I.O.S.

RRS CHARLES DARWIN

CRUISE 23/87

13 MAY – 11 JUNE 1987

# GEOPHYSICAL INVESTIGATION OF THE INDIAN OCEAN TRIPLE JUNCTION

CRUISE REPORT NO. 201

1987

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF
OCEANOGRAPHIC SCIENCES
DEACON LABORATORY

# INSTITUTE OF OCEANOGRAPHIC SCIENCES

## DEACON LABORATORY

**Wormley, Godalming,**
**Surrey, GU8 5UB, U.K.**

**Telephone: 0428 79 4141**
**Telex: 858833 OCEANS G**
**Telefax: 0428 79 3066**

Director: Sir Anthony Laughton, Ph.D., F.R.S.

*Natural Environment Research Council*

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# Geophysical investigation of the Indian Ocean Triple Junction


Principal Scientist

L.M. Parson


1987

# DOCUMENT DATA SHEET

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|---|---|---|
| AUTHOR | PARSON, L.M. *et al* | PUBLICATION DATE 1987 |
| TITLE | RRS *Charles Darwin* Cruise 23/87, 13 May - 11 June 1987. Geophysical investigation of the Indian Ocean Triple Junction. | |
| REFERENCE | Institute of Oceanographic Sciences Deacon Laboratory, Cruise Report, No.201, 24pp. | |

ABSTRACT

Underway geophysical data, comprising GLORIA sidescan, seismic reflection profiles, 3.5kHz profiles, 10kHz echo-sounder profiles, magnetic and gravity data were collected from the Indian Ocean Triple Junction and two of its component spreading ridges. The principal aim was to assess the present structure, and recent evolution of the triple junction over the past 20 million years. Additional objectives included an investigation of periodic magmatic/tectonic phases in the accretionary histories of each of the three ridges.

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| ISSUING ORGANISATION | Institute of Oceanographic Sciences<br>Deacon Laboratory<br>Wormley, Godalming<br>Surrey GU8 5UB. UK.<br><br>Director: Dr A S Laughton FRS | TELEPHONE 0428 79 4141<br>TELEX 858833 OCEANS G<br>TELEFAX 0428 79 3066 |

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|---|---|---|
| KEYWORDS | *GEOPHYSICS GLORIA TRIPLE JUNCTIONS*<br>*INDIAN OCEAN RODRIGUEZ TRIPLE JUNCTION*<br>*CHARLES DARWIN/RRS - CRUISE(1987)(23/87)* | CONTRACT<br>PROJECT 27023<br>PRICE £6.00 |

*Copies of this report are available from:*
The Library, Institute of Oceanographic Sciences, Deacon Laboratory.

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## ITINERARY

The cruise comprised a continuous underway geophysical survey between port calls at the Seychelles and Mauritius. RRS Charles Darwin departed the Seychelles on the 13th May and after entering international waters surveyed the actively spreading Central Indian Ridge en route to the main survey area. This was situated around and to the west of the Indian Ocean Triple Junction. Upon completion of this area a short additional reconnaissance survey of the South West Indian Ridge axis was made before transit for Mauritius. Charles Darwin docked at Mauritius on the 11th June.

## SCIENTIFIC PERSONNEL

| | |
|---|---|
| Parson, Lindsay (Principal Scientist) | IOSDL Geology & Geophysics |
| Beney, Martin | RVS Computer Technician |
| Berry, Amanda | Univ Liverpool, Dept Oceanography |
| Campbell, Jon | IOSDL GLORIA |
| Cherriman, John | IOSDL GLORIA |
| Le Bas, Tim | IOSDL Geology & Geophysics |
| Mitchell, Neil | Univ Oxford, Dept Earth Sciences CASE student |
| Patriat, Phillipe | Institut Physique du Globe de Paris |
| Paulson, Chris | RVS Instrument Technician |
| Searle, Roger | IOSDL Geology & Geophysics |
| Smith, Kevin | RVS Mechanical Technician |
| Strangward, John | RVS Mechanical Technician |

## SHIPS PERSONNEL

| Name | Rank |
|---|---|
| M. Harding | Master |
| R. McCurry | Chief Officer |
| S. Sykes | 2nd Officer |
| D. Thompson | 3rd Officer |
| J. Baker | Radio Officer |
| G. Batten | Chief Engineer |
| G. Robertson | 2nd Engineer |
| J. Clarke | 3rd Engineer |
| P. Edgell | Electrical Officer |
| A. Mitchell | CPO (Deck) |
| D. Bevan | Seaman 1A |
| P. Hough | Seaman 1A |
| C. Woods | Seaman 1A |
| J. Nicholls | Seaman 1B |
| M. Gemma | Seaman 1B |
| P. Harris | Cook/Steward |
| A. Thomas | Cook |
| J. McKeown | 2nd Steward |
| M. Cross | Steward |
| J. Swenson | Steward |
| K. Pratley | Motorman |

## CRUISE OBJECTIVES/INTRODUCTION

The cruise consisted of an underway geophysical survey of part of the central Indian Ocean, specifically to study the structure and evolution of the ridge-ridge-ridge (RRR) triple junction marking the conjunction of the African, Indian and Antarctica lithospheric plates. The plates meet at a point close to 25°30'S 70°00'E, and the survey was planned so as to cover a reconnaissance box approximately 200km square centred on this point, in addition to a survey west and south from this area to follow one of the component spreading axes. Additional surveys were conducted on transit from the Seychelles to the main area, covering the Central Indian Ridge (CIR) and its pattern of offsets and fracture zones, over the triple junction trace in the Indian plate, and finally from the main survey areas to Mauritius. The following geophysical equipment was run during the survey: GLORIA-2 long range sidescan sonar, 10kHz precision echo-sounder, 3.5 kHz profiler, seismic reflection profiling system, sourced by a 300 cubic inch Bolt airgun and recorded using a two-channel Geomechanique hydrophone, magnetometer, and gravimeter. The seismic system was not deployed for the full survey time. Details of the times of deployments for each individual piece of equipment are found in the following narrative, and more detailed appraisal of their performance is included in the relevant sub-headings below. Navigation was principally by transit satellite, although the Global Positioning System (GPS) allowed us up to 10 hours a day of support navigation. Additional scientific equipment in use consisted of an air particulate sampler operated by Liverpool University.

## NARRATIVE

RRS Charles Darwin departed Victoria, Seychelles at 0615 13th May (Julian day 133) (all times are GMT), in overcast weather but with calm seas. At 0630 14th May (134), in calm water, the 10kHz fish was deployed from the portside midships dedicated winch, and the 3.5kHz fish was, with not inconsiderable problems, deployed from the starboard midships coring A-frame (see below). GLORIA deployment was completed by 0820, and the magnetometer streamed by 0845. The seismics were not used during the transit passage to the main survey area. All the equipment was tested for operational status without logging and then switched off until we were outside the 200 nm limit of Crotelyn Island.

Data logging commenced at 1425 14th May (134). Initial results from the 3.5kHz profiler were poor at survey speed of 10 kts but the range of GLORIA was up to 30 km full swath, and clear insonification of slides and debris flows off the east flank of the Saya da Malha Bank was obtained. Fine weather and calm seas took us southwards in a series of dog-legs along the Central Indian Ridge (CIR), during which we insonified several charted and uncharted fracture zones and ridge offsets. The seismic reflection profiling system was first deployed 0800 19th May (139) to complete the southern section of the CIR at eight knots, but recovery was necessary at 0445 21st May (141) after a ripped trigger lead caused gun failure. It was decided to recover the streamer in the light of the small amount of sediment observed, and the survey continued at 10 knots. A series of north-south lines were set at approximately 16 nm spacing to cover the triple junction box, and these were completed by 0620 25th May (145). Between 0632 and 0747 24th May (144) we had to break off the track line to take emergency evasive action in avoiding collision with an uncommunicative tanker. At 1017 (144) we once again had to reduce speed to 4 knots to avoid collision with another vessel. At 1634 24th May (144) we slowed to 4 knots to commence a recovery of all of the equipment except the 10kHz echo-sounder fish. The defective 3.5kHz fish was replaced and the spare streamed by 1900, this time from the starboard aft schat davit. GLORIA, magnetometer and seismic system were redeployed and logging recommenced at 2008. Easterly and northeasterly track was laid to follow the triple junction trace within the Indian Plate. At 1606 25th May (145) the airgun had to be recovered following a burst air lead, but was repaired and redeployed by 1800 (145). At 0514 26th May (146) we suffered a total power shut down following the failure of an auxiliary power supply. Despite power being off for several minutes, speed was reduced to only five knots, a steady course was maintained, and all equipment remained apparently undamaged. The GLORIA vehicle reached a depth of about 95 metres during this episode. The gyros were temporarily inoperable and steering was maintained by a wheelman for a short time. Course at 063 degrees was held with good weather suitable enough for the mid-cruise barbeque, but the purpose of the excursion towards the northeast was frustrated by not being able to identify the triple junction trace. The return tracks were extended towards the west from the triple junction box to commence the survey of the South West Indian Ridge (SWIR) floor. A further failure of the airgun air lead necessitated recovery of the airgun at 0502 31st May (151). During recovery of the gun the doppler log was deployed in an effort to test the accuracy of the EM log which had proved to be suspect under-reading by about 0.5 knot. No adjustment was made to the log itself but a compensating value was included in the shipboard logging system. A further recovery of the airgun was found necessary after air leakage at 1847 31st may (151). It was decided to recover the Hydrophone as well as the airguns, since the making up of spare air lead and trigger bundles was likely to delay recommencement of seismic profiling, and the survey continued at maximum speed of 10 knots. After several east-west lines across the northern part of the SWIR crust between the triple junction and about 66°E, the seismic system was restreamed at 0500 on the 3rd June (154), prior to commencing a long southwesterly line (20A) along the southeastern limit of this survey. At 1015 on the 3rd June (154), the direct water wave developed a peculiarly dense signal, although without any change to the bottom signal. In addition, the gun was subsequently seen to be leaking, the same time at which the compressors were beginning to work harder at maintaining working pressure. Strong south westerly winds on this course kept survey speed down to less than six knots at times. A number of short tracks completed the coverage of the main area before comencing transit survey lines westward along the SWIR axis. At 1000 6th June (157), we experienced an autopilot failure during the test of the off-course alarm, and we were diverted about twenty degrees in about three minutes. The seismic acquisition system was recovered for the final time at 1831 6th June (157), serviced and stowed. Two damaged O-rings were found to be the causes of both the air leak and the signal problem. At 0413 7th June (158), both levels B and C crashed on the shipboard logging system, a failure initially thought to be a result of radio transmission. However, as this recurred four more times during the next 36 hours, with a variety of error messages, the fault remained enigmatic.

Freshening weather during days 158-160 caused persistent reduction of overall survey speed to well under 10 knots, but time was on hand to complete a series of parallel tracks over the SWIR centred on the area of around 64°00'E, a region of anomalously shallow axis, before making for Mauritius. Surveying with GLORIA continued until 1000 9th June (160), when it was recovered following a short westward digression to examine basement fabric around 25°00'S 61°30'E. The magnetometer was brought inboard temporarily during GLORIA recovery, and redeployed for the final approach lines to Mauritius. All logging of soundings and 3.5kHz recording was terminated at 0500 10th June (161), at 200 nautical miles from the Mauritian baseline.

## PROJECT & EQUIPMENT REPORTS

### GLORIA system

Twenty-six days of GLORIA survey were completed with only two breaks. On day 144 the vehicle was recovered to allow the 3.5kHz fish to be changed, and was out of the water for around two hours. On day 146, twenty-five minutes of data were lost after a complete black out of the ships supplies. Apart from these interruptions, data was logged continually and was unaffected by the few problems that did occur.

Two out of the three digital cartridge recorders were found to be suffering from severe corrosion of their capstan tacho encoders which required disassembly and cleaning to restore proper operation. Both of the line scan recorders proved a little temperamental and it was necessary to replace one of the paper feed motors. The laser filmwriter film drive was sticking at the start of the survey and the problem could only be rectified by removing the film cassette holder end-cap until each film needed to be rewound.

Finally, two new programmes for the IBM were written, one to apply a shading correction to the data, and the other to calculate the anamorphic ratios from the DX-FMT tape.

### Seismic acquisition, etc

Air system and airguns performed satisfactorily although the air hose to the gun blew out twice, and the trigger leads damaged twice. It was subsequently found upon recovery that the new type plastic-covered trigger leads created abrasion at the points where it was bound to the airhose. Using the old type of rubber-coated trigger lead, this problem did not arise, although it was found on occasion the ship was travelling in excess of eight knots (partially due to an EM log error).

The 360 Hiab crane was put out of action with two burst hydraulic hoses on the winch control although this was repaired without disturbance to cruise timing. The 180 Hiab crane also suffered damage (partially due to an awkward stowage position), which resulted in loss of oil which was also repaired without inconveniencing the cruise. Due to a blind spot during airgun deployment and recovery, while working with GLORIA mounted, a request was made to have a duplicate control on the starboard side A-frame stanchion. A request was also made about the possibility of a PES-type winch being made available for deployment of the 3.5kHz fish, this being awkward to handle in a heavy swell. Doubts were raised as to the safety of the temporary access gangway outboard of the upper deck affording access to the GLORIA portakabin-raised angle brackets attached to sea-water pipes being the method of support.

**Aerosol sampling**

Atmospherically transported material deposited on the sea surface can affect the biogeochemical processes that occur in both the water column and the underlying sediments. The Liverpool University Department of Oceanography joined cruise 23 to collect samples of the mineral aerosol (dust), since no recent data has been obtained south of 15°S in the Indian Ocean.

The two techniques employed for dust collection were: (a) high volume filtration, and (b) cascade impaction. From the first technique the crustal source can be deduced by enrichment factors which are derived from total metal concentration. Sequential leaching analysis can build up a more complete picture of the elemental partitioning in the dust. The particle size spectrum of an element in the aerosol can lead also into an insight of its source. Particle size separation is achieved by using a cascade impactor. Fourteen high volume samples were collected between 14th May and the 7th June, as well as three cascade impactor samples. However, due to unforeseen and unpredictable weather and sea-state conditions, much of the data obtained from these samples will need to be treated with caution.

**GLORIA gantry and vehicle**

Some problems were encountered on the fitting of the gantry during the ship's port call in the Seychelles. The crane supplied for lifting the gantry was not large enough, and the ship had to transfer berth from starboard to port side in order to reduce the job reach. Thereafter the emplacement of GLORIA was completed with no problems. The second problem occurred when testing the hydraulics to the gantry. The hydraulic pressure observed at the gantry gauge when in the idling mode was in fact the working pressure which caused the relief valve in the winch motor casing to blow. After various checks the problem was traced to the "tank return" line, where the quickfit connection onto the through deck fitting had failed in the shut position, thus pressurising the system. With the fitting of a new quickfit the system worked with no more problems.

After the reported difficulty of launching and recovery of the vehicle due to the low freeboard, the after clamps on the gantry were removed and their hydraulics blanked off. As a result of this, combined with a calm sea, the launching of the vehicle went very smoothly. The recovery was carried out quite smoothly in a moderate sea and a moderate to heavy swell, with GLORIA suffering minor scratching of the nose-cone. It was noticed that the brake on the winch motor was slipping a little.

**GLORIA image processing**

Because of the fall off in power from the axes of the sonar beams, the brightness of GLORIA images varies across each scan, generally being greater at mid-range and falling to zero at high and low ranges. Recently this has been corrected in post-cruise processing by applying a so-called "shading" correction; essentially this multiplies each pixel by an amplification factor that is an appropriate function of range. It was decided to try to implement such a shading correction during the in-cruise replay and processing on Darwin cruise 23. This was all done on the IBM PC-AT computer.

Since the shading correction is intended to even out the instrument response over the whole scan range, each amplification factor should be the reciprocal of the effective instrument response at that range. An approximation to the instrument response can be guaged by examining the statistics of the image over a sufficiently long period that the effects of the varying seafloor response (ie the geology) average out.

First, a programme (called AVSCAN) was written to determine the average, maximum and minimum value of the signal in each range element for an entire (slant-range-corrected) pass. The user should simply enter the required pass number (nnn) when requested; data are then read from the corrected file LASPSnnn.DAT. The programme was written in FORTRAN77, and does not have graphical output as no FORTRAN graphics is at present available on the replay system PC. If the programme is to be used extensively it would probably be worth translating it into BASIC so as to be able to add graphical output. Another useful modification would be to allow operations on only a specified range of scans (including a single one).

Typical output from AVSCAN is shown in Fig.3a, for CD23 pass 24, which was a slightly oblique crossing of the Central Indian Ridge axis including a small fracture zone. The profile of average values shows a broad peak, falling off slowly towards maximum range. The port side shows a small subsidiary peak at zero range, due to the first sidelobe. On the starboard side the sidelobe is much weaker. The average values can, however, be somewhat misleading, and in particular are strongly influenced by areas where the signal is exceptionally low (eg broad areas of acoustic shadow, especially at long range). The profile of maximum values is therefore a useful additional guide. It is clear from the maxima that the instrument response actually falls off quite slowly with increasing range; indeed on some passes it is even flatter than on pass 24, until extreme far range where it falls off sharply. The maximum profile also shows that the response holds up well until quite short range, and rises quite rapidly from the nulls between main beams and first sidelobes. Maximum values peak at intensities of about 200 (the highest seen was 210), whereas the maximum recordable is 255. Minimum values were usually zero, except for a few values in mid-range where the real signal may never have fallen to zero. There is thus no instrumental noise being recorded, and no danger of clipping high-intensity signals.

Several passes were analysed in the same way, and the results were amalgamated to produce a standard profile for the shading correction (Fig.3b). The values chosen for the mid-range maxima and far-range fall-off closely followed the observed maximum profile, but the near-range behaviour was set between those of the maximum and average profiles. The amplification factors used for the correction were then set at 200 divided by the value of the standard profile. These factors fall from highest values of 2.0 in the inter-beam nulls to mid-range values of 1.0, and then increase again to 1.61 and 1.44 respectively at far range port and starboard.

The shading correction is applied by program SHADE, which will prompt for input. It reads data, already slant-range corrected, anamorphosed, and formatted for the laser writer, from a file LASPSnnn.DAT, and writes the shaded data, in the same format, to LASHDnnn.DAT. (On CD23 the program D2L for sending data to the laser writer required input from files named LASPSnnn so the LASHDnnn files were simply renamed LASPSmmm with mmm = nnn + 100). SHADE also requires a 994-element file of correction factors; it will prompt the user for the filename.

Program SHADMK can be used for generating the file of correction factors. It prompts for the filename to be used, then prompts for pairs of pixel number and correction factor. Only a few points need be given; SHADMK interpolates the rest to fill the required 994-element array.

A trial shading correction was produced and applied to several passes of data; the resulting films and prints were then compared with unshaded data, and the correction profile was modified until a satisfactory result was obtained. The profile illustrated in Fig.3a and defined in Table 1 was eventually achieved, and was used on all the data from the Triple Junction and Southwest Indian Ridge surveys. This was stored as file SHADPF5.

This correction (Table 1) generally worked well. It slightly enhances the far range, and considerably enhances the very near range. Where there are exceptionally strong signals in the near range it actually overcorrects, and strong signals were sometimes clipped. However, this only occurred occasionally near ridge axes; elsewhere there was no clipping and the shaded profiles presented a pleasingly uniform level of picture contrast. A null still remains between the main beams and sidelobes; but our analysis shows that there is no signal here to be recovered.

The shading correction was based on and applied to slant-range corrected data. Unless slant-range correction is applied, the variation in position of salient points in the instrument response profile (ie null position, etc) is too great to allow a meaningful average to be obtained. Even with slant-range corrected data the null point varies significantly with depth, since its horizontal range depends on the depth at which its defining rays intersect the seafloor. Any further improvement of the shading correction would therefore probably require the use of a depth-dependent correction.

**Table 1**
**Details of shading correction (SHADPF5)**

| Horiz. range number (km) | Pixel factor | Correction profile | Standard |
|---|---|---|---|
| 21.9 P | 2 | 1.61 | 124 |
| 13.1 P | 202 | 1.16 | 172 |
| 9.6 P | 282 | 1.06 | 189 |
| 6.1 P | 362 | 1.00 | 200 |
| 4.3 P | 402 | 1.00 | 200 |
| 3.4 P | 422 | 1.08 | 185 |
| 2.6 P | 442 | 1.50 | 133 |
| 1.9 P | 458 | 2.00 | 100 |
| 1.1 P | 476 | 2.00 | 100 |
| 0.2 S | 497 | 1.50 | 133 |
| 0.2 S | 497 | 1.80 | 111 |
| 0.6 S | 510 | 2.00 | 100 |
| 1.1 S | 520 | 1.80 | 111 |
| 2.0 S | 540 | 1.25 | 160 |
| 3.3 S | 570 | 1.00 | 200 |
| 5.9 S | 630 | 1.02 | 196 |

**Gravity logging**

The Lacoste and Romberg gravity meter S40 worked well throughout the cruise despite long periods of poor weather and a ship's power failure. Twenty-one cross-overs revealed a mean miss-tie of 3 milligals. The gravity meter was tied to absolute gravity at Woods Hole station 419 in the Seychelles, and again to IGB station 427070 in Mauritius; the resulting apparent drift of 0.9 milligals showed a daily drift rate of +0.03 milligals per day.

**General summary**

The Level ABC Computing system logged and processed the following parameters; Em-log, Gyro, Transit Satellite, GPS, Magnetics, Gravity and Bathymetry. The Em-log and Gyro were logged once a second, the Magnetics and Gravity every 6 seconds. Provision was made to record the Bathymetry every minute and the two satellite navigation systems as they were available. Coverage by Transit satellite was in the main good with navigation fixes normally every hour, occasionally there were longer periods without fixes and more frequently periods where there were more than 2 an hour. GPS (Global Positioning Satellites) provided coverage on average for a total of 12 hours a day (during the cruise the aerial was resited alongside the Transit aerial). The GPS positional fixes were used as a check on the accuracy of the Transit satellite fixes and only used in the navigation processing when Transit fixes were not available.

The final navigation was processed to 1 minute and used to calculate both the Magnetic and Gravity Free-Air Anomalies at the same rate. A lot of time was spent in ensuring that the navigation was correct and that the computed speed and course made good did not have large jumps in value at the times of fixes. This enabled a smooth transition over the fixes time for the Gravity Free-Air Anomaly.

The Gravity Free-Air Anomaly was smoothed by a running 4 minute averaging programme.

Daily plots of the previous 24 hours navigation track were produced, as well as distance travelled every 6 minutes along the plotting sheet to enable the correct ratios to be calculated for the printing of the GLORIA photographs.

A daily tape was produced in Dxfmt format which was used by the GLORIA team to extract the depth corrections.

The computer system was also used by some members of the scientific party. The programme "Pray" which has resided in Fortran was made to work and has been added to the offline programme suite.

From an operational basis the logging side of the system (Level B) ran for the duration of the cruise. The processing side (Level C) stopped 6 times during the last few days of the cruise and at the time of writing appears to have been cured by the replacement of one of its printed circuit boards.

**Shipboard computing - PRAY program**

During the cruise there was a requirement to implement a sound-ray plotting programme. This had originally existed as FORTRAN programme PRAY on the IBM 1800, but had not been used in a subsequent version by anyone on board. Despite the fact that FORTRAN is apparently officially unsupported by the shipboard computer group, with the aid of the SCG representative on board (Martin Beney) we were able to get the programme running.

Martin found FORTRAN source code for PRAY and associated subroutines and made it available to us in the GUEST dictionary. The code was dated 1982 and had been modified from the IBM version to run on the PDP 11/34 system. Several problems were found and rectified before the programme would run successfully on the Plessey System 68. For convenience, the main programme PRAY and the subroutines PRAY1, PRAY2, PRAY3, PRAY4, PRAYA, PRAYB, PLBOX, PLPROF and PLRAYS were combined into one file. After modification, this workable version (source, compiled version and test data) was stored in directory /nerc/levc/ref/src/gloria/new_pray_ftn.

First, we found the interactive data input difficult or impossible to use with the M2250 terminal available. The data input subroutine PRAY1 was therefore modified to read data from file PRAY.DAT, which must exist before the programme is run. The data, possibly with some messages, are written to file PRAY.OUT which should also exist. In the original version a plot title was read into integer array ICOMM. This no longer works, and the title is stored in character array TITLE instead.

Plotting device initialisation is now achieved by CALL NC836, which is supported in the SPI subroutine library. This seems to work on the Calcomp 1039 drum plotter and the Microcolour M2250 terminal, which do not have initialisation subroutines in SPI.

The main problem was that the SPI subroutine SHIFT2 for changing the coordinate origin did not work correctly. Different parts of the plot were positioned wrongly relative to each other after calls to this subroutine. The solution was to modify SHIFT2 and the SPI absolute movement subroutines MOVTO2 and LINTO2, to keep track of origin changes explicitly. The existing versions did not do this; presumably the hardware devices had some way of keeping track of origin changes, thouth it was not obvious from the SPI code how that could be done. The new SPI routines were tested on PRAY and some small tests programs: no bugs were found, but they have not been checked exhaustively. The modified SPI library is now stored in /nerc/levc/ref/src/spif.

With the changes described above PRAY worked on System 68. In addition, some cosmetic changes were made to the appearance of the plot. These involved modification of the grid and annotation, direct labelling of initial ray angles, and introduction of 3-pen plotting. The program works on both the CA1039 and the M2250, but note that while scale values (XSCALE, YSCALE) are in metres per millimetre for the Calcomp, they are in metres per "screen unit" for the M2250 (1 screen unit is approximately 0.01 inch). However, some annotation is sometimes lost from the bottom of the plot when run on the M2250; changing the value of the initial coordinate shift in the CALL SHIFT2(100.,100.) in subroutine PLPROF may help.

One bug was found in PRAY but not corrected. This occurred when the sound source was on a layer boundary. Then the program would hang up after drawing as far as the first (surface) reflection of the zero take-off-angle ray. It was avoided by changing the source depth by a small amount.

## SUMMARY OF CONCLUSIONS

Fracture zones and ridge offsets of the Central Indian Ridge studied in transit to the main survey area are of widely different morphologies. Examples of short offset, "Kurchatov-type" fractures contrast with well-developed displacement zones with tightly-spaced subparallel ridge and furrow lineations, marking the transform tectonised zone of the larger features. Work on a revision of the plate rotation pole positions is underway using these new data. The Central Indian Ridge/South East Indian Ridge spreading axes image as a continuous median valley and the most easterly structured component of the slower South West Indian Ridge lies a short distance from it. En echelon inward-facing escarpments flank the propagating tip, and their fossil counterparts are seen in older crust away from the African and Antarctica plates is highly complex and appears to vary non-systematically with age. The Southwest Indian Ridge is dominated by an irregular fabric of broad, approximately ridge-parallel highs and elongate basement ridges without evidence of transform offsets.

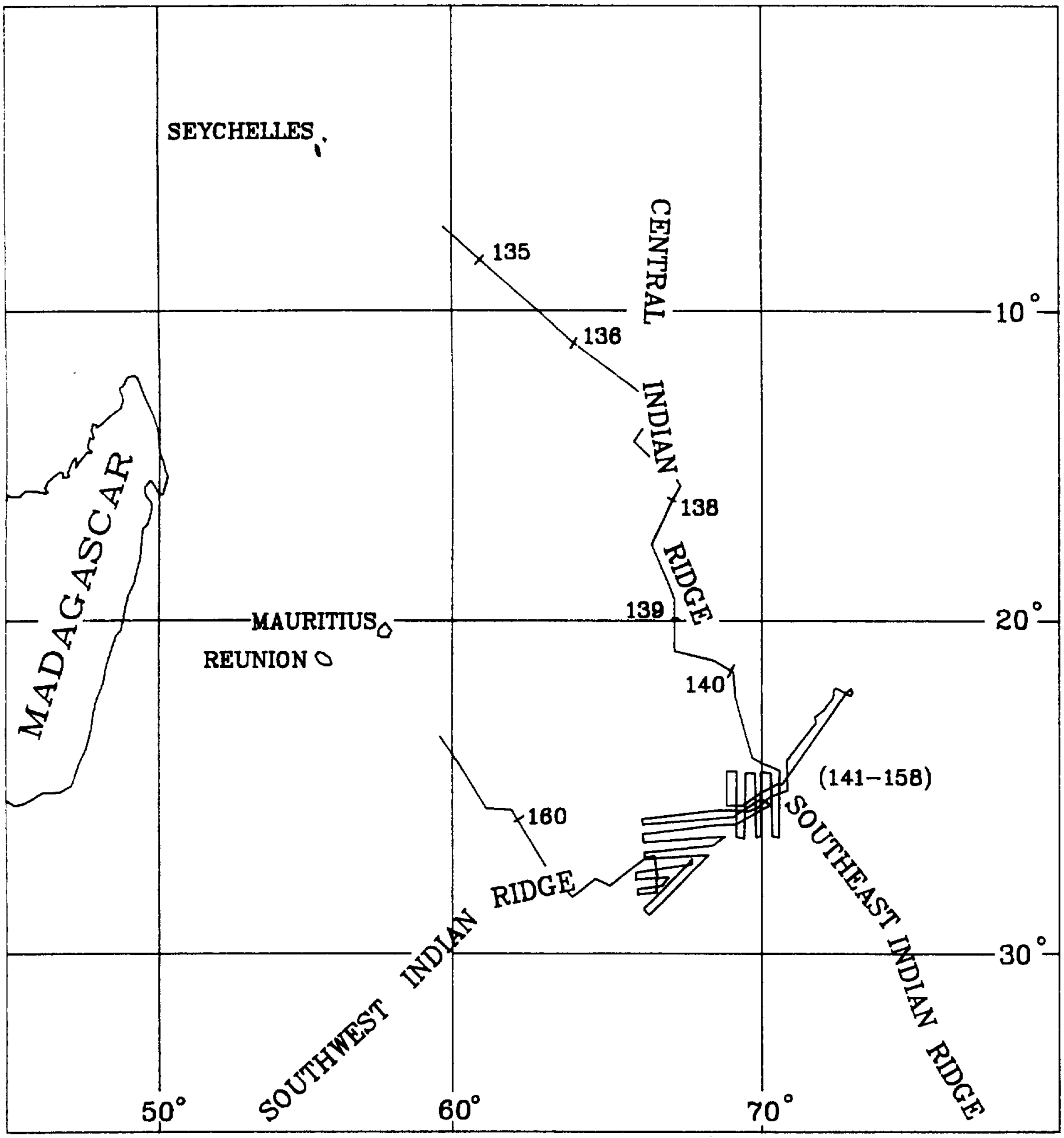


Figure 1: Track Chart: RRS Charles Darwin Cruise 23/87 13 May - 11 June 1987.

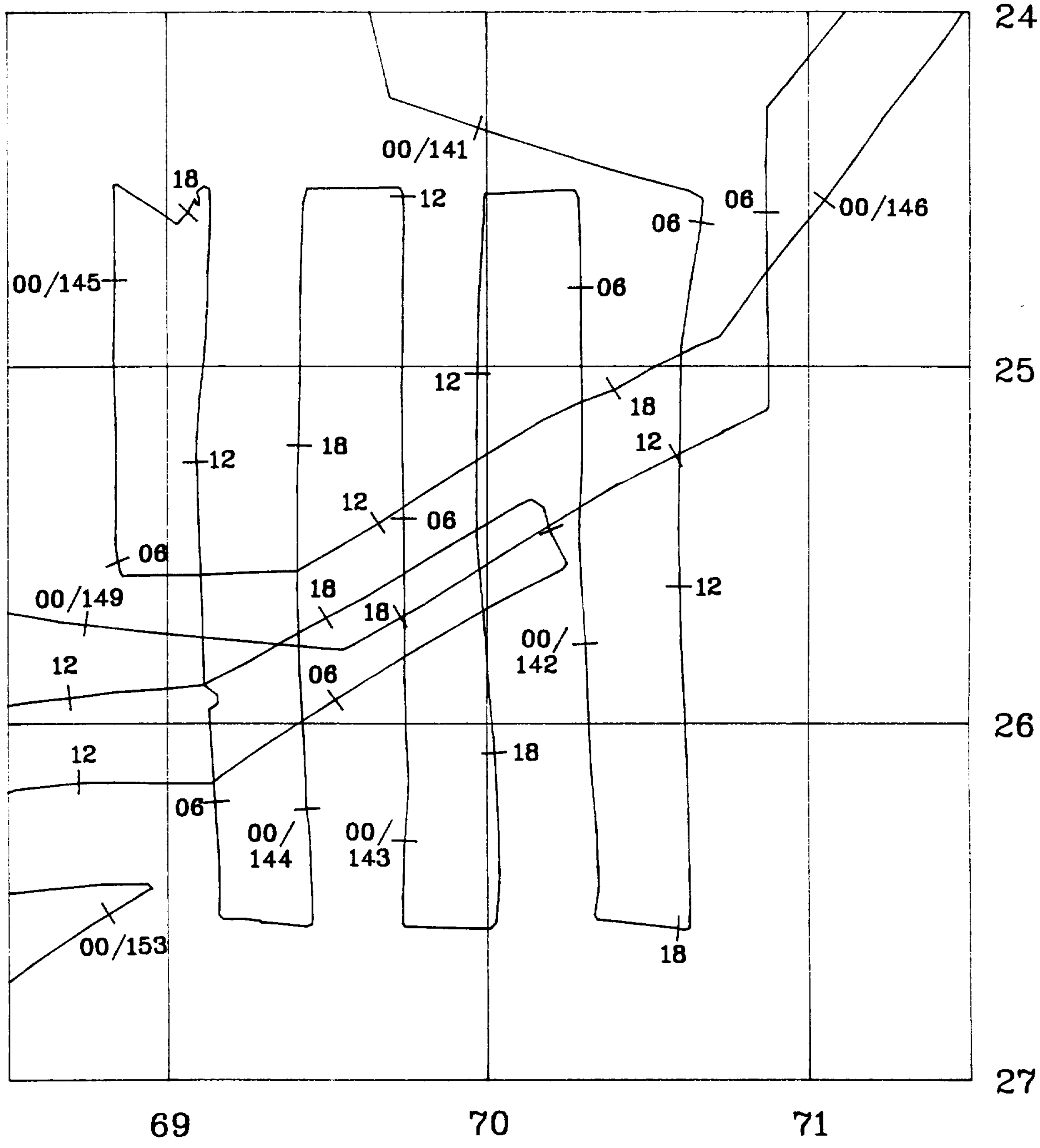


Figure 2: Track layout in the central survey area; Indian Ocean Triple Junction and South West Indian Ridge.

Fig 3a

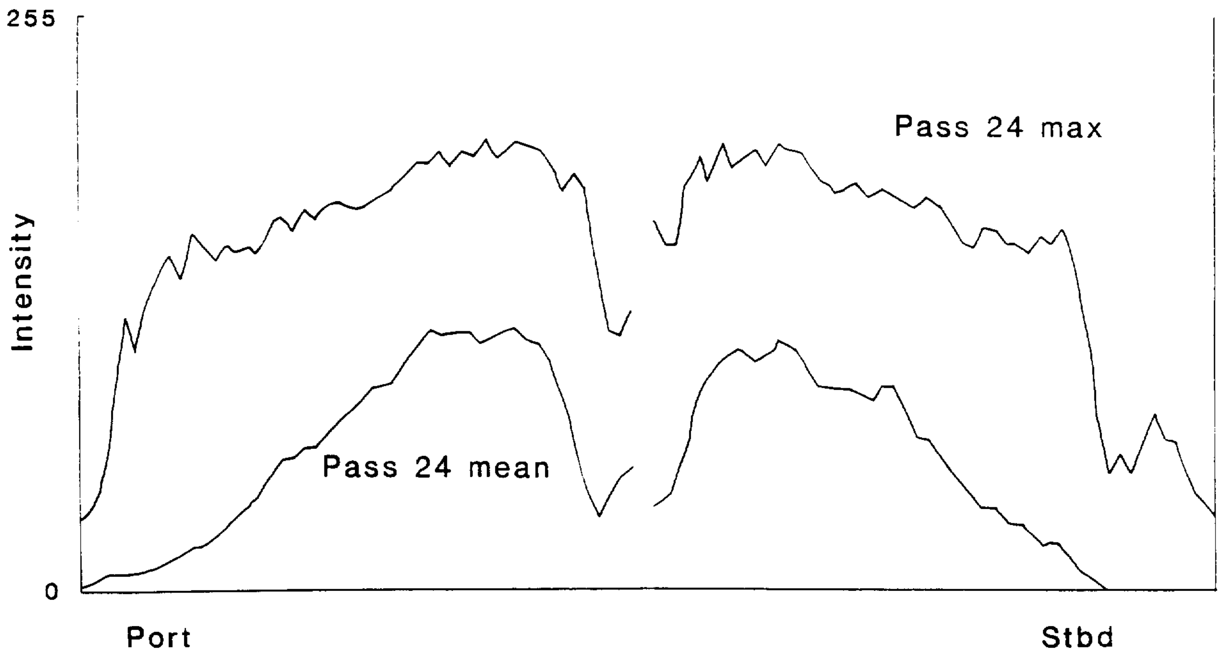


Fig 3b

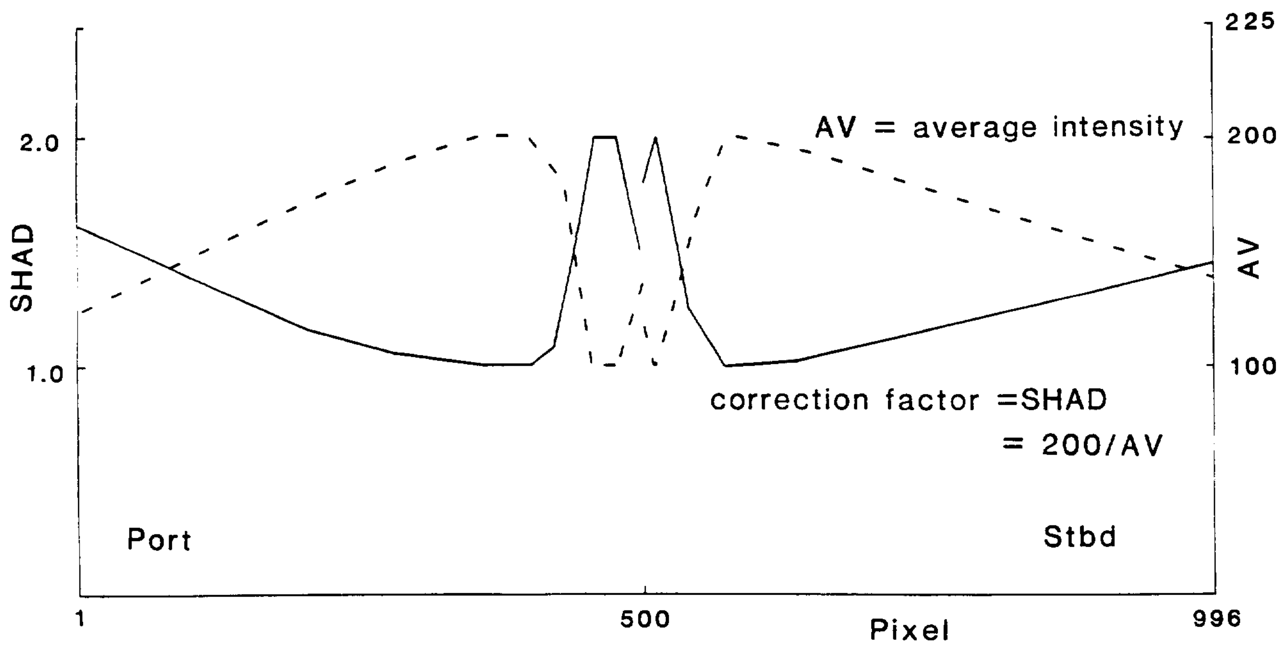


Figure 3a: Typical output from AVSCAN, a fortran program designed to determine the average maximum and minimum values of the signal in each range element for an entire GLORIA pass.

3b: Standard profile computed for use during shading correction.