I.O.S.

R.R.S. DISCOVERY
CRUISE 90

20 January - 3 March 1978

Sonar Imaging of the European-North African Continental Margin

Cruise Report No. 68

1978

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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CONTENTS

DATES

Leg 1	Departed South Shields	January 20	Day 020
	Arrived Lisbon	February 8	Day 039
Leg 2	Departed Lisbon	February 11	Day 042
	Arrived Brest	March 3	Day 061

SCIENTIFIC PERSONNEL

D.G. Roberts	Principal Scientist	IOS Wormley	Legs 1 & 2
R.B. Kidd	Geophysics	" "	Leg 1
C. Spong	Geophysics	" "	Legs 1 & 2
P. Hunter	Geophysics	" "	Leg 2
R.G. Rothwell	Geophysics	" "	Leg 1
N. Scarle	Geophysics	" "	Legs 1 & 2
W.E. Elford	Side-scan Sonar	" "	Leg 1
D.G. Bishop	SRP	" "	Legs 1 & 2
C. Flewellen	SRP	" "	Legs 1 & 2
J. Langford	SRP	" "	Legs 1 & 2
M. Somers	GLORIA	" "	Leg 2
J. Revie	GLORIA	" "	Leg 1
B. Barrow	GLORIA	" "	Legs 1 & 2
S. Willis	GLORIA	" "	Leg 1
A.W. Gray	GLORIA/SRP	" "	Legs 1 & 2
J. Krawczyk	GLORIA/SRP	" "	Leg 2
R. Bonner	GLORIA/SRP	" "	Leg 1
D. Heathershaw	DPG	IOS Barry	Legs 1 & 2
S. Audley	DPG	" "	Legs 1 & 2
M. Beney	Gravity/DPG	" "	Legs 1 & 2

SHIP'S OFFICERS

M.A. Harding	Master
S.D. May	Chief Officer (Leg 1)
P.J. McDermott	Chief Officer (Leg 2)
T.J. Morse	Second Officer
T.C. Harrison	Third Officer
A.E. Coombs	Chief Engineer
D.R. Warlow	Second Engineer
F.J. Richardson	Third Engineer
P.F. March	Fourth Engineer
P.J. Roper	Fifth Engineer
L. Wilson	Electrical Engineer
W.D. Mullan	Radio Officer
R.M. Morris	Purser/Catering Officer

SUMMARY OF CRUISE INTENTIONS

1. GLORIA Surveys

Following the successful use of the long-range side-scan sonar (GLORIA Mk II) in the Rockall Trough during Cruise 84, it was planned to make a wider study of the continental margin of northwest Europe utilising the technique of producing sonograph mosaics of substantial areas. Simultaneous bathymetric, magnetic, seismic reflection and gravity measurements would also be made. It was planned to concentrate the main effort of the cruise in the Southwestern Approaches and off Portugal with alternative areas to the south reserved as bad weather options.

(a) The continental margin in the Southwestern Approaches

The margin between the Porcupine Seabight and the Meriadzek Terrace has been extensively studied by IOS and French groups using single and multichannel seismic techniques. In addition, three holes were drilled on the margin during Leg 48 of the Deep Sea Drilling Project. These surveys have shown that the margin is underlain by a series of tilted and related fault blocks that trend northwestward and shoal towards the Goban Spur. Although now covered by later sediments, these blocks may have profoundly influenced the distribution and deposition of the sediments and thus the morphology of the margin. The GLORIA survey was designed to assess the influence of the various continental margin sedimentary processes on the morphology of the margin and to examine the linearity of fault scarps previously mapped from seismic surveys.

(b) The Atlantic margin of Iberia

The west margin of the Iberian peninsula exhibits a number of significant differences to the margin in the Southwestern Approaches. The transition between shelf and rise is broad but distinguished by the presence of several non-magnetic seamounts of which the most notable is the Galicia Bank. The northernmost part of the margin off northwest Spain is bounded by an infilled trench and overthrust structures that may be related to the Pyrenean orogen. In contrast, the rifted margin off Portugal is characterised by deeply buried fault blocks and the presence of diapirs. Further south, the Lisbon

canyon area is the site of a well-known earthquake. The northern part of the margin also includes the transition between the Iberian and Biscay Abyssal Plains. Finally part of the margin is mantled by northward flowing Mediterranean water. The principal objective of the GLORIA survey was to obtain a 'synoptic' view of spatial variation in sedimentary processes along a rifted margin of starved type.

(c) The Gulf of Cadiz

The Gulf of Cadiz was an alternative objective reserved in case of bad weather to the north. The slope in the Gulf of Cadiz is abnormally gentle and extends over some 200 n.mls. The slope is underlain by the outer part of the Rif-Betic arc and its present relief in the inner part of the Gulf owes much to the influence of the outflow of Mediterranean water.

The objective of the study was to examine the topographic expression of any structural features that might be associated with the Rif-Betic arc and to obtain a wider view of the influence of Mediterranean outflow in fashioning the relief.

(d) Cape Mazagan and the Essaouira Basin

The margin off Morocco is underlain by a relatively large field of diaperic structures well-known in the adjacent Essaouira Basin. Part of the margin is flanked by the prominent Mazagan escarpment that is apparently a carbonate platform. The principal objective of the GLORIA survey was to obtain information in the distribution of diapirs beneath the slope and rise and their influence in the morphology of the margin.

OTHER PROJECTS

2. Signal Processing and Multichannel Seismic Acquisition

It was planned to record analogue 6-channel data throughout the cruise and to interface digital tape decks with the seismic processing equipment.

3. Digital Echo-Sounder

It was planned to carry out experiments on line digitising of the precision echo-sounder.

4. 3.5 kHz Seismic Profiler

An Edo-Western 3.5 kHz seismic profiler was on board and it was planned to obtain profiles throughout the cruise.

5. Disposable Sonobuoys

It was planned to occupy wide angle reflection and refraction experiments using disposable sonobuoys.

6. 36 kHz Side-scan Sonar

It was planned to use the 36 kHz sonar in the side-scan made on the upper part of the slope and as a narrow beam echo-sounder in greater depths.

NARRATIVE

Leg 1

RRS Discovery sailed from South Shields at 0915/020 some nine days late due to delays in the refit. After sailing, compasses were calibrated and various engine trials were carried out to the requirements of A.E.I. engineers. PES watchkeeping was started at 1200/020 but it was not possible to use the side-scan sonar effectively due to the high passage speed of 13.5 knots. Discovery arrived off Spithead at 1800/021 to deploy the PES fish and side-scan sonar. At 2047 Discovery commenced passage for 49°N 6°W in Force 9 conditions pitching and rolling heavily and taking spray forward.

During 022, the IOS(W) hydrophone was streamed to check for any damage that might have been sustained during its fall at South Shields. No damage was found. The 3.5 kHz fish was also streamed from the starboard midships boom. Throughout the day, Discovery proceeded downchannel in deteriorating weather conditions and by 0800/023, the wind speed was 35 kts from the northwest. During the forenoon, the gravimeter was clamped due to the severe motion and at 1305 the side-scan sonar was retracted. The vessel finally hove to at 1540. The stormy conditions continued overnight. By 1056/024 the weather had moderated sufficiently to allow Discovery to move south to seek a lee off Northern Spain to launch GLORIA. At 1536 the weather had abated considerably and the airgun, magnetometer and multichannel hydrophone were streamed. This traverse from Cantabria

seamount to the North Spanish Trough produced excellent results clearly showing the Pyrenean frontal overthrust. At 1125/025, the traverse was completed in sheltered water off Cape Ortegal and GLORIA was launched at 1215 and the seismic profiling gear redeployed at 1518. In view of continuing bad weather in the SW Approaches, it was decided to concentrate the GLORIA survey off Galicia Bank in the hope of returning northward should the weather moderate. Our initial traverse was made parallel to the North Spanish slope with the aim of examining the ground between the Biscay and Iberian Abyssal Plains. Targets detected at extreme range on the flat abyssal plain later proved to be a series of interplain channels trending southward to the Theta Gap. The Theta Gap was crossed at 1201/027 and course was set towards the Azores-Biscay Rise. The wind speed had increased to 50 kts and at 2115/027 the main engines tripped. GLORIA descended to a depth of 850 ft and afterwards the airgun and magnetometer were recovered though the 6-channel array was left outboard. High winds continued overnight and at 0712/028, the Asdic pod was retracted to prevent damage. In the forenoon, an intermittent fault was observed on the GLORIA heading indicator. Cable damage was suspected and courses were therefore set to return to N. Spain to recover the vehicle and change the cable should this be necessary. To obtain useful results en route, seismic profiling began again at 1425 shortly before altering course to 060°. At 1630, the port life raft was lost overside following a heavy roll but was recovered by 1700. The magnetometer was streamed at 2257/028. At 0330/029, the 6-channel hydrophone tow cable parted and the hydrophone was lost. Speed was reduced to 4 kts immediately to recover the airgun and magnetometer and a Williamson turn executed at 0415. As it was dark, the hydrophone could not be seen and a search of the area was begun at first light. The tail buoy was sighted at 1015, and, with the aid of a boat party in the Zodiac dinghy, the hydrophone was recovered by 1022/029. Speed was increased to 7 kts and the IOS 2-channel array and airgun were streamed at 1324. During the period 1430/029-1215/030, a seismic profile and GLORIA traverse was occupied from the Theta Gap to the Galician margin. At 1215/030, course was set parallel to the Galician slope and the side-scan sonar deployed. During the day, a new cable was fitted to the 6-channel hydrophone and it was rewound on its winch. GLORIA

transmissions ceased at 2350/030 and overnight further seismic profiles were occupied parallel and perpendicular to the slope. Geophysical observations ended at 0630/031 and the seismic profiling gear, magnetometer and GLORIA were all recovered by 0838/031. Whilst the PDR and 3.5 kHz fishes were recovered, retraction of the side-scan sonar began. It was found to be damaged and liable to fall from the hull. At 1115, a supporting net was positioned under the ship and aligned in position using the Zodiac (an operation complicated by a total power failure). Mr S. Willis dived to check the alignment. At 1405, Discovery got underway for Muros at 5 kts and anchored there at 1630/031. Repairs to the GLORIA cable commenced immediately whilst attempts to salvage the side-scan sonar got underway. Tests in the GLORIA cable showed that the 7 main cores were open circuit presumably reflecting the twist in the cable just forward of the nose. Messrs Elford, Gray and Bonner managed to retract the sonar by realigning the pod and to support it with strops by the late evening. During day 032, the long GLORIA cable was unwound and the short cable reeved on the winch. The side-scan sonar was lifted out of the Asdic trunk and the Asdic plate secured by 2130. Anchor was weighed at 0600 and GLORIA deployed on the shelf at 0929/033. The seismic gear was deployed at 1034. Part of the GLORIA traverse made on the evening of day 030 was reoccupied as a long southward traverse was made parallel to the Iberian margin towards the Nazare canyon. Excellent sonographs of Oporto seamount were obtained. Overnight, Discovery continued southward towards the Nazare canyon where excellent sonographs were obtained. At 1303/034 we altered course to 281^{o}T and at 1616/034 to 343^{o} to return northward overlapping the southward traverse. The northward traverse was continued until 2022/035, when course was set for the northern slopes of Galicia Bank. Between 2022/035 and 1730/037, a series of east-west traverses were made of the crestal area of Galicia Bank. At 1730/037, course was set to 180^{o} to examine the outer part of the Iberian margin. At 2338/037, the correlator drum on the GLORIA console failed but was replaced by 0100/038. During day 038, the southward traverse was continued until 1636 when the seismic gear was recovered prior to the recovery of GLORIA at 1730/038. The seismic gear was streamed again at 1823 and overnight a series of seismic profiles were occupied across the Lisbon escarpment and

canyon system. The seismic gear PDR, and 3.5 kHz fishes were recovered between 0650 and 0753. Discovery docked in Lisbon at 0930/039. During the stay in Lisbon, the gravimeter was connected to the base at Alcantara. Messrs Revie, Rothwell, Willis, Bonner, Elford and Kidd left and Messrs Somers, Hunter and Krawczyk joined.

Leg 2

RRS Discovery departed Lisbon at 0900/042 and proceeded northwestward to launch GLORIA at the shelf edge. Shortly after departure, it was discovered that the port log had been damaged - apparently whilst being raised in Lisbon. The starboard log calibration constants were used along the 1800. However, leads incorrectly connected in the electronics of the port log resulted in the ship recording an apparent backward movement for 5 hours. At 1420, GLORIA was launched and the seismic gear streamed at 1548. Traverses of the Lisbon escarpment and canyons were made until 2119 when course was set southward to examine the slope as far as Cape St Vincent crossing the Cape St Vincent canyon at 0600. At 0600, a traverse was made parallel to the Algarve margin of Portugal before turning southeastward at 1515 to cross the Gulf of Cadiz. The cause of the apparently poor seismic penetration was clearly seen at the end of this profile when the front of a large gravity slide was crossed in the vicinity of the Rharb Trough. At 0800, course was set southwestward to examine the Mazagan escarpment and excellent views were obtained of mud waves on the Moroccan slope. During the day, the fore and aft component of the e.m. log was calibrated using the direct wave recorded at sonobuoy station 9747 and the bridge log repeater adjusted to its correct value. During the evening of 044, the outer part of the Moroccan diapir field was crossed in 4500 m depth. Overnight, Discovery proceeded southward parallel to the Moroccan slope and rise, altering course to occupy a further northward traverse in shallower depths at 1542 (045). At 0600/046 the GLORIA repetition rate was changed to 20 seconds to enable a more detailed examination of the ground between the preceding traverses and in shallower depth. Southward and northward traverses were occupied between 0702/046 and 0400/047, when a westward traverse was made across the Mazagan escarpment and adjacent diapir field. Linear salt diapirs were observed on this traverse. Between 1258 and 1500

disposable sonobuoy station 9748 was occupied on the Seine Abyssal Plain. At 1620/047 course was set to 094° to examine the upper part of the Mazagan escarpment before returning to the Gulf of Cadiz. At 0500, course was altered to 344° and the GLORIA repetition rate was changed to 40 seconds. Between 0500/048 and 0133/051, a series of east-west and northwest-southeast traverses were made of the outer part of the Gulf of Cadiz to examine the influence of the gravity slide on the morphology. During these traverses, compressor failures took place on several occasions and at 1300/049, the hydrophone capstan paid out for no apparent reason leaving the airgun and hydrophone being towed by the airline. No major damage resulted and the airgun system was repaired and operational by 1518/049. To safeguard against future accidents, the capstan was stropped to the crane pedestal. During day 051, Discovery proceeded northward, overlapping our southward traverse from Lisbon and occupying a further series of traverses across the Lisbon canyon system between 1008/051 and 2400/051 when course was set northward to complete the GLORIA coverage of the outer part of the Iberian margin. Disposable sonobuoy station 9749 was occupied between 1000 and 1120/052. Through the afternoon and early evening of day 052, there was a steady deterioration in the weather and by 2300, the southerly wind had increased to 30-35 kts with a heavy swell. Following a storm 10 forecast, course was set for a lee off North Spain at 2307. By 0200/053, the wind had backed to 140° x 40 kts and Discovery was riding well before the storm although taking the occasional heavy roll. At 0335, a major failure was recorded on the GLORIA console and an electrical fire found in the Portakabin. The fire, which was extinguished with CO_2 was due to leakage of the KOH electrolyte from the batteries and severely damaged the monitor harness and batteries. At 0400 course was altered to 015°T and the speed adjusted to keep the vessel stable as the harness was stripped and batteries disconnected to make the Portakabin safe. The Portakabin was manned and after 0600 inspected frequently. Airgun operations were shut down at 0400 due to compressor failure caused by severe rolling. Weather forecasts at 0930 and 1030Z did not show any improvement in the weather and at 1328 course was set to make for a lee off Corunna. The seismic gear and magnetometer were recovered

between 1700 and 1732 and GLORIA was brought aboard by 1752/053. The PDR and 3.5 kHz fishes were recovered by 1830. The streamlined lower hull of the 3.5 kHz fish was found to be missing. Discovery dropped anchor in Corunna harbour at 2145. During the run into Corunna the batteries were cleaned and a new container with dividers built to house the salvaged batteries thwartships to prevent over-spill. Part of the electrolyte was discarded. Seventy-three batteries were saved. Tests on the GLORIA cable did not show any damage. During day 054, repairs to the Portakabin were completed, a new battery charging set-up rigged and the GLORIA amplifiers modified to operate at a lower voltage. Storm damage to the starboard shelter deck bulwark (frames 22-38) was protested to the ship's agents and Discovery sailed from Corunna at 1845/054. The PDR fish was streamed at 1930 and the magnetometer at 2050 when course was set for the Trevelyan escarpment. Our overnight passage to the Trevelyan escarpment was accomplished in calm seas using three engines. Although the seas remained calm, a force 10 was forecast as imminent. To take advantage of the calm weather, the 6-channel hydrophone was streamed to check for damage possibly sustained during Leg 1 and to measure its depth. During these tests, Brest Maritime notified Discovery that no equipment could be towed because of submarine exercises until 1400/056. A cable was therefore sent to Brest asking if this applied to seismic equipment. Following a negative reply, seismic profiling was begun and a seismic profile was occupied across the eastern part of the Meriadzek Terrace until 2300 when the gear was recovered in deteriorating weather conditions. By morning the weather had improved and profiling began again at 1015 reoccupying the line aborted on the previous day. By 1400, when the French restriction on the use of GLORIA had expired, the seas were relatively calm although storms were forecast for both Biscay and Finisterre. As the barometer was continually falling, it was decided to await the 1630 forecast before launching GLORIA. At 1630, the wind veered to 300° x 20 kts as the barometer started to rise from 970.0 mbars. A storm forecast was received at 1644. During the evening of 056 and morning of 057, traverses were made across the margin by Black Mud canyon and northward toward the Goban Spur. During the morning, gusts of 55-60 kts were observed and it was

decided to carry on profiling pending an improvement in weather conditions sufficient to launch GLORIA. At 1050/058 a fresh seismic profile was occupied from the Goban Spur to the continental rise. By the late afternoon, the seas had moderated and at 1742, the seismic gear was brought inboard prior to launching GLORIA. At 1843/058 GLORIA was launched and the seismic gear redeployed by 1937. Initially, GLORIA transmissions were made only to port but by 2140, the starboard amplifier was repaired and speed was increased to 8.5 kts. A GLORIA traverse across the King Arthur Canyon system was made until 0340 when course was set to 124^{o} to make a traverse of the margin as far as the Meriadzek Terrace. At 0100/059, course was altered to the northwest to make the northwest overlapping traverse. The wind had meanwhile veered to 300^{o} x 40 kts and Discovery began to pitch heavily. The line was continued until 0630/059 when course was altered to 215^{o} to minimise potential damage to the GLORIA cable due to the severe and continuous pitching. We continued southward until 1015 when the last of our southeastward survey lines was reached. Course was altered to 125^{o}. We continued along this heading until 1550/060 when course was altered to 034^{o} to occupy a traverse perpendicular to the margin. The shelf was reached at 0225 and courses were followed to examine the Pre-Cambrian/Mesozoic contact on the shelf before seeking a lee off Ushant. This plan was adopted because of possible bad weather early on March 3rd. At 1303/061 seismic profiling ended and the seismic gear and magnetometer were brought inboard while the GLORIA cable was shortened in scope. GLORIA was finally recovered in the lee of Ushant at 1600. Discovery docked in Brest at 1900.

This was a cruise made difficult both by bad weather and a number of potentially catastrophic equipment failures. Despite these difficulties only 6.2 days were lost due to bad weather and some 4800 mls of GLORIA traverse were occupied successfully. About 100,000 sq. mls of the continental margin were mapped in this way. It is a pleasure for me to thank the scientists on board Discovery for their untiring efforts in these conditions and the Master and crew for their help.

PROJECT REPORTS

1. Continental Margin Survey in the Southwestern Approaches

Due to bad weather during Leg 1 the GLORIA survey programme was partly curtailed on the margin. Approximately 600 mls of GLORIA traverse were occupied between the Goban Spur and Meriadzek Terrace, principally on the slope and the upper part of the continental rise. Preliminary assessment of the data shows well developed linear features related to block faulting that can be followed onto the Goban Spur. Sediment drifts were observed on top of the Meriadzek Terrace. Prior to recovery of GLORIA, the opportunity was taken to examine the Mesozoic-Pre-Cambrian contact on the shelf to the west of Brittany.

2. Survey of the Iberian Continental Margin

The Iberian margin between $44^{o}30'N$ and $37^{o}N$ and between $09^{o}30'W$ and $12^{o}W$ was surveyed during three periods of the cruise. Available bathymetric data included the 1:1 Million unpublished manuscript charts of Laughton and Roberts enlarged to a scale of 1:250,000 for the survey. Survey tracks were chosen to run parallel to the margin for much of its length and east-west in the vicinity of Galicia Bank. The tracks were typically spaced at 20 n.m so that an acceptable overlap occurred between adjacent tracks. The tracks gave a total ground coverage of about 50,000 sq. miles.

First results of the mosaic show a number of unexpected features. A complete series of channels of 10-30 m relief were mapped connecting the Biscay and Iberian abyssal plains. The channels can be clearly followed into the Theta Gap. The sonographs clearly show the north Pyrenean overthrust off N. Spain. Further south, it was clear that much of the morphology at a scale of 10-50 m is due to sediment drifts often built up in the lee of seamounts. A complex series of channels could be followed from the upper slope down across the rise. Structural trends seem to align NW-SE though there is also evidence of diapirism along the presumed seaward extension of the Lusitania Basin. Between Lisbon and Cape St Vincent, numerous sediment drifts may indicate the influence of the Mediterranean outflow. The Lisbon canyon and escarpment area has been subjected to recent faulting and folding. DSDP site 398 was observed on the GLORIA sonographs.

3. Gulf of Cadiz

The seismic profiles across the Gulf of Cadiz showed almost no penetration in marked contrast to the other margins surveyed during this cruise. The exception lay at the margins where a deep reflector was observed at as much as five seconds beneath the 'opaque' layer. The opaque layer is interpreted as an olistostrome. Several GLORIA traverses were occupied in the outer part of the Gulf to determine the oceanward extent of the olistostrome. The areal offshore extent of the olistostrome is estimated at c. 4000 sq. mls. The areal GLORIA coverage in the Gulf of Cadiz was approximately 27,000 sq. miles.

4. Mazagan Escarpment and Moroccan Diapir field

GLORIA coverage of the continental slope off Mazagan and Morocco amounted to some 11,000 sq. miles. The survey was designed to examine the oceanward extent of the diapir field and its influence on the morphology of the slope and rise. First results show clearly the presence of diapirs linear over 10-15 miles and the presence of many small faults associated with diapirs indicating present day movement. Diapirism has undoubtedly influenced the development of canyons on the slope, although mud waves are well developed (linear over 20-30 miles) on the Mazagan escarpment.

5. GLORIA operations

The GLORIA system was essentially the same as on Cruises 84/85 with the following minor but important modifications:-

(a) the lower end of the gantry cradle has been altered to make recovery of the vehicle easier and less liable to damage the cable or vehicle

(b) new tape recorders have been purchased which allow an improved record and replay procedure. The new recording format uses tape at one quarter of the previous rate, only requires one recorder to be recording at any time and allows a 16 times speed-up on replay. Both these modifications have been very successful and of great value.

On Leg 1 the vehicle was launched at 1215 on day 25, and recording started on the port side only at 1522. The starboard power amplifiers gave a little trouble but were brought into operation at 2045. For the next 6 days the system operated with difficulty in appalling

weather conditions, with increasing evidence of cable damage.

The vehicle was recovered at 0800 on day 31, and the short cable was fitted and tested, the damage to the long one being confirmed. The vehicle was relaunched at 0830 on day 33 and recording proceeded uninterrupted until 1640 on day 38 when the vehicle was recovered at the end of Leg 1. Leg 2 commenced with a vehicle launch at 1500 on day 42 after clearing the Lisbon shipping lanes. Recording continued without interruption until 0340 on day 53. The ship had been rolling heavily for several hours in steadily worsening weather and this brought to a head a problem which had shown itself on Leg 1. The Power Amplifier battery pack was leaking electrolyte as a result of rolling and this drew an arc from the battery tray structure and ignited the PVC insulation of the cell voltage monitor harness, causing the harness to fuse for the length of the lower battery tray. Luckily alarms had already shown in the Plot and the fire was discovered and extinguished at this stage. The weather by now was a full storm and with the vehicle deployed and no prospect of recovery the ship had perforce to continue rolling. The battery pack was made safe by cutting out the monitor harness and disconnecting the cells. A careful survey and repairs were carried out in Corunna which was reached at 2000 on day 53. The repairs were complete and all systems tested by 1900 on day 54. 72 of the 93 cells had been saved and the power system adjusted to run on this lower voltage. The surviving cells had been turned fore and aft and bled of some electrolyte to make them tolerant of heavy rolling. The bad weather stayed with the ship for the next three days after clearing Corunna at 2000 on day 54. The bad weather persisted so long that no further launch was possible on this cruise until 1840 on day 058 when the vehicle was launched. GLORIA remained outboard until 1300/060. During the cruise, GLORIA was operated for a distance of about 4500 n. miles.

CONCLUSION

The ability of the cable to survive heavy weather provided the ship is not allowed to pitch violently was demonstrated on days 52 and 53. In addition to the IOS recording some 110 hours of recording were done for the Jet Propulsion Laboratory on their tape recorder. It

is intended that they should digitise these for computer processing as a joint IOS/JPL Project. JPL are interested in transferring space technology to other fields and IOS are keen to use any device which will augment the information extracted from the GLORIA records.

6. Gravity Meters, La Coste and Romberg S40 and G167

S40 was installed during the week prior to sailing from South Shields. A new interface had been built to output the gravity data in a compatible form for the 1800 system and was transmitted via the existing cable as installed for use with the Askania gravity meter on Cruise 84. The only programming difference between the two types of gravity meter being in the output delay of data; for the Askania 2 minutes and the La Coste 4 minutes.

Installation of the La Coste meter presented no problems, the equipment being run from the 60 Hz 240 volt ship's supply via the Electronics Laboratory and stepped down to 110 volts by a transformer in the gravity room. It should be mentioned that this was to be the gravity meter's first use since its overhaul by the manufacturers during the last few months of 1977. Two problems occurred during installation, the first being a Servo motor drive amplifier which malfunctioned and the second being a faulty reading bulb in the optics. The meter was running for three days prior to sailing to enable a gravity tie-in to be made with Newcastle University. The tie was made using a La Coste landmeter G167, which was loaned from the University for this cruise and Cruises 91 and 93. The landmeter was used to make a tie at Lisbon and is to be used at future ports of call on subsequent cruises. During the cruise the landmeter was kept on power thereby enabling a direct tie between Lisbon and Newcastle as well as with the local station set up during Cruise 84.

During Leg 1 the gravity meter, S40, had to be shut down during periods of excessive rolling. Later in the cruise it was found that the end stop rubbers associated with the roll axis on the platform were contacting the shock absorbers when the ship rolled to port. The rubbers were removed and no more down time was experienced due to rolling. The problem appears to be with the fact that the floor in the gravity room is not level when the ship is on an even keel,

with the result that the meter falls sideways to port. This does not affect the meter reading but does mean that the meter is offset to port in its frame allowing it to bottom when the ship is rolling to port. Further down time resulted from a faulty digital cable and poor board contacts. In both cases the analogue record was digitized and two minute values entered manually into the computer. In this manner most of the down time was recovered.

On course changes the Eotvos correction did not fully compensate for the change in the gravity field and a differential spike appeared on the free air anomaly. In most cases this was manually smoothed during the daily editing routine.

A check on thirteen of the crossovers made during the cruise resulted in eleven crossover errors of less than 2 mgals, one of 3.3 and another of 6.2. The 3.3 mgal error was in an area of steep gravity gradient and the 6.2 mgal error when the navigation was suspect. The greatest time difference on crossovers was 29 days when the error was 1.2 mgals. From the check on crossovers it would appear that the meter S40 is not drifting at a rate requiring a correction to be applied over the whole cruise.

If more use is to be made of gravity meters on the ship in future, the facilities of the gravity meter room will have to be improved to include an intercomm, wall sockets for equipment servicing and air-conditioning for working in the Tropics.

7. Seismic reflection profiling

During the first 24 hours of seismic profiling using a 160 cu. in. airgun, it became clear that the MSES 6-channel hydrophone was noisier than it should have been. Although fitted with depth sensors, there were no inboard monitor or calibration records. As the depth of the hydrophone was unknown the depth controllers set to a depth of 50 ft were added after recovering the array on day 025. This improved the data significantly. On day 027, the ship's propulsion failed causing the array to sink deeply. There was no apparent damage at the time but two days later the towing cable parted at 0330. Fortunately, the tail buoy supported the hydrophone and it was safely found and recovered some time later. The cable break may have been caused by imbalanced drag perhaps produced

following the implosion of the depth controller some two days earlier when the ship stopped. After this the IOS Wormley two-channel array was deployed and used successfully for the remainder of the cruise at speeds of up to 9 kts. A further test of the 6-channel array was made during day 055. This test showed the array, with an additional lead weight, at a depth of 50-60 ft but with excessive noise perhaps reflecting sea conditions or damage sustained when hanging from the tail buoy. Apart from intermittent compressor failures due to heavy rolling, the remainder of the equipment proved reliable.

It should be noted that this is the third occasion when a multi-channel hydrophone without reliable depth sensors has been provided by MSES. Depth sensors that are properly calibrated are a pre-requisite for multichannel seismic work. During the cruise, a method of independently deriving the array depth was developed.

8. Digital Signal Processing

A series of programs were developed to perform digital recording and replay of SRP data. These were initially written for 6-channel SRP data but were subsequently modified to handle 2-channel data. A number of days' data were recorded to gain experience prior to the development of a digital recording system based upon a Data General Corporation Micro Nova microprocessor. The microprocessor was delivered to the ship at the start of Leg 2 and some initial development was done.

A number of programs were developed to aid the processing of SRP data. One such program was designed to reduce the effect of the surface reflector upon the seismic data at the hydrophone and as a byproduct of the main program, the depth of the hydrophone array could be measured. This proved useful when the 6-channel array was deployed because the normal depth sensors were inoperative.

Some development work was done on a pulse compression program designed to improve the resolution of seismic reflectors.

9. Microprocessor Tracking of P.E.S. Bottom Signal

An earlier, and to date the most successful, tracking programme was set up and its output - the number of samples between the start

of sweep and the detected bottom - scaled and displayed on an alpha-numeric terminal. Phase information was entered manually.

To avoid wasting computing time while counting down to the start of the signal sampling gate, a hardware down-counter was built. Once preset this counter runs down to zero and generates an interrupt. Further hardware improvements were - the rebuilding of the input full-wave rectifier - the addition of an anti-aliassing filter - and the wiring up of an extra 16 bit input/output port.

An edge detecting programme was written to generate a pulse with amplitude related to the statistical significance of the edge in the presence of noise. When nearly completed this programme was found to have too long a running time and may have to be drastically trimmed.

At the end of Leg 2 work was still in progress on a programme using the running product of several samples, normalised by the long term average. This algorithm has been shown to have the ability to dig out a signal from below the mean noise level but tends to come unstuck when the signal/noise is good.

10. Computer Cruise Report

During Cruise 90, the IBM 1800 computer system was used to log meteorological, bathymetric, magnetic, gravimetric and, in conjunction with the Magnavox satellite navigator, positional data. Heavy demands were made on the equipment, particularly the plotter and V.D.U.

The majority of the work was done on a routine daily basis, starting immediately after the first fix of the day in order to get the previous day's navigation optimised before the GLORIA record printing commenced. An evaluation of the satellite fixes was made by examining the Magnavox output in conjunction with profiles of gyro-in-use, speed and course-made-good and Eotvos correction. Poor quality fixes were removed and track charts were produced at 1:1,000,000 and 1:250,000. Bathymetric, magnetic and gravimetric data were also edited, by the insertion of good values whenever possible, but otherwise by lowering the status. Plots of depth (corrected metres), free air anomaly and magnetic anomaly annotations were drawn at a scale of 1:1,000,000. As on previous cruises, the

meteorological data was edited on a routine basis by eliminating values affected by radio transmission. The ray plotting program (PRAY) was run on several occasions in connection with the GLORIA work and the live track plot facility was used to aid recovery of the hydrophone array.

Prior to the cruise, various software modifications were made to enable depths in metres, rather than fathoms, to be input via the P.E.S. console. Corrected fathoms are stored in CDAT as before and these values can be converted to corrected metres, if required, for print-out or display purposes.

The 1800 computer, peripherals and interfaces worked well, there being only one or two problems, which were short in duration and did not produce any 'down time'. However there was one period of about 12 hours when sampling was stopped and the disc drives turned off. This was due to rough weather, which meant there was a high risk of 'disc crashes'.

Navigation

The Magnavox Satellite Navigator generally worked well, though the programme (MXVN) was occasionally corrupted and had to be reloaded.

Our major problem was the loss of the port E/M log, noticed on leaving Lisbon. A few hours after changing all the port E/M log electronics output connectors to the starboard electronics unit, it was noticed that the fore/aft and athwartships speed to the 1800 was reversed. This was due to miswiring in the computer output of the port E/M log electronics. The connections in the port electronics were changed, for future use, and the input leads to the 1800 swapped over, so that they were acceptable for both port and starboard logs without any wiring changes. The loss of navigational data was limited to 20 minutes by software manipulation. Rough calibration constants for the 1800 starboard log input were known and these were checked and corrected using a disposable sonobuoy to check the fore/aft speed. A misalignment angle was calculated by plotting apparent currents, with respect to the ship's head, over periods when the ship was travelling at a steady speed of 8.0 knots on a steady course.

11. Meteorological Observations

Throughout the cruise, daily manual observations were made at 1100 from the following instruments:-

(1) Bridge screen thermometers (port and starboard),

(2) Bridge barometer,

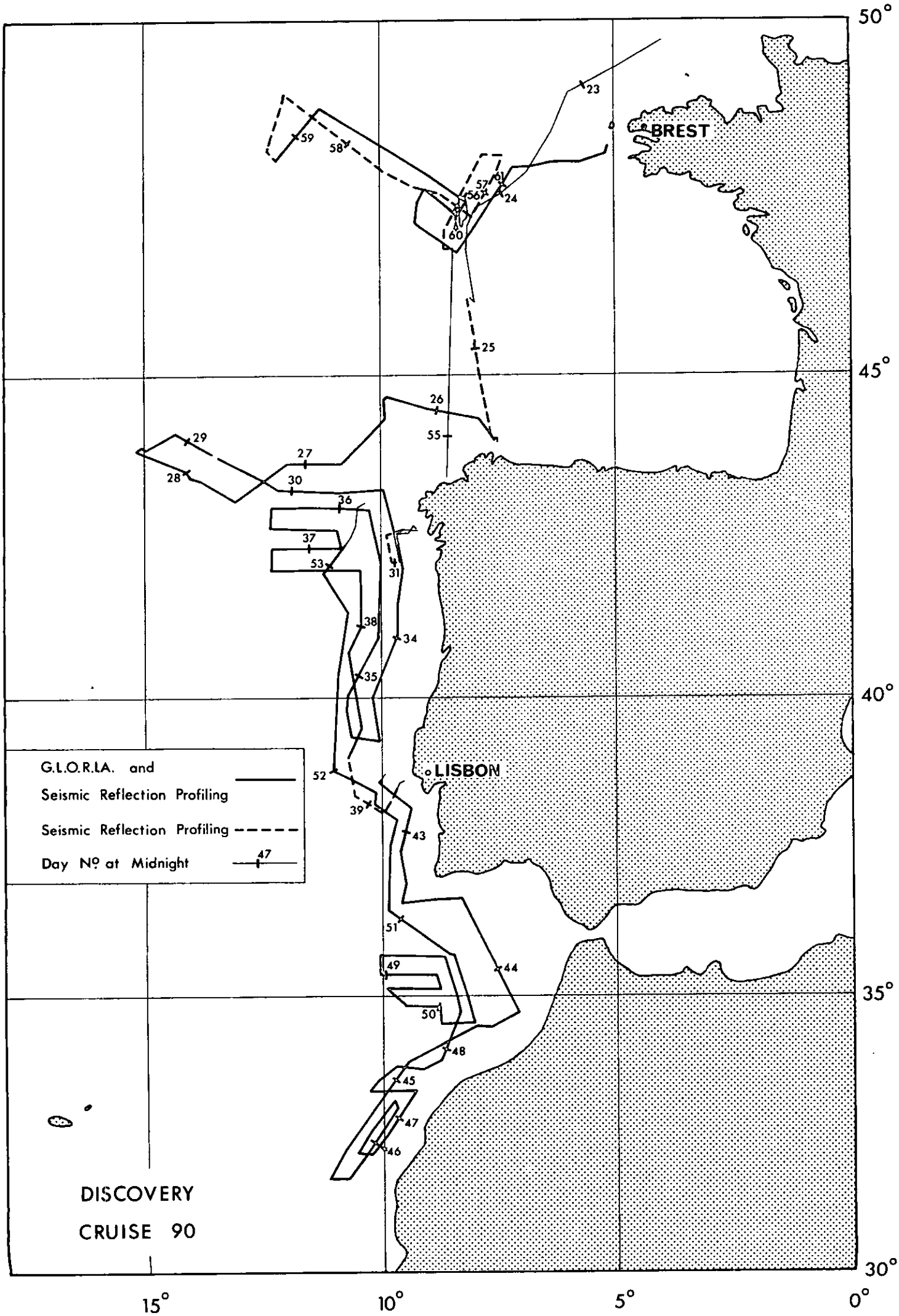
(3) M.O. anemometer (relative wind).

These readings and the corresponding data produced by the IBM 1053 computer were recorded in a meteorological log to provide a running comparison.

On analysis, the comparison shows a good correlation, indicating that the readings obtained were of good quality and that all instruments functioned well, requiring only general servicing.

TABLE I STATION LIST

Stn. No.	Type	Equipment Used	Date	Time Z/Day No. From	To	Lat. N Long.W	to	Lat. N Long.W	Comments
9747	S.Refr. /S.Refl.	Sonobuoy 160 cu.in³ airgun	13/2/78	1430Z/044	1516Z/044	34°11.9' 08°32.9'		34°08.4' 08°40.9'	Moroccan continental rise E.M. log calibration
9748	S.Refr. /S.Refl.	Sonobuoy 160 cu.in³ airgun	16/2/78	1258Z/047	1500Z/047	33°31.4' 10°05.7'		33°39.4' 09°56.3'	Moroccan continental rise
9749	S.Refr. /S.Refl.	Sonobuoy 160 cu.in³ airgun	21/2/78	1000Z/052	1120Z/052	40°15.3' 10°56.3'		40°22.1' 10°55.9'	Iberian continental rise


50°
45°
40°
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G.L.O.R.I.A. and
Seismic Reflection Profiling
Seismic Reflection Profiling
Day Nº at Midnight
47
DISCOVERY
CRUISE 90

CRUISE REPORTS

RRS DISCOVERY

CRUISE NO		REPORT NO
1	JUN - AUG 1963	1*
2	AUG - DEC 1963	2*
3	DEC 1963 - SEP 1964	3*
		NTO CR**
4	FEB - MAR 1965	4
TO	TO	TO
37	NOV - DEC 1970	37
38	JAN - APR 1971	41
39	APR - JUN 1971	40
40	JUN - JUL 1971	48
41	AUG - SEP 1971	45
42	SEP 1971	49
43	OCT - NOV 1971	47
44	DEC 1971	46
45	FEB - APR 1972	50
46	APR - MAY 1972	55
47	JUN - JUL 1972	52
48	JUL - AUG 1972	53
49	AUG - OCT 1972	57
50	OCT 1972	56
51	NOV - DEC 1972	54
52	FEB - MAR 1973	59
53	APR - JUN 1973	58
		IOS CR***
54	JUN - AUG 1973	2
55	SEP - OCT 1973	5
56	OCT - NOV 1973	4
57	NOV - DEC 1973	6
58	DEC 1973	4
59	FEB 1974	14
60	FEB - MAR 1974	8
61	MAR - MAY 1974	10
62	MAY - JUN 1974	11
63	JUN - JUL 1974	12
64	JUL - AUG 1974	13
65	AUG 1974	17
66	AUG - SEP 1974	20
68	NOV - DEC 1974	16
69	JAN - MAR 1975	51
73	JUL - AUG 1975	34
74/1+3	SEP - OCT 1975	35
74/2		33
75	OCT - NOV 1975	43
77	JUL - AUG 1976	46
78	SEP - OCT 1976	52
79	OCT - NOV 1976	54
82	MAR - MAY 1977	59
83	MAY - JUN 1977	61
84	JUN - JUL 1977	60
86	SEP 1977	57
87	OCT 1977	58

* REPORTS 1 TO 3 WERE PUBLISHED AND DISTRIBUTED BY THE ROYAL SOCIETY FOLLOWING THE INTERNATIONAL INDIAN OCEAN EXPEDITION

** NTO CR: NATIONAL INSTITUTE OF OCEANOGRAPHY, CRUISE REPORT

*** IOS CR: INSTITUTE OF OCEANOGRAPHIC SCIENCES, CRUISE REPORT

CRUISE REPORTS

CRUISE DATES	REPORT NO
RRS "CHALLENGER"	
AUG - SEP 1974	IOS CR 22
MAR - APR 1976	IOS CR 47
RV "EDWARD FORBES"	
OCT 1974	IOS CR 15 X
JAN - FEB 1975	IOS CR 19
APR 1975	IOS CR 23
MAY 1975	IOS CR 32
MAY - JUN 1975	IOS CR 28
JUL 1975	IOS CR 31
JUL - AUG 1975	IOS CR 36
AUG - SEP 1975	IOS CR 41
AUG - SEP 1975	IOS CR 44
FEB - APR 1976	IOS CR 48
APR - JUN 1976	IOS CR 54
MAY 1976	IOS CR 53
RRS "JOHN MURRAY"	
APR - MAY 1972	NIO CR 51
SEP 1973	IOS CR 7
MAY - APR 1974	IOS CR 9
OCT - NOV & DEC 1974	IOS CR 21
APR - MAY 1975	IOS CR 25
APR 1975	IOS CR 39
OCT - NOV 1975	IOS CR 40
AUG - OCT 1975	IOS CR 42
OCT - NOV 1976	IOS CR 53
MC "MARCEL BAYARD"	
FEB - APR 1971	NIO CR 44
MV "RESEARCHER"	
AUG - SEP 1972	NIO CR 60
RV "SARSIA"	
MAY - JUN 1975	IOS CR 30
AUG - SEP 1975	IOS CR 38
MAR - APR 1976	IOS CR 44
RRS "SHACKLETON"	
AUG - SEP 1973	IOS CR 3
JAN - FEB 1975	IOS CR 18
MAR - MAY 1975	IOS CR 24
FEB - MAR 1975	IOS CR 29
JUL - AUG 1975	IOS CR 37
JUN - JUL 1976	IOS CR 45
OCT - NOV 1976	IOS CR 49
MV "SURVEYOR"	
FEB - APR 1971	NIO CR 38
JUN 1971	NIO CR 39 X
AUG 1971	NIO CR 42 X