INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming, Surrey.

R. R. S. DISCOVERY CRUISE 54

29th June-15th August 1973

GLORIA STUDIES OF THE MID-ATLANTIC RIDGE (FAMOUS AREA) AND THE AZORES-GIBRALTAR PLATE BOUNDARY

I. O. S. CRUISE REPORT NO. 2

(Issued December 1973)

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DATES

Leg 1	Leave Southampton	29th June	Day 180
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	Arrive Ponta Delgada, Azores	23rd July	Day 204
Leg 2	Leave Ponta Delgada, Azores	26th July	Day 207
	Arrive Barry, South Wales	15th August	Day 227

SCIENTIFIC PERSONNEL

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SUMMARY OF CRUISE INTENTIONS

(1) GLORIA survey of FAMOUS area

The principal objective of the cruise was to use GLORIA to make a long range side-scan sonar survey of an area on the mid-Atlantic Ridge SW of the Azores. This area was chosen for study as part of the Franco American Mid-Ocean Undersea Study (FAMOUS) programme. This programme, organised by the Woods Hole Oceanographic Institution, USA and the Centre National de l'Exploitation des Oceans, France, has as its main aim, the study of the accreting margin of a lithospheric plate in the median valley of the mid-Atlantic Ridge by close observation of the sea-bed and sampling using deep submersibles and near bottom instrumentation. Surface and deep surveys of the area had already been made by the RV Knorr, USNS Hayes, ships of the USNOO, RV Jean Charcot and RV Atlantis II, and other geophysical work by RV D'Entrecasteaux and RRS Shackleton. Plans for future work include long range underwater photography and dives by the submersibles Archimede, SP 3000 and Alvin.

The survey by side-scan sonar was planned to provide a mosaic of overlapping sonographs of the entire 60 by 100 mile FAMOUS area to delineate more clearly the trends of the ridges parallel to the median valley and of the fracture zones. Secondly detailed studies of the median valley were planned using the shorter ranges and higher resolution modes of GLORIA in order to determine the positions and trends of faults and volcanic ridges within the valley that are to be the subject of closer examination by submersibles.

(2) Underwater photography in the FAMOUS area

Camera traverses were planned across features revealed by the GLORIA survey to identify the nature of targets giving acoustic echoes.

(3) Seismic refraction studies in the FAMOUS area

Seismic lines using pop-up bottom seismic recorders (PUBS) were planned in the median valley to determine structure and to locate the magma chamber, in the neighbouring ridges and across the valley. Microearthquakes were expected during recording time.

(4) Site selection for "Deep Drill 1974"

A site for drilling into layer 2, to be occupied by the Deep Sea Drilling Project in the summer of 1974, requires adequate sediment for initial support of the bottom hole assembly. Seismic reflection profiles and a seismic refraction line were planned to locate a suitable site.

(5) GLORIA traverses outside FAMOUS area

It was the intention to obtain as much coverage with GLORIA on passage as possible, especially on the route across the Azores Plateau near the mid-Atlantic Ridge and along the Azores-Gibraltar plate boundary, and fracture zones south of this.

(6) Seismic reflection profiles

Profiling at 7-10 knots was planned whenever time allowed.

(7) Seismic refraction studies of Porcupine Bank

The reversal of a refraction line shot by HMS Hecla in April 1973.

(8) Electric self-potential measurements on the bottom

Electrodes were to be towed along the bottom in the FAMOUS area as part of a Cambridge University research project.

(9) Echo-sounding and magnetic measurements

These were to be made throughout the cruise to add to the study of the bathymetry and magnetic anomaly field of the Northeast Atlantic.

(10) Velocimeter

Vertical profiles of velocity of sound in the sea are required for the interpretation of both GLORIA and PUBS results and were to be made as required.

NARRATIVE

Leg 1

R. R. S. Discovery sailed from Southampton at 1600 on 29th June (180). Off the Needles, the 36 kHz side-scan sonar was put into position in the Asdic trunk and tested, while Dr McCartney was on board.

The following morning three runs were made over the measured mile off Polperro to calibrate the newly fitted NIO port side electromagnetic log before entering Falmouth to load explosives. While coming to anchor, the sonar transducer was lost when it grounded in shallow water. 4 tons of Geophex were loaded and the ship sailed at 1700, bound for Porcupine Bank. Echo-sounding and magnetometer watches were started on 1st July (182) before crossing the shelf edge.

After a velocimeter station (8432) two PUBS were laid for seismic station 8433 at the southern end of Porcupine Bank on 2nd July (183) and a line of 110 miles shot to the north in strong southerly winds. On return to the PUBS position the following day only one surfaced on command, the other evidently failing to release its ballast due to a faulty pyro release. The weather had now improved considerably and in a flat calm and under danbuoy radar control, attempts were made to trawl the PUBS up from 260 fathoms using a hookfish pinger and the PUBS transponder for relative location. After several attempts over 12 hours during which the PUBS was thought to have been moved, it was abandoned.

At 0400 on 4th July (185) we set course towards the Azores in fine calm weather. Seismic profiling started on 5th July (186) in order to get a good section across King's Trough.

On 7th July (188) 80 miles south of King's Trough, and in fine calm weather, GLORIA was launched. Shortly after launching, a transformer burnt out in the main power amplifier and smaller power amplifiers were used until 9th July (200) when the transformer was repaired.

After an inspection of the underwater towing harness on 9th July (200) just north of Graciosa Is., the track took us between the East and West Azores Islands near to the axial region of the mid-Atlantic Ridge and the possible triple junction with the Terceira spreading centre. It was not prudent to go too close to the axial region where isolated shoals of as little as 79 fathoms are reported, since GLORIA tows at 60 fathoms. The ridge was therefore viewed from the 1000 fathom valley that runs parallel to it on its eastern side.

The FAMOUS area survey started at 1800 on 10th July (191), the first leg being through the centre to get a feel for the correct range and recording techniques to use. The legs of the survey were steamed at 7 knots with continuous seismic profiling and magnetometer recording. The survey was conducted in very calm weather and was completed by 17th July (198). Navigation was by satellite and computer interpolated dead reckoning.

During 18th and 19th July (199 and 200) close-in sonar surveys were made of the two sections of the median valley north and south of Fracture Zone B. An additional line of the main survey was completed on 20th July (201) and some special tracks then run in the NE of the area to examine the possible eastern extension of Fracture Zone A.

We left the area on the same evening steaming towards San Miguel to examine the south escarpment of the Azores Plateau, and to look for topographic trends on the Plateau west of San Miguel.

GLORIA was recovered in the lee of San Miguel on 22nd July (203) and during the night a survey was made SW of San Miguel to look for magnetic trends that might be associated with spreading parallel to the Terceira Rift.

At 1000 on 23rd July (204) we berthed in Ponta Delgada. Throughout the first leg the weather was remarkably calm (apart from the first few days out of Falmouth), the Azores high pressure system being maintained. Very variable currents were experienced in the survey area (up to 1.0 knots) and these appeared to be related to the large variations in water depth. In the calm weather, oil slicks and ruffled water could be seen associated with the larger ridges probably due to local upwelling. High productivity in these areas was indicated by the concentration of porpoises and seabirds. The current shear associated with this upwelling generated considerable yaw in the GLORIA vehicle.

In Ponta Delgada

The French ship Marcel Le Bihan and the submersible Archimede arrived in Ponta Delgada on 24th July (206) and on 25th July discussions of our FAMOUS survey results and of plans for future work were held on board R. R. S. Discovery.

Leg 2

We sailed at 0900, 26th July (207) and made all available speed towards the FAMOUS area so that we could complete our geophysical studies in the area before the Marcel Le Bihan arrived and Archimede started her diving operations. The tracks to and from the FAMOUS area were chosen so that magnetic anomalies could be correlated between tracks.

On arrival near the median valley on 27th July (208) an anchored danbuoy with radar transponder was laid (D/B 1). A seismic refraction line (8434) was shot along the axis of the median valley with a PUBS at each end near Fracture Zones A and B. One of the PUBS gave a poor record so that sections of the line were repeated on 29th July (210) with one PUBS (8437).

A velocimeter dip (8435) was made to 2000 m on 28th July (209) followed by an experiment to examine electric field anomalies near the bottom by towing electrodes and a recorder. The station (8436) was in Fracture Zone B where the topography was least rugged.

It was apparent during station 8436 that the danbuoy was dragging its moorings, so it was recovered for relaying. During recovery the battery box became flooded and new batteries had to be prepared before the buoy was relaid as D/B 2.

Following the reversal of the seismic line (8437), a photographic traverse (8438) was made eastwards across the median valley using the towed buoyant mini-camera. The pinger became stuck on rocky terrain in the centre of the valley and the ship had to retrace its tracks until the wire was vertical before it came free. However successful photographs were obtained. Once again it was apparent that the danbuoy was dragging its moorings so it was recovered and relaid further east as D/B 3.

A second attempt at the bottom electric field measurements was made in the Fracture Zone B (8439) during the night of 29th-30th July (210-211) but no results were obtained because of recorder failure.

During 30th-31st July (211-212) a seismic refraction line was shot with two PUBS on the rift mountains east of the median valley (8440). A 1000 cu. in. air-gun provided the sound source for lines both between PUBS and across the median valley. Explosive shots were used on the opposite side of the valley to examine seismic propagation across the accretion zone. This experiment used up all remaining explosives on board.

A second photographic traverse (8441) started in the median valley on 31st July (212) and ran obliquely towards the NE covering 3 miles of bottom. During the station the lens became loose and the photographs became progressively less in focus.

A third attempt (8442) at the bottom electric field measurement, this time in the smoother area near Fracture Zone A seen from GLORIA records, was successful, after which D/B 3 was recovered. Yet again the buoy had dragged its moorings to the SW.

Studies of the sediment distribution in the FAMOUS area from reflection profiles obtained during the main GLORIA survey and from data supplied by WHOI showed a possible site for the "Deep Drill 1974" hole for the Deep Sea Drilling Project. A buoy (D/B 4) was laid near the site and a site survey with seismic reflection profiles demonstrated that there was adequate sediment for spudding in and that the area was large enough to be easily found again. In order to determine the crustal structure beneath the basin, an unreversed seismic refraction line (8443) was shot using one PUBS and the 1000 cu. in. airgun. D/B 4 was then recovered.

It was intended originally to relaunch GLORIA in the area, but the weather was not good enough for this nor was there adequate time in the programme to make studies of fracture zones south and east of the area. We therefore steamed on three engines towards Santa Maria choosing a course out of the FAMOUS area to see whether Fracture Zone B extended eastwards out of the area. It was found to be blocked off, in the same way as Fracture Zone A. En route to Santa Maria an experiment was carried out to look at the signature of the airgun pulse using a deep towed hydrophone beneath the gun, so that signal processing could later be carried out on the recorded output from the towed array.

GLORIA was launched off Santa Maria on 3rd August (215), followed by the seismic reflection profiling gear. Tracks eastward were chosen to examine the possible extension of the Gloria Fault Zone south of Santa Maria, to look for topographic trends south of the Gloria Fault Zone on the African plate, and then to search for an extension of the Fault Zone east of the GIBAZ survey of Cruise 43. Three parallel tracks were run in the region immediately west of the GIBAZ survey and then a single track eastward to Josephine Bank where we arrived on 7th August (219).

Although the sea was very calm, there was too much swell from the north to allow recovery in the open sea, so course was set for Porto Santo off Madeira. The passage took us along the axis of the Madeira-Tore Rise and good sonographs were obtained of the various seamounts in the crest of the rise.

GLORIA was recovered in a fresh wind in the lee of Porto Santo on 9th August (221) after a total of 21 days operation during the cruise. On the passage back to U. K., seismic reflection profiles were obtained from the Horseshoe abyssal plain to the NW across Josephine Bank where a recent

NAVEAM (No. 227) had reported a 10 fathom shoal. A minimum depth of 120 fathoms was found and about 500 fathoms at the reported shoal position. A second traverse to the NE crossed the Madeira-Tore Rise between Tore and Josephine seamounts, and a third to the north crossed Tore seamount. The seismic gear was recovered after these profiles on 11th August (223) and course was set for U. K. with only echo-sounding and magnetic measurements.

The magnetometer was recovered at 1607 on 13th August while in heavy traffic and thick fog, and echo-sounder watches were closed down at 2200, by which time we were well onto the continental shelf.

The ship entered Barry docks at 0700 on 15th August (227).

PROJECT REPORTS

(1) Long range side-scan sonar (GLORIA)

(a) Performance of the equipment

The sonar was first launched on the 7th July (188) just north of the Azores. It was subsequently towed for 15 days, mainly in the FAMOUS area. At the start of this period a breakdown occurred in a heater transformer for the output stage of the sonar amplifier. While this transformer was being rewound an auxiliary amplifier providing 200 watts was used, enabling ridge targets on the approach to the FAMOUS area to be detected at 7 miles, due to their high target strength. Fortunately the repair was completed in time for the start of the main survey, which was made at a power level of about 5 kw. Because of ray path shadowing in relatively shallow water a track spacing of 6 miles was used, although the full range facility of 15 miles was used to obtain the longer ranges in deeper areas, giving a useful overlap with adjacent records. When the mosaic was completed short range runs were made in the region of the median valley to provide a more detailed view. Some of these runs employed a 30° wide vertical beam for the first time, which resulted in a more pleasing and even record. The wider beam was also used on the run back to the Azores, the vehicle being recovered off Santa Maria on the morning of the 22nd July (203).

On the second leg of the cruise the sonar was launched on the 3rd August (215) off Santa Maria, and used with the 15 mile range facility to investigate trends in the region of the GLORIA Fault and the plate boundary further to the east. Again use was made of the wide beam to gain experience of its performance. It was found to give an increased level of surface backscattering within the first 2-3 miles when depressed at only 10-15° for long range viewing, but this level was acceptable. The loss in transmitted directivity gain and power level (equivalent to a total of about 10 db) when the wide beam was in use was noticeable when trying to view targets with a low backscattering strength such as fractured sediments. Just a few hours before the planned recovery on the 9th August (221) the yaw gyro failed so that the 3-phase supply to the vehicle had to be shut down. A successful 'blind' recovery was made without the use of attitude, depth, and water level instrumentation, in the lee of Porto Santo. Swell conditions prevented recovery in the open ocean.

Other new features available this year were twin correlator channels and a dry paper recorder. The twin channels allowed both linear gain and automatic gain control signals to be received and recorded, and the dry paper recorder gave on-line sonographs superior to the existing Alden. The Muirhead photographic recorder was used from tape recordings in conjunction with the anamorphising Farnborough flow camera to provide high quality true scale prints off-line throughout the cruise. The true scale prints allowed for variations in ship's speed and were used for the FAMOUS mosaic. Although a slant range correction facility was available it was not used for the processing on board.

Changes in the overside gear included a new main towing cable plus redesigned module system. Because of the module change it was possible to lay the armour wires under constant tension during manufacture, and to sheath them more effectively. The cable was in good condition after 21 days use, with no cores lost, and the module system worked well. A braidline rope was used to tow the float to avoid torsional effects, proving superior to the 3-lay system previously used.

Vehicle yaw was rather severe, particularly in the FAMOUS area. This was believed to be partly due to local currents but was no doubt aggravated by the loss of three fairing lengths near the vehicle. Apart from short period yaw oscillations of +1° maximum as the rudder corrected for ship yaw, there would often be drifts in vehicle course of 1-2° per minute, lasting for 2 to 3 minutes. These could sometimes be correlated with the appearance of surface slicks. The degradation in azimuthal resolution was considerable under such yaw values for ranges in excess of about 4-5 miles.

JMSR

(b) Sonar mosaic of the FAMOUS area (Fig. 2)

Eleven parallel tracks were steamed, spaced on average by 5 miles, varying in length from 160 to 40 miles and covering an area of 9000 square miles. The track orientation of 055-235° was chosen as being best suited for viewing both median valley trends and fracture zone trends. The survey was carried out at 7 knots and took 7 days. The area was always viewed sonically from the NW with the end sections viewing inwards.

A track chart was built up at a scale of 19.8 inches per deg. longitude (the scale of bathymetric charts supplied by WHOI) since it was found that at the 32 inches scale, the sonographs were too large to be easily assimilated. It was found that greater detail and wider dynamic range was available on the AGC channel tapes and prints of sonographs from these adjusted for the correct ship's speed but not slant range corrected, were used to construct the mosaic. White echoes on a black background were used. Prints were trimmed in overlap areas to give the best target resolution and to provide continuity of features.

The following main results emerged from the survey:-

(1) The area was dominated by parallel and sub-parallel lineations,

separated on average in the central area by 1 mile, but with separation increasing to about 2 miles in the outer regions. Individual lineations could usually be followed from one fracture zone to the next, over distances of 30 miles. Between fracture zones the lineations are parallel to the median valleys trending 018°, although 20 miles from the median valley the trend was 025-030°. In places the trend changed to 055°.

(2) The fracture zones were characterised by the absence of lineations in the sediment filled parts and by the change in trend of the median valley lineations. Either side of the fracture zone, these lineations curved toward the fracture zone trend giving the general appearance of a flattened letter S. East of the median valley, the curvature was greater on the south edge of the fracture zone than on the north. This asymmetry was also shown by the bathymetric profiles on which the south side is steeper than the north side. To the west of the median valley the north side appears to be steeper.

(3) Although the fracture zones trend 090° in the central region, they curve towards 055° at 30 miles east from the axis and trend parallel to a massive ridge bordering the area. To the west a similar change of trend was observed although the fracture zones were much less clear and apparently more segmented.

(4) The area is bordered on the south east and on the north (there was insufficient data to the west) by massive ridges shoaling to less than 500 fathoms. The eastern ridge runs continuously NE to the Azores Plateau. The smooth nature of the ridge tops suggests wave zone erosion and subsidence of the whole region.

(c) Close range sonar studies of the median valleys (Fig. 3)

The median valley AB (between Fracture Zones A and B) and the median valley BC (between Fracture Zones B and C) were viewed at 7 and 3.5 mile ranges. For the 7 mile range, tracks were parallel to the valleys and viewing was from both sides. Parallel and oblique tracks were made at the 3.5 mile range.

The close-range sonographs provided a higher resolution of the valley and fracture zone features, with bottom illumination at a higher incidence angle. These gave panoramic views of the median valley and it was possible to discern the individual faults and volcanic ridges which constituted the linear patterns of the valley floor and to correlate targets between the different views. The minimum slopes of cliffs were calculated from the angles of incident rays on the bottom at given ranges (using velocimeter derived ray diagrams). Some cliffs were as steep as 70°, and the mean slope of the cliff immediately west of the median valley AB was greater than 45° for 300 fathoms vertical height. Some of the small linear ridges (3 miles by $\frac{1}{2}$ mile) in the valley floor appeared to consist of a collection of smaller hills that may be volcanic cones of the order of 200 yards in diameter. There are one or two possible instances of circular craters.

It is difficult to distinguish between the valleys between ridges and possible fissures. There is some suggestion of fissures at the northern end of median valley AB. A sonograph view of Bee Ridge (dividing median valley AB from BC) showed several narrow valleys trending 086° crossing the ridge. In Fracture Zone A, a narrow E-W ridge (3 miles long, 0.1 miles wide and 100 fathoms high)

divides the axis of greatest depth from a smooth sedimented area to the north of the ridge.

These sonographs can be related in detail to the photographic traverses described below.

(d) GLORIA traverses outside the FAMOUS area

After GLORIA was launched south of King's Trough, sonographs were obtained on passage between King's Trough and the Azores to look for topographic trends related either to the mid-Atlantic Ridge or to the Terceira Rift trends. The former were predominant, although the latter were also present. Between the East and West Azores, in the vicinity of the axis of the mid-Atlantic Ridge, strong lineations of trend 015° were seen interrupted by E-W fracture zones.

On the passage from the FAMOUS area to San Miguel, NE-SW trends were seen south of the south escarpment of the Azores Plateau. On the Plateau itself, the ridges trended parallel to the axis of the Terceira Rift.

On leg 2, the westward extension of the Gloria Fault Zone south of Santa Maria, linking it to the Trident Ridge, was clearly demonstrated. Further east, the track was south of the Gloria Fault and few targets were seen on a thickly sedimented region. The Gloria Fault was picked up at the GIBAZ survey area at 20°W but it was not possible to follow it uniquely east of there. Three parallel traverses defined a number of trends, some related to sea floor spreading axes. Further east the pattern became more complex and the targets less continuous because of the increase in sediment cover. The traverse ended on Josephine Bank where trends were evident in the exposed bedrock near the top.

On the passage to Madeira the seamounts on the Madeira-Tore Rise showed as strong targets with well developed structure.

(2) Seismic refraction shooting

Five seismic refraction stations, using 3 pop-up bottom seismic recorders (PUBS), were occupied during the cruise. The first station was a line 110 miles long over Porcupine Bank to reverse an earlier line shot on board H. M. S. Hecla in April 1973. Geophex shots up to 300 lbs were fired and good arrivals were recorded up to the maximum range. One of the two PUBS used on this line failed to release itself from the bottom although the indications were that the acoustic release receiver had operated correctly. At present it appears that the failure was in the Pyro release.

Following the loss of the PUBS on Porcupine Bank a ballast release incorporating 2 Pyro releases electrically in parallel was designed and made on board. A feature of this new release is that no part of the Pyro releases is left behind on the sea-floor. Thus it was discovered that on one occasion one of the Pyro releases, although its contents had ignited, did not part until the PUBS was lifted inboard. This experience confirmed the earlier explanation for the loss of the PUBS on Porcupine Bank.

The remaining seismic refraction work was concentrated in the FAMOUS area. Here four lines were shot. The first two yielded a reversed refraction line 33 miles long along the median valley using explosives. During one of these lines about 10 natural seismic events were recorded. The third line was reversed between 2 PUBS and was shot over the eastern crestal hills. It also included two east-west profiles across the median valley to discover whether there was any propagation discontinuity across the valley axis. Some 300 shots at 2 minute intervals from a 1000 cubic inch airgun, as well as seven explosive charges of 100 lbs, were recorded by both PUBS during this experiment.

Lastly an 11 mile long unreversed line was shot parallel to the median valley close to the sediment basin chosen as a prospective site for Deep Drill 1974. Some 100 shots from the 1000 cubic inch airgun were recorded by the single PUBS used for this experiment.

The preliminary results obtained on board ship from the FAMOUS area give consistent sets of velocities, although, due to the length of the lines, only in the median valley are velocities greater than 8 kms/sec observed. The velocities are unlike those normally found in ocean basins.

Generally the PUBS operations were successful on this cruise. One PUBS was lost out of eight deployed. Of the seven recovered from the sea two gave poor data. One of these had an insensitive hydrophone stack and the other was fortuitously laid in an area of high bottom noise, probably due to strong currents. The last two stations, which used the 1000 cubic inch airgun as a sound source, confirmed the impression gained on Cruise 43 that this airgun produces excellent results out to ranges of at least 11 miles. Future work will be aimed at extending the maximum range of this gun by the use of digital data processing.

RBW

(3) Seismic reflection profiling

S. R. P. tracks have amounted to some 3800 nautical miles at speeds varying from 2.5 kts to 10 kts. The majority of profiling has been done, however, during the deployment of GLORIA, at 7 kts.

During the PUBS refraction experiments, the airgun with a 1000 cubic inch chamber was streamed and towed at 4 kts, to supplement or replace explosives as a sound source. On replaying the PUBS tapes the large chamber was found to be quite adequate.

An experiment was carried out at 2.5 kts, towing a single sphere hydrophone beneath the airgun with a 40 cubic inch chamber, to measure and record the airgun output. With this information and the original signal from the towed array, it is hoped that some form of signal processing may be achieved in the future.

On the last profiling run before returning to Barry, it was decided to try profiling at 10 kts across Josephine Bank. About two thirds of this run was made at 10 kts and the remainder at 8.5 kts. Although somewhat noisy, the records are quite good.

The system has changed little from that of previous cruises. An E. P. C. dry paper recorder has been bought and tried on this cruise with great success. Eventually, it will replace the old Mufax recorder used at present, and the rest of the recording system will be modified to suit.

At the beginning of the cruise the Bell & Howell tape recorder, despite having just been serviced, would not record satisfactorily. On investigation, the tape transport was found to be set up incorrectly. This fault was corrected and 36 tapes were recorded at a speed of $1\frac{7}{8}$ ins/sec, amounting to 462 hours of recording.

The major source of trouble is still the Williams & James compressor, failures being caused by:-

(a) contaminated pipes causing "locking up" of the gauges and hence preventing correct unloading,

(b) suction valve on booster not seating correctly,

(c) second stage unloader kept jamming. This was replaced,

(d) high pressure cooler burst allowing high pressure air in the water system and hence burst water pipes,

(e) suspected leak on 3rd stage booster cylinder head. This was stripped and the gasket replaced,

(f) fractured pipes due to excessive vibration,

(g) unloader relay in control panel suspect.

It is becoming increasingly obvious that the Williams & James compressor will have to be replaced soon. If replaced by two compressors with the same output, it would enable the use of the larger airgun chambers at faster firing rates and also lessen down-time due to compressor failures.

Once again the high standard of servicing of the airguns has paid dividends, with only minor failures due to broken springs.

(4) Site survey for DSDP "Deep Drill 1974"

The data on sediment distribution from the main FAMOUS survey were combined with data from the previous survey of R. V. HAYES, to give an isopach map. From this, possible drill sites were selected to meet the following criteria:-

(a) sediment thickness should exceed 0.1 sec (two-way time) and the area of the pond exceed 1 mile square,

(b) the site should be clear of fracture zones,

(c) the magnetic anomaly pattern over the site should be linear and the site should lie over a magnetised block of a single polarity, preferably negative,

(d) the site should be as near to the median valley as possible and not further than 25-30 miles.

The most favourable site was chosen between Fracture Zones A and B 18' west of the median valley, and a danbuoy with radar reflector was laid for navigational control of a site survey.

Four seismic reflection profiles across the sediment body, determined that the sediment lay in a valley (Figs. 5 and 6) between basement highs which had previously been mapped by GLORIA. A maximum thickness of 0.3 seconds was found, and the area where the thickness exceeded 0.1 sec was 1.5' x 3'. The sediment is believed to have been emplaced by bottom currents channelled between the ridges.

An unreversed seismic refraction line of 11 miles (station 8443) was shot along the axis of the valley using a single PUBS and a 1000 cu. in. airgun sound source. This revealed that layer 2 consisted of two layers with a total thickness of 2.0 kms.

As a result of this survey, the recommended position for the site for "Deep Drill 1974" is 36°51.9'N, 33°38.0'W in 925 fathoms (uncorr.) water depth. A detailed report has been written and circulated on the site survey and selection.

ASL

(5) Underwater photography

Two photographic stations were occupied, both in the median valley. On both stations the towed buoyant minicamera was used. With this technique, a positively buoyant 16 mm camera and light source is tethered to a chain on the end of the main warp and towed across the target area at a speed of about 1 knot. The camera runs continuously taking one frame every 15 seconds up to about 2000 frames (about 8 hours). Successive pictures are separated by about 25 feet, assuming uniform progression over the bottom. The operation is monitored by a pinger 100 fathoms up the wire from the camera.

Station 8438 started on the western cliff of the median valley and covered 1.2 miles eastwards into the axis of the valley. The station was terminated when the pinger and camera became jammed behind a steep cliff. 700 photographs were taken, of which the last 300 were essentially in the same place.

Station 8441 started in the axis of the median valley and covered about 4 miles obliquely across the valley to the NE. A total of 1500 photographs were taken, but vibration shook loose the camera lens throughout the station and the photographs got progressively more out of focus. About the first half are easily usable but even in the later ones, the general nature of the bottom can be assessed.

Both photographic profiles can be related to the close range GLORIA surveys of the median valley and the nature and texture of sonar targets can thus be examined.

Some improvements in the towed buoyant camera system need to be made:-

(a) increase stability in towing at slow speeds,

(b) alter position of light with respect to camera to reduce back scattered light,

(c) increase format size,

(d) tow from a point nearer to end of chain to avoid lifting clear of bottom.

ASL

(6) Electric field measurements on the bottom

During Leg 2 three stations were carried out using a towed sea-floor electric field apparatus, with the object of detecting electric fields caused by mineralised sediments which may exist near the mid-Atlantic Ridge. This work was done by C. R. Brewitt-Taylor of the Department of Geodesy and Geophysics, Cambridge.

At station 8436 the record stopped about 40 mins after the apparatus reached the sea-floor, as the result of a severe jolt to the recorder case. Also the electrode array became wound round the towing wire, and the weight at the end of the array was lost, by the breaking of the rope leading to it. Useful record was obtained until this accident occurred. At station 8439 no record was obtained at the sea-floor, due to the failure of the chart drive mechanism during lowering of the apparatus. At station 8442 the apparatus worked properly, and a complete record was obtained including 1 hr 40 mins on the sea-floor, during which time the apparatus travelled about 2 miles.

The results obtained show small fluctuations of a few millivolts, measured between points 50 m apart, and changing in distance of this same order.

CRB-T

(7) Magnetic measurements

Magnetic records were taken throughout the cruise with the newly acquired Varian V-75 magnetometer. The data was automatically digitally logged by the computer, and total field and anomalies listed, checked and plotted. The IGRF correction was automatically selected, using the navigational information in the computer.

After 10 days of operation, the magnetometer became progressively noisier and finally failed to operate. The fault was traced to the relays on the preamp and relay board. These had failed also on Cruise 53, and no replacement spare had been available between cruises. Alternative higher duty relays

were wired in and performed satisfactorily. A replacement board and additional spare relays were received in the Azores. Minor faults were also found on the magnetometer/computer interface, which were put right without data loss.

Noise spikes were frequently generated as a result of radio transmission on board in spite of the new arrangements in the radio room.

ASL

(8) Topographic data

The loss of the hull mounted sonar in Falmouth prevented any narrow beam echo-sounding records being taken. Continuous echo-soundings were recorded with the NIO Mark III Precision Echo-Sounder. This has now been modified to give 2 or 6 minute time marks so that depths can be read at these intervals and manually entered into the computer which now works on even minute intervals. Matthews corrections are automatically applied by the computer, which uses the navigation data to select the correct area.

ASL

(9) Navigation

(a) The Irish Decca navigation chain 7D was used during the period up to 3rd July (184) which included seismic station 8433. Decca was also used on the final passage into U. K. from the Bay of Biscay.

(b) Two Magnavox 702CA satellite navigation receivers were on board, one with a faulty power supply as used on Cruise 53, the other on loan from RVB. The Discovery receiver worked satisfactorily with a lash-up power supply. The RVB receiver was used initially but became defective through overheating when the air conditioning in the computer room failed.

For most of the cruise, satellite fixes were used as the prime navigation aid. Regrettably bunching of satellites followed by long gaps of up to six hours without a fix made regular navigation difficult especially when attempting to follow parallel tracks in the FAMOUS survey area.

Some fixes appeared to be in error by $\frac{1}{2}$ mile or more for no obvious reason (checked by crossover values of bathymetry). This may be due to large currents, errors in speed log or minor alterations in ship's head during the fix. We badly need the more complex software to enable course changes during transit to be allowed and for current information to be used in obtaining a better input to the computation.

(c) Dead reckoning was derived by the computer from inputs of the IOS two-component EM log (port) and the ship's head. The EM log was calibrated at $10\frac{1}{2}$ kts on the measured mile off Polperro and the out-of-line sideways component measured on a still day by steaming into the wind. The appropriate calibration factors were fed into the computer calculations. The meters were

not adjusted however to agree with these calibrations until later in the cruise. An analysis of the currents while steering on a number of reciprocal courses in the FAMOUS survey showed that the EM log read 5% high and that there was a small gyro error. The log calibration factor in the computer was changed accordingly and the subsequent derived currents suggested the log now reads correctly. It was discovered however about half way through the cruise that sometimes during radio transmissions from the ship, the port log read about 15% high giving rise to spuriously large apparent currents from ahead. This interference puts into question many of the derived current values.

Troubles were experienced throughout the cruise with both the Arma-Brown and Sperry gyros. However the input to the computer appeared to be correct throughout except for a period on Day 209 when all repeaters failed.

(d) A Redifon Omega navigation NV1 was used throughout the cruise in order to assess its accuracy and usefulness in relation to other navigation systems. Redifon engineers in Southampton rectified faults that had existed on Cruise 53. For most of the cruise the receiver gave good consistent data and good records were obtained. Digital values of three station pairs AB, BD and AD were read hourly and listed by the watchkeeper, who also checked for lane slip and corrected when it occurred as a result of temporary signal failure or interference. Hourly positions from satellite data have been listed for direct comparison. For several periods of between 12 hours and several days adequate signals were not received, believed due to inadequate transmission.

Omega readings were recorded during three days in port in Ponta Delgada and after propagation corrections had been applied, positions calculated by computer. Errors of 3-4 miles occurred during the night but day positions agreed to within 2 miles.

An analysis of Omega fixes taken during the FAMOUS survey compared to satellite derived positions showed that errors seldom exceeded 3 miles and are mostly less than 1 mile. The reason for a higher accuracy in the survey area than in Ponta Delgada is not known. It was concluded that Omega is a valuable navigational aid in the absence of a satellite navigator.

(e) During the attempts at recovery of PUBS on Porcupine Bank, and during the geophysical stations in the median valley and the site survey, anchored danbuoys were used. In the FAMOUS area Decca-Alpine radar transponders were fitted giving ranges up to 17 miles in very calm weather. However all three danbuoys controlling the median valley operations (D/B 1, 2 and 3) subsequently dragged their moorings in a SW direction indicating a strong current. However the data could be used subsequently by defining the drift with satellite fixes. Danbuoy lay positions are listed in Table I.

(f) Track charts were plotted by computer after doubtful fixes had been removed. Tracks were then compiled by hand onto master plots (a) at 1:1 million scale (b) at 19.8 inches per deg. long. for the FAMOUS Survey (c) at 32 inches per deg. long. for the median valley studies, and the site survey.

(10) Surface currents

Surface currents were automatically computed and listed from pairs of satellite fixes using the dead reckoning derived from the NIO two-component EM log and the gyro. The accuracy of these currents depends on (a) the quality of the satellite fixes (poor fixes were rejected automatically if the apparent current exceeded 2.0 kts), (b) the correct calibration of the EM log, (c) the correct alignment of the gyro.

During the FAMOUS survey an apparent current from ahead on both NE and SW tracks implied a log calibration error and gyro error which were corrected. Currents prior to this adjustment were recalculated, and were plotted as vectors on this track chart.

The currents were analysed in three groups according to ship's head:-

(a) Course 235° - 40 observations gave a mean current of 294.6°, 0.06 kts.

(b) Course 055° - 47 observations gave a mean current of 268.2°, 0.13 kts.

(c) Courses various - 50 observations gave a mean current of 257.6°, 0.11 kts.

The currents varied from 0.03 to 0.90 knots with some evidence that the stronger currents were related to the large ridges. In the extremely calm weather, current slicks and races could be seen, and concentrations of fish, porpoises and sea birds implying regions of upwelling, convergences and divergences. Narrow zones of current shear produced yaw both in DISCOVERY and in GLORIA.

Further evidence of a mean WSW going current came from the drift of danbuoys after they had broken loose.

GLH and ASL

(11) Meteorological Observations

Daily meteorological readings were taken manually from the following instruments:-

1. Bridge screen thermometers (port and stb'd)
2. Bridge barometer
3. M.O. sea temperature (R.A.S.T.U.S.)
4. M.O. anemometer (relative wind)
5. Ship's speed and course

These readings and the data produced by the computer were recorded in a meteorological log to provide a running comparison.

All the 'scientific' meteorological instruments functioned well, requiring only general servicing and only two occasions arose where readings were not obtained. Between Day 209 and Day 212 the 1053 logging barometer was switched off and between Day 213 and Day 214 the bridge screen thermometers were removed.

Subsequent analysis of the comparison series obtained on the cruise has shown that the readings obtained from the following instruments:-

(a) Wheelhouse-top thermometer,

(b) Hull thermometer,

(c) Barometer,

(d) Solarimeter,

were of good quality.

The comparison between the anomometers, however, sometimes showed quite large discrepancies and although these could be attributed on some occasions to light winds, this was not always the case. Wind-data from this cruise should therefore be treated with caution.

JHH and EGP

(12) Data Editing

Navigation, bathymetric and magnetic data has been edited on board for the first time under the new MPX operating system. The procedure was similar to that used on CR 47 under the old TSX operating system; that is, navigation was plotted, bathymetry listed and magnetic profiles generated every 24 hours and checked for errors.

Navigation was assessed by inspecting the 1053 printer listings for spurious speeds and courses in the corrected D. R. data, and by comparing a running plot kept by the bridge with daily computed plots of ship's track and satellite fixes at a scale of 1 in 1×10^6. The computer automatically rejected fixes which gave rise to apparent currents between fixes of greater than 2.0 kts. Other satellite fixes were manually rejected because of too low or too high elevation, or the ship was turning during the pass. Due to the computer accepting some of these erroneous fixes, within the allowable current, some others were rejected, which were later found to be correct and these had to be reinstated. Whenever a fix was rejected or accepted an off-line program was run to do the course corrections and recompute regional magnetic fields and Matthews Area corrections.

Because there was not a suitable program available for inspecting stored total magnetic field, no editing was done during leg 1 to this parameter. A program was developed during this leg and used on the second leg, though the program needs further modification. This program displayed the stored total

field in the same form as that on the chart recorder in the magnetometer. The two records were compared for differences and in this way errors were detected and corrected. Radio transmissions caused frequent errors. Errors were found due to a faulty pre-amp board in the magnetometer and a faulty magnetometer/computer interface which were subsequently put right.

As each data disk was filled, complete profiles of total field and magnetic anomaly were generated. Any errors detected were corrected. These were assumed to be caused by errors made during previous edits.

The P. E. S. record was removed from the Mufax recorder daily and checked for mistakes. The record was then compared with a list of depths logged in the CDAT file. Any corrections were re-entered via the P. E. S. input console and written into the CDAT file during the next course correction update. After ensuring the depths were correct they were plotted out at 1 in 1 x 10^6, then hand copied onto a master chart.

Profiles of depths in corrected fathoms were generated as each data disk was filled, but because of the use of dots to show depths it made detection of spurious values virtually impossible.

Large scale track charts, and charts showing magnetic anomaly and depths were plotted for the FAMOUS area survey. Large scale track charts were also generated for certain PUBS stations.

Editing was made more difficult to start with due to the programs either not working or needing modification. Attempting to write completely general programs resulted in long complicated operating procedures making editing tedious.

It is suggested in the future that a suite of modified programs be prepared specifically for editing data on geophysical cruises.

NJO

(13) Computer

The IBM 1800 functioned reliably throughout the cruise apart from a minor fault on one of the disk drives shortly after sailing.

Of the two new visual displays the alphanumeric terminal, although not fully operational proved to be the most useful. This was used for preparing data and program tapes and for rapid display of data from core store and disk. The storage display was not used for scientific work on this cruise, although a live track plot was available. The display is likely to be of more interest when the resolution is improved and it is resited in the plotting office with the alphanumeric terminal.

The changeover to MPX together with the new suite of programs gave greater flexibility of operation and improved facilities. Examples are better quality control of data by assigning a status to each data sample, better security by storing data to two different disks each day, and faster response to certain functions (e. g. P. E. S. console) because of multi-programming.

JS

TABLE I

DANBUOY POSITIONS

D/B	Laid	Recovered	Lat. N	Long. W	Remarks
-	1540/184	0418/185	51°20'	14°07'	Passive reflector.
1	1840/208	2015/209	36°45'	33°14'	Radar transponder. Adrift when recovered.
2	2330/209	1851/210	36°44'	33°16'	Radar transponder. Adrift when recovered.
3	2030/210	2302/212	36°46'	33°11'	Radar transponder. Adrift when recovered.
4	0145/213	1330/213	36°52'	33°35'	Radar transponder.

TABLE II STATION LIST

Stn No.	Type	Equipment Used	Date	Time(Z)/Day No. From	Time(Z)/Day No. To	Lat. N Long. W	to	Lat. N Long. W	Depth Range UCF	Depth Range CF	Depth Range CM	Comments
8432	V	V	2 July	1154/183	1232/183	51°17' 14°04'		-	269	275	502	To 480 m.
8433	S. Refr.	PUBS (2)	2-3 July	1303/183	0333/185	51°19' 14°06'		53°07' 14°04'	269 - 101	275 - 103	502 - 188	110 mile line to the north. One PUBS lost.
8434	S. Refr.	PUBS (2)	27-28 July	2030/208	0956/209	36°28' 33°24'		37°02' 33°12'	604 -1680	621 -1725	1135 -3154	Median valley line.
8435	V	V	28 July	1012/209	1112/209	36°38' 33°19'		-	1530	1570	2871	To 2000 m.
8436	EP	BTE	28 July	1341/209	1803/209	36°36' 33°21'		36°33' 33°25'	1688 -1530	1733 -1570	3169 -2871	Electrodes fouled during station.
8437	S. Refr.	PUBS (2)	29 July	0025/210	1100/210	36°39' 33°21'		37°02' 33°11'	1058 -1564	1085 -1605	1984 -2935	Reversal of median valley line.
8438	TC	BMC	29 July	1245/210	1804/210	36°46' 33°19'		36°44' 33°15'	988 -1310	1024 -1344	1872 -2457	400 pictures over 1.2 miles.
8439	EP	BTE	29 July	2224/210	0431/211	36°34' 33°25'		36°35' 33°18'	1366 -1678	1401 -1723	2562 -3151	Recorder failure.
8440	S. Refr.	PUBS (2)	30 July	0608/211	0431/212	36°41' 33°10' 36°57' 33°20'		36°52' 33°04' 36°45' 33°23'	758 -1518	778 -1558	1422 -2849	Rift mountain and cross valley lines. Explosives and 1000 cu. in. airgun sound source.

8441	TC	BMC	31 July	0615/212	1522/212	36°49' 33°17'	36°54' 33°10'	1240 -1396	1272 -1432	2326 -2618	1500 pictures over 4 miles.
8442	EP	BTE	31 July	1619/212	2023/212	36°58' 33°16'	37°04' 33°13'	1394 -1110	1430 -1134	2615 -2083	Successful record.
8443	S. Refr.	PUBS (1)	1 August	0618/213	1254/213	36°47' 33°41'	36°59' 33°37'	704 -1081	723 -1109	1322 -2028	DSDP site survey. 1000 cu. in. airgun.

V	=	Velocimeter
TC	=	Towed Camera
BMC	=	Buoyant Mini Camera
S. Refr.	=	Seismic Refraction line
PUBS	=	Pop-up Bottom Seismic Recorder
EP	=	Electric Potential
BTE	=	Bottom Towed Electrodes
UCF	=	Uncorrected Fathoms
CF	=	Corrected Fathoms
CM	=	Corrected Metres

TABLE III GLORIA SONOGRAPHS

Date	Time(Z)/Day No. From	To	Range n. m.	Viewing Side	Speed	Length track n. m	Area	Comments
8-9 July	0200/189	0940/190	7'	Starboard	7 kts	211	King's Trough to Azores	Low power output.
9-10 July	1330/190	0840/191	15'	Starboard	7 kts	133	Between East and West Azores.	
10 July	0900/191	1622/191	7'	Starboard	7 kts	57	"	
10 July	1630/191	1800/191	15'	Starboard	7 kts	9	"	
10-17 July	1800/191	1518/198	15'	Alternating starboard and port	7 kts	1173	FAMOUS area.	
17-19 July	1530/198	0456/200	7' & 3.5'	Alternating	7 kts	206	Median valley studies.	
19-20 July	0500/200	0600/201	15'	Starboard	7 kts	177	Extra line for main survey.	
20-22 July	0600/201	0800/203	15'	Port	7 kts	345	South side of Azores Plateau.	
3-5 August	1220/215	1920/217	15'	Port	7 kts	380	South of Gloria Fault Zone.	
5-6 August	1930/217	0654/218	15'	Starboard	7 kts	85	Near GIBAZ survey.	
6-7 August	0707/218	1700/219	15'	Port	7 kts	232	To Josephine Bank.	
7-8 August	1700/219	2138/220	15'	Port	7 kts	195	Madeira-Tore Rise.	
8-9 August	2138/220	0715/221	15'	Starboard	7 kts	66	Approach to Madeira.	
					TOTAL	3229		

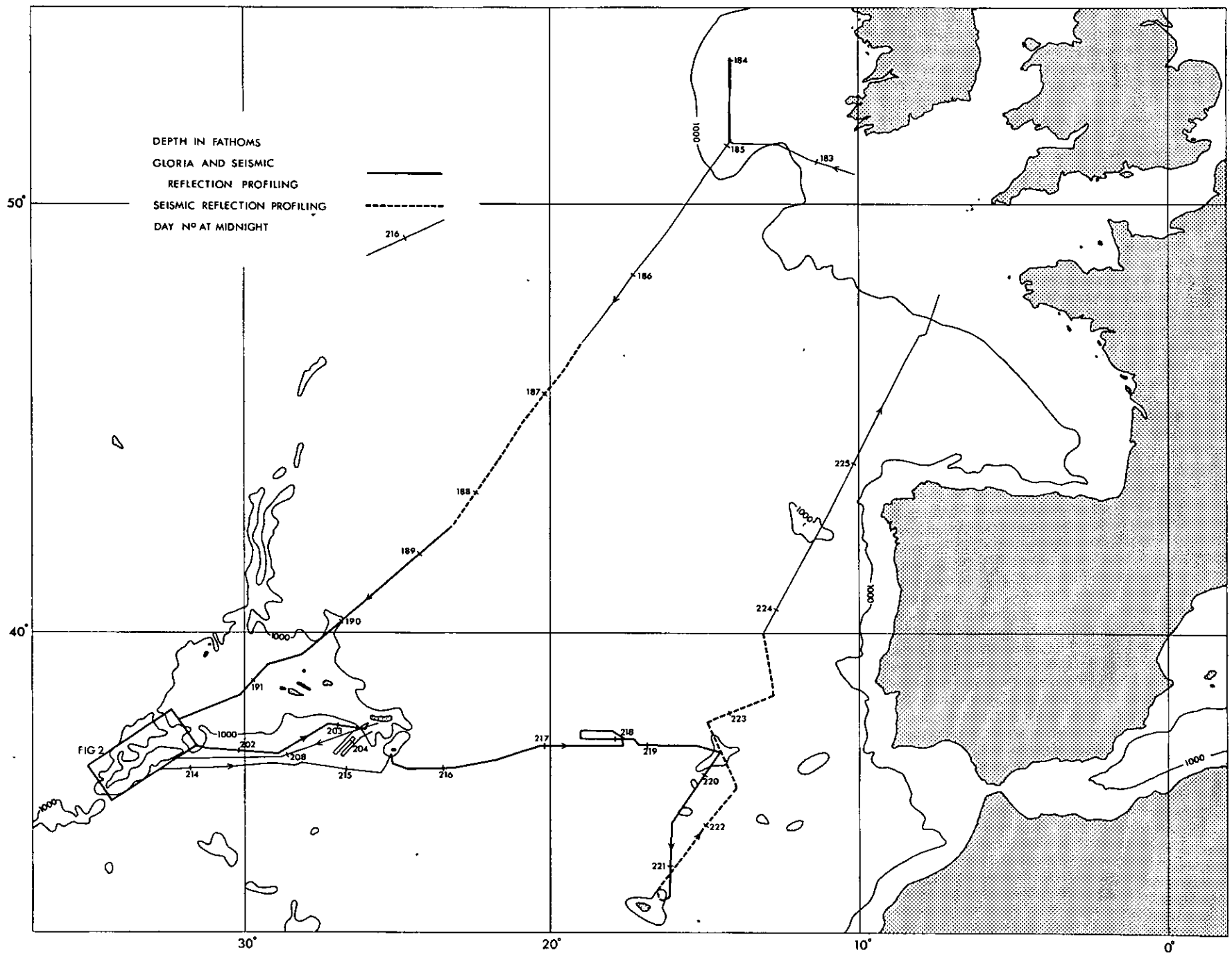
DEPTH IN FATHOMS
GLORIA AND SEISMIC REFLECTION PROFILING
SEISMIC REFLECTION PROFILING
DAY Nº AT MIDNIGHT
50°
40°
30°
20°
10°
0°
FIG 2
1000
184
185
183
186
187
188
189
190
191
202
203
204
208
214
215
216
217
218
219
220
221
222
223
224
225

FIG 1

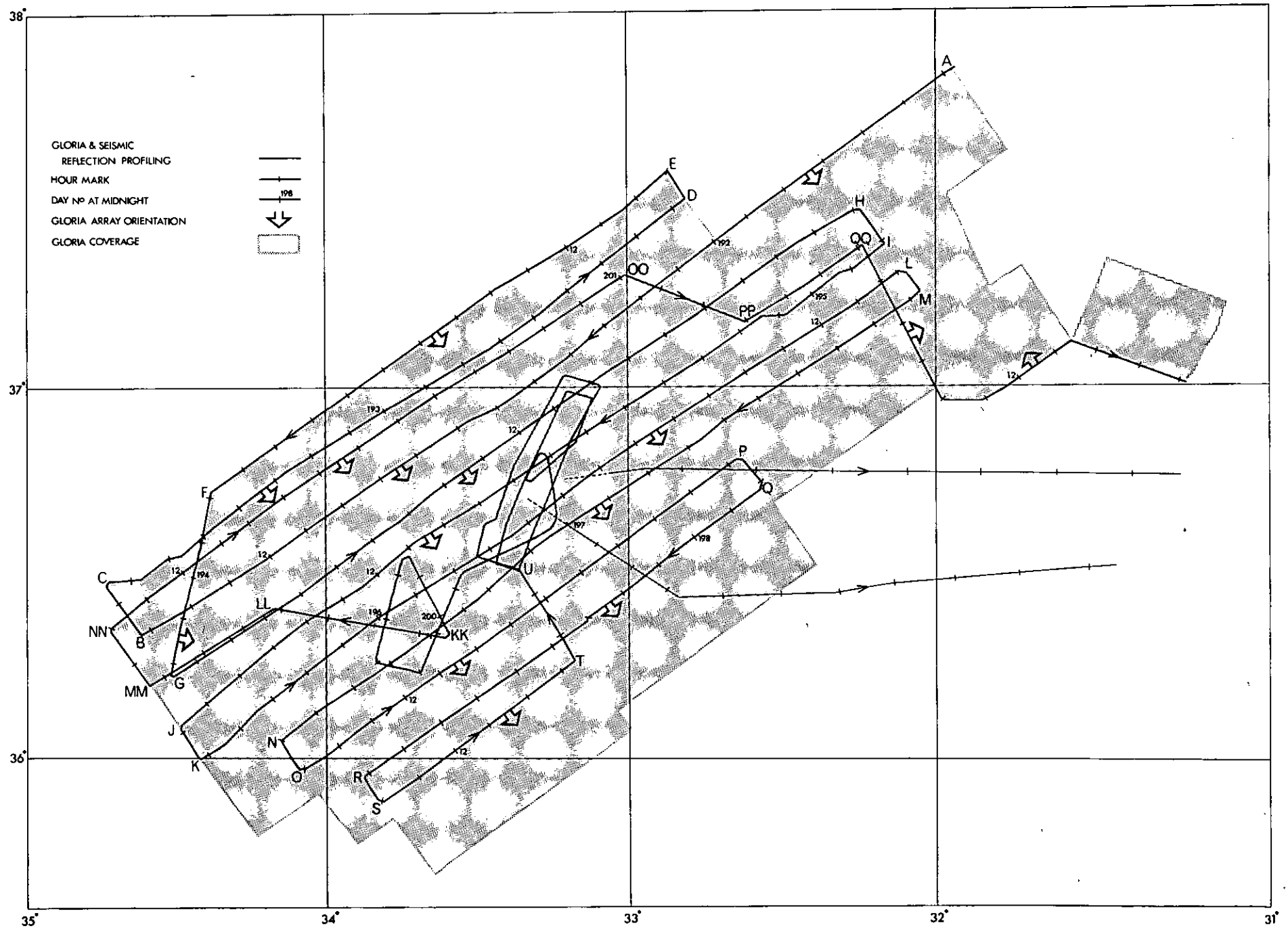
GLORIA & SEISMIC REFLECTION PROFILING
HOUR MARK
DAY Nº AT MIDNIGHT
GLORIA ARRAY ORIENTATION
GLORIA COVERAGE
38°
37°
36°
35°
34°
33°
32°
31°
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
MM
NN
LL
KK
PP
QQ
12
192
193
194
195
196
197
198
199
200
201

FIG 2

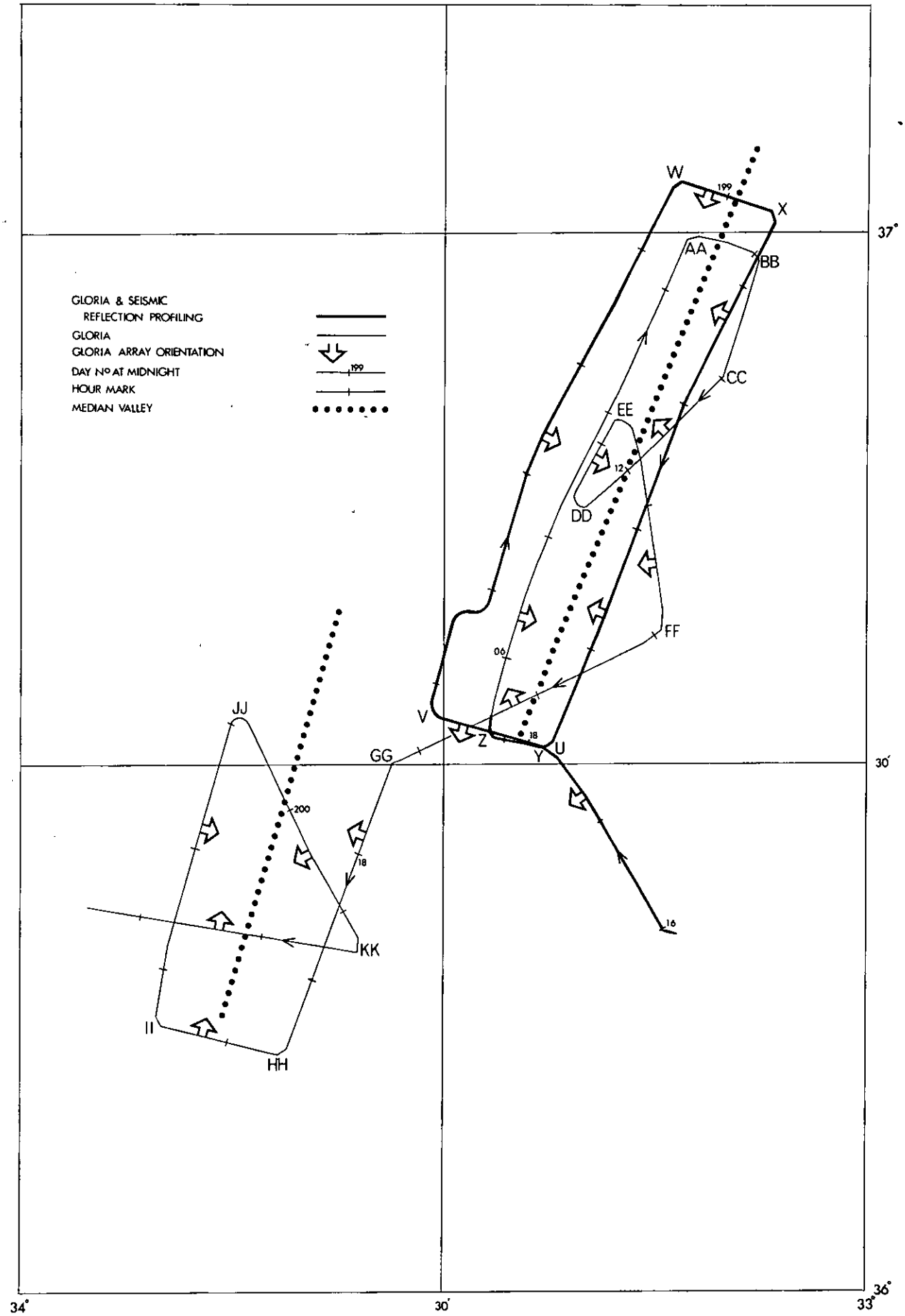
GLORIA & SEISMIC
REFLECTION PROFILING
GLORIA
GLORIA ARRAY ORIENTATION
DAY Nº AT MIDNIGHT
HOUR MARK
MEDIAN VALLEY
199
W
X
AA
BB
CC
EE
DD
FF
12
06
18
V
Z
Y
U
GG
JJ
200
18
KK
II
HH
16
37°
30°
36°
34°
30'
33°

FIG 3

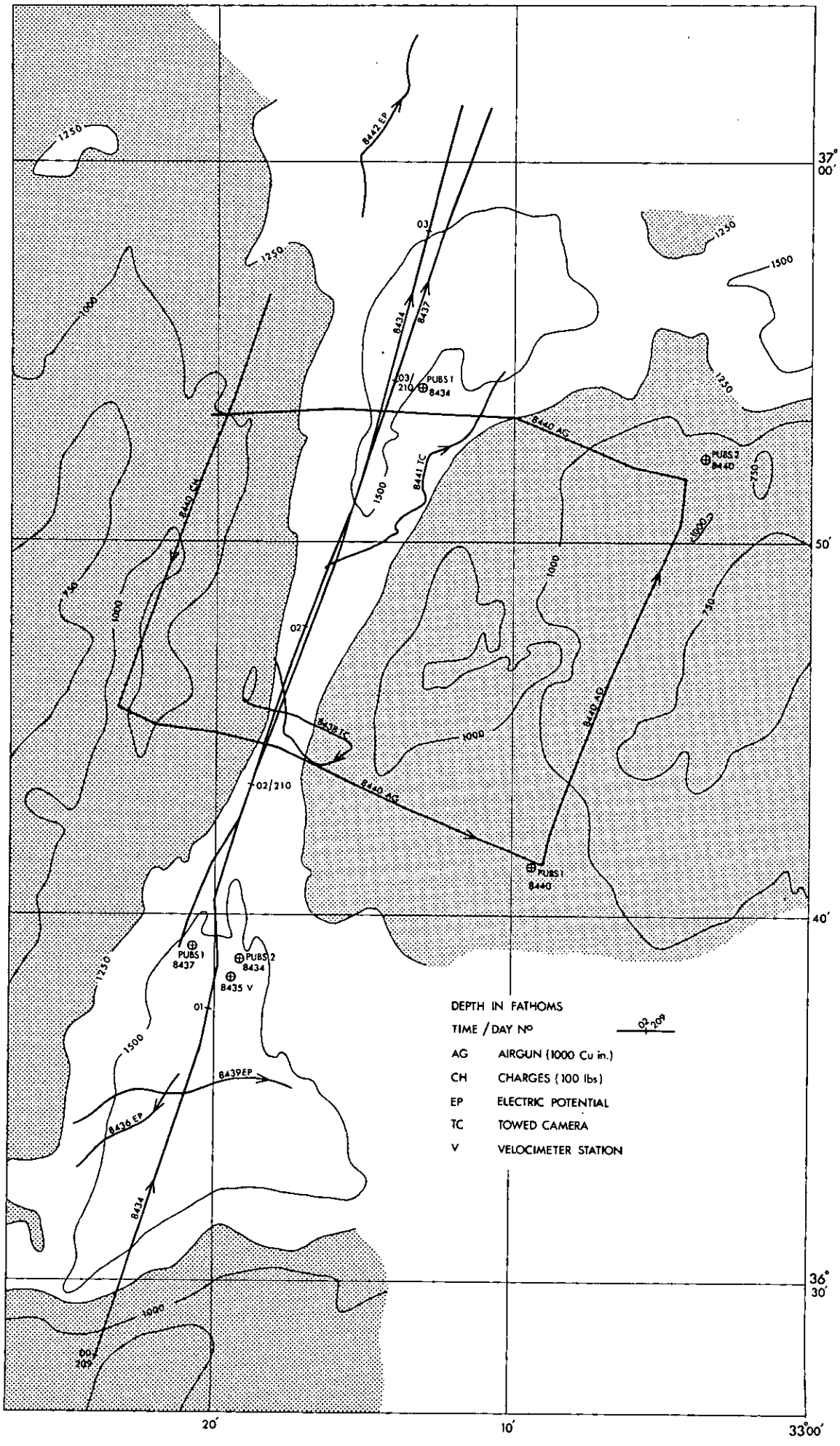
37° 00′
50′
40′
36° 30′
20′
10′
33°00′
1250
1500
1000
750
8442 EP
8431
8437
8441 TC
8440 AG
8440 CH
8438 TC
8439 EP
8436 EP
8434
03/210
02/210
01/209
PUBS 1 8434
PUBS 2 8440
PUBS 1 8440
PUBS 1 8437
PUBS 2 8434
8435 V
DEPTH IN FATHOMS
TIME / DAY Nº
AG AIRGUN (1000 Cu in.)
CH CHARGES (100 lbs)
EP ELECTRIC POTENTIAL
TC TOWED CAMERA
V VELOCIMETER STATION

FIG 4

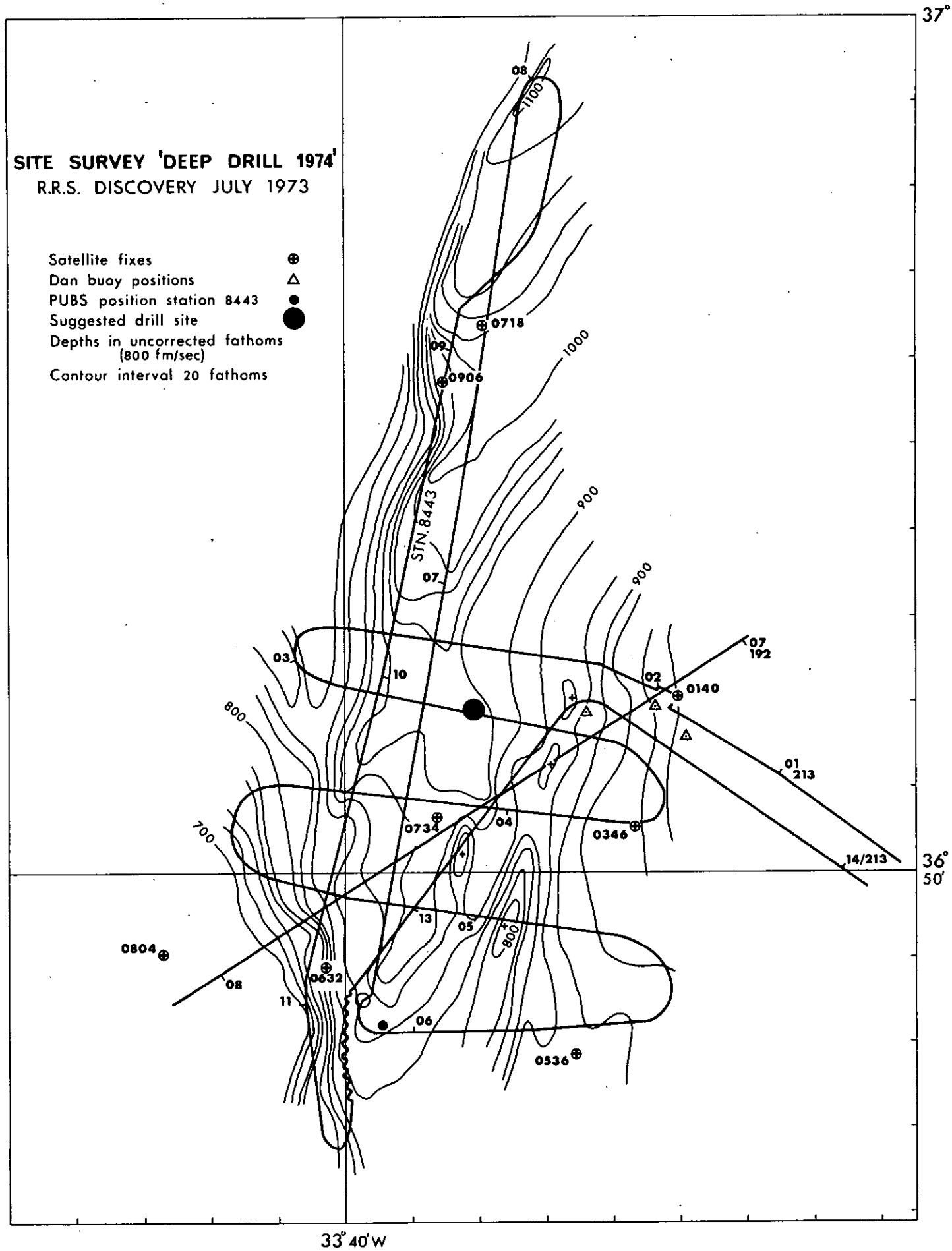
SITE SURVEY 'DEEP DRILL 1974'
R.R.S. DISCOVERY JULY 1973
Satellite fixes
Dan buoy positions
PUBS position station 8443
Suggested drill site
Depths in uncorrected fathoms (800 fm/sec)
Contour interval 20 fathoms
37°
36° 50'
33° 40' W
STN. 8443
1100
1000
900
900
800
700
800
08
09
07
03
10
02
04
05
06
11
13
01
14/213
07
192
0718
0906
0140
0734
0346
0804
0632
0536

FIG 5

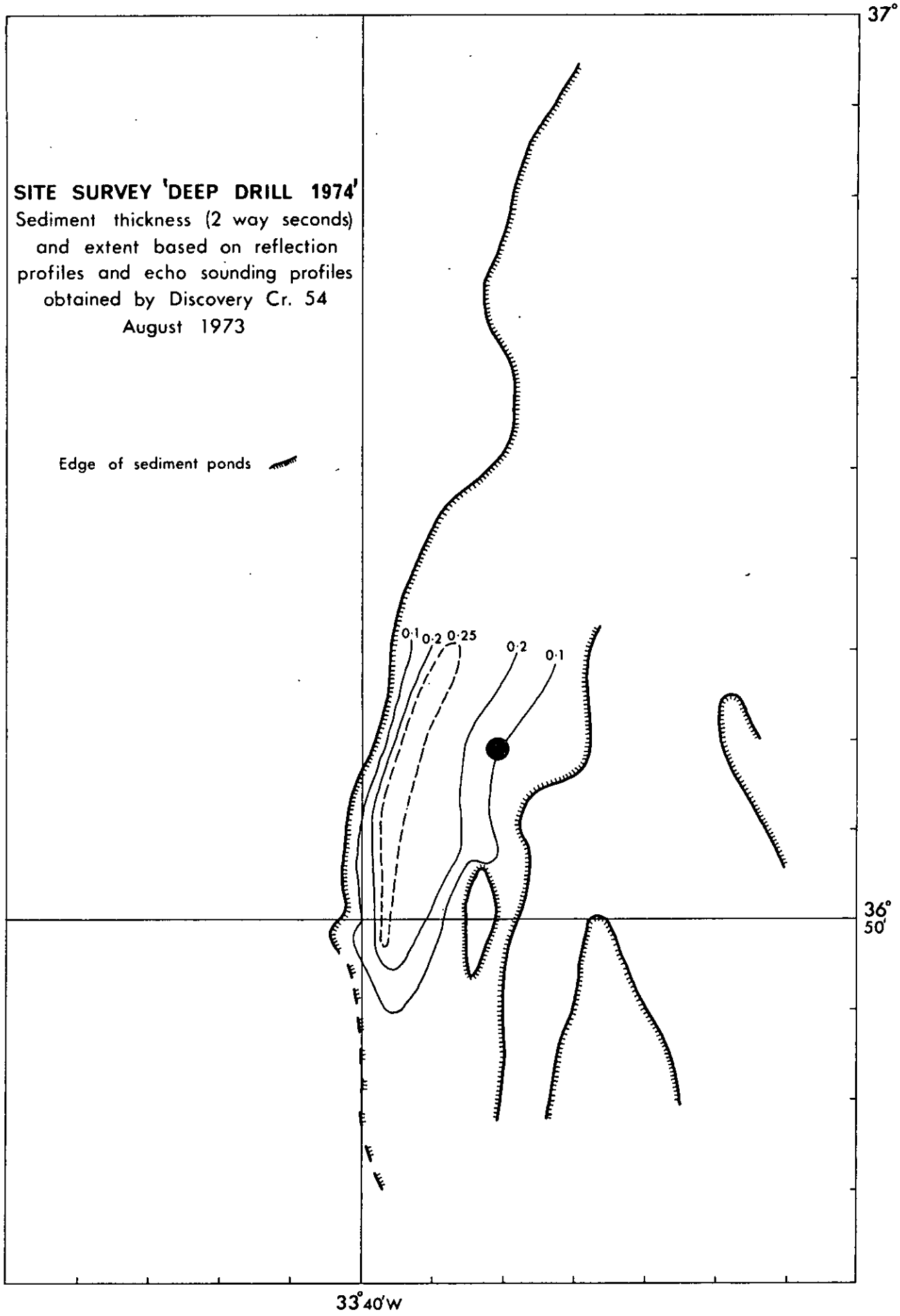
SITE SURVEY 'DEEP DRILL 1974'
Sediment thickness (2 way seconds) and extent based on reflection profiles and echo sounding profiles obtained by Discovery Cr. 54 August 1973
Edge of sediment ponds
0·1
0·2
0·25
0·2
0·1
37°
36° 50'
33°40'W

FIG 6