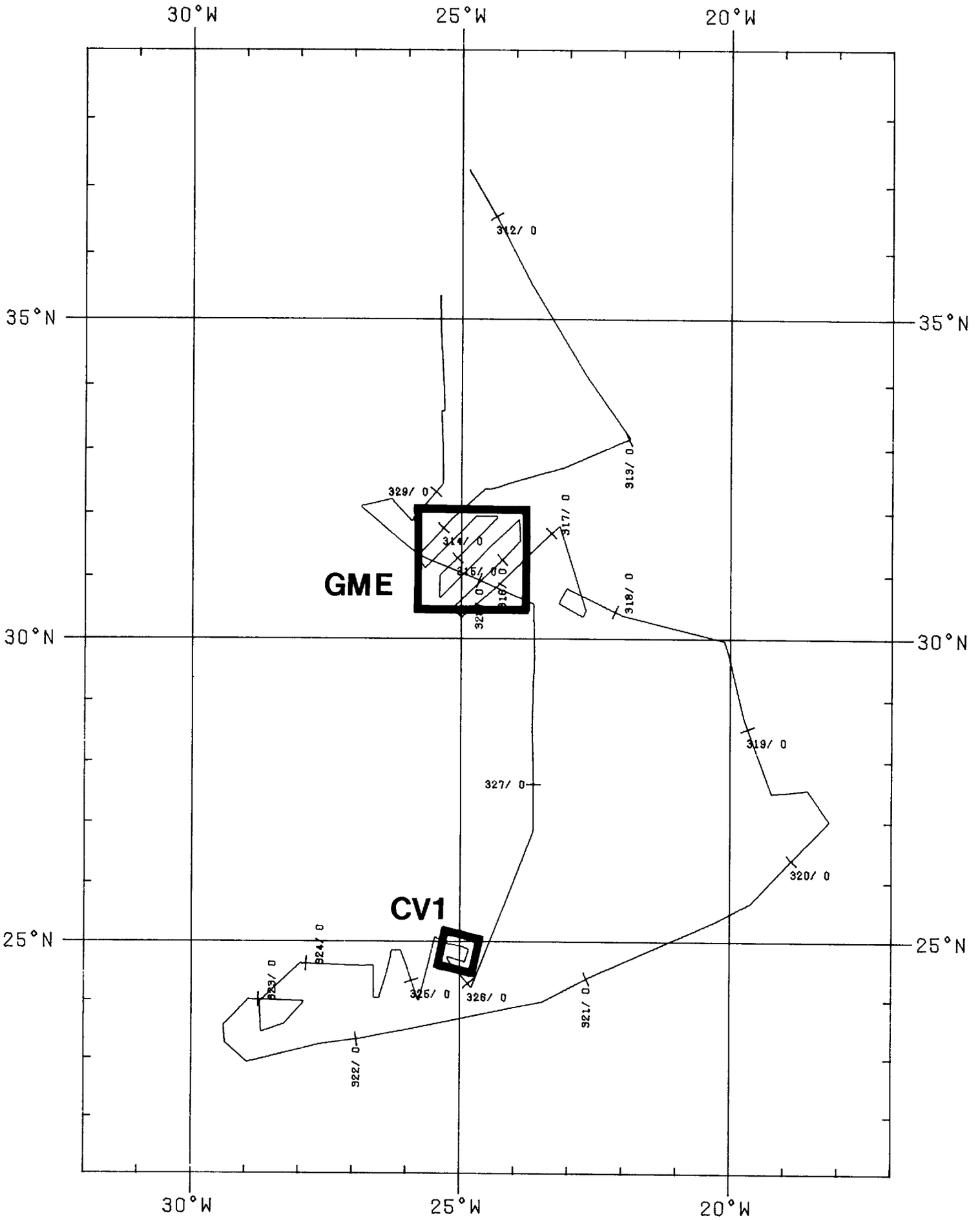
The new PDP 11/04 minilogger and PDP 11/34 G2 processing system were used throughout the leg, and proved to be very reliable. Data were edited on a

24-hour basis, and ample time and power was available for plotting and for running user programs.

RCS

TABLE 1. TIMES OF UNDERWAY GEOPHYSICAL OBSERVATIONS

Equipment	On	Off	Comments
Gloria	311/1730	311/2131	Drum correlator. Broad beam.
	311/2137	312/0138	Digital correlator
	312/0158	312/1453	Drum correlator
	312/1545	312/1614	Sections changed
	312/1620	313/1425	Digital correlator
	313/1730	314/1615	Resolver realigned
	314/1800	329/0806	Resolver realigned. All ok now.
PES	311/1530	318/1736	
	318/1909	329/1736	
Magnetometer	311/1725	329/1732	Reduced to IGRF 1975.0
Gravimeter	Ponta Delgada	325/0500	Run continuously in port
	325/0716	Ponta Delgada	Reduced to IGSN 71
SRP	313/0914	313/1642	20 cu. in. gun
	313/1727	317/1530	80 cu. in. gun + WSK
	317/1558	317/1937	20 cu. in. gun
	317/2002	319/2135	80 cu. in. gun + WSK
	322/0821	326/0921	80 cu. in. gun + WSK
Computer logging	311/1724	329/1932	


30°W
25°W
20°W
35°N
30°N
25°N
GME
CV1
312/ 0
313/ 0
317/ 0
318/ 0
319/ 0
320/ 0
327/ 0
329/ 0
324/ 0
325/ 0
326/ 0
321/ 0
322/ 0