NATIONAL INSTITUTE OF OCEANOGRAPHY
Wormley, Godalming, Surrey.

R. R. S. DISCOVERY CRUISE 33 REPORT

April - May 1970

DSDP SITE SURVEYS

and

GEOLOGY AND GEOPHYSICS AROUND KING'S TROUGH

N. I. O. CRUISE REPORT NO. 33
(Issued March 1971)

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Leg 1.	Leave Barry, S. Wales	14th April	Day 104
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	Arrive Barry, S. Wales	21st May	Day 141

SCIENTIFIC PERSONNEL

		Affiliation	Leg 1	Leg 2
A. S. Laughton	Principal Scientist	NIO	X	X
R. B. Whitmarsh	PUBS, DSB	NIO	X	X
D. G. Roberts	Data, Corer, SRP	NIO	X	X
M. T. Jones	Magnetics, data	NIO	X	X
J. J. Langford	PUBS	NIO	X	X
E. P. Collins	Cameras, explosives	NIO	-	X
R. Hibdige	Data	NIO	X	X
B. J. McCartney	SRP	NIO	X	-
A. R. Stubbs	SRP	NIO	X	X
H. M. C. Fielding	SRP	NIO	X	X
R. Peters	SRP, Workshop	NIO	X	X
M. Fasham	Comp. and data logging	NIO	X	-
D. Brown	Comp. and data logging	NIO	X	X
H. Peacock	DSB	Durham	X	-
B. J. Funnell	Dredging	UEA	-	X
A. Ramsay	Dredging	UEA	-	X
J. Anderson	Met. instruments	Cambridge	X	X
D. Spurlock		RVU	-	X

Key

NIO	National Institute of Oceanography, Wormley, Godalming, Surrey.
Durham	Department of Geology, Durham University, South Road, Durham.
UEA	School of Environmental Sciences, University of East Anglia, University Village, Norwich NOR 88C.
Cambridge	1, Huntingdon Road, Cambridge.
RVU	Research Vessel Unit, N. E. R. C., No. 1 Dock, Barry, Glamorgan.
PUBS	Pop up Bottom Seismic Recorder.
DSB	Disposable Sonobuoy.
SRP	Seismic Reflection Profile.

SHIP'S OFFICERS

G. H. Selby-Smith	Master
M. A. Harding	Chief Officer
M. Bradley	Second Officer
B. A. Chapman	Third Officer
R. J. Constantine	Radio Officer
R. D. Johnston	Chief Engineer Officer
R. K. Young	Second Engineer Officer
R. Perriam	Third Engineer Officer
S. A. Daly	Fourth Engineer Officer
J. C. King	Junior Engineer Officer
J. P. Roberts	Chief Electrical Officer
G. Burroughes	Junior Electrical Officer

SUMMARY OF CRUISE INTENTIONS

(1) The American Deep Sea Drilling Project (JOIDES) has agreed to drill several holes into the deep sea sediments at sites in the NE Atlantic suggested by UK and French scientists. These sites have been chosen on the basis of data collected over several years in the areas of Rockall, the Bay of Biscay and King's Trough. On Cruise 33 we undertook to make more detailed seismic reflection surveys of three of these sites in order to guide the choice of the exact hole position and to provide supplementary data. The following three sites were surveyed:-

Site A in the Hatton-Rockall Basin.

Site B in Rockall Trough.

Site C on the Azores-Biscay Rise.

(2) The southeast end of King's Trough (Peake and Freen Deeps) was studied in detail in Cruises 4 and 11 of R. R. S. 'Discovery' in 1965 and 1966. The results of this work (Matthews et al., 1969) were not conclusive about the origin of King's Trough. The major part of Cruise 33 was concerned, therefore, with obtaining more geological and geophysical data about King's Trough and its relationship to sea floor spreading occurring to the west on the mid-Atlantic Ridge.

Four main approaches were made to this problem:-

(a) Magnetic survey lines were run parallel to the Trough both north and south of it, and linked with other magnetic data available to provide continuous anomaly profiles from the mid-Atlantic Ridge median valley eastwards. Sufficient lines were made to establish lineation or otherwise of the magnetic anomaly pattern north and south of the Trough, and to determine whether King's Trough originated as a transform fault during a limited period of sea floor spreading.

(b) Two long seismic reflection profiles were made either side of the Trough to determine any contrasts in sedimentary history.

(c) A geophysical traverse across King's Trough towards its NW end was planned to determine tectonic movements and crustal structure. Seismic refraction profiles across this traverse were made using bottom seismic recording equipment, seismic reflection profiles were made along the traverse. Unfortunately a gravimeter was not available for this cruise, so no gravity section has been obtained. However, it is hoped that a ship of the Hydrographic Department might run the gravity traverse in 1971.

(d) Dredging and photography of the cliffs of the Trough and its associated ridges were planned to date the oldest sediments available and to obtain samples of the basement rocks.

The various tracks in the area will lead to a greater knowledge of the bathymetry and hence to the nature of the feature.

(3) Trials planned for a sea bed seismometer under development at UKAEA (Blacknest) by Dr. Francis were not undertaken since the equipment was not ready in time.

(4) It was not possible to visit the median valley for the collection of fresh basalts as originally planned, owing to shortage of time.

NARRATIVE

Leg 1

R. R. S. 'Discovery' sailed on the morning of 14th April (104) in calm misty weather that later turned to patches of fog which lasted for several days as we rounded the SW Coast of Ireland and headed NW to Rockall. Magnetometer and echo-sounder watches were started as we passed Valencia. On passage to DSDP (Deep Sea Drilling Project) Site A, we slowed several times for trials with the seismic profiling equipment.

On 17th April (107) we arrived at site A in the Hatton-Rockall Basin and laid a danbuoy (D/B I) to control the survey. After a velocimeter station (7282) the SRP survey of 7 legs of 7 miles each started, oriented such that the diagonal was along the expected strike of the basement. The survey was made at 6 knots in force 5 wind and some legs had to be repeated to get a complete coverage. On the diagonal, disposable sonobuoys (DSB) were launched to obtain data on the velocity of sound in the sediments, but noisy hydrophone conditions resulted in poor signals. A core of nearly 4 metres (7283) was taken on the site showing Quaternary ooze and lutites. The position of D/B I was determined by both satellite and Loran C fixes. Site A survey was completed by 1340 on 18th April (108).

During the passage to Site B at the south end of Rockall Trough, the weather deteriorated blowing gale force 8 from the WNW. Violent ship movement required two periods hove to, to lash gear more securely. During this time, the Loran C receiver failed and it was not repairable on board, so navigation was by satellite only.

At Site B, the aim of the survey was somewhat broader and was designed to investigate the extension SW of a change of depth of the basement with a view to finding the most suitable drilling site. The area covered was therefore larger (approximately 20 by 30 miles) and no danbuoy was used. Five lines of 30 miles each were profiled with SRP in steady 30kt winds from the WNW. Owing to a deficiency of satellite fixes, navigation was hard to control although using the computer interpolated dead reckoning, it was possible to reconstruct it later. However, the desired data on sub-bottom reflectors was obtained. A sediment velocity profile was obtained using a disposable sonobuoy. Throughout the site survey, the wind was blowing 30kts from the west and a heavy sea and swell was running. Such conditions made it impossible to take a core at this site.

On completion of Site B survey at 1800 on 22nd April (112) we steamed south for three days to the area of King's Trough. The weather improved somewhat as we progressed south, although for several days it persisted in blowing force 5 from the SW to NW.

At 1340 on 24th April (114) we started the first of six magnetic runs parallel to the axis of King's Trough. The first was to the SE and the most northerly of the six. The second to the NW was nearer King's Trough and along this we made a seismic reflection profile increasing the profiling speed from 6kts used hitherto, to 9kts. This was successful although somewhat noisier, and additional weights had to be added to the array to keep it at the appropriate depth. At the NW end of the line, we turned SW across the end of the Trough but found no good evidence of its continuation except

possibly as a sediment filled feature. The first leg south of the Trough was with magnetics only to the SE and the second to the NW with SRP.

A traverse of the Trough was then made (1600 28th April, 118) jigging along the strike of two sedimentary basins to make sediment velocity measurement with DSB. In the first run, the airgun failed after 1 hour. In the second, the DSB failed to give any radio transmission. The traverse finished at 0625 29th April (119), when we steamed south to complete as much as possible, before setting off for the Azores, of a third magnetic line parallel to King's Trough on the south side. At 0425 30th April 120), the line had to be stopped and we set course for Ponta Delgada going around the western end of San Miguel. For the last few days the weather was calm and sunny although quite cool. We berthed in Ponta Delgada at 0930 1st May (121).

Leg 2

Sailing from Ponta Delgada at 1330 on 4th May (124) we steamed to a point SE of King's Trough to obtain better magnetic coverage in the region. Whereas north of the Trough the anomalies correlated very well showing a linear pattern parallel to the mid-Atlantic Ridge, south the pattern was less well defined. The fourth magnetic line south of the Trough started with a zig-zag section and then ran parallel to the other three, crossed to complete line three and ended near the King's Trough traverse at 0140 on 7th May (127).

The track then led to the first seismic refraction station in the sediment trough immediately south of King's Trough. The choice of position for the seismic stations was determined partly by the depth limitation imposed by the reliability of the release firing mechanism on PUBS. A dan buoy (D/B II) and 2 PUBS were laid for the first half of the reversed seismic line (Station 7284) which was successfully completed in 19 hours in spite of a gale blowing up during the station.

The dan buoy was recovered and a seismic reflection profile started, to fill a gap in the first traverse of King's Trough. Another SRP followed this from the crest of Antialtair Seamount starting at 2100 8th May (128) across King's Trough to the opposite ridge. The plan was to make two crossings of this northerly ridge before choosing a place to dredge. However a steady 40 knot wind built up a heavy sea from the north and it was impossible to go on to the south going leg. Instead we continued seismic profiling steadily into the gale and found ourselves running along the ridge and then off to the north. By 1730 9th May (129) the weather had moderated enough to go back and reoccupy the south going line that was planned. This was finished (with some gaps) by early 10th May (130) in King's Trough and two more bathymetric survey lines were made across the northerly cliff before a dan buoy (D/B III) was laid for dredging.

During the last few days, very few satellite fixes were obtained due to spurious interrupts on the satellite output to the computer. This resulted in rather poor position control for our wanderings during the gale. However a rewiring job overcame this problem and by 10th May (130) regular fixes were once again coming in.

Dredging on an isolated ridge (afterwards named Hungry Ridge), where SRP had shown there to be sediment outcrops, began at 1330 on 10th May (130). Three dredge stations (7285, 7286 and 7287) were made only the first producing

any rocks and these were erratics. On the first a towed camera was lost, on the second 2600m of wire and the dredge were lost due to a failure on the A-frame and on the third the weak link above the dredge chain parted losing the whole assembly. The weather remained rough and the wind was a steady 30kts.

D/B III was lifted and D/B IV laid at the opposite end of seismic line 7284 to reverse it. Two PUBS were laid for the reversal (Station 7288) and the line was completed at 0640 12th May (132).

Using the same danbuoy, three dredge stations were made on north facing cliffs of the south side of King's Trough, again where the SRP showed outcropping sediments (7289, 7290, 7291). Again the hauls gave only erratics.

At 0430 13th May (133) D/B IV was recovered and we set off on a magnetic survey run designed to link the lines on the south side of King's Trough with some tracks of Atlantis II Cruise 32 in order to get a complete magnetic anomaly profile to the axis of the mid-Atlantic Ridge both north and south of King's Trough. On the west going leg seismic reflection profiling was also run.

On return from this survey at 2330 14th May (134) a long fully reversed seismic refraction station (7292) was run in fine weather along the axis of the ridge north of King's Trough. This station took full advantage of the immobility of PUBS equipment and also was made without using danbuoys as local navigation aids for PUBS recovery. Three PUBS were laid 20 miles apart and the entire reversed line of 60 miles was completed successfully in 24 hours.

The final bout of dredging took place on the south facing cliff of the northerly ridge, for which purpose D/B V was laid near the top at 0030 on 16th May (136). As a visual control on the dredging, a set of bottom photographs was taken (Station 7293) with the new technique of towing a positively buoyant camera six feet above the bottom on a dredge chain (this time without a dredge). Approximately 1.5 miles of traverse were obtained at 0.7kts with photographs every 15 seconds. Smears of limestone on the chain indicated that there were interesting rocks to be dredged. Three dredge stations (7294, 7296 and 7297) recovered an interesting collection of weathered basaltic rocks, lower Oligocene limestones, erratics and corals.

The dan buoy was lifted at 0100 17th May (137) completing the work in the area of King's Trough. Magnetic profiles on passage away showed the linear anomalies to extend right to the edge of King's Trough.

DSDP Site C is located on the raised portion of the Azores-Biscay Rise. A Conrad 9 profile showed uniform thickness sedimentary strata covering the ridge, and the site was selected on the basis that a relatively complete Tertiary sedimentary section might be obtained undiluted with turbidite material and lacking the chert layers which have been found elsewhere. The site survey planned a coarse star pattern of SRP, and a DSB measurement of sedimentary velocities followed by a more detailed close-in survey, and two cores. A good DSB record was obtained but limited SRP records were obtained thereafter since profiling was terminated by gun fracture. Two cores (7298 and 7299) both showed uniform quaternary globigerina ooze.

The passage back to Barry was in extremely calm seas. Scientific watchkeeping ended at 1130 on 20th May (140) at the Scilly Is. R.R.S. 'Discovery' berthed in Barry Docks at 0830 21st May (141).

PROJECT REPORTS

(1) DSDP Site A Survey

The survey was located on the east side of Hatton-Rockall Basin around an area selected from a seismic profile from 'Discovery' Cr. 29. A danbuoy (D/B 1) with an active radar transponder was laid in 1120m of water at position 57°35.51'N, 15°51.94'W as a control marker for the survey, which was navigated by radar using the Automatic Radar Plotter. The position of the danbuoy was determined from satellite and Loran C fixes taken during the survey.

The survey pattern (Fig. 2(i)) was designed so that one diagonal of the box was the 'Discovery' Cr. 29 line and the other the DSB profile. Seven profiles of six miles were run at 1 mile spacing, two of the legs being reoccupied due to failures in reflection profiling equipment. No magnetic measurements were made since the area is magnetically very smooth.

Seismic reflection profiles were obtained with a modified Lamont air gun and NIO receiving system using 30-300 Hz bandpass and time varied gain. Five main reflectors were recognised correlating with those found on 'Discovery' Cr. 29. Reflector 4, between 0.60 and 0.90 secs below the sea floor, is overlain unconformably by horizontally stratified sediments, and consists of a number of small hyperbolae suggesting a folded or fractured aspect. Below reflector 4 is a relatively transparent region underlain by an irregular reflector 5 at about 1.5 seconds. An isopachyte map of sediments above reflector 4 was prepared.

No usable data were obtained from the DSB experiment.

A core of 3.9m of Quaternary silt and mud, interbedded with ooze was obtained at the site ultimately selected for drilling.

A report, with photographs of reflection profiles, charts, etc., was prepared on board for use on Glomar Challenger Leg 12.

D. G. R.

(2) DSDP Site B Survey

A survey was carried out in rough weather without an anchored buoy over a proposed site for a hole to be drilled on Leg 12 of D/V Glomar Challenger. The site is on the western margin of the southern end of the Rockall Trough at about 53°6'N 16°43'W.

The site was proposed on the basis of a single Flexotir reflection profile obtained by Centre Océanologique de Bretagne. The 'Discovery' air-gun survey (Fig. 3) confirmed the existence of a relatively shallow "basement" under the site at a depth of 0.95 seconds and was able to define time isopachs for this reflector. Three prominent reflectors above the "basement" should be within easy reach of the drill.

In addition to echo-sounding and profiling over the site a wide angle reflection experiment using a DSB was completed from the results of which the true depths of the reflectors may be calculated.

A report, containing photographs of seismic records, charts, etc., has

prepared for use on Glomar Challenger Leg 12.

R. B. W.

(3) DSDP Site C Survey

A possible drilling site on the Azores-Biscay Rise was suggested by a Conrad-9 reflection profile. A Maltese cross survey (Fig. 2(ii)) was planned to be made without an anchored danbuoy, to investigate the N-S elongated sediment basin. The survey started with a successful DSB station. The first half of the survey was completed, however, before airgun troubles, culminating in gun rupture, prevented its continuation. Two cores were taken before leaving the site. A report was written about this site.

D. G. R.

(4) Magnetic surveys around King's Trough

Continuous magnetic measurements were taken on passages and during SRP runs, as well as during the special magnetic surveys around King's Trough, using a Varian proton magnetometer towed 500ft. astern of the ship. The magnetic readings were logged continuously by the ship's computer and stored as two minute values averaged over a period of 30 seconds. Some 497 hours of magnetic recordings were obtained during the cruise covering a total distance of 5160 nautical miles. A comparison of the magnetic data stored on disc with the magnetometer's chart record showed about 2% of the stored values to be in error. These errors were probably caused by a loose earth connection on the computer interface and were reduced to negligible proportions once this fault had been rectified. The International Geomagnetic Reference Field was used for obtaining magnetic anomaly values on board. No corrections were made for either daily variation or the effect of ship's heading.

In an effort to provide some insight into the origin of King's Trough and its relationship with the surrounding sea floor a series of magnetic tracks were made both to the north and to the south of the Trough in a direction roughly parallel to its axis. The position of these tracks was selected with an aim to:-

a) identifying the sequence of anomalies on each of the Trough with the sea floor spreading anomalies of Heirtzler et al., (1968).

b) defining the trend in the anomaly pattern on both sides of the Trough.

c) measuring the lateral displacement, if any, between the anomaly patterns on opposite sides of the Trough.

Where necessary magnetic tracks were selected to fill in gaps left by previous cruises to the area. Throughout the programme magnetic profiles were plotted automatically by computer and transferred to a 1:1,000,000 track plot for use in an "on the spot" interpretation of the data. Subsequent tracks were selected on the basis of such plots.

During Leg 1 two tracks were taken approximately 40 miles north of the axis of King's Trough at a mean separation of 15 miles to provide continuous profiles along the Trough's length. The anomaly pattern on these tracks was easily correlatable with four previous tracks further north. These tracks were further supplemented with a track at the end of Leg 2 that showed the anomalies to continue

in general up to the crest of the northern ridge of the Trough. This track was also extended eastwards to link up with the Peake and Freen surveys of 1965 and 1966.

South of the Trough, 3 tracks were taken along the length of the Trough at a mean spacing of 20 miles. Correlations of the anomalies on these tracks were not as obvious as on the northern tracks. It does however seem probably that the same anomaly sequence as observed on the North side may be identified on the southern side without any significant lateral displacement along the axis of the Trough. The 3 southern tracks were supplemented by a shorter track to the south in an attempt to locate the extension of anomaly 26 (64 m.y. B.P.) south of the Peake and Freen Deeps.

Due to the shortage of time it was not possible to extend the magnetic tracks on each side of King's Trough to the mid-Atlantic Ridge. However the tracks that were run can be linked up with other tracks obtained by 'Discovery II' in 1960 and 'R/V Atlantis' II in 1967 such that continuous magnetic profiles are now available from East of King's Trough to the mid-Atlantic Ridge on both sides of the Trough.

(5) Seismic reflection profiling

The seismic profiling system consisted of a modified free-running Lamont airgun, an N.I.O. designed hydrophone array 200ft. long towed behind 600ft. of neutrally buoyant cable depressed by a weight, time varied amplifiers, filters, and a wet paper 18" Mufax recorder with a sweep speed of 4 secs. The hydrophone output was also recorded on magnetic tape.

Several new techniques were used during this cruise. The neutrally buoyant hydrophone gave a considerable improvement in towing noise which was measured at various speeds. New arrangements were also made to the elastic accumulator towing the hydrophone and to the towing point, and sensors were used to monitor the depths of both ends of the array.

Hitherto seismic profiles have been made at 6kts. In order to obtain a greater coverage of the ground around King's Trough, profiling speeds were increased to 9 or 10 knots modifications being required in the gun and hydrophone depressor weights. Although the records were sometimes noisier useful profiles were always obtained.

Experiments with air gun shots to disposable sonobuoys for wide angle reflection work are described in section (6).

A total of 1100 miles of seismic profile was obtained, and these are listed in Table III. The profiles in DSDP sites A, B and C are described in sections (1) to (3). The remainder were around King's Trough (Fig. 4) and towards the mid-Atlantic Ridge. Two long profiles were run parallel to the Trough and north and south of it, and several profiles across it. Up to 1 sec of sediments were seen in the Trough, whereas the thickness in regions to north and south seldom exceeded $\frac{1}{2}$ sec. All the sections suggested that considerable tectonic activity had taken place subsequent to the deposition of the sediments.

B. J. McC.

(6) Disposable Sonobuoy experiments

Six disposable sonobuoys (DSB's), manufactured by Ultra Electronics Ltd., London, were used on the cruise with the assistance of Dr. H. Peacock of the University of Durham. The object was to appraise the usefulness of these buoys in conjunction with the N. I. O. air-gun system and to obtain velocity/depth information at Deep-Sea Drilling Project sites in the Rockall-Hatton Basin, Rockall Trough and near King's Trough. A further station was shot in a sediment basin south of King's Trough.

Of the 6 experiments 2 were abandoned due to extreme noise from the buoys (5ft. 6-second waves during the station) and one buoy failed to transmit. The station south of King's Trough was abandoned after 1 hour due to gun failure. The 2 stations at sites B and C gave useful results. That at site C was carried out in calm conditions to a range of 18 miles when the water wave arrivals could no longer be heard.

With the present N. I. O. air-gun and Mufax recorder system it is difficult to display the DSB signals adequately on-line but this problem is expected to be overcome on replay. An electrically triggered gun would greatly increase the precision, and improve the display, of DSB data. A variable area display with AGC operated by Dr. Peacock gave clear records when the AGC was suitably adjusted but it was difficult to achieve the required gun cycle time in excess of $15\frac{1}{2}$ seconds without the cycle time becoming unstable.

It is anticipated that DSB's will become a useful adjunct to the N. I. O. air-gun system in the deep-sea, especially if an electrically operated gun can be used.

R. B. W.

(7) Seismic refraction studies of King's Trough

4 reversed refraction stations were intended to be shot during Leg 2 as part of a geophysical section across King's Trough which will include a gravity profile. Due to lack of time only two reversed lines were obtained, one over a basin south of King's Trough and the other over the ridge immediately north of the Trough. The data is of good quality and due to the low noise on the sea bed it was found that reduced charge sizes could be used.

The use of P. U. B. S. on N. I. O. geophysical cruises has now become routine. The recorders were deployed in two ways. The first way involved closely spaced P. U. B. S. and the shooting of single refraction lines with dan buoy control during P. U. B. S. relocation and recovery. The second method used 3 P. U. B. S. spaces 20 mies apart along a line with a sequence of shots so that the line was reversed in a single operation. This experiment was conducted solely with satellite navigation and no difficulty was experienced in relocating and recovering the P. U. B. S.

Several important instrumental modifications have been made to the P. U. B. S. since the last cruise. The main one is the use of an acoustic transponder in place of a pinger. The transponders were triggered by the ship's echo-sounder out to ranges of 6 miles in depths of around 3000 metres and the return signal could be picked up by the echo-sounder, using a reduced number of elements, at ranges of up to 1.5 miles. The transponders enabled the ship to heave to directly over the P. U. B. S. before the spheres were released from the sea-bed. The quality of the

the records has been greatly improved due to a reduction of system noise. Problems still remain with the discharge tube flashing lights and radio direction finding system. The pyro-release units used to shed the ballast weight have a depth limitation of 3000 metres at present and this will have to be extended to at least 5,000 metres.

R. B. W.

(8) Dredging in King's Trough region

The purpose of these operations was to recover rocks and pre-Quaternary sediments from the walls of the NW end of King's Trough, to provide a comparison with those obtained from Palmer Ridge at the SE end, and to assist in the interpretation of the origin of King's Trough.

The localities at which dredge operations were carried out were determined by the availability of P. E. S. and S. R. P. profiles and proximity to P. U. B. S. stations. Three sets of dredge stations were attempted.

The first set was made on the N. side of the Trough on a peak, subsequently known as Hungry Hill, which forms a feature opposite (N. N. W.) of Antialtair Seamount. Inadequate knowledge of the bottom topography led to the first dredge (7185) skirting the prominence, which was proved thereby to be an isolated, rather than a ridge-like, feature as had previously been thought. During this dredge a buoyant deep-sea camera was lost from the dredge line, and a variety of erratic rocks only were collected in the dredge. The two subsequent dredges, both of which contacted either the steep slopes or crest of the 1780m peak, led to the loss of first the entire dredge assembly, pinger and 2,000m. of wire (7287). On this second occasion the shackle at the end of the wire was deeply scoured as if by rock with a hardness in excess of that of steel.

The second set of dredge stations was made on the south side of King's Trough, WNW of Antialtair Seamount. The first two were made without the benefit of dan-buoy control, but made good progress over appropriate topography. The first (7289) sampled the top of a small scarp at approximately 2815-2870m. length, but recovered only erratics (including however a piece of Ordovician shale c. 40mm. in diameter complete with trilobite and graptolites). The second (7290) on the deeper slopes between 3055 and 3225m. also recovered only erratics. The third (7291) skirted the 2400m. west of the ridge at 2850-2900m. and passed through and around it to the NW; the dredge bag was empty.

The third set of dredge stations was made again on the N side of the Trough, east of the point at which so much gear had been lost during earlier operations. A preliminary camera station (7293) was made, which brought back a smear of Oligocene limestone on the trailing chain. The first dredge (7294) was intended to sample the same traverse as the camera station but recovered only altered igneous rocks and erratics. A second attempt (7296) to sample the Oligocene limestone was successful; it also included erratics. Lastly the third dredge (7297) set to sample the higher slopes and crest of the adjacent 1600m. ridge was very successful in bringing back a mixed haul of coral, erratics, limestone and probably indigenous igneous rock. The third set of dredges was much assisted by a preliminary, brief, topographic survey and a better output from the pingers attached to the dredge line which in previous operations had proved

ineffectual in yielding a bottom echo.

The general outcome of the dredging operations was a limited collection of igneous rocks (some badly altered) originating probably in situ, some Tertiary limestones and a large number of erratics. This does not represent such a successful outcome as that obtained in 1966 from Palmer Ridge at the SE end of King's Trough, both in terms of the smaller number of in situ rocks, and in terms of the larger proportion of erratics, which although interesting are not relevant to the problem under investigation.

Summary of dredge stations

Station No.	Depth Range	Ground covered	Result
7285	2885m	1000m	Erratics
7286	1780m	35m	dredge lost
7287	2060-1815m	400m	dredge lost
7289	2870-2815m	1000m	erratics, including trilobite
7290	3225-3055m	750m	erratics
7291	-	-	nil
7293	2565-2115m	3500m	Oligocene limestone smear
7294	2370-2180m	850m	altered igneous, erratics
7296	2075-2045m	675m	Oligocene limestone, erratics
7297	1750-1600m	275m	limestone, igneous, erratics, coral

B. M. F.

(9) Coring

Three gravity cores were taken with a Cambridge corer using a 7m. barrel. Core 7283, taken at DSDP site A, gave 3.9m. of Quaternary silts and made interbedded with grey/white calcareous ooze. Cores 7298 and 7299 were taken at DSDP site C, yielding 3m. and 2.5m. respectively of mottled cream/brown Globigerina ooze of Quaternary age.

B. M. F.

(10) Underwater photography

A technique first tried on Cruise 29 was used to obtain a nearly continuous photographic profile of the bottom. An underwater camera using 16mm. film with a capacity of 2,000 frames was made buoyant with syntactic foam. This was tethered by a seven foot wire strop to a heavy chain which was dragged across the bottom at about 1 knot as if dredging. Photographs were taken every 15 seconds.

At the first station in which the camera was used (Stn. 7285), it was tethered between the chain and the dredge. During the course of the station, the 2 ton shear pins on the dredge were sheared when it was hung up on a rock and it is believed that the sudden release of tension parted the tether wire of the camera (two bridles of 1 ton breaking strain wire). The camera was lost.

On the second station (7293), no dredge was attached and a stronger tether was used. The camera was dragged across cliffs bordering King's Trough for over two hours covering a distance of 1.5 miles. Over 700 bottom photographs were obtained the great majority of which showed sediment covered slopes and 50 showed rock outcrops of loose boulders. The rock outcrops photographed were correlated with those on which the chain acquired the smears of Lower Oligocene limestone. The acquisition of these smears can also be seen in the photographs of the chain.

A. S. L.

(11) Navigation

The following navigational aids were used:-

(a) Decca SW British Chain when in range.

(b) Loran C using a Decca Loran ADL 21 receiver in Rockall area up to 19th April (109) when receiver power supply failed and was not repairable on board.

(c) Satellite Navigation System using a Magnavox C/A 702 receiver working in conjunction with the shipboard IBM 1800 computer.

(d) Anchored danbuoys with radar transponders (Decca-Alpine).

(e) Celestial observations when none of the above were available.

The shipborne computer controlled navigation system could accept either satellite or one of the hyperbolic radio systems as prime navigation aid.

Throughout the cruise satellite fixes were used as prime aid even though other fixes were stored on disc.

The satellite receiver behaved reasonably well at the start of the cruise giving about 17 acceptable fixes per day. However the number steadily fell during the first leg to about 10 a day, and in the second leg to 1 or 2 a day. This deterioration was due in part to faulty subassemblies and in part to high noise level between the receiver and the computer resulting in spurious interrupts. A rearrangement of the wiring cured this problem and in the last ten days an average of 16 acceptable fixes were obtained daily. The slight reduction of daily fixes compared with the first few days can be attributed to the 10° change of latitude.

Between satellite fixes a dead reckoning derived from the two component electromagnetic log (N. I. O. design) and gyro compass was compared by the computer with the fix positions and surface currents calculated. (The leeway due to windage is taken into account by the EM log readings). Included in these surface current measurements are errors due to fix inaccuracies which probably derive from assumptions about speed and course during the passage of the satellite. Plots of the surface current against time show a wide scatter that more likely reflects these errors than time variations in surface current.

The ship's position between fixes was computed making due allowance for these currents and the processed positions form the basis of data listing and track charts plotted on board by a Calcomp plotter.

When working near a danbuoy, all navigation was referred to the danbuoy whose position was computed by satellite fixes taken while in radar range of the danbuoy. Radar fixes on the buoy were usually obtainable out to about 10 mile range, and were plotted on a Decca Automatic Radar Plotter.

Charts were prepared at various scales on:-

(1) 1:1 million Admiralty Oceanic plotting sheets.

(2) 1:$\frac{1}{4}$ million Admiralty Oceanic plotting sheets.

(3) Automatic Radar Plotter using either 6 or 12 mile radius plots.

(12) Shipboard computer system and data logging

Since the Geophysics Cruise last year considerable experience in operating the computer system has been obtained and in March, 1970, part of the sampling and logging system was re-written to introduce some added refinements. A block diagram of the system is shown in Fig. 5 showing that the meteorological instruments have been added to the routine sampling carried out by the computer. There was no gravimeter on the cruise, and so the magnetometer was the only geophysical instrument that was logged. An example of the output produced by the typewriter as a routine log is shown in Fig. 6.

The navigational system was basically the same as for cruise 29, except that only the satellite navigator was used as prime navigational aid. The computer programs were also modified to calculate the dead reckoning position of the ship (from the last satellite fix) every two minutes in real time, a facility which proved useful

when navigating a survey grid.

Another addition to the system was a CALCOMP 30" increment plotter. Two general purpose plotting programs have been written to display data that has been stored on disk. The first of these will plot observed variables, as profiles using either time or distance axes. Fig. 7 gives an example of the output showing magnetic anomaly, ocean depth and ships course and speed, plotted against distance. The second programe will plot Mercator track charts as shown in Fig. 8. This program can also be used to plot numerical values of an observed variable, such as magnetic anomaly or ocean depth on a chart. These two programs were very time saving and enabled magnetic anomaly profiles to be examined within an hour or two of finishing a survey line. During the cruise a complete series of track charts, and profiles of geophysical and meteorological variables was produced.

A more detailed account of the system has recently been given at the conference on Electronic Engineering in Ocean Technology at Swansea (Fasham, M. J. R. (1970) "The use of a shipborne computer for navigation" Inst. Electronic and Rad. Eng. Conf. Proc. 19, 259-270).

M. J. R. F.

TABLE I

LIST OF DANBUOY POSITIONS

D/B	Laid	Recovered	Lat. N.	Long. W.	Fixed by	Remarks
I	0930/107	1320/108	57°35.5'N	15 51.94'W	(NavSat (LORAN-C	Radar transponder
II	0800/127	0217/128	44°03.95'N	23°56.42'W	NavSat	Radar transponder
III	1103/130	0710/131	44°08.56'N	22°15.30'W	NavSat	Radar transponder
IV	1353/131	0430/132	43°46.13'N	23°17.6'W	NavSat	Radar transponder
V	0122/136	0058/137	44°03.22'N	21°54.53'W	NavSat	Radar transponder

Key

AG	Air gun
BMC	Buoyant Mini Camera
C	Corer (Cambridge Gravity Corer)
CF	Corrected Fathoms (by Matthews Tables)
CM	Corrected Metres (by Matthews Tables)
D	Dredge (NIO Rock Dredge)
DSB	Disposable Sonobuoy
DSDP	Deep Sea Drilling Program (JOIDES)
PUBS	Pop Up Bottom Seismic Recorder
SRP	Seismic Reflection Profile
S. Refr.	Seismic Refraction
TC	Towed Camera
UCF	Uncorrected Fathoms (at 800 fm/sec.)
V	Velocimeter

TABLE II

CRUISE 33 - STATION LIST (Key to equipment used see page 19)

Statn No.	Type	Equip. used	Date	Time(Z)/Day No. From	To	Lat. N to Lat. N Long. W Long. W	D/B used	Depth Range UCF	CR	CM	Comments
7282	V	V	17 Ap	1025/107	1045/107	57°35.8'N 15°53.8'W	I	603	616	1128	DSDP Site A - to 1050 metres
7283	C	C	18 Ap	1001/108	1055/108	57°31.4'N 15°54.2'W	I	609	622	1138	DSDP Site A - 3.9 metres of calcilutite.
7284	S. Refr.	PUBS (2)	7/8 May	0925/127	0116/128	44°01.1'N 43°32.2'N 23°58.9'W 23°06.8'W	II	1679-1444	1721-1479	2710-3153	17 shots to 42 miles.
7285	D TC	D BMC	10 May	1330/130	1858/130	44°08.12'N 22°17.67'W	III	1540	1577	2885	Weathered basalts and erratic rocks Camera lost.
7286	D	D	10 May	2040/130	2332/130	44°06.20'N 22°13.76'W	III	950	973	1780	Bolt on A-frame parted. Dredge, pinger and 2613m wire lost.
7287	D	D	11 May	0115/131	0454/131	44°06.15'N 44°06.31'N 23°13,69'W 23°13.53'W	III	1101-969	1126-992	2060-1815	5 ton weak link parted. Dredge and chain lost.
7288	S. Refr.	PUBS (2)	11/12 May	1500/131	0638/132	43°38.4'N 44°03.8'N 23°20.4'W 23°09.2'N	IV	1458-1752	1492-1796	2730-3286	17 shots to 43 miles. Reversal of Stn. 7284.
7289	D	D	12 May	0925/132	1500/132	43°54.61'N 43°53.90'N 23°09.22'W 23°09.57'W	-	1532-1503	1569-1539	2870-2815	Erratic(?) rocks only.
7290	D	D	12 May	1622/132	2150/132	43°58.09'N 43°58.09'N 23°08.51'W 23°09.02'W	-	1720-1630	1764-1670	3225-3055	Erratic(?) rocks only.
7291	D	D	12/13 May	2350/132	0331/133	43°48.4'N 43°50.6'N 23°15.1'W 23°15.6'W	IV	1484-1422	1519-1456	2779-2663	No rocks.
7292	S. Refr.	PUBS (3)	14/15 May	2355/134	2328/135	44°30.0'N 43°50.2'N 22°38.2'W 21°32.1'W	-	730-1706	806-1749	824-3199	39 shots along 60 mile fully reversed profile

7293	TC	BMC	16 May	0354/136	0838/136	44°01.73'N 21°58.06'W	44°02.62'N 21°55.60'W	V	1370-1178	1403-1178	2565-2115	700 bottom photographs along 1.5 miles. Limestone smears on chain.
7294	D	D	16 May	0919/136	1320/136	44°02.30'N 21°56.83'W	44°02.81'N 21°56.89'W	V	1267-1165	1296-1191	2370-2180	Weathered basalts and erratic rocks.
7295	V	V	16 May	1340/136	1548/136	44°05.5'N 21°55.7'W		V	874	896	1638	To 1750 metres.
7296	D	D	16 May	1650/136	2110/136	44°03.40'N 21°55.67'W	44°03.42'N 21°55.37'W	V	1109-1092	1134-1117	2075-2045	In situ limestone and erratics.
7297	D	D	16/17 May	2200/136	0038/137	44°05.25'N 21°55.77'W	44°05.28'N 21°55.47'W	V	934-854	957-875	1750-1600	Limestones, igneous and erratic rocks. Large quantity of corals.
7298	C	C	18 May	0630/138	0842/138	43°57.94'N 16°48.26'W		-	1937	1991	3642	DSDP Site C; 3 metres of glob. ooze.
7299	C	C	18 May	1044/138	1234/138	43°58.28'N 16°48.29'W		-	1938	1992	3644	DSDP Site C; 2.5 metres of glob. ooze.

TABLE III

SEISMIC REFLECTION PROFILES

Date	Time (Z)/Day No. From	To	Position	Speed	Comments
17 Ap.	1230/107	0840/108	Within square defined by corners:- 57°36'N 57°33'N 57°30'N 57°27'N 15°52'W 16°05'W 15°48'W 16°00'W	6 kts.	DSDP Site 'A'. Seven legs of seven miles each, at one mile spacing. (60 miles). (cf. Track chart, Fig. 2(i)).
20/22 Ap.	0107/110	1712/112	Within rectangle defined by corners:- 53°19'N 53°19'N 52°50'N 52°41'N 17°17'W 16°50'W 16°30'W 16"51'W	6 kts.	DSDP Site 'B'. Five legs of about 30 miles each, at approximately 6 mile spacing. (167 miles). (cf. Track chart, Fig. 3).
25/27	2230/115	0300/117	Positions along track:- 43°49'N 44°42'N 44°54'N 44°00'N 20°15'W 22°21'W 24°38'W 25°03'W	9 kts.	Profile parallel to and north of King's Trough (200 miles) and across NW end (58 miles).
27/29 Ap.	2230/117	0655/119	Positions along track:- 42°08'N 41°57'N 43°17'N 44°52'N 20°52'W 21°02'W 24°00'W 22°40'W	9 kts.	Profile parallel to and south of King's Trough (165 miles) and across King's Trough (125 miles). Two DSB on section.
8 May	1040/128	1705/128	Positions along track:- 43°24'N 44°00'N 23°33'W 23°04'W	6 kts.	Fill in of missing section of profile across King's Trough. (42 miles).
8/9 May	2310/128	1730/129	Positions along track:- 43°38'N 44°07'N 44°43'N 44°16'N 22°29'W 21°50'W 22°32'W 22°07'W 43°57'N 22°25'W	6 kts	Profile across King's Trough (from Antialtair (41 miles), run to NW in gale (53 miles), run back to position (31 miles) and profile across cliff (22 miles).
13/14 May	1220/133	0140/134	Positions along track:- 43°03'N 43°48'N 24°43'W 27°14'W	9 kts	Profile towards Mid-Atlantic Ridge (89 miles excluding gap during breakdown).
17/18 May	2000/137	0330/138	Tracks in vicinity of:- 43°55'N 16°50'W	9 kts	DSDP Site 'C'. Maltese cross survey (46'). Ended prematurely by gun failure.

TABLE IV

DISPOSABLE SONOBUOY STATIONS

DSB Serial No.	Time (Z)/Day No.		Lat. N. Long. W.	Depth metres	Range of signals n. mls.	Comments
1004	0550/108	0609/108	57°30.78'N 15°56.79'W	1147	1	DSDP Site A. Very noisy.
1003	0609/108	0710/108	57°32.02'N 15°56.11'W	1142	4	DSDP Site A. Very noisy.
1001	1617/112	1712/112	53°8.77'N 16°40.11'W	1855	4	DSDP Site B. Transmission ceased after 1 hour.
1005	2037/118	2140/118	43°48.90'N 23°29.77'W	2952	8	Valley south of King's Trough. Air gun failure.
1002	0129/119		44°9.27'N 22°58.63'W	4381	0	King's Trough. No radio transmission.
1006	1958/137	2210/137	43°43.65'N 17°1.95'W	4023	18	DSDP Site C.

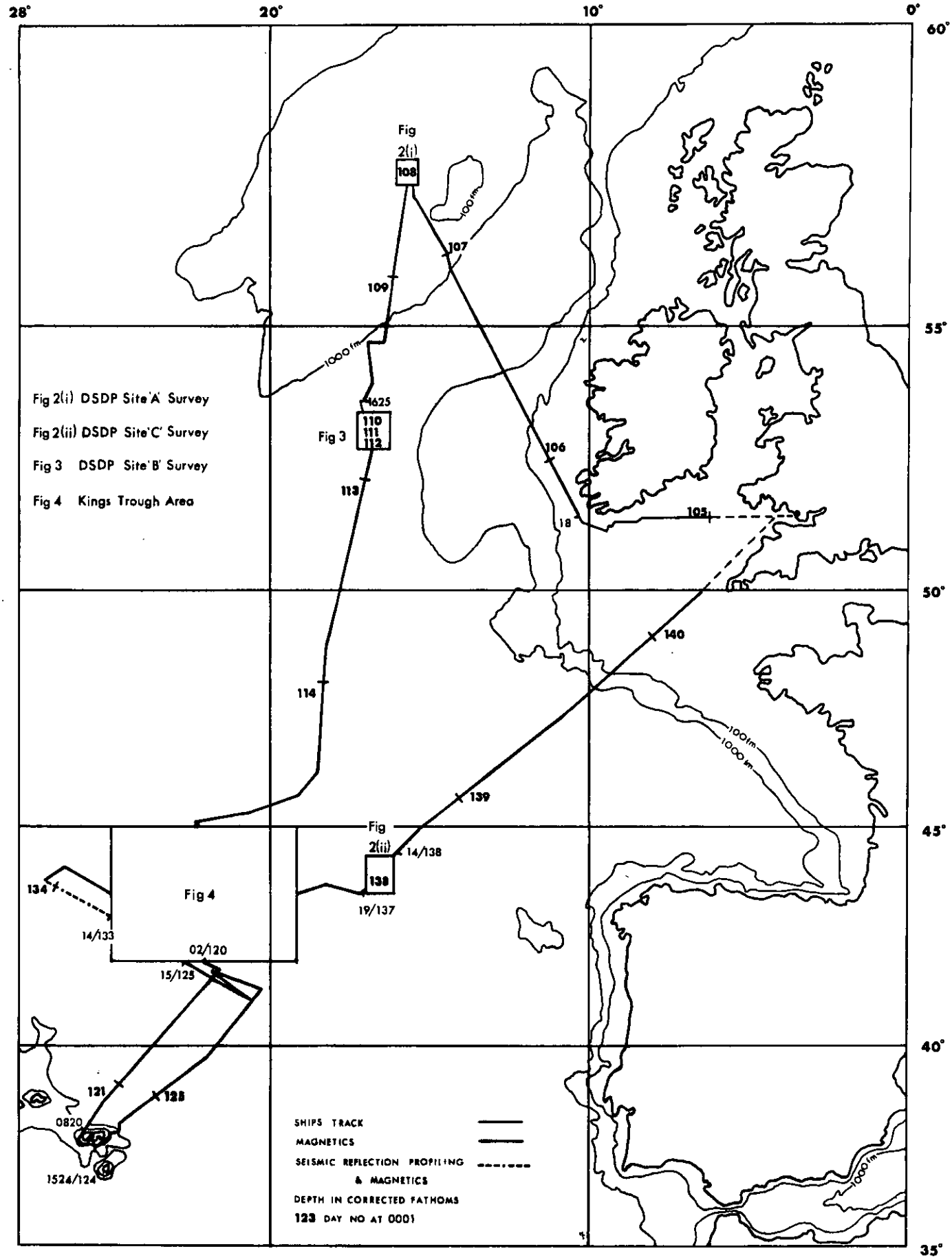
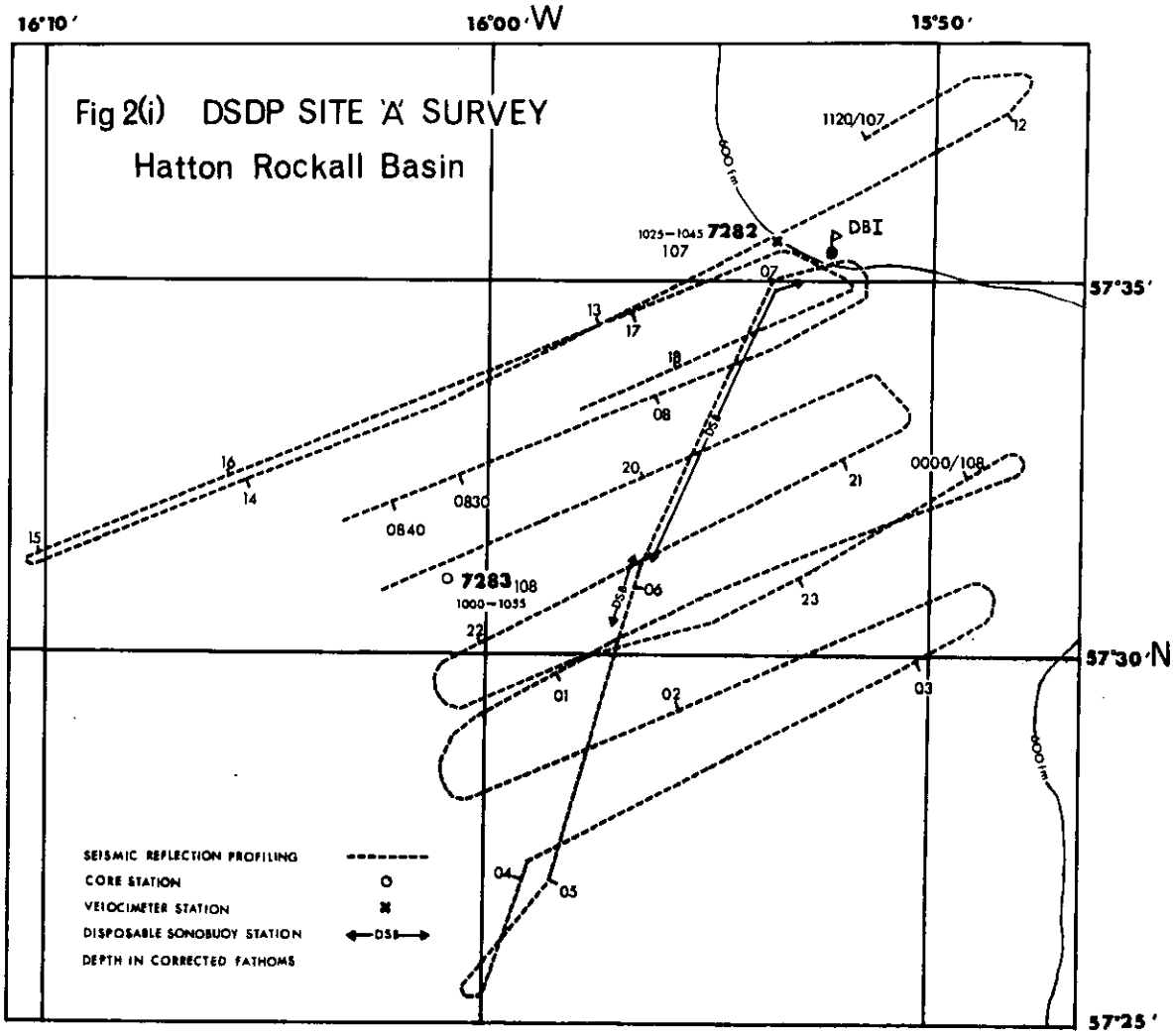
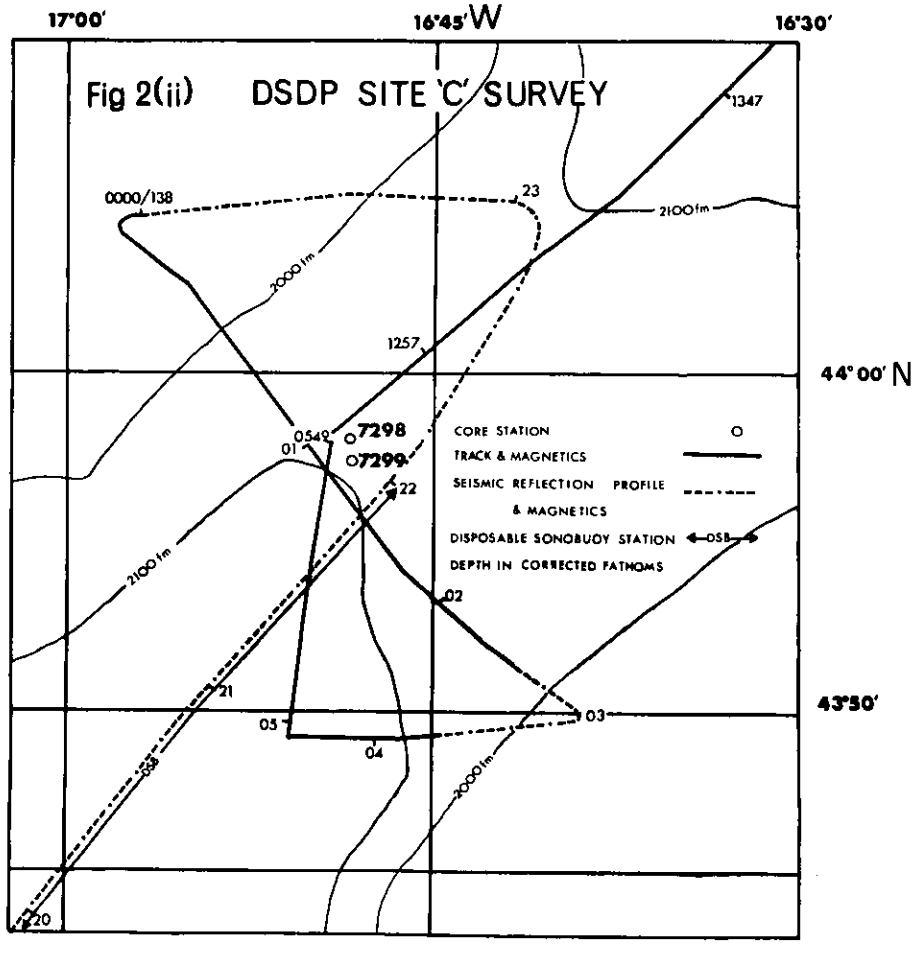

28°
20°
10°
0°
60°
55°
50°
45°
40°
35°
Fig 2(i) DSDP Site 'A' Survey
Fig 2(ii) DSDP Site 'C' Survey
Fig 3 DSDP Site 'B' Survey
Fig 4 Kings Trough Area
Fig 2(i)
Fig 3
Fig 2(ii)
Fig 4
100fm
1000fm
SHIPS TRACK
MAGNETICS
SEISMIC REFLECTION PROFILING & MAGNETICS
DEPTH IN CORRECTED FATHOMS
123 DAY NO AT 0001

Fig 1


16°10′
16°00′W
15°50′
Fig 2(i) DSDP SITE 'A' SURVEY
Hatton Rockall Basin
1120/107
12
600 fm
1025–1045 7282
107
DBI
07
57°35′
13
17
18
08
16
14
0830
0840
20
21
0000/108
15
7283 108
1000–1035
06
23
22
57°30′N
01
02
03
600 fm
04
05
SEISMIC REFLECTION PROFILING
CORE STATION
VELOCIMETER STATION
DISPOSABLE SONOBUOY STATION
DEPTH IN CORRECTED FATHOMS
57°25′


17°00′
16°45′W
16°30′
Fig 2(ii) DSDP SITE 'C' SURVEY
1347
0000/138
23
2100fm
2000fm
1257
44°00′N
0549
7298
7299
01
22
CORE STATION
TRACK & MAGNETICS
SEISMIC REFLECTION PROFILE & MAGNETICS
DISPOSABLE SONOBUOY STATION
DEPTH IN CORRECTED FATHOMS
2100fm
02
21
43°50′
05
03
04
2000fm
20

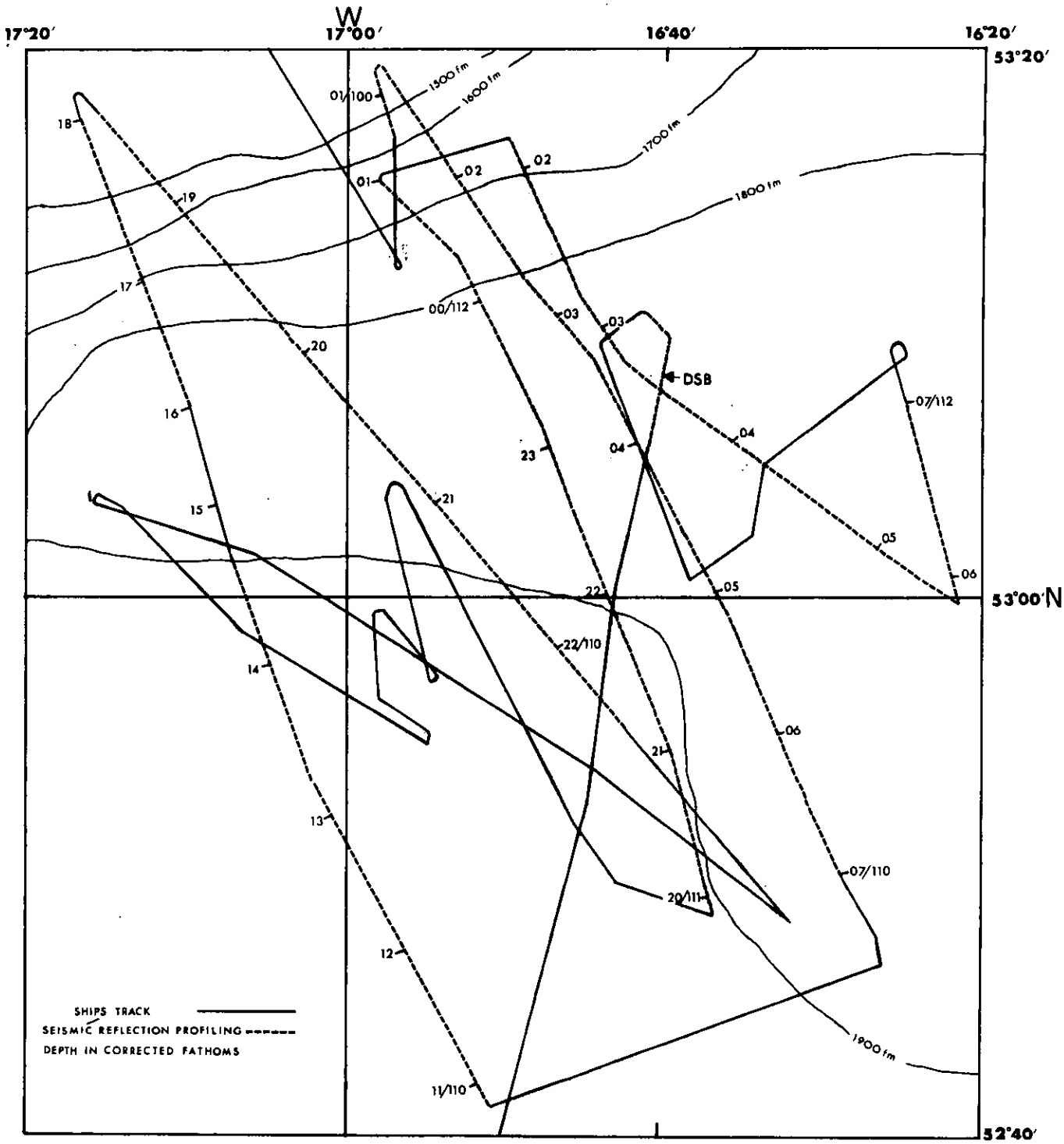


Fig 3 DSDP SITE 'B' SURVEY

Rockall Trough Site

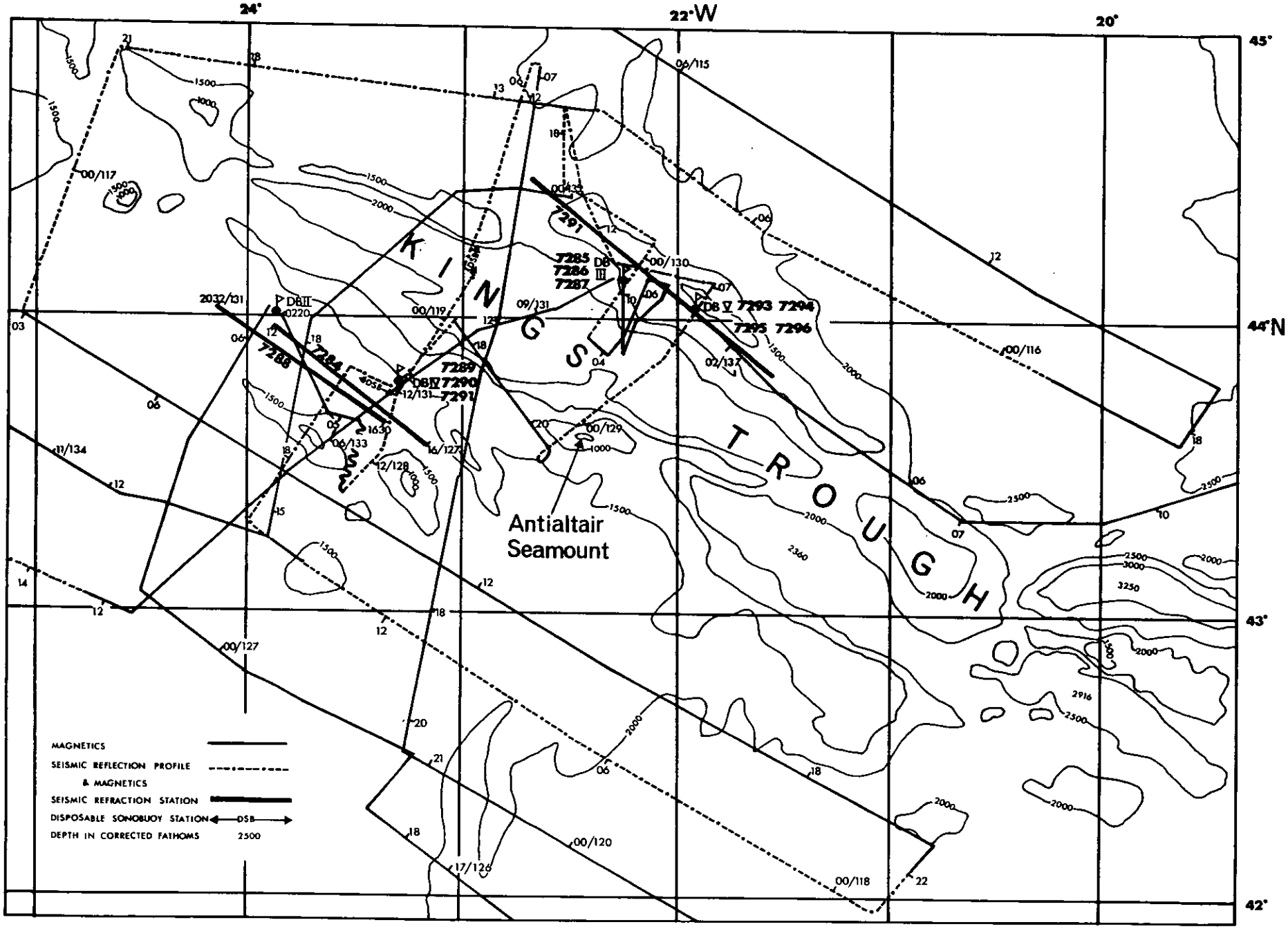


Fig 4 KINGS TROUGH AREA

Figure 5 R. R. S. 'Discovery' Shipboard computer system (from Fasham, 1970).

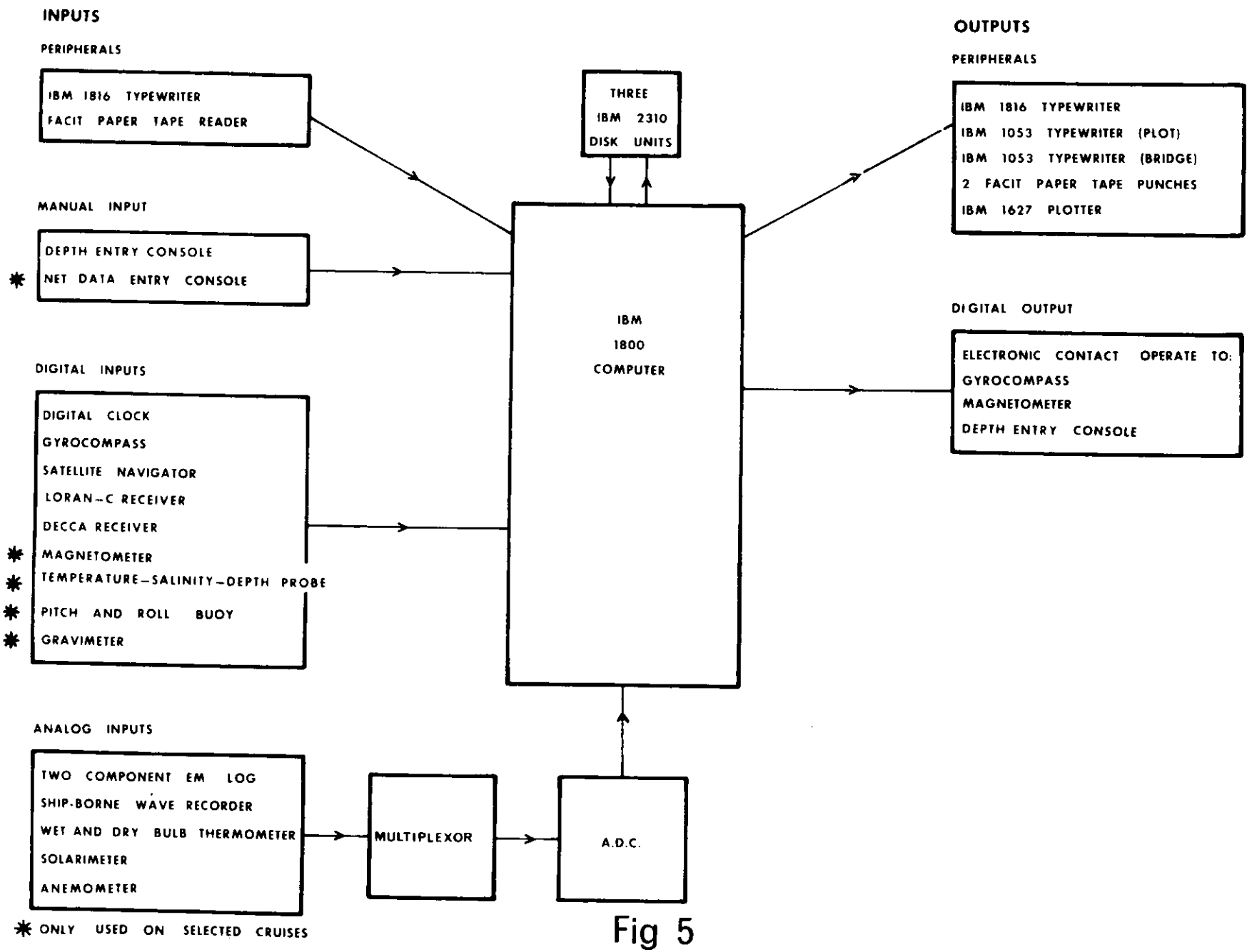

INPUTS
PERIPHERALS
IBM 1816 TYPEWRITER
FACIT PAPER TAPE READER
MANUAL INPUT
DEPTH ENTRY CONSOLE
* NET DATA ENTRY CONSOLE
DIGITAL INPUTS
DIGITAL CLOCK
GYROCOMPASS
SATELLITE NAVIGATOR
LORAN-C RECEIVER
DECCA RECEIVER
* MAGNETOMETER
* TEMPERATURE-SALINITY-DEPTH PROBE
* PITCH AND ROLL BUOY
* GRAVIMETER
ANALOG INPUTS
TWO COMPONENT EM LOG
SHIP-BORNE WAVE RECORDER
WET AND DRY BULB THERMOMETER
SOLARIMETER
ANEMOMETER
* ONLY USED ON SELECTED CRUISES
MULTIPLEXOR
A.D.C.
THREE
IBM 2310
DISK UNITS
IBM
1800
COMPUTER
OUTPUTS
PERIPHERALS
IBM 1816 TYPEWRITER
IBM 1053 TYPEWRITER (PLOT)
IBM 1053 TYPEWRITER (BRIDGE)
2 FACIT PAPER TAPE PUNCHES
IBM 1627 PLOTTER
DIGITAL OUTPUT
ELECTRONIC CONTACT OPERATE TO:
GYROCOMPASS
MAGNETOMETER
DEPTH ENTRY CONSOLE

Fig 5

Figure 6 Example of routine on-line listing of navigation meteorological and geophysical data, and print-out of satellite fixes.

SATELLITE FIX
DAY 116 TIME 2356 HOURS. SAT NO. 12 DURATION 12 MIN.
LAT. 44 28.30 LONG. -24 48.75
VEL NORTH -9.65 VEL EAST -2.95 ELEVATION 10 DEG.
SPEED 10.10 COURSE 198

DAY	TIME	CO.&	SP.TW	D.R. LAT	D.R. LONG	REL.WD	(KT)	SUN	R.HUM	SD	SW	PD	PW	REF.	MAG
117	10	197.3	10.1	44 24.90N	24 47.76W	338	13.4	-0.1	64%	11.1	8.1	11.6	9.3	10.1	46925.
117	20	196.9	10.0	44 23.27N	24 48.43W	342	10.8	-0.1	64%	11.3	8.3	11.5	9.1	10.0	46885.
117	30	197.1	10.1	44 21.62N	24 49.09W	341	11.7	-0.1	63%	11.1	8.1	11.6	9.2	10.1	46844.
117	40	196.8	10.0	44 19.98N	24 49.75W	339	12.6	-0.1	64%	11.2	8.2	11.7	9.4	10.0	46813.
117	50	196.1	10.1	44 18.33N	24 50.40W	337	14.4	-0.1	64%	11.4	8.4	11.8	9.4	10.0	46790.
117	100	196.2	10.1	44 16.70N	24 51.05W	339	12.8	-0.1	62%	11.3	8.1	11.7	9.2	10.1	46768.
117	110	197.5	9.9	44 15.08N	24 51.70W	336	15.8	-0.1	63%	11.2	8.1	11.7	9.4	10.0	46750.
117	120	196.9	10.0	44 13.50N	24 52.34W	336	16.1	-0.1	64%	11.1	8.2	11.6	9.3	10.1	20034.
117	130	197.4	10.0	44 11.89N	24 53.00W	336	16.0	-0.1	63%	11.2	8.1	11.6	9.2	10.1	46670.
117	140	196.9	9.8	44 10.27N	24 53.65W	335	16.9	-0.1	63%	11.1	8.1	11.7	9.4	10.1	23250.
117	150	197.5	9.9	44 8.67N	24 54.30W	337	14.9	-0.1	64%	11.2	8.2	11.6	9.2	10.0	46634.
117	200	197.1	9.9	44 7.07N	24 54.95W	336	15.6	-0.1	64%	11.3	8.4	11.3	8.9	10.1	46624.
117	210	197.5	9.8	44 5.44N	24 55.60W	335	16.9	-0.1	64%	11.1	8.1	11.7	9.4	10.0	46629.
117	220	198.2	9.8	44 3.83N	24 56.26W	334	17.9	-0.1	64%	11.3	8.3	11.8	9.5	10.1	46652.
117	230	197.8	9.9	44 2.23N	24 56.92W	336	15.7	-0.0	64%	11.4	8.4	11.6	9.2	10.0	46683.

SATELLITE FIX
DAY 117 TIME 220 HOURS. SAT NO. 13 DURATION 16 MIN.
LAT. 44 5.04 LONG. -24 59.34
VEL NORTH -9.41 VEL EAST -2.86 ELEVATION 29 DEG.
SPEED 9.84 COURSE 198

DAY	TIME	CO.&	SP.TW	D.R. LAT	D.R. LONG	REL.WD	(KT)	SUN	R.HUM	SD	SW	PD	PW	REF.	MAG
117	240	196.7	9.8	44 0.64N	24 57.58W	337	14.6	-0.1	63%	11.3	8.2	11.6	9.2	10.1	46708.
117	250	197.2	9.9	43 59.04N	24 58.23W	337	14.8	-0.1	62%	11.1	8.0	11.6	9.1	10.1	46724.
117	300	192.9	6.3	43 57.47N	24 58.87W	335	14.0	-0.1	63%	11.2	8.1	11.7	9.2	10.1	46709.
117	310	121.9	4.3	43 56.91N	24 58.30W	348	8.5	-0.0	62%	11.4	8.2	11.8	9.4	10.1	45694.

FIX VERIFICATION COMPLETED

Fig 6

Figure 7 Example of output of profile plotting program giving:-

(a) magnetic anomaly

(b) depth

(c) speed

(d) course (from Fasham, 1970.)

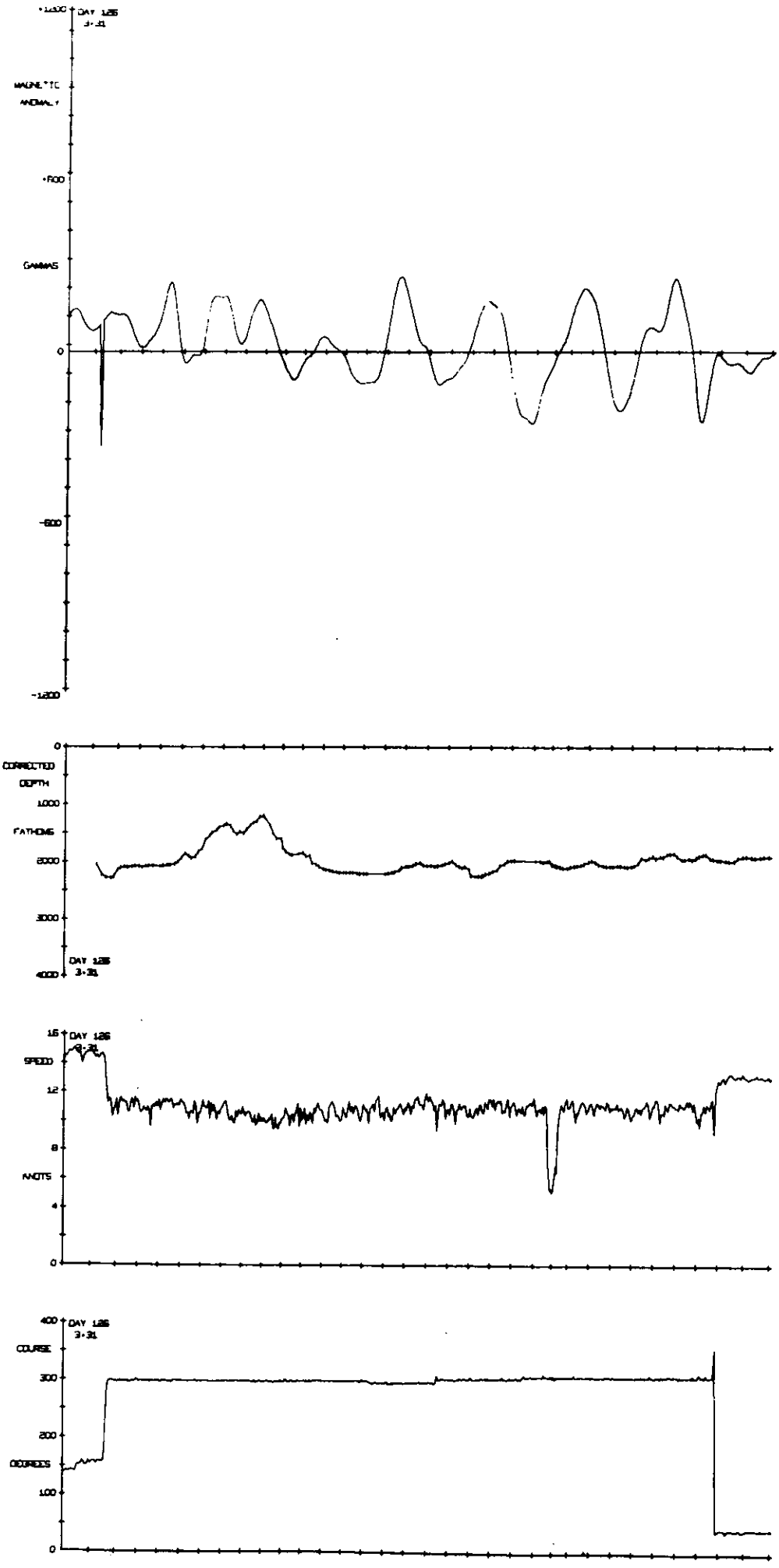
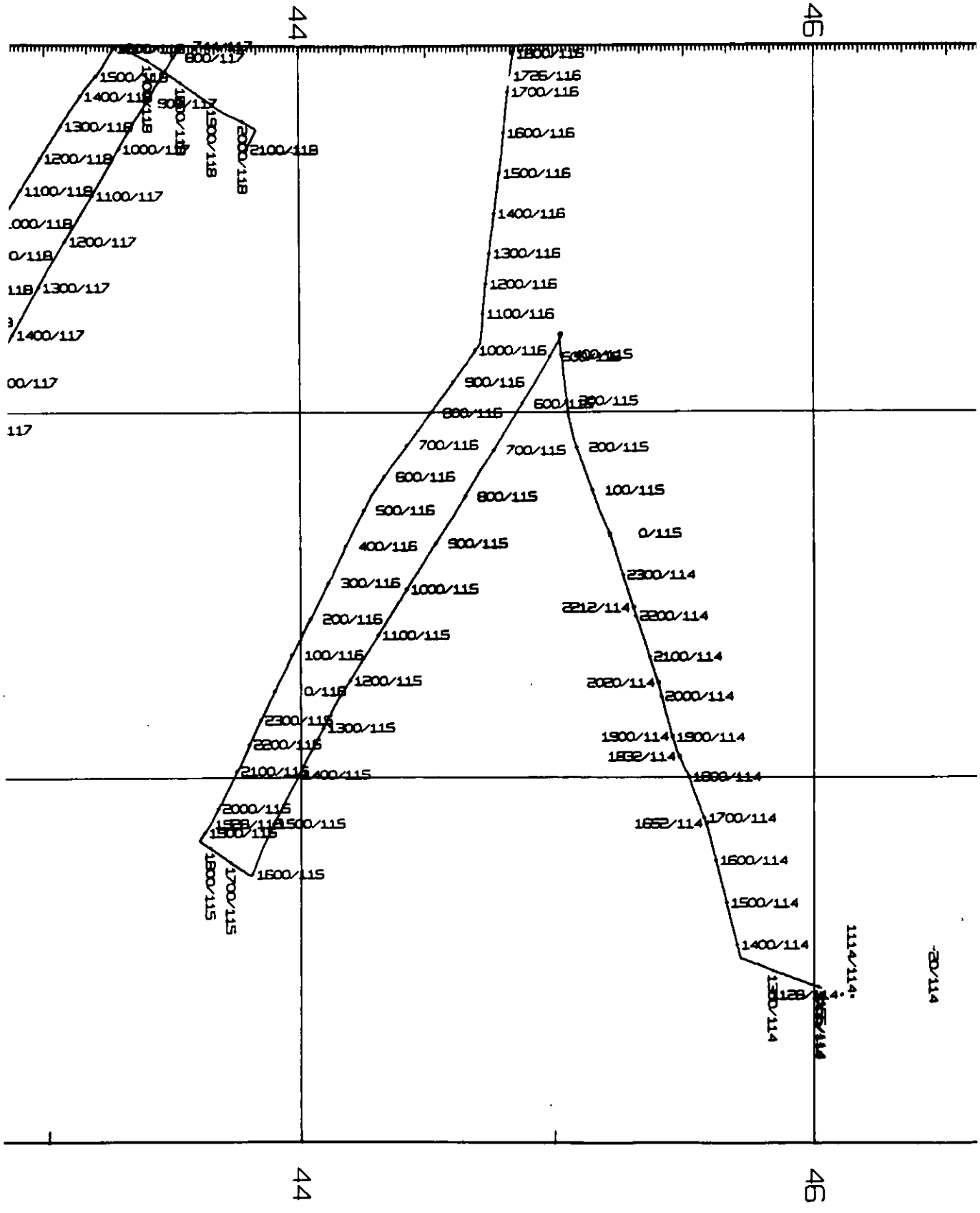

DAY 126
3-31
MAGNETIC
ANOMALY
+600
GAMMAS
0
-600
-1200
0
CORRECTED
DEPTH
1000
FATHOMS
2000
3000
4000
DAY 126
3-31
15
DAY 126
3-31
SPEED
12
8
KNOTS
4
0
400
DAY 126
3-31
COURSE
300
200
DEGREES
100
0

Fig 7


44
46
1800/115
1726/116
1700/116
1600/116
1500/116
1400/116
1300/116
1200/116
1100/116
1000/116
900/116
800/116
700/116
600/116
500/116
400/116
300/116
200/116
100/116
0/116
700/115
800/115
900/115
1000/115
1100/115
1200/115
1300/115
1400/115
1500/115
1600/115
1700/115
200/115
100/115
0/115
2300/114
2212/114
2200/114
2100/114
2020/114
2000/114
1900/114
1832/114
1800/114
1700/114
1600/114
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2100/118
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1852/114
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Fig 8